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An Ecological Study of Swidden Agriculture at a Village in Northern Thailand*

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Introduction

This paper is an ecological report of swidden agriculture, mainly at a Skaw-Karen tribe village in Northern Thailand and based on a two year field survey (August 1972 through April 1974) and subsequent laboratory work. This investigation was in the main prompted by the curiosity of a natural scientist. However, it is also expected that the quantitative data shown below will be helpful in the development of the study of the human ecology of the swidden agriculture of Southeast Asia. The scope of this report falls within that covered by the condensed review by Clarke (1976).

Most studies of swidden agriculture in Southeast Asia have been conducted by human geographers and anthropologists, such as Pelzer (1945), Freeman (1970), Conklin (1957). On the other hand, intensive research by natural scientists into this subject is, unexpectedly, relatively rare in comparison with that concerning Africa or Latin America. Of course, much important information about the natural histories of swidden areas can be found in the studies made by human geographers and anthropologists concerned with Southeast Asia, but, naturally enough, they do not usually describe the ecological aspects of swidden areas in quantitative terms. Kostermans' memorandum (1960) in the "Goroka Symposium" can be quoted here: "Most authors complain that so little is known of the seral stages of recovering, after Man has intervened, and in the available literature we find always rather fragmentary accounts. ...As stressed by all authors the secondary successions are of a very complex nature and differ considerably from place to place." Although nearly two decades have elapsed since the symposium, one feels that this statement could be made with equal validity today.

Survey Area

The survey site of this report, located in the rugged mountains of Northern Thailand, and is the *ban* (or village) of Mae Tho Yang (*Yang* or *Kariang* means Karen tribe in Thai). This village was reportedly established at least half a century ago. Administratively, it

* Some parts of the data in this paper were presented at the 22nd, the 24th and the 25th Annual Meetings of the Ecological Society of Japan in April 1975, 1977 and 1978, respectively.

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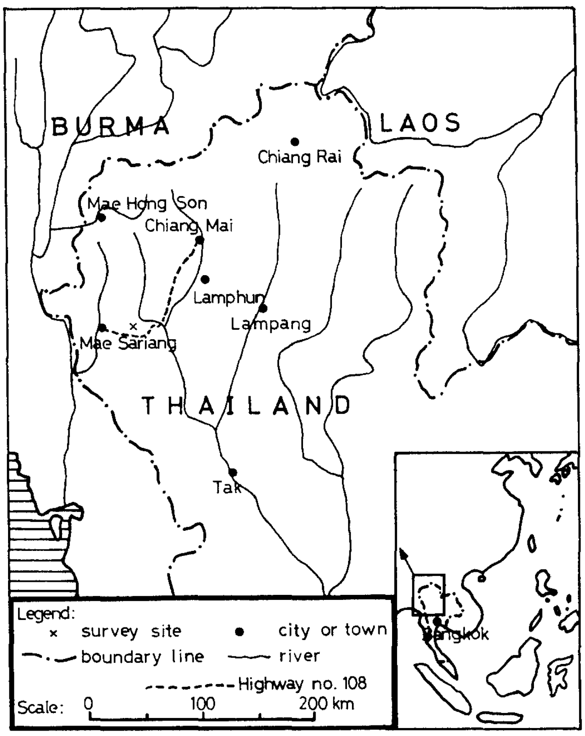
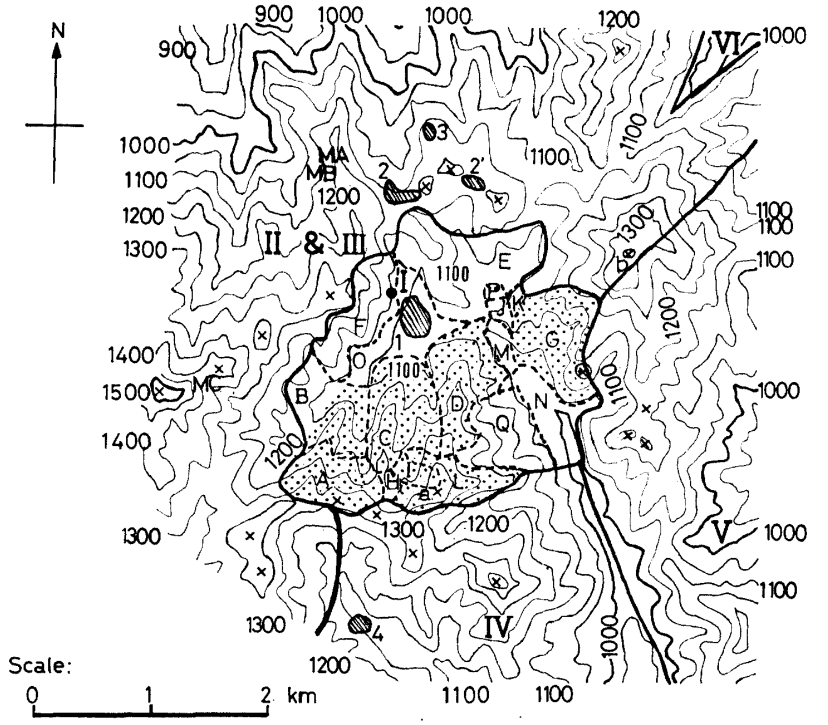
belongs to the *tambon* (or sub-county) of Bo Sali in the *anphoe* (or county) of Hot, in the *changwat* (or province) of Chiang Mai. In terms of latitude and longitude, its location is 18°15′30″N and 98°14′E. Beside this village, there is another village (Map 2) called Ban Mae Tho Meo (or Miao) where both Geddes (1976) and Chindasri (1976) conducted detailed anthropological research before I arrived. The distance between the two villages is roughly 1 km (Map 2). This survey area is near to the great watershed which divides the catchment area of the Maenam (or Chao Phraya) River from that of the Salween River and lies on the Maenam side. In order to reach there without a helicopter, one has to walk or ride a pony for four hours along a valley from the village named Konroi a few hours by car or bus, on Highway no. 108 (Map 1), from Chiang Mai City, the prime center of Northern Thailand. These villages are about 100 km to the southwest of Chiang Mai City (Map 1). The altitude of the main survey area and its surroundings ranges from 1,000 m up to 1,500 m above sea level (Map 2).

Geologically, the hills in this area are situated in one of the main granite ranges in Thailand (Pendleton, 1962). As well as outcrops of granite, a few outcrops of dark-colored (with stripe pattern) and white (largely transparent and composed of more than 99 percent quartz) rocks metamorphosed from original acidic rocks up to very high grades (Ui, 1978, personal communication) can be found there. According to Pendleton (1962), the granite rocks in the region protruded at a time later than late Mesozoic and are associated with



Map 1 Location of the Survey Site in Relation to the Whole Area of Northern Thailand and its Surroundings.



Map 2 Detailed map of the survey area and its surroundings in April, 1974. Contour lines (thin curves) are drawn every 50 m in altitude: A figure more than or equal to 900 means the elevation of the contour line in meters above sea level.

×, peak: the letters **a** and **b** denote the two peaks mentioned in the text. Hatched site, village or hamlet: 1, Ban Mae Tho Yang (Karen tribe) village; 2 and 2′ hamlets of Ban Mae Tho Meo (Meo tribe) village; 3, Boreh hamlet (Meo tribe) which administratively belongs to Ban Mae Tho Meo; 4, Ban Mae Tho Noi (Karen tribe) village.

Thick curves represent the boundaries of the claimed territories of the respective villages: I, the claimed territory of Ban Mae Tho Yang; II & III, that of Ban Mae Tho Meo including Boreh hamlet; IV, that of Ban Mae Tho Noi; V & VI, those of other Karen tribe villages.

Broken curves in the claimed territory of Ban Mae Tho Yang indicate the boundaries of the districts which are divided in accordance with the land-use pattern of the villagers as follows: District A, swiddens in 1966, which were successively re-utilized for the production of maize and opium by Meo people in 1967 and 1968; District B, swiddens in 1967 and 1973; District C, swiddens in 1968 and 1974; District D, swiddens in 1969; District E, swiddens in 1970; District F, swiddens in 1971; District G, swiddens in 1965 (perhaps) and 1972; District H, swidden in 1972; District I, swiddens in 1973 (this district contained both mature forest fallow and young forest fallow fields); District J, swiddens in unknown year (the later 1960s); District K, swiddens in unknown year and 1973; Districts L and M, mature forests; Districts N, O and P, wet paddy fields; District Q, swiddens specifically for the production of maize in 1969.

The soil samples were taken from the dotted area and the sites MA, MB and MC (M is the initial letter of Meo). The solid circle in District F shows the location of the sampling plots for the data in Table 5.

gneisis. The soils covering the hills are classified as "mainly shallow Red, Yellow Podzolic soils" in the *Great Soil Map of Thailand* by Moorman and Rojanasoonthon (1967). The topography of the survey area is shown in Map 2 which covers the area surrounding the territory claimed by the inhabitants of Ban Mae Tho Yang.

It is very difficult to describe the climate of the survey area in scientific terms, because it was impossible to make and maintain facilities to measure climatic factors there and the nearest meteorological station is at the valley-bottom town of Mae Sariang (300 m above sea level in altitude), roughly 35 km to the west of the survey site, beyond the great watershed mentioned above. Fig. 1 was made from the official meteorological records of the station in 1972, 1973 and the earlier half of 1974. The annual precipitation at the meteorological station was 1180.7 mm for 1972, 1210.7 mm for 1973 and 1280.2 mm for 1974. As is well known, hills usually have much heavier rainfall than valley bottoms because of the upward

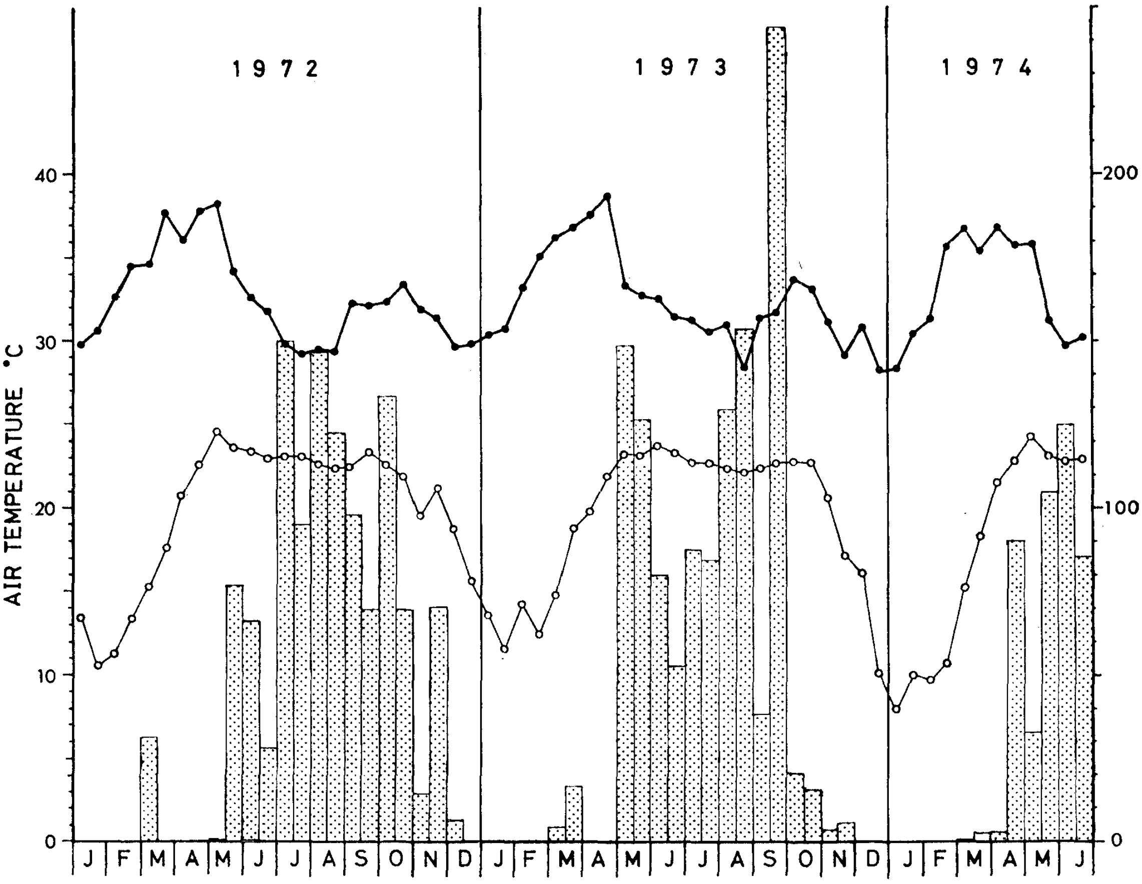


Fig. 1 Temperature and precipitation records at Mae Sariang meteorological station approximately 35 km to the west of the survey site in 1972, 1973 and the earlier half of 1974. Solid and open circles indicate the mean values of daily maximum and minimum temperatures, respectively, every half a month (1st through 15th and 16th through the end of the month) and the height of a column represents the precipitation during the half-month. Adapted from the data in Daily Weather Bulletin, Thailand (1972, 1973 and 1974) by Meteorological Department, Office of the Prime Minister (until September, 1972) or Ministry of Communications (after October, 1972), Bangkok, Thailand.

Table 1 Comparisons of Air Temperatures in 1973 between Mae Tho Meo and Mae Sariang

Season	Periods of Time for the Temperature Records at Mae Tho Meo (number of days)	Mean Values of the Temperatures at 7 a.m. for the Stated Periods (number of the days for the actual records)		Difference between Mae Tho Meo and Mae Sariang	Mean Values of the Daily Maximum Temperatures for the Stated Periods (number of the days for the actual records)		Difference between Mae Tho Meo and Mae Sariang
		A. Mae Tho Meo °C	B. Mae Sariang* °C	A.−B. °C	X. Mae Tho Meo °C	Y. Mae Sariang* °C	X.−Y. °C
Cold and Dry Season	Jan. 26–Feb. 4 (10)	15 (8)	14 (8)	less than 1	25 (5)	32 (5)	−7
	Feb. 5–Feb. 17 (13)	17 (13)	16 (13)	more than 1	no data		no comparison
	Feb. 18–Mar. 2 (13)	17 (13)	13 (13)	4	no data		no comparison
Hot and Dry Season	Mar. 4–Mar. 19 (16)	18 (11)	19 (11)	more than −1	28 (13)	37 (13)	−9
	Mar. 29–Apr. 12 (16)	20 (11)	19 (11)	less than 1	29 (12)	37 (12)	−8
Wet Season	May 22–June 10 (20)	20 (14)	24 (14)	−4	26 (12)	34 (12)	−8
	July 18–July 24 (7)	19 (6)	24 (6)	−5	23 (7)	30 (7)	−7
	Oct. 24–Oct. 31 (8)	17 (8)	22 (8)	−5	24 (7)	34 (7)	−10
Cool and Dry Season	Nov. 10–Nov. 24 (15)	17 (8)	22 (8)	−5	18 (3)	29 (3)	−11
	Dec. 13–Dec. 20 (8)	13 (8)	16 (8)	−3	22 (7)	31 (7)	−9

* Only the values on the same days as those on which records were made at Mae Tho Meo were taken from the data for Mae Sariang.

flow of wet air in the rainy season. A report of the meteorological station of Kasetsart University, at an elevation of 1,300 m on *Doi* (or Mt.) Pui above Chiang Mai City, states that a mean precipitation of 361 mm for August and 500 mm for September record during 1966–1967 (Kasetsart University, 1969), while the average rainfall in Chiang Mai valley for each of these two months, the wettest months of the year in Northern Thailand, is not more than 300 mm. Difference of the temperature between upper parts of hills and valley bottoms is also remarkable; this is due to the altitude effect and other local effects peculiar to valley bottoms where more severe heat in the hot season and more severe cold in the cold season are usually recorded in comparison with plain sites, when other conditions are equal. Therefore, meteorological records made at Mae Sariang (Fig. 1) cannot be directly applied to the survey site. Nevertheless, the trends in the weather records at the Mae Sariang station are very helpful in considering the climate of the survey site. Furthermore, I was able to record the air temperature during 1973 and these figures are shown in Table 1. In the wet season, the morning temperature at the survey site is usually lower by 4–5°C than that at Mae Sariang, whereas the daily maximum temperature is lower by 7–10°C and does not usually exceed 30°C. In the cool, dry season, the morning temperatures at the two sites are similar to each other with the exception of the earlier days of this season (Table 1). Even in the hottest season (March–April) of the year, the daily maximum temperatures at the survey site exceeded 30°C not more than 30 times owing to the altitude effect. Generally speaking, the range of both daily and yearly temperature fluctuation is not so marked as at Mae Sariang (Table 1) and the climate is fairly comfortable even for visitors from a temperate zone. At both Mae Sariang and the survey site, precipitation in the four months from the later days of December to the earlier days of April was negligible in both 1973 (including the later days of December, 1972) and 1974. Usually, the dry season starts from November. In 1972, however, the rainy season lingered until the earlier days of December. In general, the year of 1973 seems to have been normal with respect to the annual rainfall pattern.

Land-Use Patterns

All researchers concerned with the hilly regions in Northern Thailand agree that three different types of swiddeners can be identified. They are: (1) pioneer swiddeners, (2) established swiddeners and (3) incipient swiddeners (Gibson, 1976). The following summaries of the land-use patterns of swiddeners are based mainly on the brief review by Gibson (1976):

(1) Nearly all pioneer swiddeners are recent immigrants such as Meo (Miao), Yao, Lahu, and other tribes. They usually have both upland rice and opium swiddens; the latter must be above 1,000 m altitude because of climatic restrictions. They prefer to clear mature forests. Opium swiddens are often double-cropped, traditionally with maize in the first half of the rainy season. The harvest of opium latex takes place in January and February of the

next year. They utilize one field for as many years as possible, until the yields become unacceptably poor. The number of consecutive years in crop varies from only a few years to 4–6 years, sometimes up to 8–10 years. They cultivate the fields with hoes from the first year. Traditionally, after they have utilized all the available land in the vicinity of a village site they move to a new location seeking land favorable for swidden agriculture. As a rule, they do not expect to re-utilize abandoned fields in the near future.

(2) Nearly all the established swiddeners are Karen and Lawa (Lua') tribes' people. Rice is the only important crop grown and most of their swiddens are below 1,000 m in altitude. Many of them are engaged in both hill swiddens and terraced rice paddies in valley bottoms. They clear, in the main, about ten-year-old secondary forest and stop using the fields for food production, in most cases, after one year's harvest, leaving it fallow again for about ten years. They do not cultivate their swiddens with hoes or plows. They expect to re-utilize the fallowed fields cyclically. Therefore, a village is permanently located within the territory claimed by the villagers. This type of land use is probably what is called "land rotation" rather than "true" shifting cultivation (Sanchez, 1976).

(3) Almost all incipient swiddeners are derived from lowland Thai wet rice growers who have been recently forced by population pressure to utilize the hillsides. They do not practice planned rotational fallowing. Most of them grow upland rice only. Chapman (1970) reported that in the *changwat* of Nan the population pressure was so marked that fallow periods had been reduced to a few years and that some swiddeners traveled up to 7 km from their homes to find available land.

The land-use pattern of Ban Mae Tho Yang belongs to the second type mentioned above, as shown in Map 2. The villagers have both hill swiddens and terraced wet paddies. In principle, they make swiddens at a definite district in a year and a household is given the right to hold a field in the district and to re-utilize the same field when the secondary forest of the district is slashed and burned again several years later. They rotate the districts for their swiddens counterclockwise as shown in Map 2. The village site is located approximately at the center of their claimed territory. The boundaries of respective districts were drawn in Map 2 by combining various sources of information such as my own observations, information from villagers, aerial photographs (1 : 20,000). All of their swiddens are above 1,000 m in altitude. This means that their claimed territory is situated near the upper limit of the territories of the Karen people of Northern Thailand. The fallow period of their swiddens was five years when I stayed there. The land-use pattern and the history of Ban Mae Tho Meo were described in detail by Geddes (1976).

Karen people do not usually utilize the top ridges and upper slopes of hills as swiddens in so far as population pressure is not very intense. According to Marlowe (1969), "One of the most fundamental Karen models of 'being' can be defined as the view that life primarily involves the attempt to maintain a homeostatic or balanced adjustment between the social units and its natural, given and permanent environment." The unutilized zones in the upper parts of the hills play an important role not only in the maintenance of the homeostatic balance of Nature, but also in the prevention of the conflicts between the villages. Marlowe states further, "In contrast the Meo are seen as a people whose model is exploitation, exhaustion, and consequently abandonment of a series of transiently utilized natural environments." This is certainly the case with the villagers of Ban Mae Tho Meo who exploited these previously unutilized buffer zones in the sense of either natural ecology or human ecology. Since 1958 (Geddes, 1976) they have caused both disastrous deterioration of the forests of this area and numerous conflicts between the tribes there. Some episodes of serious conflicts are described by Chindasri (1976) and Geddes (1976). One of the incidents should be mentioned here. Karen villagers claimed that some Meo people had invaded their swiddens (District A in Map 2) after the Karen's harvest of upland rice in 1966. The Meo people subsequently utilized these for producing opium and maize until 1968 when they abandoned them. Consequently, the recovery of vegetation was very poor and the Karen villagers decided not to re-utilize this district as swiddens for the time being. Thus, aggressive behavior on the part of some Meo people disturbed the swidden cycle of the Karen inhabitants.

Vegetational Changes in Accordance with the Relevant Stages of the Swidden Cycle

In this chapter, quantitative data of vegetational changes during the swidden cycle at the survey site will be presented after an observational description of the vegetation in the territory claimed by the Karen villagers.

The main food crop of the Karen people at their swiddens is upland rice and their subsidiary ones are maize, sorghum, taro and cucumber. In most years, they do not produce opium. Since Meo people immigrated into the region, however, the Karen villagers also occasionally make opium fields, as is shown in the detailed map (Map 2) of Geddes (1976). Although, in 1971, they grew some opium poppies for their own consumption in a swidden in District F of Map 2 of this paper, they had no opium fields in 1972 and 1973, nor, probably, in 1974. In usual years, the Karen villagers do not lack staple food, partly because their territory holds approximately 30 ha of terraced wet paddies.

From the viewpoint of a floristic geographer, this area is in the region which de Laubenfels (1975) denoted as a "zone where holarctic and tropical floras merge at intermediate elevations as rain forest." Robbins (1964) states, "In northern Thailand, lower montane forest begins at about 3,500 feet ... and thus true montane forest does not occur in Thailand" and if we accept this description the survey area would be lower montane forest. On the other hand, according to Thai forest researchers, areas at altitudes of more than 1,000 m above sea level in Northern Thailand are covered by "Hill Evergreen Forest" (Khemnark *et al.*, 1971) and the survey area was of this type. This notation originates from *Types of Forests of Thailand* of Royal Forest Department of Thailand (1962). Pendleton (1962) calls a similar (though not precisely identical) type, "mixed pine and oak forest." Thai researchers draw a distinction between Hill Evergreen Forest and Forest mixed with Pine (Khemnark *et al.*, 1971).

In the main survey area, Districts L and M in Map 2 are covered by nearly mature forests. The dominant species there are *Castanopsis* spp. *Quercus* and *Symplocos* are other prominent genera.[1] In the middle of the dry season, the swiddeners clear the young secondary forest including both trees and undergrowth. The secondary forest is composed of many arboreal species. The prominent ones are *Callicarpa lanata* Linn., *C. arborea* Roxb., *Litsea* sp., *Mussaenda sanderiana* Ridl., *Helicia nilagirica* Bedd., *Macaranga denticulata* (Bl.) Muell. Arg., *Phoebe* sp., *Rhus chinensis* Miller, *R. javanica* Linn. The forest floor is not very dark at most stands. Karen swiddeners do not usually fell large trees. In my observation, a tree with a diameter of more than 15 cm at waist height was not felled although its branches and twigs were cut off. Thus, a considerable number of trees of the dominant species in a mature forest remain standing in the secondary forest. As well as trees whose trunks keep away from the blade of a machete due to their thick diameters, a fairly large number of younger shoots of the same species are found in the secondary forest together with the trees of the pioneer species. Some, although not many, leguminous trees are also found; these include *Caesalpinia* sp., *Bauhinia* sp., *Pueraria wallichii* DC. Cycad is another species which remains nearly intact in the cleared fields, since it is often too large to be felled. The prominent species of the undergrowth in the secondary forest are bracken (*Pteridium aquilinum* (Linn.) Kuhn), *Panicum notatum* Retz., *Carex indica* Linn., *Costus speciosus* (Koenig) Sm., *Eulalia* cf. *speciosa* (Debeaux) O. Ktze. and many others. Some shoots of *Eupatorium odoratum* Linn. which, as Pendleton (1962) states, covers a whole fallowed field at an early stage of the fallow period still survive.

In the early days of April, towards the end of the dry season, the swiddeners burn the dried vegetation debris. The grain seeds are sown before the rainy season begins. Once it starts, the seedlings of their crops and the "weeds" begin to compete in growth with one another. As pointed out by Zinke *et al.* (1970), many of the "weeds" are the suckers of felled and burned trees. According to the data collected by Zinke *et al.* (1970), at burning, the temperature at a depth of 5 cm from the soil surface is not high enough to kill the dormant meristems from which the suckers are derived. Thus, coppice shoots grow even before the first rainfall of the wet season. Some quantitative data concerning this aspect will be given later.

The weeding of land with a hoe-shaped weeding knife takes place twice, around June and August, before the time of the rice harvest (October and November). After the weeding, the vigor of the coppice shoots from the stumps and the bracken appears to be temporarily

1) Most of the specimens collected were identified by staff members at the herbarium of the Department of Agriculture, Ministry of Agriculture and Co-operatives, in Bangkhen near Bangkok. It is, however, the author that assumes all responsibility for the application of their efforts to the actual cases with which this paper is concerned.

suppressed to some extent. The rice plants are reaped at their lower part with sickles. Consequently, *Ageratum conyzoides* Linn. and *Perilla frutescens* (Linn.) Britton become the dominant species in the swiddens. However, the period when these species enjoy dominancy is not very long since they cannot flourish after the last rain of the wet season and are replaced by perennial herbs and coppice shoots in the following wet season. In the early days of the following wet season, aside from the coppice shoots, *E. odoratum*, *Erigeron* sp. and *P. aquilinum* are the prominent species. The latter two grow in patches, while the former covers the whole area of the fallowed swiddens. As the wet season proceeds, *Artemisia vulgaris* Linn. also becomes partially prominent. Towards the end of the rainy season, the coppice shoots surpass *E. odoratum* in some places. From the subsequent rainy season, the herb stage is replaced by the bush stage. Fundamentally, the species composition at the bush stage does not appear to be greatly different from that in the young secondary forest. Still, there are some species prominent specifically at this stage, such as *Rubus alceifolius* Poir, *Buddleja asiatica* Lour., *Melastoma normale* D. Don, *Desmodium heterocarpon* (Linn.) DC. In the fourth wet season of the fallow period, the bush stage changes into the secondary forest stage and the height of coppice mostly surpasses 5 m.

The livestock of the inhabitants, three elephants, about eighty-five carabaos, nearly thirty cattle and approximately one hundred pigs, sometimes wander about the secondary forests grazing the undergrowth and young shoots of the trees, grazing pressure does not seriously disturb the forest regrowth, however.

Table 2 shows the dry weight of "weeds" above the ground surface of a swidden field (District K in Map 2) two months after burning (one and a half month after sowing upland rice). The dry weight of the suckers of the trees accounts for nearly 70 percent of the total

Table 2 Quantitative analysis of plant composition (above the ground surface) in a quadrat (4 m×5 m) in a swidden of District K in Map 2 (excluding the seedlings of upland rice); Date of sampling, June 9 in 1973:

Plant	Dry weight in the quadrat
arboreal species	1010.8 g (69.5%)
Carex indica	159.5 g (11.0%)
Pteridium aquilinum	150.8 g (10.4%)
Eupatorium odoratum	59.7 g (4.1%)
Costus speciosus	42.4 g (2.9%)
unidentified forb	13.5 g (0.9%)
Dioscorea sp.	6.3 g (0.4%)
perennial grass	5.3 g (0.4%)
leguminous herbs	4.6 g (0.3%)
Erigeron sp.	2.4 g (0.2%)
Total	1455.3 g/20 m^2 (100.1%) (72.8 g/m^2)

Table 3 Quantitative analysis of species composition of the plants (above the ground surface) in quadrats (2 m×2 m each) in the old swiddens of District G in Map 2, seven months after the harvest time; Date of sampling, June 8 in 1973:

Plot 1

Plant	Dry weight in the quadrat
arboreal species (excluding legumina)	265.5 g (41.3%)
Erigeron sp.	233.9 g (36.4%)
Eupatorium odoratum	79.4 g (12.4%)
arboreal legumina	51.2 g (8.0%)
annual grass	5.4 g (0.8%)
annual forb (unidentified)	3.1 g (0.5%)
Pteris pellucida	2.1 g (0.3%)
perennial grass	1.4 g (0.2%)
Total	642.0 g/4 m^2 (99.9%) (160.5 g/m^2)

Plot 2

Plant	Dry weight in the quadrat
Pteridium aquilinum	284.0 g (33.2%)
E. odoratum	160.4 g (18.8%)
Erigeron sp.	152.6 g (17.9%)
arboreal legumina	142.9 g (16.7%)
arboreal species (excluding legumina)	72.4 g (8.5%)
Costus speciosus	26.4 g (3.1%)
perennial grass	15.5 g (1.8%)
annual forb (unidentified)	0.6 g (0.1%)
Total	854.8 g/4 m^2 (100.1%) (213.7 g/m^2)

Plot 3

Plant	Dry weight in the quadrat
E. odoratum	408.5 g (38.7%)
arboreal species (excluding legumina)	396.6 g (37.6%)
arboreal legumina	138.4 g (13.1%)
Erigeron sp.	96.9 g (9.2%)
perennial grass	6.4 g (0.7%)
unidentified forb*	5.6 g (0.5%)
Dioscorea sp.	2.1 g (0.2%)
Total	1054.5 g/4 m^2 (100.0%) (263.6 g/m^2)

Plot 4

Plant	Dry weight in the quadrat
E. odoratum	522.4 g (66.2%)
Erigeron sp.	125.9 g (16.0%)
arboreal species (excluding legumina)	77.4 g (9.8%)
arboreal legumina	46.9 g (5.9%)
perennial grass	6.1 g (0.8%)
annual forbs	4.6 g (0.6%)
unidentified forb*	3.8 g (0.5%)
Carex indica	1.9 g (0.2%)
Total	789.0 g/4 m^2 (100.0%) (197.3 g/m^2)

Mean of dry weight/m^2 of 4 plots=208.8 g/m^2
Variance=(S.D.)^2=(42.7)^2=1830.73 S.E.=21.4
Average ratio of dry weight of arboreal species (including legumina) to the total dry weight=35.7%
* This species is identical to the unidentified forb in Table 1.

Table 4 Quantitative analysis of species composition of the plants (above the ground surface) in quadrats (2 m×2 m each) in the old swiddens of District G in Map 2, thirteen months after the harvest time; Date of sampling, December 15 in 1973:

Plot 1

Plant species	Dry weight in the quadrat
Eupatorium odoratum	1604.1 g (38.3%)
Buddleja asiatica (×)	1064.4 g (25.4%)
Ageratum conyzoides	573.7 g (13.7%)
unidentified arboreal species (×)	396.7 g (9.5%)
Symplocos sp. (×)	362.0 g (8.6%)
Castanopsis sp. (×)	140.4 g (3.3%)
Oplismenus compositus	21.0 g (0.5%)
Maoutia puya	13.4 g (0.3%)
Triumfetta pseudocana	13.0 g (0.3%)
Crotalaria albida	1.6 g (0.0%)
Total	4190.3 g/4 m^2 (99.9%) (1047.6 g/m^2)

The species marked (×) are arboreal. The total dry weight of the arboreal species, 1963.5 g/4 m^2 (490.9 g/m^2), is 46.9% of the total dry weight at this quadrat.

Plot 2

E. odoratum	1091.4 g (39.5%)
Rhus chinensis (×)	983.5 g (35.6%)
Boehmeria platyphylla (×)	264.1 g (9.6%)
Castanopsis sp. (×)	247.9 g (9.0%)
Polygonum chinense	123.2 g (4.5%)
A. conyzoides	51.8 g (1.9%)
Total	2761.9 g/4 m^2 (100.1%) (690.5 g/m^2)

The species marked (×) are arboreal. The total dry weight of the arboreal species, 1495.5 g/4 m^2 (373.9 g/m^2), is 54.1% of the total dry weight at this quadrat.

Plot 3

E. odoratum	1558.7 g (76.4%)
Artemisia vulgaris	238.9 g (11.7%)
Pteridium aquilinum	155.1 g (7.6%)
Cyrtococcum accrescens	51.5 g (2.5%)
A. conyzoides	18.1 g (0.9%)
Carex indica	6.8 g (0.3%)
unidentified forb	5.5 g (0.3%)
Urena lobata	4.0 g (0.2%)
unidentified forb	0.9 g (0.0%)
Total	2039.5 g/4 m^2 (99.9%) (509.9 g/m^2)

No arboreal species were found in this quadrat.

Plot 4

B. asiatica (×)	558.6 g (32.5%)
E. odoratum	488.5 g (28.4%)
Quercus sp. (×)	202.2 g (11.8%)
P. aquilinum	192.4 g (11.2%)
unidentified arboreal species (×)	102.0 g (5.9%)
Panicum notatum	77.2 g (4.5%)
Rubus alceifolius (×)	28.5 g (1.7%)
Setaria pallide-fusca	18.6 g (1.1%)
Eulalia sp.	15.8 g (0.9%)
Capillipedium paroiflorum	11.7 g (0.7%)
C. indica	7.3 g (0.4%)
unidentified vine species	6.9 g (0.4%)
Rostellularia chiengmaiensis	4.5 g (0.3%)
A. conyzoides	3.6 g (0.2%)
Bauhinia sp.	3.0 g (0.2%)
Total	1720.8 g/4 m^2 (100.2%) (430.2 g/m^2)

The species marked (×) are arboreal. The total dry weight of arboreal species, 891.3 g/4 m^2 (222.8 g/m^2), is 51.8% of the total dry weight at this quadrat.

Plot 5

E. odoratum	1240.8 g (49.2%)
B. asiatica (×)	482.2 g (19.1%)
Maoutia puya	246.6 g (9.8%)
unidentified arboreal species 1 (×)	163.4 g (6.5%)
unidentified arboreal species 2 (×)	113.8 g (4.5%)
P. notatum	81.7 g (3.2%)
Costus speciosus	55.2 g (2.2%)
C. paroiflorum	32.8 g (1.3%)
Eulalia sp.	27.0 g (1.1%)
P. aquilinum	21.6 g (0.9%)
unidentified forb	20.7 g (0.8%)
Bauhinia sp. (×)	15.6 g (0.6%)
Pteris pellucida	13.1 g (0.5%)
Callicarpa arborea (×)	8.9 g (0.4%)
Total	2523.4 g/4 m^2 (100.1%) (630.9 g/m^2)

The species marked (×) are arboreal. The total dry weight of arboreal species, 783.9 g/4 m^2 (196.0 g/m^2), is 31.1% of the total dry weight at this quadrat.

Mean of dry weight/m^2 of 5 plots $=661.8$ g/m^2
Variance $=(\mathrm{S.D.})^2=(238.4)^2=56833.08$ S.E. $=106.6$
Average ratio of dry weight of arboreal species to the total dry weight $=38.8\%$

weight of the plant cover, excluding the seedlings of the paddies, in a quadrat (4 m×5 m).[2] This feature was observed at all Karen swiddens. This fact suggests that the secondary succession in the swiddens after burning does not start from the initial stage of its process but from a halfway stage.

In spite of the suppression of coppice shoots by means of "weeding" in the farming year, stumps in the fallowed swiddens still have the ability to resprout new suckers in the early days of the following wet season although the relative amount of coppice shoots in the vegetation is not so great as in the first year after burning. This observation can be supported by the data shown in Table 3, where the relative quantity of arboreal species in the four quadrats is 35.7 percent, approximately half of the 69.5 percent in Table 2. These data were obtained from the fallowed fields (District G in Map 2) in the territory claimed by the Karen villagers. Quadrats (2 m×2 m each) were chosen at random about half a year after the harvest of upland rice and all the plants on the ground surface within them were reaped. There were only a few new seedlings of woody species growing from seeds.

The data in Table 4 were similarly obtained from the same district as those of Table 3 just after the end of the wet season, six months after the day when the data of Table 3 were obtained. Thus, they concern the vegetation of the old fields approximately one year after the start of the fallow period. The ratio of dry weight of the arboreal species to the total dry weight above the ground surface in the quadrats indicates a similar value on average to the corresponding ratio of Table 3. This does not necessarily imply that the value of the ratio in question remained almost unchanged throughout the rainy season. From the difference in mean values between Table 3 and 4, the net increase of the standing crop above the ground surface in the first wet season of the fallow period was estimated to be about 450 g/m^2 in the case of District G in Map 2. In the dry season, the tall perennial herbs lose a higher percentage of above-ground parts. On the other hand, the shoots of evergreen trees can fully enjoy the benefit of sunshine. When the following rainy season comes, many shoots of the arboreal species can compete with the perennial herbs for a share of sunshine. Consequently, the plant community of the fallow field is ready to move on to become a secondary forest. After this stage, under ordinary conditions, the ratio of the woody plants to total vegetation will increase.

However, another set of circumstances could be observed in part of the old fields in the territory claimed by Ban Mae Tho Yang. Table 5 shows this case. The data therein were taken from plots along a stream in District F in Map 2 (where the sampling plots are shown by a solid circle) towards the end of the wet season one year after the start of the fallow period.

2) The plant samples for determining the oven dry weights shown in Table 2 and following tables were first air-dried at the survey site and then carried by pony to Ban Konroi and then to Chiang Mai or Bangkhen. Facilities at the laboratories of Chiang Mai University in Chiang Mai or of Kasetsart University in Bangkhen were used for the measurements. None of the quadrats in the data of Tables 2–7 of this report contained big trees which had not been felled.

Table 5 Quantitative analysis of species composition of the plants (above the ground surface) of quadrats (1 m×1 m each) in an old swidden of District F in Map 2 along a stream one year after the harvest time; Date of sampling, October 25 in 1972:

Plot 1

Plant species			Dry weight in the quadrat
Artemisia vulgaris	stalks leaves	1501 g 490 g	1991 g (85.4%)
Eupatorium odoratum			340 g (14.6%)
Total			2331 g/m² (100.0%)
Maximum height			3.5m

Plot 2

Plant species			Dry weight in the quadrat
A. vulgaris	stalks leaves	1038 g 641 g	1679 g (84.7%)
E. odoratum			303 g (15.3%)
Total			1982 g/m² (100.0%)
Maximum height			3m

Plot 3 (near the slope)

Plant species	Dry weight in the quadrat
Pteridium aquilinum	363 g (47.4%)
E. odoratum	243 g (31.7%)
A. vulgaris	150 g (19.6%)
perennial grass	5 g (0.7%)
Rostellularia chiengmaiensis	5 g (0.7%)
Total	766 g/m² (100.1%)
Maximum height	1.5 m

In this part of the fallow fields, the species composition is quite simple and arboreal species are rare, particularly at the sites nearer to the stream (Plots 1 and 2). *A. vulgaris* appears to be vigorous at wet sites and the standing crops at Plots 1 and 2 shown in Table 5 show higher values than those at any plots in Table 4. It is impossible to affirm definitely the existence of a causal relationship since I was not able to observe the site throughout the rainy season, but it seems probable that, at very favorable sites for *A. vulgaris*, the canopy of this species easily surpasses the coppice shoots from the stumps and consequently suppresses them. Moreover, perennial herbs do not lose their upper layer till late in the dry season owing to the favorable soil moisture conditions. Thus, the movement towards the establishment of a secondary forest is very slow. Circumstances similar to the Table 5 site could be observed in other parts of old fields along valley bottoms, where the recovery of the secondary forests was more or less retarded. However, these cases were not typical of the main survey area.

In the third or the fourth wet season of the fallow period, the standing crops grew too much to take several quadrat samples because the survey site was very remote and it was impossible to hire a sufficient number of assistants. Nevertheless, two quadrat samples (2 m×2 m each) were obtained from old swiddens (District E in Map 2) just after the third wet season in the fallow period. One quadrat (Plot 1) appeared to be at a high level as to the standing crop of this stage and the other (Plot 2) appeared to be at a lower level. These data

Table 6 Quantitative analysis of species composition of plants (above the ground surface) in quadrats (2 m×2 m each) in the old swiddens of District E in Map 2, three years after the harvest time; Date of sampling, December 15 in 1973:

Plot 1

Plant species	Dry weight in the quadrat
Castanopsis lanceifolia (×)	5616 g (37.7%)
Phyllanthus emblica (×)	4205 g (28.2%)
Callicarpa arborea (×)	2586 g (17.4%)
unidentified arboreal species 1 (×)	791 g (5.3%)
Eupatorium odoratum	487 g (3.3%)
Eulalia sp.	383 g (2.6%)
Macaranga indica (×)	272 g (1.8%)
Pteridium aquilinum	199 g (1.3%)
Castanopsis purpurea (×)	143 g (1.0%)
Quercus sp. (×)	73 g (0.5%)
Panicum notatum	61 g (0.4%)
unidentified arboreal species 2 (×)	43 g (0.3%)
Castanopsis sp. (×)	30 g (0.2%)
Dioscorea sp.	11 g (0.1%)
Dryopteris sp.	1 g (0.0%)
Total	14901 g/4 m² (100.1%) (3725 g/m²)

The species marked (×) are arboreal. The total dry weight of the arboreal species, 13759 g/4 m² (3440 g/m²), is 92.3% of the total dry weight at this quadrat.

Plot 2

Melastoma normale (×)	841 g (26.4%)
P. aquilinum	693 g (21.7%)
Rubus alceifolius (×)	433 g (13.6%)
E. odoratum	303 g (9.5%)
Litsea sp. (×)	293 g (9.2%)
Eulalia sp.	174 g (5.5%)
Artemisia vulgaris	109 g (3.4%)
Rhus javanica (×)	102 g (3.2%)
P. notatum	102 g (3.2%)
M. indica (×)	49 g (1.5%)
Buddleja asiatica (×)	24 g (0.8%)
C. arborea (×)	22 g (0.7%)
C. lanceifolia (×)	16 g (0.5%)
unidentified arboreal species (×)*	10 g (0.3%)
Dioscorea sp.	7 g (0.2%)
Hedyotis kerii	5 g (0.2%)
Crotalaria sp.	5 g (0.2%)
Total	3188 g/4 m² (100.1%) (797 g/m²)

The species marked (×) are arboreal. The total dry weight of the arboreal species, 1790 g/4 m² (449 g/m²), is 56.1% of the total dry weight at this quadrat.

* This species is identical to the unidentified arboreal species 1 at Plot 1.

Table 7 Comparison of the amounts of arboreal plants above the ground surface between a fallowed swidden made from a mature forest and another fallowed swidden made from a secondary thicket in the same district (District I in Map 2) as the former, during the first dry season in the fallow period; Date of sampling, March 9 in 1974 (4 months after the harvest time):

Dry weights in the quadrats (5 m $\times$ 5 m each)

A) old swidden made from a mature forest

Plot 1	730 g	mean=610 g/25 m^2 (24.4 g/m^2)
Plot 2	1070 g	Variance=(S.D.)^2=(382.6)^2
Plot 3	170 g	=146400.00
Plot 4	470 g	

B) old swidden made from a secondary thicket

Plot 1	660 g	mean=1708 g/25 m^2 (68.3 g/m^2)
Plot 2	1200 g	Variance=(S.D.)^2=(930.1)^2
Plot 3	2610 g	=865025.33
Plot 4	2360 g	

are presented in Table 6. From this table, one can recognize that a few of dominant species of the mature forest in this region have already obtained hegemony, albeit partial, at this juvenile stage of development towards secondary forest.

Freeman (1970) observed during his field research in the lowland dipterocarp forest area of Sarawak that "One of the great advantages of farming virgin land is that weeds are few, and fairly easy to control." Perhaps, this phenomenon is due to smaller number of suckers in swiddens made from a virgin or a mature forest than in those made from young secondary ones. Table 7 seems to support this inference. Small-sized swiddens on an upper part of a hill were made at District I in Map 2 in April, 1973. These swiddens were cleared from an area of secondary forest and a peripheral zone of mature forest (District L in Map 2) near the peak **a**. The data in Table 7 were obtained from quadrat samples (5 m $\times$ 5 m each) on a day in the later part of the first dry season after these swiddens entered the fallow period. A t-test (two sides) indicates that the difference in the mean of the dry weights of the coppice shoots above the ground surface between the quadrat in the young forest fallow and that in the mature forest fallow is statistically significant at the 10 percent level. A considerable number of the coppice shoots in the quadrats were probably resprouted after the harvest season. Nevertheless, the result of the t-test implies that the sucker density in the part of the swidden made from the mature forest was less than the density in the part of the swidden made from the young secondary forest, although it is impossible to come to a firm conclusion from the data in Table 7 alone. On the day of sampling, herbs were scarcely found. In contrast, the coppice shoots in the old swidden made from the young secondary forest were clothed with green leaves despite the negligible quantity of rain which had fallen in the previous three months.

In a mature forest, trees are not so dense as in a young secondary forest. The number of suckers thus depends to some degree on stump density. Furthermore, big trees in a mature forest do not have great capacity to sprout suckers after being felled because they have a smaller number of dormant meristems capable of being activated, in their sub-surface parts. In consequence, the density of coppice shoots in a swidden which was originally a mature forest is sparse in comparison to shoot density in a swidden made from a young forest. Therefore, as Freeman (1970) points out, the amount of labor necessary for weeding will be relatively small in a swidden made from a virgin or a mature forest. This aspect is extremely important for our understanding of why a swiddener is reluctant to reduce the fallow period of his swiddens to less than a certain number of years.

Most of the Meo's abandoned fields are covered by tall grasses, of which *Neyraudia reynaudiana* (Kth.) Keng ex Hitchc. and *Saccharum arundinaceum* Retz. are dominant and reach as high as 3 m in the later part of the wet season. *Andropogon ascinodis* C. B. Clarke and *Themeda triandra* Forssk. are other species often found. In the Meo's territory, too, *E. odoratum* is found in patches at some sites. *Tithonia diversifolia* (Hemsl.) A. Gray is dominant around the village site. Of the dwarf trees on which the liverstock does not graze, *Boehmeria platyphylla* D. Don is prominent. The grassland is lightly burned every year towards the end of dry season. No specimens of the notorious *Imperata cylindrica* (Linn.) Beauv. were found in the area of Map 2.

It is widely recognized among investigators of swidden agriculture that the use of land as a swidden in successive years usually greatly retards the recovery of the vegetation towards a secondary forest. Even some anthropologists give a correct, if not comprehensive, account of the biological reasons for this retardation in the ecological succession. Miles (1969) briefly states, "But if the land is used for two or three years in succession, tree seedlings are mostly killed and the only sources of new arboreous vegetation are the bearers in the surrounding jungle whose seeds might be blown onto the farm. In the meantime the spores of ferns and grasses flourish amongst the weakened tree growth. The weeds are mostly fire-resistant and every successive burn helps them at the expense of the shrubs which they finally overwhelm." The repeated weedings during the farming years kill most of the meristems for the shoots from the stumps and, in addition, cause the stumps to exhaust their food reserve thus cutting off the energy and nutrient supply to the surviving meristems. The eco-physiological mechanisms between defoliation, which is closely connected with "weeding," and the growth-retardation of woody plants through the exhaustion of their own food reserve were quantitatively discussed in detail by Nakano (1975, 1977a and 1977b).

Soil-Fertility Changes in Accordance with the Relevant Stages of the Swidden Cycle

Traditionally, the concern of science with swidden agriculture has been, in the main, with the soil-fertility changes after burning. Many authors have discussed the role of the ash of slashed vegetation in the farming of swiddens. Nye and Greenland (1960), Sanchez

(1976) and others have already published valuable reviews of the problem of soil-fertility changes under shifting cultivation. Amongst the points elucidated by them is that there is a lack of intensive data on this problem with reference to Southeast Asia. In particular, scientific data concerning swiddens in the montane regions of continental Southeast Asia is extremely sparse. The following data of the chemical analyses of the soil samples from the districts denoted in Map 2 are indicative of the approximate trends of fertility changes in the surface soil during the swidden cycle. Ideally, the samples should have been taken from one district for successive years. However, the situation did not permit me to do so as well as many other authors. In order to solve this dilemma, the measure was adopted of combining data on quantitative changes of the chemical components of soil obtained over a year or so in various places.

Soil samples were collected from the dotted area in Map 2 during the dry season (December–April). The dotted area of Districts A, B, C, D and I in Map 2 consists of slopes directed towards a common valley from the high peak **a** and the ridges around it, whereas District G consists of slopes from another high peak **b** and its accompanying ridges. The soil textures of the samples from the former areas mostly belong to the category of loam, while those from District G belongs to that of sandy clay loam.[3] It seems that the soils covering Districts B, C and D (not the whole district, but the dotted zone in Map 2 in so far as the last district of the three is concerned) may be regarded as very homogeneous due to the contiguity of the districts and the similarity of their topographical features. All the methods of the soil chemical analyses were, except for the Truog method for the "available" phosphorus contents, performed in accordance with the instructions given in a currently standard manual of soil fertility analysis edited by the *Dojo-yobun sokutei-ho iinkai* (1975). The determination of the "available" phosphorus contents by the Truog method was made according to the instructions in the handbook edited by Allen (1974). The analyses carried out on the air-dried samples were as follows:[4]

pH—by glass electrode and pH meter, on a 1 : 2.5 soil suspension in distilled water.

Total carbon and total nitrogen—through C–N Corder made by Yanagimoto Manufacturing Co. Ltd. Japan. The principle which this apparatus uses is the dry combustion method.

Inorganic nitrogen—by distillation with Devarda alloy and titration after the samples (10 g each) were shaken in 2 N KCl solution (100 ml each) for one hour according to the instructions in the manual (*Dojo-yobun sokutei-ho iinkai*, 1975).

Readily available phosphorus—by the Truog and the Bray I methods according to the

3) The analyses of the textures were made by the staff members at Soil Analysis Laboratory of the Department of Agriculture, Ministry of Agriculture and Co-operatives in Bangkhen.

4) All the air-dried samples were sent to the Ecological Laboratory, Department of Botany, The University of Tokyo. I carried out several kinds of chemical analyses, during the years 1976 and 1977. The "available" phosphorus content was determined, using the Bray I method, in collaboration with the staff of a company, The Institute of Environmental Technology, Tokyo.

Table 8 Contents of the Chemical Components

District denoted in Map 2 (Soil texture)	Cropping year or years of the district	Sampling time Month, Yr.	State of the district at the sampling time	Depth of sampling layer of soil cm	Number of samples	Total Carbon % Mean±S.D.	Total Nitrogen % Mean±S.D.	Inorganic Nitrogen ppm Mean±S.D.
A (Loam)	'66–'68	Mar., '74	Grassland	0- 5	6	3.92±1.07	0.29±0.059	23.9±9.9
		Mar., '74		15-20	6	1.95±0.42	0.15±0.028	no data
B (Loam)	'67, '73	Feb., '73	Before clearing	0- 5	2	4.96±0.18	0.35±0.011	25.5±3.5
		Feb., '73		15-20	2	2.31±0.64	0.16±0.067	no data
		Apr., '73	After burning	0- 5	20	4.55±0.96	0.35±0.071	85.0±15.0
		Jan., '74	After harvest	0- 5	14	4.44±1.00	0.34±0.063	28.9±5.5
C (Loam)	'68, '74	Feb., '73	One year before clearing	0- 5	6	4.41±1.61	0.33±0.112	36.0±15.1
		Feb., '73		15-20	6	1.97±0.84	0.16±0.070	no data
		Feb., '74	Before clearing	0- 5	10	5.31±0.55	0.37±0.049	41.6±20.6
		Feb., '74		15-20	10	2.30±0.38	0.18±0.032	no data
		Apr., '74	After burning	0- 5	15	4.78±0.81	0.35±0.060	77.4±22.3
D (Loam)	'69	Feb., '73	4th year in the fallow period	0- 5	10	4.34±0.95	0.28±0.087	40.2±16.6
		Feb., '73		15-20	10	1.86±0.59	0.13±0.052	no data
I (Loam)	'73	Apr., '73	After burning	0- 5	10	5.34±1.28	0.37±0.073	89.4±30.7
		Jan., '74	After harvest	0- 5	5	5.60±0.89	0.35±0.039	34.0±12.7
		Jan., '74		15-20	5	2.55±0.38	0.15±0.026	no data
L (Loam)		Feb., '74	Mature forest	0- 5	6	4.21±1.26	0.22±0.067	30.0±11.4
		Feb., '74		15-20	6	1.82±0.71	0.097±0.040	no data
G (Sandy clay loam)	'65, '72	Dec., '72	After harvest	0- 5	10	5.37±1.30	0.38±0.098	38.8±13.1
		Dec., '72		15-20	10	2.28±0.70	0.17±0.055	no data
		Mar., '74	One year after harvest	0- 5	10	4.64±0.96	0.32±0.069	20.7±4.1
		Mar., '74		15-20	10	2.11±0.54	0.14±0.036	no data

in the Soils Sampled from the Dotted Area in Map 2

C/N ratio Mean± S.D.	Readily available Phosphorus: Truog method ppm Mean± S.D.	Readily available Phosphorus: Bray I method ppm Mean± S.D.	Exchangeable cations: Potassium mg eq./100 g soil (% to CEC) Mean±S.D.	Exchangeable cations: Calcium mg eq./100 g soil (% to CEC) Mean±S.D.	Exchangeable cations: Magnesium mg eq./100 g soil (% to CEC) Mean±S.D.	Cation exchange capacity (CEC) mg eq./100 g soil Mean±S.D.	pH Mean± S.D.
13.3±1.32	9.2±10.0	10.5±8.97	1.25±0.20 (5.87±1.59)	10.15±3.91 (44.33±12.87)	2.33±0.68 (10.63±3.29)	22.4±5.3	6.3±0.36
12.7±1.17	2.6±0.48	no data	0.70±0.34 (4.47±2.12)	5.84±3.48 (34.88±18.15)	1.42±0.66 (8.90±4.44)	15.6±3.1	5.9±0.31
14.2±0.92	2.7±0.14	5.3±2.47	1.23±0.21 (4.80±0.85)	9.60±1.33 (37.50±5.37)	3.63±0.44 (14.20±1.84)	25.6±0.14	5.8±0.07
14.5±1.98	1.8±0.28	no data	0.51±0.18 (3.25±0.49)	2.37±2.59 (13.90±13.86)	1.42±1.24 (8.55±6.29)	15.5±3.2	5.3±0.35
13.0±0.73	29.5±15.5	24.9±14.3	1.96±0.87 (7.61±2.93)	15.83±4.91 (62.13±19.45)	3.70±1.24 (14.27±3.11)	25.6±4.4	6.6±0.43
13.1±1.54	10.8±7.6	9.4±4.29	1.07±0.33 (4.69±1.47)	15.00±6.10 (63.15±19.28)	2.97±1.01 (12.71±3.39)	23.2±4.1	6.4±0.35
13.2±1.10	4.0±0.81	4.7±1.43	1.31±0.47 (5.19±1.72)	19.26±13.30 (68.85±37.64)	3.40±1.49 (12.45±2.45)	26.4±8.5	6.1±0.32
12.8±1.06	1.8±0.49	no data	0.72±0.37 (4.65±1.52)	5.36±2.97 (33.73±16.49)	1.39±0.84 (8.45±4.19)	14.9±4.0	5.7±0.35
14.3±1.15	5.9±2.39	6.6±1.82	0.93±0.40 (3.37±1.18)	10.79±6.31 (38.19±20.41)	3.32±1.40 (11.99±4.07)	26.8±4.2	5.9±0.33
13.2±1.37	2.3±0.44	no data	0.59±0.54 (3.76±3.21)	3.15±3.49 (18.80±20.11)	1.09±0.84 (6.69±5.04)	15.7±3.0	5.5±0.35
13.7±0.82	31.9±13.7	22.1±9.48	1.78±0.55 (7.47±2.39)	14.15±5.02 (58.78±19.33)	4.58±1.49 (18.90±5.00)	24.0±3.2	6.6±0.32
15.8±1.96	4.6±1.22	7.4±2.23	0.88±0.41 (4.07±1.43)	7.82±7.76 (29.82±20.20)	3.12±2.02 (13.46±4.48)	21.6±8.6	5.5±0.48
14.8±2.34	2.3±0.84	no data	0.55±0.33 (3.73±1.44)	2.01±3.28 (10.23±13.94)	1.29±1.50 (7.52±5.78)	14.2±4.8	5.2±0.32
14.3±0.83	16.9±9.12	no data	1.34±0.45 (5.57±1.70)	9.77±4.62 (39.89±15.70)	3.22±1.30 (13.22±4.17)	24.1±3.7	6.2±0.48
16.1±2.16	6.9±2.63	no data	0.92±0.81 (3.92±3.02)	4.82±3.27 (21.28±11.87)	2.36±1.33 (10.46±4.51)	21.7±3.0	5.7±0.33
17.1±1.48	2.4±0.31	no data	0.45±0.33 (3.18±2.19)	0.32±0.44 (2.12±2.91)	0.52±0.36 (3.6±2.32)	14.2±1.9	5.2±0.15
19.0±0.75	4.9±1.20	14.6±5.46	0.45±0.45 (2.88±2.08)	1.14±0.76 (7.88±4.53)	0.84±0.60 (5.57±3.33)	14.4±3.7	5.2±0.37
18.9±1.36	1.8±0.30	no data	0.065±0.044 (0.88±0.81)	0.03±0.07 (0.37±0.90)	0.20±0.10 (2.28±0.88)	8.4±1.8	5.0±0.19
14.3±0.71	19.0±16.8	7.6±3.92	1.28±0.43 (4.18±0.96)	22.34±6.86 (71.99±9.35)	4.72±1.90 (15.09±3.77)	30.7±7.3	6.5±0.46
13.3±1.25	2.2±0.65	no data	0.59±0.19 (3.23±1.35)	8.49±3.34 (43.42±11.30)	2.88±0.98 (15.59±6.13)	19.1±3.8	5.9±0.37
14.8±0.55	15.4±10.6	8.0±3.67	1.05±0.36 (3.66±0.98)	17.55±4.71 (60.84±10.45)	3.66±1.16 (12.70±2.90)	28.7±5.0	6.4±0.29
15.1±1.22	2.3±0.67	no data	0.69±0.31 (3.87±1.41)	7.69±3.22 (42.84±13.60)	2.00±0.76 (11.05±2.91)	17.8±3.3	5.6±0.39

instructions in the manuals (Allen, 1974; *Dojo-yobun sokutei-ho iinkai*, 1975; respectively).

Exchangeable cations—by displacement from the soil samples with 1 N ammonium acetate at pH 7 using the semi-micro procedure modified, according to the instructions in the manual (*Dojo-yobun sokutei-ho iinkai*, 1975), from the original method by Schollenberger and Simon (1945) and analysis of the extract for:

Potassium, calcium and magnesium—by atomic absorption spectroscopy.

Cation exchange capacity (CEC)—by distillation and titration method according to the instructions in the manual (*Dojo-yobun sokutei-ho iinkai*, 1975).

Table 8 presents the results of chemical analyses of the samples from the dotted area shown in Map 2. At some sampling times, soils from 15–20 cm layer were obtained. However, comparisons of mean values between the relevant stages are possible only for the top soils because samples of the soils of the deeper layer were not taken from all of the sites. Unfortunately, I was unable to take samples for the values of the bulk density of soils. Nonetheless, it is possible to compare the quantities of chemical components of surface samples taken from one district at different times if we are allowed to apply similar information collected by other investigators to the data in Table 8. Popenoe (1959) reports that the bulk density of the two to four inch layer of Guatemalan volcanic soils increased from 0.56 to 0.66 g/cc as a result of clearing, and decreased from 0.74 in cleared land to 0.70 g/cc three or five years after forest regrowth. Khemnark concludes, from data obtained by himself and his students at Chiang Dao in Northern Thailand, that the bulk density of the swidden area soil will not change so much in a short period of time (1976, personal communication). Although the amount of information concerning the changes of the bulk density of top soils during the swidden cycle is extremely sparse, it can be tentatively concluded from the foregoing that the value of bulk density increases by approximately 10 percent at burning, and gradually decreases during the farming and fallow stages. Thus, in comparisons of the quantities of the components, a 10 percent increase in the value of bulk density at burning should be taken into account here, and its subsequent changes over a year or so is to be ignored, however.

Mineralogical analyses of a few 15–20 cm layer samples performed by Shoji (1978, personal communication) revealed that their major components were quartz and kaolinite (the state of crystalization was not firm in all of them, probably due to further weathering processes) and that a brick-colored sample obtained from a plot on the upper slope (near the ridge) in District D of Map 2 contained Al-vermiculite as a minor component. From this analysis, it can be concluded that most plots of the dotted area in Map 2 are covered by soils consisting of more than 50 percent quartz, roughly 25 percent kaolinite plus, in some cases, illite, far less than 10 percent amorphous iron oxide and residual minor components including goethite, amorphous aluminium oxide and others. Most of these soils have reddish colors at the sub-surface layer and red-brownish colors at the surface layer. Some soils are red-purplish, some are brick colored.

The following can be pointed out from Table 8 as the general features. The total carbon and the total nitrogen contents of the top soils covering the dotted area in Map 2 show higher values compared with those given in the review by Nye and Greenland (1960). Soils with both high carbon and high nitrogen contents are not, however, very rare in the "Hill Evergreen Forest" region of Northern Thailand, as indicated in the data by Tsutsumi *et al.* (1966). In addition, it is notable in Table 8 that top soils available in the forest or bush area for the actual swidden cycle are fairly rich in the exchangeable potassium component when compared with a typical forest soil in a tropical region.

The data concerning the deeper layer (15–20 cm) indicate that the mean values of the respective districts, except those of District L (mature forest), are not markedly different as regards most columns in Table 8. This fact suggests that the aftermath of the actions of swiddeners on the soil-fertility components of the sub-surface soils in quantitative terms is not quantitatively very great although not negligible. In contrast with this, in many cases the quantitative changes of the soil-fertility components of the top-soil samples are clear, even in a year.

Before considering further developments of this report, attention should be paid to the data concerning District L (mature forest) because the soil of this district can be regarded as nearest to the "control," the material of the final stage of a long fallow. One of the distinctive features of the soil of this district is the high values of C/N ratio in both top and sub-surface layers in spite of a total carbon content similar to those of the samples from the area of actual swidden cycle. Moreover, samples from this mature forest are low in pH, CEC and contents of exchangeable cations. In particular, the extreme scarcity of exchangeable bases at the sub-surface layer is noticeable. This feature can be considered to have appeared as a result of leaching processes during a fairly long fallow period. However, it may be due partly to the topographical features of District L which lies on the top of a hill. It is very risky to draw a general conclusion about the effects of a long fallow on the states of the soil under a forest without considering soil types and climatic and topographical features.

In order to express, by a simple line, the relative trend in quantity of the chemical components of top soils in accordance with the relevant stages of the swidden cycle, it is necessary to take account of the above-mentioned changes in bulk density, to make one or more statistical tests for mean values of an identical district between the different phases and, finally, to combine the respective shorter trends into a longer trend throughout a whole swidden cycle. It is in this way, although not without encountering a few difficult problems, that Figs. 2a–j have been made. In these figures, the initial levels of the lines are tentatively assumed to be the same as the final levels. As for the data of exchangeable cations, only their relative values on the basis of corresponding CEC values are presented, since their trends appear to be clearer than those of the absolute values. In regard to the trend lines in Figs. 2a–j, a typological classification has been attempted as follows:

(1) The type of total carbon and total nitrogen contents and CEC shows no distinct changes during a whole swidden cycle. Nevertheless, it seems justifiable to depict the trend

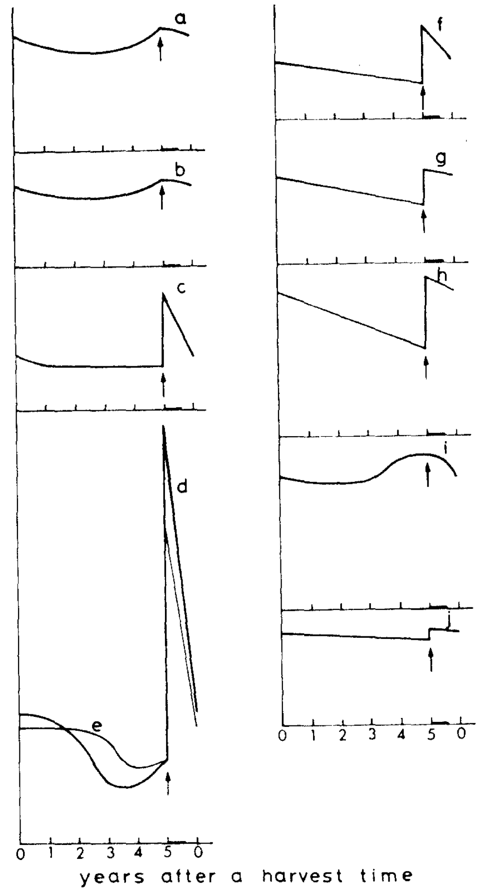


Fig. 2 Schematic representations of the quantitative trends of the chemical components of top soil (0–5 cm) in accordance with the relevant stages of the Karen's swidden cycle on the basis of Table 8. a, Total carbon; b, Total nitrogen; c, Inorganic nitrogen; d, Readily available phosphorus in the Truog reagent; e, Readily available phosphorus in the Bray I reagent; f, Exchangeable potassium/CEC; g, Exchangeable calcium/CEC; h, Exchangeable magnesium/CEC; i, CEC (Cation exchange capacity); j, pH. The thick bars on the abscissae represent the farming stage. An arrow mark indicates the time of burning for making a swidden.

lines (Figs. 2a, b and i) from the mean values in Table 8. In this type, the level appears to reach its lowest point in the middle of the fallow period of five years. (2) The type of "readily available" phosphorus, whether by the Truog or Bray I reagent, exhibits a dramatic increase at burning and subsequently, a rapid decrease during the farming stage (Figs. 2d and e). The trend of inorganic nitrogen (Fig. 2c) is similar to the pair of trends of "readily available" phosphorus. The level of "readily available" phosphorus reaches its lowest point in the course of the fallow period as well as the foregoing type and rises again significantly towards the end of it (Figs. 2d and e). The trends of the phosphorus quantities extractable in the Truog and Bray I reagents are similar to each other in the present case (Figs. 2d and e). However, a large difference in the phosphorus contents between the Truog and Bray I reagents is found in the case of the soil samples from District L (mature forest at the top of a hill), as shown in Table 8. The quantity of inorganic nitrogen does not appear to significantly rise in the course of the fallow period (Fig. 2c). (3) The type of pH and the relative values (exchangeable bases/CEC) shows the obvious effect of burning and, subsequently, suggests that loss continues until the next burning time (Figs. 2f, g, h and j). These decreasing trends are probably due mainly to the effects of continuous leaching of the top soils. Of the three kinds of exchangeable bases, the top soil which contains ash appears to be most selectively deprived of potassium in relative terms during the farming year (Figs. 2f, g and h) as it is also in the case of the slash burning practice of forest management in the northwestern states of the USA (Greier and Cole, 1971). Nonetheless, the absolute level of exchangeable potassium is not low at all even at the clearing stage (Table 8). It was considered impossible to draw a trend line of C/N ratio.

With reference to District A, grassland which does not undergo annual burning, the quantitative levels of chemical soil components at the surface layer are mostly similar to their counterparts at the end of the farming stage. Those of a few components are lower than at the end of the farming stage (Table 8). From the foregoing data on District A (Table 8), however, no one can conclude that the soil fertility in this district is chemically far more meager than that in the other fallowed districts of the actual swidden cycle.

Some soil samples were taken from the Meo swidden area. The sampling sites are shown by MA, MB and MC in Map 2. Analyses by the staff members of the above-noted laboratory in Thailand show that the textures of these samples belong to the categories of sandy clay loam (MA and MB) and sandy loam (MC). The analytical data of chemical components in the samples are exhibited in Table 9. Both sites MA and MB were small (less than 0.5 ha) rice swiddens under cultivation at the sampling time and they lay side by side. Therefore, direct comparison of MA and MB is possible. The swidden MA had reportedly been continuously cultivated for four seasons in total (one season of maize and poppy and three seasons of upland rice), whereas the swidden MB had reportedly been similarly cultivated for seven seasons in total (three seasons of maize and poppy, one season of maize and red kidney bean, and three seasons of upland rice). Aside from a few components, the soil fertility of MA is considered to be more favorable than that of MB (Table 9). Actually, in 1972, the yield of upland rice from a unit area in the swidden MA was much better than at the swidden MB and considerably better than in the swiddens of Karen people for 1972. No input of manure or fertilizer was reported at either swidden MA or MB. The swidden MB was abandoned in 1973. Attention should be paid to the fact that the "readily available phosphorus" content (extracted into the Bray I reagent), of the top-soil samples from MB, statistically shows a significantly higher mean value than the corresponding one of the samples from MA (Table 9). This fact suggests that the inorganic phosphorus content of the top-soil layer is not always closely related to the actual yield of grains in the prolonged phase of swidden farming.

The site MC was located in an area of old swiddens, now covered by tall grasses, which was subjected to light burning towards the end of every dry season and was under the heavy

Table 9 Contents of the Chemical Components of the Soils of

Site denoted in Map 2 (Soil texture)	Cropping years of the site	Sampling time Month, Yr.	State of the site at the sampling time	Depth of sampling layer of soil cm	Number of samples	Total Carbon % Mean±S.D.	Total Nitrogen % Mean±S.D.	Inorganic Nitrogen ppm Mean±S.D.
MA (SCL)**	Since '69	Dec., '72	After harvest	0- 5	4	4.95±0.35	0.38±0.021	54.3±7.5
		Dec., '72		15-20	4	2.80±0.23	0.25±0.028	no data
MB (SCL)**	Since '66	Dec., '72	After harvest	0- 5	3	3.81±0.45	0.29±0.039	41.1±1.5
		Dec., '72		15-20	3	2.66±0.51	0.22±0.033	no data
MC (SL)**	Unknown years	Dec., '72	Grassland with annual burning	0- 5	3	10.82±1.01	0.78±0.090	52.5±2.1*
				15-20	3	5.96±1.82	0.48±0.14	no data

* Means and standard deviations are derived from only two samples.
** SCL, Sandy clay laom; SL, Sandy loam.

grazing pressure. The top-layer samples from MC are very abundant in total carbon and total nitrogen (Table 9). This fact, however, does not necessarily imply that the absolute quantities of both total carbon and total nitrogen at the soil surface layer in this grassland were noticeably larger than the quantities of the both components in the territory claimed by the Karen people because the top soil at the site MC appeared to exhibit much lower values in its bulk density. It is remarkable that the samples from the site MC are not abundant in exchangeable potassium content in either top or sub-surface layer, this contrasts with the very high contents of total carbon and total nitrogen (Table 9). A top-layer sample was mineralogically composed of roughly 60 percent quartz, approximately 20 percent kaolinite plus illite (the former exceeding the latter in quantity), about 8 percent amorphous iron oxide and other minerals including amorphous aluminium oxide (Shoji, 1978, personal communication). From this results, it seems that the mineralogical features of the surface soil at the MC plots in Map 2 are not substantially different from those of their counterparts in the dotted area of Map 2. Nevertheless, the chemical components indicative of soil fertility are considerably different as a consequence of the manner of land use.

Discussion

More than a generation ago, Pelzer (1945) wrote, "As forest land is generally free from weeds or grasses and the soil is usually rich in humus and well supplied with the ash of burned plant matter after clearing, it produces a very good, or even excellent, first harvest; the second the Sampling Sites MA, MB and MC in Map 2

C/N ratio	Readily available Phosphorus		Exchangeable cations			Cation exchange capacity (CEC)	pH
	Truog method	Bray I method	Potassium	Calcium	Magnesium		
Mean±S.D.	ppm Mean±S.D.	ppm Mean±S.D.	mg eq./100 g soil (% to CEC) Mean±S.D.	mg eq./100 g soil (% to CEC) Mean±S.D.	mg eq./100 g soil (% to CEC) Mean±S.D.	mg eq./100 g soil Mean±S.D.	Mean±S.D.
13.2±0.18	16.4±9.07	6.3±1.99	2.41±0.58 (6.93±1.80)	23.02±0.84 (65.75±1.20)	5.86±0.83 (16.78±2.49)	35.0±1.6	6.4±0.08
11.3±0.38	1.9±0.62	no data	1.87±0.21 (6.60±0.69)	14.00±1.30 (49.35±4.35)	4.37±0.99 (15.38±3.22)	28.4±0.6	6.3±0.21
13.0±0.21	23.4±11.1	10.3±1.56	1.59±0.78 (5.73±0.65)	16.77±2.43 (59.93±4.54)	4.15±0.32 (14.93±1.34)	27.9±2.3	6.2±0.23
11.9±0.66	6.9±5.08	no data	1.32±0.38 (5.30±0.95)	13.50±0.49 (55.40±8.84)	3.59±0.53 (14.60±1.14)	24.6±3.1	6.4±0.46
13.9±0.46	13.6±10.3	20.1±24.2	0.67±0.064* (21.7±0.19)	10.28±4.36* (34.60±19.80)	2.74±1.36* (9.30±5.94)	31.2±5.2*	5.9±0.15
12.5±0.10	3.2±2.52	no data	0.25±0.19 (0.95±0.58)	2.93±1.89 (13.40±9.61)	1.09±0.51 (4.93±3.11)	24.2±5.7	5.4±0.40

harvest begins to show a decline in yield, and thereafter the returns diminish rapidly. Grasses and weeds invade the clearing. Rather than battle these, the peasant abandons his old ladang and cuts and burns a new patch of forest." The majority of the people who are interested in swidden agriculture would not disagree with Pelzer's statement. Nor have I any substantial disagreement. Nevertheless, the above-mentioned common knowledge is worth scientifically re-examining.

Many authors emphasize the significance of ash in swidden farming. For example, Clarke (1976) says, "This of course is in line with the idea that tropical nutrient inventories are mainly in the plant cover rather than in the soil." On the other hand, Greenland and Kowal (1960) concluded from their own data that the top 30 cm layer of a West African Alfisol contained a far greater quantity of total nitrogen than the biomass, and about the same amount of exchangeable calcium and magnesium as total plant calcium and magnesium and that it held 75 percent of the biomass potassium but only 9 percent of the biomass phosphorus as available phosphorus. According to the classical view, the ash of vegetation supplies the swiddens with readily available phosphorus and exchangeable bases but not nitrogen. Recently, however, Sanchez (1976) quoted the results of ash component analyses by Seubert (1975) showing that the ash contained 1.72 percent of nitrogen. In Fig. 2c, too, the increase of inorganic nitrogen content at the top-soil layer after burning is fairly impressive. The increase of inorganic nitrogen, especially, ammonia nitrogen, after burning has been widely recognized (Viro, 1974). Many authors, for instance, Viro (1974), ascribe this mineralization to the heating effect on the soil organic matter. Considering the data of Seubert (1975), however, the possibility that the increase of inorganic nitrogen after burning is due partly to ash cannot be ruled out. As well as the inorganic nitrogen content, the "readily available" phosphorus and the exchangeable base contents and, in addition, the pH value evidently increase after burning (Table 8), probably owing to the components in the ash, whereas the C/N ratio appears to be slightly lowered (statistically significant at the 5 percent and 20 percent levels in the cases of 1973 and 1974 burnings, respectively). The changes of total carbon and total nitrogen contents and CEC values due to burning are not clear (Figs. 2a, b and i).

The most important contribution of the ash of vegetation to the swidden farming in a tropical region is the supply of readily available phosphorus. Many experts in agricultural sciences in tropical regions place stress on the seriousness of phosphorus deficiency or unavailability in tropical soils. In their textbook of tropical agriculture, Williams and Joseph (1970) state, "Phosphate fertility is one of the most central problems of tropical agriculture." The dependability of available phosphorus in the biomass seems much more important than that of other nutrients, as the above-mentioned data by Greenland and Kowal (1960) indicate, although potassium available from the biomass is regarded as indispensable in some swiddens. Watters (1971) writes, "the big increase in phosphorus would seem to be a sufficient explanation for the good yields that some peasants obtain from their burned milpas..." Agboola and Oko (1976) claim that the correlation coefficients for yield vs. extractable P test were low in the cases of some soil types under shifting cultivation in Western and Lagos States, Nigeria, and that organic phosphorus is important to plants in the tropics. Their view seems quite reasonable. At sites where the decomposition rate of organic matter is high, such as in humid tropics, the supply to plants of the available phosphorus from the "storehouse" of organic matter in the soil will be a considerable percentage of the total amount of phosphorus absorbed by the plants if the soil is abundant in organic matter.

The data from MA and MB seem to be compatible with this theory. The top soil at MB has a significantly larger content of inorganic phosphorus extractable into the Bray I reagent than its counterpart at MA, whereas the former is significantly less abundant in the content of total carbon than the latter (Table 9). However, the poor yield of upland rice at MB obliged the peasant to abandon the swidden in the following year although this was possibly due partly to significant declines in other factors such as nitrogen content.

Notwithstanding the facts stated above, the soil fertility index indicated by the amount of extractable phosphorus is considered meaningful in most cases because inorganic and extractable phosphorus is easily absorbed by plants. At least in the earlier phase of swidden farming, the inorganic phosphorus derived from the ash components must contribute greatly to crop growth. After burning the relative increase of phosphorus extractable into either the Truog or Bray I reagent is more noticeable than increases of other components (Fig. 2). From Fig. 2, however, it cannot be concluded that the effectiveness of "readily available" phosphorus added to the top soils of swiddens by ash lasts for more than one year.

There are, however, vast number of swiddens which are utilized for more than one year as, for instance, are those of the Meo people. It is reasonable to assume that the effectiveness of fertilization would last for more than one year in the swiddens of the Karen villagers because of relatively large amount of ash created by clearing a primary forest. It is hardly likely, however, that this effectiveness would extend for several years. On the other hand, some swiddens made from primary forests in Northern Thailand are utilized for more than five years. This is also the case with the swidden MB in Map 2. In such swiddens, the phosphorus available for the crop growth is mainly supplied by the soil organic matter. For the purpose of actively promoting the rapid decomposition of soil organic matter, besides the purpose of suppressing the weed growth, the step of cultivating the swidden with the hoe in the prolonged phase becomes very significant, as Gourou (1969) points out without mentioning the detailed reasons stated above. Favorability for crop growth due to a rise of pH value (this rise may not be favorable in the case of an alkaline soil) and a rise of exchangeable base contents in the top-soil layer lasts a little longer than the duration of favorability due to a rise in "available" phosphorus and inorganic nitrogen contents (Fig. 2). Gourou (1969) cites a report in Zambia that the swiddeners there bring a great quantity of plant matter into their future swiddens from the outside before burning. Most swiddeners recognize the effectiveness of ash on cropping. Nevertheless, when we consider the duration of the effectiveness of the ash, it is very doubtful whether the primary purpose of burning is to obtain a large amount of ash. The primary purpose is probably to prepare fields for cropping with the technically easiest means and the least amount of time and labor.

The classical view of the reason why swiddeners abandon their fields emphasizes the loss of soil fertility there and Gourou (1969) supports this view. To the contrary, some investigators consider the invasion of "grasses and weeds" to be the prime reason for the abandonment (see the foregoing quotation from Pelzer (1945)). Freeman (1970) is also one of these.

Some researchers indicate the significance of the labor productivity in swidden farming as an index which takes account of these two factors in one term. Watters (1971) states, "Undoubtedly weed invasion is the dominant factor in many regions, involving soils such as those described by Vine (1953) as retaining much of their fertility under prolonged cropping. Usually this factor is closely associated with labor input, for the cultivator invariably seeks to obtain from his site maximum gain in return for the minimum effort." For several decades, valuable efforts to obtain data on the labor productivity of swiddens have been made by anthropologists concerned with Southeast Asia (Freeman, 1970; Conklin, 1957; Walker, 1976).

Although the factor of weed invasion is considered the prime reason why swiddeners abandon their fields, the other factor of the soil-fertility decline cannot be ignored. As has been already discussed, the dramatic effect of the ash components on soil fertility is not considered to continue for more than one year (Fig. 2). Consequently, hoeing is indispensable in the prolonged phase of swidden farming. Thus, further labor input is required to obtain a sufficient amount of yield for a subsistence economy. Evidence of a declining trend in yield from a swidden in subsequent crops has been collected in a review by Sanchez (1976). Such a trend is, undoubtedly, due partly to the soil-fertility decline although Sanchez (1976) points out, "Unfortunately very little correlation has been found between yield declines and measured soil changes before and after cropping." In the case of the swiddens MA and MB in Map 2, some of the correlations stated above can be recognized.

From the data in Tables 2 and 3, though the sampling sites are not the same, a comparison of the amount of weeds and coppice shoots in the early part of the wet seasons of the first and second year after burning is to some degree possible. In Table 2, the standing crop of weeds plus coppice shoots is 73 g d.w./m^2 excluding the standing crop of rice seedlings. On the other hand, it increases to 209 g d.w./m^2 in the second year after burning according to Table 3. If the Karen swiddeners had planted upland rice at the swiddens in the following year, the standing crop of weeds plus coppice shoots there would have shown little affect on the day of sampling. Thus, as the years after burning elapse, the amount of weeds plus coppice shoots seems to tremendously increase although the coppice shoots will decrease in either number or absolute quantity because of continual performance of weeding.

Accordingly, the labor input needed for weeding will increase. The index of labor productivity can contain these two factors, namely, the soil-fertility decline and the labor-input need, in one term. I quite agree with Watters (1971). In order to understand the reason why swiddeners abandon their fields, more intensive studies in quantitative terms regarding the labor productivity of swidden agriculture are necessary. Those studies must be based on actual observations. The efforts of Rappaport (1968, 1971) are truly admirable in this respect.

Noguchi *et al.* (1977) revealed through their experimental study in Japan that the growth of weeds either during or after the cropping years depended upon the kind of crop—upland rice, wheat, soybean and so on. According to their results, upland rice allows weeds to grow most vigorously. This study suggests the possibility that the duration of availability of a swidden in a tropical region may depend on the kind of crop grown although their experiments were conducted in a temperate country.

Nye and Greenland (1960) lay stress on the importance of nitrogen recovery in the soil during the fallow period. The widely-held belief about the recovery in the soil fertility should be re-examined on the basis of scientific data. Certainly, Table 8 indicates a rise of "readily available" phosphorus content at the young forest stage in the fallow period. As for the top soil of District L (mature forest), the phosphorus content extractable in Bray I reagent is much higher than the fallow stage of the actual swidden cycle (Table 8). The recovery of other factors, however, is not so clear in Table 8. This may be due partly to the insufficiency of the period of time between the sampling dates in a district. Nevertheless, one can even find data which suggest a slowly decreasing tendency in exchangeable base contents at the top-soil layer throughout the fallow period (Table 8). This tendency is consistent with the data from District L, where the exchangeable base contents in soil are rather low (Table 8).

These facts are not unexpected in the case of some soil types in which the leaching rate is high. Of course, the mature forest fallow is desirable for preventing the top soils from being eroded.

Zinke *et al.* (1970) report very similar data of soil-fertility changes during the fallow period in Northern Thailand. Their survey area is very near to mine and under a similar land-use pattern. The fallow period there is nine years. Unfortunately, however, their study area is under a different type of potential vegetation from mine due to slightly lower elevations and they did not sample the soils of any district more than once. Nonetheless, some points of their results should be mentioned here. In their data, both total carbon and total nitrogen quantities of the top soil respectively reach their lowest points in the middle of fallow period (Zinke *et al.*, 1970). The trend of CEC value is similar. As for the trends of exchangeable cations during that period, the quantities at the soil surface layer suggest slowly declining tendencies which are similar to my analysis shown in Figs. 2f, g and h. The trend of pH value is also similar to that of the data in this paper (Fig. 2j). However, the top soil of an unburned old forest is abundant in exchangeable bases (Zinke *et al.*, 1970). In their data, the quantity of the phosphorus extracted into a bicarbonate solution from the top soil declines as well.

In conclusion, in many cases, it seems that when considering the significance of the fallow period too much emphasis should not be placed upon the recovery of the fertility of the fallowed soil itself although a great amount of nutrient components may be stored in the vegetation during this period. According to Greenland and Kowal (1960), "It is widely believed that an important function of forest fallows in restoring soil fertility is to withdraw nutrients from the subsoil and store them in the vegetation until such time as the forest is cleared and the nutrients added to the surface soil as ash." Believers in this attractive idea consider the forest as if it were an aggregate of huge pumps for nutrients. The accumulation of phosphorus easily available for the crops is regarded as particularly important, as has been already discussed above. Some soil scientists in the temperate zone suggest that pedogenetically younger soils can supply a larger amount of readily available phosphorus than older soils (Walker and Syers, 1976). Generally, the soil at a deeper layer is genetically younger than that at an upper layer. However, Greenland and Kowal (1960) themselves do not support this view and Richards (1973) also rejects it. The reason is that most roots in a tropical rain forest do not penetrate to the deep soil layer. Still, in some tropical regions with a cooler montane climate such as the survey area for this report, this view may be valid.

The significance of fallowing is to be found primarily in weed and pest suppression. Generally, the most laborious effort in weeding is occasioned by light-loving perennial herbs and coppice shoots. When a forest is cleared after a long fallow, both light-loving perennial herbs and the coppice shoots sprout only a little, as has been already discussed using the data of Table 7. Darkness is the best way to kill light-loving perennial herbs. In a young secondary forest, the forest floor is not so dark and *E. odoratum* actually survived under young forest even up to the time of clearing after five year's fallow.

Weeding and felling are a couple of the major labor inputs in swidden agriculture (Conklin, 1957) except for guarding which is usually not laborious. If the swiddeners utilize a young secondary forest, they have to spend much of their working time in weeding (Conklin, 1957). If they utilize a mature forest, they have to spend much of it in felling huge trees (Conklin, 1957).

As a final conclusion, I should like to state that a basic tool for a deeper understanding of the ecological aspects, as well as the economic aspects of swidden agriculture must be an intensive study of its labor productivity in quantitative and scientific terms. All of us should remember Watters' statement (1971), "What is needed is the accumulation of reliable quantitative data..."

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* Quoted in Walker (1976).

** Quoted in Sanchez (1976).

Plate 1 Mature forest on a ridge (District L in Map 2). Taken in December, 1972.

Plate 2 Secondary forest roughly one year before clearing for burning (District C in Map 2). Taken in December, 1972.

Plate 3 Cleared forest (District K in Map 2). Taken in February, 1973.

Plate 4 Swiddens before sowing rice (District C in Map 2). The scorched debris of the felled logs is utilized for marking the boundaries of swiddens. A number of big trees remain standing. Taken in April, 1974.

Plate 5 Old swidden after the first wet season in the fallow period (District G in Map 2). Taken in the blooming season of *Eupatorium odoratum*, December, 1973.

Plate 6 Old swidden three years after the harvest time (District E in Map 2). Taken after sampling Plot 1 of Table 6 in December, 1973.

Plate 7 Grassland in an abandoned swidden of the Meo people. Taken in December, 1972.

Plate 8 A weeding team of Karen maidens. A distant view of the old swiddens (one and a half year since the outset of the fallow period) can be seen. Taken in June, 1973.