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5
Rainfed Cropping Systems in Northeast Thailand

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Approximately 80 percent of the 15 million people in Northeast Thailand (Figure 5.1) are engaged in agriculture, and the per capita income of the region is lower than in any other part of Thailand. Northeast Thailand covers an area of 17 million ha (about one-third of the country); 10.5 million ha of the region are arable, with 3.6 million ha of the arable land being suitable for rice paddy agriculture and 6.9 million ha being suitable for upland crops (Asian Institute of Technology 1978).

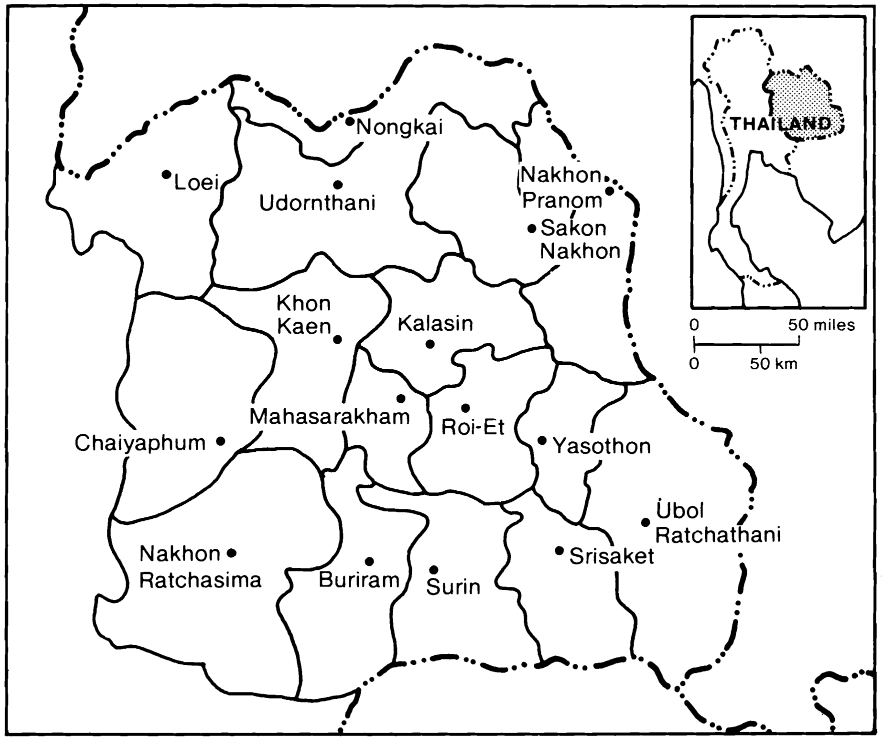
The major constraint to crop production is rainfall (Figure 5.2). Although the region has an average annual rainfall greater than 1,200 mm, the seasonal distribution is poor. Almost all of the rainfall occurs from March to November. The date of onset of the rainy season (and the quantity and continuity of rainfall at the beginning of the rainy season) vary considerably from year to year, the ending of the rainy season also varies, and there is usually a dry period in the middle (June or July).

Another important constraint is soil quality. Soil in the region is sandy with high salinity, a low water-holding capacity, low organic matter content, and consequently poor fertility (Moorman and Rajanasoontorn 1972). For some crops there is also a problem of poor growth patches in otherwise normal fields.

To compensate for the unreliable rainfall, the government of Thailand has increased the land area under irrigation, but the area now in irrigation is only 2.4 million rai out of a total cultivated area of 47.8 million rai (6.25 rai = 1 ha). Only 10 million rai could be irrigated, so the vast majority of the agricultural crops in the Northeast will continue to be grown under rainfed conditions, and more than 80 percent of the agricultural population will continue to be heavily dependent upon rainfed agriculture. As a consequence, the government of Thailand is concentrating also on the development of rainfed agriculture.

This chapter describes existing farming practices in Northeast Thailand and examines strategies for new or modified cropping systems to meet the

Figure 5.1. Map of Northeast Thailand



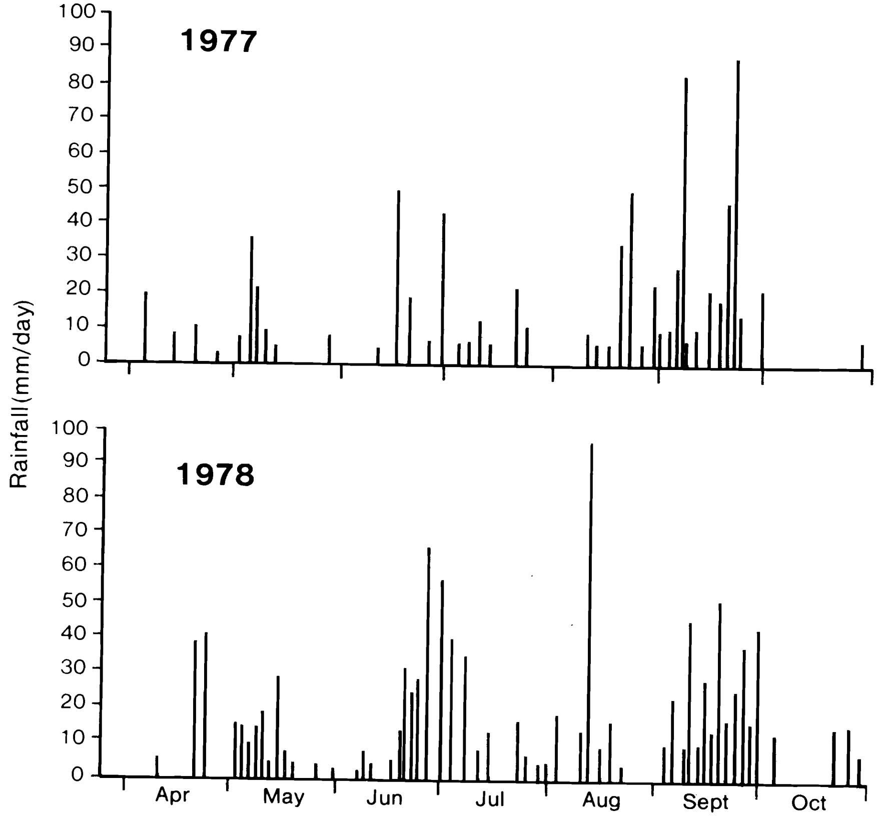
changing needs of the area. It relates some experiences of the Cropping Systems Project at Khon Kaen University (Limpinuntana et al. 1982), which has attempted to develop better cropping systems for the region. The chapter includes suggestions for agroecosystem research that can help to understand the ecological basis of existing farming practices, so that traditional agricultural technology could be incorporated into future agricultural development.

EXISTING CROPPING PATTERNS

As in Northern Thailand, there are three categories of agricultural land on the undulating terrain in Northeast Thailand (see Figure 4.5). They are uplands, upper (middle-terrace) paddy fields, and lower (low-terrace) paddy fields. The major crops in upland areas are monocroppings of cassava and kenaf (*Hibicus subdarrifa*). Rice is the primary subsistence crop in lower paddies and upper paddies, but upper paddies may be left idle if rainfall is insufficient or arrives too late to plant rice.

The role of cassava in upland agriculture has become a major concern in recent years. Kenaf used to be the main crop in upland areas, but about twenty years ago farmers from the Northeast started to do temporary work in east Central Thailand, where they learned to grow cassava. They introduced cassava to the Northeast when they returned, because cassava is easy to cultivate and has few insect or disease problems. They found cassava to be the best crop for the erratic rainfall in the Northeast, giving a satisfactory yield even on infertile soils.

Figure 5.2. Daily Rainfall at Khon Kaen University During the Wet Season



Formerly, the cash income from the kenaf and cassava in upland areas was sufficient to cover the living expenses of a household for a year, and the rice from paddy fields was enough for home consumption. Excess rice was usually sold for additional cash income and, if there was enough, to generate savings. This pattern was possible due to the larger landholdings and higher soil fertility than in recent years. In recent years the cash income from kenaf and cassava has not been sufficient to cover living expenses, and there seems to be only enough rice for home consumption. Farm families have therefore attempted to find ways of increasing their incomes in order to maintain or improve their standard of living. They have:

- Increased off-farm income by means of home industry or off-farm labor;
- Expanded the area under cultivation; or
- Increased yields per hectare by intensifying inputs or changing from monocropping to multiple cropping.

Some farmers still have forested land that can be cut to expand the area under cultivation to major crops. For other farmers, however, there is no place for expansion, so increasing cash income by increasing yields per hectare becomes particularly important. It is not usually practical for farmers to provide more inputs to increase yields per hectare for upland crops, because fertilizers and insecticides are costly and the increase in crop yields is not in proportion to the rate of fertilizer application. This is because frequent dry spells, sandy soils, and soil acidity lead to inefficient fertilizer use. A strategy based on more intensive inputs (e.g., fertilizers) is more attractive for paddy fields (especially lower paddy fields) during an assured rainfall period. It is therefore most attractive to increase cash income, particularly from upland crops, by means of multiple cropping. Farmers say, "spending more labor is better than spending more money."

Upland Areas

The following are the most common multiple cropping systems in upland areas:

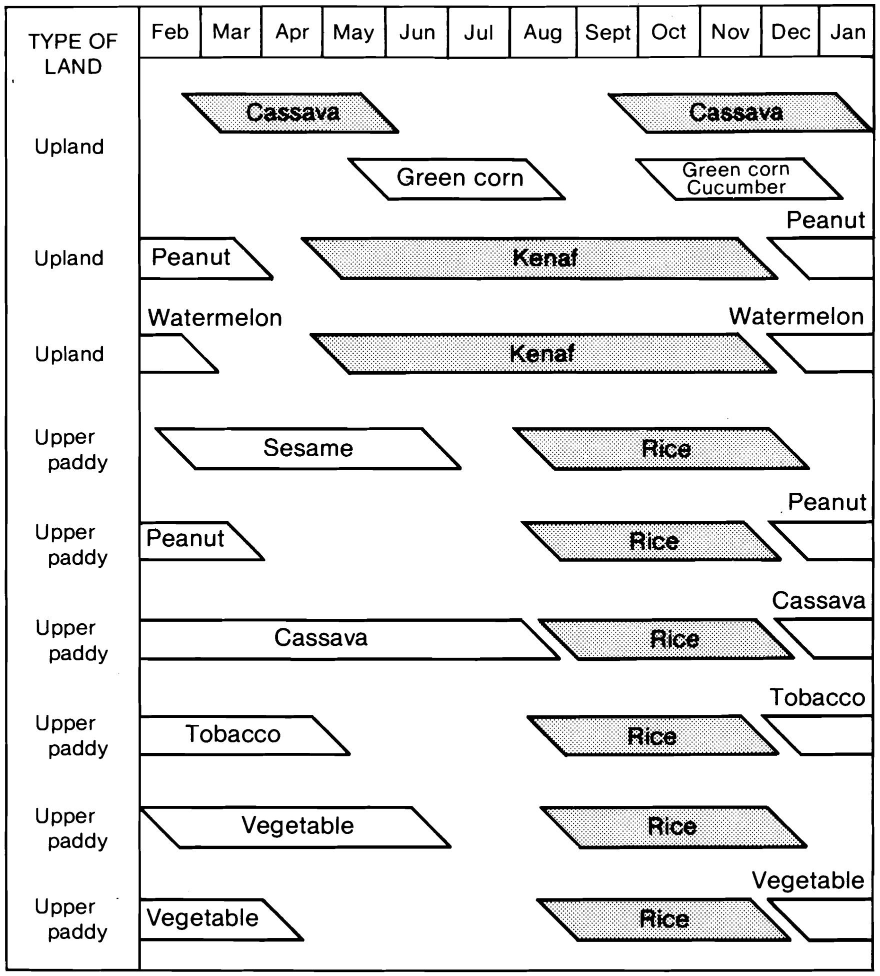
- *Intercropping cassava with green corn*—Cassava is planted in March–April and single rows of green corn are added in May.
- *Mixed row cropping of cassava with green corn and cucumber*—In September, cassava is planted in mixed rows with green corn and cucumber on beds having furrows for drainage.
- *Relay cropping cassava with watermelon*—Cassava is planted in March–April, and watermelon is interplanted in October (immediately after cutting off the cassava tops.)
- *Double cropping kenaf with watermelon*—Kenaf is planted in March–April, cut in November, and followed by watermelon.
- *Double cropping kenaf with peanut*—Kenaf is planted in March–April, cut in November, and followed with peanuts planted in November.

Figure 5.3 shows existing cropping patterns in the Northeast. The cropping patterns of farmers in upland areas are built around the two major crops (cassava and kenaf), keeping the planting and harvesting dates at the normal times. The planting dates for minor crops such as corn, watermelon, and peanuts depend upon soil moisture regimes in each location. The manure that is applied to minor crops helps maintain general soil fertility and provide nutrients not only for the minor crops but also for cassava or kenaf.

Upper Paddy Fields

Upper paddy fields are the most useful agricultural lands because water can be regulated. There is a more reliable water supply than in the uplands

Figure 5.3. Common Cropping Systems in Northeast Thailand (major crops are shaded)



where drought damage is often a problem. The kind of flooding that occurs in lower paddies during heavy rainfall can be prevented in upper paddies by drainage systems that carry the water farther downhill. As a consequence, farmers have considerable flexibility as to whether to plant rice in upper paddies early or late in the rainy season, leaving the possibility of a field crop (e.g., sesame, peanuts, cassava, tobacco, or vegetables) before or after the rice.

Sesame Before Rice. This pattern is found in Buriram and Mahasarakam provinces. Sesame is planted when the rain comes during February–April.

There is a single plowing, followed by broadcasting seed and harrowing. If the soil is moist and can easily be plowed, the farmer can expect sufficient soil moisture for plant growth up to the seedling stage when additional rain should be forthcoming. There is no weeding or insecticide application. Farmers go to the fields at night with kerosene lamps and catch beetle pests by hand to eat them or sell them for food in the local market. Root rot and stem rot are controlled by crop rotation or by letting the field fallow.

The limiting factor for this cropping system is the level of the water table, which must be sufficiently high to compensate for the sparse and unpredictable rainfall. Because sesame is photoperiod sensitive, it must be harvested during the dry season (June–July), when it does not interfere with normal rice transplanting. After sesame is harvested, the slash is plowed in as a green manure.

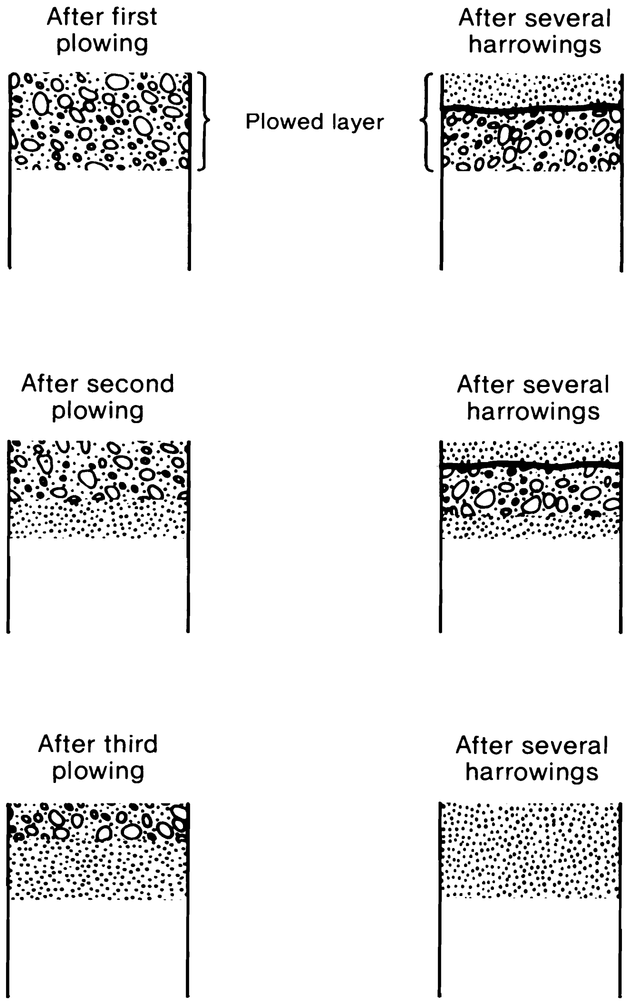
Peanut After Rice. This cropping system is found in Surin and Buriram provinces, where the surface soil is a fine sandy loam underlain by clay loam. Peanuts are planted from the last week of November to the second week of December, after harvesting rice. Because this is the dry season, the peanuts must start their growth on water remaining in the soil after the rice cultivation.

Land preparation is critical for raising a field crop after rice. The flooding for rice cultivation destroys soil structure and, except for a few millimeters at the surface, changes the soil from an oxidized to a reduced condition. The soil is still wet right after the rice harvest (October–November), but it becomes hard with a high bulk density as it dries. As neither wet nor dry soil in this condition is suitable for field crops, it is necessary to restore a granular structure to the soil, with a minimal loss of the stored soil moisture. As a first step, the farmers allow water buffalo in the paddy fields to feed and trample the green rice straw. Some farmers cut the straw by sickle near the soil surface and throw it on the bunds bordering the paddy fields.

The first plowing is undertaken as soon as the soil has dried. Water buffalo are used to plow the land, usually three times. Each plowing is followed by several harrowings. A soil with a high clay content requires more plowing than lighter soils, and the soil is allowed to dry for about two to three days after each round of plowing and harrowing. Plowing breaks the soil into large clods, which are further broken apart by a special harrow with teeth pointing backward at an angle of 45 degrees so they break up the clods and form a smooth layer at the soil surface without actually turning over the soil. Subsequent plowing turns the pulverized soil layer to the bottom and brings new clods to the surface. The new clods are again pulverized with a harrow, and the process continues until the entire plowed layer has a fine tilth (Figure 5.4).

Generally, peanuts are planted from the last week of November to the second week of December. The peanut seeds are soaked in water for a day before planting, giving them the water they need for initial growth. The

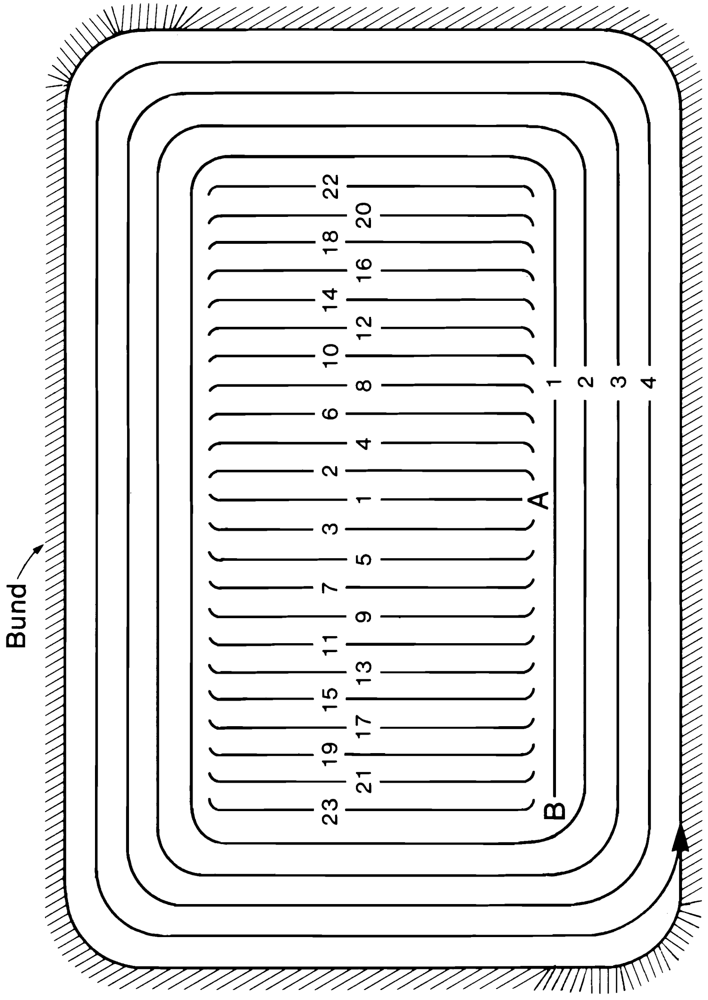
Figure 5.4. The Land Preparation Process for Peanuts After Rice in Surin Province



seeds are dropped in 10- 15-cm-deep furrows as they are plowed with a water buffalo and are automatically covered with soil when the adjacent row is plowed. The farmers maintain a loose soil surface to facilitate emergence of the peanut seedlings by following a plowing pattern that allows them and their buffalo to do the entire field without ever stepping on the soil where seeds have already been placed (Figure 5.5).

Residual soil moisture is sufficient for growth and pegging of the peanuts during their first two months (December and January). In fact, farmers say

Figure 5.5. Plowing Pattern for Planting Peanuts in Rice Paddy (Surin Province)[a]



[a]Plowing begins at point A, rows are completed in numbered order, then perimeter plowing begins at point B.

that if planting is accomplished in time, the stored soil moisture is usually sufficient for satisfactory yields even if there is no rainfall. They also say that rainfall during the first two months is detrimental because it can lead to soil compaction and poor development of the peanut gynophores. When there is too much rainfall during the seedling stage, the peanuts are replanted if extra seeds are available. If replanting is not possible, hoeing between rows helps to alleviate soil compaction.

Normally no chemical fertilizers or pesticides are applied. There may be occasional hand weeding depending on need and the availability of household labor. The harvesting method depends on soil surface conditions. If the soil is loose, the individual plants are pulled out and the pods are separated manually. If the soil surface is compacted due to rainfall, however, hoeing is necessary to remove the peanuts. Peanut slash is used as fodder for water buffalo or green manure for rice.

The yield normally depends on the quantity of stored moisture for the first two months after planting and the distribution of rainfall between February and April (Jintrawaet et al. 1982). Generally, peanuts give the best yields when the rains come early in February, providing water needed by the peanuts during their pod-filling stage. For example, peanut yields were higher in 1981 (averaging 1,843 kg/ha) when it rained early in February, than in 1982 (averaging 1,312 kg/ha) when the rainfall began later (Figure 5.6). Rain at harvest time is detrimental to the mature pods and can reduce the yield.

Rice and peanuts fit together well as a cropping system. Peanuts are a reasonably drought-resistant crop that can make good use of residual moisture after the rice harvest. Being legumes, the peanuts fix nitrogen, making it available for the subsequent rice crop, and they provide a protective soil cover against erosion between rice crops. Water buffalo are an integral part of the rice-peanut system, using peanut slash for fodder and in turn providing manure for the soil.

Rice straw provides a mulch for the peanut crop, and rice stubble may be incorporated into the soil or used in compost pits. Peanuts are particularly well suited to the marginal water conditions outside the rice cropping season. Peanut yields can be particularly high if the water table is shallow enough for the peanut roots to reach it, in which case pod formation can continue even in the absence of surface soil moisture (Stern 1968). Deep sowing of the peanuts is particularly useful if the water table is high enough to be of use, because it puts the plants closer to their water supply. Peanuts are known for their ability to emerge from deep plantings, and they also have the ability to send their roots to a soil depth of as much as 2 m to extract moisture from the water table. The roots of peanuts are known to grow downward in response to drought stress even when the tops have stopped growing.

Peanuts are a viable crop even when the water table is not shallow enough to be reached by the roots, and the farmers' practice of three plowings and harrowings appears to increase the yield (Table 5.1). The key

Figure 5.6. Rainfall in Surin Province During the Peanut-Growing Season in Two Consecutive Years

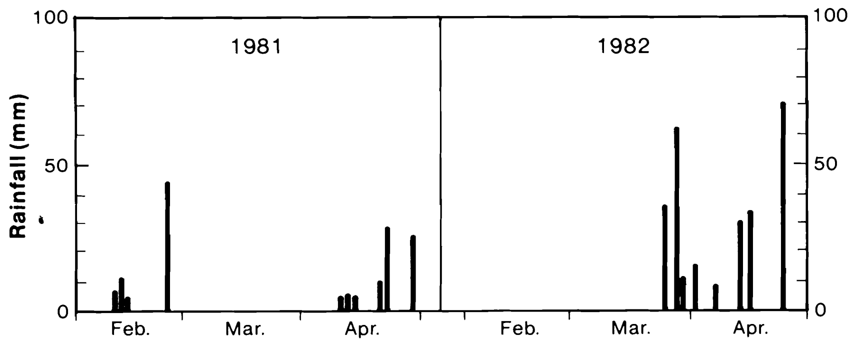


Table 5.1. The Effects of Land Preparation on Peanut Yields under Different Water Table Conditions

Land Preparation	Yield (kg/ha) Shallow Water Table	Deep Water Table
One plowing and one harrowing	1406	189
Three plowings and three harrowings	1725	325

Source: Jonthron (1982).

is probably conservation of residual soil moisture despite the fact that, first, tillage would normally reduce the soil moisture in the upper, plowed layer (Zandstra 1982), and, second, a lack of tillage could result in loss of soil moisture through deep soil cracks that occur when paddy soils (especially clay) dry out. The actual mechanisms by which the plowing increases yields are not yet known, however.

Cassava After Rice. This cropping system is found in certain areas of Khon Kaen Province. Cassava is planted after rice is harvested in December–January. The cassava is harvested seven to eight months later, in June–July, before rice transplanting begins. Because the growing period allowed for cassava in upper paddy fields is shorter than in upland areas, cassava is planted with a spacing narrower than normal (0.5 by 0.5 m rather than 1.0 by 1.0 m), in order to maintain the same yield per unit area. Cassava is started with residual soil moisture left from the previous rainy season and matures during the subsequent rainy season. There is one hand weeding during the growing season.

Tobacco After Rice. In Roi Et and Khon Kaen provinces, tobacco is planted under the supervision of private companies after the rice is harvested in November–December. Water for tobacco must be controlled throughout the growing period, because absorption of excess water produces poor quality leaves. This makes tobacco particularly suitable in areas where water is in short supply or where water is available only for a short period after the rice harvest. Tobacco is hand irrigated the first three to four weeks, using water from shallow wells.

Vegetables After Rice. This cropping system occurs in most areas in Northeast Thailand. Vegetables are planted after the rice harvest in January–February and irrigated by hand using water from small ponds constructed in paddy fields to store water from the rainy season. This contrasts with other cropping systems where water is obtained from the water table. Vegetable crops such as green corn and yard long beans are grown not only for commercial use but also for home consumption. The small ponds are also used for fish culture.

Vegetables Before Rice. This cropping system is found in certain areas of Roi Et and Khon Kaen provinces during February–March. Vegetables such as cucumber, eggplant, pumpkin, and watermelon are hand irrigated with water from shallow wells during their early growth stages. Growth is completed with the small amount of water at the onset of rainfall during February–April. Manure is applied as fertilizer before planting.

Vegetable yields in this cropping system depend on the amount and frequency of rain during February–April. Farmers hand irrigate only for vegetable survival, because of the high labor cost of hand irrigation. The labor requirement is reduced if there is more rainfall, which leads to higher yields. Rice straw may be used as a mulch to decrease the rate of evaporation from the soil surface and control weeds.

Lower Paddy Fields

Rice for home consumption comes from lower paddy fields rather than upper paddy fields. With early flooding of lower fields, soil moisture can be maintained longer than in the upper paddy fields. Rice varieties with a medium or long growing period are used in lower paddy, while early-harvest varieties are used in the upper paddy, because it dries out sooner. Rice yields in lower paddy fields are higher than upper paddy fields because of the longer growing period and the ample supply of soil moisture throughout. Every household cultivates a number of local rice varieties each season, including varieties that are slightly sweet but taste good enough to be eaten with salt or as a fried paste when there is no other food to eat.

Field crops cannot be grown before or after rice in lower paddy fields because of early flooding in the rainy season and late harvesting of rice. Land preparation at the onset of rainfall is difficult because lower paddy soil usually has a high clay content, and even a small amount of rainfall will not permit plowing. The soil is sticky after rice harvesting, and it is hard when dry.

FARMERS' DECISION MAKING

A typical household in the Northeast is faced with a series of decisions each year concerning the cropping systems it will employ on upland areas, upper paddy fields, and lower paddy fields. Five major factors affect the decisions, and they are constantly changing, particularly the economic ones.

Natural Factors

The number of crops that can be grown in the Northeast is limited by the erratic rainfall and poor soil quality, with cassava and kenaf giving the most reliable yields. As a consequence, farmers continue to reserve part of their fields for cassava even though the price has dropped in recent years.

Economic Factors

Farmers risk a low income if they restrict themselves to the major crops, because the prices of major crops fluctuate so much from year to year. The risk is exacerbated by the fact that major crops usually have a long growing season and therefore represent a commitment for a major portion of the year. As a consequence, an area is often set aside for miscellaneous food crops or for intercropping such crops with major crops. These minor crops can be sold in the local market and provide an early and potentially high cash income. Even if the price of the minor crop drops sharply, the minor crop provides soil fertility improvement from animal manures whose nutrients serve not only the minor crops but also the major crops that follow.

Social Factors

Traditional ceremonies in the Northeast can be classified into two types: family ceremonies and village ceremonies. There are eleven ceremonies every year, each ceremony having a different purpose, such as:

- Requesting the best rainfall distribution for better crop growth from a god;
- Requesting good health for the family and happiness for those family members who have died; and
- Enjoying entertainment after working hard in the fields.

There are three village ceremonies that affect intensive agriculture: Bun Songkrant, Bun Prawaed, and Bun Bangfai. These ceremonies are essential because they request the best rainfall distribution and forecast the rainfall for the coming year. Because they are time-consuming and many villagers participate, they compete with farm work, especially early planting at the onset of rainfall, so farmers prefer to plant crops that require less care during this period (February–March). Everyone takes part in the ceremonies, but farmers have adapted to modern economic pressures by decreasing the time allotted to them.

Other village traditions are prohibitions and labor exchange. Some prohibitions relate to cropping practices, such as not plowing before the fourth week of April to ensure that crops are not planted before this time when they would suffer a water deficiency due to the small amount of rainfall. Generally, however, this prohibition is observed strictly only by farmers who can obtain sufficient cash income from the old cropping patterns to cover their living expenses.

Labor exchange consists of family labor exchange (for transplanting and harvesting rice) and village labor exchange (e.g., working on schools, temples, ponds, canals, roads). Family labor exchange has become less important as people devote less time to their farms and more time to securing off-farm income. Village labor exchange, however, has been maintained by a change in style. The village head divides villages into small groups, so they can schedule their village labor to minimize conflicts with crop activities.

Information Resource Factors

As farmers consider new crop varieties and cultivation practices to increase their cash income, their cropping decisions are affected by information from nearby farms, villages, relatives, and extension workers. They place more faith in innovations from nearby farms or villages than from extension workers. They say: "The farmer believes the farmer more than he does the extension worker." There is less risk if a farmer first has the opportunity to observe the new technology in action with other farmers for a substantial time under circumstances much like his own.

The extension method of technology transfer is usually ineffective, even when extension workers offer a technology that is appropriate for the farmer's circumstances. Farmers may fail the first year they attempt what they have seen on experimental demonstration plots or heard from extension workers because they are not familiar with the new methods. If a new crop fails once, a farmer will not try it again because of the strong impact on his cash income.

Nutritional Factors

Food is the largest cash expense for most families. Sources of protein in fish, wild animals, insects, and mushrooms are diminishing as the expanding human population cuts back forests to put the land into agriculture. In the past, fish from paddy fields in the rainy season were sufficient for home consumption, and farmers could sun dry the excess or preserve it in a jar with salt as food for the dry season. But now there are not enough fish for home consumption because the larger human population consumes all the fish during the early rainy season, when previously only the most mature fish were taken. Moreover, some farmers are growing new rice varieties and applying insecticides that kill the fish in their paddy fields. Because of the loss of these foods that have traditionally supplemented rice in the diet of Northeast Thai families, field crops such as vegetables planted before or at the end of the rainy season are important not only for commercial production but also for home consumption.

Rice is the major food crop in the Northeast. Farmers strongly prefer cultivating rice, even though upper paddy fields are more suitable for crops other than rice. Farmers still retain the idea: "With enough rice for home consumption, no chance for death, but if we have money but no rice, we might be dead." Rice growing is so important that upland rice has become a significant crop in upland areas where the amount of paddy field area per family has decreased. The basic strategy is to cultivate a sufficient quantity of the traditional glutinous rice to meet all the household's rice consumption needs. Additional production is devoted to nonglutinous rice (i.e., improved varieties) or other crops intended primarily for sale. The particular crops to be grown are dictated primarily by environmental conditions in rainfed areas but more by market conditions in irrigated areas.

EXISTING CULTIVATION PRACTICES

Planting and Cultivating Cassava

Cassava has become the major upland crop in the Northeast because it is best suited to the erratic rainfall and poor soil fertility. It can be planted or harvested at any time during the year since it is drought tolerant. However, farmers prefer planting cassava at the onset of rainfall (March–April) or after the end of the rainy season (October–November), because weeding is easiest in these periods, and there is better crop establishment. These are also periods when there is less competition for labor with other crops such as rice. The amount of land planted to cassava each year depends on local prices. Cassava planting methods depend on rainfall. After a small amount of rainfall, or when there is residual soil moisture at the end of the rainy season, farmers simply drop cassava cuttings in furrows made by a water buffalo or hoe and cover them with soil. During heavy rainfall, however, the cuttings are placed vertically in the soil, so the top extends about 5–8 cm above the soil level. The cassava cutting would rot before it germinated if the first method were used during heavy rains.

Farmers in some villages cut the top one-third of their cassava plants to increase tuber yields. Field trials have shown that cutting cassava tops six to seven months after planting increases tuber dry-weight yields, because the cutting stimulates a greater quantity of young, actively photosynthesizing leaves (particularly in soil high in nitrogen). At the same time, cutting cassava tops removes foliage that shades out the lower leaves of the plant, which constitute the main source of photosynthetic product that passes for storage into the tubers. In contrast, cutting cassava tops eight to nine months after planting increases the wet-weight yield without increasing dry weight, because more water is stored in the roots when transpiration is reduced due to a lower leaf area. Some farmers cut their cassava tops at eight to nine months, but the merchants who buy the cassava can generally recognize tubers with a higher water content and pay correspondingly less for them.

Weeds are not a problem during the early part of the rainy season because rainfall is only sporadic and the intense sunshine at this time dries out the soil surface too much for weeds to survive. Weeds are also not a problem at the end of the rainy season, as they are shaded out by the mature cassava plants and the soil surface is once again dried out by intense sunshine. As a consequence, the middle of the rainy season is the main time for weeding. If farmers weed by hoe, they usually leave the weeds in the field because of the labor involved to remove them.

In some villages they weed by plowing between cassava rows. The water buffalo's mouth is usually covered by a bamboo bucket to keep the animal from eating the cassava. The first weeding is twenty to thirty days after planting the cassava, while the weeds are still young. Plowing close to the cassava throws soil to the middle of the space between the rows, covering the weeds and killing them. Weeds are removed by hoe from between the plants and from areas the plowed soil has not covered. The second weeding is done fifteen to twenty days after the first, depending on weed population and weed growth, before the cassava roots penetrate to the middle of the rows. This time a water buffalo pulls the plow twice between the rows, so the soil covers the weeds to either side of the cassava on the forward and return passes. The second weeding produces furrows for draining water during the coming rainy season. As before, weeds between plants or in areas not covered by soil are removed by hoe.

The main value of weeding by water buffalo is the reduced labor compared with hand weeding, but weeding by buffalo also results in higher cassava yields than weeding by hoe alone. This may be due to the collection of water in the furrows after the first weeding, better drainage during heavy rainfall after the second weeding, and aeration promoted by the deep plowing. In addition, the cassava obtains nutrients from decomposition of the weeds. The farmers also apply manure but seldom use chemical fertilizers for cassava.

Planting Kenaf

Kenaf is a traditional crop of Northeast Thailand that is well adapted to the erratic rainfall and low soil fertility characteristic of the area. The kenaf is planted at a depth of 5–8 cm in furrows 25–30 cm apart plowed by water buffalo. There is no harrowing because a rough soil surface captures more water than a smooth one. The kenaf is seeded deep in the soil to ensure that germination does not occur until there is enough moisture in the soil to sustain it even if there is no rainfall during the first several weeks after germination.

The rainy season usually starts in February or March, but at first the rain is too sporadic and light to sustain crop growth. Many farmers wait until mid-April or later before planting their kenaf. By this time the rainfall has increased sufficiently and the soil has been wetted to a depth where farmers know the crop will have the moisture it needs. Some farmers prefer to plant their kenaf during the last week of March or the first week of April, however, while the soil is still dry. These dry-planted seeds do not germinate until there is sufficient soil moisture, three or more weeks later. While they are waiting to germinate, the seeds are protected from insects by chemical toxins they contain, and their hard seed coat protects them from desiccation due to high soil temperatures.

It appears the dry-seeding practice can make a significant difference to the success of the kenaf crop. This was demonstrated with field trials on a poor, acidic soil (organic matter, .59 percent; total nitrogen, .025 percent; available phosphorous, 2.50 percent ppm; surface pH, 4.2), following traditional agricultural practices as closely as possible. A traditional Thai variety ("green stem") was planted in rows 30 cm apart with a spacing of 10 cm between plants. The first plowing was done by water buffalo in the third week of February, as soon as the first rainfall made the soil moist enough for plowing. Dry seeding took place in the last week of March. Seeds were planted at a depth of 5 cm in furrows made by water buffalo, and the seeds in one furrow were covered with soil when the plow made its pass on the next row. Wet seeding took place three weeks later, in the middle of April, immediately after a rainfall of 12 mm, when there was sufficient soil moisture for germination. Cultivation practices for the two treatments were the same. Fields of both treatments were thinned ten days after the wet-seed planting, and there was a single weeding done by hand ten days later. No fertilizers or insecticides were employed. There were three replicates of each treatment following a randomized block design.

The germination rate was the same in both treatments (approximately 80 percent), but dry matter production and yields were different. The dry-seeded kenaf germinated about five days before the wet-seeded kenaf, and the plant height, stem biomass, root biomass, and fiber yields of dry-seeded plants were greater than those of wet-seeded plants (Table 5.2). It appears that dry-seeded kenaf performs better because it gets an earlier start, even though the soil is dry when it is planted. Seeds can absorb enough moisture from the water vapor in dry soil to swell and initiate initial stages of the germination process (Marcus and Feeley 1964). This start appears to give dry-seeded kenaf a higher drought tolerance during the initial growth period, an advantage over weeds that is reflected in a lower weed biomass at the time of weeding (Table 5.2), and a greater resistance to leafhopper damage (Katanyukul et al. 1977).

Intercropping Green Corn with Upland Rice in a Bed-Furrow System

In some villages the rice produced in paddy fields is not enough for home consumption and farmers must expand rice cultivation to upland areas to meet their needs. Upland rice is intercropped with green corn in June–July, after the dry spell, using a bed-furrow system constructed by water buffalo. Since the water requirements of the two crops are different,

Table 5.2. Comparison of the Performance of Wet-Seeded and Dry-Seeded Kenaf[a]

	Wet Seeded	Dry Seeded
Plant height (cm)		
15 days	7.7	10.1
30 days	13.3	17.3
45 days	28.5	33.7
Stem biomass (gm/m^2)		
15 days	2.3	4.1
30 days	14.0	17.8
45 days	48.1	58.0
Root biomass (gm/m^2)		
15 days	2.1	3.1
45 days	10.0	14.2
Weed biomass (gm/m^2)		
20 days	8.9	5.5
Fiber yield (kg/ha)	1415	1500

[a]All times are number of days after wet seeding.

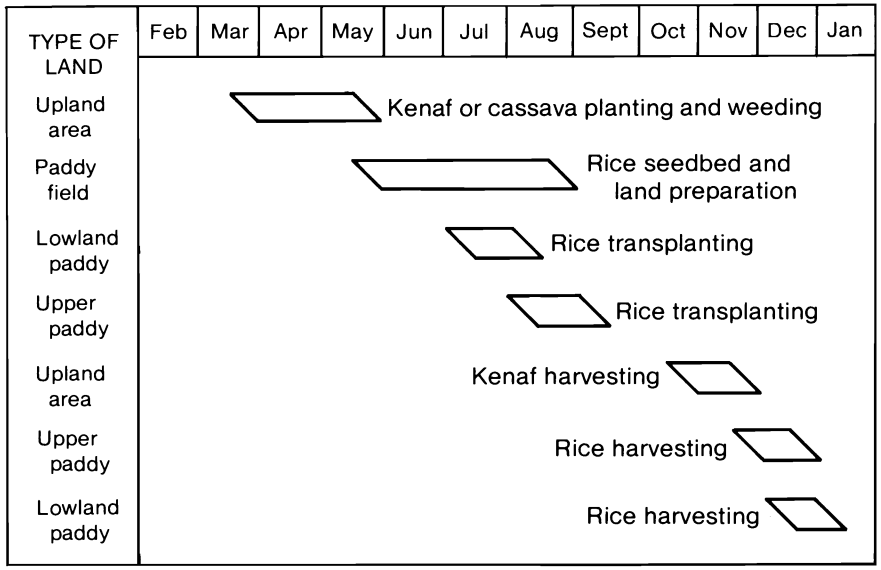
green corn is grown on the shoulders of the beds and upland rice in the furrows. The corn provides cash during the early part of the rainy season.

Harvesting Sesame

Farmers in Buriram and Mahasarakam provinces grow photoperiod-sensitive varieties of blackseed sesame that are harvested during the dry spell in June–July. Sesame capsules nearest the stem normally ripen first, while those toward the tip ripen last. Thus, much of the seed formed at the base would be scattered and lost if the mature plant were allowed to stand for any length of time prior to harvest. The traditional method of harvesting sesame ensures that all the capsules, particularly those nearest the tip, produce mature seed, allowing a maximum yield from the crop. Farmers know it is nearly time for harvest when they observe that many of the sesame leaves have turned yellow. At this point they open the third capsule from the top and decide that it is time to harvest if the seeds inside are brown.

They cut down the plants with a sickle or pull them from the ground and stack them in piles about 1.5 m high, 1.5 m wide, and two stem-lengths long. All the stems in the pile are placed parallel to each other, with the tops of the plants at the centers. Each pile is covered with rice straw and is sun cured for seven to ten days, depending on the amount of sunshine. All of the seed capsules within the pile mature due to the

Figure 5.7. Seasonal Distribution of Labor for a Farmer Cultivating Small Plots on Lower Paddy, Upper Paddy, and Upland



high temperature, and no seeds are scattered and lost. At the end of the curing period, farmers tie the sesame into bundles 25 cm in diameter. Three bundles are tied together to form a tripod-like structure, which is left in the field to intercept more sunshine until the top capsules open. The farmers then turn the bundles upside down and shake the seeds out onto sheets of plastic. This technique allows them to harvest mature seeds from all capsules without any loss. In addition, sun curing decreases the labor required for harvesting and threshing.

Insect Control

Subterranean ants are a major pest of peanuts in Northeast Thailand, damaging the peanuts within their shells at the filling stage of growth. Farmers control ants by treating seeds with kerosene before planting. The kerosene may repel the ants initially or it may be absorbed by the seeds to affect the ants later. Subterranean ant damage is less in upper paddy fields than in upland areas, perhaps because the ants are killed by flooding during the rainy season.

Farm Labor Distribution

The farm labor in traditional systems is distributed evenly throughout the year (Figure 5.7). The cropping sequence resembles triple cropping, except the crops are cultivated in an overlapping sequence in different areas. The first crops are upland crops, the second crop is rice in lower paddy

fields, and the third is rice in upper paddy fields. The only times there is no work are after transplanting rice in mid-September to October and after harvesting rice in January–March.

The seasonal sequence of crops that a family employs on the different kinds of land at its disposal depends upon the amount of upland area, the paddy field, and labor available. As farmers increase their cropping intensity in response to modern economic pressures, they cultivate additional crops primarily when the major crops are not demanding their labor. The crops and cultivation techniques they select depend on water resources and rainfall distribution, but the seasonal sequence of labor must always fall within the bounds of labor available. It is possible, for example, to handle crops in the upland area and upper paddy fields at the same time, because crops in the upper paddy do not demand much attention. In all cropping sequences, the first priority goes to labor for transplanting rice in July–September. The labor available for upland areas depends on the amount of family paddy field and the duration of rice transplanting.

Soil fertility in the Northeast is declining gradually, and crop yields are also declining because farmers rarely apply fertilizer. Fertility is declining most rapidly in upland soils under cassava cultivation for two reasons. First, farmers plant cassava during the onset of rainfall with a wide row spacing (1 by 1 m) and weed before the heavy rains start. There is therefore considerable soil erosion and loss of soil organic matter during the early rainy season, when the cassava and weeds have not yet attained sufficient cover. Second, no crop residues from cassava are returned to the soil to maintain soil organic matter since the roots are sold in the market and the stems are used for planting stock in the next growing season. In contrast, kenaf is planted at a high density with close rows (30 by 5 cm) so it quickly establishes a canopy that protects the soil from rainfall. Moreover, the fibrous kenaf roots hold the soil and continue to do so even after harvesting, because they are left in the ground.

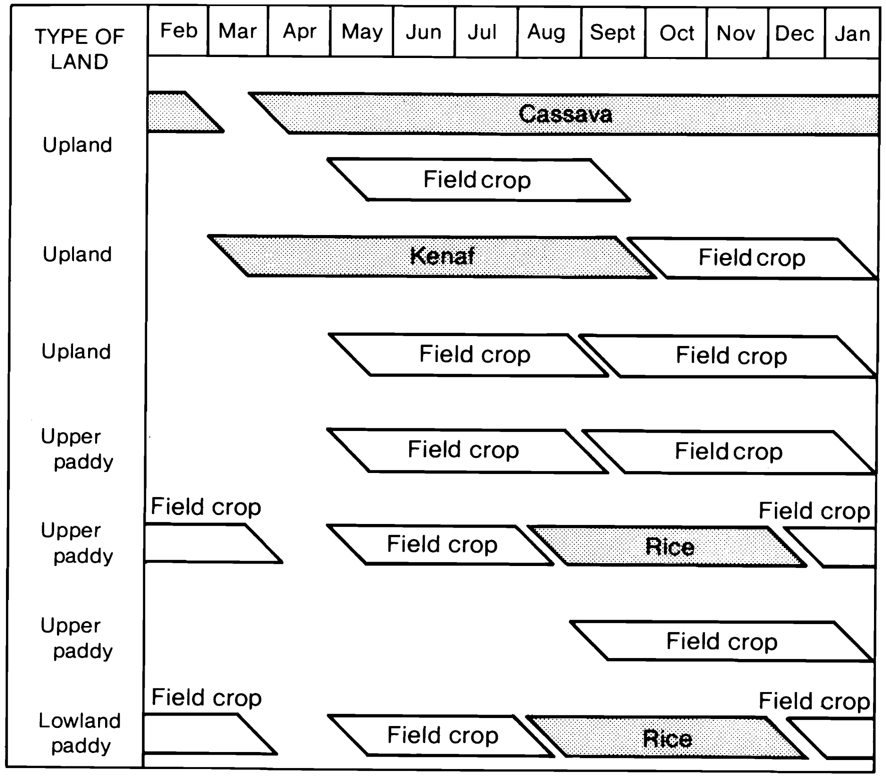
EXPERIENCES TESTING NEW CROPPING SYSTEMS

The Cropping Systems Project at Khon Kaen University was established to develop improved cropping systems for the area. The specific objectives of the project were:

1. To develop cropping systems suitable for cultivation in rainfed areas of Northeast Thailand;
2. To identify crop varieties and improved cultivation practices suitable for rainfed conditions; and
3. To provide a research framework for the participation of university staff and students in problem-solving efforts.

The following new cropping systems were tested because they appeared to have the best prospects for success (Figure 5.8):

Figure 5.8. New Cropping Systems Tested by the Cropping Systems Project (major crops are shaded)



Upland

1. Intercropping cassava with field crops.
2. Double cropping kenaf with field crops.
3. Double cropping field crops.

Upper paddy

4. Double cropping field crops.
5. Double cropping a field crop before or after rice.
6. Planting a late field crop when there is not sufficient rainfall for rice.

Lower paddy

7. Double cropping a field crop before or after rice.

The new cropping systems were tested on the university farm and in villages. A standard experimental design with several replicates was used on the university farm. Experiments in the villages were classified into three types according to the level of management:

1. Field trials conducted by project staff on fields rented from farmers. Treatments were arranged according to the usual experimental design and included replication.
2. Field trials conducted by farmers on their own fields under project supervision. The project provided all inputs, e.g., seeds and insecticides. Experimental plots were large and arranged for demonstration without replication.
3. Field trials conducted by farmers on their own fields. The project provided credits to the farmers for necessary inputs, e.g., seeds and insecticides.

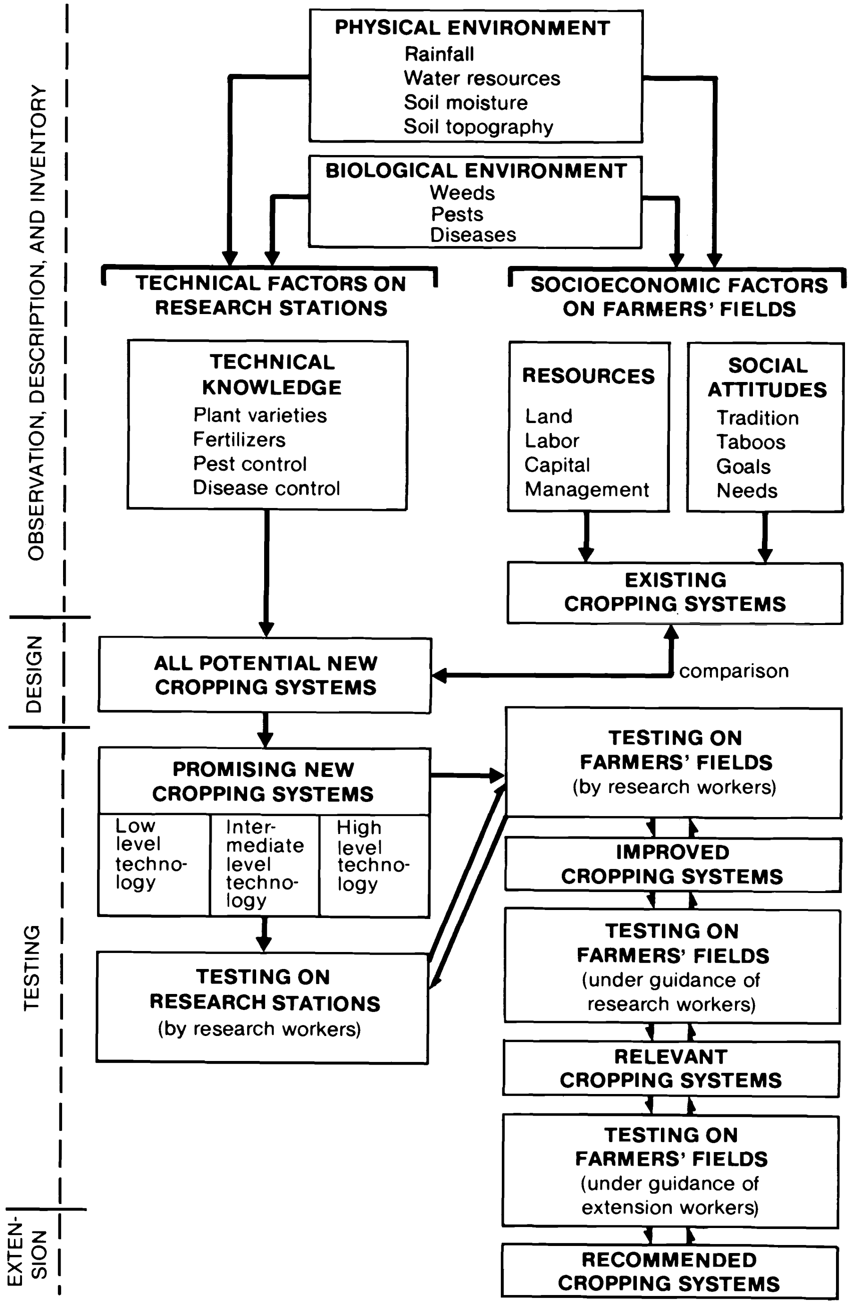
In the first phase of testing, a variety of cropping systems was tested and screened for inclusion in the second phase. In the second phase, the most promising cropping systems were tested and screened for further testing during the third phase (Figure 5.9). There was an emphasis on adapting modern farming techniques to village conditions rather than drawing upon traditional farming technology.

Intercropping Cassava with Field Crops (Upland)

Farmers usually plant cassava with a row spacing of 1 m, which leaves space between the rows to interplant field crops during the first three to four months, until the cassava canopy closes over completely. However, the customary practice of weeding by plowing between rows of cassava with water buffalo presents a complication for intercropping field crops with cassava. Farmers are reluctant to give up this practice in order to interplant field crops, since plowing requires less labor than weeding by hoe and gives higher yields due to better soil aeration and drainage.

A number of field crops were tested for intercropping with cassava during May–July: peanuts, mung beans, soybeans, cowpeas, corn, and sorghum. Interplanted legumes, such as peanuts, mung beans, and cowpeas, gave the best results because interplanted legumes usually cause little or no reduction in cassava yields. When field crops were planted with cassava at the onset of rainfall (March–April), their yields were generally low because of insufficient moisture during the seedling stage. When field crops were interplanted with cassava at the end of the rainy season, their yields were still generally lower than when planted alone, except in areas where there was a high water table or where soil moisture persisted well after the end of the rainy season.

Figure 5.9. Research Framework Employed by the Cropping Systems Project



Intercropping field crops with cassava has become more attractive in recent years because of declining cassava prices and lower cassava yields due to decreasing soil fertility. The higher net income from interplanting field crops is apparent to all, and legumes help to maintain soil fertility. Therefore, interplanting field crops with cassava appears attractive, especially to farmers with small rice fields who have greater flexibility in their planting schedule because not all their labor is needed for rice cultivation.

Double Cropping Field Crops with Kenaf (Upland)

Kenaf was grown for fiber in the past, but the quality of the final product was usually poor because of insufficient water and labor for processing. Processing is not as great a problem now because there is a pulp factory with sufficient capacity to purchase kenaf from a 100-km radius.

Kenaf is grown with a narrow spacing between plants, because wider spacing causes branching that reduces fiber quality. Because it is not practical to interplant field crops with kenaf, any improvement in the cropping system must be based on planting a field crop after the kenaf. Though kenaf is normally harvested in November, earlier cutting (in September) would be desirable to ensure sufficient soil moisture for the field crop.

Peanuts, mung beans, soybeans, cowpeas, corn, sorghum, and pearl millet were tested, but none proved economically viable. Early harvesting of kenaf caused a significant reduction in fiber yield, and the yield from the field crop was not sufficient to compensate for this loss. However, in certain areas where soil moisture persisted longer after the end of the rainfall period, kenaf yields were sufficient (particularly with peanuts) to make the double cropping worthwhile. Even if the yields from this cropping system are profitable, early harvesting of kenaf is of limited appeal to farmers with a large amount of paddy land, because September is the time they are busy transplanting rice in upper paddies. It is also difficult to sun-dry kenaf in September.

Double Cropping Field Crops (Upland)

Crops tested as the first field crop were mung beans, cowpeas, sorghum, and peanuts; second crops were peanuts, mung beans, cowpeas, sorghum, and pearl millet. The best results were obtained from mung bean-peanut, mung bean-cowpea, cowpea-mung bean, cowpea-peanut, peanut-mung bean, and peanut-cowpea double cropping sequences.

The yield of the first crop (planted in May) was often reduced by a dry spell during the flowering or grain-filling stage. Any delay in planting the first crop impeded land preparation and seedling establishment for the second crop due to water logging during the rainy season (August–September). If the second crop was planted too late (in October) there was not sufficient soil moisture to last the entire growing period, and poor yields resulted. More reliable results were obtained where post-rainy-season soil moisture was sufficient to last longer. The results were also less variable when mung beans or cowpeas were planted early (last week of April to second week of May) as a first crop, in order to harvest in the dry season and plant the second crop in July before the heavy rainfall started.

Double cropping field crops in upland areas does not appear sufficiently reliable to be adopted by farmers, particularly where cassava yields and prices are high. It involves higher cash inputs, more labor, and greater risks than cassava monocropping, though the long-term net income from double cropping is higher than cassava monocropping because of the progressive decline in cassava yields and prices.

Double Cropping Field Crops (Upper Paddy Fields)

Upper paddy land is often left idle if there is insufficient rainfall to permit puddle transplanting of rice during the rainy season. Without puddles there is no assurance of sufficient water to sustain rice growth until harvest, particularly if there is not much rain at the end of the rainy season when rice is in its grain-filling stage. Double cropping short-duration field crops would appear reasonable whenever upper paddies do not have enough water for a rice crop.

All combinations of field crops that were tested for double cropping on upper paddy fields gave satisfactory yields. Nonetheless, it is unlikely farmers will adopt this system because they believe rice should always take precedence over a cash crop. It is important to them to produce and store a surplus of rice for future home consumption in the event a drought or other natural disaster destroys a rice crop.

Field Crops Before Rice (Upper Paddy Fields)

Rice is usually the only crop planted in upper paddy fields. Because farmers transplant rice in upper paddies after lower paddies (August–September), upper paddy fields are idle for three to four months before transplanting. It seems possible to plant short-duration field crops before rice, at the onset of rainfall. Mung beans, cowpeas, peanuts, soybeans, and sorghum were tested. The yield was highly variable from field to field and year to year, depending on rainfall distribution and drainage management. The system worked well one year, when the first rains were light; but it gave poor yields another year, when the early rains were heavy, because the crops suffered from waterlogging.

Land preparation after rice harvesting made field crop yields the following year less variable because the field crops could be planted earlier, when there are fewer weed problems. The most reliable results were obtained by planting mung beans and cowpeas early (from the last week of April to the second week of May), in order to harvest them before the heavy rainfall started in August. On the other hand, peanuts, soybeans, and sorghum have a longer growing period (four months) and are therefore always vulnerable to flooding before harvesting unless there is good drainage. Moreover, long-duration field crops like peanuts, soybeans, and sorghum delay rice transplanting, which in turn reduces yields. Peanut-rice double cropping was successful when the peanuts were planted very early and harvested green or immature before flooding, for use as boiled peanuts.

Late Monocropping of Field Crops (Upper Paddy Fields)

If upper paddy fields are not planted to rice because of insufficient rainfall, late planting of field monocrops might be feasible because they require less water than rice throughout their growing period. The soil is generally too wet in late September, however, for good land preparation and planting. Planting conditions are better in October, but then there is not enough soil moisture to last the field crop through the grain-filling stage. A number of field crops, including peanuts, mung beans, cowpeas, soybeans, pigeon peas, sorghum, and pearl millet, were tested over a range of planting dates from mid-September through October. All gave poor yields except when rainfall extended through November.

Field Crops Before Rice (Lower Paddy Fields)

Early planting of short-duration field crops (seventy to seventy-five days) may be possible in lower paddy fields at the onset of rainfall before rice transplanting begins in July. Mung beans and cowpeas were the crops tested. There was often heavy flooding, however, that led to crop failure or poor yields. Efforts to develop a drainage system to eliminate flooding were not successful.

Field Crops After Rice (Upper and Lower Paddy Fields)

A number of field crops—peanuts, mung beans, cowpeas, pigeon peas, and sorghum—were tested after rice in both upper and lower paddy fields. The objective was to take advantage of residual soil moisture at the end of the rainy season. Several seeding methods were tested, including sowing with and without land preparation, direct seeding in rice stubble, and broadcasting seeds before rice harvesting. None of the crops produced satisfactory yields. The seeds germinated and grew well at first, but the plants later died or produced little because of insufficient soil moisture at the end of the growing period.

CONCLUSIONS

Improving on existing cropping systems in Northeast Thailand is difficult because the existing cropping systems are so highly adapted to the ecological and social conditions of the area. It appears that the most viable strategy for improving the agriculture of Northeast Thailand is to develop modifications of existing cropping systems, drawing as fully as possible on existing practices through an in-depth understanding of their ecological basis.

Constraints due to socioeconomic factors and the physical and biological environment should be considered along with the usual technical factors that agricultural scientists take into account when designing improved cropping systems. This is not only a matter of recognizing that farming practices are integrated into coherent farming systems but also that farm families look to the whole social-environmental system for survival as they make their farming decisions; they do not farm for economic reasons alone. Most improved cropping systems can be expected to disrupt the existing life-style of farm families to some extent, and they will not be accepted unless the disruption is within reasonable bounds.

From the beginning, promising new cropping systems should be tested in a village environment under practical farming conditions rather than at research stations. Farmers should be active participants in the research process, so the fullest possible use can be made of their wisdom and technology.

TOPICS FOR AGROECOSYSTEM RESEARCH

Understanding the ecological basis of existing farming practices can help to transfer successful cropping systems to new areas with similar social and ecological conditions, to make viable improvements in existing cropping systems, or to incorporate existing technology into radically new cropping systems. The agroecosystem research topics listed here are aimed at a deeper understanding of traditional cropping practices, explaining how farmers adapt their cropping systems to local ecological and social conditions.

Understanding Traditional Cropping Practices in the Sesame-Before-Rice System (Upper Paddy Fields)

- *Existing practice*: Farmers are able to plant sesame (before rice) during the onset of rainfall in some areas, even though the rains are still light and sporadic. *Research question*: Is this because farmers take advantage of a high water table?
- *Existing practice*: There is no weeding in sesame fields. *Research question*: Is this because not many weeds develop or because normal weed populations have little detrimental effect on yields?
- *Existing practice*: Insects (e.g., beetles) in sesame fields are controlled by handpicking (with the aid of devices such as kerosene lamps at night) and used for home consumption as a source of protein or sold as a source of cash income. *Research question*: What are the advantages and disadvantages of this practice?
- *Existing practice*: Sesame roots are left in the fields before planting rice. *Research question*: Are the physical properties of the soil improved due to better aeration when fibrous plant roots are present? Are nutrients increased due to sesame root decomposition?
- *Existing practice*: Sesame slash after threshing is plowed into the field as green manure. *Research questions*: Does the green manure increase soil fertility for the rice crop? Are there fewer weeds in the rice field due to the previous sesame crop?
- *Existing practice*: Little cash is spent on the "sesame before rice" system. *Research question*: Is risk minimized with this practice?

Testing Modifications of Existing Practices in the Sesame-Before-Rice System (Upper Paddy Fields)

- *Existing practice*: The local photoperiod sensitive Buriram variety is planted at any time from February to April. *Research*: Experimental trials of four varieties in rented farmer's fields at three planting dates from February to April. The varieties to be tested are Pitsanulok, Nakorn-sawan, Buriram (photoperiod sensitive), and W-53 (nonphotoperiod sensitive).
- *Existing practice*: The field is plowed and sesame seed broadcast as soon as the rains start. *Research questions*: Is it better to sow sesame by drilling into the dry soil before the rains start (i.e., immediately after harvesting the rice in February)? Does land preparation after rice harvesting keep soil moisture close to the soil surface by cutting capillary water and reducing transpiration from weeds and stalks?
- *Existing practice*: Rice is transplanted by planting the seedlings in puddles; but some years the rain comes late or is not sufficient for making puddles, and upper paddies are left idle. *Research questions*: Can direct-seeded rice give better rice yields where there is insufficient rain for transplanting? Are there fewer weed problems with direct-seeded rice when it is preceded by sesame?

Understanding Traditional Cropping Practices in the Peanuts-After-Rice System (Upper Paddy Fields)

- *Existing practice*: Peanuts are planted after rice even though there is no rainfall during the first two months of growth. *Research question*: Is this because of a high water table or planting techniques (good land preparation, deep planting, pregerminated seed)?
- *Existing practice*: There is no weeding of the peanuts. *Research question*: Are there fewer weed problems when land preparation is more intense?
- *Existing practice*: No insecticides are used to control subterranean ants or nematodes. *Research question*: Is there no damage because the ants and nematodes are killed by flooding?
- *Existing practice*: There are variable yields of peanuts within individual fields. *Research question*: What is the cause of the unproductive spots in the fields?

Testing Modifications of Existing Practices in the Peanuts-After-Rice System (Upper Paddy Fields)

- *Existing practice*: No lime or fertilizer is applied. *Research question*: Do lime or fertilizer applications increase peanut yields?
- *Existing practice*: Peanuts are planted as a monocrop. *Research question*: Are there advantages to interplanting castor beans with peanuts?

- *Existing practice:* Peanut slash is fed to water buffalo, rather than plowed in as a green manure for rice. *Research question:* Is peanut slash better used as a green manure?

Understanding Traditional Cropping Practices in the Vegetable-After-Rice System (Upper Paddy Fields)

- *Existing practice:* Mulching and hand irrigation are employed. *Research questions:* Does mulching decrease weed problems, thereby decreasing the rate of evapotranspiration and reducing the need of labor for hand irrigation? Are yields greater with hand irrigation than from rainfall alone? Is the extra effort of hand irrigation worthwhile because these vegetables are a significant source of food for home consumption during the dry season (in addition to being a cash crop)?
- *Existing practice:* Manure fertilizer is applied to vegetables. *Research question:* Does the manure fertilizer that is applied to vegetables improve soil physical properties and increase rice yields the following year?

Testing Modifications of Existing Practices for Field Crops (Upper Paddy Fields)

- *Existing practice:* Eggplant, cucumber, pumpkin, and green corn are planted as monocrops. *Research questions:* Is there an increase in the efficiency of water utilization when these vegetables are mixed-row interplanted? What is the effect of mulching on mixed-row intercropping?

Understanding Traditional Cropping Practices in the Cassava and Kenaf Systems (Upland Areas)

- *Existing practice:* Weeding by water buffalo is preferred over weeding by hoe. *Research questions:* Are the yields higher? Are the apparent increased yields due to better soil drainage and aeration?
- *Existing practice:* Kenaf is planted with a closer spacing than cassava, and there appears to be less soil erosion with kenaf. *Research questions:* Is erosion greater under cassava than under kenaf? If so, is it because of the spacing or because kenaf roots are more fibrous and hold soil better?

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