Agroecology and Small Farm Development

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19 SMALL-SCALE AGRICULTURE IN SOUTHEAST ASIA

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I. INTRODUCTION

Southeast Asia is a region of impressive cultural, environmental, and agricultural diversity. Much of the region is mountainous, and there is a broad range of temperatures from tropical in the lowlands to temperate in the highlands. There is also a broad range of topographic conditions, from flat alluvial valleys and coastal plains in the lowlands to undulating terrain, hills, and mountains in the uplands and highlands. Most of Southeast Asia is in the humid tropics, but there is great variation in the distinctness and duration of the dry season. Most of the land is now under agriculture (Table 1).[1]

Much of Southeast Asia is blessed with fertile volcanic or alluvial soils. Such areas, particularly the river valleys, have high human populations. Many of the mountainous areas have been dominated by forests until recent decades, but they are rapidly being transformed to agriculture as a consequence of logging and the movement of expanding human populations into land available for farming. Some areas of Southeast Asia have extremely poor soils. Until recently, most of those areas were forested and had small human populations, usually practicing shifting agriculture. Commercial logging and colonization projects are now transforming the landscape in many of those areas to agriculture.

The overriding theme of Southeast Asian agriculture is change. In addition to the spread of agriculture into forest lands, recent decades have seen major changes in agricultural technologies as a consequence of international and national programs for agricultural development. In fact, throughout the centuries there has been an influx of new agricultural technologies to Southeast Asia as various world powers have asserted their influence in the region. Farmers in the region have always been receptive to new agricultural technologies that promised to improve their lot, and the present time is no exception. However, the pace of change has quickened. Many farmers in Southeast Asia now work with a mix of traditional and modern technologies.

Along with the adoption of modern technologies, there has been a rapid transformation to a cash economy. While even remote areas of Southeast Asia bartered for certain goods (e.g., salt or cooking utensils) throughout the centuries, most farmers in the region produced almost entirely for home consumption until a few decades ago. Meeting basic household food needs is still the priority of most Southeast Asian farmers. However, most also produce as much surplus as possible to meet cash needs generated by expanding public education, rural electrification, modern communications (e.g., radio and television), and modern transport that has tied farm families to major cities in their region. Some households now specialize in one or two high-value crops and purchase most of their food.

Scientists in the Southeast Asian Universities Agroecosystem Network (SUAN) have been particularly concerned with the implications of these changes [2] Can large human populations and intensive agriculture be sustained in hilly or mountainous areas that have had forests until recently? Can introduced high-yield varieties and high-yield technologies (based on high levels of energy and chemical inputs) be expected to continue to provide high yields on a long-term basis? SUAN scientists have addressed these questions concretely in terms of the specific environmental conditions and agricultural technologies in their areas.

SUAN scientists have also been concerned with interactions between the agriculture in their areas and the social systems of farmers who practice the agriculture.[3,4] The scientists want to understand the farmers' living circumstances and their bases for making agricultural decisions, in order to know what kinds of improvements in agricultural technology will be relevant and appropriate to the farmers' needs. The scientists also have come to appreciate the need to comprehend the major social forces (e.g., transformation from a subsistence to cash economy) that are driving agricultural changes, so they can anticipate needs and guide their research accordingly.

Three broad types of small-scale agriculture are prominent throughout the region: ricefields, rainfed fields, and

TABLE 1
Land Use in Southeast Asia (1980)[1]
(thousands of hectares)

Country	Total land area	Annual cropland[a]	Perennial cropland[b]	Permanent pasture[c]	Forest and woodland[d]
Burma	65,774	9,573	450	361	32,167
Indonesia	181,135	14,200	5,300	12,000	121,800
Kampuchea	17,652	2,900	146	580	13,372
Laos	23,080	860	20	800	13,000
Malaysia	32,855	1,000	3,310	27	12,300
Philippines	29,817	7,050	2,870	1,000	12,300
Thailand	51,177	16,250	1,720	308	15,790
Vietnam	32,536	5,595	460	4,870	10,330
Total	434,026	57,428	14,276	19,946	241,149

[a] Land under temporary crops (double cropped areas are counted only once), temporary meadows for mowing pasture, land under market and kitchen gardens, and land temporarily fallow or lying idle.

[b] Land cultivated with crops that occupy the land for long periods and need not be replanted after each harvest, such as cocoa, coffee, and rubber; it includes land under shrubs, fruit trees, nut trees, and vine but excludes land under trees grown for wood or timber.

[c] Land in permanent (5 years or more) herbaceous forage crops, either cultivated or growing wild (wild prairie or grazing land).

[d] Land under natural or planted stands of trees, productive or not, includes land from which forests have been cleared but will be reforested in the foreseeable future.

homegardens. Rice is the staple food of most Southeast Asians, and flooded rice paddies dominate most agricultural landscapes in Southeast Asia. Rice is particularly prominent in floodplains and alluvial valleys, but terraced rice is also common in upland areas wherever irrigation water is available.

Rainfed fields are also common, particularly in upland areas where irrigation is not available. Rainfed fields consist primarily of annual field crops, often several different kinds interplanted in the same field. Sometimes there are fruit trees or other perennial crops scattered through the field as well. Many rainfed fields are permanent; others are rotated with a forest fallow. Paddy fields can function as rainfed fields during the dry season if they have field crops at that time.

The third major form of agriculture, homegardens, though less extensive in area than ricefields and rainfed fields, is no less ubiquitous. Nearly every house in the region is surrounded by some kind of garden, usually a mixture of shade trees and fruit trees and sometimes containing a selection of vegetables or other annual crops. Homegardens are almost always rainfed, though select crops in the garden may be hand irrigated.

This chapter will describe the agriculture of three Southeast Asia locations that have been studied by SUAN scientists (Figure 1): the Cordillera highlands in the Philippines; the uplands of West Java, Indonesia; and Chiangmai Valley in northern Thailand. These three areas represent not only a progression from highlands to lowlands but also a progression from highly traditional and subsistence agriculture to agriculture that is more modern and involved in a market economy. Each of these areas has all three types of agriculture mentioned above (i.e., ricefields, rainfed fields, and homegardens), though the details of their organization are different in each area.

Each of these areas has been selected because its agriculture has functioned so well. At the same time, the agriculture in each of these areas is changing rapidly. The changes are a response to compelling needs, but as we shall see, the changes have run into ecological and social problems. The challenge presented by these problems cannot be ignored when setting an agenda for agricultural research and development.

II. PHILIPPINE CORDILLERA (BONTOK)

The Bontok are highly traditional subsistence farmers at an altitude of 600 to 2100 m in the Cordillera of the Philippines. Villages have 600 to 3000 inhabitants who occupy a territory of 10 to 30 square kilometers. The Bontoks provide an example of agriculture that has been sustained on steep mountain slopes for centuries without ecological degradation. The following description is based on studies by the Cordillera Studies Center (University of the Philippines, Baguio) and the Institute for Environmental Science and Management (University of the Philippines, Los Baños).[5-10]

There are five major land uses: rice paddies, swidden fields, grazing areas, forest, and villages (including homegardens). Most agricultural labor is devoted to the paddy fields, which are terraced and occur primarily on the lower portions of mountain slopes wherever streams are large enough to provide irrigation water. The fronts of the terraces are held in place by stone walls. The main crop is traditional rice, which is cultivated during November to July, when sunshine is at a maximum during the dry season. A second crop, rice or field crops such as sweet potatoes, is grown in

FIGURE 1. Location of the Philippine Cordillera, West Java, and Chiangmai Valley in Southeast Asia.

paddy fields during the wet season (July to December).

Swidden fields are located higher on the slopes and are primarily rainfed. The swidden fields contain interplanted crops such as millet, sweet potatoes, beans, squash, corn, bananas, and fruit trees. Planting starts with the first rains in April, and harvests continue to the end of the rainy season in December. The timing of each swidden crop is critical, so it does not overshade or otherwise interfere with other crops in the same field. Swidden fields and traditional rice compete for labor during April to July, but the rice always has priority.

The swidden fields are not terraced, but they usually have earthen or wooden fences to hold the soil and exclude wild animals. Logs and sticks are often aligned along the contour to help hold the soil. A swidden field is cultivated for several years until yields start to decline. It is then left to fallow for about 5 years before resuming cultivation.

Higher on the slopes are pine and oak forests, which are exploited for timber (for house construction in the village), medicinal plants and herbs, mushrooms, wild animals, rattan vines, and bamboo. Level portions of the hilltops often have pastureland, which is used for grazing water buffalo and cows and as a source of grass for thatched roofing. While ricefields and swidden fields are owned individually, forest and pasturelands are owned communally by the village.

The agricultural calendar and cultivation practices of these farmers are a matter of long-standing tradition, interpreted and enforced by village elders. The elders organize labor for maintaining irrigation canals and make decisions on the timing of land preparation, transplanting, and other activities for the traditional rice crop.

Pigs occupy a central role in the village economy. They are the major source of meat for religious ceremonies and the major source of animal manure for paddy fields. Pigs are kept in stone-lined pits between the houses, where they are fed kitchen garbage, cooked sweet potatoes, and raw sweet potato tops. The pits are slanted so manure falls to one end, where it is composted with dry grass, rick husks, straw, and human wastes that are thrown into the pit. Some of the sweet potatoes are grown between the houses and constitute the major component of village homegardens.

A. Terraced Rice Paddies

Paddy field preparation begins in October by using a spade to turn over weeds and rice stalks from the previous harvest, trampling them into the mud to rot. The field is then harrowed. A man stands on the spike harrowing board as a buffalo pulls it through the mud, scattering decaying rice stalks so they cannot take root. The field is then flooded so the farmers can level the mud with the palms of their hands. Communal labor groups clean out irrigation canals at this time.

Mud from the paddy fields is packed on top of the bunds surrounding the fields and against all paddy field margins to plug holes and improve the moisture seal of the field. Taro is planted along the terrace top or laced on the rims of the paddy field. Beans or sweet potatoes may be planted at the sides of the bunds. A few weeks later it is time to weed the empty paddy fields again. The stone walls of the terraces are also weeded (with a trowel), and rat holes are stuffed with weeds. Weeds are collected from slopes immediately above the field, thrown into the fields and trampled into the mud. Pig manure compost is brought from the village in baskets and mixed into the mud.

Seedbeds are established in paddy fields with a history of high fertility and a water supply that will not be interrupted by paddy field preparation and cleaning of irrigation canals. A small section of a field is blocked off for the seedbed, so it can be drained even when the rest of the field is flooded. The seedbed is strewn with rice husks, dried bean pods, and sunflower leaves and stems, which are trampled into the mud to rot. Rice pannicles with the largest quantity of grain are chosen for the seedbed during the previous harvest.

Seedbeds are planted in November to January; pannicles about a foot in length are pushed into the mud and bent so the rice grains lie flat on the ground. Water is temporarily drained from the seedbed so the pannicles do not float. The seedbed is flooded with 1 to 2 cm of water, which discourages animals such as rats and birds from eating the seedlings. If the seedlings do not appear healthy, ashes are spread around them to increase the fertility of the bed.

Seedlings are ready for transplanting in February and March. In preparation, paddy fields receive their final smoothing, kneading, and leveling. The earth is reworked with a harrow or spading fork and subjected to another puddling with the feet. The field is drained, and the top 12 to 15 cm of soil is given a final working and leveling either with the hands or with a board that is dragged around the field by a buffalo. Farmers believe that mud in shallower water is warmer and enhances growth and flowering of the rice plants.

Women do the transplanting in groups. While some plaster mud on the margins of the fields, others bring bundles of five or six pannicles (approximately 100 to 150 seedlings) from the seedbeds. (Seedlings from seedbeds with nematodes are not used.) Different rice varieties are planted in different fields. For example, one variety does best in paddy fields that were drained during the fallow while another variety does better in fields that could not be drained.

The women tear the top leaves off the seedlings as they plant them. This is said to make the rice plant mature faster, perhaps by reducing transpiration and making the seedlings more resistant to drought. Shorter seedlings are also more resistant to being blown over by wind. The seedlings are pushed into the mud 10 to 15 cm apart with only the top 10 to 12 cm above the surface. High tillering varieties and high fertility paddies are planted less densely (i.e., 15 cm spacing). Seedlings that die after transplanting are replaced by seedlings from other parts of the field or from other fields.

A continuous supply of water is essential once the rice is transplanted. There is a village system of water rotation among the fields, but each household finds it advisable to oversee personally the delivery of water to its fields, in order to ensure its fair share. Disputes may arise and tempers wear thin as the season progresses and the supply of water diminishes.

The paddy fields are weeded 1 month after transplanting. This is the only weeding after transplanting and must be completed before appearance of rice fruitheads, which are susceptible to damage by body contact. *Azolla*, which fixes nitrogen, as well as other floating aquatic plants like *Lemna* and *Spirodela*, have spread over the surface of the water by this time and are allowed to coexist with the rice plants. These floating plants suppress the growth of rooted weeds that compete with the rice crop for soil nutrients. Fresh water snails and edible plants growing in the paddy (e.g., *Monochria vaginalis*) are gathered as food.

Once the rice heads begin to form, the main activity is setting up scarecrows. However, after a few weeks the scarecrows are no longer so effective, as the birds become accustomed to them and the maturing rice grains become more attractive. Sometimes the scarecrows are strung together with long strings attached to a paddle placed in a stream to move the string and make tin cans bump each other to produce a clanging sound. Village elders may find it necessary to announce a special day for a coordinated village effort to rid the rice fields of rats and birds. Rat holes are plugged with grass. Children and elderly people stay in small huts around the fields so they can operate noisemaker lines throughout the day.

The rice is ready for harvest by late July. This is a time of particular hazard because the typhoon season is about to start. An entire season's crop can be destroyed by typhoons if the harvest is not on schedule. Moreover, once the crop is ready, it must be harvested quickly, because even a few days' delay can lead to shattering and loss of over-ripe grain. Sufficient labor for harvesting is assured by staggering activities on the different fields of different households and deploying cooperative labor groups on each field at the proper time.

Each harvester wears a ring with a blade that is used to cut the top 30 to 35 cm from the rice stalks. Bundles of the cut pannicles (3 to 5 cm in diameter) are tied with a bamboo strip pulled tight by the front teeth. The bundles are spread on the ground to dry in the sun for at least 3 days before placing them in the granery. It is important for the grain to be completely dry to prevent molding or premature germination. Properly stored grain can last for as much as 8 to 10 years.

Yields are high, typically 6 t/ha, even though many of these paddy fields have been used continuously for centuries without chemical fertilizer. Soil fertility is maintained through organic matter and mineral inputs from pig manure compost, forest soil, weeds, and rice straw, as well as detritus and dissolved minerals in the irrigation water. Inputs of 260 kg/ha nitrogen and 120 kg/ha phosphorus have been measured from pig manure compost alone.

About half the paddy fields are drained after harvest and left to fallow the rest of the year. The other half is planted to a second rice crop or a field crop such as sweet potatoes, peanuts, beans, or garlic. The second rice crop employs varieties that mature more quickly than the first. They are ready for harvest 4 months after transplanting, but yields from the second rice crop are correspondingly lower. Cultivation procedures for the second rice crop are similar to the first, but labor groups are smaller and there is no coordination of labor by the village elders. A disadvantage of a second rice crop is that it may compete with labor for swidden fields. It is also difficult to harvest the second rice crop in time to prepare fields for the first rice crop. A delay in starting the first can be particularly serious if it is not harvested before typhoons begin.

Sweet potatoes are the most common crop in drained paddy fields during the rainy season. The field is prepared in September by ditch mounding soil over beds of rice straw. Sweet potato cuttings are inserted into the mounds, which are weeded as soon as new roots have formed and runners appear. Farmers say that drying out the paddy soil with a sweet potato crop is important because it reduces stunting and mortality of rice seedlings during the first critical week after transplanting.

The sweet potatoes are harvested in December. They are stored in a corner of the house without washing off soil clinging to the surface because it is said the soil protects them from deterioration. Young runners on sweet potato vines are gathered for human consumption, and mature leaves are used to feed the pigs.

B. Contemporary Changes

Bontok farmers have tried to be selective in adopting only those outside agricultural practices they can control, thus avoiding dependence that might interfere with village affairs. Nonetheless, there has been an increasing impact from the outside world due to greater cash needs, outmigration of villagers, their involvement in nontraditional employment, and a growing presence of the national government. Villagers are now selling some of their surplus of swidden and drained paddy-field crops such as beans, eggplant, and fruit. They have started to plant garlic in their drained paddy fields. Garlic commands a high price in the urban market but is sold locally to middlemen who pay a much lower price. Villagers at higher altitudes are growing vegetable cash crops such as potatoes, cabbages, tomatoes, stringbeans, and carrots in any paddy fields that lack sufficient irrigation water for a rice crop.

As cash has become more essential to pay for college educations, hospital bills, bad business deals, lawyers' fees, and construction of "modern" houses, villagers are working away from the village more (e.g., in nearby copper and gold mines). The result has been an agricultural labor shortage in the villages, especially during harvest time. Farmers employed away from the village are increasingly lending out their paddy fields on share-cropping arrangements or selling them for cash, and reciprocal labor groups are beginning to be paid in cash when the owner of a paddy field is employed outside the village and cannot reciprocate the labor exchange. A paddy field that is left unflooded and uncultivated for more than a year develops an overgrowth of grass and bushes whose roots may break up the stone walls holding up the terraces. The terraces may collapse if the mud at the edge of the field dries out and starts to crumble. Some of the swidden gardens have been neglected in recent years due to insufficient labor, and an increasing number have passed into fallow.

Commercial fertilizers were not taken up by the villagers during the 1960s and 1970s, but chemical fertilizers are now being adopted by farmers who have sufficient cash but are short on the household labor to carry bulky compost to the fields. Some farmers who have adopted commercial fertilizers in the past 5 years are beginning to complain about a change in the consistency and stability of their paddy field soil. Although they agree that yields have increased, they also say they are able to maintain higher yields only by increasing the amount of fertilizer they apply each year.

Farmers in the nearby Loo Valley now devote all of their land to cabbages and potatoes for the urban market. Wide swings in the market prices of these two crops (as much as fivefold in a few months) offer an opportunity for enormous profits if a large harvest is realized when the price is high, but the experience of most farmers in the Valley is much more modest.

The costs of inputs for Loo Valley have become oppressive, as it has become necessary to apply massive quantities of chicken manure (averaging 7 t/ha/year) and NPK fertilizer (averaging 1 t/ha/year). The fertilizers have caused severe soil acidity, and the large areas in continuous monoculture of these vegetables have led to severe pest and disease problems. Pest control, which has changed from traditional removal by hand and use of extracts of avocado, tobacco, and chili pepper leaves to modern pesticides, is far from satisfactory. The diamondback moth, for example, has already evolved resistance to malathion, methylparathion, DDT, diazmon, mevinphos, and carbaryl, forcing the farmers to employ restricted insecticides that are hazardous to their health and to consumers.

Cabbage yields in the Loo Valley are double what they were 20 years ago, but input costs have increased 20-fold; input costs for potatoes are ten times as great with no increase in yields. Because the farmers must borrow money to cover the costs of these inputs, they have been forced into a cycle of high interest payments and cumulative debt that recently has led some of them to turn to lower-value crops (e.g., sweet potatoes) that do not demand such costly inputs. Severe erosion, due to the lack of ground cover under continuous vegetable production and the fact that farmers cannot spare their labor for terracing or other erosion control measures, combined with diminishing water supplies from mountain streams that serve as irrigation sources, have placed in doubt the entire future of commercial farming in the Valley.

TABLE 2
Land Use in West Java (1980)[12]

Land use	Area (ha)
Ricefields	1,168,691
Plantations	670,979
Forest	968,166
Upland fields and homegardens	1,609,567
Total	4,417,403

III. UPLANDS OF WEST JAVA

West Java is an area of fertile volcanic soils and exceptionally high population density, typically 600 to 1200 inhabitants per square kilometer. The terrain is hilly in the uplands (500 to 1200 m in altitude), where gently terraced rice fields occupy the lower and flatter areas. Villages are usually located on slightly elevated land at the edges of the rice fields. Land above the village is dominated by rainfed upland fields that contain a variety of interplanted annual and perennial crops (Table 2). The highest parts of the hills usually have forest or woodlots. West Java provides examples of highly intensive agriculture that has been maintained for centuries on an ecologically sustainable basis, despite severe land scarcity. The following description is based on studies by the Institute of Ecology, Padjadjaran University, Bandung.[11-15]

Virtually every family in the uplands of West Java has a garden around its house, and most families have at least some rice paddies or upland fields (Table 3). The total area of land available to each household is small, however. Few have access to more than a hectare of land and for most it is less than half a hectare. Each household's land is usually scattered in parcels one tenth hectare or less in area. The rice paddy zone has a rather uniform appearance, but the landscape above the ricefields has more of a patchwork appearance because each of the upland fields may contain different crops. Most villages have several hundred different crop species in their homegardens and upland fields (Table 4).

The single most important crop is rice. Most paddy fields are irrigated and planted to two rice crops each year, one during the rainy season (September to February) and one during the dry season. Some irrigated paddies are planted continuously to rice, five crops every two years. Rainfed paddies can be planted to rice only once each year, during the rainy season. They may be planted to other crops such as tobacco, beans, corn, or vegetables after the rice.

Most farmers put the bulk of their labor into their ricefields. They work their homegardens in their spare time. Labor demands in ricefields, upland fields, and homegardens compete at some times of the year and complement each other at other times (Figure 2).

Production is first and foremost for home consumption, but the surplus production of most households is sufficient for them to sell about half of their total production on average. Rice is the main source of calories, protein, and

TABLE 3
Landholdings, Crop Diversity, Income Characteristics of Households in the Jatigede Area, West Java[13]

	Poor		Well-off	
	Near market	Far from market	Near market	Far from market
Percentage of households with homegardens	97	100	99	97
Percentage of households with upland fields	57	89	82	97
Percentage of households with rice fields	73	100	91	97
Average size of homegardens (m^2)[a]	223	297	417	394
Average size of upland fields (m^2)[a]	1,120	2,604	3,995	7,174
Average size of rice fields (m^2)[a]	2,050	2,426	6,853	5,240
Total area farmed (m^2)	2,254	5,037	9,962	12,366
Average number of plant species in homegardens	14.3	20.4	20.0	21.9
Average number of plant species in upland fields	4.1	10.8	10.7	11.4
Average annual cost of farm inputs (×1,000 rupiah)[b]	48	78	156	223
Average annual gross farm income (×1,000 rupiah)[b]	114	143	654	508
Average annual off-farm income (×1,000 rupiah)[b]	108	103	550	236
Average family size	4.6	4.8	4.9	3.9

[a] Average based only upon households having that agricultural system.
[b] One U.S. dollar = approximately 670 rupiah.

certain vitamins (e.g., niacin and thiamine), but upland fields and homegardens produce the fruits, vegetables, and pulses to compensate for amino acid deficiencies in rice and provide vitamins and minerals (e.g., vitamin A, vitamin C, riboflavin, calcium, and iron) for which rice is insufficient (Figure 3). Many households earn an annual net income of about $500 from their farming, but many other households earn considerably less (Table 3). A typical household purchases about one quarter of the food it consumes.

A. Homegardens

Homegardens are a mixture of trees, field crops, ornamental plants, medicinal plants, and animals on the land surrounding a house (Figure 4). Ornamentals are more frequently planted in front of the house, while valuable crops (e.g., clove, oranges, and mangoes) are also planted in the front yard where the owners can keep an eye on them. Coffee may be planted along the side and back as a hedge. Vegetables are usually grown in the front and side yards, where there is sufficient light because tall trees rarely are planted in those areas. Spices, taro, and vegetables (e.g., chayote and eggplant) are planted close to the latrine and fish pond where soil moisture is high. Crops with high nutrient requirements (e.g., banana, mango, jackfruit, and other fruit trees) are

TABLE 4

Crops Observed in Homegardens and Upland Fields of Jatigede Area, West Java[13]

Latin name	Local name	English name
Grains, starchy roots, and sugar		
*Amorphophallus campanulatus	Suweg	Elephant yam
*Amorphophallus variabillis	Iles-iles	Elephant yam
*Arenga pinnata	Aren	Sugar palm
A. saccharifera	Kawung	
*Canna edulis	Ganyong	—
*+Colocasia esculenta	Taleus, Keladi	Taro
*Colocasia nigrum	Talas	Taro
*+Dioscorea alata	Ubi manis Ubi tiang	Yam
*+Dioscorea bulbifera	Ubi atas	Yam
*+Dioscorea esculenta	Gembili Ubi kamayung	Yam
*+Dioscorea hispida	Gadung	Yam
+*Ipomoea batatas	Ketela rambat, Ubi jalar	Sweet potato
+*Manihot glaziovii	Singkong karet	Manicoba
+*Manihot utilissima	Singkong, Ubi kayu	Cassava
Maranta arundinacea	Sagu patat, Arut	Arrowroot
+Oryza sativa	Padi	Rice
Oryza sativa var. glutinosa	Beras ketan	Sticky rice
Saccharum officinarum	Tebu	Sugar cane
Sorghum vulgare	Gandrung, Cantel	Sorghum
+Zea mays	Jagung	Maize, corn
Fruits		
Achras zapota	Sawo	Sapodilla, Naseberry
*Anacardium occidentale	Jambu monyet	Cashew nut
*Ananas comosus	Nenas	Pineapple
*+Annona muricata	Nangka belanda, Sirsak	Soursop
Annona reticulata	Buah nona	Sweetsop
Annona squamosa	Sarikaya	Custard apple
Artocarpus communis	Keluwih	Breadfruit
Artocrapus champeden	Sukun	Breadfruit
*+Artocarpus integra	Nangka	Jack fruit
*Averrhoa carambola	Blimbing	Star fruit
*+Carcia papaya	Pepaya	Papaya
Citrus aurantifolia	Jeruk nipis	Lime
*Citrus aurantium	Jeruk manis	Tangerine
*Citrus maxima	Jeruk bali	Pomelo
*+Cocos nucifera	Kelapa	Coconut palm
Durio zibethinus	Durian	Durian
Erioglossum rubiginosum	Kilalayu	—
*Eugenia aquea	Jambu air	Rose apple
Eugenia cumini	Juwet —	Java plum Teste foure
Eugenia cymosa	Kopo	—
Eugenia malaccensis Syzgium malaccensis	Jambu bol	Malay rose apple
Fragaria xananasa	Arben	Strawberry
Garcinia mangostana	Manggis	Mangosteen
Lansium domesticum	Duku	Lanseh
Lansium sp.	Pisitan Langsat	—
Mangifera foetida	Limus Bacang	Horse mango
*+Mangifera indica	Mangga	Mango
Mangifera odorata	Kuweni	Mango
Morus alba	Murbai	Mulberry (white)
*+Musa paradisiaca, M. sapientum	Pisang	Banana
*Nephelium lappaceum	Rambutan	Rambutan
Persea americana P. gratissima	Apokat	Avocado
Phyllanthus acidus	Cereme	Gooseberry
Zalacca edulis	Salak	Salacia
Spondias dulcis S. eytherea	Kedongdong	Otaheite-apple
Tamarindus indica	Asam	Tamarind
Vegetables (including legumes)		
+Amaranthus hybridus	Bayam	Spinach
Apium graveolens	Seledri	Celery
+*Arachis hypogaea	Kacang tanah, Suuk	Groundnut Peanut
Benincasa hispida B. cerifera	Beligo	Wax gourd
Cajanus indicus C. cajan	Kacang kayu Hiris	Pigeon pea
Cucumis sativus	Bonteng, Ketimun	Cucumber
Cucurbita moschata	Waluh	Squash
Cucurbita pepo	Waluh, Labu besar	Sweet gourd Pumpkin
Dolichos lablab	Kara	Hyacinth bean, Bonavista bean
Glycine max	Kedele	Soybean
Gnetum gnemon	Belinjo	—
Ipomoea reptans	Kangkung	Unchoy
Kaempferia rotunda	Temu kunci	—
Lagenaria leucantha	Kukuk, Labu air putih	Bottle gourd
Limnocharis flava	Genjer	Hermit's water
Luffa acutangula	Emes, Oyong Gambas	Raggourd Wild petola
Momordica charantia	Paria, Pare	Bitter melon
Moringa oleifera	Kelor	Horseradish
*Nothopanax scutellarium, N. fruticosum	Mangkokan	False panax
Pangium edule	Picung Keluwak	Pangi
*+Parkia speciosa	Pete, Petai besar	Locust bean
Phaseolus lunatus	Kacang uci	Rice bean
Phaseolus radiatus	Kacang hijau	Mung bean
Planchonia valida	Putat	Planchonia
Polyscias fruticosa	Kedongdong pagar	Hedge panax
Psophocarpus tetragonolobus	Kecipir, Jaat	Wing bean Goa bean
Raphanus sativus	Lobak	Chinese radish
Sauropus androgynus	Katuk	Sweet shoot
Sechium edule	Labu siam	Chayote
*Solanum lycopersicum	Tomat	Tomato
*Solanum melongena	Terong	Eggplant
Solanum nigrum	Leunca	Black nightshade
Solanum torvum	Takokak, Cepoka	Eggplant
+Vigna cylindrica	Kacang panjang	Cowpea
Vigna sinensis	Kacang panjang	Cowpea

TABLE 4 (continued)
Crops Observed in Homegardens and Upland Fields of Jatigede Area, West Java[13]

Latin name	Local name	English name	Latin name	Local name	English name
Spices			Piper betle	Sirih	Betel vine
Aleurites molluccana	Kemiri	Candle nut,	+Pithecellobium lobatum	Jengkol,	—
		Indian walnut		Jiring	
Allium cepa	Brangbang,	Onion	Ricinus communis	Jarak	Castor oil plant
	Bawang merah		Strobilanthes crispus	Keji beling	—
+Allium fistulosum	Bawang daun	Green onion	Thea sinensis	Teh	Tea
Allium sativum	Bawang putih	Garlic	Tinospora tuberculata	Bratawali	—
*Allium schoenoprasum	Bawang kucai	Chive	Zingiber aromaticum	Panglay	—
Amomum kepulaga	Kapulaga	Cardamom	Zingiber odoriferum	Lempuyang	—
Capsicum annum	Cabe	Chili	**Trees (building material)**		
	Lombok	Red pepper	*Albizia falcata	Sengon laut	—
*+Capsicum frutescens	Cengek,	Little pepper		Albasia	
	Lombok rawit		+Albizia sp.	Jeungjing,	—
Chysopogon nardus	Sereh	Lemon grass		Sengon tarisi	
Cymbogon citratus			Canangium odoratum	Kenanga	—
*+Curcuma domestica	Koneng,	Turmeric	Dalbergia latifolia	Sonokeling	—
	Kunir		Dixolylon caulostachyum	Kedoya	—
*Eugenia aromatica	Cengkeh	Clove tree	+Gigantochloa apus	Bambu apus	Bamboo
Ocimum canum	Surawung,	Hoary basil	+Gigantochloa verticillata	Bambu gombong	Bamboo
	Kemangi		*Swietenia mahogani	Mahoni	Mahogany
Phaeomeria speciosa	Honje	—	Tectona grandis	Jati	Teak wood
Piper nigrum	Lada,	Black pepper	**Trees (fuel wood)**		
	Pedes,		Acacia auriculiformis	Akasia	—
	Merica		Albizia lebbeck	Tarisi	—
Sesamum indicum	Wijen	Sesame	Albizia procera	Kihiang	—
Syzygium polyanthum	Daun salam	Bay leaf	Bridellia monoica	Kanyere	—
Eugenia polyantha			Cassia bicapsularis	Bungur	—
*Zingiber officinale	Jahe	Ginger	Cassia siamea	Johar	Senna
Medicinals			Casuarina equisetifolia	Cemara laut	Ironwood
Areca catechu	Jambe,	Betel palm	*Ceiba pentandra	Kapok	Kapok
	Pinang			Randu	
Blumea balsamifera	Sembung	Camphor plant	Ficus virens	Bisoro	—
Cassia fistulosa	Ketepeng	Golden shower	Hibiscus macrophyllus	Tisuk	Hibiscus
C. sappans	Trengguli	Indian laburnum	Hibiscus tiliaceus	Waru	Hau tree
Citrus hystrix	Jeruk purut	Bitter orange	H. semilis		Hibiscus
Coffea arabica	Kopi	Coffee	Kleinhovia hospita	Bintinu	—
C. robusta			Lanea grandis	Kedongdong	—
Costus speciosius	Pacing	Ginger lily		Jaran	
Erythrina lithosperma	Bintinu	—	Lantana camara	Sahari,	Hedge flower
	Dadap			Temblekan	
+*Kaempferia galanga	Kencur,	—	*Leucaena glauca	Lamtoro	Leucaena
	Cikur			Petai cina	
+*Languas galanga	Lengkuas	Galangal	Melia azedarach	Mindi	Persian lilac
	Laja		Piper aduncum	Kiseureuh	—
Morinda citrifolia	Mengkudu	Fish-eye wood,	Sansevieria trifasciata	Lidah mertua	Bowstring hemp
		Noni	Semecarpus sp.	Renghas	—
Mucuna pruriens	Coas	Florida velvet	Sesbania grandiflora	Turi	—
		bean	Toona sureni	Suren	—
Nicotiana tabacum	Tembakau	Tobacco	Cendrella toona		
Orthosiphon stamineus	Kumis kucing	Cat's whiskers			

Note: * Common in homegardens. + Common in upland fields. *+ More common in homegardens. +* More common in upland fields.

planted near the livestock pen, fish pond, or compost heap. Plants used for daily cooking (e.g., chili peppers, languas, lemon grass, and tomatoes) are planted close to the kitchen for convenience. Coconuts and tall trees for building materials and firewood are usually grown in the back, away from the house, so the house will not be damaged if the tree falls during a storm. A portion of the front yard shaded by fruit trees is kept clear as a play area for children and for socializing with neighbors.

Homegardens have a seasonal rhythm. Annual plants are grown throughout the year, but it is usually necessary to water by hand in the dry season. Some perennials (e.g., coconuts, bananas, and jackfruit) bear fruit throughout the

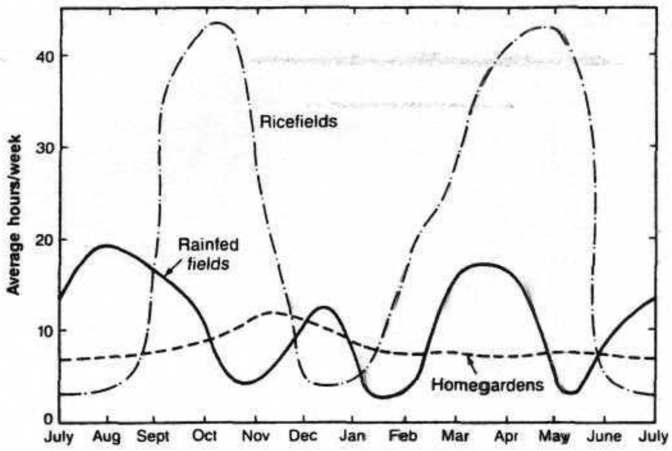

FIGURE 2. Seasonal labor patterns in ricefields, upland fields, and homegardens of the uplands of West Java. (From Iskandar, J. and Abdoellah, O. S., in *Agroecosystem Research for Rural Development*, Rerkasem, K. and Rambo, A. T., Eds., Chiang Mai University, Thailand, 1988, 237. With permission.)

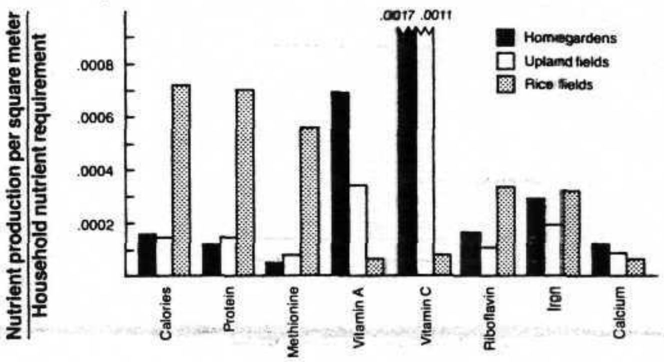

FIGURE 3. Comparison of the average production of human nutrients from a square meter of ricefield, upland field, or homegarden in the Jatigede area of West Java. (From Marten, G. G. and Abdoellah, O. S., *Ecol. Food Nutr.*, 21, 17, 1988. With permission.)

year while other perennials have restricted fruiting seasons. For example, *duku (Lansium domesticum)* fruits in December to January, *jambu semarang (Syzygium javanicum)* in April to June, mango in September to November, and durian in October to February. This pattern of harvesting provides a continuous supply of food for daily subsistence needs, minimizes risks of failure, and increases a household's financial stability by spreading cash income over the year.

B. Rainfed Upland Fields

Upland fields are typically a mixture of interplanted crops of various heights. The lowest layer consists of creeping plants such as peanuts, soybeans, cucumbers, and melon. Above them are taller vegetables such as chili peppers and eggplant. The top layer is occupied by maize, tobacco, cassava, or leguminous vines (e.g., wingbean or longbean) supported by bamboo poles. The field may also contain scattered fruit or other trees (e.g., *Albizia).*

Field preparation is in August. Farmers first weed the field and till the soil with a hoe. They cut down any unwanted perennial vegetation and leave the slash to dry. Litter, leaves, and slash are burned in small piles at the end of August. Different fields may contain completely different groups of crops, but each consists of crops which the farmers have found by experience to be compatible with one another. For example, bananas, sweet potatoes, peanuts, corn, and beans can be grown together, but cassava cannot be included because it will crowd out the other crops.

The following is an example of how an upland field consisting of bitter melon, hyacinth beans, cucumbers, bitter solanum, chili peppers, and cassava is organized. Bitter melon seeds are planted at the beginning of September, just

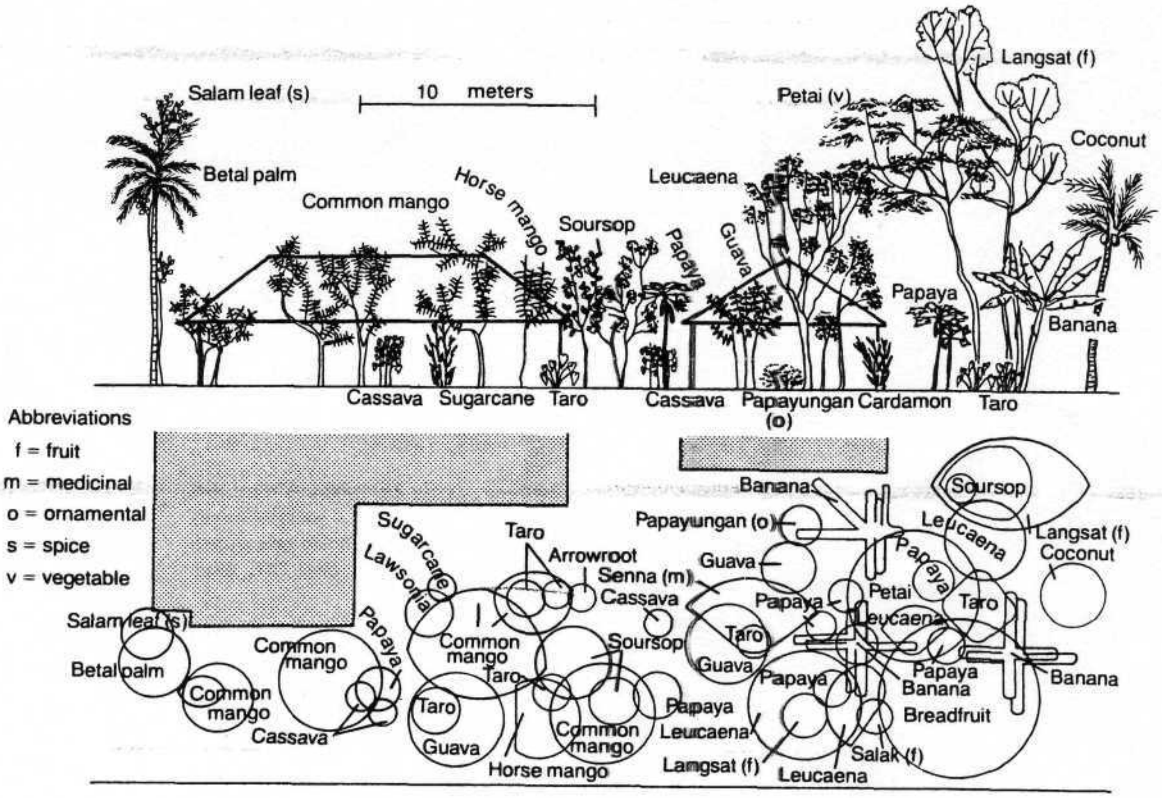

FIGURE 4. Example of a homegarden layout in the uplands of West Java. (From Christanty, L., Abdoellah, O. S., Marten, G. G., and Iskandar, J., in *Traditional Agriculture in Southeast Asia*, Marten, G. G., Ed., Westview Press, Boulder, CO, 1986, 132. With permission.)

after the first rain. Ash from the burn and manure from the homegarden are used to fertilize around the seeds. Hyacinth beans are planted 2 weeks after the bitter melons, when cassava may be planted along the edges of the field as a hedge. Cucumbers are then planted in shallow furrows between the rows of bitter melon and hyacinth beans. Finally, by the end of September, bitter solanum and chili peppers are planted around the cucumbers once they have sprouted. All crops are then fertilized with urea and compost. The crops are treated with pesticides only if a serious infestation occurs. Numerous species of insects and other animals (some of them pests) are present, but seldom is any one species sufficiently abundant to warrant pesticides.

The first harvest starts with cucumber at the end of October and continues every 5 days for 2 months. There is another weeding at the end of December to clear paths between the rows. Starting at the beginning of January, bitter melon is harvested continuously for about 3 weeks, bitter solanum is harvested weekly, and chili peppers are harvested every 2 weeks for 4 months. Hyacinth bean is harvested in mid-April. If there is enough rain after harvesting the hyacinth beans, the land can be tilled again and used to grow green beans, which are harvested at the same time as cassava in July.

Cassava is usually the main crop in the second year and is planted at the beginning of September. A higher layer may consist of scattered bananas, bamboo, or trees. The cassava is ready for harvest 9 or 10 months after planting.

By this time the perennial foliage may have expanded to where it is intercepting most of the light and limiting the possibility for growing further crops unless the perennials are cleared. It is common practice at this time to allow the perennials to take over the field for 3 or 4 years as a managed "fallow". The perennials can be fruit trees, trees for firewood and building materials, or bamboo. Fruit trees require considerable care (e.g., pruning), while fuelwood trees and bamboo can be left to take care of themselves. If trees are of different ages, harvesting can be by selective cutting, and field crops may be interplanted in the more open spaces during the rainy season. If the trees are homogeneous in age, it is common to harvest by clear-cutting in August, as preparation for returning the field to annual crops.

While the tree or bamboo fallow provides a harvest of construction materials, it also reconditions the soil for annual field crops. After 2 years of field crops, weeds have increased and organic matter and mineral nutrients have declined. (Cassava has removed particularly large quantities of phosphorus and potassium from the soil.) Further harvests can only be maintained by much heavier weeding and much heavier chemical fertilizer applications than were necessary during the previous 2 years. After several years of tree or bamboo fallow, weed seeds have diminished and litter fall has returned organic matter to the surface soil at its previous level. Ash from the burn provides mineral nutrients and a liming effect. Perhaps most important are the numerous fine roots of trees or bamboo that have permeated the soil and decompose to release mineral nutrients during the first 2 years of field crops. The mat of tree or bamboo roots at the soil surface, along with slash left around the field, helps to protect the soil from erosion.

C. Contemporary Changes

Government programs to modernize rice production have brought major changes in recent years. Traditional wet-rice varieties have disappeared from all but the most remote areas, and large quantities of pesticides and chemical fertilizers are essential to realize expected yields. Insect pests (e.g., the brown plant hopper), which were of no consequence several decades ago when traditional varieties were in use, can now cause total crop failure unless intensive control is maintained.

As wealthier people in the village (particularly those who own larger amounts of paddy land) have become more commercially oriented, their sense of obligation to other villagers has deteriorated. Traditionally, villagers who participated in the harvest received a share of the crop, but the larger landowners are now evading sharing their harvest with other villagers by selling their crop to middlemen who bring in their own crews to do the harvest.

Many homegardens and upland fields are still largely traditional. Most still feature an interplanting of local crop varieties and use chemical pesticides only when absolutely necessary. However, in areas with readily available transport to urban markets, many upland fields are now a monoculture of high-value vegetables grown from introduced seed, and large quantities of chemical fertilizers and pesticides are essential. An increasing number of households in areas connected to outside markets are also devoting a major part of their homegardens to tree crops of high commercial value, such as hybrid (dwarf) coconut, cloves, oranges, or guava. While the rest of the homegarden may still function without the benefit of pesticides and chemical fertilizer, the high-value tree crops generally require substantial quantities of these chemical inputs. Many orange plantations have been wiped out by the CVPD virus, though the virus has not been a problem for orange trees interplanted with other crops in homegardens. Clove plantations have had a serious problem with leaf disease.

IV. CHIANGMAI VALLEY

The Chiangmai Valley is a floodplain at 300 m altitude in northern Thailand. The rural population of 900,000 people farms 150,000 ha, one half of which is irrigated by a combination of local (traditional) and government irrigation systems. Agriculture in Chiangmai Valley is representative of that in many floodplains and river basins in the lowlands of Southeast Asia. The following description is based on studies by the Multiple Cropping Centre at Chiangmai University.[16-20]

Double cropping is the norm (Figure 5). The first crop is traditional glutinous rice for home consumption, grown during the wet season (July to October). The glutinous rice is followed by a cash crop during the cool season (November to March). The major cool-season crops are improved varieties of nonglutinous rice, soybeans, garlic, tobacco, shallots, chili peppers, peanuts, or vegetables.

Most households farm a bit less than a hectare of land spread over a number of small plots. About one third are tenant farmers. Yields and farm incomes on the fertile alluvial soils of Chiangmai Valley are relatively high. The average annual net income is about $500 per household. A typical household grows nearly all of its own rice but purchases most of its meat and vegetables. Homegardens provide most of the fruit as well as some local vegetables and herbs. There are usually some pigs and chickens as well.

A. Rice Cultivation

A traditional rice variety that matures quickly (in about 3 months) is used before early cool-season crops such as chili peppers or garlic (Figure 5). Late-maturing traditional rice varieties are often cultivated in sequence with soybeans. Most people in northern Thailand prefer to eat glutinous rice, but rice purchases by a government marketing agency have stimulated the cultivation of improved varieties of nonglutinous rice as a cash crop during the cool season. R.D.7 rice is also grown in the hot season (April to June), when most fields are in fallow because of insufficient water. Hot-season crops (e.g., R.D.7 rice or vegetables like Chinese cabbage) must be irrigated or planted in waterlogged areas where there is sufficient soil moisture.

About half the farmers apply chemical fertilizer to traditional rice 20 to 25 days after transplanting, and some make a second application. Most apply chemical fertilizers to improved varieties. The farmers consider animal manure and lime to be the most effective treatments for soil problems (Table 5), but they often use chemical fertilizer instead because animal manure is not available.

Heavy rain during the wet season can lead to rice diseases (e.g., blast, stem rot, or collar rot) that is followed by an attack of cutworms. A dry spell during the hot season can lead to an outbreak of thrips or armyworms on the rice. About half the farmers use chemical insecticides, and all use poisons for birds, rats, and crabs. The average annual expense for agricultural chemicals and other cash inputs is about $200 per household.

Most households have a buffalo for plowing and harrowing. Nearly all farmers use the traditional method of weeding; few use herbicides. The traditional method is to pull the weeds by hand, laying the larger ones on the paddy bund and trampling the small weeds into the soil. The bulk of the labor for all farming activities comes from household members, since every effort is made to minimize cash outlays for production.

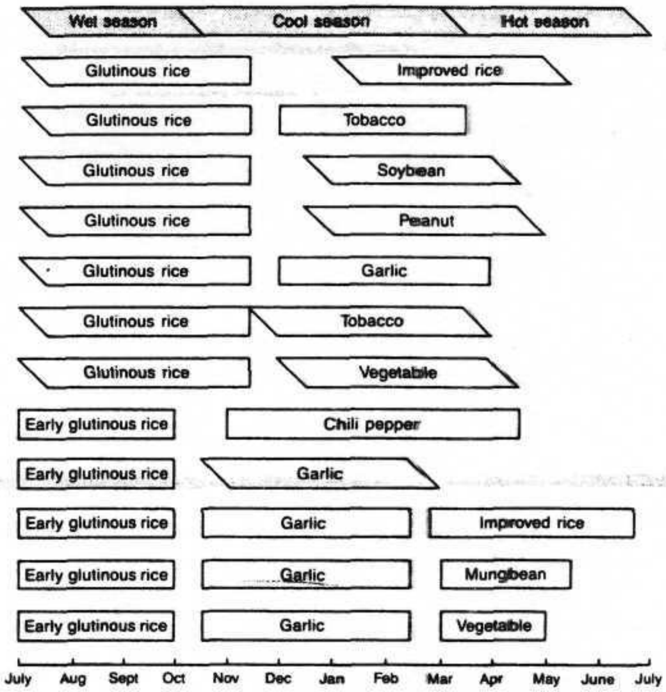

FIGURE 5. Common double cropping and triple cropping sequences in Chiangmai Valley. (Figures courtesy of Multiple Cropping Project experiment station at Chiang Mai University, Thailand.)

Table 5
Farmers' Perceptions of the Values of Various Soil Treatments for Dealing with Different Soil Problems at Chiangmai Valley, Thailand[18]

	Problems			
Treatments	**Difficult to plow**	**Low soil fertility**	**Sandy soil**	**Soil pests**
Apply animal manure	H	H	H	O
Apply lime	L	L	O	L
Irrigate before plowing	L	O	O	O
Apply chemical fertilizer	O	L	O	O
Apply green manure	O	O	L	O
Plow and sun dry	O	O	O	L

Note: H = Higher value. L = Lower value. O = No value.

B. Field Crops (Cool Season)

The crops selected for cultivation in the cool season depend to a large extent on the market price and availability of water. Planting decisions generally are based on prices from the previous year. A key question is also whether the irrigation canal will provide enough water in the dry season to sustain the crop. This depends upon the location of a particular field in the irrigation network and can be judged only from previous experience with different crops.

Chili peppers, garlic, tomatoes, vegetables, watermelon, and tobacco demand large amounts of water, labor, fertilizer, and pesticide inputs. Farmers usually grow these crops only when they have enough capital and labor. Soybeans and peanuts need smaller amounts of all these inputs, are less risky, and add nitrogen to the soil. Soybeans have become particularly popular in recent years (Figure 6). Cucumbers also need fewer inputs but are risky unless a reliable supply of water is available. Low-input crops can be grown farther from the houses because they have a lower value and do not need to be watched so carefully. The prices of low-value crops like soybeans, peanuts, and nonglutinous rice are relatively stable from year to year, but prices of the high-value crops fluctuate considerably.

Each field is a monoculture, but farmers tend to have different crops on different fields. This way they spread their risks, while also spreading out their labor as much as possible. There are two basic strategies that the farmers can follow. One strategy aims at minimizing risks in the presence of constraints on water, chemical inputs, or crop security; the other strategy aims at maximizing profits when none of these constraints is a serious problem. Most farmers follow a mixed strategy. They typically cultivate a quarter hectare with high-input, high-value crops and three quarters of a hectare with safer but lower-value crops. Other things being equal, a crop that has worked successfully in the past will be the one of choice.

C. Contemporary Change

Population growth has reduced the size of landholdings in the Valley. Twenty years ago, approximately one half the farmers had more than a hectare of land. Now only one

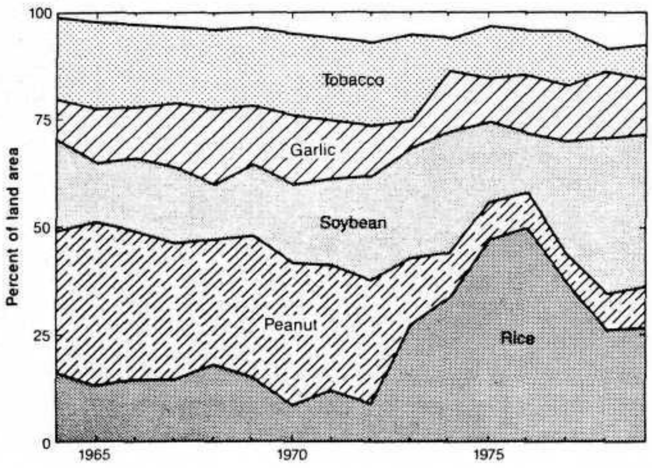

FIGURE 6. Changes in the land area planted to major cool-season crops in Chiangmai Valley. (From Rerkasem, B. and Shinawatra, B., in *Agroecosystem Research for Rural Development*, Rerkasem, K. and Rambo, A. T., Eds., Chiang Mai University, Thailand, 1988, 124. With permission.)

quarter of the farmers have this much land. The percentage of landless villagers has increased.

Cultivation practices for the traditional rice crop have not changed much. Most farmers still use few chemical inputs, and yields have been consistently around 4 t/ha over the past 10 years. However, the diversity of traditional rice varieties in the Valley is diminishing rapidly. While there were hundreds of local varieties a few decades ago, there are now only a few dozen, and many farmers no longer use them at all. Buffalos are beginning to disappear from the scene as the farmers acquire hand tractors.

The costs of inputs for cash crops have increased dramatically in recent decades. There are not enough nutrients in the soil to generate satisfactory yields unless fertilizers are applied, and pests are much more serious than before. Chemical inputs for soybeans have increased from virtually nothing 15 years ago to the present average of more than $40/ha. Soybean yields have increased 40% during the same period, but net income is lower because of higher input costs. Insect pests are more of a problem with improved varieties of rice than with traditional varieties, and birds are more of a problem for early-maturing improved varieties when their harvest is out of synchrony with the rest of the rice crop in the area.

Some of the differences between traditional and introduced cultivation practices can be illustrated with soybeans. The traditional method is to sow soybeans into the rice stubble immediately after burning the rice straw, cover them with ash, and flood the paddy. This method involves no other land preparation. Most farmers apply chemical fertilizers to the preceding rice crop on fields of low fertility and do not apply chemical fertilizer to the soybeans because they believe there is enough left over from the rice to meet the needs of the soybeans. Weeds are not a problem because weeds and weed seeds are killed when the rice straw is burned. The main problems are fungi and insects, and many farmers who otherwise follow traditional management practices now control insects with sprays.

Recently introduced practices for soybeans differ from the traditional in two major respects: preparation of raised beds and use of chemical fertilizers. The new practices have allowed soybean cultivation to expand to problem areas (e.g., infertile or waterlogged soils) where soybeans were previously not feasible. However, most farmers, particularly those who were growing soybeans already, have not adopted the new practices because on good soils the new practices provide only slightly higher yields than traditional methods, despite substantially higher costs for labor and chemical inputs.

Farmers in Chiangmai Valley are intensely interested in any new agricultural practices that will increase their income. Most farmers listen to agricultural programs on the radio for information concerning new technologies, markets, and weather. Chemical fertilizers are discussed with extension agents and neighbors more than any other aspect of soil management because farmers do not feel they know precisely which formulas and levels of application are best for each of their cropping systems on the different kinds of soils. Additional problems perceived by the farmers include a shortage of irrigation water in the dry season, rice stem borers, and weeds in their rice fields. Some problems that concern agricultural scientists are nematodes in the rice fields and the low quality of improved-variety rice seeds.

Recently triple cropping (Figure 5) has been practiced in some areas where there is a reliable supply of irrigation water throughout the year. While the third crop (usually a fast-maturing variety of nonglutinous rice) offers an opportunity for extra income, it is also somewhat marginal because risks are higher and yields generally lower than with the second crop. A serious difficulty with the third crop is the large quantity of labor necessary to squeeze three crops into a year, and the possibility that the traditional rice crop (i.e., the first crop) will be delayed if the third crop finishes late. There have also been social effects from triple cropping. Villages with triple cropping have experienced reduction in their religious festivals because people no longer have the time. Cooperative labor has also declined for the same reason, and paid labor has replaced exchange labor.

Perhaps the most serious consequence of triple cropping has been a reduction in yields (often as much as 50%) after triple cropping for 5 years (Figure 7). All crops are affected, including the first and second crops. Two of the problems are soil acidity and boron depletion, the correction of which can return some field crops to their normal yields, but so far a complete solution has not been found for some of the other crops, including rice. As a consequence, many farmers that ventured into triple cropping have now abandoned it to return to double cropping.

V. SALIENT FEATURES OF SMALL-SCALE AGRICULTURE IN SOUTHEAST ASIA

A. Farm Integration

Most small-scale farms in Southeast Asia are managed by

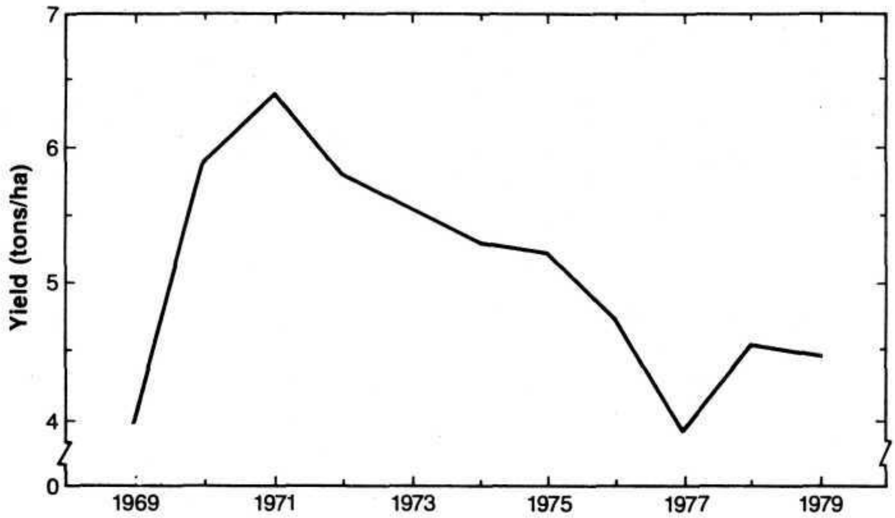

FIGURE 7. Increase in rice yields due to modern technology (1969—1971) followed by decline under triple cropping (1971—1979).[16] These figures are from the Multiple Cropping Project experiment station at Chiangmai University; the same changes occurred on farmers' fields.

extended-family households. Because a household may have several parcels of land, each with its unique capabilities, most households plant different crops on different parcels and on the same parcel at different seasons of the year. When deciding which crops to plant in which parcels, and during which seasons of the year, the first priority of most households is to satisfy the bulk of their food needs. The second priority is to produce additional crops to generate as much income as possible from available household labor.

The basic strategy is to select crops with (a) an assured market at reasonably high prices, (b) reliable yields, and (c) low cash inputs for hired labor, fertilizers, pesticides, and other costs such as rental of tractors or draft animals. Conditions for farming may be more favorable during some seasons of the year than others, but an effort is made to spread farming activities across the year in order to take full advantage of household labor throughout as much of the year as possible. At the same time, the total demand for labor from various overlapping farm activities at any one time must be kept within bounds so it does not exceed the capacity of the household to do the work.

A prominent feature of small farm organization is full utilization of all products. For example, rice is not the only product from rice paddies. They are also a major source of fish, and in many areas paddies are public domain for harvesting animals such as rice rats and aquatic invertebrates (e.g., crabs). This practice not only leads to full utilization of animal production in the paddies but also provides an incentive for keeping the numbers of edible animal pests (e.g., rats that feed on rice grains or crabs that cut the stalks of rice seedlings) below the point where they do serious damage to the rice. The same principle applies in swidden fields, where traps may be set for bush pigs that are attracted to the crops.

The various crops employed by a single household are often mutually reinforcing by providing materials or services to one another. Residues from one crop may be used as green manure for other crops that follow on the same field or for crops on different fields. Livestock are used to transfer crop residues from one field to another by grazing the livestock on one field after harvest, collecting manure in the corral, and distributing it to other fields. Chemical fertilizers applied to one crop (e.g., rice) may also provide nutrients for the crop that follows (e.g., vegetables). Irrigation for rice can provide residual soil moisture for vegetables that follow. Mineral nutrients (from chemical or organic fertilizer applications) that are lost from an irrigated field as water drains from the field are carried by the same water as inputs to other fields.

B. Diversity

Perhaps the most conspicuous feature of small-scale agriculture in Southeast Asia is its overwhelming diversity. Variation in environmental conditions from lowlands to highlands and from flat lands to hilly or mountainous lands leads to a corresponding variation in crops to fit the conditions. Even in one place the landscape is usually a patchwork of hundreds of small fields, each with its own crop or mixture of crops. Lowland areas of extensive rice cultivation may not present such a varied landscape, but on close inspection even these areas have considerable diversity. A variety of field crops or trees may be planted along the bunds, and the gardens around the houses may present a diversity of dozens or even hundreds of plant species. Once the rice season has passed, paddies may be converted to a patchwork of dozens of different field crops.

Even a continuous expanse of rice may not be as uniform as it appears. Many traditional villagers maintain dozens of local rice varieties, each adapted to perform best under particular environmental conditions. A single household may plant half a dozen different varieties during the same season, a monoculture of each variety in each paddy but different varieties in different paddies, based on explicit knowledge of the characteristics of each variety and how each fits into a total cropping strategy. A similar varietal diversity exists for most of the others of the hundreds of crops in Southeast Asia, though very little of it has been documented.

C. Flexibility

The diversity of Southeast Asian agriculture translates into flexibility that underlies (1) adaption of the agriculture to local environmental and social conditions and (2) adaptiveness of the agriculture through time.

The particular crops and crop varieties, and details of cultivation practices, are different in each region in accord with topography, soil conditions, and seasonal weather patterns. Equally important, the crops, varieties, and practices are tailored to each agricultural field and even to varying conditions within a field. This is essential for dealing with the heterogeneity of soil conditions on undulating or hilly topography, a situation in which a large percentage of Southeast Asian agriculture must be pursued. Decisions on these matters derive largely from the knowledge and experience of each farmer.

The agriculture is also adaptive through time. There is nothing unusual about this. Southeast Asian agriculture has always been in a state of evolution, even in the most remote and subsistence-oriented societies. Most farmers are constantly seeking information from other farmers (and any other available sources) on new crops and new production technologies that enable them to improve the returns from their agricultural activities. Many continuously experiment with promising new possibilities on a small portion of their land and cautiously expand the scale when results are encouraging. Keeping open as many options as possible is the key to their flexibility—assuring that they can modify their agriculture in response to changing needs or opportunities and withdraw from changes that do not work out.

D. Intensification

The most significant trend throughout Southeast Asia in recent years has been an increase in agricultural production. This increase has been driven not only by the increase in human population but also by the spread of a market economy that has created a demand for cash earnings. The area under cultivation has increased immensely. Only a few decades ago many parts of Southeast Asia had agriculture only in the flatter areas. Sloping or hilly areas were covered by forest. Now agriculture is moving progressively up the hills as new settlements and new fields displace the forest. One of the major consequences of this trend is an increasingly quantity of agriculture on land that is marginal with respect to soil quality or water supply, where yields (and returns to labor) are lower and permanent cropping may not be possible. Soil erosion on steeply sloping lands can be severe, and land degradation is exacerbated by the many farmers in hilly areas who are recent immigrants from the lowlands and lack the knowledge (and sometimes the motivation) to practice sustainable agriculture under these conditions.

The other way that agricultural production has been increased has been through higher production per hectare. A major part of the strategy has been more intensive chemical inputs—fertilizers to increase soil fertility and pesticides to reduce crop damage—along with improved crop varieties to take full advantage of the inputs. This kind of intensification has been most pronounced for rice, but it is also becoming common for other major food crops (e.g., corn, peanuts, potatoes, and various kinds of beans) and commercial vegetables (e.g., cabbage). In general, tropical fruit trees have experienced less intensification of this sort, with local varieties still prevailing in many areas, but a number of temperate fruits and a few select tropical tree crops (e.g., cloves and some citrus fruits) have experienced considerable intensification because of their high commercial value.

Multiple cropping (i.e., a sequence of crops on the same field during a year) has been another common means of increasing total agricultural production per hectare. In rainfed areas with a distinct dry season, where until recently there was only one crop a year (e.g., rice during the rainy season), many farmers are now attempting to grow a second crop (e.g., vegetables) after the rice. In many cases the second crop is risky because of unreliable water supplies.[21] In irrigated areas, where water is not a problem and where until recently there were two crops a year, some farmers are now attempting to squeeze in a third crop. Many are running into the kinds of difficulties described for Chiangmai Valley.

In upland areas where swidden cultivation prevails, a common means of intensification has been to shorten the forest fallow between cropping periods. For example, in the hills around Chiangmai Valley, the traditional fallow is 10 years in duration. However, an increasing number of farmers in that area do not have enough land at their disposal to leave their fields in fallow so long. Many are returning their fields to crops after a fallow of only 2 or 3 years, insufficient time to complete soil regenerative processes performed by the fallow.

While intensification has increased the quantity of agricultural production from available land, it often has reduced the efficiency of production with regard to labor or cash inputs. It is common for national policies to place a top priority on increasing the production of rice or other basic foodcrops, in order to attain national self sufficiency or even produce surpluses for export. However, such policies may not be in the interests of farmers whose production is limited primarily by the supply of household labor or cash for agricultural inputs.

E. Autonomy vs. Dependence

A prominent feature of most small-scale agriculture in Southeast Asia is its ecological self sufficiency. One of the keystones is mineral nutrient recycling.[22] In traditional subsistence agriculture, where nearly all of a household's agricultural production is used for home consumption, kitchen wastes (and the mineral nutrients they contain) are returned to the fields, thereby completing the cycle. A field's loss of nutrients through harvests, leaching, or erosion is balanced by nutrient inputs from kitchen wastes, animal manures, weeds, and other organic materials that are thrown onto the field. Much of the agriculture is also energetically self sufficient. Energy for land preparation, harvesting, weeding, and other agricultural activities comes from human labor and draft animals, which derive their energy from pasture and farm produce. The traditional farm is also genetically self sufficient, employing local crop varieties adapted to local environmental and social conditions.

Much of this is changing today with agricultural intensification and modernization and expansion of a cash economy. Cash incomes of highland farmers depend to a large extent on urban demands for temperate vegetables. Cash incomes can even depend upon international marketing arrangements, such as cassava in northeast Thailand, which is sold to Europe for animal feed. Farmers are adopting high yielding varieties and need to purchase the various chemical inputs necessary to realize their potential. Because pesticides have rendered many ricefields unfit for fish, many farm households now have to purchase fish to replace the ones they no longer obtain from their own fields. Petroleum energy is replacing animal energy as minitractors replace water buffalos. As buffalo disappear from the scene, their manure also disappears, increasing the need to purchase chemical fertilizers as a substitute. Buffalo wallows are disappearing, and with them a variety of ecological services they have performed, such as reservoirs for ricefield fish during the dry season.

F. Risk Management

Most farmers operate in the face of numerous risks such as short-term droughts, attacks by crop pests or diseases, typhoons, or uncertain prices for their products. They deal with these risks, first, by employing crops and cropping practices that are explicitly directed toward ameliorating the hazards. Local varieties are adapted to drought, frost, pests, etc. The planting of crops is timed to avoid periods of droughts or typhoons and to avoid seasons of the year that are particularly favorable for key pests.

Almost everyone employs a diversified cropping strategy to reduce risks. With "fallback" crops, at least some production is likely even under the worst of circumstances. Some rice varieties are more resistant to drought than others. Shorter varieties are more resistant to lodging while taller varieties are more resistant to flooding. At least one will survive whether the year is unusually dry or unusually wet. For cash returns, farmers who grow several different kinds of vegetables have a hedge against price fluctuations.

In paddy fields on elevated topography, where the irrigation supply is unreliable, vegetables may be planted to replace the rice halfway through the wet season if there has not been enough water to expect a good rice harvest. In rainfed fields, the highest yields of corn can be realized from varieties that take the longest time to mature, varieties that risk failure because they must be planted at the beginning of the growing season when rainfall is unreliable. However, if a long-term variety fails at the beginning of the growing season, it can be replaced with a faster maturing (but lower yielding) variety for the rest of the season.

G. Sustainability

Most traditional agriculture in Southeast Asia has continued for centuries on a sustainable basis. By recycling plant residues and animal manure to the fields, soil quality is maintained without depending on materials or energy from outside the farm. Pest damage to crops is maintained at tolerable levels by using pest resistant crop varieties, intercropping different crop species so pests do not find large quantities of their host plants in any one place, and relying upon natural enemies of the pests to keep them from getting out of hand.[23] Weeds are removed from the field by burning or by letting it fallow. Weeds are also used to provide soil cover for preventing soil erosion. In general, traditional agriculture has been structured as much as possible to mimic natural ecosystems, so farmers expend as little effort as possible struggling against natural ecological processes.[24,25]

The trend in modernizing and intensifying agriculture has been to make the fields less like natural ecosystems so a higher share of ecosystem production can be channeled to human use. The benefits are indisputable, but they have been achieved at a cost. As a rule, higher yields can only be sustained by means of costly chemical inputs. More intensive cropping often means that the soil is exposed to erosion and leaching more of the year, and more mineral nutrients are removed in the harvest.

A reduction in soil fertility can be compensated by chemical fertilizer applications, but the organic matter content of the soil often declines as chemical fertilizers replace organic fertilizers. With consequent reduction in the soil's cation exchange capacity and moisture storage capacity, even heavier chemical fertilizer inputs become necessary. With some of the fertilizers in common use, this leads to progressive soil acidification, which may affect the crop not only directly, but also indirectly if there is phosphorus fixation by iron or aluminum oxides, leading to a need for increasingly heavy phosphorus fertilizer applications.

The same cycle of increasing chemical applications can also occur with pesticides. Pesticides often kill natural enemies (e.g., predators and parasitoids) more effectively than the pests themselves and this can lead to a loss of control by these natural enemies. As pests evolve resistance to the pesticides, the quantity and number of different kinds of pesticides that are applied continually increases. As the quantities of chemical fertilizers and pesticides increases, cash outlays for these inputs also increase. This trend has been exacerbated because the chemical inputs are tied to increases in the price of petroleum energy. In the end, it may be necessary to abandon the crop.

There is also the risk that modernized agriculture cannot be resilient to sudden and unexpected hazards such as the appearance of a pesticide resistant pest biotype, a drop in market prices (or loss of the market if it depends upon contractual arrangements), unusually severe weather conditions (e.g., drought, floods, or typhoons), or sudden increases in the cost of inputs. This trend reflects the general principle that increases in production, and improvements in the stability of production, often reduce resilience because of (a) dependence on outside resources that are not reliable or (b) a failure to exercise a capacity for dealing with particular hazards. As an example of the latter, if irrigation is brought to a rainfed area, farmers can realize higher and more reliable yields without resorting to their traditional drought resistant varieties or specialized cultivation techniques for coping with vagaries of rainfall. These varieties and techniques may eventually drop from the scene, even though they could be highly useful if siltation or some other problem should someday prevent the irrigation system from providing a reliable water supply.

VI. CONCLUSIONS

While the modernization of Southeast Asian agriculture is generally increasing agricultural production and farm incomes, in many instances there are serious doubts as to how reliably and for how long the gains can be sustained. There are also doubts about their costs in social and environmental terms.

Resisting change is not a realistic option; modernization is a fact of life in Southeast Asia. Population growth of the past 50 years had rendered yesterday's agriculture obsolete, and aspirations aroused by the universal spread of a cash economy mean that farmers will change their agriculture to increase their earnings in any way available to them. It is a responsibility of agricultural scientists to provide farmers with new technologies that offer not only higher yields and higher incomes but also sustainable yields and prudently low levels of environmental degradation and social disruption.

It is not reasonable to expect centrally developed agricultural packages to satisfy these criteria.[25] The environmental and social conditions in which agriculture must be applied are so variable that new technologies must be tailored not only to a region of the country but also to different villages, different households, and even different fields. While agricultural research and extension can offer farmers some of the tools they need to improve their agriculture, a major part of the research and development process will have to lie with the farmers themselves. Most farmers are well prepared for such a task by virtue of their experience experimenting with new crops and techniques to fit their farm operation.

Effective agriculture should be adaptive through time. One major way to maintain the flexibility necessary for adaptive agricultural development is to retain as much of the existing agricultural diversity in Southeast Asia as possible. This includes maintaining the wealth of crop varieties and production technologies in the region's traditional agriculture. Traditional agriculture in most areas cannot be expected to meet modern needs without modification, but its proven record of sustainability is a strength that farmers cannot afford to ignore. Agricultural scientists and farmers have a responsibility to ensure that this valuable heritage is not lost in the course of modernization. The challenge is to combine the best of traditional and modern technologies.

There is ample experience that high-yield agriculture is not sustainable when it is socially or environmentally exploitative, but there is also ample evidence that agriculture can be organized to make increased productivity and sustainability mutually reinforcing.[26] Although the use of chemical fertilizer can lead to soil degradation if the fertilizer is used to compensate for soil-degrading agriculture practices, higher yields from chemical fertilizers can in fact be used to improve and sustain soil fertility if a significant proportion of the crop biomass is returned to the soil. To take another example, multistory intercropping that makes fullest use of space, soil, and water (as described for homegardens and rainfed fields in West Java) can also provide an environment where crop pests are not a serious problem even without the use of pesticides. Identifying ways to improve production on a sustainable basis may involve retention or adaptation of agricultural design features (e.g., recycling crop residues or intercropping) that are still common in Southeast Asia. It may also involve new designs appropriate to changing conditions and changing needs, but the prospects for new designs will be most promising if they build on insights from past experience with agricultural and natural ecosystems.

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