Part III

INTEGRATIVE CASE STUDIES
living scattered throughout the rain forests of Peninsular Malaysia are small aboriginal populations. Known collectively by the Malay term "Orang Asli," meaning "original people," their social systems have evolved over thousands of years of selective pressure from the forest environment. The resulting biological, social, and cultural adaptations have been much discussed in the ethnological literature (Rambo 1979b). Less commonly recognized is the fact that the Orang Asli have also exerted selective pressures on the rain forest ecosystem, causing it to have different characteristics than would be the case in a truly pristine situation. The reality is thus one of coevolution with human social systems adapting to conditions of life in the rain forest while the rain forest ecosystem simultaneously is modified by human activities. It is with these complex interactions between Orang Asli social systems on the one hand and the tropical rain forest ecosystem on the other that this chapter is concerned. It will first describe

1 Virtually nothing is known about the prehistory of the Orang Asli although at least one archaeologist has suggested that the Semang and Senoi are descended from the Hoabinhian cultures that inhabited the peninsula at the end of the Pleistocene period (Solheim 1980). The Proto-Malays appear derived from more recent immigration from Indonesia, a process that has continued into the present era, as in the case of the Orang Kubu who came to Selangor from Sumatera following World War II (Ali M. A. Rachman: pers. com.). The politically dominant Muslim Malay population is in part derived from Proto-Malays who early converted to Islam, in part from 19th century immigrants from Indonesia.
the ethnological background, then examine the nature of Orang Asli ecological adaptation, followed by consideration of their impact on the tropical rain forest ecosystem. Finally, a few concluding comments will be made on the probable future of the Orang Asli in the rapidly changing environment of modern Malaysia.

ETHNOLOGICAL BACKGROUND

The approximately 50,000 Orang Asli are found living in hundreds of isolated settlements scattered widely across thousands of square kilometers of rugged forested terrain. Not surprisingly under such conditions, considerable biological and cultural differentiation has occurred with more than a score of distinctive ethnolinguistic “tribal” groupings recognized by ethnologists. In fact, real diversity is far greater than is admitted by the tribal taxonomy with every local population displaying at least some distinctive features from even its closest neighbors. Among the Temuan Proto-Malays, for example, at least three major cultural subdivisions are recognized by the people themselves.

Confronted with such diversity, ethnologists have developed a simplifying system of classification that lumps all the hundreds of local populations into three major ethnic categories. First adumbrated by Skeat and Blagden (1906) in their pioneering study, *Pagan Races of the Malay Peninsula*, the tripartite classification was given its modern form by Father Paul Schebesta (1926) who proposed that the aboriginal peoples of the Malay Peninsula could be classified into three distinct ethnic groups, which he labeled as the Semang, Sakai, and Jakun. With minor terminological modification (Negrito is sometimes substituted for “Semang”; Senoi has replaced the pejorative “Sakai”; Proto-Malays, the too-limited “Jakun”), this classification remains to the present day the unchallenged Malayan trinity in ethnological descriptions of Southeast Asia.

According to Schebesta’s classification, each of the three aboriginal ethnic groups displays the following racial, linguistic, and cultural attributes:

**Semang (Negritos):** Very short (under 1,500 mm) with long trunk and arms, dark, almost black skin color, dark-colored hair having wooly or spiral form. Speakers of distinctive Austroasiatic languages having somehow lost their original Negrito language. Culturally very primitive nomadic hunters and gatherers who have retained their original monotheistic religion.

**Senoi (Sakai):** Slight in build but taller (> 1,520 mm) and with fairer skin than the Semang. Wavy, dark-colored hair often displaying a chestnut tint. Speakers of Austroasiatic languages closely related to those spoken by the Montagnards of Indochina. Culturally more evolved than the Semang, the Senoi are shifting cultivators living in large extended family dwellings and believing in animistic religions.

**Proto-Malays (Jakun):** Physically closely resemble the Muslim Malays with heavier body build and darker skin color than the Senoi. Straight or
lanky dark-colored hair. Speakers of Austronesian languages, the Proto-Malays are culturally the most evolved aboriginal group engaging in large-scale horticulture with a complex social organization.

This classificatory scheme, encompassing racial, linguistic, and cultural attributes, all set in a progressive cultural-historical sequence, reflects nineteenth century unilinear evolutionary assumptions. For Schebesta assumes not only that race, language, and culture form stable associations that persist through time and across space, but he also assumes that such ethnic assemblages represent from the cultural-historical point of view "three stages of development, although it must not be assumed that any one of them is based upon another" (Schebesta 1926, 276). In his scheme, therefore, the supposedly most primitive Semang are seen as the earliest wave of migration to reach Malaya. Subsequently the more advanced Senoi arrived and pushed the Semang into marginal areas of the peninsula only to be themselves displaced by the even more advanced Proto-Malays.

While virtually no modern anthropologist would accept the premises on which Schebesta's classification is built, it still continues to be used as the organizational framework in the most recent accounts of Orang Asli ethnology (Carey 1975, LeBar et al. 1964). This is unfortunate because its static nature impedes thinking about the dynamics of ethnic diversification, a central question in considering the evolving relationship of the Orang Asli to the Malaysian environment. If, however, the assumption that the Semang, Senoi, and Proto-Malays represent stable racial-linguistic-cultural types who came to Malaysia in discrete waves of migration is cast aside, and instead the view adopted that these groupings roughly correspond to three distinct kinds of ecological adaptation (Rambo 1982), then the classification still has utility. From this perspective, which is the one employed in this chapter, Semang refers to nomadic foragers, Senoi to swidden farmers, and Proto-Malay to complex horticulturalists.

At present, the three categories of Orang Asli occupy discrete, nonoverlapping habitats. The Semang occupy the foothills of the Main Range in the northern and northeastern parts of the peninsula; the Senoi are found in the central Main Range, while the Proto-Malays are spread across the southern part of the peninsula, primarily in the interior valleys. According to the 1970 census, there were approximately 53,000 Orang Asli of which some 2,000 were Semang, 30,000 Senoi, and 21,000 Proto-Malays (Carey 1975, 8-11).

ADAPTATION OF THE ORANG ASLI TO THE TROPICAL RAIN FOREST ECOSYSTEM

The idea that human societies are somehow fitted to specific environments is an old one in Western thought, but it was only with the emergence of an ecological perspective in the social sciences in recent years that systematic investigation of human adaptations began (Rambo 1979a). Such research suffers from serious theoretical problems, especially its often
tautological character (if an institution exists it must, by definition, serve an adaptive function) and a continuing failure to identify the unit (individuals, societies, cultural traits?) on which natural selection acts in sociocultural evolution. Despite such limitations, considerable insight has been gained into human adaptation to the environment.

Unfortunately, as I have elsewhere pointed out (Rambo 1979b), no one has as yet published a systematic description of the ecological adaptation of any specific Orang Asli community. Instead, the existing literature contains dozens of scattered references to the posited adaptive functioning of a variety of social institutions in different Orang Asli groups. Rather than attempting to synthesize these into some sort of generalized comprehensive model, it appears more profitable to examine a few specific cases in greater depth. Four different kinds of adaptation have been selected: (1) biophysical characteristics, (2) population dynamics, (3) weapons technology, and (4) environmental knowledge.

1. Biophysical characteristics: Virtually all research done prior to the 1950s on the biology of the Orang Asli was based on the assumption that physical characteristics were significant as racial markers—stable and persistent indicators of genetic affiliation. Thus, if short, dark-skinned, frizzy-haired people were found in Peninsular Malaysia, as well as in the Andaman Islands and the Philippines, this was taken as evidence that a “pygmy” race once extended over all of Southeast Asia. It was even believed that there must be a genetic connection between the Southeast Asian Negritos and the pygmies of central Africa.

In the 1950s, however, physical anthropologists recognized that many supposedly stable racial traits actually had adaptive significance and thus were subject to selection under changing environmental pressures. It was demonstrated, for example, that abnormal hemoglobins, such as the sickle-cell trait commonly found among black Africans, were adaptations to endemic malaria. Similarly, the big incidences of Hemoglobin E and GP6D deficiency among Malaysian aborigines also very probably represent response to malarial selection (Livingstone 1967, Lie-Injo and Ganesan 1977).

If one looks at reported physical differences between the Semang and the Senoi from such an evolutionary perspective, a new hypothesis explaining the existence of these two groups is suggested: Rather than representing two successive racial waves of migration into the peninsula, they may have arisen in situ by a process of divergence from a single, common ancestral population, with many of their supposed racial differences actually reflecting their adaptation to differing habitats.2

A tentative reconstruction of this process would be that some ten thousand years ago, before the beginnings of agriculture in the peninsula,

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2 Solheim (1980) has proposed a similar hypothesis from an archaeological perspective.
populations ancestral to the Orang Ali were primarily living along the coast and in major river valleys, reflecting the relatively greater abundance of food resources in such ecotone situations, in contrast to the scarcity of foods consumable by man in the deep forests (see in this regard the chapters by Marten and Hutterer in this book). The subsequent development of agricultural settlements in the coastal zones, which also served as exchange centers for the developing overseas trade in forest products, created a new niche for groups specializing in the collection of forest products that could be traded for the food needed to sustain nonfarming forest collecting populations, which over time became ethnically identified as the Semang. The adoption of swidden agriculture also permitted farming populations to establish themselves in the interior mountains where they became ethnically identified as the Senoi. Therefore, biological and cultural differentiation may have occurred because the forest collectors (Semang) and the swidden farmers (Senoi) occupied very different ecological niches.

If we compare the characteristics of their niches to the physical characteristics of the ideal type Semang and Senoi described by Schebesta, we find that all differences between the two groups are in the directions that one would predict based upon ecological theory (Table 15.1). The Semang appear biologically well adapted to life as nomadic foragers in the hot, humid, dimly-lit lowland rain forest; the Senoi, on the other hand, appear well adapted to working as farmers in cooler, less humid, sun-lit fields in the mountains. Admittedly, correlation does not establish causality, but in this case, I doubt that we are dealing with the accidental outcome of random events.

Population dynamics: Fertility in primitive human populations is often assumed to be a purely natural phenomenon, with fecundity at the biological maximum, and runaway population increase contained only by the grim checks of Malthusian theory. Recent research on hunters and gatherers has indicated that such a view is incorrect. Instead, such populations often display low fertility rates reflecting culturally sanctioned family planning. A recent comparative study by Gomes (1979, 1982) of the population dynamics of the Jahai Semang and Temuan Proto-Malays provides convincing evidence that the practice of fertility control is directly related to the mode

3 Benjamin's (1976) reconstruction of the historical development of the Semang and Senoi languages provides interesting linguistic support for this hypothesis. He argues that the principal Semang languages (Northern Aslian) and the Senoi languages (Central Aslian) have evolved from a common ancestral Proto-Aslian language. Using the admittedly less than perfectly reliable method of lexico-statistics, he dates the beginning of their divergence as separate languages as some time between 6610 and 6410 years ago, a period he believes to coincide with the introduction of agriculture into the peninsula. Benjamin has also forcefully argued (1980) that the Semang and the Senoi (and even the Malays) basically share a common fundamental cultural base despite the many differences of detail reflecting their distinctive modes and adaptation. He still appears, however, to accept the conventional view that the Semang are genetically descended from an ancient Negrito racial stratum whose original language was somehow lost and replaced with "Proto-Aslian."
### Table 15.1. Comparison of Ecological Niches and Physical Adaptations of Semang and Senoi

<table>
<thead>
<tr>
<th></th>
<th>Semang</th>
<th>Senoi</th>
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<tbody>
<tr>
<td>1. Ambient temperature</td>
<td>Constant, warm; Average 78°F; Daily range 71°—90°</td>
<td>Variable, cool; Average 64°F; Daily range 55°—73°</td>
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<tr>
<td></td>
<td>Small stature and elongated extremities increase rate of metabolic heat loss (Bergmann and Allans Rules)</td>
<td>Larger stature reduces metabolic heating requirements</td>
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<td>Dark skin color may enhance radioactive heat loss at certain wavelengths</td>
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<td></td>
<td>Spiral hair form permits increased cranial heat radiation</td>
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<tr>
<td>2. Relative humidity</td>
<td>Constant, high; Average 85—90%</td>
<td>Variable, low; 65—75%</td>
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<tr>
<td></td>
<td>Flattened nose with broad nostrils (nasal index 97)</td>
<td>Longer narrower nostrils (nasal index 69) moisten drier air</td>
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<tr>
<td></td>
<td>Dark skin color (Gloger’s Rule)</td>
<td></td>
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<tr>
<td>3. Solar radiation</td>
<td>No direct exposure under forest canopy</td>
<td>Extended exposure to intense radiation in high elevation swidden clearings</td>
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<tr>
<td></td>
<td></td>
<td>Light skin color increases reflectivity and reduces heat load</td>
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<tr>
<td></td>
<td></td>
<td>Chestnut hair color increases reflectivity and reduces heat load</td>
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<td></td>
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<td>Wavy hair form shields head from direct radiation</td>
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Table 15.1. (Continuation)

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<th>Semang</th>
<th>Senoi</th>
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<td>4.</td>
<td>Nutritional stress</td>
<td>Supply of carbohydrates limited and erratic</td>
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<td></td>
<td>Limited and erratic</td>
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<tr>
<td></td>
<td>Small stature minimizes caloric demands</td>
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<td>5.</td>
<td>Mobility</td>
<td>Nomadic foraging</td>
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<td></td>
<td>Nomadic foraging</td>
<td>requires frequent rapid cross-country</td>
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<tr>
<td></td>
<td>travel through forest</td>
<td>travel through forest</td>
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<tr>
<td></td>
<td>Small stature allows</td>
<td>Small stature allows</td>
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<td></td>
<td>easier movement through forest</td>
<td>easier movement through forest</td>
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<tr>
<td></td>
<td>undergrowth</td>
<td>undergrowth</td>
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<tr>
<td>6.</td>
<td>Labor power</td>
<td>Foraging and blowpipe hunting</td>
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<tr>
<td></td>
<td>Hunting requires light</td>
<td>hunting requires light</td>
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<tr>
<td></td>
<td>Labor input</td>
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<td>7.</td>
<td>Human predation</td>
<td>Slave raiding by</td>
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<td></td>
<td>Slave raiding</td>
<td>neighboring Malays a</td>
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<td>constant threat (until late nineteenth</td>
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<td></td>
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<td>Dark skin color is effective</td>
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<td>camouflage under forest conditions</td>
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of ecological adaptation. The Semang have low fertility, whereas the horticultural Temuan have a much higher birthrate. This difference reflects deliberate efforts at birth control on the part of the Semang, who use a variety of herbal contraceptives as well as having a strongly enforced postpartum sex tabu lasting for two or more years, whereas the Temuan make much less use of contraceptives and refrain from sexual intercourse for only a few weeks after childbirth.

According to Gomes, the Semang practice birth control because having more than one small child to carry at the same time would interfere with the ability of a woman to participate in the frequent movements of these forest
nomads. Moreover, caring for children reduces her economic productivity while children are, in any case, an extra burden on the family economy rather than a productive asset. In contrast, Temuan children contribute valuable labor to agricultural activities from an early age and place much less of a restriction on their mothers' economic activities, which are largely centered in the settled village and its nearby fields.

Rather dramatic confirmation of Gomes's argument that high fertility is an adaptation to a settled agricultural mode of life is provided by the fact that birthrates soared among the Semang bands he studied following their relocation into a government-sponsored agricultural development project. In this permanent settlement, women no longer have to be highly mobile and children, who receive a generous school food ration that they share with the rest of their family, are a positive economic asset.

3. Weapons technology: The blowpipe is the best-known weapon of the Orang Asli. Some two meters in length with a bore about one centimeter in diameter, it can project its poisoned dart accurately out to a range of 20 to 30 meters. It is a weapon well suited to hunting in the rain forest where the bulk of small game animals live in the upper canopy, out of range of hand-thrown weapons such as spears. Its darts are not lethal, given their light weight and low muzzle velocity, but they are coated with a poison made from the sap of the *Ipoh* tree (*Antiaris toxicaria*) that can, given sufficient time, kill even large animals, including man. The Orang Asli, however, generally restrict the use of blowpipes to hunting squirrels, monkeys, and birds, with the Senoi and Proto-Malays using traps to catch larger game animals such as wild pigs and deer.

It is a curious ethnological fact that while all of the Orang Asli tribes now use blowpipes, until relatively recently many of the Semang used bow and arrows to hunt large game animals, with the last of these weapons dropping out of use in the early 1900s. There has been considerable speculation among anthropologists as to why the Semang changed from using bows to blowpipes. Both Schebesta (1954, 67) and Endicott (1974, 113) have suggested that blowpipe hunting gives marginally better returns than bow hunting so that over time cultural selection would favor the former weapon. This may be true but then one must ask why the Semang only made the change so recently. I have elsewhere suggested (Rambo 1978) that the bow was displaced not by the blowpipe but by firearms, which only became available to the Orang Asli around the turn of the century. Guns are clearly superior to bow and arrows for hunting large game animals. The blowpipe, on the other hand, is both cheaper and more efficient than either guns or bow and arrows for hunting smaller, tree-dwelling animals so that it was retained as a weapon when bows were given up. Once abandoned, the use of bows could not readily be taken up again because far longer practice is required to become proficient in archery than is needed to shoot a blowpipe. Hence, when imposition of more effective government control over the firearms trade in the post-World War II period cut off the supply of guns and ammunition to the Semang, they were
unable to return readily to using the bow and arrow and were left with only the blowpipe as their primary hunting weapon. This has put the Semang in the curious situation of lacking the technology necessary to effectively kill large game animals since, unlike the Senoi and the Proto-Malays, they have little skill in making traps. As a consequence of this technological change, the Semang, who are often referred to as hunters and gatherers, actually consume meat less frequently than do the agricultural Senoi and Proto-Malays.

4. Orang Asli environmental knowledge: Dunn (1975) has pointed out the critical role that environmental knowledge plays in the adaptation of the Orang Asli to the forest ecosystem. Because the tropical forest is such a complex system, people who live in it must possess an amazingly detailed knowledge of its components. This is shown by the possession by all Orang Asli groups so far studied of extremely comprehensive classification systems for plants, mammals, and birds (Rambo 1980). Any normal adult Temuan, for example, can identify literally hundreds of plant species although the taxonomic criteria employed are very different from those used by a scientific botanist, and consequently Temuan and Linnean species lists are not isomorphic (Stephenson 1977). The Orang Asli tend to be “splitters” with regard to cultivated crops and fruits, “lumpers” when confronting noneconomic plants such as mosses and ferns. Similarly, they distinguish mammals and birds much more carefully than they do most kinds of insects, which are important to them mostly because of their nuisance value.

With regard to other domains of environmental knowledge, there is considerable variation between the three categories of Orang Asli. None of the groups have a detailed system of classification for stones, which play a generally insignificant role in their technology; but the Semang, who make the most use of stones, also appear to have the most elaborate naming system. In contrast, the Semang lack even a native term for stars, probably reflecting the lack of astronomical, observational opportunities for a forest foraging people, whereas the Temuan Proto-Malay horticulturalists identify several constellations, whose appearances have calendrical significance in their annual agricultural cycle (Rambo 1980, Stephenson 1977).

The principal adaptive significance of Orang Asli environmental knowledge is that it gives them a competitive advantage over other Malaysian ethnic groups in exploiting forest resources. What is a familiar and comfortable environment to the aborigines is an alien and hostile world to their coastal-oriented neighbors. All possess essentially the same material technology but only the Orang Asli have the necessary background knowledge to use it efficiently and safely. The others are, as Hutterer (1977, 793) observes, locked out of the forest ecosystem by their lack of adequate mental maps to its complex reality.
ORANG ASLI IMPACT ON THE TROPICAL RAIN FOREST ECOSYSTEM

Ecologists have often underestimated the impact that primitive societies have on the environment. Richards (1973, 25), for example, asserts that the Orang Asli have had “. . . no more influence on the vegetation than some of its other animal inhabitants.” Certainly, when looking at the vast expanse of rain forest carpeting the Main Range, it is hard to imagine how a thinly scattered human population equipped only with axes and blowpipes could exert much ecological influence, but I think that the available evidence support the conclusion that Orang Asli activity has profoundly modified the structure and functioning of the rain forest ecosystem. Their impact has been exerted in four ways: (1) direct selection, (2) dispersal, (3) habitat modification, and (4) domestication. Each of these types of impact will be discussed in turn below.

1. Direct selection: Man, as a heterotroph, is wholly dependent on plants and animals for his energy supplies. The foraging Semang meet their nutritional requirements by hunting, fishing, and collecting wild species and thus function as a selective agent for these species. Experts differ about the extent to which primitive hunters have affected animal populations. Some archeologists (Martin 1973) have attributed the extinction of the North American Pleistocene megafauna to overhunting by the paleo-Amerindians. T. Harrison and B. Harrisson (1969-70) argued that the tapir, tiger, and giant pangolin (Manis palaeojavanica), fossil remains of which have been found in Niah Cave in Sarawak, were all “exterminated by the aggressive hunters of Borneo in the past,” a claim strongly and convincingly contradicted by Medway (1977). Such dramatic extinctions do not in any case appear to have occurred in the peninsula but hunting by Hoabinhian and successor Orang Asli populations may have exerted selective pressure on many local animal populations. Faunal remains recovered from several Hoabinhian archaeological sites in the peninsula indicate that a wide range of species were killed by these early hunter-gatherers. Remains of the Lesser One-horned or Javan Rhinoceros (Rhinoceros sondaicus), Selalang or Gaur (Bos gaurus), Serow (Capricornis sumatrainsis), Barking Deer (Multiacus muntjak), Sambar Deer (Macaca nemestrina), along with other unidentified primates, various squirrels, porcupines (Hystrix sp.), Malayan Sun Bear (Helarctos malayanus), tortoises and soft-shelled turtles, Bamboo Rat (Rhizomys sp.), and many species of marine and freshwater bivalves, snails, and fish have all been found in their camp sites (Gorman 1971).

Contemporary Orang Asli populations exploit an equally wide variety of wild animal species. The Jahai Semang observed by the author in Kelantan

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4This section is based in large part on a paper that I presented to the SABRAO (Malaysia) Workshop on Genetic Resources of Plants, Animals, and Microorganisms held at the University of Malaya, May 19-20, 1978, and was subsequently published under the title “Primitive man’s impact on genetic resources of the Malaysian tropical rain forest” in Malaysian Applied Biology 8(1):59-65. 1979.
catch and eat virtually all animals found in their habitat with the exception of snakes, earthworms, leeches, and some terrestrial snails that are tabu for ritual reasons, but heaviest hunting pressure is exerted against wild pigs, monkeys, and squirrels. An indication of the extent of Orang Asli hunting pressure on wild species is provided by records kept by one of my students of animals killed by ten Temuan Proto-Malay households over a ten-day period in the Ulu Langat District of Selangor. Using shotguns, blowpipes, catapults, and traps, they killed a total of 92 animals including 4 wild pigs, 45 birds, 5 porcupines, 15 monkeys, 15 frogs, 5 monitor lizards, 1 barking deer, 1 snake, and 1 flying fox. The same ten households caught 191 fish of eight species during the same period (Zainuddin 1977).

Little information is available on prehistoric aboriginal man's use of plants, but contemporary Orang Asli know and utilize a wide range of wild plant species for food, medicine, and making of cultural artifacts. No complete inventory has been made for any aboriginal group but another of my students, in a brief survey, identified several dozen species named and used by the Temuan of Ulu Langat (Stephenson 1977).

The nomadic Semang, in particular, are heavily reliant on wild plants for their supply of carbohydrates, collecting wild yams and other tuberous plants in great number (Endicott 1979a). In some cases they are said to reset the tops to promote further growth; but in other cases that I have observed among the Jahai Semang, they make no effort to ensure such regeneration. More devastating for floristic resources than gathering for direct consumption is collection of plants and plant products for trade with the external market system. Rattan, petai (Parkia speciosa) and kerda (Pithecellobium jiringa), and numerous different medicinal plants are gathered in vast quantities by the aborigines for sale to Malay and Chinese middlemen. That this trade in forest products is a very ancient one in Malaysia has been shown by Dunn (1975). Many forest areas today are almost denuded of rattan because of over-exploitation, while at the turn of the century ruthless overcutting killed off many of the trees providing “dammar” resin for the lucrative export trade.

Slash-and-burn agriculture as practiced by the aborigines may also exert considerable selective effect on the floristic composition of the forest. In clearing plots certain large white-barked trees, called “tualang” (Koompassia excelsa), are left standing because their wood is so tough that, as one of my Jahai informants said, “the axe can’t eat it.” This tree is a popular nesting site for wild bees, which is another reason that it is not cut by the Semang who are avid honey collectors.

2. Dispersal: In a paper published in 1983 “on the dispersal of seed by mammals,” Ridley called attention to the role played by the Orang Asli in spreading of fruit trees in the forest. He observed that seeds of rambutans were often swallowed whole and later germinated near deserted encampments where they had been excreted. When walking in the forest with Orang Asli, I have several times observed them picking wild fruits, which they then proceed
to eat as they walked along the track casting the seeds down as they went. As tracks tend to have disturbed soil surfaces and to be more open to sunlight than the forest floor, the chances of successful germination of such seeds are presumably higher than in the deep forest.

Numerous cultigens such as manioc, pineapple, papaya, banana, areca palm, coconut palm, and marigold are also introduced by the Orang Asli into their swidden plots inside the forest. At least some of these plants, especially the areca palm, pineapple, and banana, often persist in a feral state for many years after these temporary clearings are abandoned and succession back to forest has begun. I have visited settlement sites abandoned at least 20 to 30 years earlier and now covered with forest that are still identifiable by the high concentration of palms and fruit trees. Some of these feral plants, especially fruit trees such as durian and rambutan, may backcross with wild relatives, thus altering the genetic pool of the forest varieties.

3. Habitat modification: The Orang Asli modify the habitat of forest organisms in two ways: First, their mere presence establishes a new component of the forest ecosystem with which other components establish interactive relationships, and second, their activities cause changes in a wide variety of ecosystem variables.

Simply by being present in the forest ecosystem, man provides a food resource to other organisms. The Jahai Semang, for example, have a well-founded fear of tigers stemming from their having killed Jahai within the memory of living people. The aborigines, however, are probably a much more important food source for smaller parasitic forms such as leeches, mosquitoes, various protozoa, and other disease organisms, many of which are specifically adapted to human hosts.

It is man's ceaseless activity rather than his mere presence that results in the most significant changes in the forest ecosystem. Orang Asli agricultural activities have a particularly profound impact on the habitat. Clearance of even relatively small plots can radically change the microclimate of the area. The plant community is vastly simplified compared to the complex community of the rain forest, and the faunal species inventory is correspondingly reduced. In a ten-day study of a swidden field west of Jeli in Kelantan, I observed only eight species of resident birds (Greater Coucal, Giant Spinetail Swift, House Swift, Common Brown Babbler, Yellow-vented Bulbul, Magpie Robin, Wren-Warbler, and White-rumped Munia) and seven occasional visitors over a nine-day period. All are species known for their opportunistic character in exploiting disturbed habitats. In contrast, Dunn (1975) reports observing about 130 species in an undisturbed forest area in Ulu Selangor.

While any single swidden plot is impoverished in species diversity in comparison to the mature forest, the aggregate effect of Orang Asli shifting cultivation is to create within the total area they are exploiting a very complex mosaic environment, composed of patches in various stages of succession from newly cleared and planted fields through scrub (belukar) to
20- or 30-year-old secondary forest. This mosaic as a whole supports a far greater diversity of plant and animal life than would a comparable area of unbroken climax rain forest. It can be argued that the major impact of the Senoi and the Proto-Malays on the rain forest ecosystem is their generation of greatly increased patchiness. Even the Semang may have some impact in this regard, with each of their overnight campsites representing a mini-patch where existing vegetation is cut down to clear space for the shelters and the soil surface disturbed and enriched by human activities.

Few mammals are found near occupied human settlements; but swiddens that have been recently abandoned, or that are isolated from settlements, are favorite foraging grounds for wild pig, various deer, and the seladang. Wharton (1968) has suggested that the very survival of wild cattle in Southeast Asia is linked to the grazing opportunities provided by abandoned aboriginal agricultural clearings, while Medway (1977) has made a similar suggestion with regard to the Malaysian tapir.

Forest clearance also provides ideal breeding conditions for the Anopheles maculatus, the major malaria vector in the uplands of Malaysia, which requires clear, moving, sun-lit streams for its larvae. Human settlement sites also offer desirable niches for a number of species, in particular cockroaches and houseflies, which cannot survive in undisturbed forest. The rubbish tips associated with human settlements offer zones of enhanced soil fertility and hence ideal nurseries for a variety of plants. Some theorists such as Sauer (1963) have even suggested that agriculture originated on the basis of "weeds" that colonized such tips.

Practice of swidden agriculture on tropical soils, if continued for a long enough period, may lead to ultimate exhaustion of the supply of nutrients with consequent changes in the faunal communities supportable by these soils. Stark (1978) suggests that some tropical soils in the New World may have a "biological life span" of under two hundred years if exposed to slash-and-burn cutting on a thirty-year cycle. Such exhausted soils can support only the earliest successional stages as may be the case with some overexploited lateritic soils in Malaysia that can only support Imperata grass similar to the kind described by Sajise in Chapter 8. In general, however, aboriginal populations have been too small and widely dispersed to have had any significant impact on soil fertility. The question should be raised, however, although available data are wholly insufficient to answer it, of the long-term effects of the external trade in forest products on the nutrient balance of the interior rain forest ecosystem. As already noted, Orang Asli have engaged for thousands of years in collecting rattan, gums and lacquers, and medicinal plants to exchange for metal tools, cloth, and rice with Chinese traders. Quantities extracted per hectare per year are, of course, small but the outflow of nutrients contained in these products over a period of several millenia may possibly represent in aggregate a substantial drain on the limited nutrient pool of the forest ecosystem.
4. Domestication: As Hutterer makes evident in his chapter in this book, one of the few things about which archaeologists concerned with Southeast Asia agree is that domestication must be seen as a long-term, ongoing process rather than as a discrete event: To speak of an "agricultural revolution" as we speak of the "industrial revolution" gives a wholly misleading impression of an evolutionary change process that began some 15,000 years ago and is still continuing among the aboriginal populations of Malaysia. In the course of this evolution, man's relation to several plant and animal species has gradually shifted from that of predator to protector to producer of new varieties.

Even hunters and gatherers, who are generally thought of as purely predatory, actually show amazing knowledge of the propagation and growth habits of many useful wild plants and systematically apply this knowledge to manipulate their productivity. As was already mentioned, the Semang sometimes reset the tops of wild yams they have harvested to ensure their regeneration. The Jahai Semang, as well as other Orang Asli such as the Temuan, also deliberately set fire to wild clumps of bamboo each year. The burning clears away the accumulated litter, making it easier to cut the bamboo and also, according to my informants, promotes the vigorous growth of new shoots.

The step from such protective manipulation of wild plants to actual domestication is not a big one, and it has probably been taken many times in the past by different forest populations with regard to many different species. A Temiar group that I studied in Ulu Kinta, Perak, is presently actually taking this step with regard to domestication of the leguminous tree petai (Parkia speciosa). With no encouragement or support from scientists or government agencies, they have begun collecting petai seedlings in the forest and transplanting them into their swiddens in order to establish permanent orchards. They have carefully noted which plants do well and which fail in the new environment and now only draw on those wild stocks that appear best adapted to cultivation.

Domestication of animals presumably followed a similar pattern. Contemporary Orang Asli keep a wide variety of wild birds and mammals as pets including pigs, monkeys, bamboo rats, woodpeckers, etc. The keeping of captured baby jungle fowl and wild boar may have resulted in the domestication of the chicken and the pig--Southeast Asia's most important contributions to modern livestock resources.

THE FUTURE OF ORANG ASLI RELATIONS WITH THE MALAYSIAN ENVIRONMENT

Orang Asli social systems and the rain forest ecosystem have coevolved over millennia reaching in the process an accommodation compatible with the survival of both man and nature. Current rapid development of the natural resources of the peninsula is threatening this accommodation. Vast areas of forest have been cleared and planted into monocultural stands of rubber and
ORANG ASLI INTERACTIONS WITH RAINFOREST

Oil palm. Most of the remaining lowland forest will be gone by the end of the century, depriving the Semang of their native habitat in the process. Many bands have already been regrouped into government-organized agricultural development schemes where they are expected to become sedentary farmers. Results to date are not encouraging given the incompatibility between their traditional nomadic cultural values and the demands of settled agricultural life (Endicott 1979b).

Although the upland forests are less immediately threatened, the Senoi are also being resettled into large-scale development projects, largely for security reasons. Not only will this have a major effect on their culture, but removal of people from large areas of forest will presumably have an impact on ecosystem functioning (Rambo 1982).

The concurrent loss of ecological and cultural diversity is lamentable, but given the demographic and political dynamics of modern Malaysia, inevitable. It is even less possible to preserve traditional human adaptations in reservation settings than it may be to save sufficiently large tracts of undisturbed habitat to support viable populations of wild species. The Malaysian Government's Department of Orang Asli Affairs has been wise enough to recognize this and has attempted to design its programs to try to make the transition from traditional to new ways of life as smooth as possible. Human interaction with the environment will continue but with outcomes very different from those explored in this chapter.

ACKNOWLEDGMENT

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A village in a rural area is not an independent unit. It depends on other parts in the area for its existence. It interacts with them, being influenced by them and influencing them in a variety of ways. Energy, matter, and information flow between them in a complex pattern of output-input and feedback loops. Together they function as a whole in an orderly manner. Therefore, these interdependent parts form a rural ecosystem. Naturally, the components of a rural ecosystem differ from place to place. In the inland areas of Java they typically consist of a village, the cultivated land (ricefield and dry land), the forest, and the river. The components themselves consist of parts that also interact with each other. In the village, for example, people, plants, animals, and nonliving parts, such as soil and water, are interacting. Hence, each of these components may be considered as a subecosystem of the whole rural ecosystems.

The boundaries of a rural ecosystem can be set according to the need of the studies. For instance, when dealing with studies on water resources management, it is convenient to use the ridges of a watershed as the boundaries. Generally, however, the setting of boundaries is not an easy task.

Rural ecosystem studies can be approached from two directions. First, by a broad survey to identify the key components and obtain a general picture of the interrelationships between them. At least some of these
components can be considered as black boxes. As the need arises, these components and their interaction are studied in more detail. A second approach is to start from the details and gradually build up the whole picture by tracing the flow of energy, matter, and information. The final picture may eventually cover a large area; but whichever the approach, we should be constantly aware that the essential aim of ecosystem study is to understand the whole rather than the parts, and that the whole has characteristics of its own (what Conway in Chapter 2 refers to as “emergent properties”) that are different from the sum of its parts.

RURAL-URBAN INTERACTIONS

The rural ecosystem is in turn not isolated but interacts with the urban ecosystem. Energy, matter, and information are flowing in both directions. Generally, the less developed the communication system between the two ecosystems, the less intense are the flows and vice versa. The energy flow is often accompanied by matter, while information exerts great influence on the quantity and direction of flow of energy and matter (i.e., a system that controls the quantity, quality, and time of information flow will also control the flow of energy and matter). This is particularly true in ecosystems in which man is involved. Science, technology, and political power, which are centered in cities, are powerful regulatory forces of information flow, and hence also of the flow of energy and matter. Therefore, in the rural-urban relationship, the urban ecosystem dominates the flow of information. It screens the flow in both directions in terms of kind, how much of each kind, and the timing. The screening is based on considerations of the interest of the city or on what it perceives to be good for the village. Conversely, the village has a limited capacity to obtain and select the information it needs. Often it has to accept whatever information is transmitted from the city, even when it is unpleasant, such as decision of a project that uses a large area of prime agricultural land. Indeed many times the information flow is intended, consciously or unconsciously, to increase the flow of energy and matter from the village to the city. Thus, while the improvement of the communication system between the city and the village is a requirement for rural development, it also facilitates the exploitation of the village by the city. This dual and contradictory role of the communication system (i.e., an infrastructure for development on the one hand, and a tool of exploitation on the other) is generally not recognized. As a result, by and large the city gains more than the village in this relationship, although it does not necessarily mean that the village suffers a net loss. If we assume that both the city and the village invest a certain percentage of their gains in development, they will both undergo growth. However, since the city can invest more than the village, and the city has also more knowledge and skill than the village in investment, the rate of growth of the city will be larger than the village. Consequently, the gap between the two will become larger with time. Therefore, although in absolute terms the standard of living of the village is
improving, and after a certain period it will cross the threshold of poverty, discontent will increase, since what matters to the people is not only the absolute level of living standards but also—and often more importantly—its relative level. Thus ironically, the improvement of living standards is accompanied by increasing discontent.

However, a gap always exists in any society and to a certain extent is acceptable to the people. It serves as a stimulus to motivate people to work harder, if they know that hard work improves their lot. If no gap exists, something that cannot happen in the real world, the capable and industrious people would feel unfairly treated and thus would be inhibited from working hard, while those who are lazy would not be stimulated either. The net effect on society would be negative. As the gap increases, the capable and industrious people will become stimulated. But as a gap becomes larger, more resources are concentrated in the hands of fewer people. Therefore, its positive effect levels off and declines after a while. On the other hand, its negative effect increases steeply. This is presented qualitatively in Figure 16.1. The figure shows that between a certain minimum and maximum value, the positive effect of a gap is larger than its negative one; in other words, the gap is beneficial. However, if the gap is allowed to increase uncontrolled, which can result from an excessive rural-urban exploitation, it can cause collapse of the society (e.g., by a social revolt). Therefore, gaps should not be eliminated, as has often been suggested, but managed within certain limits. These limits are not fixed values but vary with the cultural and political system of the society concerned.

THE DEVELOPMENT OF THE RURAL ECOSYSTEM

Because Java is in the wet tropics, it is safe to say that Java was covered by forests a long time ago. It must have been inhabited for many hundreds of thousands of years, since the fossils of the primitive Java man were found there. Prehistoric settlements were also found. Those in West Java, near Bandung, are thought to be of the time of the ancient Bandung Lake, some 6,000 to 10,000 years ago. Agriculture should have been developed quite early, perhaps by shifting cultivation, remnants of which are still found in West Java. When the Indians came to this island in the early centuries of the Christian calendar, they already found rice and appropriately called it Java Dvipa, or rice island. It is not clear whether it was upland or wet rice. These are indications that the rural ecosystem already existed in Java for at least many centuries. The development of the rural ecosystems may have followed the pattern as shown in Figure 16.2.

THE VILLAGE

The People

The rural ecosystem of Java is inhabited by three main ethnic groups: the Javanese in Central and East Java, the Sudanese in West Java and the
Figure 16.1. The positive and negative effects of gap. Gap should not be eliminated but managed between certain minimum and maximum value in which the positive effect is larger than the negative one. Between these values, gap stimulates development; but when the gap exceeds the maximum value, development becomes unsustainable.
Madurese along the northern coast of East Java. Each has its distinct but related languages. For example, the Javanese do not understand Sudanese and vice versa; but since independence, all groups were united by the Indonesian national language.

The people, of course, live in the village. Population density in Java is high. According to the 1980 census, the average population density on this island was 690 people per square kilometer (km$^2$) (Central Bureau of Statistics 1982). Although it comprises only 7 percent of the land area of Indonesia, it was inhabited by 62 percent of Indonesia’s total population. With the exception of Jakarta, which is practically an urban province, the highest population density was found in the Special Province of Yogyakarta (868 people/km$^2$), and the lowest in West Java (593 people/km$^2$), but, again excepting the special case of Jakarta, this latter had the highest annual population growth rate of 2.66 percent, while the lowest was in Yogyakarta (1.10 percent); the average of Java was 2.02 percent, and the national average 2.32 percent (Table 16.1). Close to 60 percent of the people still live in rural areas at densities often exceeding 1,000 people/km$^2$ (e.g., Penny and Singarimbum 1973, Institute of Ecology 1979). Because a high percentage of the people are farmers in the rural areas, the high population density has the consequence that the average landholding per farmer is low. According to the agricultural census of 1983, the average for Java was 0.63 hectares (ha) per household (Central Bureau of Statistics 1984). This census also revealed that of 11,000 farm households, 36 percent had less than 0.25 hectares, 26 percent had between 0.26 to 0.49 hectares, and 39 percent had more than 0.5 hectares. According to the census of 1980 in Java, the average number of people per household was 4.6. Hence the average landholding per member of a farm household was only 0.14 hectares. Although this average figure was already low, lower figures are frequently found. As an example, in the upper Cilanang River basin in West Java, the average landholding per farm household was only 0.35 hectares or 0.08 hectares per member of the household. Calculations have shown that for a standard of living at the poverty level, which according to the criteria of Sayogja (1977) is an income equivalent to 320 kilograms (kg) of rice per person per year, on the average 0.25 ha/person of ricefield will be required (see Table 16.1). Clearly, the average of Java, and particularly that of the upper Cilanang River basin, is below this requirement for a standard of living at the poverty level. At the same time, off-farm employment is scarce. Therefore, it is not surprising that a lot of poverty is still found in the rural areas, although considerable improvements have been achieved in the past decade. This widespread poverty has serious environmental consequences.

By and large the villagers are traditional, maintaining traditional beliefs and practices. Western science and Western ways of thinking are weakly developed, if at all. Technical skills are scarce. This is because a large number of people are unschooled or only have primary school education. However, traditional beliefs and practices are not always bad. In fact, studies have
Figure 16.2. Evolution of rural ecosystem from the forest and the establishment of the village and agricultural land.
<table>
<thead>
<tr>
<th>Province</th>
<th>Area (km²)</th>
<th>% of Indonesia</th>
<th>Population in 1980</th>
<th>Farmers (% of Total Population)</th>
<th>Annual Population Growth 1971-80 (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>People</td>
<td>People/km²</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>6,503,449</td>
<td>11,023</td>
<td>2</td>
</tr>
<tr>
<td>DKI Jakarta</td>
<td>590</td>
<td>0.03</td>
<td></td>
<td></td>
<td>3.93</td>
</tr>
<tr>
<td>West Java</td>
<td>46,300</td>
<td>2.41</td>
<td>27,453,525</td>
<td>593</td>
<td>53</td>
</tr>
<tr>
<td>Central Java</td>
<td>24,206</td>
<td>1.78</td>
<td>25,372,889</td>
<td>742</td>
<td>60</td>
</tr>
<tr>
<td>D.I. Yogyakarta</td>
<td>3,169</td>
<td>0.17</td>
<td>2,750,813</td>
<td>868</td>
<td>68</td>
</tr>
<tr>
<td>East Java</td>
<td>47,912</td>
<td>2.50</td>
<td>29,188,852</td>
<td>609</td>
<td>55</td>
</tr>
<tr>
<td>Java</td>
<td>122,177</td>
<td>6.89</td>
<td>91,269,528</td>
<td>690</td>
<td>52</td>
</tr>
<tr>
<td>Indonesia</td>
<td>1,919,443</td>
<td>100.00</td>
<td>147,490,298</td>
<td>77</td>
<td>58</td>
</tr>
</tbody>
</table>

shown that these beliefs have given rise to ecological wisdom, which guides the people in their utilization of the resources in their environment (Soemarwoto 1983). People believe that they are part of their environment and any damage of the environment will adversely affect them. They also believe that sinful actions will cause repercussions; for example, they may cause outbreaks of epidemic diseases or eruptions of volcanoes. Consequently, although the biophysical factors of the environment are considered as resources, they exploit them very carefully. They also avoid over-exploitation because the search for excessive material wealth is considered sinful. As a result, such practices as contour planting have already been developed many centuries ago. It is locally known as nyabuk qunung in Central and East Java, which means building belts around the mountain, and ngais qunung in West Java, meaning to carry the mountain as a child with a batik cloth. The latter term also expresses love for the mountain. The extensive terracing in Java demonstrates how much energy and time have been invested in protecting the mountain slopes from erosion.

But beliefs are not constant and are subject to outside forces, and they change in time. With it, traditional ecological wisdom also undergoes changes, for the better or for the worse. Modernization causes beliefs to loosen and it also brings rising demands. These, together with poverty, stimulate people to act opportunistically to obtain material gains, either to satisfy the rising demands or merely to fulfill the essential daily needs, such as food. Such opportunistic actions have caused considerable environmental damage (e.g., deforestation and erosion). On the other hand, modernization also brings knowledge and skills to the people, which makes them capable of using new technology. For example, the increase of rice production in recent years has been quite astonishing.

The Homegarden

In Java, a village not only functions as a settlement but also in a variety of other roles. In a typical village in Java, the houses are almost completely concealed by trees. These trees are planted in the homegardens, which are locally known as pekarangan. The land around each house is planted with a mixture of many species, both annuals and perennials. Its area varies from about 100 square meters (m²) to two or three hectares. Generally, the homegardens in Central and East Java are larger than in West Java, and those in the lowlands are larger than in the highlands.

Homegardens can be classified as an agroforestry system. An agroforestry system is defined as a land-use system that resembles a forest in structure and combines the natural functions of a forest with those for fulfilling the socioeconomic needs of the people. The natural functions of a forest encompasses hydrologic and erosion control, gene bank, and microclimatic effects, whereas its socioeconomic functions include subsistence and commercial production, and social and aesthetic values. Structure and function are closely related.
Structure. The plants in the homegarden vary in height from those creeping on the ground surface (e.g., the sweet potato) to tall trees reaching 20 meters or more (e.g., the coconut), with shrubs (e.g., guava), occupying the space in between. Climbers are also often found in the homegarden, for example, chayote (Sechium edule) and bitter melon (Momordica charantia).

Christanty et al. (1980) observed that on the basis of light interception by the plant canopies, five stories can be distinguished in a homegarden at Babakan Cinjur near Bandung, West Java. It has a curve which strikingly resembles the vertical distribution of light in the Pasoh forest in Malaysia as measured by Yoda (1974). By measuring the coverage of canopies, Karyono (1981) also established the existence of the multistory structure in homegardens in the Citarum River basin in West Java. Table 16.2 summarizes the results of studies by Christanty et al. and those of Karyono. In both instances the second story had the highest light interception and canopy coverage.

As a consequence of the multistory structure and the successive interception of light, the plants in the lower stories mostly grow in half-shade and full-shade. Although at first sight the plants are randomly placed in the homegarden, studies have shown that there was a high correlation between the grouping of plant species by the villagers into full-shade, half-shade, and full-sun plants and their photosynthetic characteristics as a function of light intensity (Christanty et al. 1978). Therefore, the villagers know from experience where to place the plants to obtain the best results. By doing so, light is used effectively in a successive way by the plant canopies at different heights. The space is fully utilized in three dimensions.

Table 16.2. Multistory Structure of Homegardens

<table>
<thead>
<tr>
<th>Story</th>
<th>Height (m)</th>
<th>Light Interception (%)</th>
<th>Story</th>
<th>Height (m)</th>
<th>Coverage of Canopy (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>4.8 - 6.0</td>
<td>20</td>
<td>1</td>
<td>&gt;10</td>
<td>16.3</td>
</tr>
<tr>
<td>2</td>
<td>3.0 - 4.8</td>
<td>64</td>
<td>2</td>
<td>5 - 10</td>
<td>36.1</td>
</tr>
<tr>
<td>3</td>
<td>1.5 - 3.0</td>
<td>10</td>
<td>3</td>
<td>2 - 3</td>
<td>25.1</td>
</tr>
<tr>
<td>4</td>
<td>0.3 - 1.5</td>
<td>Very little</td>
<td>4</td>
<td>1 - 2</td>
<td>8.9</td>
</tr>
<tr>
<td>5</td>
<td>0 - 0.3</td>
<td>5</td>
<td>5</td>
<td>&lt;1</td>
<td>13.6</td>
</tr>
</tbody>
</table>

Source: Christanty et al. (1980) and Karyono (1981).
Soil Erosion Control and Recycling. Because of the multistory structure and because plant litter is not removed from most parts of the homegarden, the soil is well protected against erosion. No quantitative measurements have been made of the hydrology and erosion in homegardens. However, visual observations show that erosion in homegardens is generally minimal. In critical areas, such as in the upper Solo River basin in Central Java, a stark contrast exists between the heavily eroded lands outside the village and the well preserved soils in the homegardens. Particularly in the dry season the areas outside the village are bleak, while the villages are pleasantly green.

Another important factor, which accounts for the maintenance of soil fertility and productivity, is that there is also an efficient recycling system. Plant litter is not removed from the homegarden, except in a small area, which is called the buruan, located in front of the house. The buruan is kept clean, since it is used as a playground for children and as a place for adults to congregate in the afternoons. Recycling also exists between man, plants, and animals. Using West Java as an example, this recycling system is described here. Fish are grown in the fish pond, which are found in many homegardens. They are fed with table scraps, leftovers from the kitchen, and leaves from the homegardens (e.g., cassava and taro). Pens for chickens and horses, and toilets are often built above the pond and the droppings of animals and human feces and urine fertilize the ponds or are partly directly eaten by the fish. At harvest time of the fish pond, which occurs about once every four or five months, the mud of the pond is removed, mixed with goat or sheep manure, and composted. The compost is used to fertilize the plants. We see that man, plants, and animals are integrated into a food chain. In these traditional villages, the people do not have the concept of waste to be thrown away. Rather, residues of a process are a resource to be used in other processes. As a member of the food chain, man gains nutrients in a most economic way. The more traditional a village and the less developed the market economy, the less matter is exported from the system and the more closed the cycling of matter. But as the market economy develops, more cash crops are grown, and more plant and animal produce is sold, and, hence, more matter is exported from the system and less is cycled. Therefore, to maintain productivity, fertilizers will have to be imported into the system, so that it will turn from a nonsubsidized into a subsidized ecosystem. This can be readily seen in homegardens in which commercial crops, such as cloves and citrus, are grown.

The people do not use the polluted water of the fish pond but pipe water with bamboo from a higher source. When the population density was low, the distance in place and time between use and reuse of the water was large, and the water had time to undergo a self-purification process. But as population density increased, the distance between use and reuse became smaller. As a result, the water now does not have sufficient opportunity for self-purification, so that the people are using more polluted water. Therefore,
outbreaks of cholera and other gastrointestinal diseases have become common. Research is urgently needed to overcome this serious problem. However, the research question should not be to find ways for the disposal of animal and human wastes but rather to develop hygienic methods of using wastes as a resource, which is in accordance with the concept of the people.

Gene Bank. Plant diversity is generally high in the homegardens. In a sample of 351 homegardens in the Citarum River basin, Karyono (1981) found 501 plant species. Abdoellah et al. (1978) reported in a total census of plant species in 41 homegardens of Cibakung—a small hamlet near Bandung—there were 219 species with 11,264 individuals in the dry season and 272 species with 19,259 individuals in the wet season. In Bantarkalong at the border of West and Central Java, they found 196 species with 39,804 individuals in 36 homegardens. In the Citarum Riber basin the average area of the homegarden was 314 m$^2$ and in Bantarkalong 1,500 m$^2$. These figures show that the density of plants in the homegardens is very high.

The species in the homegarden are often represented by many varieties. Some varieties are selected improved cultivars, others are semiwild with less desirable qualities (e.g., mango or rambutan with sour fruits). In a survey in the Citarum River basin, Abdoellah (1977) found 34 varieties of banana. The large number of species and varieties constitute a rich gene bank, which should be useful for future breeding programs to assure long-term sustainability of development.

The high plant density with a multistory structure is also an effective means to screen off solar heat. Sun glare is much reduced as one can deduce from the curve of light interception by the multistory structure; thus, the house in the homegarden is pleasantly cool.

From the preceding description we can firmly conclude that a homegarden resembles a forest in structure and that it also has the natural functions of erosion and microclimatic control, mineral cycling, and gene bank.

Sociocultural Values. Homegardens also have sociocultural functions. As mentioned earlier, an area of the homegarden in front of the house is used for children to learn cultural and social values from their elders (Achmad et al. 1978). Children from the neighborhood are always welcome to play there, and the owner of the homegarden is responsible for the safety of the children who are playing there.

A homegarden is an important status symbol. People who do not have a homegarden and who therefore have to build their house on someone else’s homegarden are considered of lower status.

Many homegardens have a fence, but they are seldom completely closed. Therefore, neighbors can enter it freely (e.g., to use the well for bathing, to do the laundry or to get water, or simply to pass through it). In West Java, many bathrooms are built above the fish ponds. While waiting for their turn,
the people chat with each other; thus, these bathrooms have become important places for communication.

Products of the homegardens are also used for social functions. For example, neighbors can ask for fruits, leaves, or other produce for religious or medicinal purposes.

Many plant species are specifically grown for aesthetic purposes, for example, the yellow bamboo and bougainvillea. However, in many instances the ornamentals are planted for other purposes as well. For example, the yellow bamboo is also grown for its supposedly magic power to avert bad luck, and imba (*Polyscias fruticosa*) and beluntas (*Pluchea indica*) are used as ornamental plants in hedges and at the same time are popularly used as vegetables.

Comparison of homegardens in villages far from cities, near cities, and those in cities shows that as we go closer to cities the social function of homegardens diminishes. They become more closed (i.e., fences are built around them and people are not able to enter them freely, but only by invitation). On the other hand, their aesthetic function becomes stronger with ornamental plants displacing food crops. In cities, aesthetic considerations play an important part in designing a homegarden.

**Production Function.** The production function of homegardens is generally quite important. Table 16.3 shows an example of a comparison between income derived from homegardens with total income, and Table 16.4 with that from *sawah* and ricefield, respectively (Danoesastro 1980). Gross income from homegardens varied between 6.9 percent to 77.9 percent of total income with an average of 24.9 percent, while net income from homegardens varied between 6.6 percent to 55.7 percent of total income with an average of 21.2 percent. Figures of income from the homegarden were reported by Ochse and Terra (1937) to be 20 percent of total income, by Ramsay and Wiersum (1974) 18 percent, by Stoler (1975) 17 percent, by Breure et al. (1976) 18 percent, and by Achmad et al. (1978) 22 percent to 30 percent. These figures show the importance of homegardens as a source of income for the villagers. Most income was derived from fruit trees and cash crops, such as cloves (Achmad et al. 1980). The cost of production as a percentage of gross income was generally low, varying between 4.7 to 28.5 with an average of 15.1. Only in Rongkop was the cost of production high.

According to Ochse and Terra (1937), only 7 percent of the labor and 8 percent of the total cost of village production were spent in the homegarden. Achmad et al. (1980) reported that in Cibakung, West Java, work in the homegarden was done only in otherwise free time and mostly by women and children.

Table 16.4 shows that gross income from the homegarden was invariably lower than of ricefield and dry land, respectively. With the exception of Wongsoredjo, the net income from the homegarden was higher than from
### Table 16.3. Income from Homegardens Compared to Total Income

<table>
<thead>
<tr>
<th>Subdistrict (kecamatan)</th>
<th>Province: Yogyakarta</th>
<th>Average Total Income (Rp)</th>
<th>Average Income from Homegarden</th>
<th>Cost</th>
<th>Total Income (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Berban</td>
<td></td>
<td>727,077 Gross</td>
<td>144,682</td>
<td>6.2</td>
<td>20.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>135,769</td>
<td></td>
<td>18.7</td>
</tr>
<tr>
<td>Sewon</td>
<td></td>
<td>355,931 Gross</td>
<td>88,323</td>
<td>9.8</td>
<td>24.8</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>79,681</td>
<td></td>
<td>22.4</td>
</tr>
<tr>
<td>Rongkop</td>
<td></td>
<td>199,507 Gross</td>
<td>155,333</td>
<td>28.5</td>
<td>77.9</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>111,108</td>
<td></td>
<td>55.7</td>
</tr>
<tr>
<td>Kalibawang</td>
<td></td>
<td>387,367 Gross</td>
<td>26,703</td>
<td>4.7</td>
<td>6.9</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>25,444</td>
<td></td>
<td>6.6</td>
</tr>
<tr>
<td>Average</td>
<td></td>
<td>417,471 Gross</td>
<td>103,760</td>
<td>15.1</td>
<td>24.9</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>88,001</td>
<td></td>
<td>21.1</td>
</tr>
</tbody>
</table>

1 Cost expressed as percent of gross income.

Source: Danoesastro (1980).

...these other land uses because production cost was much lower in the homegarden.

The products of homegardens do not only have commercial value as a source of income, but they are also consumed by the people. This is quite apparent from the results of the studies of Danoesastro and his students (1980) in Central Java and East Java (Table 16.5). Products consumed varied from 21.1 percent to 85.1 percent with an average of 44.4 percent, and those sold varied from 14.9 percent to 78.9 percent with an average of 55.6 percent of total value. Hence, on the average, close to half of the products was consumed by the owners themselves and half of them sold. Based on their studies at Cibakung, Achmad et al. (1978) reported that the harvest from the homegarden decreased during the time of the rice harvest and less of the products were sold. At that time the people had sufficient money from the rice harvest and there was little need for additional income. But between the rice harvests, the so-called paceklik time, when rice as a source of food and income became short, the harvest from the garden rose and more of it was...
Table 16.4. Income from Homegardens Compared to Income from Ricefield and Dry Land, Respectively

<table>
<thead>
<tr>
<th>Subdistrict (kecamatan)</th>
<th>Province: East Java</th>
<th>Average Income</th>
<th>Average Income from Homegarden</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Ricefield</td>
<td>Cost&lt;sup&gt;1&lt;/sup&gt;</td>
<td>Dry Land</td>
</tr>
<tr>
<td></td>
<td>(Rp/ha/yr)</td>
<td>(%)</td>
<td>(Rp/ha/yr)</td>
</tr>
<tr>
<td>Sumbergempul Gross</td>
<td>932,575</td>
<td>66.6</td>
<td>957,363</td>
</tr>
<tr>
<td></td>
<td>311,120</td>
<td>215,130</td>
<td>483,566</td>
</tr>
<tr>
<td>Wongsoredjo Gross</td>
<td>1,187,834</td>
<td>47.4</td>
<td>366,250</td>
</tr>
<tr>
<td></td>
<td>624,271</td>
<td>173,275</td>
<td>278,736</td>
</tr>
<tr>
<td>Ngimbang Gross</td>
<td>–</td>
<td>–</td>
<td>361,838</td>
</tr>
<tr>
<td></td>
<td>–</td>
<td>–</td>
<td>267,526</td>
</tr>
<tr>
<td></td>
<td>–</td>
<td>124,825</td>
<td>214.3</td>
</tr>
<tr>
<td>Average Gross</td>
<td>1,060,205</td>
<td>55.9</td>
<td>561,817</td>
</tr>
<tr>
<td></td>
<td>467,696</td>
<td>171,077</td>
<td>309,643</td>
</tr>
</tbody>
</table>

<sup>1</sup> Cost expressed as percent of gross income.

Source: Danoesastro (1980).
Table 16.5. Subsistence and Commercial Production of Homegardens

<table>
<thead>
<tr>
<th>Subdistrict (kecamatan)</th>
<th>Consumed (RP)</th>
<th>Consumed (%)</th>
<th>Sold (RP)</th>
<th>Sold (%)</th>
<th>Total (RP)</th>
<th>Total (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Province: Yogyakarta</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Berbah</td>
<td>64,732</td>
<td>42.6</td>
<td>87,372</td>
<td>57.4</td>
<td>152,104</td>
<td>100</td>
</tr>
<tr>
<td>Sewon</td>
<td>45,450</td>
<td>38.0</td>
<td>74,040</td>
<td>62.0</td>
<td>119,490</td>
<td>100</td>
</tr>
<tr>
<td>Rongkop</td>
<td>111,178</td>
<td>85.1</td>
<td>19,430</td>
<td>14.9</td>
<td>130,608</td>
<td>100</td>
</tr>
<tr>
<td>Kalibawang</td>
<td>11,459</td>
<td>50.2</td>
<td>11,362</td>
<td>49.8</td>
<td>22,819</td>
<td>100</td>
</tr>
<tr>
<td><strong>Province: East Java</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sumbergempul</td>
<td>26,387</td>
<td>21.4</td>
<td>97,167</td>
<td>78.6</td>
<td>123,554</td>
<td>100</td>
</tr>
<tr>
<td>Wongsoredjo</td>
<td>39,413</td>
<td>21.1</td>
<td>147,320</td>
<td>78.9</td>
<td>186,733</td>
<td>100</td>
</tr>
<tr>
<td>Ngimbang</td>
<td>66,436</td>
<td>52.3</td>
<td>60,684</td>
<td>47.7</td>
<td>127,120</td>
<td>100</td>
</tr>
<tr>
<td><strong>Average</strong></td>
<td>52,151</td>
<td>44.4</td>
<td>71,054</td>
<td>55.6</td>
<td>123,204</td>
<td>100</td>
</tr>
</tbody>
</table>

Source: Danoesastro et al. (1980).

Table 16.6. Production from Homegarden, Talun-kebun, and Ricefield at Sinargalih and Warudoyong, West Java

<table>
<thead>
<tr>
<th>Production</th>
<th>Sinargalih</th>
<th>Warudoyong</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Homegarden</td>
<td>Talun-kebun</td>
</tr>
<tr>
<td>Rupiah/m²/yr</td>
<td>49.9</td>
<td>42.9</td>
</tr>
<tr>
<td>Caloric/m²/yr</td>
<td>543.0</td>
<td>558.3</td>
</tr>
<tr>
<td>Protein g/m²/yr</td>
<td>6.5</td>
<td>7.6</td>
</tr>
<tr>
<td>Calcium mg/m²/yr</td>
<td>93.1</td>
<td>88.8</td>
</tr>
<tr>
<td>Vitamin A IU/m²/yr</td>
<td>918.7</td>
<td>741.6</td>
</tr>
<tr>
<td>Vitamin B ng/m²/yr</td>
<td>0.3</td>
<td>0.3</td>
</tr>
<tr>
<td>Vitamin C mg/m²/yr</td>
<td>49.6</td>
<td>44.4</td>
</tr>
</tbody>
</table>

sold. Thus, during the paceklik time the villagers depended more on the homegarden for their food and income. These results show that the homegarden and the ricefield are interdependent. This interdependency has been overlooked by development planners.

Because much of the produce is consumed by the villagers, it should be interesting to know the nutrients contained in the produce. Table 16.6 presents the productions of three land-use types—homegarden, talun-kebun, and ricefield—in the villages of Sinargalih and Warudoyong in West Java. The talun-kebun is discussed in a later section.

At Sinargalih the production of the homegarden and the talun-kebun in terms of money was higher than of ricefield, but at Warudoyong the ricefield produced more than in the other two land uses. In the two villages, calorie and protein production from the ricefield was higher than from the homegarden and the talun-kebun. However, both the homegarden and the talun-kebun were good sources of calcium, vitamin A, and vitamin C. In these calculations, animal products, such as fish and chicken, meat and eggs, were excluded. According to Harjadi and Setialti (1975), in the Lawang villages, East Java, the daily production of homegardens was on the average 983.4 calories, 28.8 grams protein, 16.4 grams fat, 185 grams carbohydrate, 218 milligrams calcium, 14.4 milligrams iron, 1,181.2 milligrams vitamin B, 305 milligrams vitamin C, and 6,682 IU vitamin A. Ochse and Terra (1937) reported that the homegarden could produce 44 percent of the total carbohydrate and 32 percent of the total protein of the village production. When computed on the basis of food intake, the contribution from the homegarden amounted to 15 percent of the total carbohydrate and 14 percent of the total protein. Therefore, from the nutritional point of view, the homegarden is also an important component of the rural ecosystem.

A significant difference between the harvesting of ricefield and homegarden is that the harvest of rice has a distinct time, whereas the harvest from the homegarden is continuous, because this latter is a polyculture. Daily harvests of a few vegetables (e.g., chili pepper, cassava leaves, coconut and taro) are commonly done by the villagers for their own consumption or for sale. Fruit trees offer harvests at their respective seasons, which occur at different times. For example, the fruiting season of rambutan (Nepheleum lappaceum) is about December to February, duku (Lansium domesticum) about February to March, citrus about May to July, mango about August to October, and durian about November to January. Therefore, throughout the year, the villagers can obtain food and income from their homegardens, although the products fluctuate from time to time. This extended and readily available harvest is important for the villagers, many of whom are poor and do not have fixed income.
THE AGRICULTURAL LANDS

The Annual Crops

Methods of Rice Cultivation. When irrigation is available or rainfall is sufficient, rice is the primary crop and is grown in the wet ricefields commonly known as sawah. In the irrigated areas rice is grown the year-round, whereas in the rain-fed areas it is grown in the wet season alternating with upland crops in the dry season, if sufficient soil moisture is available. Otherwise the land is left fallow in the dry season. In rain-fed areas with unpredictable rainfall, rice is often grown between strips of a mixture of upland crops, locally called the surjan system. The plots of upland crops are about 50 to 60 centimeters higher than the sawah, so that they remain dry. This is a traditional method of risk management. When rainfall is good, both the rice and the upland crops grow well. However, when rainfall is low, the rice harvest will be minimal, but the upland crops will still yield fairly well. This cropping pattern is extensively found in the southwestern plains of Central Java.

Another method of wet rice in rain-fed areas with short wet seasons is gogorancah. Rice is planted in the early rainy season, when water is not sufficient yet to flood the fields. Thus in the first few weeks of its growth, it is essentially upland rice. When rainfall is sufficient, the dikes are closed and the fields become sawah. This method gains time, so that a second crop can be grown at the end of the wet season and the beginning of the dry season when soil moisture is still sufficient to allow growth of the crop.

In the mountain regions and in the absence of irrigation, rice is also grown as an upland crop. This method is found rather extensively in West Java, where it is called huma.

In many areas, particularly in West Java, fish are also raised in the sawah. Fish can either be raised together with the rice plants, or fish ponds are constructed in the ricefield. Table 16.7 summarizes freshwater fish culture in Java.

There is extensive fish culture in West Java, both in ricefields as well as in fish ponds. Total area of fish culture in West Java was 74.6 percent of Java and 38.2 percent of Indonesia, while total production in West Java was 89.7 percent of Java and 76 percent of Indonesia. The yield per hectare in rice-fish culture and in pond culture in West Java is both higher than the respective average yield in Java and in Indonesia. These figures show the importance of freshwater fish culture in West Java.

Except in East Java, the integration of rice and fish gave lower yields of fish than in fish ponds. But studies have shown that the integration of rice and fish can increase the income of the farmers (Djajadiredja et al. 1980). However, because of the increasing use of pesticides for the control of rice pests, fish production in sawah is declining. This is regrettable because fish is
<table>
<thead>
<tr>
<th>Province</th>
<th><strong>Rice-fish Culture</strong></th>
<th></th>
<th><strong>Pond Culture</strong></th>
<th></th>
<th><strong>Total</strong></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Area (ha)</td>
<td>Production (ton)</td>
<td>Area (ha)</td>
<td>Production (ton)</td>
<td>Area (ha)</td>
<td>Production (ton)</td>
</tr>
<tr>
<td>DKI Jakarta</td>
<td>550</td>
<td>64</td>
<td>0.12</td>
<td>900</td>
<td>539</td>
<td>0.60</td>
</tr>
<tr>
<td>West Java</td>
<td>19,250</td>
<td>14,962</td>
<td>0.78</td>
<td>16,946</td>
<td>41,294</td>
<td>2.44</td>
</tr>
<tr>
<td>Central Java</td>
<td>4,654</td>
<td>192</td>
<td>0.04</td>
<td>1,516</td>
<td>2,086</td>
<td>1.38</td>
</tr>
<tr>
<td>DI Yogyakarta</td>
<td>1,376</td>
<td>88</td>
<td>0.06</td>
<td>210</td>
<td>207</td>
<td>0.99</td>
</tr>
<tr>
<td>East Java</td>
<td>1,010</td>
<td>1,214</td>
<td>1.20</td>
<td>2,079</td>
<td>2,100</td>
<td>1.01</td>
</tr>
<tr>
<td>Java</td>
<td>26,890</td>
<td>16,520</td>
<td>0.61</td>
<td>21,651</td>
<td>46,226</td>
<td>2.14</td>
</tr>
<tr>
<td>Indonesia</td>
<td>60,607</td>
<td>21,383</td>
<td>0.35</td>
<td>34,235</td>
<td>52,631</td>
<td>1.54</td>
</tr>
</tbody>
</table>

Source: Djajadiredja et al. (1980).
an important source of protein and income for the rural people. This is an example of an information flow from the urban to the rural ecosystem to maximize the flow of energy and matter, in this case rice, in the opposite direction at the expense of the interest of the rural ecosystem. Therefore, it can be categorized as an exploitative relationship.

Sociocultural, Economic, and Environmental Aspects. Rice plays an important role in the life of the people in Java. Among farmers there is still the belief that it originates from the incarnation of Dewi Sri, the wife of the god Wisynu. As such, rice is considered sacred and used in numerous religious ceremonies. Its planting and harvesting are also accompanied by religious rituals, although lately, because of the modernization process, these rituals are on the decline. However, rice as a status symbol is actually being strengthened. This status symbol is spilling over to other parts of the country, which used to have staple food other than rice.

The status symbol is not only limited to the eating of rice, but extends to its growing (i.e., a sawah carries more prestige than dry land). Therefore, whenever the opportunity arises to grow rice (e.g., by the availability of irrigation water), a farmer will inevitably change his dry land to sawah. This has desirable as well as undesirable environmental effects. In the mountain regions, it can be used to control soil erosion, because terraces have to be built for the cultivation of sawah, and this technology is well known by the people. Therefore, by constructing an irrigation canal at the highest possible contour line, the farmers will terrace the land below the irrigation canal by themselves without the need of extension and financial or technical help. On the other hand, the availability of irrigation water year-round has eliminated crop rotation and rice is being grown continuously.

At the same time in an effort to boost rice production, the traditional rice varieties have been replaced by the high-yielding varieties, primarily the semidwarfs bred by IRRI. More than 50 percent of the rice area is now planted with these semidwarfs dominated by one or two varieties only. In the early 1970s, IR-8 became victim to the rice tungro virus disease, which was transmitted by the green leafhopper (Nephotettix virescens). The epidemic outbreak stopped when IR-8 was replaced by the virus tolerant IR-20. But in the early 1970s the wereng (brown planthopper, Nilaparvata lugens), which was a minor pest, flared up and became the major cause of serious rice yield losses. The pest was suppressed by the release of IR-26, but the wereng shifted from the biotype 1 to the biotype 2 for which IR-26 was not resistant. An outbreak of the brown planthopper occurred again until the planting of the resistant IR-36 in 1977 and 1978 stopped the epidemic. However, in the beginning of 1982 new populations developed, which were controlled by the release of IR-56 (Birowo et al. 1978, Yoshida and Oka 1982, Chang 1984). Although the new high-yielding varieties have been responsible for the dramatic increases in rice yields, the disease and pest outbreaks show the vulnerability of the rice culture because of the
combination of several factors, particularly its continuous cropping made possible by the availability of irrigation water the year-round and genetic uniformity by the cultivation of a single high-yielding variety in large areas.

Another effect of the excessive stimulation of rice cultivation is also that it has strengthened its role as a status symbol and has made the nation more dependent on one staple food, which in turn has also made the nation ecologically vulnerable. Rice cultivation also requires a lot of water, and large amounts of money and energy have to be spent to satisfy the demand for water; whereas, with a rational crop rotation of rice and upland crops, much less water is needed for agriculture.

Curiously, however, in spite of the strong status symbol of rice, a new development of growing mandarin oranges in ricefields has occurred in the southwestern part of Central Java reaching to the border of West Java. The mandarin trees are grown on individual mounds about 75 to 100 centimeters high amidst the rice plants. This may be an indication that economic considerations are replacing social and religious values.

Rice also has an important social function. In traditional societies land preparation, planting, weeding, and harvesting are not carried out on a commercial basis, but rather governed by social rules. The patron-client relationships are intricate and complex. Its outcome is that poor and also landless farmers have a certain right to a portion of the harvest. Generally, relatives of the landowner have more right, fellow residents of the village who are not relatives have less, and people from other villages have the least right. Those who have helped in the preparation of the land and the planting are given priority to help in the harvesting. A patron also has certain responsibilities to look after the welfare of his clients.

Rice is also distributed from the well-off people to the less privileged ones by the numerous religious rituals, the so-called selamatan, which are essentially offerings to the gods to ask for clemency, health, or to express thanks to Dewi Sri, the rice goddess, for the good harvest. This tradition is widespread, even though Islam is the religion of the majority of the people. It shows that traditional beliefs are well entrenched in the life of the people.

However, the Green Revolution has also weakened the social value of rice. Rice growing has become more commercialized. For example, rice harvesting is no longer always done on a cooperative basis. Instead a rice merchant comes and negotiates the price of the rice crop with the owner. After an agreement has been reached, the merchant calls in his crew to harvest it. The rice grains, which traditionally have been hulled by women pounding them with a wooden stick, are increasingly being hulled by mechanical hullers. Consequently, less benefit is distributed to relatives of the owner and fellow village residents. It has been estimated that the rice hullers have displaced many thousands of women. The new development of growing mandarin trees in the ricefields, as mentioned earlier, will also have a significant long-term effect on the village social structure.
Other Annual Crops. Other annual crops, such as corn, soybean, sweet potato, and peanut, are considered less important than rice. They are usually grown when rice cannot be grown (e.g., when there is insufficient water or in the highlands, which are too cool for rice). Even when these crops give higher economic returns than rice, they are generally given second priority after rice. However, this may change in the future, as already indicated by the cultivation of mandarins in the ricefields.

Unlike rice, which is grown in monoculture, the other crops are usually grown in mixture. The mixture may be regular (e.g., rows of peanut alternating with rows of corn) or, more commonly, the crops may be mixed without any discernible pattern. The mixture may consist of many species (e.g., corn, peanut, cassava, chili pepper, and eggplants). Harvesting is not done at once like in rice but is carried out over an extended period.

Because less importance is attached to these crops, less labor is devoted to these crops and practically no chemical inputs are used. The government also pays relatively little attention to these crops. Little research is carried out on them, such as in the field of agronomy, crop protection, and genetic improvement. Therefore, yields are usually low. An exception are the European vegetables, such as cabbage, carrot, potato, and tomato, which are cultivated in the highlands. They are labor-and capital-intensive. In many cases pesticides are applied excessively.

Integration of Rice with Upland Crops. From the foregoing discussion, there is a close relationship between rice and the upland crops. Traditionally they have been planted in an integrated manner, either simultaneously or sequentially. However, modern agricultural research and development neglect this integrated characteristic of traditional agriculture. Overemphasis has been placed on rice, which, as we have seen, has caused the rice culture to become ecologically vulnerable. Therefore, much research is needed to reinstate the integration of rice and upland crops.

Talun-kebun

A talun-kebun is a typical agroforestry system. The talun itself is planted with a mixture of perennials and annuals, giving it a structure familiar to a forest. It is generally found outside the village and only rarely inside the village. As shown in Figure 16.2, the talun originates from the forest by selection of the forest species and introduction of new ones. Although it consists of a mixture of many species, one or more species may be dominant (e.g., bamboo [*Gigantochloa* spp.]). In such a case it is called a talun awi (bamboo talun). Some perennials, which are commonly found in taluns, are several species of bamboo (*Gigantochloa apus, Gigantochloa verticillata*), jeunjing (*Albizia falcataria*), kihiang (*Albizia procera*), jackfruit (*Artocarpus communis*), petai (*Parkia speciosa*), banana, and coconut.

Two types of taluns can be distinguished: permanent talun and talun-kebun. In a permanent talun the trees are typically densely spaced and
the canopies are closed. Hence, little light penetrates the canopies and only a few shade-tolerant species are planted, such as the taro-like xanthosoma, arrowroot (Canha edulis), turmeric (Curcuma domestica), and ginger (Zingiber officinale). These crop species and weeds form the undergrowth of the talun. However, a bamboo talun is almost completely devoid of undergrowth because the canopy is dense. The bamboo canopy then forms the lowest story, and canopies of tall trees, such as Albizia falcataria, sugar palm (Arenga pinnata), coconut, and fruit trees (e.g., jackfruit, durian [Durio zibethinus], and rambutan [Nepheleum lappaceum], are about it.

In some taluns the trees are sparsely planted, so that more light can reach its floor. In such cases many annuals are grown (e.g., corn, cassava, and sweet potato). Many weeds are also found in the talun. Such taluns are usually called kebun campuran, which means mixed garden, denoting a mixture of annuals and perennials.

In a permanent talun, the wood of the trees (e.g., bamboo or albizia) is harvested by selected cutting and by light pruning of dead or old wood from the fruit trees. Consequently, the general structure of the talun remains intact. The harvested wood is sold for construction material. For example, bamboo is sold by truckloads to the cities to aid in the construction of buildings. Small branches or dead wood are used for fuelwood. It is usually consumed locally by the villagers or sold in the neighboring small towns. In larger towns and cities, fuelwood is increasingly being replaced by kerosene, gas, and electricity.

In the talun-kebun system, however, a clearing is deliberately made in the talun at the beginning of the rainy season, either by clear cutting (e.g., bamboo), or by selective cutting (e.g., albizia) and heavy pruning of the remaining perennial trees. The clearing is small, usually about 500 m² to 1,500 m². The trunks and large branches are taken out of the clearing and sold for construction material and fuelwood, and the twigs and leaves are spread out for sun drying. When they are dry, they are piled and burned. The ash is collected and mixed with cattle dung, which is brought in from the village.

A mixture of annual crops are grown in the clearing and it is then called kebun, which literally means garden. The major crops grown depend on such factors as soil, climate, and market demand. For example, in Soreang and Ciwidey, southwest of Bandung, the bean, Dolichos lablab, is the main crop, whereas in Paseh, southeast of Bandung, the main crops are tobacco and onion. The crops are manured with a mixture of dung and ash and often also with urea, which is imported from the nearby city or town.

The planting of the different crops are not done at once but in successive order. Harvesting is also carried out over an extended period. At the harvest of the last crop, which is about 18 months after the clearing, the trees have resprouted. Bamboo, for example, has reached a height of about 2 meters and the canopies have almost closed. People then clear another area and repeat
the process. Consequently, the kebun moves around inside the talun with a cycle of about six to eight years. Because of this cyclic conversion of talun to kebun and back to talun, we call it the talun-kebun system. Essentially, it is a shifting cultivation, but with the following significant differences.

A traditional shifting cultivation is practiced in a forest. A group of people or a tribe has territorial rights to an area of forest, but the landownership is not well defined. The purpose for cutting the trees is to make a clearing for the garden and to obtain minerals for the crops by subsequent burning. The cleared trees do not have commercial value. The planted crops are primarily for subsistence use, although certain variations, in which cash crops are grown, also exist. Generally, no fertilizers are applied.

The shifting cultivation in a talun-kebun system is practiced in a man-made forest and landownership is well defined. A farmer practically has title on the land, although theoretically it may be owned communally by the village. The clearing of the trees is actually a harvest and the trees are sold as a commercial commodity. Only a small part of the cut trees is burned to release minerals. Likewise, most of the annual crops are grown for commercial purposes; hence, the talun-kebun is a market economy-oriented system. Because the trees and the crops are sold, considerable amounts of minerals are exported from the system. To more or less balance this export, manure and synthetic fertilizers are imported from the village and the city, respectively.

Another important difference is that the traditional shifting cultivation is only capable of supporting a low population density, whereas the talun-kebun system is able to support a high population density. The reasons are that the talun-kebun system is geared to the market economy and is a subsidized system. In addition, it is also coupled to the wet rice culture, which provides much of the carbohydrate requirement of the people.

<table>
<thead>
<tr>
<th></th>
<th>Shifting Cultivation</th>
<th>Talun-kebun System</th>
</tr>
</thead>
<tbody>
<tr>
<td>Forest</td>
<td>Natural</td>
<td>Man-made, i.e., the talun</td>
</tr>
<tr>
<td>Landownership</td>
<td>Not well defined</td>
<td>Well defined</td>
</tr>
<tr>
<td>Clearing</td>
<td>To open a space for the garden</td>
<td>To harvest the planted trees and thereby creating an opening for the kebun</td>
</tr>
<tr>
<td>Burning</td>
<td>Almost all parts</td>
<td>Only a small part</td>
</tr>
<tr>
<td>Mineral cycling</td>
<td>Almost closed, little minerals exported; no import of minerals</td>
<td>Open, a lot of minerals exported and balanced by an import of minerals</td>
</tr>
<tr>
<td>Economy</td>
<td>Subsistence</td>
<td>Market economy</td>
</tr>
<tr>
<td>Population density</td>
<td>Low</td>
<td>High</td>
</tr>
</tbody>
</table>
The comparisons between the traditional shifting cultivation and the talun-kebun system are summarized in Table 16.8.

From visual observations, soil erosion in a talun is minimal. When measured by splash boards, splash erosion in a talun is low, as shown in Figure 16.3. In the intact talun (T.2) and bamboo talun (B.2), erosion did not increase with higher rainfall. In the talun, there were litter and undergrowth, and in the bamboo talun there was a thick layer of litter but no undergrowth. When the undergrowth and litter were removed, the erosion in both the talun (T.1) and bamboo talun (B.1) increased substantially. The increase of erosion in T.1 was greater than in B.1 because the leaves of bamboo have driptips that reduce the size of the throughfall drops (Williamson 1981). Splash erosion in the control (K), which were open plots without trees and in which weeds and litter were removed, was also high but below that of T.1 and B.1. This coincides with the result of other experiments in which splash erosion by throughfall was higher than that by rain (Institute of Ecology 1980). Runoff in a bamboo talun is also small (Christanty, pers. com.). Hence, the talun in general and the bamboo talun in particular have a well-developed hydrologic and erosion control function.

![Figure 16.3](image)

Figure 16.3. Splash erosion in intact talun (T.2) and talun bamboo (B.2) was minimal. When the undergrowth and litter were removed, erosion rapidly increased (T.1 and B.1). K was erosion in control plots (no trees; weeds and litter removed).
A talun is generally a rich gene bank because of the high diversity of plant species, whereas in a bamboo talun the number of species is usually small.

The economic function of talun-kebun is quite important. The income from bamboo talun, for example, is comparable to that from a ricefield as shown in Table 16.8. Asdak (1984) estimated that to support a standard of living at the poverty line a bamboo talun of 0.39 hectare would be needed compared to a ricefield of 0.25 hectare. Taluns are also a good source of nutrients (Table 16.6). A talun does not require much labor. Although the kebun in a talun is labor-intensive, its area is small so that the total labor requirement is also low. Chemical input is also low and limited to the kebun only. In contrast, a ricefield is labor-intensive and when high-yielding varieties are planted, as is common now, it requires high inputs of fertilizers and pesticides.

The talun-kebun system also has a social function. Landless and poor farmers are allowed to take fallen branches and twigs or to cut dead wood for fuelwood, but are not permitted to harvest the produce, such as fruits, tubers, and wood. During the harvest these landless and poor farmers, who help in the harvesting, receive a portion of the harvest.

We can therefore conclude that talun is also an agroforestry system in that it has the structure of a forest and combines the natural function of a forest with those for fulfilling the socioeconomic needs of the people. The principal difference between a talun and a homegarden is that there is no house on a talun, whereas the essential criteria of a homegarden is that there must be a house on it.

THE FOREST

In 1981, the forests in Java had an area of 23,960 km² or 18.1 percent of its total land area. The corresponding figures for Indonesia were 1,130,770 km² or 58.9 percent (Central Bureau of Statistics 1982). In Java the natural lowland forests are practically gone, because they have been converted to agricultural land, settlements, and other land uses. A relatively large area of lowland forest is found in Ujung Kulon, West Java, which is a famous national park because of the Javanese rhino (Rhinoceros sundaicus). Other smaller forests are found in Leuweung Sancang in West Java, and Meru Betiri and Baluran in East Java. Baluran has been declared a national park and the other two are nature reserves.

Production forests are found rather extensively in the lowlands, mostly consisting of teakwood. These forests were established in the prewar years by the Dutch and are administered by the state company Perhutani. Therefore, although these production forests are geographically located in the rural areas, economically they do not belong to the rural ecosystem. They are an important source of income to the cities but give only marginal benefits to the villages.
Most forests in Java are found in the mountain regions. They are like islands surrounded by a landscape that has been extensively modified by man. But even in the mountain regions, pressure on the forests is high and they are gradually being destroyed. While traveling through Java, it is not uncommon to find hills and mountains that have been completely denuded of forests. This is not surprising when we reexamine Table 16.1. High population density, high population growth, high percentage of farmers, and scarcity of off-farm employment combine forces to press the villagers to clear the forest to grow their food crops and to obtain fuelwood. Other important forces of forest destruction are of economic nature (i.e., the cultivation of vegetables and the development of tourist resorts). These forces originate in cities that own the capital for these enterprises. Often they neglect the rudimentary rules of hydrology and soil conservation. For instance, vegetables are often grown in rows down steep slopes. Destruction by economic pressure can be easily seen on the slopes of Mt. Gede and Mt. Pangrango, south of Jakarta, in the surroundings of Bandung in West Java and Malang in East Java.

Maps constructed from satellite imagery overlaid on forest maps have revealed extensive damage of forests. Typically the damage occurs along the borders of the forests. From these maps we can deduce that the people extend their activities into the borders of the forests and gradually go deeper into the forests and higher up the mountain slopes.

Of course, the extensive forest destruction has very serious environmental consequences. The genetic resources of the lowland forests have mostly been decimated. Because the highland forests are relatively small "islands," with low temperature and low solar radiation due to many cloudy days, and often also because of volcanic activity, they are unable to support many species. As a result, they are rather poor gene banks. Because of the special environment, however, these genetic resources are important, at least from the scientific point of view.

Generally, the highlands have a high rainfall. The topography is also rugged with many steep slopes and deep ravines. Consequently, the highland forests have an important hydrologic and erosion control function. It is, therefore, fortunate that there are still highland forests, although their extent is far from adequate. Only 5,790 km$^2$ or 24.1 percent of a total of 23,960 km$^2$ of forests in Java have the status of protection forests. In relation to the total land area of Java, this protection forest was only 4.4 percent, a low figure indeed.

Efforts have been made to rehabilitate the damaged forests by reforestation, the so-called *reboisasi*. One of the methods of reforestation is the *taungya* system or locally known as *tumpangsari*. This method allows the villagers to grow their crops (e.g., rice, corn, and vegetables) between the rows of tree seedlings, with the understanding that they take care of the seedlings and that after about five years they must leave the reforested area. However, because many of these villagers are landless, jobless, and have no place to go,
they often deliberately kill the tree seedlings to be able to remain in the area. In general the success rate of reforestation has been low, as was stated by the Minister of Forestry Soedjarwo in parliament in December 1983, although large amounts of reforestation does not reduce population pressure, but actually increases it by reducing the area illegally cultivated by the villagers, the chances of success are indeed small. It has been suggested, therefore, to invest the money in reducing the population pressure instead (e.g., by creating off-farm employment in the villages [O. Soemawoto and I. Soemawoto 1983]). In doing so, the need for land would be reduced, so that the people could be kept away from the forests. Under the edaphic and climatic conditions of Java, plants would then rapidly invade the deforested areas and the hydrologic and erosion control would be quickly restored, as demonstrated by Coster (1938). Such approach would also have the effect of directly improving the standard of living of the villagers.

Still another approach would be to legitimize the illegal occupation of the forests by the people and to change the status from forest land into agricultural land. Because generally the people have knowledge of soil conservation, it can be assumed that they would invest their energy and time in terracing the land, if they were assured of their right on the land. However, the present Indonesian law would make this very difficult or even impossible as a general approach. Furthermore, if the population pressure is not reduced, such an approach would eventually cause the disappearance of the forests.

THE RIVER

The river is an important source of water for the people. A river serves many functions for the villagers: bathing, washing their clothes and household utensils, fishing, irrigating, and bathing their animals. Its water is also often used for cooking. Java rivers are infrequently used for transportation because many rivers are shallow and have large fluctuations of water flow between the rainy and the dry season. Large rivers, which were formerly used for transportation (e.g., the Solo River in Central Java) have now become too shallow for boats because of sedimentation.

Rivers, of course, are greatly influenced by the condition of the forests in their watersheds. The disappearance of large areas of forest have caused the water yield to increase. For example, in the Citarum River basin between 1919 to 1933, 47 percent of rainfall became river flow, but between 1970 to 1975 the percentage increased to 52 percent (Institute of Ecology 1979). However, between 1920 to 1940, the ratio between the total flow in the wet season to that in the dry season was 3.0 and increased to 4.1 between 1963 to 1977. Such changes were caused by the reduction of evapotranspiration and increase of runoff, as a result of the decrease in forest areas. Comparison of satellite imageries of 1974 with land-use maps, which were made on the basis of data collected before 1970, showed that the dense forest areas in the
Citarum Basin were reduced by 38,355 hectares or 33.7 percent of the total forest area before 1970 (Soemarwoto et al. 1976).

Another serious effect of forest destruction is soil erosion. Generally, river basins in Java suffer heavy erosion rates. Examples are Serayu 4.2 millimeters per year (mm/yr), Pekacangan 5.6 mm/yr, and Merawu 8.0 mm/yr (SMEC 1974), all located in Central Java; and the Citarum in West Java, estimated between 2.6 mm/yr (NEWJEC 1978) and 3.4 mm/yr (Institute of Ecology 1979). A more serious concern is that these rates are increasing over time. For example, the Cilutung River basin in West Java was reported by Van Dijk and Vogelzang, as cited by SMEC (1979), to have an erosion rate of 0.9 mm/yr in 1911 to 1912 and 1.9 mm/yr in 1934 to 1935. Recent measurements indicate that the erosion rate between 1948 to 1969 was on the average 9.0 mm/yr (SMEC 1979).

The changes in river flow and the high erosion rates also have serious repercussions for the people. Risk of floods has increased, which in turn increases the risk of property damage and even human casualties. Bojonegoro in Central Java and South Bandung in West Java suffered seriously from floods in 1984. Indeed big floods seem to occur routinely every year in Java.

Erosion also causes reduction in soil fertility, resulting in lower agricultural yield. The high sediment loads in rivers reduce fish yield and fish ponds. Because of the lower yields, more land is needed to support the people, thereby increasing deforestation. Thus a vicious cycle of poverty—deforestation-erosion-lower yield-more poverty-more deforestation, etc. has been triggered. The cycle again illustrates the interdependent nature of people, forest, river, and agricultural land. Therefore, to cut the cycle and to reverse the downward spiral into an upward one requires a holistic approach of development, an approach that recognizes the interdependencies of the components of the rural ecosystem.

HOLISTIC APPROACH OF DEVELOPMENT

The focus of rural development in Java has been on agriculture, particularly rice. This is understandable, since the majority of the villagers are farmers and rice is the most important single item in the life of the people. The results in the increase of rice production have been dramatic. However, although there is still a large gap between yield in experimental plots and yield in farmer's fields, indicating that there is still a large potential for increasing rice yields, there is increasing concern that rice yield is leveling off. The bust and boom of rice population, because of pest and disease outbreaks, is another serious concern.

We have seen that rice is only one component of the farming system in Java. Traditionally it is rotated with upland crops. Relatively little has been done to increase production of upland crops, and because of the Green Revolution the tradition of crop rotation is on the decline. Much less is being done on the homegarden and nothing on the talun-kebun, which are
important components of the agroecosystem, as evidenced by Tables 16.3, 16.4, 16.6, and 16.7. Our bias toward rice has caused us to look at rural development in a “tunnel vision” way: rural development has been equated with better rice production and more or less neglecting the other crops. Fish and other animal production also receive a much lower priority than rice.

To correct this shortcoming, an alternative approach to rural development is suggested in which the center of development is the rural people because, after all, development is for the people and by the people. We have seen that poverty is still widespread, although much improvement has been achieved; population continues to grow at a high rate; most people are farmers or dependent on farming for their living, and off-farm employment is scarce. Because of these factors, population pressure is high, which increases the risk of deforestation, floods, and erosion. A quantitative model of population pressure has been proposed (Soemarwoto 1984), which takes the form of:

$$\begin{align*}
PP = \frac{fP_0 (1 + r)^t}{a - \frac{L}{t}}
\end{align*}$$

in which $PP =$ population pressure, $a =$ minimal hectares (ha) of land required for a “decent” living, $f =$ number of farmers expressed as percentage of the total population in the area, $P_0 =$ total population at the reference time, $r =$ annual population growth rate (%), $t =$ time period of study, and $L =$ total farmers’ land (ha). In this model, population pressure is defined as a potential force that presses the farmers to extend their agricultural land with a factor equal to the value of the population pressure. When population pressure is 1, there is no urge of the farmers to extend their farm land. The minimal hectares for a decent living is not a biological variable that can be fixed at a certain level, but rather it is a social one that changes from time to time according to the level of standard of living. Presently, because of the still widespread occurrence of poverty, the level of decent living can be conveniently set at twice above the poverty line. With this qualification, the use of this model in development planning implies that the aim of development is to improve the general standard of living of the villagers to a decent level. If development could reduce population pressure to 1, with the qualification of the $a$ value, the quality of life of the villagers would be improved, and deforestation and erosion would be controlled.

The model shows that to reduce population pressure to minimal levels, hopefully to 1, the factors $a$, $f$, and $r$ should be reduced and the factor $L$ increased. However, in Java the increase of $L$ is generally impossible without creating environmental hazards. We see then that agricultural development should be integrated with efforts to create off-farm employment and family planning.
Table 16.9. Average Minimal Hectares for a Decent Living ($a$ Value)

<table>
<thead>
<tr>
<th>No.</th>
<th>Farming Type</th>
<th>$a$ Value (ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Wet rice</td>
<td>0.49</td>
</tr>
<tr>
<td>2.</td>
<td>Corn</td>
<td>1.02</td>
</tr>
<tr>
<td>3.</td>
<td>Cassava</td>
<td>0.51</td>
</tr>
<tr>
<td>4.</td>
<td>Sweet potato</td>
<td>0.72</td>
</tr>
<tr>
<td>5.</td>
<td>Peanut</td>
<td>0.44</td>
</tr>
<tr>
<td>6.</td>
<td>Soybean</td>
<td>0.59</td>
</tr>
<tr>
<td></td>
<td><strong>Average</strong></td>
<td><strong>0.63</strong></td>
</tr>
<tr>
<td>7.</td>
<td>Silkworm</td>
<td>0.39 - 0.78</td>
</tr>
<tr>
<td>8.</td>
<td>Freshwater fish pond</td>
<td>0.13</td>
</tr>
<tr>
<td>9.</td>
<td>Running water fisheries</td>
<td>$4 \times 10^{-4}$</td>
</tr>
<tr>
<td>10.</td>
<td>Orchid</td>
<td>$4 - 65 \times 10^{-4}$</td>
</tr>
<tr>
<td>11.</td>
<td>Chicken</td>
<td>$10 - 40 \times 10^{-4}$</td>
</tr>
</tbody>
</table>

Notes: Decent living is here defined at twice above the poverty line, which is at an income level equivalent to 650 kg/rice/person/yr.

Nos. 1 to 6 were calculated from statistical data of the Central Bureau of Statistics (1982). Nos. 7 to 11 are from resettlement studies of Saguling (Institute of Ecology, 1979).

Average values of $a$ have been calculated for several farming types (see Table 16.9). The table shows that fish culture, particularly running water fisheries, and orchid and chicken farming, have extremely low values of $a$. These can be developed in homegardens. Fish culture and chicken farming could stimulate local production of fish and chicken feed, which would create markets for upland crops, such as corn, peanut, and soybean, which in turn would stimulate crop rotation. The processing of corn, peanut, and soybean for fish and chicken feed would have a value-added effect and presumably would reduce the $a$ value of these crops. Therefore, by looking at potential resources, such as the availability of year-round flowing water and potential markets, such as nearby towns and cities, agricultural development options can be widened, and thus not necessarily be limited to rice.

Off-farm employment can be created by the development of postharvest technology, such as processing of fruits, wood, bamboo, and, as mentioned
above, the production of feed from upland crops. Such creation of off-farm employment should be coupled to the development of homegarden, *talun-kebun*, and dry lands. It is also conceivable to develop home and village industries using as raw material rubber, steel, and petrochemical products (e.g., for the production of household utensils and spare parts of cars, motorcycles, and industrial machineries).

*A sine qua non* for the success of the creation of off-farm employment is the provision of training for certain technical as well as management and marketing skills, and the availability of credit. Without such efforts, the villagers would not be able to reap the benefits of rural development; instead, these would go to city people. The exploitative nature of the urban-rural relationship would predominate, defeating the very purpose of rural development and making it unsustainable (see Figure 16.1).

Many development projects (e.g., industrial estates, tourism, and toll roads) use large areas of agricultural land. In such projects almost all benefits go to city people. It is a prime example of the exploitative urban-rural relationship. It is imperative that in such cases the exploitative role of the relationship be minimized. An example to achieve this is to use the market value of the land as a share in the enterprise and to train the owner to work on it. He would then become a shareholder and employee, which would assure him of a long-term income. In this way nonagricultural development would become integrated in rural development. In order that off-farm employment can eliminate population pressure, the wage plus the income from farming, or even better the wage itself, should be minimally at the level of decent living.

If the percentage of farmers can be reduced substantially, the attitude of the people toward children would presumably change. Fewer children would be preferred, which would reduce the population growth rate. In any case the family planning program should be integrated in rural development.

Another important consideration is not only the integration of the components of the rural ecosystem, but also the integration of the functions of those components. For example, the natural functions of homegarden and *talun-kebun* in hydrology and erosion control and as a gene bank should be preserved as much as possible. The preservation of the gene bank may be difficult or even impossible *in situ*. For this purpose the creation of a botanic garden of economic plants may be considered. Likewise, the social function of these land uses should not be lost to avoid the creation of social problems.

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Williamson, G. S.  

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CHAPTER 17

Medical-Geographic Aspects of Agroecosystems: Endemic Goiter in Central Java

Barbara A. Chapman

This chapter is an exploration of the idea that certain agroecosystems are limited in their ability to provide essential nutrients to their human communities, although these limits may not be immediately obvious if the criterion of evaluation is bountiful crops. As an example, I will draw from a medical-geographic investigation of endemic goiter in the highlands of Central Java. There the poverty of the rural communities and the local nature of their food supply system combined with the availability of certain minerals to produce a public health problem difficult to solve.

CULTURAL ECOLOGY: MODEL FOR DATA GATHERING

This research grew out of what has generally been known as human ecology. This school of thought, developed in anthropology, holds that cultural variety—the multiple of technologies, organizations for work and play, and even religious and philosophical beliefs—is not just decorative or interesting in itself, but serves a "higher" evolutionary purpose as suggested by Darwin. All human activity is ultimately held to be "adaptive" or functional in keeping the particular population alive, minimizing their harvest

of consumable minerals and energy from their environment. A considerable number of cultural ecology studies have focused upon disease as one of the important environmental challenges man must meet not only with a biological response, but also a complex cultural response.

The commonalities among the subset of biocultural studies as delineated by Bennett et al. (1975) are:
1. The focus is upon specific individuals and populations as a unit.
2. There is a multidisciplinary frame of reference.
3. They study specific human behavior, not generalized norms or averages.

My study shares most of the above-mentioned characteristics. I observed and documented a particular place, a particular population, and a cultural adaptation to a local disease hazard—endemic goiter. My background in cultural and biological anthropology and medical geography heavily influenced the choice of data and the methods used to retrieve it. The study methodically investigates cultural behavior patterns relating to the distribution and consumption of goiter-relevant foods at three levels of generalization, the village as a whole, the households varying by resources, and individuals.

Man is able to cooperate with others of his species to a degree unknown to other animals. By importing and exporting commodities, he mitigates the limits of any particular environment. Herein lies the fallacy of simple coincidence mapping of disease and mineral abundance in a single area. Man also selects and rejects items from the wide range available in the environment and distributes these chosen items very unequally throughout the population by attributing unequal values to them. The medical geographic approach utilized here incorporates much of the above-mentioned characteristics of a human ecological study while maintaining several time-honored approaches in geography. As with other geographic studies of a place, this study has considered details of people-environment interactions in the particular place, and it has integrated data and literature from several different academic spheres within a single area in an attempt to explain the unique etiology of endemic goiter in the highlands of Central Java.

I would like to comment on the ecological model's usefulness at particular phases in medical geographic research. Especially in the proposal writing and fieldwork phases of the research, ecological modeling encouraged the inclusion of relevant aspects of human behavior and the environment in the study, whether or not these factors have been typically included in studies of endemic goiter. During the fieldwork phase, the data indicated considerable human response to ameliorate the shortage of iodine in the area. However, driven by the ecological framework, I found many local behavior patterns that are deleterious to the iodine balance, such as dietary preference for cassava and papaya leaves and the importation of large amounts of cabbage.
Based on the resulting understanding of the endemic goiter complex in the highlands of Java, it is possible to see how the problem is related to local agriculture, trade patterns, poverty, and dietary habits. As such, it is a better basis for planning for the development of the area than a conventional report on endemic goiter, which would have presumed simple iodine deficiency. It is clear that agricultural development in this area cannot afford to ignore the nutritional well-being of the farming communities. Past introductions, such as those that led to the focus of mass production of cabbage in the Dieng Plateau, have had a dramatic but unacknowledged effect on the health of the producers and surrounding communities.

THE MEDICAL-GEOGRAPHIC MYSTERY OF GOITER

Goiter affects 400 million people throughout the world. Diagnosis is a simple physical examination and, until recently, it was also thought to be easily explained and treated. Research established the role of iodine in hormone production in the early years of the twentieth century. The thyroid, a bilobed gland at the base of the neck, traps iodine from the circulating blood supply and later produces ideo-proteins, which are necessary for normal growth and metabolism. Iodine deficiency results in compensatory growth of the thyroid tissue. Continued severe iodine deficiency may result in hypothyroidism in the goitrous individual and debilitating cretinism or deafness in the offspring of a goitrous mother.

In the first quarter of the twentieth century, Western countries acted to reduce endemic goiter by supplementing basic foodstuffs, usually salt or bread, with iodine. This effort coincided with a dramatic decline in the incidence of goiter and cretinism, confirming to health authorities the efficacy of iodine supplementation. The effect, however, may have been partially due to concurrent diversification and expansion of food systems in industrialized countries. As food preservation techniques and transportation systems improved, communities formerly dependent on local agricultural products came to draw upon whole continents. In developing countries today, however, rural communities remain largely dependent on local food sources. Perhaps this is one reason why prophylaxis campaigns focusing exclusively on iodine supplements have often failed. It suggests that some goitrogenic agroenvironments are more complex than simple iodine-deficiency models propose. Evidence has been accumulating over the past 20 years, which indicates that simple iodine deficiency is not always a sufficient explanation for the existence of endemic goiter. Several studies have found that simple iodine availability in drinking water was not predictably related to the distribution of the occurrence of goiter (Ekpechi et al. 1965, Petola 1965). Other reports have noted “epidemics” of goiter in places where it had previously been absent (Negri 1965, Henschen 1966). After 15 years of iodine supplementation in a valley in Colombia where goiter was endemic, goiter prevalence initially declined from 52 to 30 percent but then leveled off at the 30 percent plateau. Goitrogenic factors in the drinking water were
implicated (Gaitan 1973). A recent review (Delange and Ermans 1976) cites 35 studies of goiter endemics in 16 countries, all of which are attributed to dietary factors other than iodine deficiency.

Because of the low level of success of iodization programs in developing countries where there was no accompanying rapid economic progress, goiter has again become a medical mystery, stimulating a search for other environmental associations as clues to the etiology of a disease that is incompletely understood (Pyle 1979). Four associations to explain the distribution of goiter have been suggested (Pyle 1979): (1) an absolute environmental shortage of iodine; (2) an excessive presence of other minerals in the water, such as calcium of fluoride, competing with iodine for uptake by the thyroid gland; (3) a diet predominated by the Brassica family of plants; or (4) a relatively unexplored thesis that some forms of goiter may be infectious. Learmonth (1978) advances some familiar theories to explain the uneven distribution of endemic goiter. He points out that Northern Hemisphere goiter endemias often correlate with areas with recently glaciated soils; and that leached soils in areas of high rainfall may account for some tropical endemias. Alternative theories propose drinking water high in calcium from limestone catchments or diets with high levels of goitrogenic plants as possible causes for goiter levels unexplainable geographically. Researchers now consider goitrogenic substances in food and water supplies to be likely factors explaining the distribution of intractable endemic goiter areas (Barzelatto 1970, Underwood 1973, Nutrition Reviews 1975) and adhere less strictly to the former theory of simple iodine deficiency.

Several lines of microlevel research reveal that the concentration of iodine in plants corresponds very closely to the iodine concentration in the supporting soil (Menzel 1965). First, despite iodine's essential role in animal metabolism, higher plants do not require it. This probably explains why iodine is not included in the indices of several well-known soil science texts I reviewed (Mohr and Van Baren 1972, Brady 1974). Second, the iodine content of soil appears to be derived from the organic material it supports and is relatively unrelated to the parent rocks. Consequently, mature soils with a long history of supporting vegetation tend to be richer in iodine than undeveloped soils. Iodine and nitrogen contents of soils are also closely related (Aston and Brazier 1979). The mechanism for this process is the absorption of iodine from rainwater through the leaves of plants (Vought et al. 1970). Third, some investigations focus on the antithyroid activity of Cruciferae under different growing conditions. The goitrogenicity of cabbage (Sedlak 1961) varies directly with the amount of sulfates provided in the growing medium. Rats fed on high sulfate cabbage develop goiters, whereas those fed on cabbage with the lowest concentration of sulfate do as well as controls on a normal diet.

We can briefly summarize the associations posited to explain the occurrence of goiter: (1) relatively young soils contain little iodine, whether
their youth is due to glaciation, volcanism, or erosion, exposing the populations who live on them to the hazard of absolute iodine shortage; and (2) in spite of local iodine supply, or in some cases in addition to iodine shortage, there are several environmental factors that can act as active goitrogens. One such class of goitrogens is comprised of antithyroid agents that block the uptake of iodine by the thyroid. Among these are other elements, cobalt, calcium, or flouride, and also compounds, such as perchlorate and thiocyanate, which occur in food plants such as cassava. A second class of goitrogens blocks the production of iodine-containing hormones within the thyroid. These thiouracil compounds, found widely in many cultivars of the Cruciferae, Umbelliferae, and Compositae families, cannot be overridden by supplemental iodine and therefore present a difficult public health problem. Local conditions leading to endemic goiter range from the simple situation of absolute iodine shortage to a variety of interactions between the population, iodine supply, and several types of active antithyroid agents. As a basis for understanding the unique human interactions with particular environments, we must first examine the normal geochemical cycling of iodine.

THE GEOCHEMICAL CYCLE OF IODINE

The iodine cycle is one of the most simple of the sedimentary biogeochemical cycles in which human beings participate. Iodine compounds ionize readily and are soluble at normal temperatures; consequently, the largest repository for iodine is the sea. Iodine is the eighteenth most abundant element in the oceans (at 280 tons per cubic mile), but it is so rare on land that it is not listed among the 67 most abundant elements in the earth (Reynolds 1974). Most organisms known to contain appreciable amounts of iodine are also from the sea, for example, seaweed and fish (McClendon 1933, Grimm 1952, Underwood 1973). Elsewhere, iodine is distributed in rather minute amounts over the earth. The only natural mechanism of recycling iodine from the sink in the sea, other than harvesting fish and seaweed, is through wind action. This involves collecting iodine from the wind-roughened surface of the ocean, after iodine molecules are produced from iodide in the water surface by ultraviolet light (Vought et al. 1970). Through this process, iodine is suspended in the air and eventually precipitated in rain on the land. Studies by Vought et al. (1970) suggest that the main mechanism of iodine replenishment in the soil is through absorption into the leaves of plants; terrestrial sources of iodine are the decaying remains of plants and animals and do not depend on the parent rock type (Aston and Brazier 1979). Food and water supply most of man’s iodine. Except in unusual conditions of air pollution, atmospheric iodine is a minor source of human iodine (Vought et al. 1964). Given the unequal distribution of iodine in the environment and the human requirements, there are problems in the procurement and distribution for inland communities.
Human occupation of an environment is far from the passive coincidence of a people and an environment. Because systems of exploiting the environment have developed over centuries, the flow of nutrients in human food chains is as much a social process as it is a physical process. Iodine or goitrogens may enter the human food system from water, food, or medicines. Available iodine and goitrogens are distributed in culturally patterned ways. Patterns of consumption may vary by area, by season, or as a result of the social roles assigned to individuals within a cultural group. Because some of the goitrogens involved in endemic goiter cannot be overridden by supplementation with excess iodine, the system of goitrogenesis in particular places must be studied in some detail before programs of amelioration can be planned.

A CASE STUDY

As a case study, I will describe the iodine cycle in Central Java, Indonesia, which has developed over a thousand years to serve populations living far inland in iodine-deficient areas. The traditional iodine-supply system involves the seaside producer, middlemen, purchasing households, recipes for preparation, and rigid dictates for consumption, depending on one's role within the household. It is a traditional iodine-supply system undergoing changes caused by original research I carried out between 1976 and 1979 in the goitrous community of Prigi, supplemented by secondary sources and older studies.

The Setting

Java is an island where very few places are more than 50 kilometers from the iodine-rich sea; yet, health surveys reveal that goiter and cretinism — diseases characteristic of iodine deficiency — are endemic in the interior. It is not uncommon for 60 to 80 percent of elementary school pupils to exhibit the tell-tale sign of swelling at the base of the neck. This is surprising because, in general, foods from iodine-rich environments tend to provide adequate food sources of iodine, and in Java, specifically, seafoods are commonly preserved and consumed. Why then, in a potentially iodine-rich environment, is goiter so common?

Several varieties of antithyroid vegetables play an important role in the diet of the area: the cabbage family (*Cruciferae*), bean family (*Leguminosae*), and cassava (*Manihot*). Tracing iodine and antithyroid compounds through the goitrous community of Prigi was an exacting task because their vehicles — the particular seafoods bearing iodine and the individual vegetables bearing antithyroid compounds — are processed into a great variety of foods and then allocated to various individuals, according to culturally established patterns, depending on economic status, sex, and age of the recipient. The subdivision of goiter-relevant foods into iodine-bearing foods and goitrogen contributors hopes to simplify what is in fact a highly complex goiter endemia.
The Iodine Supply

The youthfulness of Javanese soils of recent volcanic origin is probably a major cause of marginal dietary iodine supply. At the source of the Serayu River in the Dieng Plateau area, continuing geologic activity manifests itself in sulfur outcroppings and steam vents. Here the goiter lobes are the size of grapefruit. Farther down the river valley, in the research area, goiters are smaller, but the prevalence is 62 percent, and there is considerable incidence of cretinism.

Since the iodine content of locally grown plant foods and consumption of iodine-rich foods imported from more favorable habitats reflect the low level of iodine available in the soil, we must examine the origin of the major foods eaten in this goitrous community. The rich and the poor alike largely consume locally grown foods, with a few important exceptions: rice, preserved sea products, and a complex of temperate crops, including cabbages, beans, and spices from the nearby Dieng Plateau. Since sea products are the only likely sources of iodine in this inland village, the pattern of seafood importation and consumption reveals something of the distribution of iodine within the area, suggesting a long-standing cultural adaptation to iodine shortage.

Inland settlements have traditionally traded for several iodine-bearing sea products including sea salt, dried fish and fish flakes, and fermented fish paste. Coastal settlements received inland fruits, vegetables, and starchy staples in return for their seafood. This coastal-inland exchange is old, but relatively fragile. For example, it became much less effective during the economic depression of the 1930s, when inland populations lacked the economic resources necessary to acquire these coastal products, as a result of the global drop in demand for their own produce (Scheltema 1939). Also, villagers remember that salt became expensive during the ten years of military action that began with World War II and ended with Indonesian independence. The delicate systems of production and transportation to inland areas, involving innumerable middlemen and repeated sun-drying of the products, were disrupted.

The ocean products consumed regularly in Prigi are sea salt; salted dried fish; *trassi*, a fermented fish paste product usually adulterated with banana or some other starchy filler; and two kinds of a very fine dried-fish product, one a very small shrimp and the other some shredded fish flakes (Table 17.1). This last category, *rese*, I will call fish flakes. Two possible seafoods sometimes wrongfully attributed a role in the rural Javanese diet are fish sauce and seaweeds. Neither of them was commonly sold or consumed in the area of my research.

In general, the iodine content of seafoods is between 10 and 30 times as concentrated as land-derived plants and animals. The extent to which it may be affected by storage and processing is not well documented. Sea salt, the most commonly used salt in Java, is low in iodine (Driem et al. 1963,
Table 17.1. Sea Products Important for Iodine Supply in Central Java, Indonesia, 1976-79

<table>
<thead>
<tr>
<th>Seafood</th>
<th>Consumption (times per week)</th>
<th>Equitability of Distribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fish flakes</td>
<td>3</td>
<td>Equitable</td>
</tr>
<tr>
<td>(rese)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dried fish</td>
<td>1</td>
<td>Inequality determined by cost</td>
</tr>
<tr>
<td>(age, status, sex, taste)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fish paste</td>
<td>1</td>
<td>Inequality determined by age, sex, taste, cost</td>
</tr>
<tr>
<td>(trassi)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sea salt</td>
<td>7</td>
<td>Equitable</td>
</tr>
<tr>
<td>Seaweeds</td>
<td>Never</td>
<td>a</td>
</tr>
<tr>
<td>Fish sauce</td>
<td>Never</td>
<td>a</td>
</tr>
</tbody>
</table>

aNot consumed in rural Central Java.

Kusumopradono (1976). Preserved ocean fish products, on the contrary, are relatively high in iodine. Any loss in the drying phase occurs when liquid escapes from the flesh. In boiling or frying, some iodine is lost to the cooking oil or water (Harrison et al. 1965, Aitken and Connell 1979). However, any iodine lost in this way is conserved in the larger pattern of Javanese cooking and eating habits. The cook reuses oil until one or another food has absorbed the lost iodine carried by the seafood products. The consumption patterns of seafoods are complicated by differing levels of economic prosperity and by customs of food allocation within each household. Each of the three products has its own unique distribution pattern, dictated by custom and economics.

For instance, *trassi*, the fermented fish paste product, is used in 20 percent of the households in sparing amounts as an ingredient in a salt-and-chili relish. This relish is added to the rice plate of adults but is not commonly consumed by children under the age of ten. The poor make their relish without *trassi*; thus, the distribution of *trassi* within the village and within households is less than uniform.

Small dried fish are a common item in the diet; 58 percent of the households cook fish within any given two-day period. Very small amounts of dried fish are involved; 1 metric ounce is the most common amount. These small filets are a fine source of iodine, but their distribution within each household lessens their potential for iodine supply. Strongly held beliefs and customs determine the distribution of the fish within the household. The fish are very salty, even to the taste of the villagers. From the cook's economic...
point of view, this is a virtue, for the fish are highly desirable as a side dish. Housewives expressed the concept that if the fish were not salty, everyone would eat much more of them; thus, the extreme saltiness of the fish limits its consumption. In wealthier households, the fish may be soaked once and sun-dried before frying. There are, however, classes and categories of people who, according to local custom, should not consume dried fish filets. Pregnant or nursing mothers avoid fried dish, so that their milk will not be fishy. Young children are not given fried fish until they are five years old. As a remedy for scaly skin, the child may be put on a fish-free diet by the traditional medical practitioner or by the public health nurse. As a result, women in their childbearing years and young children do not consume much dried fish. Since the small dried fish are preferentially served to whoever has the highest status in a house, the elderly, the adult men, or possibly guests are the only members of the village who regularly benefit from small dried fish as a source of iodine.

Rese consists of two separate products: tiny sun-dried shrimp and fish flakes. These are not used as food but as a condiment in vegetable side dishes. The flakes and spices (and the soluble iodine) are suspended in the soupy portion known as *kuah*. As such, the fish flakes escape the tabus and social pressures applied to *trassi* and fried fish. In fact, the *kuah* of all cooked foods is believed to contain certain strength-giving properties. Therefore, it is liberally ladled onto the rice portions of children. This is done even for children who are considered too young to eat the side dish itself. Thus for those between the ages of one and three, the diet might consist largely of rice with *kuah* ladled over it and occasional starchy snacks or banana. Other members of the household also ladle the spicy water over their rice and comment on its health-giving properties. The soluble iodine from fish flakes is thus rather equally distributed to the various ages and sexes within the household.

To summarize, consumption of iodine-rich sea products in this endemic goiter community is restricted by economic limitations and by customs of food allocation within the household. Women, children under the age of ten, and everyone in the poorest households are unlikely to partake of dried fish or *trassi*. Therefore, the role of fish flakes as a source of iodine in the diets of these vulnerable groups cannot be overstated.

Considering the above reconstruction of the distribution of preserved sea products in the village, with its emphasis on the importance of the fish-flake condiment for certain vulnerable groups, let us examine the results of a diet survey I conducted covering six consumption days in each of the 25 households between October 1977 and June 1978. Generally speaking, the diet of the rich showed a trend toward more variety, not only in the number of vegetable dishes cooked over the six days but also in the occasional use of eggs, chicken, and milk. The rich cooked an average of 7.6 vegetable dishes over the six days, whereas the middle-range households cooked 6 and the poor only 5.7 (Table 17.2). A newly introduced spice, monosodium
ENDEMIC GOITER AND AGROECOSYSTEM

Table 17.2. Use of Fish Flakes and MSG Condiments at Three Economic Levels

<table>
<thead>
<tr>
<th>Income Group</th>
<th>Number of Households</th>
<th>Number of Vegetable Dishes Prepared</th>
<th>Dishes Containing MSG Only (%)</th>
<th>Dishes Containing Fish Flakes Only (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rich</td>
<td>5</td>
<td>7.6</td>
<td>30</td>
<td>39</td>
</tr>
<tr>
<td>Middle</td>
<td>8</td>
<td>6.0</td>
<td>59</td>
<td>26</td>
</tr>
<tr>
<td>Poor</td>
<td>12</td>
<td>5.7</td>
<td>73.4</td>
<td>26.4</td>
</tr>
</tbody>
</table>

aData from a 6-day diet survey.

glutamate (MSG), is competing successfully with the traditional fish-flake condiment. The rich had more tendency to add MSG to a recipe already containing fish flakes than did the middle income or the poor. Thus, the rich seem to have adopted MSG as an additional spice, but the poor have replaced one flavoring with another and recently virtually eliminated an important iodine source.

To address the original question, is the traditional system of iodine-bearing foods adaptive to the iodine shortage and goitrogen potential of the area? The development of the coastal-inland exchange system, which in 1977 imported and distributed 8 kilograms of dried sea products into a hamlet of 125 households every two days, appears to merit an affirmative evaluation; but a more rigorous microscale examination of the distribution pattern makes the answer less clear. Although the groups whose need for iodine is greatest are women in their fertile years, teenagers coming into puberty, pregnant women, and growing children, these groups do not receive an equal share of the seafoods imported into the village. Their disadvantage is increased by the recent trend toward replacement of fish flakes with MSG in cooking.

Goitrogens

The supply and consumption patterns of suspected antithyroid-containing vegetable foods must also be considered in order to understand the cultural-environmental system that produces endemic goiter in Prigi. Prigi is also involved in a smaller scale food exchange with the cool, high-altitude region of the Dieng Plateau. The region is too high to raise rice or coconuts; instead, it grows a complex of crops that are termed “Dutch” or “Chinese” by the Javanese, reflecting the American and continental-Asian origin of the many varieties of cabbages, potatoes, and corn. Proximity and ease of transport suggest that the cabbage products of the Dieng Plateau would be conspicuously present in the periodic fresh vegetable markets of the lower villages, and such indeed is the case.
Marketing

Markets are held in the early morning at the entrance to Prigi on two out of every five days of the traditional Javanese market week. This small market features only two vegetable merchants and a dry-goods outlet selling oil, sugar, flour, and a variety of dried spices. The clientele represents roughly 150 households, not all of whom shop every market day. The total volume of vegetables, which passes through the market, is small by outside standards; but since few villagers shop away from the village, it is a major portal for nonlocal produce, contributing to both the iodine and antithyroid supply.

On an average market day, between the months of April and November, 73 kilograms of cruciferous vegetables are sold. The selection of Cruciferae is composed of a variety of cabbages, cresses, and mustards originating in the Dieng Plateau region. Nearly 0.5 kilo of crucifers are available for each household. From the end of the dry season, extending into the rainy season before any crops are ready for harvest (roughly between November and March), only 36 kilos of crucifers are for sale on an average market day. This pattern reflects the high value the villagers place on the cabbage family for side dishes to accompany rice. During the part of the year when they can afford to, they eat cabbage in considerable quantities. It is a must for wedding parties and ritual feasts. Prices did not show seasonal patterns except that prices rose annually before and during the Rhamadan feasting. The pattern of seasonal production and the ability of the villagers to buy their favorite vegetables.

Consumption Patterns: Goitrogens

Frequency of cabbage consumption (versus locally gathered vegetables), as determined in a diet survey conducted in three seasons, reveal the following patterns: Consumption of locally (i.e., nonmarketed) gathered leafy vegetables is high in all seasons, with a slight dip in October — the driest season when people complained that there were very few leaves to gather. Cruciferae consumption, on the other hand, shows a distinct pattern, with half of the surveyed households cooking cabbage in June directly after the big rice harvest and only 7 percent of the households eating cabbage in February. This is the rainy season, when wild leaves are abundantly available, but there is very little money or work in the village since the rice and corn are planted but not ready to harvest. October, with the fewest opportunities for gathering in the village, shows considerable cabbage consumption, with 28 percent of the households cooking cabbage in the two days of the diet survey and 45 percent responding that cabbage was a common food in that season.

Generally speaking, cabbage from the nearby Dieng Plateau is a tasty variation in a monotonous diet in the spring and summer months during which the villagers enjoy harvest proceeds and have some money to spend. Even in October, they buy small amounts to accompany the staple because leafy greens for gathering are scarce in the dry season. The lowest cabbage consumption level is during the preharvest waiting period of January through
March, when there is little cash work available in the village and when wild and semiwild leafy green vegetables are readily available.

CONCLUSION

Upon examination of the food supply system in rural Central Java, the existing goiter endemia appears to be complex. Food supplies are largely local, forcing the population to depend on soils that are of fairly recent volcanic origin and consequently deficient in iodine. Despite the development of a traditional iodine-supply system from the sea to the interior, incorporating preservation techniques, a complicated market system, and elaborate rules for distribution, goiter still persists. The traditional iodine-supply system has proven fragile under the stress of economic and political disruptions and recently has partially succumbed to the competition of an introduced substitute, MSG.

As serious a problem as the vagaries of the iodine-supply system is the presence of goitrogens in the diet. Cruciferous products from the nearby Dieng Plateau are consumed in great quantities by the residents of lower areas peripheral to the plateau. The contribution of these products to the goiter endemia in Central Java is probably considerable, although it is difficult to quantify. The goitrogenic potential of Cruciferae varies with the sulfate content of the soil. Data are unavailable, but the presumption of a high sulfate content for the soils of this active geologic area is not unreasonable. In addition, the nature of the goitrogenous compound in Cruciferae is such that it cannot be overridden by iodine supplementation.

Recently the national health department has taken several steps to alleviate the goiter endemia in Central Java—specifically through the distribution of iodized salt; and in areas where cretinism is found, iodized oil injections for individuals under 40 years of age at a cost of US$5 per shot. These efforts are handicapped by limited funds and the shortage of management skills, storage, and transport facilities common to developing countries. Even if the goal of iodine supplementation were achieved, success would be limited by the causes of endemic goiter. This endemic goiter is not the result of simple iodine deficiency but is complicated by the role of Cruciferae in the diet.

The high prevalence of goiter and cretinism in Central Java appears, upon the evidence of the food supply system, to originate in the unique complex of locally circulating soil nutrients. The poverty of the rural population in combination with undeveloped transport and food production systems has restricted them largely to locally grown foods. This is unlikely to change in the near future. Much research remains to be done, but there appears to be limits to the potential of this agroecosystem to provide a healthy diet for the local population.

This public health nutrition problem has implications for any transfer of agricultural technology to the area. Iodine deficiency in the soil is not a limiting factor to plant growth but strongly affects the health of the people.
who live there. Increased cabbage production may mean an increase in goiter prevalence.

In light of the special human health problem of the area, I would like to advance several suggestions for consideration by agricultural researchers:

1. Human health and nutrition should be firmly emphasized as a major goal and criterion of agricultural development.
2. Iodine in soils should be considered as a limiting factor in the production of nutritious crops and be included in the battery of minerals routinely tested in soils.
3. Soil mineral supplementation efforts should consider not only plant requirements but also human nutritional benefits. Research could be done on the possibility of supplementing fertilizer with iodine. In the light of the role of high-sulfate soils in the production of highly goitrogenic Cruciferae, careful consideration of the health problems of particular areas should precede any supplementation with sulfates.
4. The poverty of the populace and the local nature of their diets should be considered in agroecosystem development interventions.

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Northern Thai farmers have employed a vast range of plant genetic resources in the highly diverse rice-based agricultural systems of the Chiang Mai Valley. In this chapter we will attempt to describe the various ways in which farmers have selected different rice varieties to fit different agroecological conditions and constraints to crop production.

Rice-Based Systems of the Chiang Mai Valley

A more detailed description of the Chiang Mai Valley agricultural system has been presented elsewhere (Gypmantasiri et al. 1980). The valley is a contiguous piece of alluvial plain covering an area of 160,000 hectares. Most of this has been bunded and leveled for the cultivation of wetland rice, which covers the entire valley throughout the wet season. The valley supports some 100,000 agricultural households, most of which grow glutinous rice for their own consumption. About 70 percent of the wet season rice crop is irrigated with water diverted from the Ping River and its tributaries. Some of these traditional irrigation systems date back before A.D. 1200 (Sektheera and Thodey 1975). Dry season irrigation is available to about 60 percent of the land. Two-thirds of the area has sufficient water for one more crop after rice, and rice is succeeded by two subsequent crops in the remaining one-third. Subsistence requirement for glutinous rice, the availability of water for the dry season, and the pattern of multiple cropping are three of the critical factors that influence the use of rice varieties by farmers in the valley.
DIVERSITY PATTERNS OF RICE IN THE CHIANG MAI VALLEY

Northern Thailand has been designated as one of the centers of diversity of *Oryza sativa* (Chang 1976a, 1976b, Morishima et al. 1980). Diverse forms of wild rice (*O. perennis*), considered to be the progenitor of common rice, are commonly found in the area (Morishima et al. 1980; Prapas Weerapaeet, pers. com.). Excavations at Spirit Cave in Mae Hongson west of Chiang Mai revealed evidence that Gorman (1969) interprets as a rice culture that was dated as far back as 6000 B.C. The majority of rice grown in the Chiang Mai Valley, as in other parts of the upper north, is of the glutinous type. This seems to have always been the case (Golomb 1976). Visitors to the area have often been impressed by the number of local rice varieties. Watabe (1967) noted, "There must be several hundred varieties of glutinous rice in the whole of Northern Thailand." The varieties differ greatly from valley to valley. For the Chiang Mai Valley, a collection at the Rice Department (now Rice Division of the Department of Agriculture) dated 1950-64 listed 33 named varieties of glutinous rice. Watabe (1967) listed 12 glutinous rice varieties commonly grown in the Chiang Mai Valley and referred to five to six others which are also grown.

In November and December 1981 we made ten one-day trips throughout the valley and collected 55 grain samples, mostly as panicles from plants just as they were being harvested in the field. A few exceptions were those earlier varieties that had to be collected from bulk in a barn. It must also be mentioned that these varieties were grown among improved and recom­mended varieties from the Ministry of Agriculture, which we did not collect. In all, we talked to 50 farmers, often in labor exchange groups. We learned about the farmers’ reason for growing a particular variety, its history, the crops that were to follow rice in the dry season, the size of farm, other rice varieties that are also grown, and other background information about the farm and rice. Our experience sharply contradicts earlier reports that farmers were “uneducated” (Dasananda 1968) and that they have little comprehen­sion of “variety distinction” (Watabe 1967). On the whole we found that farmers had a good appreciation of the concept of “variety” and “selection.” It does not seem likely that they have learned all this knowledge only in the past ten years or so. We asked for seed samples, 50 panicles or 500 grams of bulk seed, by stating that we needed to preserve these indigenous varieties as our local heritage and to show them to students. Most farmers became very enthusiastic about this and left their harvesting to help collect the panicles. Although they could not specify the selection criteria, they were able to distinguish a particular named variety from other materials and did not hesitate in telling us that we had picked “wrong” panicles. Some of the off-types that were pointed out included a wild “civet cat” rice (*Khao E-hen*), nonglutinous panicles, and panicles of other named varieties. We noted that farmers distinguished the varieties on the basis of the appearance of the grain (i.e., color, shape and size, panicle branching and size).
The seed samples were divided into two sets. One set was sent to the Rice Division germ-plasm storage in Bangkok and the other was planted by Dr. Boriboon Somrit at San Patong Rice Station in the dry season of 1982. Seed size and weight were measured by Phrek Gypmantasiri of the Department of Agronomy, Chiang Mai University.

From the 55 accession number, 42 distinct varieties were identified by the appearance of grain and panicle. There appeared to be no variation within each sample. This was confirmed by the appearance of the seedlings in the nursery and in the field based on seedling height, leaf angle, and droopiness. The seed weight of the different varieties ranged from 20 to 38 grams (g) per 1,000 seeds; the majority were between 26 to 36 g. Grain shape, designated by length/breadth ratio, varied between 2.5 and 3.5. When plotted into the background of rice collected from all over the upper north by Watabe in 1967, the material collected in 1981 in the Chiang Mai Valley appeared to be within the same boundary as the older set.

The development of flowers and panicles in dry season planting, when day length is becoming longer, is an indication of the degree of sensitivity of a variety. Before the introduction of the nonphotosensitive RD varieties at the end of the 1960s, there were several varieties of rice that were grown in the dry season in the Chiang Mai Valley. The Rice Department collection dated 1950-64 listed three dry season varieties: Chao Daw, Leuang Lang, and Bai Lorb. Watabe (1967) noted that the Daw Luey variety had "less photosensitivity" than the standard varieties, making it possible to cultivate it in both main and dry season. Now, all these varieties have virtually been replaced by new nonphotosensitive varieties from the Rice Division’s breeding program such as RD 1, RD 7, and RD 10. When planted in January 1982, all varieties in the collection flowered within six months; but there were large variations in the number of days that each took to flower and the intensity of reproductive development. The percentage of tillers, which produced panicles, ranged from 20 to 80 percent. It can be expected that these varieties will also differ in their response to the lengthening day length within the wet season. Our own detailed study of one early maturing Daw Prao variety showed that the difference in sowing dates over four months from June to September could result in a marked difference in plant growth and in the number of days that it took to flower and mature. It may be noted that the date of maturity of the variety was only slightly affected by the date of planting.

In the Chiang Mai Valley most of the wet season rice crop is planted in July and August. Dates of maturity of the material collected determined by the actual time of harvest by farmers varied from early November to the end of December.

In addition to maturity range, we also recorded special characteristics of each variety as perceived by farmers (Table 18.1). Some of these characteristics, such as tolerance to deeper water, lodging resistance, and kneeing ability, could be easily verified in the field. Some other characteristics were not so
Table 18.1. Some Varietal Characteristics of Rice as Perceived by Farmers

<table>
<thead>
<tr>
<th>Variety^a</th>
<th>Characteristics</th>
<th>Immediate Verification in the Field</th>
</tr>
</thead>
<tbody>
<tr>
<td>Daw b Sam Deuan, Kam Daw, Daw Khao, Kaew Daw, Daw Dawk Ngae, Daw Nam Pung, Daw Horm, Daw Lai Kaset, Daw Noi, Daw Tammada, Daw Wang Hak</td>
<td>Earliness</td>
<td>Yes</td>
</tr>
<tr>
<td>Dawk Pud</td>
<td>Kneeing ability</td>
<td>Yes</td>
</tr>
<tr>
<td>Kaew Daw, Leb Mue Nang Kloui</td>
<td>Lodging resistance</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td>Adapted to low fields with water depth up to 30 cm</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Easier to thresh</td>
<td>No</td>
</tr>
<tr>
<td></td>
<td>High milling percentage</td>
<td>No</td>
</tr>
<tr>
<td></td>
<td>Better eating</td>
<td>No</td>
</tr>
<tr>
<td>Daw Dawk Ngae, Rod Nee</td>
<td>Better than recommended variety</td>
<td>No</td>
</tr>
<tr>
<td>Khao Kon Cham</td>
<td>Selected out of standard variety</td>
<td>No</td>
</tr>
<tr>
<td>Nor Phrea</td>
<td>Tillering well</td>
<td>No</td>
</tr>
<tr>
<td></td>
<td>Good eating</td>
<td>No</td>
</tr>
</tbody>
</table>

a Many of the names are explanatory, which may be true or merely wishful thinking. For example, Daw Wang Hak means broken beam, indicating a harvest so heavy that the beam in the rice barn breaks; Rod Nee means debt free; Daw Sam Deuan means three months' rice.

b Daw in Northern Thai means earliness.

readily verifiable. We also came across some small plantings not more than 10 square meters of some odd varieties, with apparently no obvious practical value.

**PATTERN OF UTILIZATION OF RICE VARIETIES**

With the availability of numerous rice varieties, farmers of the Chiang Mai Valley do not just grow any variety at random. They appear to exercise a considerable degree of deliberate choice. The subsistence requirement for glutinous rice appears to be the most overriding factor. Up to 95 percent of farmers in the Chiang Mai Valley grow some glutinous rice for their own consumption (Gypmantasiri et al. 1980). Since 1956 the Ministry of
Agriculture has introduced several improved varieties of rice into the valley. Many of these were simply selected from local materials; others were introduced from different parts of the country. Since the end of the 1960s, the so-called modern high-yielding varieties were also added. The Ministry of Agriculture introduced the following rice varieties:

Local selection or improved: Glutinous Rice
- Muey Nawng 62 M;
- Daw Leuang 88;
- Niaw Sanpatong; Gam Pai 15;
- RD 6, RD 8

Nonglutinous
- Leuang Yai 34; Dawk Mali

Modern bred lines: Glutinous rice
- RD 2, RD 10

Nonglutinous
- RD 1, RD 7

There is no record of the area under each variety of rice grown per year during the wet season in the valley. Our own estimates for the wet season of 1981 are shown in Table 18.2. Niaw Sanpatong, a mutant from Leuang Yai 34, which is a Central Plain rice, is the standard glutinous variety for the valley. It was released at the end of the 1950s. It is a mid-season variety with reasonable yield potential and exceptional cooking quality; however, it is not suitable for every farm. The nonglutinous Dawk Mali is grown by the larger farmers who hope for a better price of high-quality nonglutinous rice. Other major factors, which determine the farmers' choice of variety, are listed in the following paragraphs:

Table 18.2. Percentage of Rice Land in the Chiang Mai Valley Planted to Different Varieties

<table>
<thead>
<tr>
<th>Variety</th>
<th>Rice land (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Niaw Sanpatong</td>
<td>45</td>
</tr>
<tr>
<td>Dawk Mali</td>
<td>10</td>
</tr>
<tr>
<td>Early maturing “Daw” varieties</td>
<td>20</td>
</tr>
<tr>
<td>Nonphotosensitive RD 1 and RD 7</td>
<td>5</td>
</tr>
<tr>
<td>Traditional full season varieties</td>
<td>20</td>
</tr>
</tbody>
</table>

a Also other medium season varieties such as Gam Pai, but to a much smaller extent, and most recently, RD 6 - a glutinous mutant of the scented Dawk Mali which is becoming extremely popular.

b For example, Khao Kaew and Khao Pah, which mature immediately toward the end of December.
Multiple Cropping

In terms of area the biggest cropping system in the valley is probably rice-soybean. The soybean is planted in late December through mid-January. This system fits ideally with mid-season varieties, such as Sanpatong, Dawk Mali, and RD 6, which are harvested at the end of November or early January. Other major cropping systems (i.e., rice-garlic, rice-tobacco, and rice-vegetables), however, require earlier rice harvest. For these, most farmers use the various "Daw" varieties that are available. A few farmers are now incorporating the modern RD 1, RD 7, and RD 10, which are not sensitive to photoperiod to meet this need.

On one occasion we came across farmers who grew just one rice crop a year but who preferred to grow the early maturing variety. The choice of variety in this case was influenced by the rice-garlic area nearby. One rai of garlic requires three rai of rice for the mulching straw; hence, there is a large demand for the long straw of the traditional variety in early December. The single rice farmers in areas next to the rice-garlic area can earn 600 to 800 baht from straw in early December.

Deep Water and Late Draining Soil

Rice fields in the valley are quite variable. At the valley level, there is a large area of about 20,000 hectares to the southwest of the town of Chiang Mai, which has no water control and is prone to flooding. At another level, along each irrigation canal there are usually about 20 percent of the fields lower than the rest. Another flood prone area is along the Ping River. All of these are problem lands for two specific reasons: deeper than normal water depth and late draining of field at harvest. In these areas some of the full season varieties (i.e., Khao Kaew and Khao Pah) are the standard because fields could not be drained early enough for the more popular mid-season varieties such as the Niaw Sanpatong. We also came across the variety Khao Kloui, which was claimed by farmers in four different locations to be well adapted to low spots. Many of the farmers who grew this variety have actively sought it out after having been informed about it by friends, neighbors, or traveling village traders.

Poor Farmers

An observation that we have always made in Chiang Mai is that many of those who still persist in growing some of the older late maturing varieties were the poorer farmers who own only 2 to 3 rai of land. The explanation that the farmers themselves normally give is that Niaw Sanpatong, the standard variety, is too nice to eat, so that the family tend to eat too much of it. Aversion to risk with new technology is an explanation we get from our social scientists. We have discovered another explanation. November to December is probably the busiest time in the valley, with labor demand at its highest. The rice has to be harvested and preparation must also be made for
the second crop to follow. The poorer farmers supplement their income by hiring themselves out during these peak periods. Therefore, they would prefer a rice variety that does not compete for their own labor with their wage earning harvest.

Problem Areas with the Standard Variety, Niaw Sanpatong

Niaw Sanpatong is definitely the most successful single variety of rice that has been introduced into the valley since its discovery as a mutant from Leuang Yai in the 1950s. However, a number of the farmers who have grown it have found that there are considerable problems for two reasons:

1. "Deterioration" of the eating quality. Many farmers claim that the rice becomes hard after it has been grown on the same land for a few seasons. The normal farm practice to overcome this is to renew the seed stock with seed from other parts of the valley or outside the valley every three or four years.

2. Six farmers out of the 50 from whom we collected the traditional varieties of rice said that they had grown Niaw Sanpatong before, but that it was unsatisfactory because the percentage of infertile grains was too high.

IMPLICATIONS FOR DEVELOPMENT: RICE IN THE CHIANG MAI VALLEY

Determinants of Varietal Choice

From the preceding analysis we have seen that for farmers to select a variety of rice, it must satisfy a set of agroecological constraints. For rice in the Chiang Mai Valley, these constraints are human preference and habit (i.e., glutinous rice habit), physical constraints (water depth), socioeconomic (relative price glutinous/nonglutinous rice, farm size, labor profile), and agronomic practice (cropping systems). These constraints must be considered for any new variety in relation to each other depending on farmers’ strategies and tactics.

Impact of New Innovations

Glutinous Rice Habit. Of all the modern rice varieties introduced since 1969, RD 6 seems to be the most successful in terms of farmers’ acceptance for the wet season. This variety is a glutinous mutant of the scented Khao Dawk Mali. Its major attribute is that it offers another alternative to the mid-season glutinous variety with high grain quality.

In contrast, RD 2, a nonphotosensitive variety released in 1972, is much less widely adopted because its eating quality is considered unsatisfactory.
Cropping Systems. The semidwarf varieties RD 1, RD 7, and RD 10 are beginning to make an impact in areas with rice-tobacco and rice-vegetables. In Harn Kaew and Mae Kung, the two Multiple Cropping Project testing villages between 1973 to 1977, the proportion of farmers growing traditional varieties is now much lower than in other parts of the valley. The adoption of the nonglutinous RD 1 and RD 7 has been restricted to farmers who operate farms of sufficient size to produce crops in excess of their subsistence rice requirement. These farmers sell the early nonglutinous rice immediately upon harvest and use the proceeds to finance the normally high-cash input, cool-season crops. The glutinous RD 10, with its reasonable cooking quality, is beginning to make an impact on those farmers who have to meet their subsistence requirements for glutinous rice.

The impact of these modern varieties on areas of cropping systems that require early maturing rice is not expected to extend into those areas where rice straw for mulching is an essential input in the cropping systems (i.e., rice-garlic, rice-shallot, and rice-onion). In these areas, high straw yield and quality seem to be essential qualities of the rice variety. Early maturing traditional “Daw” varieties will continue to be dominant. In the rice-onion system, the requirement for early rice harvest is bypassed; farmers grow their onions in seedling beds, which formerly were rice seedling beds. The onions are transplanted toward the end of the year. This enables them to grow medium or full season varieties of rice.

In summary, the adoption of new varieties requires that the innovation meet the various socioeconomic and physical constraints that made the old variety to be replaced essential in the first place. Borrowing the concept of an ecological niche, we argue that to ensure adoption of an innovation its agroecological niche must be correctly identified. Failure to do so will mean limited adoption as we have seen in Chiang Mai. A worse outcome would be the cropping up of second generation problems. The Chiang Mai Valley has been spared of this, perhaps because the farmers were free to choose or reject new varieties and there was a wealth of traditional varieties from which to choose.

For all the different kinds of constraints we have identified, the kind of rice needed can be agronomically classified as early, mid-season, and full season. Within each group, major desirable characteristics include glutinous and nonglutinous and high straw yield.

We have identified the areas where there is some need for improvement:

- Full season varieties, mainly glutinous, but some nonglutinous.
- The numerous traditional early varieties should be selected for adaptation and yield improvement (e.g., for lodging resistance, better yield).
- The reason behind the failure of standard varieties such as Sanpatong should be identified.
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Watabe, T.
Effective human management of agricultural, forest, aquatic, and other ecosystems necessarily requires improved scientific understanding of the properties and dominant interactions occurring among the biological, physical, sociocultural, and institutional components of these ecosystems. In order to understand these relationships, a new kind of research approach is needed. It is called interdisciplinary by some, and others use the word multidisciplinary, but in this chapter the term transdisciplinary research will be adopted. Multidisciplinary implies that research is being conducted by researchers coming from different disciplines but not necessarily sharing a common framework or communicating with each other. Interdisciplinary research connotes some degree of integration of a limited number of disciplines. Transdisciplinary research as used in this chapter involves a higher level of disciplinary integration where several researchers try to look at a common situation or problem area, adopt a common framework, and relate findings of one discipline with another. An example is the sort of human ecology perspective Rambo referred to in Chapter 3.

At present, however, the transdisciplinary approach is still in its infancy. This is reflected in the varied perceptions of different scientists who have been engaged in this type of research approach. In the view of the late George Van Dyne (pers. com.), who headed the International Biological Program,
U.S. Grassland Biome Project, "Interdisciplinary work is not collected research but collective research." On the other hand, P. A. Morrison of the Rand Corporation (as cited by Norman 1974) has said, "The hallmarks of an interdisciplinary study are that it seems overpriced, it shows that everything depends on everything else (and that) nobody really understands what it says." There is much to be learned yet. But the fact is that things happen out there in the real world not because there are only plants, not because there is only water, not because there are only animals, not because there are only people, but because there are all of these together, and it is this total reality that must be properly perceived and analyzed. This is the basic rationale for the use of the transdisciplinary research approach in the study of rural ecosystems (Lipton 1970, Norman 1974). The identification of the most appropriate organizational structure and processes for transdisciplinary research, which can generate relevant information ordinarily difficult to obtain with the monodisciplinary approach, is an immediate challenge. At this point in time, it is useful to look at the experience of one "pocket" of transdisciplinary research—the University of the Philippines at Los Baños (UPLB) Upland Hydroecology Program (UHP)—in order to help answer the following questions:

1. What are the more common and important requirements of an effective transdisciplinary research approach?
2. What are the unique requirements of transdisciplinary research due to differences in particular cultures and institutional settings?

Answers to these questions will be necessary if transdisciplinary research is to reach an acceptable level of effectiveness as a research approach that can generate the data base for ecosystem management.

This chapter is based upon the five years of experience in transdisciplinary research of the UPLB Hydroecology Program. These insights were mainly condensed from the author’s perspective while he was a Study Leader and Co-coordinator of the program from 1976 to 1980.

BRIEF DESCRIPTION OF THE UPLB UPLAND HYDROECOLOGY PROGRAM

This transdisciplinary research program, which consisted of a group of 20 scientists from various disciplines and units of the university, was formed in 1976. The general objectives of the program were (1) to broaden the basic understanding of upland ecosystem dynamics in order that schemes for land-use classification/allocation of upland areas and the management of swiddenfields, grasslands, second growth forests, and industrial plantations as protective watersheds in the Philippines might be improved or developed appropriately; (2) to establish a training center for applied research on upland ecosystems in the Philippines; and (3) to organize a national applied research network, which would serve primarily as field validation stations for all
technical recommendations evolved and developed from the basic and applied studies at the UPLB program base. There were five units at UPLB that were involved in the program: The College of Agriculture, College of Forestry, College of Arts and Sciences, Institute of Agricultural Engineering and Technology, and the College of Development Economics and Administration. Staff members from the Ministry of Natural Resources and the Bureau of Animal Industry were also recruited into the program. Funding for the program was provided by three local national agencies—National Irrigation Administration (NIA), Bureau of Animal Industry (BAI), and Ministry of Natural Resources (MNR)—and the Ford Foundation. The Ford Foundation funding sustained the program during critical periods when national agencies were hesitant to commit funds before the viability of the transdisciplinary program had been demonstrated.

THE TRANSDISCIPLINARY RESEARCH PROGRAM AND ITS FORMATION

An effective transdisciplinary research program should be endowed with a structural organization that promotes the process of effective data acquisition and synthesis for the solution of a problem or concern such as the appropriate management of natural resources for rural development. This is analogous to a water system that consists of a particular structural design to promote the function of providing a reliable and adequate water supply (Figure 19.1).

There are some recognizable factors that can serve as catalysts in the formation of a transdisciplinary research program:

1. Recognition of a common problem area by a number of scientists belonging to different disciplines,
2. High probability of obtaining funds for research on this particular problem area,
3. Availability of committed multidisciplinary manpower,
4. Frustration with the inadequacy of compartmentalized approaches in analyzing a dynamic and multifaceted ecosystem management area,
5. Strongly felt commitment by scientists to rural development,
6. Challenge and motivation to start a new research approach, and
7. Historical involvement of researchers in similar work or approach.

The widely deteriorating condition of upland areas in the Philippines is a well-recognized problem. Scientists who became involved in the UHP were mostly those who already had varying exposures to this problem area because of their disciplinary interest or place of origin. It became obvious later on that members of the group who were very interested and who could most readily relate to the work came from areas where this problem existed. Informal exploratory discussions with some funding agencies, especially the
UPLAND HYDROECOLOGY: AN INTERDISCIPLINARY RESEARCH

Figure 19.1. Water pump as an analogy of transdisciplinary research.
Ford Foundation, also indicated interest in supporting this type of approach and problem area.

Previous research involvement of scientists participating in the program already had a high degree of relevance to the problem area of upland resource management. Their research activities had included grassland ecology, multiple cropping, reforestation, watershed management, drought tolerance, and soil fertility. The university was indeed a good place for the initiation of this transdisciplinary research program because of the availability of highly trained manpower from a variety of disciplines.

SOME CRITERIA FOR DETERMINING THE COMPOSITION OF THE TRANSDISCIPLINARY RESEARCH TEAM

The composition of the transdisciplinary research team of UHP has changed several times during the course of the program. This changing pattern of membership has contributed to establishing some criteria for identifying individuals who can work successfully in a transdisciplinary team. The following are some useful guidelines for selection of participants:

1. Their particular disciplines or expertise are needed in tackling the problem area, or for the realization of program objectives. The composition of the transdisciplinary team must include representatives of the biological, physical, and social sciences. It must also include representatives of both general as well as specialized types of disciplines (Figure 19.2). Generalist members, or members with broad training, orientation, or exposure, will be involved in conceptualizing of the research program, setting up the research framework, and synthesizing the activities. Disciplines, which were identified with this group in our program, were ecology, cultural anthropology, systems analysis, hydrology, economics, and soil science/agronomy. The specialist members of the group will have a better chance of fitting into a transdisciplinary team if they are willing to absorb the inputs of other disciplines.

2. High sensitivity and commitment to the problem area focus in the research: Our experience at the UHP shows that this characteristic is important in sustaining the interest of members of the transdisciplinary team.

3. Demonstrated dedication and interest in research: A dedicated researcher is an important asset in a transdisciplinary team where everybody is expected to "express" his discipline to improve the understanding of highly interactive components of the natural resource system.

4. Generally share common philosophy on research and rural development.

5. Hold positions that can facilitate transdisciplinary work: Approximately 40 percent of the UHP team members were department chairmen. This was important because the departments comprise the basic functional unit at UPLB. The interest of the different units in the university is thus automatically built into the inter-unit transdisciplinary program if the
Figure 19.2. Transdisciplinary work group composition of the UPLB Upland Hydroecology Program.

department chairmen are members of the team. Arrangements of this nature tend to promote efficient use of resources at the university in support of the transdisciplinary research program.

6. Have credibility and patience: Since transdisciplinary research is a new and evolving approach, these qualities of the researchers are necessary, especially because there might be a need to test new methods and strategies just to bring the group to work together.

Usually, the request to add new members to the team should also come from within the group. These new members are personally known to the group members and are deemed appropriate to the needs of the transdisciplinary work.
STRUCTURAL ORGANIZATION OF THE TRANSDISCIPLINARY TEAM

The structural organization of a transdisciplinary team would depend on the scope of the work and size of the team. The UHP was a relatively large group consisting of at least 20 study leaders and almost the same number of research assistants as the main research work force. After five years of operation, it had linked up with five outreach, upland development programs in several parts of the country. Its organizational structure, therefore, may have had some unique features to suit the particular needs of this group.

The changing pattern of the UHP organizational structure is shown in Table 19.1. An interesting aspect to note is the later addition to the project structure of an institutional liaison officer, data systems manager, publication/synthesis officer; and research liaison person. These were components that were not perceived to be necessary at the beginning but later on became necessary for increased effectivity and sustainability of the program.

Administration

Some research study leaders also performed administrative jobs for the transdisciplinary research program. Better check and balance was also attained in the program by having two coordinators. However, it is important to delineate the administrative functions of the two coordinators for more effective coordination of activities in the program.

The institutional liaison officer is one of the study leaders who assumes the responsibility of linking with interested external agencies to maintain the communication channels for funding assistance and policy purposes. This was not a component of the UHP at the beginning and the program suffered as a result in terms of continuity of funding and temporary isolation from national agencies who should have been involved in the program.

Research

There is one overall coordinator for the research group who facilitates the group interaction to generate the research framework, analysis, and synthesis of data; to communicate among different members of the group; and to synchronize properly the activities of the team.

The study groups, in general, can be divided into subgroups or subdivisions. During the survey or inventory phase of the program, subgroups could represent the different components of the ecosystem (i.e., primary producers, consumers, decomposers, hydrometeorology, soils, and socioeconomic aspects). After this phase, the subgroups can represent the more dynamic aspects of the ecosystem (i.e., nutrient cycling, hydrology, energy balance, and socioeconomic relations). At the same time, these investigations can be focused on identified applied concerns in the uplands, which are reforestation, agroforestry, and land-use planning.
Table 19.1. Organization Structure of the Upland Hydroecology Transdisciplinary Team (20 members)

<table>
<thead>
<tr>
<th></th>
<th>First Year</th>
<th>Second Year</th>
<th>Third Year</th>
<th>Fourth Year</th>
<th>Fifth Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. Administrative</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Coordinator(s) — $C_1, C_2$</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>2. Administrative assistant</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>3. Supply requisition officer</td>
<td>-</td>
<td>-</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>4. Outreach station manager</td>
<td>-</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>5. Institutional liaison officer</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>X</td>
</tr>
<tr>
<td>B. Research</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Overall coordinator</td>
<td>$C_1$</td>
<td>$C_1$</td>
<td>$C_1$</td>
<td>$C_1$</td>
<td>$C_1$</td>
</tr>
<tr>
<td>2. Division leaders</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>2 a. Study leaders</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>b. Research assistants</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>3. Data systems manager</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>X</td>
</tr>
<tr>
<td>4. Publication/Synthesis officer</td>
<td>-</td>
<td>-</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>C. Outreach station coordinator</td>
<td>-</td>
<td>$C_2$</td>
<td>$C_2$</td>
<td>$C_2$</td>
<td>$C_2$</td>
</tr>
<tr>
<td>1. Research liaison</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>D. Program committees</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Planning — $C_1, C_2, C_2, B_2$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Personnel — $C_1, C_2, A_2, B_2$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Budget — $A_2, A_5$</td>
<td></td>
<td></td>
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<td></td>
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</tr>
</tbody>
</table>

$X =$ present; $-$ = absent.
The organizational development of the research set-up is highlighted by the following:

1. Addition of the data management, synthesis, and research publication components in the research set-up during the third year of operation,
2. A research-liaison arm and an outreach station coordinator became necessary when the applied verification stations increased in number,
3. Participatory planning and personnel management were also necessary and program committees were established to meet these needs, and
4. Budgetary planning is critical for effective program management, and a committee was also set-up for this purpose.

In retrospect, much of the instability and vulnerability of the transdisciplinary program to rapid turnover of manpower was due to the inability of the program to cope with budgetary intricacies and its "loose" linkages with local national agencies.

SOME KEY PROCESSES INVOLVED IN TRANSDISCIPLINARY WORK

There are some recognizable processes associated with transdisciplinary work. These are necessary to promote the group process of conceptualization of the research design, data collection, synthesis, and evaluation. They can also provide the basis for assigning priorities for allocation of project funds. Key processes include the following:

1. Formal and informal group discussions and seminars: These are necessary and effective mechanisms in promoting transdisciplinary research. The value of these mechanisms can be described in terms of two types of synergistic actions or relationships, namely, (1) human to human and (2) discipline to discipline.

   a. Human-to-human interactions: A transdisciplinary program involves not only different disciplines but also scientists (who are also human beings) with different personalities. During the proposal stage, the objectives of UHP were stated in a general way so that during the implementation stage, there was the tendency for scientists of each particular discipline to do their own particular studies regardless of what others were doing. For example, a soil scientist will just go on analyzing the soil of the study area using standard methods of his discipline without being particularly concerned about whether his work can be related to the work of the mycologist, soil microbiologist, or botanist. There was also the tendency to get as much support as possible from the general research fund for their own special studies. It was also the feeling among some workers, especially among natural scientists, that they were doing more work than others. For example, they observed that the social scientists only visited the field sporadically to observe and conduct interviews, whereas they had to be in the field more regularly. This feeling
also pervaded the ranks of the research assistants and created problems on promotion.

Formal meetings to discuss and promote a common understanding of what the program is really all about, why there is a need for it, and how specific objectives tied up with the general objectives of the program helped resolve many of these misunderstanding among different personnel of the program. However, our experience has shown that other than or even more than the formal meetings, informal meetings can help improve the human-to-human relationships for better communication and cooperation in transdisciplinary research. The UHP benefited much from long distance trips to outreach stations in cars where scientists from different disciplines could talk and discuss for hours within the confines of the vehicle or during outings or parties held during some special occasions. Meetings were also used in the UHP to reduce tensions on issues related to (1) use of data and credit for published work, (2) synchronization of research activities, and (3) personnel promotion. For example, there was a time when the research team was planning to conduct a study on “fire ecology of the grassland,” and a study leader was quite insistent on starting the burning treatments right away. During the meeting, however, it was pointed out by the mycologist and soil microbiologist in the team that they were not quite ready to handle the volume of samples that was expected after the burning treatments. This led to the group decision to postpone the start of the burning treatment to a later date.

Some important guidelines on philosophy for UHP must also be discussed by the whole group. These are issues regarding priority research thrust and how to deal with some results with strong political implications. After long discussions during meetings, the group agreed that (1) the transdisciplinary research should emphasize the study of the situations of the upland farmers, where they are, and why they are doing what they are doing now, and (2) that the position of the program is to relay the results of the study to the community where it was conducted and not to decide for the community what must be done; that if a researcher should assume a stand or a position on an issue resulting from the study, that this position should be the individual’s position and not that of the group or the program.

It became quite clear toward the later stages of the program that a scientist who is strongly individualistic has a difficult time working with a transdisciplinary research group.

b. Discipline-to-discipline interactions: Perhaps the greatest benefit generated by the UHP was the demonstration to traditionally and strongly disciplinary-oriented scientists that a greater understanding of the upland ecosystem can be attained if viewed in the context of contributions from both the natural and social sciences. As indicated earlier in this chapter, the bulk of the researchers in UHP consist of natural scientists. In fact, the program was originally conceived by natural scientists, and is reflected in the
kind of studies initially conducted in the program. For example, in trying to answer the question of why upland farmers are planting particular kinds of crops at some particular time and place in the uplands, the research outputs of the meteorologist, soil scientist, entomologist, and agronomist can only provide some partial explanations (i.e., infestation of mung beans by some pests can be related to rainfall data, that the planting of crops or the location of the upland farms is related to the depth and quality of soil, and that fertility of the surface soil can be related to activities of earthworms). However, when the sociologist and economist joined the group, it became apparent from their results that the aspirations, expectations, and work capacity of farmers were also important determining factors influencing the decision of upland farmers on the choice of upland crops. For example, the social scientists were able to show that security of land ownership, labor availability and allocation, and the market also significantly influenced the decision of the upland farmers as to what kinds of crops to plant during a particular time of the year. This was appreciated by the natural scientists in the same manner that the social scientists were able to realize that rainfall, soil type, and pests and disease problems could not be ignored in an upland ecosystem. A regular seminar designed to acquaint each one involved in the transdisciplinary research program with the terms and methodologies used by each discipline greatly facilitated the communication process across disciplines. An indication of the effectivity of this process is that the social scientists began using terms learned from the biologists and vice versa.

2. Organization into working groups depending on the needs of the program: This was elaborated in the previous section on research organization.

3. Synchronization of activities: Transdisciplinary work demands effective synchronization of activities of various team members of groups. Some effective means of doing this are:

   a. Use of fund control for assigning relative priorities to activities. This requires good teamwork between the coordinator(s) and the administrative assistant or whoever programs or handles the financial components of the program,
   
   b. Group consensus can help facilitate proper synchronization of activities, and
   
   c. Good interpersonal relations.

4. Adopt a system of data collection, sharing, storage, retrieval, and synthesis: Effective transdisciplinary group work can be measured in terms of how much each specialized research group depends upon or utilizes the data generated by other groups on the team. However, common guidelines for sharing of data and publication of research results of the program can be formulated and agreed upon at the beginning to avoid problems later, which could be inimical to group work.
5. Conduct periodic internal evaluation and group introspection: This is a delicate process that is needed as a feedback mechanism to improve the work of the group. A facilitator is needed for this process.

6. Develop external linkages that can promote inputs of views on research methodology and policy implications into the program.

FACILITATING MECHANISMS FOR TRANSDISCIPLINARY RESEARCH ACTIVITIES

A facilitating mechanism for transdisciplinary research is like oil to a machine. You have to apply it at the right place and at the right time. The type of oil applied must also suit the kind of machine involved. Some of these mechanisms may be generally applicable to all types of transdisciplinary work, whereas others may only be applicable to our specific institutional set-up or even the cultural milieu at UPLB.

1. Group participation in generating research framework, methodology, and synthesis of results: This strategy as a facilitating mechanism should be undertaken collectively by the group. The presence of systems-trained or oriented members in the group can be helpful for the purpose of formulating the framework, but it is essential that the whole group accept this framework. A framework, however well conceived, that is acceptable or understandable only to the coordinators or to a few members of the group will not produce high-quality transdisciplinary research. It is also necessary for the group to be able to modify the framework or methodology as the program evolves. An example of such a framework that was evolved by the transdisciplinary group of the UHP appears in Figure 19.3. The framework does not need to be sophisticated at the beginning, as long as it is understood by the group.

2. Provide opportunities for regular meetings and discussions: Trips together, group projects, field work, and other group activities can provide the time and environment for "transdisciplinary immersion." Such joint activities provide the opportunity for developing a better understanding of personalities and an appreciation of the role of other disciplines involved in the group research.

3. Set up criteria for data management, reporting, and an incentive system agreeable to the group.

4. Provide mechanisms for group exposure to other ideas: Sometimes getting an independent outside opinion can help resolve some basic disagreement in research philosophy and methodology within the group.

5. Provide an appropriate support set-up as already discussed under organizational structure.

6. Develop appropriate mechanisms for internal and external evaluation of the program.

7. Develop a communication strategy and common vocabulary between
and among members of the team. This is very important because transdisciplinary research work will require an effective communication strategy that occurs at various levels. It is useful to construct a matrix to ascertain that all of these levels are considered (Table 19.2). The role of the program coordinator as a nodal point in this communication process is an important one. Communication strategies utilized in the UHP were the following:

a. Holding of regular meetings,
b. Making arrangements to promote physical proximity of offices and laboratories to allow for constant and informal interactions,
c. Publishing an internal newsletter, and
d. Carrying out joint field work.

Figure 19.3. Transdisciplinary research framework of the UPLB Upland Hydroecology Program.
<table>
<thead>
<tr>
<th>Level 1</th>
<th>Coordinator</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Informal but frequent consultation</td>
<td></td>
</tr>
<tr>
<td>2. Office located in the same building</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Administrative staff</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level 2</td>
</tr>
<tr>
<td>1. Regular meeting</td>
</tr>
<tr>
<td>2. Office located in the same building</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Group leaders</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level 3</td>
</tr>
<tr>
<td>1. Regular meeting</td>
</tr>
<tr>
<td>2. Coordinator visits laboratories</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Study leaders</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level 4</td>
</tr>
<tr>
<td>1. Regular meeting</td>
</tr>
<tr>
<td>2. Coordinator visits laboratories</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Research assistants</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level 5</td>
</tr>
<tr>
<td>1. Regular meeting</td>
</tr>
<tr>
<td>2. Newsletter</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Research aide/ laborers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level 6</td>
</tr>
<tr>
<td>1. Regular meeting</td>
</tr>
<tr>
<td>2. Field visit</td>
</tr>
<tr>
<td>3. Newsletter</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Level 7</th>
<th>Group leaders</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Regular meeting</td>
<td></td>
</tr>
<tr>
<td>2. Office located in the same building</td>
<td></td>
</tr>
</tbody>
</table>

| Level 3 |
| 1. Regular meeting |

| Level 4 |
| 2. Coordinator visits laboratories |

| Level 5 |
| 1. Levels 3 and 4 regular meetings |
| 2. Newsletter |

| Level 6 |
| 1. Level 5 regular meeting |
| 2. Newsletter |

| Level 7 |
| 1. Regular meeting |
| 2. Newsletter |

| Level 8 |
| 2. Level 7 regular meeting |

| Level 9 |
| 1. Level 9 regular meeting |
| 2. Field visits |

| Level 10 |
| 1. Level 10 meeting |
| 2. General meeting |
There are some useful considerations to bear in mind regarding things to avoid in pursuing and promoting transdisciplinary work:

1. Do not overemphasize your own discipline: In transdisciplinary group work it is better to actually show what your discipline can contribute in the understanding of ecological problems instead of emphasizing it during group discussions.

2. If you are a natural scientist, do not say that you are a better sociologist than a social scientist.

3. Do not use the research assistant of another study leader to do something for you without first asking for the study leader's permission.

4. Do not publish results of the work of your team members without proper acknowledgments.

5. Do not use I to refer to group work, especially when being interviewed by the media or when talking to others.

6. Do not keep your data to yourself if it is needed by your fellow team members.

7. Do not be absent from group meetings and synthesis work without letting the group know of your reasons.

8. Do not delay your inputs if they are needed by other team members.

9. Do not be disrespectful to your team members especially during group meetings.

10. Do not use the name of the group to serve your own interests.

11. Do not attempt to start independent research without first consulting the group, especially if you are the leader.

12. Do not be late in submitting your report to the group.

13. Do not be aloof from other members of the group.

14. Do not tell your research assistant what you do not like about other study leaders.

CONCLUSION

Because transdisciplinary work is in its early developmental stage, there are few examples available of this type of research approach today. The need to provide a holistic perspective and integrated data based for the rational management of ecosystems will necessarily require greater use of this type of research approach in Southeast Asia. There are some organizational strategies, facilitative mechanisms, and guidelines that can increase the probability of success of transdisciplinary human ecology work. However, before we can fully operationalize and realize the benefits of transdisciplinary research to understand human-environment interactions, we must first scale the barriers
of human-human relations. As Norman (1974) has indicated, “A research worker who is often academically oriented in a single discipline makes great efforts to preserve what he considers the ‘integrity’ or ‘supreme relevance’ of his discipline which is ‘softened by his contact with practical realities’.” It is hoped that the five years of experience in such work by the UPLB Upland Hydroecology Program reported above can offer some useful guidelines to other researchers in the region seeking to carry out transdisciplinary programs on resource management.

REFERENCES

Lipton, M.

Norman, D. W.