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AGRO-FORESTRY IMPROVEMENTS FOR SHIFTING CULTIVATION SYSTEMS SOIL CONSERVATION RESEARCH IN NORTHERN THAILAND

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ABSTRACT Large test plots were constructed for soil erosion and conservation determinations on steep mountain slopes (54 percent grade) at an altitude of 1,240 m above sea level. The 24 by 5-metre test plots were planted with a mix of traditional swidden and introduced agro-forestry systems crops at Mae Muang Luang, Huai Thung Choa research area, 75 km northwest of Chiang Mai. During 1981 comparisons were made of runoff, soil loss, labour input, and crop yield. Soil losses from agro-forestry test plots were 10–22 $t \cdot ha^{-1} \cdot yr^{-1}$, or 4–9 times lower than from traditional upland rice (89 $t \cdot ha^{-1} \cdot yr^{-1}$). Labour inputs were 50–150 percent higher, but subsistence crop yields were comparable despite a reduction in cultivated area. This is probably due to fertilizer input from the coffee plantation. Additional years of data are required for verification.

RÉSUMÉ *Améliorations agraires et forestières pour les systèmes d'agriculture itinérante: Recherche de conservation des sols au nord de la Thaïlande.* Sur les fortes pentes de montagnes, à 1240 m d'altitude, de grandes surfaces d'expérimentations furent aménagées pour déterminer l'érosion et la conservation des sols. Les surfaces de 5 m de largeur, 24 m de longueur et inclinées de 54 pourcent à Mae Muang Luang dans le domaine de recherche Huai Thung Choa, qui se trouve à 75 km au nord-ouest de Chiang Mai, furent cultivées avec un mélange de riz sec traditionnel et de systèmes agro-forestiers importés.

Des mesures comparées furent effectuées en 1981 à propos de l'écoulement en surface, de l'érosion du sol, du travail nécessaire à la culture des surfaces ainsi que des rendements.

Les pertes de sols des surfaces agro-forestières, qui représentent par année entre 10 et 22 tonnes par hectare, furent 4 à 9 fois inférieures aux surfaces de riz traditionnelles (89 $t \cdot ha^{-1} \cdot a^{-1}$). Le travail nécessité par contre fut de 50 à 150 pourcent supérieur à celui du système importé. Le rendement de la denrée alimentaire essentielle, le riz, resta inchangé malgré la réduction des surfaces cultivées, remplacées par des arbres, des caféiers, des bandes d'herbe et des fosses d'écoulement. Ce résultat est probablement conditionné par l'utilisation d'engrais pour le café.

Il est nécessaire d'effectuer des mesures encore quelques années afin de confirmer les résultats très positifs de cette première année agro-forestière. Des restrictions supplémentaires, engendrées par des facteurs socio-économiques, légaux, religieux ou politiques devraient rendre une application généralisée encore plus difficile que la solution décrite des problèmes technologiques et écologiques.

Une expansion des expériences sur les terrains des habitants de montagnes est une condition indispensable et un premier pas dans cette direction.

ZUSAMMENFASSUNG *Agro-forstwirtschaftliche Verbesserungen für Wander-Hackbau-Systeme: Bodenkonservierungs-Forschung in Nord-Thailand.* An steilen Gebirgshängen in 1240 m Höhe wurden grosse Experimentierflächen zur Bestimmung von Bodenerosion und Bodenkonservierung errichtet. Die 5 m breiten, 24 m langen und 54 Prozent geneigten Flächen in Mae Muang Luang im Huai Thung Choa Forschungsgebiet 75 km NW Chiang Mai wurden mit einer Mischung von traditionellem Trockenreis-Anbau und eingeführten Agro-Forstwirtschafts-Systemen bestellt. Vergleichende Messungen von Oberflächen-Abfluss, Bodenabtrag, Arbeitsaufwand zur Bearbeitung der Flächen, sowie Ernteertrag wurden 1981 durchgeführt.

Die Bodenverluste von den Agro-Forstwirtschafts-Flächen, mit jährlichen Mengen zwischen 10 und 22 Tonnen pro Hektare, waren 4 bis 9 Mal geringer als von der traditionellen Reisanbau-Fläche (89 $t \cdot ha^{-1} \cdot a^{-1}$). Der Arbeitsaufwand hingegen war 50 bis 150 Prozent höher im eingeführten System. Der Ernteertrag des Grundnahrungsmittels Reis blieb trotz der Reduktion der angebauten Fläche durch Bäume, Kaffeebüsche, Gras-Streifen und Abfluss-Gräben gleich. Dieses Resultat ist wahrscheinlich durch den Dünger-Einsatz für den Kaffee bedingt.

Weitere Messjahre sind erforderlich, um die für Agro-Forstwirtschaft sehr erfolgversprechenden Ergebnisse dieses ersten Jahres zu verifizieren. Zusätzliche Beschränkungen durch sozio-ökonomische, legale, religiöse oder politische Faktoren dürften eine verbreitete Anwendung noch schwieriger gestalten als die beschriebene Lösung der technologisch-ökologischen Probleme. Eine Ausdehnung der Experimente auf die Felder der Hügelbewohner ist eine wichtige Voraussetzung und ein erster Schritt in dieser Richtung.

INTRODUCTION

The Huai Thung Choa research area is part of the mountain region of Northern Thailand and lies some 60–75 km northwest of Chiang Mai. Elevations range from about 800 m to 2,000 m above sea level, embracing a dis-

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tinct series of altitudinal belts extending across the Highland-Lowland Transitional Zone (Uhlig, 1980) into the higher parts of the Mountain Zone. Since the area is located south of latitude 20° North in Southeast Asia, it is characterized by a tropical monsoon climate which gives rise to altitudinal forest belts of dry deciduous and moist mixed deciduous, coniferous forest, and lower montane forests with increasing elevation. Physically the area displays a series of long, steep ridges and small basins and valleys draining eastward into the Mai Ping and westward into the Salween rivers. It has been utilized for several centuries by groups of swidden farming highlanders, including Hmong, Lisu, and Karen and, more recently, by ethnic Northern Thai.

The Huai Thung Choa Highland Project was initiated in 1975 by Dr. Pisit Voraurai and Mr. Prakorn Jringsoongnoen as a joint undertaking between the Royal Department of Forestry and Chiang Mai University. In 1978 the United Nations University, through its Agro-forestry and Highland-Lowland Interactive Systems projects, began collaboration with Chiang Mai University. This resulted in a broadening of the scope of the original project (Ives et al., 1980). One component of the enlarged project involved soil erosion studies under different types of land use. The establishment of the soil erosion test plots and analysis and discussion of the initial results are provided by Hurni (1982).

THE PROBLEM

In an area with traditional swiddening (slash-and-burn agriculture) very high soil erosion rates of damage will occur on steep slopes if the traditional long forest fallow periods cannot be maintained in face of accelerating population growth. Even within the traditional land-use pattern without population pressure, high rates of soil erosion will occur while the fields are being cropped, but this will be compensated for by soil-forming processes during the subsequent long period of fallow. For many generations this pattern of land use ensured a remarkable level of environmental stability and sustained food production for traditional swiddeners. In recent decades, however, population growth throughout the hill and mountain lands of Northern Thailand, and adjacent areas, has forced a progressive shortening of the fallow period to the point that deforestation and spread of *Imperata* grassland has occurred. This in turn has led to increasing soil degradation and critical absolute amounts of soil loss (Kunstadter *et al.*, 1978).

Population pressure on the last remaining forests of the mountains of Northern Thailand appears to have become an uncontrollable process (as elsewhere in tropical forest lands). Thus, it appeared necessary to develop measures to reduce soil erosion in order to facilitate a shortening of the fallow periods without long-term deterioration of the basic soil resources. It is believed that the identification of agricultural systems appropriate to the changing present-day situation is a key issue for the recovery of large parts of the tropical forest lands. The term *appropriate,* in this case, refers both to the natural environment and to the local inhabitants. This renders the design and carrying out of acceptable solutions extremely difficult, yet worthy of high priority attention.

During the early stages of the United Nations University–Chiang Mai University project at Huai Thung Choa soil erosion damages and processes were assessed by Hurni (1979, 1980). He estimated that soil losses from traditional upland rice swiddens averaged about 70 $t \cdot ha^{-1} \cdot yr^{-1}$ on a 20 m-long slope with a gradient of 50 percent. Micro-test plots of 3 m length at 50 percent gradient were designed and operated during the 1980 monsoon season. The data were analysed using the Universal Soil Loss Equation (Wischmeier and Smith, 1978). From this work annual soil losses from traditional upland rice fields were calculated at about 100 $t \cdot ha^{-1} \cdot yr^{-1}$ for a 20 m 50 percent slope (Hurni, 1982). He concluded that "the introduction of an agro-forestry system, in terms of soil erosion, will only be successful if the reduction of soil erosion (in percent) is always greater than the reduction of the subsistence crop yields (in percent)". Thus, in order to sustain annual cultivation of a slope, as distinct from a traditional system where cultivation and fallow are in a proportion of about 1:10, soil losses must be less than 10 $t \cdot ha^{-1} \cdot yr^{-1}$ if ecological stability is to be maintained. In addition, the same yield of basic food as that of the traditional system must be maintained without any significant increase in labour input.

THE EXPERIMENT

Hurni (1982) designed a series of test plots for the study of soil loss, runoff, and labour input for the 1981 monsoon season and later years. These were located at Mae Muang Luang, altitude 1,240 m a.s.l., in the Huai Thung Choa area (Figure 1). They were designed to determine whether or not agro-forestry systems could be successfully introduced into the area and meet the requirements of reduced soil loss, food production, and labour requirements. Six test plots, 24 m long and 5 m wide, were constructed on a 54 percent slope (Figure 2). Traditional upland rice of the highlanders was planted in 1981 in Plot I. Plot II was prepared as fallow soil without a vegetation cover as a control. Plots III to VI were planted as agro-forestry plots with a mixture of trees (*Erypthrina, Melia*), coffee, drainage ditches across the slope, lemon grass strips along the contour, and a basic crop (upland rice, maize, peanuts).

Runoff and soil loss were ascertained for each plot by use of double sediment tanks (Figure 3). The test plots were not ready for operation until June 1981, two months late for the collection of data for the complete agricultural year,

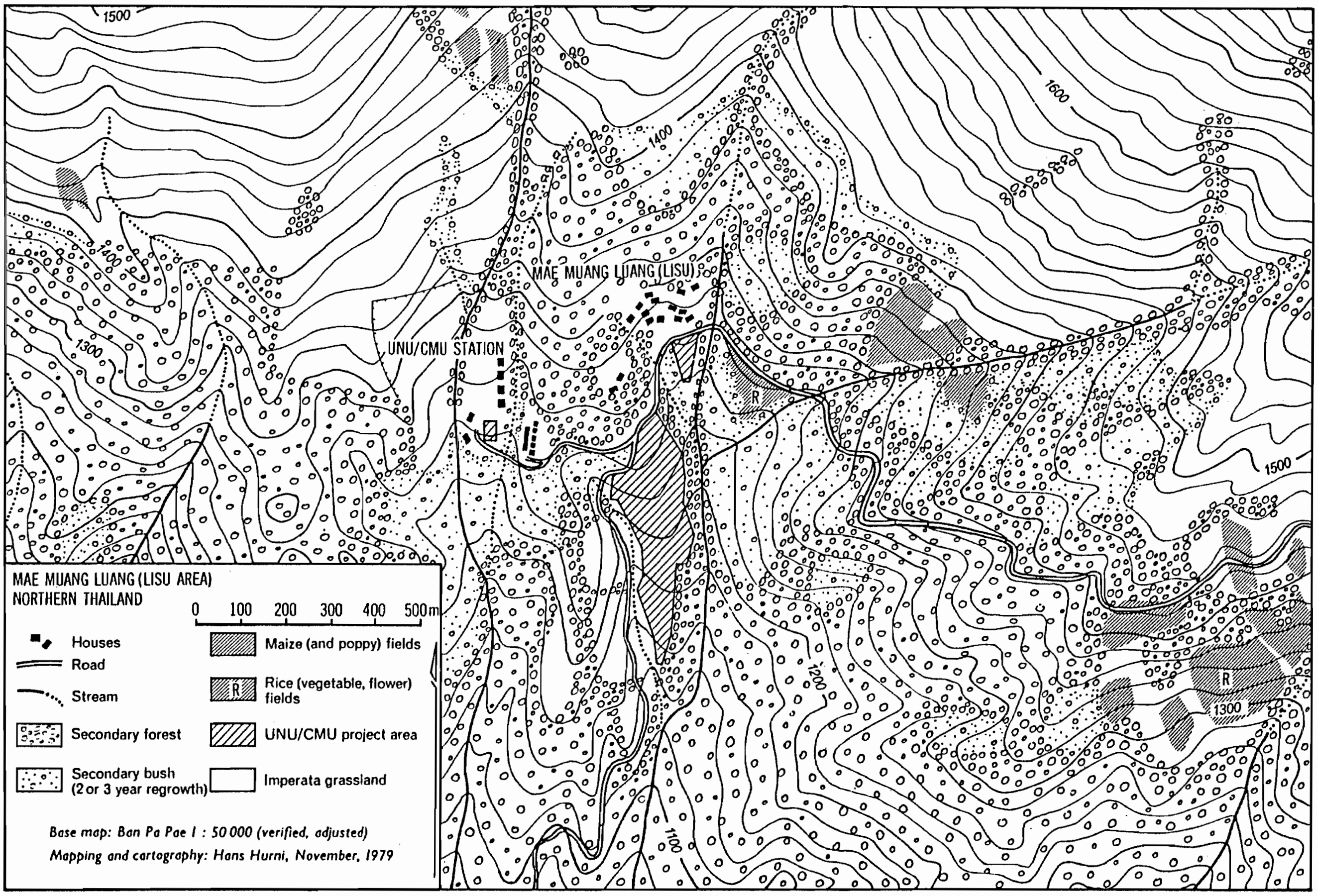


Figure 1. Map of the Huai Thung Choa research area showing land use, roads, and houses.

and several severe storms in April and May were not recorded. Precipitation was recorded throughout the year using a pluviometer and a rainfall inclinometer which provided rainfall intensities and directions. Methods of data analysis are described in Appendix I. Records were also made of crop yields and labour inputs since these data are also critical to the study and necessary for determination of the possible extension of the experiment into the regular farmers' fields.

THE RESULTS

Monthly totals of precipitation, erosivity, runoff, and soil loss are summarized in Table 1. Since runoff and soil loss studies were not begun until June, some of the June and July data are of limited accuracy because of initial organizational and instrument problems. In addition, data for the storms of high erosivity that occurred in May were extrapolated using the average June-November values for runoff and soil loss and the average April-November values for erosivity.

Precipitation

The annual precipitation for Mae Muang Luang (1981) totalled 1,700 mm, which approximates the average precipitation for Huai Thung Choa (range from 1,000–2,400 mm). Monthly distribution was also close to the Huai Thung Choa average, but with slightly higher than average values for June, July, October, and November. The rainfall inclinometer recordings indicated that the rainfall at Mae Muang Luang was almost vertical throughout the year.

Rainfall Erosivity

The annual erosivity for Mae Muang Luang was R = 800 $10^2 \cdot \text{Joules} \cdot m^{-2} \cdot cm \cdot h^{-1}$. This is higher than the 6-year average erosivity (R = 687) calculated by Hurni (1982). The soil loss was actually measured during storms with a total erosivity of R = 494 from June to November; the remainder, bringing the total to R = 800, was extrapolated. Monthly erosivities were average, with peaks at the beginning (June) and end (September) of the monsoon season. The failure to record soil loss and runoff during the high erosivity storms in May meant that 35 percent of the annual total had to be derived. As an example of the conditions during May, two extreme storms produced 79 and 54 mm during 85-minute periods. This results in R = 162.9. These early May storms are especially important because they occurred at a time of low vegetation cover in the swidden fields. Thus the actual soil losses may have been higher than the extrapolated results.

Soil Loss

The results provided in Table 1 are discussed for each test plot individually:

Plot I: Annual soil losses from this traditional upland rice test plot amount to 89 $t \cdot ha^{-1}$, a result that lies exactly between the field evaluations and the predictions from the micro-test plots (Hurni, 1982). Figures for June and July are extremely low, despite the low vegetation cover. This is probably due to the deep hacking (breaking of the soil surface with hand tools) at the time of planting and the consequent high storage capacity of the soil.

Plot II: Fallow test plots should produce the highest soil losses if they are kept in continuous fallow and tilled up and down the slope. The annual loss of 58 $t \cdot ha^{-1}$ for Plot II, however, is significantly lower than the figure of 89 $t \cdot ha^{-1}$ obtained from Plot I. This is due to the fact that this plot was not kept in continuous fallow so that the rapid growth of weeds provided protection against rainfall impact. The experiment will have to be repeated.

Plots III–VI: All agro-forestry plots effectively reduced soil loss to annual totals of 22, 13, 10, and 10 $t \cdot ha^{-1}$ respectively. These results are from 4 to 9 times less than soil losses under traditional practices (Plot I). Thus it seems that soil loss tolerances of 10 $t \cdot ha^{-1} \cdot yr^{-1}$ for the region are almost attainable. This would allow cultivation every second year or even more frequently. If an agricultural system involving alternate years of cropping and fallow can be obtained, in contrast to the traditional average of 1:10, a system currently practised by the Karen highlanders, then a significant change can be envisaged. However, before such an approach can be propagated throughout the highlands questions of production and labour input must be taken into consideration. Similarly problems of fertilizing, crop diseases, and weed control must be carefully explored.

Runoff

Between 10 and 25 percent of the rainfall became immediate runoff on the test plots. However, since this was the first year of experimentation, equipment problems are believed to have affected these figures. For instance, the sediment tanks were leaking slightly, so that the actual runoff figures may have been higher than those given in Table 1. The leaking did not affect the soil loss figures.

Labour Inputs

Labour requirements for the maintenance of the agro-forestry test plots were 50 to 150 percent higher than for maintenance of the traditional plot. For Plot I labour input was 40 work-days. Plot III required 108 work-days; Plot IV, 78; Plot V, 73; and Plot VI, 57 man-days (cf. Figure 2). These results are not surprising when it is considered that the agro-forestry plots, in addition to maintenance of the traditional crops, necessitated the planting of coffee, lemon grass, and trees, and the construction of drainage ditches. This raises a number of questions: if the highlanders can put this much labour into the new farming systems during the first year of planting, and if the resulting crop yields provide suitable returns, and if it can be assumed that less labour will be required from the second year onwards, can the additional constraints be overcome to ensure a successful change from traditional practices to agro-forestry patterns? Additional constraints will include crop diseases, fertilizer requirements, weed control, as well as a certain resistance to change characteristic of traditional subsistence societies.

Crop Yields

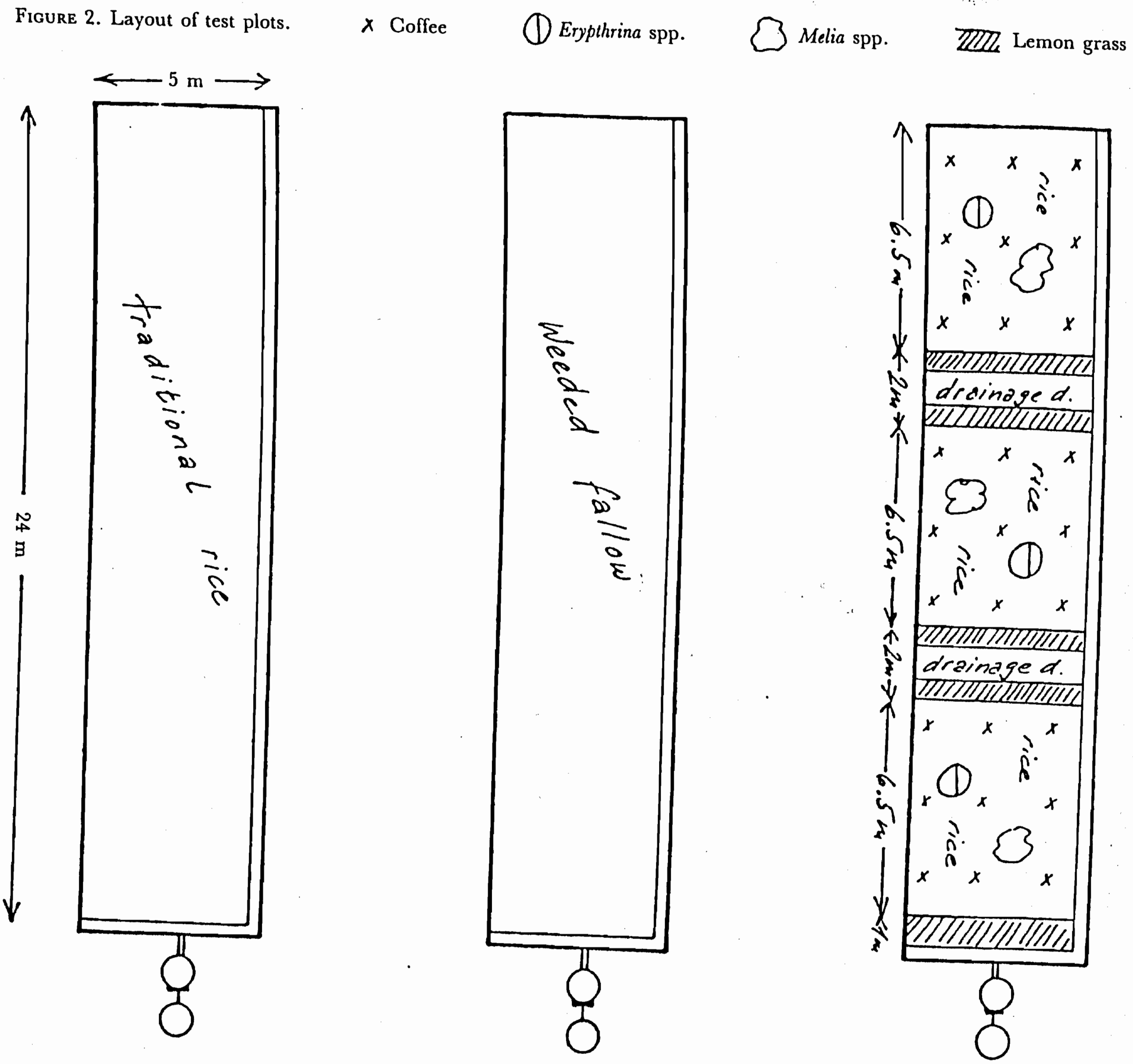
The yields of the main crops in the test plots for 1981 are summarized in Table 2. A comparison between Plot I and Plot III indicates that, although the latter had about 20 percent less area under rice (cf. Figure 2), yields were higher than those of the traditional plot. One explanation is that the fertilizer treatment provided for the coffee in Plot III had a positive impact on rice yield. However, enough data are available to suggest that with the introduction of an agro-forestry system the size of the swidden may not have to be enlarged to secure adequate yields. This is a critical point in favour of any proposal to introduce agro-forestry systems and appears to contradict the preliminary conclusions of Hurni (1982). However, the problem of the possibility of coffee fertilizer impact indicates an additional need for continuation of the experiments for several years.

CONCLUSIONS

The results derived from the first year of data collection from the agro-forestry test plots are sufficiently suggestive to warrant further study. It has been demonstrated that drainage ditches and strips of lemon grass along the contour can reduce soil losses by at least five times those experienced on the traditional swiddens. First-year labour inputs into planting will have to be doubled compared to traditional swiddening yet, with the addition of limited amounts of fertilizer, food crop yields may be maintained at adequate levels. If it is possible to cultivate sufficient upland rice or maize within the agro-forestry systems for about five years, and if no other constraints appear, then the agro-forestry systems may enable the highlanders to reduce the total amount of land needed for subsistence to about one fifth of that required under traditional systems.

The conclusions drawn from the results of this first year of experimentation with the test plots, however, may be somewhat over-optimistic. It is obvious that extension of the study into the farmers' fields will be necessary before plant disease and weed control incidence can be assessed. It is also apparent that such a change, from a series of slash-and-burn systems (differing both amongst the main ethnic groups, and within groups) to one of sustained use of the same fields year after year, will create a major adjustment

Figure 2. Layout of test plots.



Test Plot I: Traditional upland rice cultivation similar to highlanders (tree logs removed).

Labour Input

Preparation of field:
12 men, 15 hours = 180 work-hours
Planting of rice:
9 men, 8 hours = 72 work-hours
Weeding and insecticide treatment:
10 men, 24 hours = 240 work-hours
Harvesting:
3 men, 8 hours = 24 work-hours

Total labour input into Test Plot I:
39.5 work-days (at 8 hours).

Test Plot II: Fallow with some weeding (not continuous fallow with tillage up and down the slope as used in soil erosion studies. Therefore, soil erodibilities could not be determined with the results).

Labour Input

Preparation of field:
9 men, 7 hours = 63 work-hours
Hacking:
3 men, 8 hours = 24 work-hours
Weeding:
13 men, 37 hours = 481 work-hours

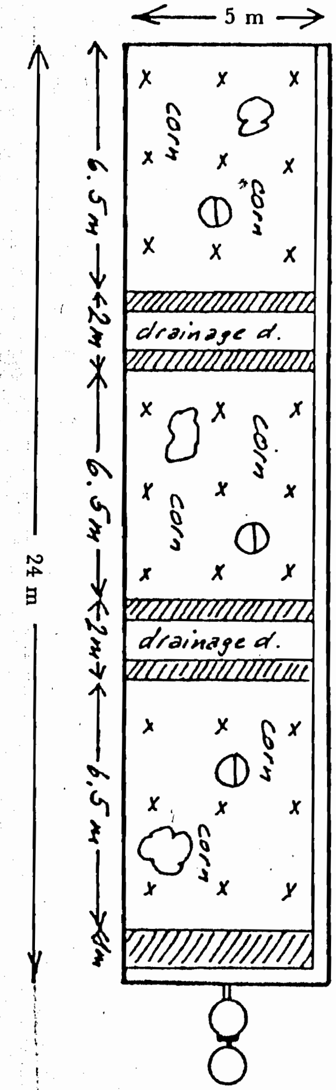
Total labour input into Test Plot II:
71 work-days (at 8 hours).

Test Plot III: Agro-forestry with trees, coffee, lemon grass strips, drainage ditches, and between: upland rice cultivation (first year).

Labour Input

Preparation of field:
13 men, 8 hours = 104 work-hours
Planting rice, coffee, lemon grass, *Erypthrina:*
24 men, 16 hours = 384 work-hours
Weeding:
11 men, 30 hours = 330 work-hours
Treatments of fertilizer, insecticide, mulching:
6 men, 3 hours = 18 work-hours
Harvesting of rice:
3 men, 8 hours = 24 work-hours

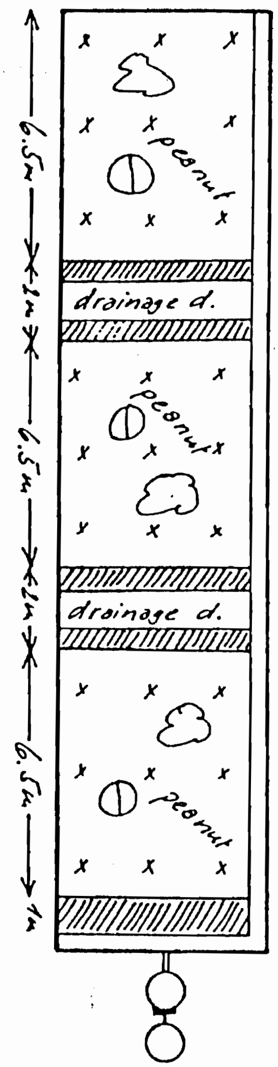
Total labour input into Test Plot III:
107.5 work-days (at 8 hours).



Test Plot IV: Agro-forestry with trees, coffee, lemon grass strips, drainage ditches, and between: maize (corn) cultivtion (first year).

Labour Input
Preparation of field:
14 men, 7 hours = 98 work-hours
Planting of maize, coffee, lemon grass, *Erypthrina:*
17 men, 12 hours = 204 work-hours
Weeding:
11 men, 22 hours = 242 work-hours
Treatment of fertilizer, insecticide, mulching:
7 men, 5 hours = 35 work-hours
Harvesting maize:
6 men, 8 hours = 48 work-hours

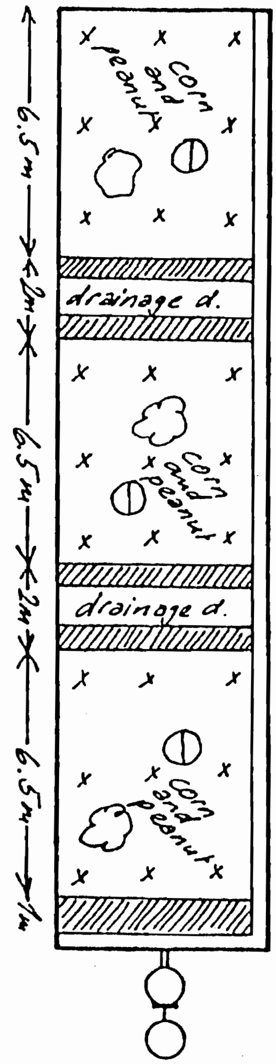
Total labour input into Test Plot IV:
78.4 work-days (at 8 hours).



Test Plot V: Agro-forestry with trees, coffee, lemon grass strips, drainage ditches, and between: peanut cultivation (first year).

Labour Input
Preparation of field:
13 men, 7 hours = 91 work-hours
Planting of coffee, peanuts, lemon grass, *Erypthrina:*
16 men, 17 hours = 272 work-hours
Weeding:
11 men, 18 hours = 198 work-hours
Treatment of insecticide, mulching of coffee:
5 men, 2 hours = 10 work-hours
Harvesting peanuts:
4 men, 3 hours = 12 work-hours

Total labour input into Test Plot V:
72.9 work-days (at 8 hours).



Test Plot VI: Agro-forestry with trees, coffee, lemon grass strips, drainage ditches, and between: maize (corn) and peanuts as multiple crop cultivation.

Labour Input
Preparation of field:
13 men, 7 hours = 91 work-hours
Planting of corn, peanuts, coffee, lemon grass, *Erypthrina:*
15 men, 8 hours = 120 work-hours
Weeding:
9 men, 18 hours = 162 work-hours
Treatment of fertilizer, insecticide, mulching of coffee:
7 men, 4 hours = 28 work-hours
Harvesting of maize (corn) and peanuts:
6 men, 9 hours = 54 work-hours

Total labour input into Test Plot VI:
56.9 work-days (at 8 hours).

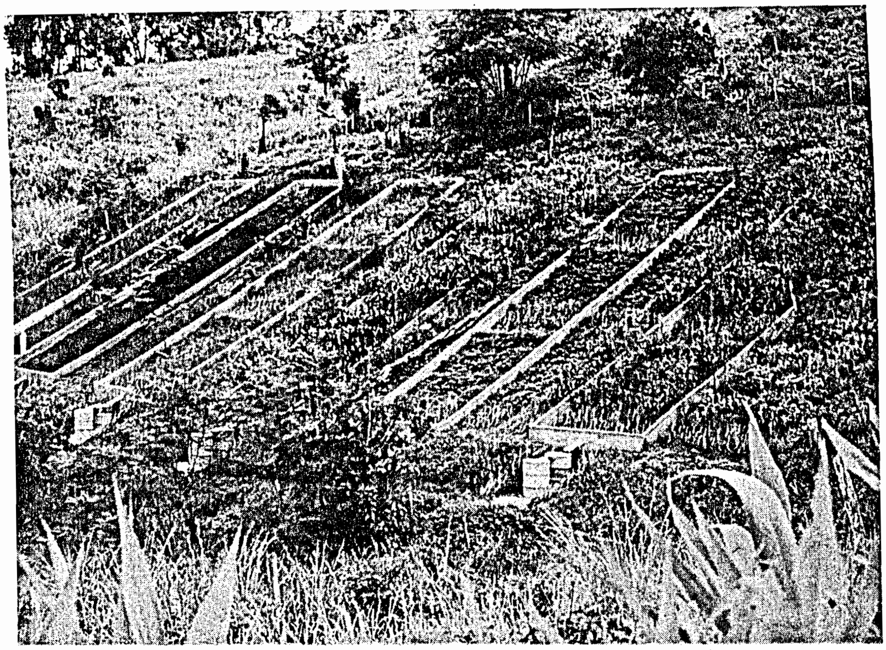


FIGURE 3. The test-plot experimental site at Mae Muang Luang. November 1981.

TABLE 1

Main results of the 1981 experiments of soil loss and runoff from traditional and agro-forestry test plots (24 m length, 5 m width, 54 percent gradient), at Mae Muang Luang, Huai Thung Choa, Northern Thailand

Experiment / Time Scale 1981	Jan–Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total June–Nov	Annual Total[1]
Rainfall (mm)	14	91	282	279	250	267	216	185	113	–	1310	1697
Erosivity (10^2·Joules·m^{-2}·cm·h^{-1})	0	51	256	187	53	67	98	62	26	–	494	801
Plot I: Traditional upland rice cultivation												
Runoff (% rainfall)	0	(12)	(12)	10	6	9	23	16	5	–	12	(12)
Soil loss (t·ha^{-1})	0	(9.7)	(27)	4	0.3	27	19	2	0.2	–	52.5	(89)
Plot II: Fallow (not continuous, rarely weeded)												
Runoff (% rainfall)	0	(11)	(11)	13	8	9	11	13	7	–	11	(11)
Soil loss (t·ha^{-1})	0	(3.7)	(18.5)	4	0.5	6	2	23	0.1	–	35.6	(58)
Plot III: Agro-forestry upland rice, ditches, lemon grass, coffee, trees												
Runoff (% rainfall)	0	(16)	(16)	24	11	15	23	8	8	–	16	(16)
Soil loss (t·ha^{-1})	0	(1.4)	(7)	5	0.3	6	2	0.1	0.1	–	13.5	(22)
Plot IV: Agro-forestry maize, ditches, lemon grass, coffee, trees												
Runoff (% rainfall)	0	(10)	(10)	20	8	9	9	7	6	–	10	(10)
Soil loss (t·ha^{-1})	0	(0.8)	(4.1)	7	0.2	0.5	0.1	0	0.1	–	7.9	(13)
Plot V: Agro-forestry peanut, ditches, lemon grass, coffee, trees												
Runoff (% rainfall)	0	(10)	(10)	21	6	7	7	6	6	–	10	(10)
Soil loss (t·ha^{-1})	0	(0.6)	(3.1)	5	0.2	0.5	0.1	0	0.2	–	6	(10)
Plot VI: Agro-forestry maize, peanut, ditches, lemon grass, coffee, trees												
Runoff (% rainfall)	0	(12)	(12)	22	8	11	11	8	6	–	12	(12)
Soil loss (t·ha^{-1})	0	(0.6)	(3.2)	5	0.2	0.6	0.2	0.2	0	–	6.2	(10)

( ): = Reconstruction with average Jun–Nov values of soil loss, runoff, and erosivities.
[1] = December not recorded at time of analysis, but considered zero for all records.

TABLE 2

Production figures of annual crops in test plots I–VI at Mae Muang Luang, Huai Thung Choa, Northern Thailand, from June to November 1981

Unit / Plot	I (rice)	III (rice)	IV (maize)	V (peanut)	VI (maize)	VI (peanut)
kg/plot 120 m²	8.5	11.3	37.3	—	27	—
kg/rai	113	150	497	—	360	—
kg/ha	706	938	3106	—	2250	—

in terms of socio-economic patterns. It will also raise the difficult question of land tenure since, under the existing Thai constitution, highlanders do not have the right of holding title to land. As with many attempts to introduce alternate technologies into the societies of Developing Countries, and especially into minority groups within those countries, socio-economic, legal, religious, and political constraints may prove greater obstacles than the technological problems. Nevertheless, the current research has demonstrated, in a first instance, that the chances of finding a potentially effective agro-forestry technology are sufficiently great that additional work should be undertaken while the remaining problems are assessed.

ACKNOWLEDGEMENTS

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APPENDIX

Methods of Analysis

1. *The Test Plots:* Figure 2 shows the layout and design of each test plot and Figure 3 is a photograph of the six plots. The borders are made of cement bricks; on the left side there is a cement waterway, and a cement collection ditch at the bottom leads water and soil sediment to the collection tanks. The tanks have a 600-litre capacity; the second tank is designed to take only 0.07 (1/15th) of the overflow of tank 1, so that the full capacity is 9,500 litres. Labour inputs are classified and listed in Figure 2; runoff and soil loss data are given in Table 1.
2. *Rainfall Data:* Pluviometer recordings give mm rainfall per any unit time of 5 minutes or more. According to the results of Hurni (1982), the best erosivity factor was the EI(30) > 1.25 cm index of Wischmeier and Smith (1978). A standard form was developed which was used for recording the data from each individual storm. Periods of uniform intervals of rainfall intensity were used separately for computing erosivities according to the explanation given.
3. *Runoff Recordings:* A standard form was also developed for use in the field to record data as the tanks were emptied after each storm, according to a manual designed by the first author. An additional form was used for the compilation of the data to facilitate computation of runoff amounts for individual storms and for each test plot.
4. *Soil Loss Recordings:* Soil samples and filter papers were oven-dried at 105°C for 24 hours to determine the oven dry weight. Total soil-loss was analysed according to the design of a final form, using the data from the runoff forms together with the measured soil loss samples.

N.B. Copies of the manual and the set of standard data recording and computing forms are available from the first author.