

Development of a Comprehensive Series of Technologies for Upland Cropping Systems in Northeast Thailand

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Abstract

A comprehensive series of technologies was developed for improved soil conservation, water conservation, labor use reduction, and diversification of crop production for improvement of cropping systems in undulating upland areas (100~200 m above sea level) in Northeast Thailand. ① Alley cropping combining reforestation and crop production was effective in supplying organic matter through periodic pruning of trees, as well as preventing soil erosion in a sloping field. ② A subsoiling treatment which cracked the upper soil layer (50~60 cm depth) was effective in trapping runoff rain water on sloping fields, which benefited the growth of crops through enhanced soil moisture availability in the dry period. ③ No-tillage crop production was effective in preventing erosion, suppressing weed proliferation and maintaining soil moisture. A no-tillage seeder which was developed in this research performed satisfactorily in sandy soil. ④ Plastic mulching was appropriate for the production of underground crops such as groundnut, by facilitating the growth and harvest of underground parts of crops while maintaining soil structure after tillage. ⑤ Labor saving technology for the production and incorporation of green manure crops was established through a combination of mechanized operations. ⑥ Mechanical weeding with inter-tillage between crops rows using a soil cultivator was effective in controlling dominant upland weeds. ⑦ Growth characteristics of various crops were evaluated for diversification of upland cropping, and an appropriate crop sequence was proposed together with specific production techniques.

Key words : Alley cropping, Subsoiling, No-till, Mulching, Mechanical weeding

Introduction

Once covered with tropical trees, Northeast Thailand has undergone rapid deforestation since the 1960's. Large areas were converted into undulating sloping upland fields (100~200 m above sea level) with production of sugarcane and cassava as the main agricultural activities, making this area one of the most important centers of export crop production in Thailand²⁾. However, agricultural production over this large area has been restricted due to several constraints related to its tropical monsoon climate.

The main problems in the rainy season are soil erosion in sloping fields and anaerobic conditions due to heavy rainfall. The sandy soils prevalent in the region are not only easily washed away, but also interfere with the growth of crops through crust formation and soil compactness that result in anaerobiosis or physical barriers around roots. Drought occurs frequently even in the rainy season due to unstable rainfall, and severely limits the growth of crops in the dry season. Common problems in both rainy and dry seasons are hard and inefficient work in sloping fields, damage from insects, diseases and weeds, and low physical and chemical properties of the sandy soils. Fluctuation of farm product prices, particularly sugarcane and cassava which are affected by supply and demand in the international market, is another problem that destabilizes farmers' income.

The development of sustainable farming systems to overcome these complex constraints is essential not only to secure farmers' incomes, but also to promote national land planning. A comprehensive series of technologies was therefore developed with the objective of simultaneously addressing the multiple constraints of soil erosion, poor root penetration, poor water retention, labor use, and over-dependence on two upland crops. This complex of technologies may offer new components for more sustainable future cropping systems in Northeast Thailand⁵⁾.

Materials and Methods

All research was carried out at the Khao Suan Kwang Demonstration Farm of the International Training Center for Agricultural Development (ITCAD) in Khon Kaen Province, on 20 ha of sloping upland fields.

1. Soil-conserving alley cropping system

To prevent soil erosion and increase the supply of organic matter, a model field for alley cropping (0.5 ha:50x100 m) was set up in 1996 with a leguminous tree species, *Leucaena leucocephala*, on contour lines in a field with a 5% slope. Interrelationships of trees and crops were investigated along with production practices for appropriate management of the system in 1997~2000.

2. Water-conserving subsoiling

To trap and accumulate rain water in soil layers of sloping fields, subsoiling was carried out in the direction of the contour lines in 1999~2000. Crop growth and changes in soil properties were monitored to evaluate treatment effects.

3. Soil- and water-conserving no-tillage

A prototype no-tillage seeder was manufactured and tested in 1998. No-till production of crops was assessed in 1999~2001 in terms of crop productivity, soil properties, and effects on water conservation.

4. Soil- and water-conserving mulching

To assess techniques for soil and water conservation, mulching of groundnut was carried out using plastic film in 1999.

5. Labor-saving production process for green manure crops

Labor saving production and incorporation of crops and green manures (maize, sorghum and pearl millet) using various types of agricultural machinery were investigated in 1998.

6. Labor-saving crop management for upland crops

Labor-saving crop management practices for land preparation, seeding, weed control and harvest using various types of agricultural machinery were investigated in 1998~2000.

7. New crops and cropping patterns for diversification

As the basis for more diversified cropping systems, growth characteristics of crop species were assessed for adaptability to conditions in Northeast Thailand in 1997~2000. Appropriate cropping patterns in combination with specific cultivation methods were investigated in 1999~2001.

Results and Discussion

1. Soil-conserving alley cropping system

Alley trees were periodically pruned and incorporated into the soil to supply organic matter (Photo 1). *Leucaena leucocephala* pruned at 40 cm height from the soil surface at the beginning of the rainy season (May) showed vigorous growth, reaching 5 m in height with 4.5 m canopy width in October. When trees were pruned every month, twig regeneration followed a pattern similar to the pattern of precipitation over the course of the year (Fig. 1). The amount of organic matter supplied to the field, equivalent to the accumulated regeneration of twigs, was superior in plots with longer pruning intervals, but increased difficulty of incorporation of larger twigs and increased labor requirements reduced the practicality of longer intervals. The optimum frequency of pruning was found to be three times in a year, two times in the rainy season and one time in the dry season. Crop growth between tree rows was inhibited by shading by the tree canopy in the rainy season and by depletion of soil moisture by tree roots in the dry season. The distance from the tree rows in which crops were affected differed with crop species, 2~3 m for legumina (groundnut, mungbean) and 5~6 m for maize. The optimum width between tree rows for crop production, field operations

and prevention of soil erosion was found to be 20 m (Table 1).

2. Water-conserving subsoiling

Soil erosion due to surface runoff of rain water is a major cause of the loss of fertile top soil needed for good crop production. Moreover, water runoff itself is a problem in terms of efficient water utilization in sloping fields⁸⁾. Effects of subsoiling on the trapping and accumulation of rain water in soil layers of sloping fields was therefore assessed. Subsoiling was done at the start of the rainy season by cracking the subsoil layer with a vibrating blade attached to the tractor power take off and inserted into the soil to a depth of 50~60 cm, where an underground tunnel (15 cm diameter) was formed with a bullet-type digger (Photo 2). Subsoiling was done in the direction of contour lines on the sloping field at intervals of 120 cm width. Soil moisture retention measured with tensiometers installed at the different soil layer depths increased during the dry season, reflecting the soil drying process. Subsoiling maintained soil moisture in the deep soil layer at higher levels than the control until the late stage of the dry season. This appeared to be due to the accumulation in

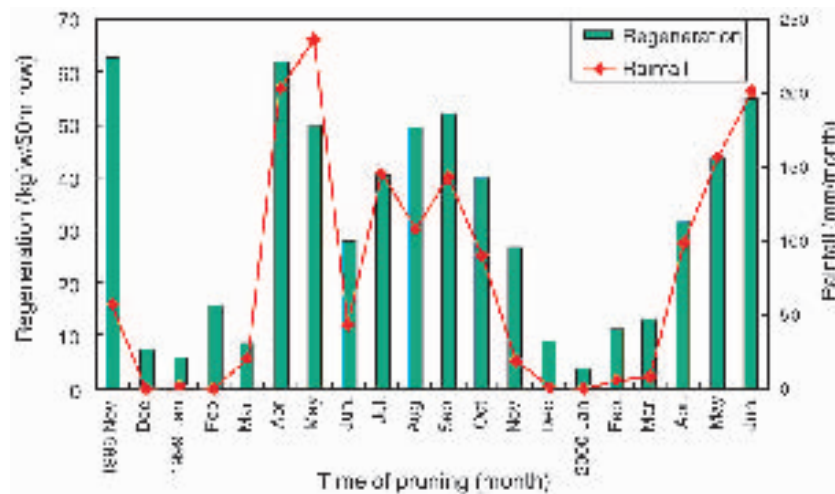


Fig.1 Seasonal pattern of regeneration of *Leucaena leucocephala* after pruning.

Table 1. Effect of alley width on sweet corn growth (final dry weight)

| Planting system | Alley width between tree rows (m) | Growth (final dry weight, g/m ²) | | | |
|-----------------|-----------------------------------|--|---|-------------------|---|
| | | 1998 rainy season | | 1999 rainy season | |
| Alley cropping | 5 | 260 | a | 308 | a |
| | 10 | 905 | b | 760 | b |
| | 20 | 1413 | c | 1293 | c |
| Sole cropping | — | 1389 | c | — | — |

the soil of runoff water in the rainy season (Fig. 2). Soil hardness of the no-till field in the dry season was decreased by subsoiling, presumably due to the infiltration and distribution in the soil profile of rain water in the rainy season. Crop growth was markedly improved with subsoiling. This effect was more conspicuous in the dry season than in the rainy season. Vigorous crop growth was observed in the subsoiling treatment while plants in the control plot showed symptoms of wilting due to water stress. The effects of subsoiling were also observable in plots where subsoiling had been done the previous year (Table 2).

3. Soil- and water-conserving no-tillage

Land preparation in sandy upland fields in a monsoon climate has several problems. Tillage at the beginning of rainy season must be done in between short intervals of rain and sometimes leads to soil erosion due to heavy rainfall in sloping fields. Tillage in the dry season is hindered by soil hardness and at the same time leads to loss of soil moisture, with consequent adverse effects on crops. No-till seeding was assessed as a means of more efficient, labor-saving upland production.

No-till seeding was done with a specially manufactured no-till seeder with a rotary disk and drill

seeder. This worked satisfactorily on sandy soil, giving accurate grooving and seeding (Photo 3). The hard soil surface under no-till made seeding operations easier even under rainy conditions. Soil erosion which was commonly observed in tilled plots was hardly observed in no-till plots in the sloping field. The field was treated with herbicide (Glyphosate) before seeding. Since soil was not disturbed in no-till seeding, the occurrence of weeds was less than that in tilled plots. Subsequent weed growth was suppressed by mulch formed by wilted weeds (Photo 4). Soil moisture content, a critical factor for crop growth in the dry season, was higher in no-till plots than in tilled plots. Soil hardness was higher in no-till and inhibition of crop root elongation was occasionally observed in dry season (Table 3). Crop germination in no-till was generally superior to that of tillage seeding. In the rainy season, crust formation on the soil surface inhibited the germination of leguminous crops in tillage seeding. Higher soil moisture in no-till contributed to good germination in the dry season. Crop total dry weight at harvest was also higher in no-till.

4. Soil- and water-conserving mulching

While no-tillage is effective in reducing labor for crop production, it is not appropriate for root crop

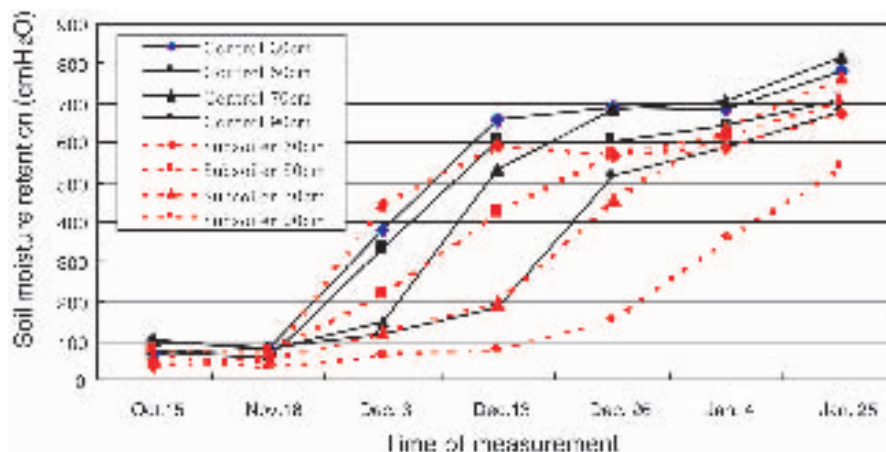


Fig. 2. Changes of soil moisture retention in the different depth (1999: Dry season)

Table 2. Effects of subsoiling on crop growth (2000)

| Season(2000) (Crop) | Treatment | Total dry weight (g/m ²) | |
|----------------------------|------------|--------------------------------------|--------------------|
| | | Subsoiling in 2000 | Subsoiling in 1999 |
| Rainy season Sweet corn | Subsoiling | 1455 (156) | 1164 (122) |
| | Control | 927 (100) | 955 (100) |
| Dry season Sorghum | Subsoiling | 921 (203) | 739 (138) |
| | Control | 453 (100) | 535 (100) |

production due to soil hardness. As a technique more suitable for root crops, plastic mulch was tested for groundnut production. The seed bed was prepared with a rotary tiller and mulch layer attached to a tractor, which reduced labor for land preparation and spreading of plastic sheets. Groundnut grown under plastic mulch showed superior growth in the rainy season, presumably due to improved soil conditions. In the rainy season, heavy rain increased soil moisture and compactness, resulting in increased hardness of the upper soil layer. Mulching maintained initial soil properties at seeding and created conditions more favorable for the growth and harvest of underground crops such as groundnut (Table 4). Suppression of weed emergence was another advantage of production using plastic mulch.

5. Labor-saving production process for green manure crops

While the application of green manure or crop residues has been proved to be effective in raising the crop productivity by improving soil chemical and physical properties, it is not widely practiced by farmers

due to high labor requirements under tropical conditions. To promote soil improvement in upland fields, a labor-saving system for the production and incorporation of green manure crops was developed. Seeding with a no-till seeder, weeding with a cultivator, chopping with a flail mower and incorporation into the soil with a rotary tiller were effective in reducing labor for the application of green manure such as sorghum, pearl millet and maize, resulting in a total operation time of 18 hours per hectare (Table 5, Photo 5).

6. Labor-saving crop management for upland crops

Field operations in upland areas are hard work due to high temperatures and humidity. Diversified agricultural activities such as large scale cultivation of seed crops and intensive management of vegetable and fruit crops require complex crop management with labor-saving, precision technologies. With this objective, various kinds of agricultural equipment were introduced and tested for adaptability in Northeast Thailand (Table 6).

Table 3. Comparison of soil properties between tillage and no-tillage

| Treatment | Rainy season (1999) | | | | Dry season (1998) | | | |
|------------|---------------------|------|---------------------------------|------|-------------------|------|---------------------------------|------|
| | Moisture (%) | | Hardiness (kg/cm ²) | | Moisture (%) | | Hardiness (kg/cm ²) | |
| | 10cm | 20cm | 10cm | 20cm | 10cm | 20cm | 10cm | 20cm |
| Tillage | 6.04 | 9.44 | 0.1 | 3.0 | 1.77 | 3.08 | 3.3 | 3.9 |
| No-tillage | 8.50 | 9.82 | 9.0 | 13.1 | 2.79 | 4.08 | 7.4 | 17.9 |

Notes: Soil moisture and hardness were measured at 10 and 20cm depth in October 1998 (dry season) and July 1999 (rainy season).

Table 4. Groundnut dry weight and soil properties with and without plastic mulching

| Treatment | Dry weight (g/hill) | Soil moisture (%) | | Soil hardness (kg/cm) | |
|------------|------------------------|-------------------|------|-----------------------|-------|
| | | 10cm | 20cm | 10cm | 20cm |
| Mulching | 45.0 | 3.90 | 4.93 | 3.80 | 9.30 |
| Nomulching | 25.0 | 10.62 | 9.65 | 6.10 | 12.70 |

Notes: Soil moisture and hardness were measured at depths of 10 and 20cm in August, and dry weight of groundnuts was measured at harvest (October) 1999.

Table 5. Operation time for production and incorporation into soil

| Crop production activity | Equipment | Operation time (hr/ha) |
|----------------------------------|----------------|------------------------|
| Herbicide application | Boom sprayer | 1.1 |
| Seeding & fertilizer application | No-till seeder | 3.0 |
| Weeding | Cultivator | 7.7 |
| Chopping | Flail mower | 2.8 |
| Incorporation into soil | Rotary tiller | 3.2 |
| Total | | 17.8 |

Table 6. Application of agricultural equipment for crop management

| Management activity | Machinery | Effects |
|---------------------|--|---|
| Land preparation | Rotary tiller, Subsoiler Bottom plough, Plosoiler | Fine pulverization, Leveling Cracking of hard pan, Deep tillage |
| Seeding | Drill seeder, Mulch layer No-tillage seeder | Labor saving and large scale seeding Seed bed preparation |
| Weed, pest control | Boom sprayer, Broadcaster Cultivator | Large scale uniform treatment Operations in crop rows |
| Harvesting | Potato digger, Flail mower Binding harvester | Labor saving and large scale harvesting Treatment of crop residues |

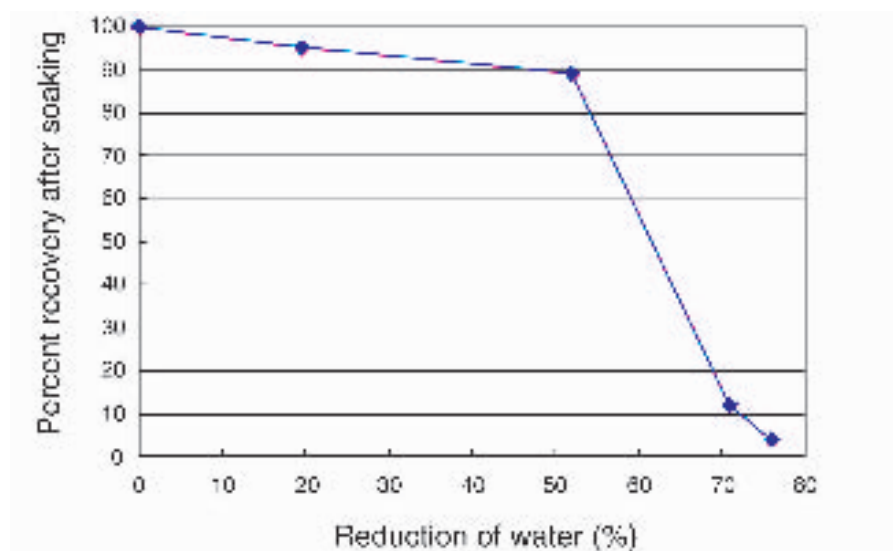


Fig. 3 Relationship between reduction of water and recovery of weeds after mechanical weeding.

Tillage with a rotary tiller achieved fine pulverization of the soil and leveling of the field. A bottom plough and a plosiler were used for deep tillage. A subsoiler was used to crack the hard pan of the soil layer and eventually facilitated a deeper distribution of crop roots. Labor saving seeding operations were achieved by the adaptation of a drill seeder to carry out seed row opening, fertilizer application, seed placement, and soil compaction in a single operation. A no-till seeder was adapted for large scale seeding. A mulch layer was used for laying plastic mulch before crop seeding or transplanting. A boom sprayer was used for herbicide or pesticide application using a boom which extends horizontally over a distance of 5 m. A broadcaster effectively distributed soil conditioners such as lime and fumigated rice husks. A shoulder broadcaster for application of granular pesticides and fertilizer was used for operations between crop rows. A potato digger was used for harvest of underground crops such as sweet

potato and groundnut. A binding harvester simultaneously did cutting and binding, which speeded up crop removal from fields. A flail mower chopped standing crop residues in the field for subsequent incorporation into the soil.

Mechanical weeding with the use of a small rotary tiller attached to a cultivator was effective in controlling the dominant upland weed, *Richardia scabra* L. Intertillage between crop rows could be carried out at walking speed (1.6 m/min), alleviating hard labor for hand weeding (Photo 6). Weeds lost water content after uprooting and eventually withered to death when some 60% of water was lost (Fig. 3). Under field conditions, 2~3 hours was enough to reach this critical water deficit, which could be used as a criterion for operations under variable weather conditions³⁾.

7. New crops and cropping patterns for diversification

Sugarcane and cassava are the main crops in upland

areas in Northeast Thailand. While these two crops have the advantages of tolerance to drought and poor nutritional conditions, they cause deterioration of the soil through erosion and fertility decline. Price fluctuations also destabilize the income of farmers. Introduction of new crops is indispensable for the diversification of crop production in the region. The growth characteristics of crop species were examined in terms of germination, overall growth, tolerance to drought or flooding, damage from insects or diseases, and nitrogen fixation. Sweet corn, groundnut, sweet potato and sunflower as upland crops; sorghum, pearl millet and crotalaria as forage or green manure crops; lettuce and cabbage as vegetables, and papaya and mango as fruits were evaluated for their adaptability to conditions in Northeast Thailand.

Introduced crops were classified into four groups based on their growth periods. The first group are crops with voluminous products such as sweet corn, sweet potato and forage crops. These crops require ample water to produce large biomass, and are suitable for production over the whole rainy season. Legumes and sunflower whose economic product are seeds after a drying process form the second group. These crops should be grown so that their harvest comes after the beginning of the dry season. The third are vegetables, which are suitable for growing in the dry season under dry and comparatively low temperature conditions. Fruits such as papaya and mango that grow all year round form the fourth group. They bear fruit at a fixed period in the year. Based on the results obtained in field trials, an example of a suitable crop sequence was proposed, along with appropriate production techniques (Fig. 4).

General Discussion

A multidisciplinary approach was adopted with the collaboration of researchers from various specialized fields to develop technologies for upland cropping in Northeast Thailand. While each technology can be used individually in specific situations, their mutual relationships can be depicted in the diagram shown in Fig. 5.

Soil conservation is the first priority since sustainability of upland cropping in Northeast Thailand is in peril due to soil degradation from erosion and decreased soil fertility⁹⁾. Introduction of trees into farm fields, such as through alley cropping, is effective not only in preventing erosion, but also in supplying organic matter through pruning of trees. The role of trees in the daily life of farmers is important⁶⁾, and utilization of *Leucaena* for alley cropping has been reported to be effective in North Thailand⁷⁾. Soil incorporation of crop residues and green manure is valuable for improving soil chemical and physical properties. Subsoiling in sloping fields is effective for trapping and accumulating runoff rainwater in deep soil layers, which benefits crop growth under dry condition.

Diversification comes as the next step after the achievement of soil conservation. Agriculture in Northeast Thailand is characterized by overreliance on monoculture crops such as sugarcane, cassava and rice, for which prices fluctuate greatly depending on demand and supply in international markets⁴⁾. The introduction of new crops is essential for increasing and stabilizing the income of farmers. The development of appropriate production techniques for each crop, including no-till and mulching, and appropriate crop sequences based on

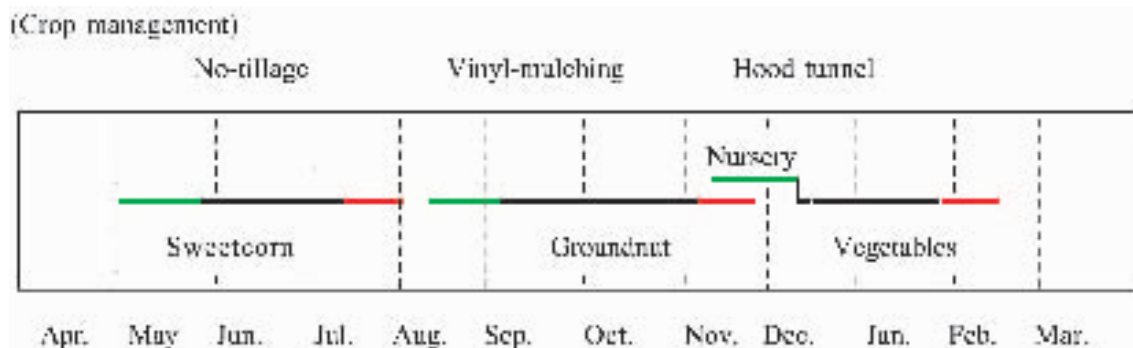


Fig. 4 An example of crop sequence for upland cropping.
 (Seedling (Transplanting) : Green line, Harvest : Red line)

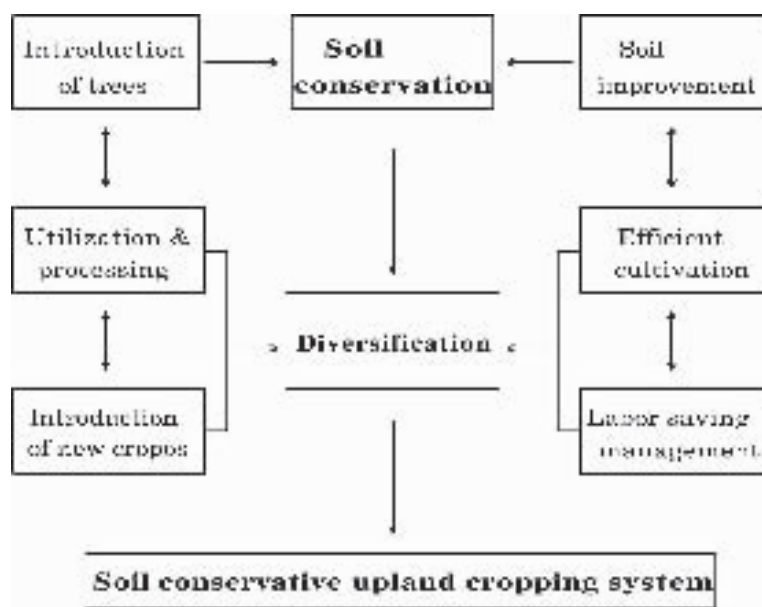


Fig. 5 Technology components for future sustainable upland cropping systems.

rational use of the climatic conditions of the rainy and dry seasons, is indispensable for the diversification of agriculture. Improvement of crop management technologies with the introduction of small agricultural machinery serves not only to supplement the decreasing agricultural population in Northeast Thailand but also to develop intensive value-added agricultural production.

Adaptation of the technologies developed through this research to actual production sites involves further steps, since each site has specific natural and social conditions in which economic factors play a crucial role¹⁾. The combination and modification of these technologies to adapt them to local situations through collaboration with farmers is necessary for their effective dissemination.

References

- 1) Caldwell, J.S. 2000. Potential of farming systems research for the development of sustainable agriculture. Proceedings "Linkages between Biological and Social Science Research in Northeast Thailand Comprehensive Project" Khon Kaen, Thailand, June 2000: 19-25
- 2) Fukui, H. 1996. Transformation of agriculture in Northeast Thailand. Southeast Asian Studies, Vol.33(4): 3-184
- 3) Morita, H. and N. Kabaki 2000. Characteristics of weed emergence and control of dominant upland weed, *Richardia scabra* L, in Northeast Thailand. J. Weed Sci. Tech. Vol.45 (Extra): 172-173
- 4) Nawata, E. 1997. The present situation and future problems of field crop production in Northeast Thailand. JIRCAS Working Report "Development of Sustainable Agricultural Systems in Northeast Thailand" 61-68
- 5) Oka, M. 1997. JIRCAS Comprehensive Research Project -A comprehensive study on sustainable agricultural systems in Northeast Thailand-. JIRCAS Working Report "Development of Sustainable Agricultural Systems in Northeast Thailand" 1-18
- 6) Prachaiyo, B. 2000. Farmers and forests: a changing phase in Northeast Thailand. Southeast Asian Studies, Vol.38(3): 3-178
- 7) Sampet, C., R.J. Van Den Beldt and V. Pattaro 1994. Leucaena in Thailand. Proceedings of a workshop on "Leucaena - Opportunities and Limitations" Bogor, Indonesia: 199-201
- 8) Ueno, Y. 1990. Effect of organic mulches on soil and water conservation in the tropical upland fields. Technical Document of TARC No.79: 1-94
- 9) Wada, H. 1994. Improvement of problem soils in Northeast Thailand. AICAF 16(4): 32-47



Photo 1 Pruning of trees in alley cropping



Photo 2 Subsoiling on the contour line

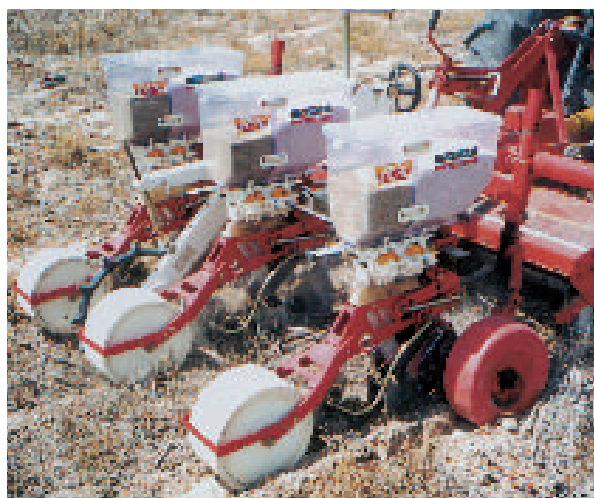


Photo 3 Seeding with a no-till seeder



Photo 4 Germinated crop in a no-till field



Photo 5 Chopping of green manure crops



Photo 6 Mechanical weeding

タイ東北部における土壤保全型畑作システムの開発

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摘 要

タイ東北部の丘陵畑作地帯(海拔100-200m)において、畑作システムを改良するための総合研究を実施し、土壤保全、水保全、省力、および作物多様化の技術を開発した。①アレイクロッピングを造成して管理方式を確立することにより、土壤浸食の防止と有機物の供給を図ることができた。②サブソイラによる下層土破碎は、表面を流失していく降雨水を土壤深層(50-60cm)まで浸透させて作物の生育に好影響を及ぼした。③不耕起栽培は浸食防止、雑草抑制、土壤水分保全に効果的であっ

た。不耕起播種機を試作し、砂質土で十分に機能できた。④落花生等の地下作物の栽培法としては、プラスチックマルチ栽培は土壤構造を維持し、地下部の生育を促進し、収穫を容易にした。⑤緑肥の省力栽培および鋤き込み体系を確立できた。⑥管理機による機械除草は畑地優占雑草に対する除草および省力効果が大きく、適用性が高かった。⑦多様化を図るために導入作物の生育特徴を評価し、個別の栽培技術および輪作体系を確立した。

キーワード：アレイクロッピング、下層土破碎、不耕起、機械除草