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5-2-23

PN-AAP-862
ISN-34365

The Natural and Cultural History of Southeast Asian Agriculture:

Ecological and Evolutionary Considerations

Abstract. – *Recent archaeological discoveries in Southeast Asia and the Pacific have led to provocative claims regarding the prehistoric origins and development of agriculture in those regions. The present paper reviews the available evidence in the light of general ecological and evolutionary principles and presents a tentative framework for the prehistory of Southeast Asian agriculture. It is found that traditional culture-historical reconstructions of the Southeast Asian "Neolithic" are unable to account for the ethnographic and archaeological evidence. The archaeological data are, on the other hand, presently insufficient to support any specific new reconstruction. The proposed framework for the origin and development of Southeast Asian agriculture is dynamic, taking into account continuous interactions between humans and their environments. However, it is acknowledged that this framework is speculative and needs to be tested through further archaeological research. The major purpose of the proposal is to lend methodological focus to future field investigations.* [Southeast Asia, Archaeology, Agriculture, Ecology]

1. Introduction

Over the past two decades, archaeological work in Southeast Asia and the western Pacific Islands, particularly New Guinea, has generated much excitement among people interested in plant domestication and the beginnings of agriculture. A number of tantalizing findings have been reported:

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archaeological plant remains; indirect evidence of early cultivation; and traces of prehistoric field systems. The fact that these findings were made was not all that surprising in itself. After all, Southeast Asia constitutes one of the important regions of agricultural production in the world today, and it has long been understood that many of the region's crops and agricultural practices have their roots in prehistory. What was a major surprise, however, was the unexpectedly early date of many of the findings, several of them apparently indicating an early agricultural phase about eight to ten thousand years ago.

These early dates were all the more interesting as they were being announced at a time when a general reinterpretation of Southeast Asian history and prehistory was going on. Up to about 1950, it had been widely accepted that Southeast Asia was for the most part a culturally passive region and that its most significant cultural, technological, and political achievements had come about under the influence of the two great and ancient civilizations of the Orient, namely India to the west and China to the north (e.g., Clark 1965: 201). With the end of the colonial period after World War II, indigenous as well as many foreign scholars started to question this assumption and began to perceive the region as being essentially culturally autonomous, having experienced independent and important historic and prehistoric developments in its own right. The discovery of apparent evidence for extremely early local developments in the domestication of plants and animals came at this time of reorientation and was eagerly accepted as a significant piece of evidence for the independence of developments in Southeast Asia and even the possibility of this region having played a leadership role in world prehistory (Solheim 1972). Not surprisingly, in the first flush of excitement, there was a tendency to be somewhat uncritical in accepting and interpreting new discoveries. As a consequence, issues and evidence have occasionally become somewhat confused and distorted.

Actually, the possibility that Southeast Asia may have been an ancient center of plant domestication and agricultural innovation has been raised since the 1930s by several investigators from a variety of fields (archaeology, botany, phytogeography, genetics, etc.) (e.g., Haudricourt and Hédin 1944; Menghin 1931; Sauer 1952; Vavilov 1950; Werth 1954; Wissmann 1956). Until recently, however, none of these proposals had received broad attention, at least in part because of entrenched Indo-centric and Sino-centric biases, and in part because of an absence of solid archaeological or other culture-historical supporting evidence.

There were, of course, culture-historical reconstructions on a regional and sub-regional level, based largely on ethnographic distribution studies of crops, cultivation practices, linguistic terms, and related items of material culture (tools, terraces, etc.). On that basis, it was widely, although never universally, believed that agriculture in Southeast Asia started with a slash-and-burn type of dry land cultivation, and the cultivation in inundated fields came into practice only quite late in prehistory, probably introduced from

the outside through migrations or other forms of cultural contact. Similarly, culture-historical interpretation of ethnographic patterns seemed to suggest a sequence of dominant cultigens proceeding from root crops to cereals. It was further assumed that the beginning of cereal agriculture occurred in the context of dry field cultivation, while wet rice agriculture would represent the most advanced and most recent innovation (or, more precisely, introduction) in Southeast Asian subsistence technologies (cf. Burkill 1951; Heine-Geldern 1923; Linton 1955; Pelzer 1945 and 1978; Spencer 1966). Some authors have felt that the cultivation of a millet cereal (*Setaria*) preceded that of rice (e.g., Kano and Segawa 1956).

The new archaeological evidence (from Thailand, Taiwan, Indonesia, New Guinea) seemed to offer not only a point of radical departure from the traditional picture (e.g., Gorman 1977) but also a small body of firm empirical evidence against which any theoretical model could be evaluated. Unfortunately, surprisingly little progress has been made in settling long-standing controversies over the period of time that much of the new evidence has been presented (Reed 1977). It has become painfully clear that the archaeological information available to date falls far short of expectations in terms of both quality and quantity. This is not entirely the fault of the archaeologists. As I will argue below, the complexity of the process of domestication and cultivation, particularly in the tropics, is such that the empirical evaluation of theoretical models demands voluminous and highly controlled data sets. Yet, conceptually and technically sophisticated archaeological research in Southeast Asia has barely begun (Hutterer 1982*a* and n.d.).

Thus, whether we like it or not, we continue to be limited for the time being to tinkering with *a priori* models. This is not all bad, however, since such models, be they explicit or implicit, exert a powerful influence over the ways in which we gather empirical evidence and analyze it. It may benefit further research, therefore, if we turn our attention once more to general theoretical issues concerning prehistoric domestication and cultivation in Southeast Asia. In the following essay, I will examine these issues from the viewpoint of evolutionary ecology, in the belief that such a perspective would be able to integrate otherwise disperate lines of reasoning into a cohesive processual view. The object of the exercise is two-fold: *(a)* to suggest, in the barest outlines, an alternative sequence of Southeast Asian cultural development; and *(b)* to sketch a perspective of Southeast Asian subsistence complexes that might be of value in assessing the evolutionary and ecological potential of contemporary agro-ecosystems and their contemplated further development. Thus, the present discussion involves more than an idle academic exercise. As Southeast Asian nations struggle to increase the agricultural productivity of their lands, it will be of practical value to understand the ecological and evolutionary background of their principal food crops and, particularly, to understand the context in which indigenous cropping systems and agricultural practices have developed.

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In presenting this outline, I can claim neither complete originality nor comprehensiveness in discussing the issues and data involved. In conceptualizing basic ecological relationships, I have relied on a number of authorities, most notable among them Anderson (1954), Barrau (1965, 1974), Flannery (1968, 1973), Ford (1977), Harlan (1975), and Harris (1969, 1972, 1973, 1977). Unfortunately, many important issues cannot be discussed at all in the present context, while others can only be touched on, and complex realities often have to be dealt with in highly over-simplified summary statements. I find this particularly troublesome with regard to the exceedingly broad and complex topic of tropical ecology. Readers should be aware of these limitations. Statements about tropical ecology made here are based on an extensive review of the relevant literature presented elsewhere (Hutterer 1982*b*).

2. Basic Concepts

It is good practice in any discussion to define the pivotal concepts at the start. This seems particularly desirable in the present context, as the interest in plant domestication and prehistoric agriculture has a long and venerable history. Over time, the basic concepts have been formulated and reformulated in many different ways and, in the process, have become worn and shapeless like an old dress remade a few times too often. We are interested here in a definition of the key concepts from an ecological point of view.

a) What Is "Agriculture"?

There has been a tendency to exaggerate the difference between subsistence technologies based on hunting-and-gathering on the one hand, and those based on "food production" on the other. According to a wide-spread popular notion, hunters simply harvest what grows naturally, while farmers produce food artificially. Although nobody would go so far as to say that farmers make food materialize from ideas or synthesize it from inorganic elements, it is generally assumed that agricultural subsistence is fundamentally and utterly different from a hunting subsistence. Yet, farmers also harvest what nature produces. It is true that agriculturalists manipulate the environments from which they derive their food and other necessities: they concentrate the plants they are particularly interested in into dense stands through such methods as artificial seed dispersal (sowing) or other means of propagation (e.g., planting cuttings, etc.); they protect these plants against competition and predation by other organisms, both plants and animals (e.g., clearing of natural vegetation, weeding, fencing, protection from insects, etc.);[1]

[1] It is not always understood that the suppression of competition through destruction of natural communities (clearing) and weeding constitutes probably the most important human action in raising the productivity of cultivated species. Concentration into

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in many cases they supply the concentrated stands with special subsidies of mineral nutrients or water beyond what the natural environment would provide; and so on. All these manipulations may lead to a significant increase in the productivity of the particular plant organisms that are the focus of the farmer's interest, although not necessarily to an increase in the productivity of the ecosystem as a whole.

The central point is, then, that farmers manipulate their environment. However, so do hunters, both deliberately and inadvertently. A survey of ethnographically documented hunting-and-gathering societies will show that virtually all of them interfere with their environments in a variety of ways, many of which result in some increase in the productivity of particular plant and animal species (cf. Campbell 1965). Human hunters act as deliberate and inadvertent dispersal agents for plants (e.g., Coursey 1976: 402; Rambo 1979: 62, 1980: III-37; Schebesta 1928: 83; Steward 1941: 232); they often look after plants of particular interest to them and suppress their natural enemies and competitors (Rambo 1980: III-38); they set fire to dead or dry vegetation to clear away the detritus and allow fresh growth to develop (Rambo 1980: III-37; Lewis 1980 and n.d.); they have even been known to dig canals (Lourandos 1980; Steward 1934: 247-250); and they engage in many other acts of environmental modification (Rambo 1980). The difference between hunters and farmers is, therefore, not so much one of kind but of degree.

This is not a trivial point because, as others have made clear (Flannery 1968), successful hunters have to be well attuned to their environments, including the reproductive behavior and life cycles of economically important plants and animals. Thus, hunters and foragers do not have to discover that plants grow from cuttings or seeds. There is no reliable ethnographic report of any human group being unaware of this fact today; it is a peculiar carry-over of Victorian attitudes about "savages" to assume that the highly skilled hunters and foragers of the Upper Pleistocene were in the dark about this important aspect of their environment. However, while knowledge of plant reproduction and of the possibility to manipulate this process is a necessary precondition to formal agriculture, it is definitely not a sufficient condition. This is clearly illustrated by the continuing existence of hunting and foraging groups in Southeast Asia and central Africa. These groups are of particular interest in the present context because *(a)* they live in environments that would allow them to practice agriculture; *(b)* they clearly have knowledge of highly developed agricultural practices and systems now; and *(c)* there is good evidence that they have had such knowledge for a long time since their

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dense stands does not necessarily increase the productivity of individual plants—in fact, it often depresses it—although it does usually increase the productivity of the species per unit of land area and, by increasing density and size of food patches, decreases search and pursuit cost in the sense of optimal foraging models of subsistence activities (cf. Reidhead 1979).

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ancestors have been in contact with agricultural populations for many centuries: at least for several hundred years in the case of Southeast Asia (Dunn 1975; Hutterer 1976: 226), and possibly as long as over two thousand years in the case of central Africa (Schebesta 1938: 5-11).

In all, it would clearly be unrealistic to think that the origin of agriculture was based on a discovery. Rather, agriculture developed incrementally out of hunting and collecting in concert with a continuing increase in the extent and intensity of the manipulation of natural ecosystems by human populations. Consequently, since the development of agriculture is a continuing process (which, in fact, is still going on today), it is quite meaningless to fix a point when it first occurred, although it may be quite possible to define relatively short periods of time when the process of environmental manipulation intensified very rapidly and when new technological tools appeared in connection with this manipulation (e.g., terracing, irrigation, plow, etc.).

Considered from this point of view, the significant question is not *when* agriculture developed and from where it spread, but rather *why* humans in various places and at various times felt a need to increase the time and effort spent in wrestling with their environment to coax it to produce a greater amount of food. If we approach this question within the framework of human ecology, it will be almost intuitively clear that it is unlikely that we will ever have a simple answer that will be of universal validity.

b) Types of Agriculture

What has just been said about the difference between hunting and agriculture can also be extended, in some way, to differences between distinct types of agriculture. It need not be pointed out here that there are, in fact, many different forms of agricultural subsistence and technology. Some scholars prefer to use the more general term "cultivation" to refer to all forms of environmental manipulation in which there is a relatively regular, formal, and systematic interference with the natural ecosystem (i. e., deliberate tillage of the soil, sowing, planting, weeding, etc.), resulting in a significant increase in the productivity of the cultivated crop(s) beyond what they would have shown under entirely natural conditions.[2] Cultivation, then, is a general term that applies to all forms of agricultural activity.

The term "agriculture" itself is often reserved for highly intensive forms of environmental management that generally involve cultivation in relatively large, and generally permanent, field plots (e.g., Kroeber 1948: 691). Frequently, such intensive cultivation systems involve the use of fairly

[2] This formulation is very vague and it is, in fact, quite difficult in some empirical cases (both in archaeology and ethnography) to decide whether a particular human group should be classified as hunters or farmers. This should not be surprising after what has been said in the preceding section.

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specialized technological methods, such as the use of animal-drawn plows for tillage. Less intensive forms of cultivation are referred to as "horticulture" (*ibid.*). In these systems, fields tend to be relatively small, they are often impermanent (shifting cultivation), and tilled with simple technological means (e.g., digging stick, human labor only). Needless to say, there are many forms of agriculture as well as many forms of horticulture. In connection with what has been said above, it also stands to reason that the two types of cultivation systems do not really represent sharply distinct types but rather analytically defined points along a continuum. In practice, it is again often difficult to characterize a given subsistence system as being clearly horticultural or agricultural.

What has been said so far would imply that the configuration of a particular subsistence system represents not simply a cultural choice but that it is conditioned, even determined, by the play of a number of ecological variables. The choice between tubers, rice, or corn, or between planting hill rice in swidden fields and planting wet rice in pond fields has, therefore, much less to do with whether a community is ethnically Thai or Vietnamese, or Hmong or Karen, than with the ecological conditions of its existence (climate, topography, soils, drainage, natural vegetation, population size, population density, availability of land, exchange relationships, etc.). This consideration has very imporant implications for interpreting prehistoric changes in subsistence technology: it means that the appearance of new subsistence techniques does not necessarily imply the presence of new and different populations, or the diffusion of the subsistence techniques from an outside source, but it reflects first and foremost an ecological change. It remains, of course, to investigate the causes of change; the influx of a new population may well figure as such a cause. However, there are also many other possibilities, including conditions of external environmental change (e.g., climatic change, erosion, etc.), and internally generated conditions such as population growth or technological innovation. Isolating a single cause will often be difficult, if not impossible, because of the dynamic interaction between the various elements constituting the ecological system.

It should be added here that the diffusion of cultivation techniques does, of course, occur. It is important to recognize, however, that new subsistence techniques are generally not accepted simply because they are available but only if they are seen as desirable and advantageous in a given ecological situation.[3] Once a new technique has been accepted, be it imported or locally developed, it will have its own impact on the ecological system and may, therefore, become an agent of further change.

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[3] This explains in part why hunters-and-gatherers still exist in Southeast Asia although these groups have been in contact with agriculturalists for centuries and perhaps millennia. It also explains why sometimes well-intentioned attempts by development agencies to "improve" indigenous cropping techniques are not being accepted by the local populations.

c) **Cultivation and Domestication**

Another concept that is occasionally misunderstood is that of "domestication." Although they are often used interchangeably, the terms cultivation and domestication refer to two very different processes, with neither of them necessarily depending on the other. In other words, it is possible to cultivate non-domesticated plants (or husband wild animals), while it is also conceivable to have domesticated plants or animals without raising them in a formal cultivation (agricultural) system. The former case is a familiar one: it happens, for instance, when people plant wild flowers in their gardens or when zoos breed lions and giraffes. However, this situation may also occur among hunter-gatherers. Malaysian negritos, for instance, deliberately or accidentally disperse in the vicinity of their camp sites the seeds of highly valued fruit trees found in the forest (Rambo 1980: III-37; Schebesta 1928: 83). The resulting seedlings and trees almost certainly benefit from a variety of ecological conditions that are peculiar to camp site locations and are related to human activities. In addition, these trees become personal properties of individuals who watch over and protect them. It is possible to say, therefore, that the Semang engage in a simple form of silviculture by raising wild fruit trees. Similarly, Australian aborigines used to use several species of wild tobacco *(Nicotiana)* that are native to Australia (Latz 1974). They collected the plants and often brought them home for consumption in the camp. In this way, the seeds were dispersed in and around camp sites, including caves that were sometimes used as temporary habitation shelters. The nutrient-rich, moist soils and shady location of such caves often led to the growth of small but dense and vigorous stands of tobacco plants. Today, the growth of tobacco in rock shelters and in the mouth of caves in central Australia is usually a good sign that these sites were utilized prehistorically by aborigines (personal observation). Again, wild plants of value to human populations grow here under environmental conditions set by humans. Perhaps even more poignant is the case of several species of cultivated plants ("cultivars") which were widely raised by agricultural groups of North American Indians and which were important in their subsistence systems but were never domesticated (e.g., *Chenopodium bushianum* Allen [lambsquarters] and *Phalaris caroliniania* Walt [maygrass]—Ford 1981: 10).

It is somewhat more difficult to think of examples of the opposite case, the presence of domesticates without cultivation. Although such situations are considerably rarer, they do exist. The most striking instance is perhaps the domestication of the dog which appears in several parts of the world definitely in the context of hunting-and-gathering societies (Olsen and Olsen 1977). Another, and perhaps even more intriguing, example may be seen in the evolution of weeds. At least some of the plants classified as weeds clearly evolved as distinct new species in response to human habitat manipulation and through direct or indirect selective pressures exerted by man (De Wet and Harlan 1975). Not surprisingly, many weed species do have

economic uses,[4] and their propagation often depends greatly on human activity, so that it may be difficult to draw a rigid line between cultigens and weeds.

What, then, is the essence of domestication? Most basically, it represents a process of genetic rather than environmental manipulation. That is, humans interfere with the process of propagation of natural populations of plants and animals by acting as agents of genetic selection. This is being done by conferring some sort of reproductive advantage on individuals who have particularly desirable characteristics (e.g., large fruit size, high meat ratio, sweetness, docility, features that make a plant easier to harvest, and so on). In principle, the process of domestication is not all that different from genetic change that occurs through natural selection except that an important selective agent here is man. The fundamental similarity with natural selection is indicated by the fact that, with sufficient time, artifically selected (domesticated) populations may vary from their ancestral populations to such a degree that they will not be able to interbreed with them successfully and must, therefore, be classified as new species. Most often, domestication and cultivation do go hand-in-hand. In these cases, domestication may progress to a point where the domesticated species ("domesticate") cannot survive outside the special environmental conditions maintained for its cultivation by man.

3. The Ecology of Domestication and Early Agriculture in Southeast Asia

I have said above that the process of cultivation entails human manipulation of natural environments, and that the process of domestication entails human manipulation of the gene pool of natural populations. The genetic make-up of natural populations of plants and animals itself is, of course, at least partially determined by environmental conditions. It follows, therefore, that an ecological appraisal of native environments, and of potential cultivars and domesticates found in them, is essential to an understanding of prehistoric domestication and the development of agriculture.

a) The Natural Ecology of the Indo-Pacific Region

Southeast Asia and the islands of the Western Pacific fall entirely within a broad environmental zone of the world referred to as "tropics." It is difficult to make generally valid statements about tropical environments since they are extremely diverse as well as complex. In addition, a large portion of the area under consideration here consists of islands of varying size.

[4] A study in West Bengal, India, showed that of 158 weed species collected in rice fields, 124 are of some kind of economic importance (Datta and Banerjee 1978)!

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Islands maintain a range of ecological conditions of their own which depend on island size, topography, distance from a continental land mass, and so forth (MacArthur and Wilson 1967). Nevertheless, for the purpose on hand, it is defensible to divide tropical environments into two very broad categories: humid tropical environments and seasonally dry tropical environments (Barrau 1965). It is important, however, to keep in mind that there is in reality a continuous range of variability from one extreme to the other and that there is much variability even within each major division.

Climatically, the *humid tropics* can be somewhat simplistically characterized as a region where temperatures are consistently high and where the amount of rainfall exceeds evaporation throughout the year or, even more roughly, where average monthly rainfall is not less than 100 mm. for any month of the year. The Solomon Islands, the New Hebrides, New Ireland, New Britain, much of New Guinea, much of Celebes, Borneo, western Java, Sumatra, the Malay Peninsula, the eastern part of the Philippines, Mindanao, and major portions of the coastal fringe of mainland Southeast Asia meet this condition (see Fig. 1). The major natural vegetation type of the humid tropics is the evergreen rain forest. It typically consists of a very tall and extremely lush vegetation, exceedingly rich in species which, however, are often highly dispersed.

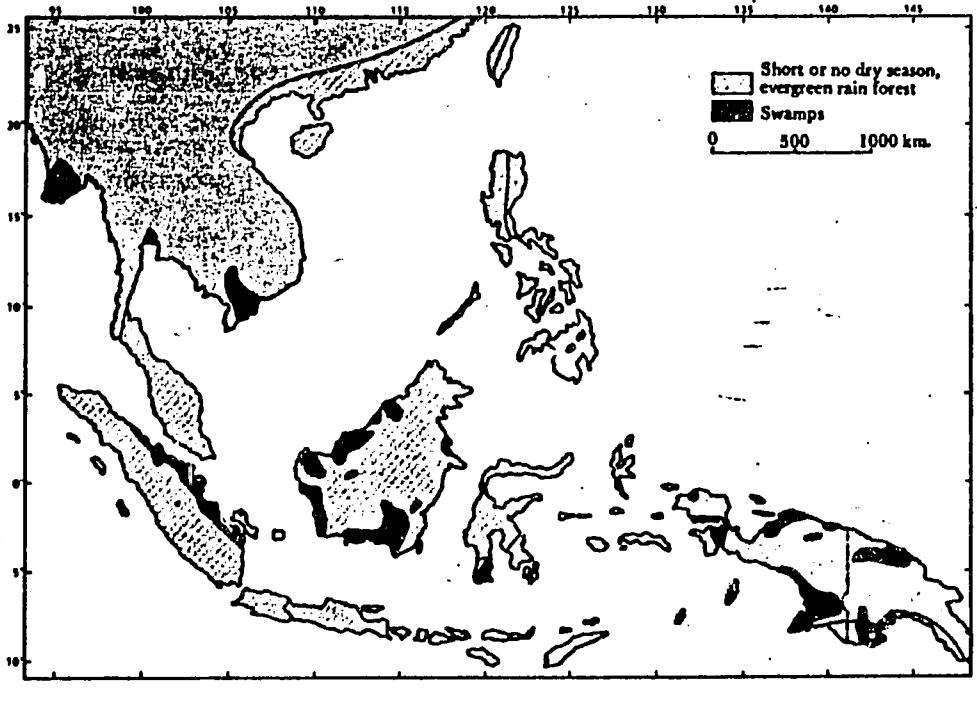

Fig. 1

Major vegetational formations in the Southeast Asian region.
(Note: Delineating the boundaries of vegetational formations involves, to some extent, arbitrary decisions on a variety of definitional matters in tropical ecology. The present map is compiled from several sources, including Barrau [1965], Flenley [1979], and Walter *et al.* [1975]).

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The very lushness of this vegetation is somewhat deceptive from the point of view of the human forager. Rain forests have generally little vegetation at ground level. Most of the potential plant food occurs high above the ground in the canopy of tall trees and much of it is, in addition, poisonous to humans. Species richness and the high degree of dispersion usually force human foragers to keep track of a large variety of resources that are thinly and unevenly distributed. In the absence of major seasonal environmental stress, most rain forest plants also engage in relatively little energy storage in reproductive organs (palms are among the exceptions) such as storage of starch and fats in seeds and nuts, or storage of carbohydrates in underground tubers and rhizomes. These environments are, therefore, often deficient in carbohydrate plant foods for human occupants and have been described as "green deserts." By comparison, animal protein is more easily available, although game animals are also usually not present in huge numbers and rarely in herd-like groups (exceptions are found primarily in the New World tropics). Nevertheless, a variety of herbivores are able to utilize plant energy available throughout the tall forest structure (from the forest floor to the top canopy) and to break down specific organic compounds found in plants that are poisonous to humans. These animals, in turn, can then be "harvested" by hunters.[5] Although there are still some questions about this, it appears that it is the scarcity of carbohydrates rather than protein that represents a major limiting factor for low-density human foraging populations in rain forests (Hutterer 1982*b*: 132-149).

Thus, rain forests (in general) do not represent rich environments for human populations. They have one positive aspect, however, in that the productivity of many of the rain forest plants is relatively easily manipulated. Many of these plants can reproduce vegetatively, that is, they can produce new plants from cuttings and suckers. This makes it relatively easy to interfere with the distribution of these plants by concentrating them in favorable locations and by transferring them to places to which humans have easier and more regular access. Vegetative reproduction also makes it relatively easy to "fix" aspects of genetic (and phenotypic) variation by raising a population, under human protection and encouragement, that is in reality a clone of a single individual that carried the desired characteristic. At the same time, given the extremely crowded conditions of rain forests, it is not surprising that many of the plants occurring naturally in these environments are limited most strongly by competition from other plant species. They may react, therefore, with a very strong increase in productivity, if this com-

[5] Many human groups have, of course, developed techniques that enable them to extract poisonous compounds from otherwise nutritious food plan. This fact does not affect the basic argument developed here.

petition is suppressed to some extent through human interference (e.g., reducing the shade by cutting trees, pulling up competitors, etc.).

In all, it can be said, then, that minor manipulation of rain forest environments by human occupants is feasible, in fact relatively easy, and has the potential of increasing within limits the productivity of carbohydrate plant foods. Major environmental modifications, on the other hand, are far more difficult to achieve and are possible only with a relatively highly developed technology. While some forest clearance was undoubtedly accomplished prehistorically with stone axes, this must have been a very slow and highly labor intensive process. Since standing rain forests are not amenable to being burned, effective clearing requires the use of metal tools to cut the trees.

Seasonally dry tropical environments (see Fig. 1) contrast in many ways with the humid tropics. Climatically, they are characterized by one or two dry seasons per year, that is, periods of varying lengths during which evaporation exceeds the amount of moisture derived from rain. These periods constitute, therefore, seasonally occurring droughts when plant growth is slowed or halted. Yearly average temperature is still very high in the seasonal tropics, although daily and seasonal fluctuations tend to be considerably more pronounced than in the humid zone. It is the total amount of rainfall, however, and its distribution throughout the year, that constitutes the most important variable distinguishing the two major categories of tropical environments.

The native vegetation of the seasonal tropics varies with the rainfall patterns. In situations where the seasonal drought is short (less than three months), the typical vegetation consists of forests which are still very similar to the evergreen forests of the humid zone. As length and severity of the drought period increase, however, there is a correlated reduction in the height of the forest, in its density, and in its species richness. At the same time, there is an increasing tendency for the various species of trees, shrubs, and herbs to synchronize their reproductive activities in response to the drought conditions. Vegetational communities of the seasonal tropics are not only much less rich in species, but tend also to have a great deal more clustering of individuals of the same species. When the drought season exceeds about six to eight months in length, the forest breaks up altogether, and is gradually replaced by tree savanna, bush savanna, grass savanna, scrub savanna, and eventually desert.

Excluding conditions of extreme deserts, seasonally dry tropical environments provide as a rule relatively more plant food for human consumption than to do rain forests. Most plants go through a burst of rapid production during the rainy period. Toward the end of that season, many of them accumulate energy stores in the form of starches and fats in seeds, nuts, and underground organs. These energy reserves allow the plants to react to the

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first rains after the dry season with a new spurt of activity.[6] These carbohydrate-rich plant tissues are, of course, a major focus for human collectors. One important point has to be kept in mind, however: unlike the humid tropics, these plant foods are for the most part available on a highly restricted seasonal basis only. In order to be maximally useful in terms of food supplies throughout the year, they require extensive management in the form of concentrated and coordinated harvest activities during brief periods and subsequent storage. Both are aspects of certain kinds of agriculture and may be considered pre-adaptations for cultivation.

There is one other element that is of great importance: most seasonal tropical environments are very easily modified on a large scale through a rather simple tool: fire.[7] This simple device makes it possible not only to clear dry forests and savannas with relative ease but also to clear very large areas. Finally, it is also noteworthy that the soils of the seasonal tropics are often highly fertile and can be very productive if they are supplied with a sufficient amount of water.

b) The Ecology of Domestication

By comparison with temperate zones, the tropics are enormously rich in species of plants and animals. This species richness means that tropical environments contain a correspondingly larger number of potential domesticates as well (Barrau 1974). Indeed, a large variety of plants from all major tropical areas of the world have been domesticated, although relatively few of them are widely known by virtue of their having become important staples in our world food economy. Most of these domesticates are, of course, well known to tropical peoples themselves as well as to academic specialists. But there are also a number of domesticated plants that have been replaced during the last few hundred years in local economies by introduced economic plants and have consequently been effectively forgotten. As many as 100 and more species of useful plants have been reported to occur in swidden fields (Conklin 1957: 75-87; Kunstadter 1978: 133). The majority

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6 There are some broad ecological tendencies in reproductive strategies of herbaceous plants noted by Harris (1973: 397): vegetative reproduction from underground organs (tubers, rhizomes, etc.) is most common in seasonal tropical environments with short dry seasons, while reproduction from small, hard-shelled, energy-rich seeds predominates in semi-arid to arid environments. However, it should be noted that representatives of each reproductive strategy are found in the native floras of all major types of tropical environments from humid to arid.

7 The use and management of fire was acquired early in human evolution, at least on the *Homo erectus* stage, about one to two million years ago. This does not mean, of course, that hominids at that time already used fire to clear large tracts of savanna but it does raise the possibility that this was done quite early in prehistory.

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of these are cultivated, but a number of others are not and must be considered weeds or commensals. It is possible, however, that at least some of the latter represent minor indigenous domesticates that lost their economic importance after the introduction of new cultivars from Africa and particularly the New World beginning primarily in the late fifteenth century.[8]

In principle, each phytogeographic region is inhabited by a distinctive and unique set of plants which, being separated from other phytogeographic regions by ancient and major environmental barriers (oceans, high mountain ranges, etc.), share a common evolutionary history. Within such regions, minor environmental barriers exist in the form of geographical variations in a series of important variables such as temperature, rainfall, soil, drainage, and so forth. These minor environmental barriers constitute important selective factors in the evolution of plants within a region and account for a differential distribution of plant species, genera, and families. While some plant families or genera have remained, or become, restricted to narrow sets of environmental conditions, others have evolved series of related species that have colonized the total range of environmental zones. In consequence, each phytogeographic region (e.g., North America, South America, Malaysia, etc.) confronts human occupants with a radically different set of raw materials which they can manipulate in the course of domestication and cultivation. To a lesser degree, each environmental zone within a region offers a different set of resources as potential domesticates and cultigens as well. For each tropical region, this means that there are in principle at least two rather distinctive suites of plants, one adapted to humid conditions in the equatorial region, the other to seasonally dry conditions in the outer tropics.

For a variety of reasons, some of which will become clearer in the following discussion, it is often very difficult to reconstruct the history of domestication of a particular plant, or even to identify its wild ancestor with certainty.[9] A partial list of staple crops domesticated in Southeast Asia and the western Pacific would include the following, tentatively separated into two groups according to broad adaptation of assumed wild ancestors: *(a)* plants domesticated in the humid tropics (in alphabetical order): aroid tuber *(Amorphophallus campanulatus)*, banana *(Musa* spp.), Job's tears *(Coix lachrima-jobi)*, rice *(Oryza sativa)* (?), sago *(Metroxylon sagu)*, taro *(Colocasia* spp., *Alocasia* spp., *Cyrtosperma chamissonis)*; *(b)* plants domesti-

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[8] Cases in point may be the root crop Pueraria *(Pueraria lobata)* which was discovered as a domesticate in Highland New Guinea in the 1960s (Watson 1964 and 1968) and the cereal Job's tears *(Coix lachrima-jobi)* which is found as a minor cultigen or volunteer throughout much of South and Southeast Asia (Arora 1977; Burkill 1966).

[9] The complexity of the domestication history of a tropical crop is well illustrated by the case of maize, probably the archaeologically and genetically best-studied tropical domesticate (Brown 1974; Flannery 1973).

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cated in the seasonal tropics: arrowroot *(Tacca leontopetaloides)*, millet *(Setaria italica)* (?),[10] Pueraria *(Pueraria lobata)*, rice *(Oryza sativa)* (?), sugar cane *(Saccharum officinarum)*, yam *(Dioscorea alata, D. esculenta)*. Besides these species which may be considered as staples since they supply starches and sugars, there are also many species of vegetables, spices, as well as fruits and nuts. All of these played, and continue to play today, important roles.

It is not possible in the present context to attempt to give a complete list of all these domesticates. Nor is it possible at present to characterize many of these plants as domesticates of the humid or dry tropical zone. Generally, among the vegetables are amaranths (*Amaranthus* spp.), eggplant *(Solanum melongena)*, and many pulses (beans). Most of the world's important spices originated in the Southeast Asian region. Among them are black pepper (*Piper nigrum*), cardamom *(Elettaria cardamomum)*, clove *(Syzygium aromaticum)*, ginger root *(Zingiber officinale)*, nutmeg *(Myristica fragrans)*, and turmeric *(Curcuma longa)*. Tree crops play a very important, and possibly quite early, role among the domesticates of this region. Particularly noteworthy are: breadfruit *(Artocarpus communis)*, many species of citrus *(Citrus* spp.), coconut palm *(Cocos nucifera)*, durian *(Durio zibethinus)*, jackfruit *(Artocarpus integrifolia)*, mango *(Mangifera indica)*, rambutan *(Nephelium lappaceum)*. In addition, there are numerous plants that are domesticated for their narcotic properties, such as the betel nut *(Areca catechu)*, the betel leaf *(Piper betle)*, and for their fibers, such as cordyline *(Cordyline fructicosa)* and manila hemp *(Musa textilis)*.

Among the important effects of genetic changes brought about through domestication are not only morphological changes but also changes in the general ecological adaptation of plants and animals. Such changes may entail development of a tolerance for a wider range of habitat conditions, and consequently a dispersal of the species beyond its natural range, or (more commonly) a new adaptation to habitat conditions that differ radically from those of the wild ancestor. In most cases, the new adaptations are to habitats with characteristics that can be more easily managed or maintained artificially than those of the plant's native habitats. This transfer of crops into new habitats, often far removed from the native environments of the wild ancestors, can make it quite difficult to trace the history of domestica-

[10] Plant geographers, botanists, and culture historians have pointed to millet *(Setaria italica)* as an important early cultigen in Southeast Asia, probably preceding rice as a major staple crop (e.g., Barrau 1974; Bellwood 1980; Burkill 1966; Chesnov 1973; Li 1970). The cereal is widely distributed in the region today, and there seems to be good evidence in a number of cases of its having been displaced as an important staple by rice within historic times. In spite of this, however, the empirical case for its great antiquity in Southeast Asia is still largely circumstantial. Most authorities assume that the cereal was first domesticated in eastern or central Asia and brought from there to Southeast Asia, possibly at a very early time. Fogg (1978) has recently argued for its domestication in Southeast Asia.

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tion. The problem is aggravated by the fact that, for the great majority of Southeast Asian domesticates, we lack sufficient palaeobotanical information to trace prehistoric distributions as well as sequences of morphological changes, and data are presently inadequate to establish secure genetic relationships between wild, weedy, and cultivated forms. For all these reasons, it is often difficult to identify wild ancestors with confidence and to reconstruct the conditions under which the first steps of domestication would have taken place. In fact, as the following section will show, the roots of the problem may lie a good deal deeper than with crop dispersals and relative lack of empirical evidence. In any event, it is important to stress the hypothetical nature of the above list.

It should also be pointed out here that domestication is not a completed process but continues today in several forms and in several different contexts. Its most visible form is the highly accelerated, deliberate, and scientific breeding of new varieties of usually long-established domesticates (e.g., in the International Rice Research Institute in the Philippines).[11] However, a certain amount of genetic change and further selection continues to occur also in farmers' fields where often highly domesticated plants cross with weedy varieties and species. Rice is well known für its tendency to be accompanied by weed varieties and for crossing with these weeds (Harlan 1975: 95). Such crosses do provide a source for genetic change and selection. A low level of cultural selection probably continues to occur also with regard to a variety of useful plants that are extensively consumed and often cultivated but can at present not be said with certainty to be domesticated. Examples of these are, to name just a few, such fruits as rambutan *(Nephelium mutabile)* and mangosteen *(Garcinia mangostana)*, the narcotic betel nut *(Areca catechu)*, and a number of spices such as cardamom *(Elettaria cardamomum)* and nutmeg *(Myristica fragrans)* (Vavilov 1950: 30-31). Finally, there are ethnographic reports about contemporary tribal peoples deliberately bringing seeds of valued forest plants into their garden plots for planting and, presumably, effecting some amount of genetic selection in the process (Rambo 1979: 63).

c) The Ecology of Cultivation

There are two major cultivation systems in Southeast Asia (and tropical areas in general) involving the use of wet and dry fields respectively. Although there is no empirical proof at this time, ecological considerations indicate that these two systems reflect independent agricultural developments in the two broad environmental categories of the tropics: humid and seasonally dry.

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[11] There is one significant difference between pre-industrial domestication and modern plant breeding. Pre-industrial domesticators select from genetic variation that is provided and maintained by natural processes, while modern breeders often artificially induce mutations.

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Wet field cultivation represents a system that quite likely originated in the humid tropics. It involves the raising of humid tropical crops such as rice and taro in swampy or inundated habitats. It probably has its origin in the manipulation of natural plant communities in swamps and flood plains. Very fundamental ways of manipulating these environments would involve attempts to regulate the water level by draining water, by retaining it through bunds, by heaping soil up to raise it above the water level, or by artificially channelling additional water into the field. All these options entail some labor investment in the engineering of more or less permanent modifications of the landscape. This in itself would tend to promote repeated use of such fields. In addition, agricultural systems that involve temporary or continuous inundation of the fields generally derive a major portion of their nutrients from minerals and organic materials that are dissolved and suspended in the water that flows into the plots. Wet field systems are, therefore, able to maintain fertility over very long periods and are, consequently, in most cases permanent field systems.

Artificial irrigation makes it possible to expand these systems into environmental zones where they would otherwise not be found. Conversely, artificial drainage permits the transformation of swamp environments into dry land habitats. In other words, canalization makes it possible to establish in the seasonal tropics habitats that are typical of the humid tropics and vice versa. Through this creation of artificial habitats it becomes possible to raise crops outside their natural range, in many cases without necessitating major changes in the ecological adaptation of the crops themselves.[12]

Cultivation in dry fields represents a system that is originally adapted to the dry tropics and involves the raising of seasonal tropical crops such as yam and millet.[13] Before a plot can be planted, it has to be cleared of its natural vegetation which is primarily accomplished through burning, although it usually involves also some cutting and felling of larger vegetation elements. The burning not only disposes of unwanted natural vegetation but also releases from it a considerable amount of mineral nutrients which are often essential for the productivity of the field. However, this nutrient

[12] A word of caution is advised here. While I believe that the argument presented here is correct in its basic outline, it is admittedly highly simplified. Thus, swamps exist also in relatively dry tropical environments, and even deserts, on a seasonal basis. At the same time, there is no assurance that domesticated rice, for instance, derives from an ancestor adapted to the humid tropics. It is conceivable, therefore, that wet field cultivation developed in dry tropical environments as well and that it went hand in hand with the domestication of rice there.

[13] The idea is not new that cultivation in dry fields and inundated fields does not so much present a sequence of agricultural evolution but rather two separate developments under different ecological conditions. It was suggested by Bartlett (1962) who, however, proposed the opposite ecological rationale of the one allowed here: he felt that cultivation in flooded fields originated in seasonally dry environments, while dry field cultivation originated in the humid tropics.

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supply is soon exhausted both through being taken up by the cultivated crop and through leaching, which occurs at an accelerated rate in the cleared plot.

Since there are very few natural processes that can replenish nutrients in swidden fields at a rate that is even remotely similar to that of the nutrient drain, these fields decline rapidly in fertility after the first few crops have been harvested. In addition, competition by non-cultivated plants (weeds) is suppressed for a short period through the burning but becomes usually a problem one or two years after initial clearing. Old fields are, therefore, abandoned and new fields are cleared. With time, the abandoned plots will return to a climax vegetation.[14] Thus, the shifting of plots is an important aspect of dry field cultivation in the tropics although it is not entirely synonymous with it. In many parts of Southeast Asia where environmental conditions make the construction and maintenance of wet fields unreasonably costly if not impossible, but where there is insufficient land available for an "integral" shifting cultivation (Conklin 1957: 3) system, dry field cultivation in essentially permanent plots is usually found with short fallow periods. In these cases, the fallow fields return only to a grass vegetation which, however, is still cleared at the end of the fallow period with the help of fire. Such systems are often incorrectly described as "shifting cultivation." A case in point are many of the Philippine *kaingin* systems of cultivation (Olofson 1980).

In principle, dry field cultivation is possible also in the humid tropics. However, as pointed out above, the climax vegetation of the humid tropics, the evergreen rain forest, is a formidable vegetation type which is very difficult to clear with non-industrial technologies. It is not susceptible to fire unless it is first cut and left to dry. This, I have said, is possible with stone axes but becomes feasible on a larger scale only with the availability of metal tools. It must, therefore, be assumed that the expansion of dry field cultivation techniques into rain forest areas is a relatively late prehistoric event. Significantly, swidden plots in rain forests in almost all cases tend to be quite small.

Following views expressed by Geertz (1963), many investigators have pointed out that systems of swidden cultivation, while involving an interference with "natural" environments, replace native communities with cultivated communities that are structurally similar (e.g., Harris 1969: 6) and thereby minimize the disturbance by the human cultivator. While there is some truth to this, the similarity should not be overestimated. Clearly, the

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[14] Quite commonly, ethnographic swidden cultivators reuse areas before they have completed the full series of natural succession, that is, areas that are covered by secondary rather than primary forest. In many cases, the reason may not so much be insufficient land—and therefore an accelerated swidden cycle—but a human tendency to avoid the larger amount of labor involved in clearing primary forests.

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magnitude of the disturbance depends largely on the size of the clearing. However, as measured by Rambo (1980: III-12-16), even very small clearings entail significant changes in air and soil temperatures, relative humidity and air movement and, consequently, in potential evapotranspiration ratio. The latter is an extremely important variable determining tropical life conditions (Huttere: 1982*b*: 5). On this basis, it can be said, then, that the expansion of dry field cultivation into the rain forest through slash-and-burn technology represents the artificial creation of micro-habitats with climatic conditions that resemble those found in the drier tropical zones. This makes it possible to grow seasonal tropical crops in the humid tropics.

Agricultural ecologists often speak about a third type of cultivation system in Southeast Asia and Oceania: the house garden (Terra 1954 and 1958). It involves the use of small plots adjacent to houses. They are utilized on a relatively permanent basis, that is, continuously at least for the period of time during which the house stands and is inhabited. House gardens differ significantly and in several respects from either dry field or wet field cultivation. In terms of crops, the emphasis in gardens is on supplemental food sources, fruit trees, vegetables, spices, and some industrial materials (fibers), while swidden fields and pond fields are used primarily for the production of staples. The long-range maintenance of fertility in house gardens has to do in part with the complex organization and structure of the cultivated vegetation in these systems, and in part with the fact that these plots usually are supplied with extra nutrients by their cultivators, mostly in the form of organic debris and waste products from the household.

The selection of crops found in house gardens as well as the interactions between these systems and their cultivators make it seem likely that these cultivation systems have evolved from vegetational complexes (and their interaction with human groups) that were probably found associated with refuse areas surrounding camp sites of foraging populations (cf. Anderson 1954: 120-130). While the one-time notions about the "discovery" of plant propagation in connection with these refuse heaps strikes us today as overly simplistic, there is no doubt that they do represent a very special kind of human interaction with the environment. If this is so, it seems likely that house gardens may represent extremely early, and distinctive, forms of cultivation in the tropics.

4. Prehistoric Agriculture in the Indo-Pacific Area – The Data

Before reviewing the presently available archaeological data bearing on prehistoric domestication and the beginning of agriculture in Southeast Asia and the western Pacific, it is perhaps good to review briefly the main

points made above. First, it has been said that domestication and cultivation represent two different processes of human manipulation of nature that need not necessarily go hand in hand, although they very often do. Second, both domestication and cultivation are continuous processes. It is, therefore, intrinsically impossible to designate any point as the "first beginning" or "first occurrence" of domestication or agriculture except on an arbitrary basis. It is, however, possible to observe specific events in that process with reasonable accuracy archaeologically. Third, there are two groups of domesticates, one deriving from ancestors adapted to the humid tropics, the other deriving from ancestors adapted to the seasonal tropics. Genetic changes accomplished through domestication have made it possible, in part, to grow many of these crops outside their native ranges. Fourth, there are two major systems of cultivation, in wet fields and dry fields, which were developed in the humid and seasonally dry tropics respectively. Certain technological innovations made it possible to transfer these cultivation systems to environmental zones other than those where they were originally developed. This establishment and maintenance of artificial humid and dry tropical microenvironments generated further possibilities to grow crops outside their natural range. The introduction and spread of such technological innovations may be among the events in the development of cultivation systems that can be observed archaeologically. Finally, house gardens may represent a third and independent cultivation system.

It is necessary to pause here for a moment to consider the potential complexity of the interaction of processes involved in the evolution of agriculture. The situation is never static. Human interaction with ecosystems in the form of habitat modification and manipulation of gene pools does not stop with the transfer of crops and habitats into new environmental regions but continues there and is likely to lead to further significant changes and innovations. As a result, there may be repeated transfers of crops and habitats which need not all be in the same direction but may, and very often probably do, involve a return of highly modified forms back to an ancestral region. As crops and habitats get shifted around, there is a continuing opportunity for feral and weedy varieties of crops to establish themselves. Such local weed populations constitute additional sources of genetic variability that may contribute to the further development of domesticates through interbreeding and backcrossing. Because of human communication and exchange, often over long distances, the increasing number of populations of a single crop, existing in different areas and under different environmental conditions, represent an ever increasing genetic pool for further manipulation. A modern extreme can be seen in the case of rice: in 1964 it was estimated that the International Rice Research Institute in the Philippines had collected 10,000 races of rice and was using them in breeding experiments to create new varieties (Chang 1964: 49). Recently, it was stated that about 120,000 races of rice are thought to exist world wide and that the IRRI is attempting to collect them all for its breeding program by 1985 (Lewin 1982).

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Given the complexity of this scenario, it should not be surprising that it is often exceedingly difficult to trace the history of particular crops and cultivation systems. Harlan (1971) has suggested that it may, in effect, be impossible to pinpoint specific geographical centers of origin for tropical crops because most of them were domesticated not in a narrow area but in a broad zone of interaction. However, the basic model presented above should apply, at least in principle, to all climatic regions of the world, even though certain aspects may be somewhat more extreme in the tropics than elsewhere. Indeed, Harlan has recently questioned whether the apparent existence of centers of domestication for temperate region crops may not, at least in part, be an artifact of incomplete and biased evidence (Harlan 1975: 56). In any event, it is quite clear that the empirical verification of the model sketched here demands a very large body of highly reliable data from a variety of fields, including archaeology. As the following review will show, Southeast Asian archaeology does not, at present, have such a body of data.[15] What we do have are just a very few glimpses, of low resolution and low reliability. Nevertheless, it is worthwhile to review the material on hand very briefly.

It is, unfortunately, not possible here to consider in detail every scrap of archaeological evidence bearing on the domestication of Southeast Asian and Pacific crops. It would be particularly desirable to assess the bearing of archaeological evidence against arguments put forward by plant geneticists and plant geographers. Since there is insufficient space to do so here, interested readers are advised to consult the relevant literature in that regard. The present paper is primarily concerned with ecological arguments and I will limit myself, therefore, to evaluate the more important cases of archaeological evidence and interpretations in the framework of these arguments.

a) Evidence for Domestication

There are several reasons for the fact that archaeological evidence for the history of domestication and cultivation of Southeast Asian and Pacific crops is still very rare and spotty: a rather small number of archaeological excavations; a largely erroneous but long-held belief that botanical remains do not survive in tropical soils which has discouraged the application of modern techniques to recover such remains in the process of excavations; and a strong emphasis on the excavation of cave sites which, for a variety of reasons, are much less likely to contain domesticated, and particularly cultivated, plant materials than most open sites.

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[15] This is not to say that evidence regarding botanical systematics, plant geography, ethnobotany, ecology, genetics, and cytogenetics is generally adequate and satisfactory.

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Fruits, vegetables, condiments, stimulants, medicines. — Perhaps the most widely known, and most controversial, group of archaeological plant finds is that from the Spirit Cave site (Fig. 2) in northwestern Thailand. There, Chester Gorman excavated in 1966 evidence of the occupation of this small cave by hunters and collectors, dating from about 9,500 to 5,500 B.C. (Gorman 1970). This excavation yielded for the first time a significant number of preserved plant remains, evidently left by the prehistoric inhabitants of the site. Among them are a number of tree crops such as candle nut *(Aleurites)*, canarium nut *(Canarium)*, butter nut *(Madhuca)*, almond *(Prunus)*, terminalia nut *(Terminalia)*, and a chestnut-like nut *(Castanopsis)*; several vegetables, among them cucumber *(Cucumis)*, bottle gourd *(Lagenaria)*, water chestnut *(Trapa)*, possibly pea *(Pisum)*, bean *(Phaseolus)* or soy bean *(Glycine)*, and broad bean *(Vicia* or *Phaseolus)*; as well as mild narcotics or condiments such as betel nut *(Areca)* and betel leaf *(Piper)*. A second excavation at Spirit Cave in 1973/74 added to this list bamboo, hackberry *(Celtis)*, caster oil *(Ricinus)*; as well as bitter melon *(Momordica)*, lotus *(Nelumbium)*, and melon *(Trichosanthes)* or gourd *(Luffa)* (Yen 1977). Excavations at two other caves in the same general region, Banyan Valley Cave and Tham Pa Chan added mango *(Mangifera)* and rice *(Oryza)* (Yen 1977). The occupation of Banyan Valley Cave is tentatively dated from about 3,500 B.C. to A.D. 770; that of Tham Pa Chan from about 5,500 B.C. to 3,500 B.C.

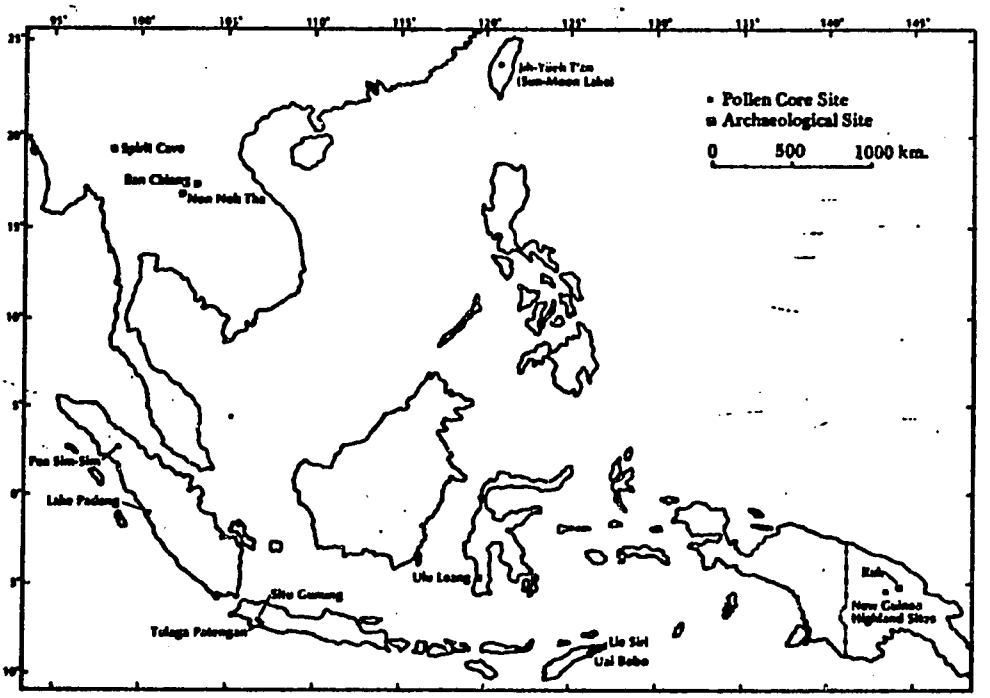

Fig. 2

Map of archaeological sites and pollen core sites mentioned in the text

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The Spirit Cave finds created at first a good deal of excitement, as there seemed to be some reason to believe that some of the remains were of domesticated plants, or at least of plants that were well along the path of domestication (Gorman 1969; Solheim 1969: 131 and 1972: 364). In that case, they would have been among the earliest instances of domestication known at that time. However, the ethnobotanist Douglas Yen, who originally identified the archaeological plant material and subsequently carried out extensive fieldwork in northwestern Thailand, has firmly stated that there is at this time no unequivocal evidence for domestication among these finds (Yen 1977). Most of the tree crops are found wild today in primary and secondary forests in the area. The vegetables are today cultivated in swidden plots and house gardens in connection with a variety of other staples. Some of them have also feral or wild forms in the area. It is, of course, possible that some of the species found in the archaeological assemblage reflect plant/man interactions of the sort discussed earlier in this paper: the dispersal of seeds and cuttings of preferred food plants in the vicinity of camp sites and the eventual development of variants that thrived particularly in the disturbed and enriched habitats typical of such locations. In that case, we would be certainly dealing with plants that cannot simply be classified as wild. Unfortunately, the presently available evidence is insufficient to identify such a situation.

A series of caves in eastern Timor, particularly Lie Siri and Uai Bobo 1 and 2 (Fig. 2), excavated by Ian Glover in 1966/67, yielded an archaeological plant assemblage that overlaps partially with that from Thailand (Glover 1971, 1977, and 1979). The occupation of the sites spans at least 12,000 years from about 12,000 B.C. to the time of Christ or later. In the levels predating 3,000 B.C., candle nut *(Aleurites)*, hackberry *(Celtis)*, betel nut *(Areca)*, pepper/betel *(Piper)*, and Job's tears *(Coix)* were recovered, with hackberry being the most common find. In levels postdating 3,000 B.C., there is no hackberry but a number of other plants appear, among them the Polynesian chestnut *(Inocarpus)*, bamboo *(Bambusa)*, bottlegourd *(Lagenaria)*, and possibly foxtail millet *(Setaria)*. Finally, in the top levels of these sites, several introduced New World crops occur such as peanuts *(Arachis)*, soursop *(Annona)*, and maize *(Zea)* together with Southeast Asian—or generally Asian—natives, including coconut *(Cocos)*, mangosteen *(Garcinia)*, almond *(Prunus)*, and a cucurbit. With the exception of the introduced species, there is again no satisfactory evidence of the status of domestication of these plants. As Glover (1979: 18) points out, the plant assemblages from Thailand and Timor share only a few species, but there is a good deal of similarity between them in terms of the emphasis on fruit trees, stimulants, vegetables, and medicinal or poisonous plants. At the same time, there are virtually no staples in either of the assemblages indicating that they give an incomplete picture of the total subsistence contribution from plants.

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More recently, Ian Glover recovered from Ulu Leang cave in southern Sulawesi (Fig. 2) a considerable amount of prehistoric plant materials (Glover 1976, 1977, 1978, 1979). Occupation of this site dates from about 9,000 to 1,500 B.C. Only a partial and tentative identification of the plant remains is available at present. The excavator has said that there is less emphasis on tree fruits and stimulants in the Ulu Leang finds but that there are more grasses, herbs, and shrubs (Glover 1979: 20). Perhaps of more interest is the presence of abundant remains of rice which have evidently been clearly identified as domesticated *(Oryza sativa)*. The rice grains were associated with a hearth which, however, is so far not reliably dated. In any event, this brings us to the question of rice.

Rice. – Plant geneticists and plant geographers have contributed many and diverse arguments concerning the domestication of rice, the probable wild ancestry of the domesticated species, and the likely geographic region or zone of domestication of this important staple (e.g., Angladette 1966; Chang 1964 and 1976; Grist 1974; Oka 1975; Vishnu-Mittre 1975; Whyte 1977). These cannot be reviewed here. It is important, however, to remind the reader that the major wild form of rice in Asia, *Orzya perennis*, is a perennial adapted to swampy rain forest habitats. A major point in the debate revolves around the question whether the domesticated annual species *O. sativa* evolved directly from *O. perennis*, or whether it derived from an intermediate wild ancestor, possibly an annual that had itself evolved from *O. perennis* with an adaptation to a seasonally dry environment.

If the complex scenario of plant domestication presented above resembles even remotely what happened in history, there can be no doubt that this question, and others, cannot be resolved on the basis of either archaeological or botanical evidence alone. Information from a number of areas such as phytogeography, ecology, ethnobotany, archaelogy, systematics, genetics, and cytogenetics has to be used simultaneously. As indicated above, information from all these areas is presently inadequate, but it is probably most unsatisfactory in the field of archaeology. Unfortunately, in the absence of a solid body of data, phytogeographers and plant geneticists have often taken recourse to hopelessly outdated conjectural reconstructions of Southeast Asian prehistory to support hypothetical models of rice phylogeny and domestication history of their own (e.g., Chang 1976; Grist 1974; Hill 1977). In any event, it is necessary to review very briefly the nature of the archaeological evidence available to date.

Physical remains of prehistoric rice have been found in several Southeast Asian sites, but in all cases there are problems of identification, or dating, or both. The botanical identification of archaeological rice finds is complicated by the fact that the systematics and taxonomy of wild, weedy, and domesticated rices are generally still controversial. Furthermore, as indicated

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earlier, *Oryza* exhibits enormous genetic diversity (indicating at least in part a long history of human manipulation of the gene pool), but a surprisingly narrow range of morphological variation. With regard to the classification of archaeological specimens, the problem has been further compounded by conflating the concepts of domestication and cultivation, so that laboratory investigations of botanical remains were expected to furnish evidence on both aspects simultaneously. It should be clear, however, that botanical specimens can furnish direct evidence only on the status of domestication, not on that of cultivation.

The best known finds are probably from Non Nok Tha and Ban Chiang in northeastern Thailand (cf. Fig. 2). The sites represent a settled agricultural hamlet and a village respectively and have become famous for the apparently very early presence of bronze metallurgy. Rice occurs in the basal layers of both sites (Bayard 1970; Gorman and Charoenwongsa 1976). Unfortunately, there are some unresolved problems concerning the dating of these sites. Thus, the rice finds could conceivably date to as early as about 4,000 B.C. but they could also be between 1,000 to 2,000 years younger (Bayard 1979; Higham 1981; Higham and Kijngam 1982). More important is the fact that botanists have characterized the finds at Non Nok Tha as "intermediate between the wild race and the weed race" (Chang 1976: 146). No official identifications are yet available for the Ban Chiang finds, although intensive work is continuing on the precise botanical characterization of the rice remains from both Non Nok Tha and Ban Chiang (Yen 1982). The already mentioned rice finds from Banyan Valley cave in northwestern Thailand, dating to somewhere between 3,500 B.C. and A.D. 700, have been attributed to a wild form (Yen 1977: 588 and 1980: 142). At this time, the findings from Thailand could fit into a variety of scenarios concerning the domestication of rice.

The rice remains found at Ulu Leang cave in Celebes are of particular interest because they have been classified as fully domesticated *(Oryza sativa)* by the same investigator, T.T. Chang, who judged the finds from Thailand as representing intermediate and wild forms (Glover 1979: 23). It is unfortunate, therefore, that the dating of this find is unresolved.[16] If the originally assumed date of ca. 4,000 B.C. were correct, this would represent the oldest find of fully domesticated rice in Southeast Asia so far. One might also attribute further significance to the fact that the site lies within,

[16] Stratigraphic evidence suggested at first a date of about 6,000 B.P. However, a C14 date on charcoal from the hearth with which the rice grains were associated indicated a date of only about 2,000 B.P. (Glover 1979: 24). Although no final evaluation by the excavator is available at the time of this writing, prudence suggests to accept the more recent date until definitive evidence to the contrary is published.

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or at the edge of, the humid tropical zone. A date of ca. 0 B.C., on the other hand, has at present little influence on arguments concerning the history and ecology of rice domestication.

Since many specific areas within a very large region stretching from India to South China have at some time or other been considered as possible "hearths" for the domestication of rice, we need to touch very briefly also on archaeological finds of rice made elsewhere within that zone. Prehistoric remains of rice have been recovered in a number of Indian sites. They generally date from about 2,000 B.C. or later and at least some of them seem to be confidently identified as domesticated (Glover 1979: 28-30; Vishnu-Mittre 1975). There has also been a report of finds of domesticated rice dating to before 4,500 B.C. (cited in Glover 1979: 29), but I am not aware of any further confirmation. Physical remains of prehistoric grains of presumably domesticated rice have also been recovered in sites of the Dong Dau phase of the Phung Nguyen period in Vietnam with dates ranging between 1,000 and 2,000 B.C. (Davidson 1976: 84; Hà Văn Tãn 1980: 126). Since very little specific detail is available on this archaeological work, however, it is difficult to evaluate both dating and botanical identification. Claims by Vietnamese archaeologists of rice cultivation in "early neolithic" context (Bac-sonian) should at this time be understood as hypotheses or expectations rather than statements based on positive evidence (Davidson 1976: 84; Hà Văn Tãn 1980: 119). Similarly, a number of finds of what is said to be *Oryza sativa* have been reported from sites in both North and South China (Chang 1977; Ho 1975). Not surprisingly, the oldest dates occur in the South and are said to reach back to beyond 4,000 B.C. Again, there is insufficient information for an independent evaluation of dating and botanical determinations of domestication. The latter appear to be quite secure, while there is some reason to hesitate in accepting the dates at face value at this time.

In all, then, the presently available archaeological information is inadequate to reconstruct the process of domestication of rice, or even to test hypotheses developed by plant geographers and geneticists.

Root crops. — In spite of the fact that a number of root crops are among the important staples domesticated in the Southeast Asia—western Pacific region, and that some of them play an essential role in the subsistence economy of many traditional peoples of that region even today, no archaeological remains of these crops have been found whatsoever.[17] It is not possible, therefore, to comment on the history of domestication and cultivation of these staples from an archaeological point of view, and arguments in this regard remain for the time being entirely in the hands of botanists and ecologists.

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[17] However, some carbonized remains of root crops have been found in Polynesia.

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b) **Evidence of Cultivation**

Since domestication and cultivation constitute two different processes of human manipulation of the environment which can occur independently, the finding of domesticated plant remains does not necessarily constitute evidence of agriculture (although such an inference is often correct), nor does the finding of wild plant remains indicate with certainty the absence of it. This state of affairs complicates considerably the archaeological search for evidence bearing on the development of cultivation. For the most part, the archaeological evidence is of an indirect nature. Even when actual cultivation tools (e.g., hoes, digging sticks) or cultivation features (e.g., irrigation canals) are unearthed, they are often difficult to identify and interpret by themselves. This should not be surprising, since cultivation systems are complex systems that involve the interaction of a large number of physical, biological, and cultural variables. Any one of these elements could, in a similar or identifical form, be part of a number of different systems. Reconstruction of prehistoric cultivation systems and cultivation practices involves, therefore, usually multiple lines of evidence.

It was at one time believed that certain technological elements such as polished stone axes and pottery were marks of a "neolithic" phase of cultural development and, by implication, of plant cultivation. It is now known that the archaeological presence of such technologies by itself has little to do with agriculture and that both pottery and axes may be present among hunter-gatherers, while agricultural subsistence systems can exist without either of these elements.[18] This fact, demonstrated well archaeologically, removes from consideration in the present context a large series of finds from Southeast Asia. Nevertheless, there are a few pieces of evidence that do constitute indirect evidence of cultivation.

Glover believes that the appearance between 3,000 and 1,500 B.C. of pottery, the introduction of pig, monkey, and civet cat, and a more or less simultaneous increase in the intensity of use of the sites in eastern Timor indicates "the arrival of some form of agriculture" (Glover 1979: 18). The argument itself is resasonable but, as Glover himself points out, there is no evidence for the particular form of agriculture that may have been present, or the kinds of crops cultivated.

A somewhat similar situation exists in the case of pollen evidence for the removal of native forest vegetation and its replacement with savanna or grassland environments. In certain cases it can be argued that such a change

[18] Examples of hunting-gathering cultures with elaborate pottery may be found in the Jomon Period of Japan (ca. 6,000-850 B.C.; cf. Chard 1974), while archaeological finds from Australia indicate that aboriginal populations there possessed edge-ground stone axes by about 20,000 B.C. (White 1971). The later prehistory of Polynesia furnishes some of the best examples of agricultural societies without pottery (Bellwood 1978).

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could only have been brought about through human interference with the forest climax, that is, agricultural clearing. This is particularly true when the change in pollen spectra is accompanied by a sudden rise in the amount of small fragments of charcoal in the soil which presumably derive from the use of fire in clearing the forest. While such evidence is extremely important, it is often unable to provide specifics about agricultural systems and crop complexes. Evidence of this sort exists in the form of a pollen core from Sun-Moon Lake in central Formosa (Fig. 2) which supposedly shows a dramatic increase in charcoal content around 9,000 B.C. and a steep increase in the pollen of grasses and Chenopodiaeciae around 2,000 B.C. (Chang 1967, 1970; Tsukada 1967). The validity of the 9,000 B.C. date, however, has been questioned (Gorman 1970: 103) and has not been further promoted by the original investigators. Pollen cores from Lake Padang, actually a swamp, in central Sumatra (Fig. 2), show an appearance and quick increase in grass pollen starting around 2,000 B.C., and similar evidence from the Pea Simsim Swamp on the Toba Plateau in north Sumatra (Fig. 2) indicates such a change taking place as early as 5,500 B.C. (Flenley 1979: 122; Maloney 1980; Morley 1982: 181). This has, again, been attributed to human destruction of the natural forest environment and its replacement with a cultivated landscape. Two pollen cores from West Java, taken at Situ Gunung and Telaga Patengan (Fig. 2) show a shift in forest vegetation around 3,000 B.C. The investigators there discount human interference as a cause, at least in part because they consider the date too early (Van Zeist *et al.* 1979: 50; Morley 1982: 181).

The most striking, and most surprising, evidence comes from the Central Highlands of New Guinea from where we have both pollen cores and excavated agricultural features and tools. A significant number of palynological studies have been conducted in the New Guinea highlands. Several cores indicate forest clearance by about 3,000 B.C. followed by more or less periodic fluctuations in forest cover. Among them are Lake Birip, Lake Inim, Draepi Swamp, and Sirunki Swamp, all situated in altitudes ranging from 1,900-2,500 m. (Flenley 1979: 124; Powell *et al.* 1975; Walker and Flenley 1979). At the same time, archaeologist Jack Golson and his associates excavated at Kuk Swamp (Fig. 2), situated in the Upper Wahgi Valley at an elavation of about 1500 m. remains of five different systems of drainage ditches which were constructed and abandoned during alternating periods (Golson 1977). The greatest archaeological surprise after discovery of these drainage canals was the extremely early date for their first construction which goes back to about 7,000 B.C.[19] Unfortunately, in spite of the multiple evidence which

[19] The New Guinea evidence is particularly intriguing from the point of view of history of science. Before European exploration of the Highlands in the early 1930s, it was generally assumed that these forbidding mountains were essentially uninhabited.

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includes also well-preserved wooden tools such as digging spades, it is unknown what crops were cultivated in these drained swamps, and numerous other important details remain unclear as well.

5. Discussion

a) Questions of Sequence

There are a number of traditional concerns regarding the development of domestication and agriculture in Southeast Asia that need to be briefly addressed in the present context. They have to do with proposed sequences of plants or crops undergoing the process of domestication or being taken under cultivation, and their spread from putative centers into out-lying areas.

Traditional views of prehistoric agriculture in Southeast Asia, incorporating sequences of development from slash-and-burn to permanent field systems, from dry to wet cultivation, from dibble stick to plow, and from root crops to cereals, are almost exclusively based on culture-historical interpretations of ethnographic data. They are predicated on a series of, generally implicit, assumptions about cultural organization and change that in almost all cases can be shown to be unsupportable or at least questionable. The most serious and far-reaching of these are: that subsistence practices are essentially a matter of cultural preference; that subsistence practices as well as related cultural elements (mythology, beliefs and ritual complexes, formal aspects of material culture, etc.) are basically conservative; and that plow cultivation of cereals in permanent fields is intrinsically superior and preferable to the cultivation of root crops and the shifting of fields.

Basic ecological considerations as well as the results of a growing series of empirical investigations stand against these assumptions. Although it has been difficult for some western-trained development experts to appreciate this, it is clear that intensive permanent field cultivation is often inappropriate under tropical conditions and can be maintained only at the cost of enormous energy subsidies and at the serious risk of environmental degradation (Janzen 1973). It has also been shown that non-industrial farmers are

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When Europeans finally penetrated these areas, however, they found that some of the highland valleys and plateaux maintained extremely high population densities, in many cases far above those of coastal plains. In the 1950s and 60s, it was thought that this high population density was a relatively recent phenomenon, having come about in the wake of the introduction of the sweet potato in historic times (cf. Watson 1965). This New World crop, it was believed, quickly became the basis of highly productive horticultural systems that would have been impossible with native crops only. The new evidence now indicates that highly intensive cultivation systems were present periodically long before the sweet potato could possibly have been present, even if it was introduced prehistorically, and that these systems were probably associated with substantial populations.

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not at all conservative but are, on the contrary, engaged in constant experimentation and are open to innovation (Johnson 1972).[20] Finally, a variety of studies of development failures have shown that, in most cases, the reluctance of farmers to adopt new crops or cropping techniques has little to do with cultural preferences but rather with a misunderstanding on the part of outside experts of crucial economic relationships operating in small local systems (e.g., cost and supply of labor; cost of flood control versus derived benefits, measured in terms of the local economic system; cost of fertilizer versus benefit of increased yield; benefit of increased yield through chemical weed control versus cost in terms of incidental suppression of minor but important supplemental food sources; etc. Cf. Gladwin 1980).

These considerations are of direct relevance to the question of the culture-historical interpretation of ethnographic subsistence patterns. Taking the example of shifting cultivation systems, these agricultural economies have often been viewed as survivals of some prehistoric stage (commonly identified as "neolithic") of agricultural development (e.g., Linton 1955; Provencher 1975). Such a view assumes a very high degree of cultural and social stasis. Assumptions of this sort are contradicted not only by common anthropological observations of the dynamic nature of social systems, but also by documented cases of agricultural colonists who came from populations that practiced intensive cultivation of permanent fields but reverted to slash-and-burn agriculture in the newly settled land (e.g., Pelzer 1957). It is clear that these were cases of adjustment to changed ecological conditions. Even if one could demonstrate in specific ethnographic cases an unbroken historical connection to a remote prehistoric past, one would still have to assume that the system had undergone a variety of changes over the course of that history. A good demonstration of the openness of "primitive" agricultural economies to innovation can be seen in the fact that all Southeast Asian societies practicing shifting cultivation have incorporated into their economies, to a greater or lesser degree, New World crops (e.g., corn, sweet potato, cassava, etc.). Indeed, in some cases New World crops constitute the dominant staples. The fact that there is a certain amount of correlation between cultivation practices, crops, tool types, and even social organization and spatial patterning among shifting cultivators throughout Southeast Asia is not surprising and cannot be taken as a sign of shared history and common origin. For the most part, such correlations can be comfortably explained through the operation of ecological factors.

[20] If farmers were really so conservative, it would be difficult to explain how agriculture ever developed to the point where it is now. Of course, there is always the *deus ex machina* of introductions through foreign invasions and such. But then, it has to be explained how a highly sophisticated agricultural complex came into existence elsewhere. Are farmers more conservative in some parts of the world and less conservative in others?

This argument does not suggest that ethnographic subsistence systems have no historical background and depth. It does suggest, however, that a historical reconstruction cannot be successful unless it is based on a consideration of ecological and evolutionary principles. Within such a framework, it seems impossible to ascribe historical priority to a particular type of crop or type of cultivation system. As far as crops are concerned, it must not be thought that single natural species were ever manipulated in isolation. Rather, sets of species, or communities, were manipulated that would have varied in terms of the plant types they contained as well as the importance and role particular species had in the subsistence economy. The specific configuration of such sets would have depended on given ecological conditions. It seems likely that both broad groups of Southeast Asian domesticates, originating in the humid and seasonally dry zones respectively, would have included representatives of tubers, cereals, vegetables, fruit trees, and so on. Similarly, the two major cultivation systems do not represent successive stages of development but rather different ecological backgrounds. This does not mean, however, that there may not have been, and probably were, major historic and prehistoric changes in terms of the importance certain crops had in their contribution to the total subsistence effort of human populations in various parts of Southeast Asia. Again, it can be postulated that such changes occurred in relationship to ecological changes in the broad sense, which include environmental transformations brought about through social and cultural changes (e.g., internal population growth, immigration, technological innovation, availability of suitable new cultigens introduced from the outside). It is quite clear, for instance, that the dominant role rice occupies as a staple crop today is, for large parts of the region, a relatively recent phenomenon. However, this has little to do with the antiquity of rice as a cultigen and domesticate.

The historical reconstruction, and the search for empirical evidence, is considerably complicated by the fact that both genetic and environmental manipulations involved in domestication and cultivation make it possible to transfer crops and cultivation systems into different environments. This can, in fact, happen relatively early in the process. It is possible, and even to be expected, that major elaborations and modifications of cultivation techniques occur in connection with such habitat transfers. At the same time, it must also be kept in mind that specific environmental, technological, and sociological conditions may set limits to habitat transfers, and it is here that the explanation has to be sought for the diversity of cultivation practices found in Southeast Asia today, and probably also in prehistory.

The transfer of crops from one environmental zone into another, the independent evolution in different environments of feral and weedy species from the varieties undergoing domestication, back-crossing with these weedy and feral forms, and repeated exchange of domesticated forms between areas and environments can lead to an exceedingly complex and complicated history of these crops. It is unlikely, therefore, that we will be able to pin-

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point for most crops a narrow geographical locus as "the hearth" of their domestication, or that we will be able to reconstruct a simple unilineal history of their development.

One specific argument raised traditionally in favor of a sequential development of a root crop phase followed by a phase of cereal (rice) cultivation must be briefly mentioned. It has to do with the total absence of cereal cultivation in the pre-modern subsistence systems of the Pacific Islands, including New Guinea, and a reliance there on root crop staples. This would indicate, so the argument goes, that the expansion of Austronesian settlers from Southeast Asia into the Oceanic region occurred at a time when these pioneers were familiar with root crop horticulture but not with cereal agriculture. Thus Southeast Asian root crops and other economic plants diffused with them, but not rice. A number of voices have been raised against this argument (e.g., Gorman 1977), but it is most seriously weakened by strong linguistic evidence that the ancestral population(s) of the Pacific Austronesians already had rice cultivation in their subsistence repertoire (Blust 1976). An ecological explanation is probably most compelling in explaining the absence of rice in the Pacific (cf. Bellwood 1980: 66), although we lack at present sufficient information (archaeological, palaeoenvironmental, etc.) to construct a specific argument of that sort with confidence. According to my own view of the human ecology of the region, which leans to the assumption that the earliest phase of the domestication and cultivation of rice occurred in the humid tropics, it seems reasonable to propose that the Austronesian expansion took place at a time when rice cultivation had not yet been adapted to dry tropical environments. As the Austronesians expanded into the relatively arid zone of eastern Indonesia, therefore, it was ecologically advantageous for them to abandon the cultivation of rice and rely on tubers and other crops instead. Consequently, the population directly ancestral to the settlers of the Pacific had neither seeds nor cultivation methods of that cereal to take with them.

b) Aliens in the Field

A word should be said at this point about introduced crops and how they fit into the picture of agro-ecosystems evolution sketched here. Without exception, contemporary agricultural systems, in Southeast Asia and elsewhere, differ very significantly from their prehistoric counterparts because they have incorporated historically introduced crops that originated in distant phytogeographic regions.[21] In the case of Southeast Asia, the

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[21] There are also a few cases of documented as well as suspected long-distance crop introductions in prehistoric times. An example is the introduction of the sweet potato from S. America into Polynesia, possibly as much as 1500 years ago (Bellwood 1979: 140-141; see also Yen 1974).

great majority of introduced species of subsistence crops originated in the Americas. Among them are: corn *(Zea mays)*, sweet potato *(Ipomea batatas)*, manioc *(Manihot esculenta)*, peanut *(Arachis hypogaea)*, pineapple *(Ananas comosus)*, papaya *(Carica candicans)*, avocado *(Persea americana)*, peppers, including chili *(Capsicum* spp.), tomato *(Lycopersicon esculentum)*, to name just some of the more important ones. Also all the major plantation crops of Southeast Asia, with the exception of coconut *(Cocos nucifera)*, represent introductions, among them tobacco *(Nicotiana tabacum)* from S. America, rubber *(Hevea* spp. etc.) from S. America,[22] oil palm *(Elaeis guineensis)* from Africa, and coffee *(Coffea* spp.) from Africa.

In a number of cases, introduced crops have become important staples in Southeast Asian agricultural economies, while in others they figure as essential spices and condiments in local cuisines (e.g., chili pepper). The success of such introductions has a variety of reasons. In general, the transfer of crops from one phytogeographic region to another took place between analogous habitats, be they natural or established and maintained through human manipulation. However, in their native region, the species had coevolved with a host of competitors and predators (the latter particularly in the form of insect pests and disease organisms). In most cases, these "natural pests" were not transferred with the crops, so that introduced crops often show greatly improved vigor and productivity outside their native region (Jennings and Cock 1977).[23] Thus, the introduced species often compared favorably with their native counterparts in terms of productivity, the amount of labor they required in tillage and weed control, and the amount of losses they suffered through insect pests and diseases. In addition, alien species were often able to exist, and produce, under environmental conditions (rain

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[22] Rubber is a particularly interesting case in the present context. There are many families and about 80 genera of plants, found in all tropical floras, that contain a milky sap from which latex can be extracted. One of a number of such plants, native to the Southeast Asian rain forest, is *Palaquium gutta* ("gutta percha"), a member of the Sapotaceae family. This species is still exploited today and is now sometimes grown in plantations. However, the economically most significant rubber trees belong to the genus *Hevea*, with *H. brasiliensis* being the most important and productive. *Hevea* trees are native to the rain forest of lowland S. America and were domesticated around the turn of the century in the context of their introduction to Malaysia and Sumatra and their cultivation there in large plantations (Bücher 1977: 243-252). *Hevea* plantations have, on the other hand, been quite unsuccessful in Brazil, primarily because of problems posed by indigenous pests.

[23] Jennings and Cock (1977) point out that, for several reasons, there is a tendency for agricultural crops to be more productive outside their centers of origin. It is interesting to note in this context that rice is more productive in the seasonal tropics than in the humid equatorial part of Southeast Asia (Grist 1974: 11-12). Some (e.g., Bellwood 1980: 66) have taken this as an indication that rice had originally come under domestication and cultivation in the seasonal zone of the region. The observations by Jennings and Cook would suggest the opposite.

fall, temperature, soils, etc.) under which no native cultigens could be economically raised. Finally, in some cases, there may have been a certain serendipity in the introduction of foreign species. Such species may have furnished minor but very important nutritional complements that interacted with the established diet synergistically and thereby raised the nutritive value of the native subsistence crops in general. Or they might have increased the utility of the native crops by making possible new forms of food preparation and storage.

In general, the fact of diffusion of economic plants between continents may be seen largely as an historical accident in the context of human exploration and expansion. However, the acceptance of such plants into an existing cropping complex is in no way accidental or subject to human fancy and whim. On the contrary, it is predicated on the economics and ecology of a human group. The integration of introduced species into agro-ecosystems is subject to the same dynamics of evolutionary ecology as the development of locally domesticated and cultivated crops.

c) Prehistory, Ecology, and Development

This brings us finally to the question of general relevance of the present discussion. The foregoing essay on the evolutionary ecology of domestication and cultivation in Southeast Asia has primarily focused on the prehistoric development of agricultural patterns and complexes. However, considering the fundamental nature of the principles and processes involved, it can now be stated that they are not solely of academic interest but have some very practical and contemporary implications. Regardless of the degree of human management and technical sophistication, even contemporary and future agricultural systems have to operate within a framework of ecological relationships. An understanding of the ecological and evolutionary principles and processes involved in the development of crops and cropping complexes will clearly be helpful in evaluating both the ecological stability and the evolutionary potential of existing agro-ecosystems. This question is of particular interest and urgency at this time, when many local, national, and international organizations are engaged in deliberately promoting agricultural change, and the rate of genetic and environmental modifications is proceeding at an unprecendented pace.

A series of specific questions might be asked. For instance: Is there a limit to the degree to which genetic and environmental systems can be manipulated? Is there a point at which the efforts expended in the manipulation of natural systems are met with diminishing returns or even become counterproductive? Or indeed, is there a point at which the objects of our interference themselves (populations, species, and communities of plants and animals) are put at risk and we are in danger of effecting the very opposite of our original intent?

It has often been suggested that such critical points do exist (e.g., Myers 1979), although it has been difficult to define them in any specific, yet generally valid, way. This is not the place to discuss this problem in detail. However, what can be asserted is that an understanding of the ecological background and evolutionary history of agricultural crops and systems makes it possible to assess how far human manipulation has removed them from natural conditions, and that this may be taken as a measure of their stability and the relative cost involved in their maintenance.

As argued above, there are, broadly speaking, tree major avenues by which the productivity of selected aspects of the biological environment can be increased in order to increase the carrying capacity of ecological systems from the point of view of human populations (or, more simply, to produce more food for more people). One is by direct genetic manipulation of species; the second is by transferring species into habitats that are relatively free of competitors and predators; and the third is to establish and maintain habitats artificially that give selected species a competitive and productive advantage. As a rule, all three approaches are used in conjunction and interact with each other. It may be suggested that, with regard to all three strategies, the further a situation is removed from a natural state,[24] the more fragile it becomes and the more energy is required to maintain the *status quo*. It can be further suggested that the relationship between energy expended in increased manipulation of natural systems and the food energy harvested in return is not a linear one. On the contrary, this relationship becomes increasingly unprofitable the more highly manipulated such systems are. Eventually, points are reached in these relationships where systems will collapse or where energetic relationships will show a negative balance. An excellent example of the latter situation may be seen in many highly manipulated agricultural systems in the United States, where more energy in the form of fossil fuels, fertilizers, and pesticides is invested in the process of agricultural work than is harvested from the fields in the form of food or industrial crops.

The point of these remarks is not to propose a pat formula by which to measure the robusticity and development potential of a given agro-ecosystem. Too many theoretical as well as empirical questions remain to be solved. However, I believe that the general point is valid and that an appreciation of the principle may have a positive effect on the perception of agricultural experts and planners. It can be said that, in a manner of speaking, the future lies in the past. The natural resources we manipulate have evolved in the

[24] It is difficult to define precisely what constitutes a "natural state," since ecosystems are constantly changing in relation to a variety of sources of perturbation and change. Very roughly, however, I would suggest to consider native climax communities as a natural baseline.

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context of broad ecological relationships. This natural historical dimension inexorably defines boundary conditions for a successful human interaction with the environment.

Writing of this essay was assisted by a grant from the Joint Committee on Southeast Asia of the Social Science Research Council and the American Council of Learned Societies. While writing the essay, I held concurrent fellowships at the Center for Asian and Pacific Studies, University of Hawaii, and the East-West Environment and Policy Institute, East-West Center, Honolulu. I am also indebted to many friends and colleagues with whom I have discussed portions of this article and who have contributed valuable ideas and corrections, foremost among them R.I. Ford, T.N. Headland, L.R. Heaney, A.T. Rambo, and W.G. Solheim II. The final responsibility for statements made here remains my own.

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