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Thai - Australian Highland Agricultural Project

FINAL REPORT ON AGRICULTURAL RESEARCH AND DEVELOPMENT IN THE HIGHLANDS OF NORTHERN THAILAND

JUNE 1981

For Universities Bureau and the Department of Public Welfare of the Kingdom of Thailand and the Australian Development Assistance Bureau

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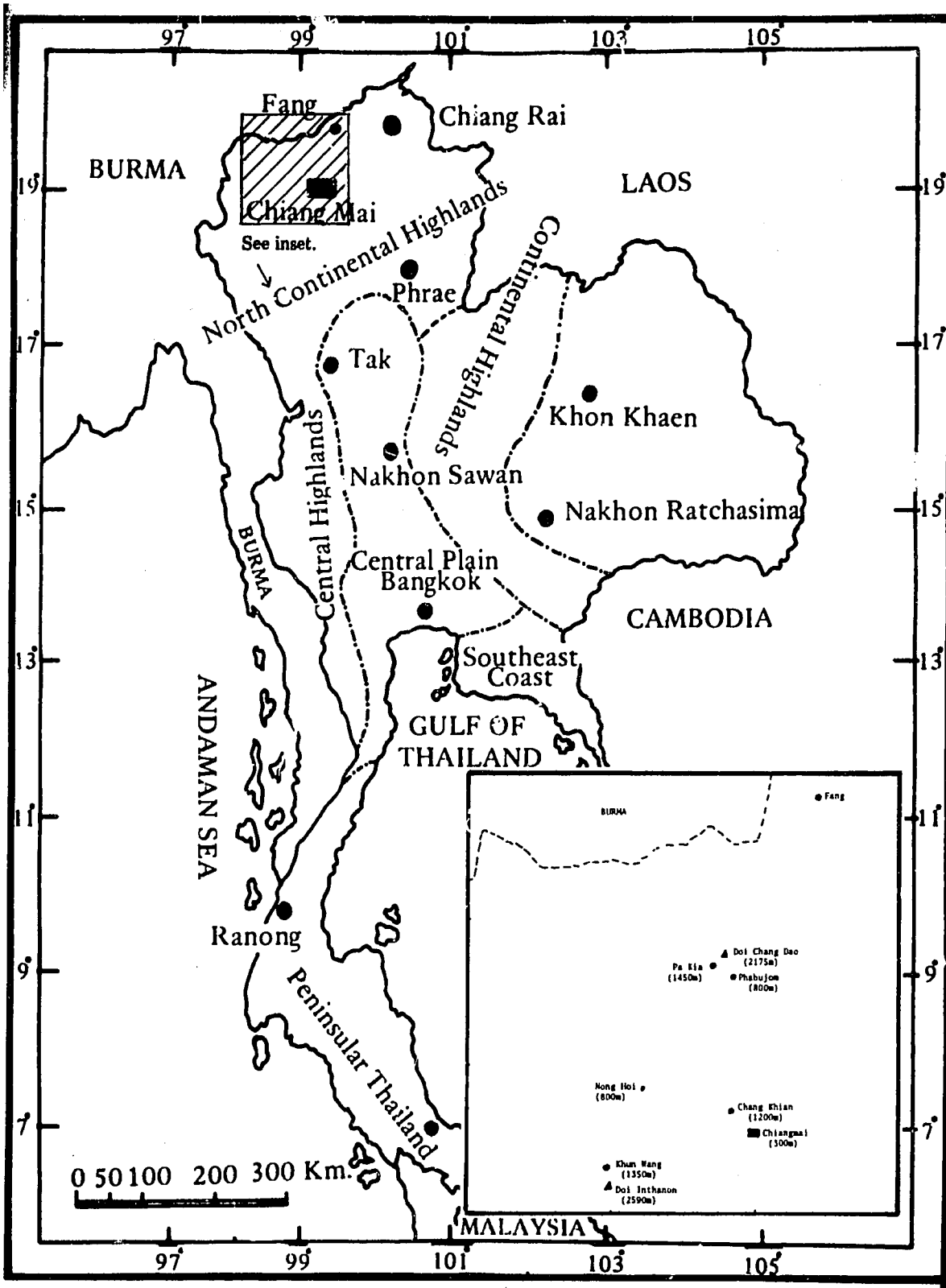
LOCATION MAP



Inset showing TAHAP field sites at Pa Kia, Phabujom, Nong Hoi, Chang Khian and Khun Wang.

AUSTRALIAN EMBASSY,
BANGKOK.
FROM THE AMBASSADOR

File : 156/28/5

12 November 1980

Your Excellencies,

I have the honour to present the fifth and final report of the Thai-Australian Highland Agricultural Project.

Over the past eight years Australian and Thai personnel have worked together on the research and pilot development activities described in this report. This work, aimed at improving the agricultural utilisation of highland areas, has been a cooperative effort between the Hilltribe Division of the Department of Public Welfare; the Faculty of Agriculture, Chiang Mai University and an Australian Colombo Plan advisory team.

The research activities have concentrated on ways of improving the productivity of local farming systems among the hill-tribe people of northern Thailand. This has included research to improve the production and utilisation of food crops including grain legumes, pasture agronomy and the study of the effects of diet supplementation for cattle grazing low quality native pastures.

The last two years of project operations have shown significant progress in the development of an extension methodology for hill-tribe development teams. The techniques developed through this work already have gained some international recognition and are providing a sound basis for the training of new extension officers.

The project has also provided a framework for many levels of training opportunities both in Thailand and overseas for staff of the Thai institutions involved. During these final two years of project operations a number of Thai university staff have returned from post-graduate studies in Australia to take up and extend some of the research program developed by Australian personnel. Similarly Public Welfare Department officers have returned from post-graduate studies in Australia to continue their field development work. The project has sponsored workshops and seminars in Thailand to provide a forum for the exchange of views and information on highland agricultural development. More recently the project has provided the opportunity for officers of the Public Welfare Department to visit other countries and exchange ideas on approaches to the development of agricultural minority groups.

Australia is concluding its involvement in the Thai-Australian Highland Agricultural Project at the end of 1980, confident that the project has not only made a significant contribution to the growing body of knowledge about highland agriculture and its potential for development, but has also contributed to the pool of skilled manpower with expertise in those areas that will make a positive contribution to the development of highland areas of Thailand.

In submitting this report I would like to convey my appreciation to the staff of the Department of Public Welfare and Chiangmai University and the University of Queensland, for their cooperation in the implementation of the Thai-Australian Highland Agricultural Project.

Please accept, your Excellencies, the assurances of my highest consideration.

(G. A. Jockel) CBE
Australian Ambassador

(His Excellency
Minister of Interior

(His Excellency
Minister for University Affairs

SUMMARY

1. INTRODUCTION

The Thai Australian Highland Agricultural Project (TAHAP) commenced in 1972 and was supported by the Australian Development Assistance Bureau and the Thai Government for eight years. It was primarily involved in applied research to improve the livestock industry and subsistence food production of the hilltribe people of northern Thailand. A further objective was to assist in the training of extension officers of the Department of Public Welfare involved with highland development, and to help the Faculty of Agriculture at Chiagmai University increase its capacity to train scientists and to undertake research in the highlands.

The highland population of approximately 400,000 consists of nine ethnic hilltribe groups as well as a large group of northern Thai who cultivate the lower highlands. They are spread over 54,000 km^2 of highlands at elevations above 500 m a.s.l. from the Lao to the Burmese border. Climate is monsoonal with an annual rainfall of 950-2000 mm, and low temperature at high altitudes >1000 m is a limitation to growth during the maturation period of tropical crops.

The Thai Government has established a policy of stabilization of tribal agriculture, conservation of watersheds, re-afforestation of steeper slopes and integration of tribal populations into the Thai nation. An ongoing research programme is necessary to provide the innovations for rural change and highland development. The results and recommendations of a wide range of TAHAP activities, presented in this report, will provide useful background information as well as options for development which may be considered by Thai Government agencies concerned with the welfare of the hilltribe people.

2. HIGHLAND FARMING SYSTEMS OF NORTHERN THAILAND

Highland farmers occupy land above 600 m altitude along the mountainous ridges of Northern Thailand in the watershed of the Chao Phya river. They have no legal title to land which is nominally under the control of the Royal Forestry Department; they practise shifting agriculture methods and some cultivate opium, hence the social significance of the area.

Rice is the most important subsistence food crop and is cultivated in a cyclical re-occupant system by the Karen which allows for regeneration of forests between crops. A second form of shifting agriculture, practised by the Meo, involving successive cropping of rice, maize and opium, is very destructive of natural vegetation and leads to *Imperata* dominant grassland.

As the bush fallow period shortens under increasing population pressure, crop yields and availability of forest products decline and minimum income and human nutrition levels can only be maintained by seeking off-farm income. At present livestock raising is minimal and there is no substantial income from tree crops.

Although cash crops of opium, potatoes and native peach return higher incomes, farmers prefer to grow rice from which they derive 70-90% of their human energy and 60-80% of their dietary protein. In the villages studied it was estimated that 90% of their subsistence area was sown to rice with an average labour input of 180 mandays per household Periods of peak labour demand fall in February (preparation of swiddens), May-June (planting) and in November (harvesting). Surplus labour is available at other times of the year for the establishment of permanent tree crops which could supplement hilltribe income.

About half of the rice consumed by hilltribe people is from rainfed hillrice (swiddens), one third is imported from the lowlands and the remainder is from paddy rice cultivated by hilltribes on valley floors. Swidden yields are rarely greater than 1 t ha^{-1}; paddy fields are higher and more reliable but the area available for bunding is limited.

Only a small area (10%) of the farm gardens studied was allocated to other food crops; these included corn, cucurbits, chilli, banana, sesame, grain legumes and sweet potato.

3. CROP AGRONOMY

Crop agronomy research commenced in 1976 and was directed at subsistence food crops. It commenced with the evaluation of a range of grain legumes and some cropping systems based on rice and maize. Pigeon pea *(Cajanus cajan)* was one of the few grain legumes not to suffer serious damage from fungal attacks and from the beginning of 1978 cropping research was concentrated on upland rice and pigeon pea.

3.1 Upland Rice

Upland rice yields are usually poor at altitudes over 1000 m. This is often due to weed competition, but it was shown that the major cause of low yields at high altitudes was floret sterility, probably induced by low temperatures. There was considerable genotype variability in resistance to cool temperatures with several varieties being completely sterile at Pa Kia (1450 m altitude).

A range of varieties was screened for performance at Pa Kia; the best currently available is Khichang which, despite 40% sterility, yielded 2.7 t ha^{-1} under experimental conditions. Unfortu-

nately, it is susceptible to lodging. At lower elevations (Phabujom, 800 m) sterility is not a problem and yields of 5 t ha^{-1} were obtained. At Pa Kia, the low temperatures compared with Phabujom reduced crop growth rate and extended crop duration so that crops planted after rice was harvested were unsuccessful because of severe water stress.

3.2 Grain Legumes

Twelve species were tested at Pa Kia but fungal diseases were a major problem and only pigeon pea *(Cajanus cajan)* and lab lab *(Lab lab purpureus)* produced satisfactory yields over several years. Soy bean *(Glycine max)* and common bean *(Phaseolus vulgaris)* produced good yields (0800 kg ha^{-1}) in one year but subsequently failed due to fungal attack. Early plantings (July) produced the highest yields, but herbaceous grain legumes are better suited to lower elevations.

3.3 Pigeon Pea

Detaled research on pigeon pea centred on varietal selection, general agronomy and mixed cropping. Four types were selected to suit different cash and subsistence crop needs. These were:–

(i) Dwarf short season – UQ insensitive dwarf.
(ii) Medium height, mid season – 4F38
(iii) Medium height, late maturing – UQ70
(iv) Tall, late maturing – UQ34

The optimum plant density depended on varietal size and planting date and ranged from 60 plants m^{-2} for the dwarf variety to 2 plants m^{-2} for very tall, late maturing types. Pigeon peas planted in hedge rows yielded up to 200 g per metre of row with optimum spacing of 12.5 to 25 cm between plants. Early planting produced highest yields and from the August planting (of 4F38) yields were only one quarter of those from a June planting. Phosphorus and sulphur fertilizer applications increased yields (more than 100%) and were most effective at high plant densities. Insect pests, particularly pod borers, were a constant problem and a spray programme was necessary to achieve high yields.

Mixed cropping trials with pigeon pea and rice indicated that it is difficult to get good yields of both rice and pigeon pea if the two crops are planted together. Pigeon pea planted at the same time as rice depressed rice yields, and if pigeon pea planting was delayed until two weeks after rice, then rice yields were unaffected but pigeon pea yields were poor. An alternative planting pigeon pea in widely spaced hedge rows within the rice crop is proposed.

4. IMPROVED PASTURES

About 4% of the highlands of Northern Thailand have been converted from forest to grassland as a consequence of shifting agriculture and frequent fires. These grasslands are dominated by *Imperata cylindrica* which is relatively unproductive. A research programme was commenced in 1973 to rehabilitate these grasslands for ruminant animals and to improve watershed characteristics through the introduction of selected pasture legumes and grasses.

Greenleaf desmodium *(Desmodium intortum)* and Archer axillare *(Macrotyloma axillare)* proved to be the best legumes for grazed pastures at elevations above 1200 m, while at lower elevations (600-1200 m) perennial stylo *(Stylosanthes guianensis)* and Greenleaf were the most productive. Greenleaf is an admirable legume cover in coffee, tea or orchard planting. The best grasses, irrespective of altitude were setaria *(Setaria anceps)* and signal grass *(Brachiaria decumbens)* with Kikuyu *(Pennisetum clandestinum)* favoured for drains and adjacent to cattle yards. Greenleaf and setaria are considered the best mixture for cut and carry pasture systems at any elevation above 600 metres. The shrub legume leucaena *(Leucaena leucocephala)* is not widely adapted to the highlands but grew well on more fertile soils (limestone) at elevations below 1000 metres.

Sulphur was identified for the first time as a key nutrient deficiency of the highlands, and phosphorus and sulphur fertilizers promote the growth of all legume species and are essential for Greenleaf based pastures. Rate trials indicated that an initial rate of 500kg ha^{-1} of rock phosphate and 100kg ha^{-1} of gypsum was appropriate for the most common granite soils. Legume establishment was enhanced by (i) grazing prior to sowing, (ii) fertilizer, (iii) fencing to exclude livestock and (iv) slashing of regrowth after sowing. Cultivation reduces *Imperata* regrowth but is not essential if points (i) to (iv) are carried out.

Cutting trials indicated that Greenleaf-setaria pastures will produce six to ten tonnes of dry matter per hectare per year with an average forage protein content of 12%. There was a decline in total yield in the third and fourth years, paralleled by a decline in legume content of mixed sward. For cut and carry systems, grass dominance is a common problem as the swards get older. This can be overcome by sowing Greenleaf first and transplanting setaria cuttings into the sward in the second year at one to two sprigs m^{-2}.

Weed invasion, especially by *Eupatorium adenophorum*, is the main technical problem of grazed pastures. Separate studies underlined the importance of improved grasses, adequate fertilization of the legume and frequent slashing to reduce the incidence of weeds. Internal parasites may reduce cattle productivity and one trial indicated that an-

thelmintics would increase production from improved pastures especially during the wet season.

Grazing trials showed that highland cattle would gain 100kg hd^{-1} yr^{-1} on improved pastures at a stocking rate of 1.5 beasts ha^{-1}, which represents a thirty-fold increase in production compared to native range. Despite this, the conomics of grazed improved pastures are doubtful, especially if the farmer has to buy cattle, and the utilization of small areas of improved pasture cut and fed to animals as a supplement to the native range is likely to be more profitable. Because of economic limitations, land tenure problems and social constraints on commercial cattle raising within the existing farming communities, fenced grazed improved pastures are not recommended for the highlands at this stage. For development agencies who decide to sponsor improved pastures in spite of these limitations, some recommendations are given on site selection, stocking rates and weed control.

5. ANIMAL PRODUCTION

5.1 Cattle and Buffalo

The cattle research programme was preceded by a survey of 42 villages representing 7 ethnic groups of the region. Ownership of cattle or buffalo varied with ethnic groups, the range being from 33% (Yao) to 88% (Karen). Cattle were owned primarily as an insurance against crop failure or for sacrificial purposes and were rarely sold purely for profit even when herds exceeded optimal sizes. Management inputs were minimal; little or no herding was practised, extra feeding was not provided except for occassional salt drinks. Veterinary treatment was provided in only a few instances. Productivity was very low, with the principal problems being disease, theft, predators and poor nutrition. Buffalo appeared to be more profitable than cattle but cattle were adapted to a much wider area. Income was derived from sales, agistment and leasing for draft purposes. Goats were kept by many villages but were unpopular with development projects while sheep were located in highland villages only as the result of some outside initiatives.

Predictive liveweight curves of highland cattle with respect to girth size and age were determined. Mature highland cattle had live weights of 250 kg at about 6 years of age. Data on seasonal live weight grains, calving and weaning percentage, calf weight, and carcass quality are presented from a project herd grazing native pastures.

Samples taken from fistulated animals and supportive data from faecal studies showed that the animals on the native pastures selected forage above 50% digestibility and above critical nitrogen (1%) and phosphorus (0.15%) levels, but below the critical sodium level (0.1%) for animal growth. Supplementary feeding studies showed a positive response to sodium in liveweight gain (30%), reproductive rate and reduced calf mortality. This response was confirmed by faecal, saliva, rumen fluid and blood serum sample measurements. There was no response which could be attributed to phosphorus or trace elements. Chromium sesquioxide markers suggested that intake of cattle grazing native pastures in the highlands was restricted (less than 2% of body weight) due to limited grazing times, difficult terrain and poor feed quality. Nightly supplemental feeding of cut improved pasture to cattle grazing native rangeland increased liveweight gain by 30%. This response was attributed to increased feed intake (energy) rather than to the increased protein in the diet.

5.2 Pigs

Surveys of the pig industry in the highlands showed that 90% of households owned pigs, usually raised as scavengers with very low levels of management. Productivity was low due to diseases and poor nutrition. The villages showed clear preference for the local breed which had a high fat content and research concentrated on improving the nutritional quality of local feedstuffs for local pigs. Traditional feeds consisted of banana stalk with rice, bran or corn. Significant liveweight increases were recorded when high protein grain legumes such as red kidney bean and pigeon pea were added to the basal ration and it was recommended that pigeon pea should be boiled and fed as a supplement at a rate of 1% of liveweight per day. A separate series of trials showed that sweet potato was a better source of carbohydrate than Irish potatoes and that both of these were superior to rice bran and banana stalks. When sweet potato was used there was also a positive response to vitamin and mineral supplements.

5.3 Sheep

The sheep research programme showed that German Merino native cross sheep produced faster growth rates, higher lambing percentages, more wool and higher edible portion of carcass than the native or Burmese breeds which were also found in the highlands. Another study demonstrated the necessity of anthelmintics to control internal parasites of sheep in this region. The management inputs required to raise sheep in the highlands were defined, but sheep are not recommended due to lack of market demand and the high level of management needed.

6. GRAZING IN FOREST PLANTATIONS

Species of *Pinus* and *Eucalyptus* were planted with and without fertilizer (N, P, K, S) and cattle were introduced into some sites one or two years after planting. Fertilizer increased the early growth

of eucalypts, but not pines. The growth and survival of pines was superior to the eucalypts over four years. Cattle had little effect on height or percent survival of the trees, indicating that the dual use of land for forestry and grazing is feasible. However, the practical value of this finding is reduced by the tendency of the rangelands to become invaded by unpalatable weeds except under very low stocking rates.

7. HIGHLAND EXTENSION STRATEGIES

The Hilltribe Division of the Department of Public Welfare has placed mobile teams in highland villages to provide agricultural information to farmers as well as an educational and health service. Despite a very favourable farm family to extension officer ratio of 150:1 the extension of new information has met with problems due partly to the need for better training of Government officers and also to the need for a more suitable extension methodology for the highlands.

The World Bank has proposed the Training and Visit System (T & V) which involves the transmission of simple improvements through fixed and regular meetings with farmers interspersed with meetings with subject matter specialists for instruction on practices to be recommended to farmers in the next period.

An alternative extension strategy is presented which can be integrated with the T & V system to increase the involvement of the farmer and his existing practices into the extension process. The technique calls for measurement and description of the existing farming system and farm resources of land, labour and capital as a starting point for the identification of on-farm problems and limitations to improved production. Discussion groups involving farmers allows the extension workers to understand the needs of village people and to discuss with them the problems which have been identified from the baseline survey.

The outcome of this process is that research and extension become relevant to the genuine needs and situation of farmers. More complete details of the method are given in Section 10 of the report.

8. FERTILITY, MICROBIAL POPULATIONS, EROSION HAZARD, AND PHYSICAL PROPERTIES OF SOILS IN KAREN SWIDDEN AGRICULTURE.

Some data from the Department of Soil Science is summarised as an example of the research being undertaken by Chiangmai University.

Sites were chosen in a Karen village 100 km west of Chiangmai at an elevation of 900-1000m a.s.l. to represent the recently slashed and burnt, deserted one year, two years, five years and ten years, and undisturbed virgin forest phases of the Karen swidden cycle. Measurements were made on fertility, microbial populations, soil erosion and physical properties of soils at each site.

Soil pH was in the range 5.3 – 5.7 except for recently burnt areas which ranged from 6.1 – 6.9. There were no significant changes in organic matter over the ten year period. Phosphorus levels extracted by the Bray No. 2 method were high immediately after burning (106 ppm) but dropped to 35 ppm after one year and averaged 15 ppm in ten year deserted and virgin forest areas. The effect was confined to the surface layer. Soil potassium, sulphur and calcium levels also increased immediately after burning but the effect was short lived. There were no significant effects on magnesium or on zinc which was low in all soils.

These soil analysis results were confirmed by a pot omission trial with rice and mung bean. No nutrient deficiencies were detectable on a soil from the recently burnt area but phosphorus deficiency was apparent in mung bean on soil from an area that had been deserted one year.

The bacterial plus actinomycete population in the soil was significantly higher following slashing and burning but subsequently decreased with length of bush fallow. It was postulated that the increased microbial population was due to the favourable soil pH (6.9) and increased availability of nutrients immediately following burning. The mineralization of nitrogen was highest in ten year deserted and virgin forest soils.

Measurement of soil losses through erosion showed great variability, but indicated a high mean soil loss of 57 t ha^{-1} during the wet season of 1979, a drier than average year.

Data on soil physical characteristics showed only small variations at different sites and depths. Soil porosity and aeration were suitable for plant growth and available moisture levels ranged from 9 – 19%. There was considerable variation in hydraulic conductivity.

The maintenance of soil fertility in highland agricultural system is central objective in the continuing research programs.

1. INTRODUCTION

The Thai-Australian Highland Agricultural Project (TAHAP) commenced in 1972 in association with the Thai Department of Public Welfare (D.P.W.). Early work was directed towards improving the productivity of the *Imperata* grasslands in the highlands. *Imperata* is the end result of intensification of shifting agriculture and is considered deleterious to the hydrological properties of water catchments, an unsatisfactory resource for continuing shifting cultivation, and a poor forage for livestock.

It was subsequently ascertained from satellite images that the area of the highlands dominated by grassland was only 4% and of much less importance than initially suspected. It also became clear that the socio-economic characteristics of the hilltribe population made Australian pasture improvement technology less relevant than was originally hoped, although there were some useful achievements from this early work.

The scope of the project was broadened in Phase II of the project (1975–1977 inclusive) to involve both the Department of Public Welfare and the Faculty of Agriculture at Chiangmai University. A livestock officer was appointed to study the biology and socioeconomic structure of the highland livestock industries and the focus of TAHAP livestock research subsequently switched from intensive pastures to the study of supplementation strategies for cattle grazing native pastures and for pigs fed traditional feeds such as chopped banana stalk.

It became apparent that subsistence food crops of hilltribes were accorded less weight by other Government agencies in favour of the politically more important opium replacement programme. In Phase III (1978–1980 inclusive) a TAHAP agronomy research programme was commenced on the most important crop of the hill people, upland rice, and a high protein grain legume – pigeon pea. Concurrently with the above research and survey programmes, a major effort was initiated to study the highland farming systems and to develop a suitable agricultural extension methodology.

The status of the hilltribes is in considerable flux due to declining areas of forest available for swidden agriculture, increasing population caused by inward migration from other countries and upward migration from the lowlands, restrictions placed on their movements by Thai authorities, and political pressure from many quarters to reduce opium production and stabilize their systems of agricultural production. This has added to the complexity of designing relevant and practical research programs.

Despite this difficulty, considerable progress has been made towards understanding and making recommendations for improvement of many aspects of the agricultural systems of the hilltribe people. If stable rather than shifting agriculture becomes essential to counter problems of shortage of agricultural land and destruction of the natural environment, information presented in this report will prove valuable to those planning and implementing changes. The report covers a great diversity of fields including a description of highland farming systems; the major results and recommendations of the upland rice, pigeon pea, multiple cropping, pasture improvement and livestock research programmes; and extension methodologies suitable for hilltribe farmers. Some preliminary soils research information is also included.

A comprehensive bibliography of TAHAP publications is given for any who may wish more detailed information on topics of interest.

Significant investment has been directed to the training of extension officers of the Department of Public Welfare and the Royal Forestry Department and the academic staff of Chiangmai University.

The success of this report is due to the considerable efforts of our resident staff at Chiangmai: Mr Peter Hoare (Extension Officer and Project Manager), Mr Lindsay Falvey (Livestock Officer), Dr Alan Andrews (Pastures and Pigeon Pea Agronomist) and Dr Rod Chamberlin (Rice Agronomist) and their Thai colleagues.

L.R. Humphreys
Head
Department of Agriculture

H.M. Shelton
Overseas Project Co-ordinator

University of Queensland
November, 1980

2. BACKGROUND TO THE PROJECT AREA

2.1 Location and Topography

Northern Thailand in this report includes the eight provinces comprising Chiang Rai, Chiangmai, Nan, Mae Hong Son, Lampang, Lamphun, Phrae and Tak and which lie between 18° and 20° N latitude. The area covers 90,000 km^2 (17% of Kingdom of Thailand area) and can be divided into three physiographic zones as follows:

(a) the lowlands (10% or 9,000 km^2) comprise the alluvial basins of the Ping, Wang, Yom and Nan rivers which flow south into the Chao Phya River system; and the Mae Kok and Mae Ing Rivers which flow north into the Mae Kong River. Topography is nearly level. Principal wet season land use is rice while 10% of the area is double cropped with tobacco, soybeans, peanuts, non-glutinous rice, garlic and onions.

(b) the uplands (30% or 27,000 km^2), consisting of undulating or hilly terrain to about 500 m a.s.l. lying between the tributaries of the rivers and along the footslopes of the ranges. Principal land use is the swidden cultivation of upland rice to supplement lowland paddy production.

(c) the highlands (60% or 54,000 km^2), which range in altitude from 500-2,500 m a.s.l. are rugged inaccessible masses varying from flat plateaux to steep sided mountains with less than 1% of valley floors. The maximum altitude is 2,590 m at Doi Inthanon, the highest peak in Thailand. A variety of crops are cultivated in swiddens including upland rice, maize, opium, vegetables and cotton.

2.2 Climate

Climate is monsoonal with annual rainfall varying from 950-2,000mm.

The average yearly rainfall at Chiangmai is 1,260 mm and at the highland field site at Pa Kia 1,620 mm. The rainy season extends from May to October/November followed by a cool dry period until February and a hot dry period until the rains commence. Within this general pattern there are many different micro-climates created by the mountainous terrain. Maximum and minimum temperature at Chiangmai (300 m altitude) varies from 29°/13°C in January (cool season) to 36°/21°C in April (hot season). Temperature decreases with altitude at about 0.5°C for each 100 m, and at Pa Kia (1,450 m altitude) the corresponding values are 20°/11° in January and 27°/17° in April. Frosts occur in sheltered highland locations.

2.3 Soils and Vegetation

Highland soils have not been extensively studied but they are mostly residual soils weathered from parent materials of granite, gneiss, schists, shales, sandstones and limestones and may be classified as mainly red-yellow podzolics with small areas of reddish-brown laterite overlaying basic rocks. Some red-brown earths occur between limestone crags.

Scattered alluvial soils are found on valley bottoms and colluvial soils on lower footslopes but are limited to about 1% for valley bottoms and about 5% for colluvial footslopes. The main limiting factor for agricultural production is excessive slope. It has been estimated that 25% of the highlands is suitable for perennial plantation crops and only 5% for annual cropping. The remaining 70% should be left under permanent forest.

The climax vegetation above about 1,000 m is a closed evergreen forest, except on the poorest soils, where open pine forests predominate. Below 1,000 m the vegetation is semi-deciduous forest.

2.4 Population

About 10% of Thailand's population (4.4 million) live in north Thailand. This includes 0.6 million urban and 3.8 million rural Thai plus 300,000-400,000 hilltribe people most of whom live in the highlands and uplands. Due to inward migration of hilltribes the lower population estimate may be quite conservative and many believe that there are now close to 400,000 people in the highlands.

The tribespeople consist of nine ethnically different groups. They may be separated into long-term immigrants, e.g. the Karen from Burma, and recent immigrants (in the last 100 years) such as the Meo and Yao from China and the Lahu, Lisu and Akha from both China and Burma.

2.5 Present Land Use

Hilltribe people practise two forms of swidden (slash and burn) agriculture. The first is a cyclical reoccupant form (50% of population – Karen) where the swidden system involves a 5-10 year rotation allowing for regeneration of forests following cropping with upland rice, sometimes intercropped with maize, beans or vegetables. This system is self-sustaining and permits families to satisfy basic food and animal cash requirements. Many of these tribes have terraced small areas of valley bottoms for supplementary rice production. This group is located at an elevation range of 500-1,000 m a.s.l.

Shifting agriculture practised by the second group (Meo, Yao, Akha, Lahu and Lisu) is more destructive because of the techniques involving successive cropping of maize followed by opium poppy. In this system original vegetation is completely removed. Following several years of culti-

vation, fields are abandoned because of excessive weed growth and declining fertility. The practice usually leads to an *Imperata* dominant grassland and regrowth of secondary forest is controlled by regular burning. Opium growers migrate to new areas when their fields are exhausted. This group is located at elevations about 1,000 m a.s.l.

A third type of opportunistic or supplementary shifting cultivation is practised by lowland Thai wet-rice growers who have been recently forced by population pressure to utilize the hillsides. Their swiddening practices are as destructive as those of the opium growers: they do not exercise care in confining fires and do not practise planned rotational fallowing. They single-crop mainly with rice.

After opium, miang tea is the main cash crop and is cultivated by highland Thai. Production techniques to produce this lactic acid fermented product are primitive and many growers now sell fresh leaves for black or green tea production. Many other cash crops have been tested as possible substitutes for opium including cereals, food legumes, vegetables, mushrooms, flowers and flower seeds, edible and essential oils, pyrethrum, stick lac, fruit trees, potatoes and Arabica coffee. Arabica coffee shows the greatest potential of these and plans have been initiated to expand the current small areas under production and to improve techniques of seedling propagation, leaf rust control, site selection, shading of crops and pruning. The production of kidney beans for export and potatoes for the domestic market also shows promise. Kidney bean is promoted by the Office of Narcotics Control Board (ONCB) and 100 tonnes were produced by hilltribe farmers this last season.

2.6 The Problem of Shifting Cultivation

Shifting cultivation as practised by the Karen is a balanced and stable form of agriculture provided fallow periods are sufficiently long to permit adequate regeneration of forests. Good yields of swidden crops can be maintained if healthy forests are available for slashing and burning to return a high level of plant nutrients, in the form of ash, to the soil surface. In addition, many forest products are consumed including leaves, roots, mushrooms, natural fruits, wild game and grubs from bamboo. Life and health of hilltribes are closely related to the health and abundance of forests. The Akha tribe always reserve a ring of natural forest around their village with swiddens outside (L. Atting – pers. comm.).

It is clear that in many areas due to excessive population the stability of the shifting agricultural system is at risk and food production is insufficient to meet yearly needs. This can be attributed to too frequent cultivation of land, the degrading effect of opium production and the plunder of forest reserves for timber and firewood. In some villages domestic rice production is consumed after 5-6 months and meagre monetary income obtained from cash cropping and off-farm activities is used to purchase rice.

The amount of forested area remaining in each province was ascertained from satellite imagery by Mr T. Gibson and staff of the Northern Region Agricultural Development Centres (NADC). They showed that the percentage forest cover in the highlands varied from 78% in Tak Province to 95% in Lamphun Province. However, much of this forest is on inaccessible or unusable land. Migration to new sites on new mountains via the lowland road system is discouraged by Thai authorities, which places additional pressure on existing village locations.

In the Akha village studied by Dr. Atting, villagers are experiencing difficulty in locating good forests for swidden and malnutrition is common, especially after the rice supply is consumed. The shortage of rice has adverse implications not only for the nutrition of hilltribes but also for their social cohesion. Rice is central to the mythology and ritual which is mostly concentrated around ancestors. In the Akha culture there are about 10 major ceremonies based around rice and the current shortfalls in production threaten the moral fabric of their society (L. Atting – pers. comm.).

Many studies in the tropics have shown that shifting agriculture is an efficient system (given sufficient land) for subsistence farmers who have no access to modern inputs and technology. However, its intensification is difficult as modern techniques of row planting, proper spacing, weeding, fertilizing and spraying cannot be used on swidden fields which are steep and covered with stumps and other forest debris.

Therefore stabilization and intensification of crop production, notably rice, requires that shifting cultivation be replaced rather than improved. Such a change would have far reaching implications for the hilltribes since their traditional subsistence farming systems are closely linked to deeply rooted social customs. Some groups have demonstrated a capacity to break with these traditions, under the pressure of limited land, by terracing valley bottoms and cultivating rice under the more stable, bunded paddy system.

2.7 Development Potential

There is a clear need to examine the agricultural and social problems of the hilltribes and potential for improvement and change of highland agricultural systems undoubtedly exists. The Thai Government has established a policy of stabilization of tribal agriculture, conservation of watersheds, reafforestation of steeper slopes and integration of tribal populations into the Thai community. Achievement of these goals is likely to involve radical change of present hilltribe farming and social traditions, and such changes will not occur rapidly.

The Thai Government has received a World Bank loan to implement a pilot project comprising the permanent settlement of hilltribe villages based on small scale irrigated and rainfed bench terraces on valley floors associated with coffee and other crop plantings and reafforestation on steeper slopes. This is the first concerted effort to achieve these goals.

An ongoing applied research programme is crucial to these development goals which are dependent for success on new innovations. Several institutions in the north have research capability and the research achievements and training work of the Thai Australian Highland Agricultural Project provide a solid platform for continuing research and development to upgrade the subsistence base of hilltribe farmers.

A close up of the mixture of upland rice, vegetable and grain legume seeds sown in a Karen swidden.

Rice planting is a communal effort. The larger trees are not killed but trimmed and regrowth is encouraged by excluding fire after rice harvest. The Karen cyclical swidden system can support a population density of about 30 persons/km^2.

Karen upland swiddens an example of highland conservation farming. Particular care is taken to confine fire to this years swidden, unlike the Meo, Yao, Lahu and Lisu who practise uncontrolled firing. The strip of trees between the two fields has been left as a soil conservation measure.

3 SCOPE OF THE PROJECT

3.1 Project Objectives

(a) To improve production and utilization of food crops, (rather than cash crops).

(b) To investigate stable agricultural land use systems involving legumes, pastures and livestock.

(c) To ensure that sufficient counterpart personnel are adequately trained to assume research and extension duties by the end of the Australian involvement.

(d) To develop an agricultural extension methodology which will be effective among the hilltribe people.

3.2 Method of Operation

Resident Australian staff worked closely with Thai counterpart staff from Chiangmai University, the Department of Public Welfare and the Royal Forestry Department. Wherever possible, Australian staff members acted mainly in an advisory role, but were also involved in day to day management of research programmes and analysis of experimental data. After a period of at least one year's work with TAHAP, counterparts were given the opportunity to undertake post-graduate training at Australian universities, and they were encouraged to carry out independent research within the project on their return. Technicians were employed to carry out chemical analyses, to supervise field experiments, and to assist in large scale surveys. There were permanent staff at each field site.

Australian staff were involved to a small extent with undergraduate training through student research projects and, occasionally, lectures to final year students.

The project has sponsored training courses and workshops in conjunction with the Northern Region Agricultural Development Centre to inform local extension officers of research findings and to upgrade their knowledge of extension methodology.

Some research projects within the Faculty of Agriculture, Chiangmai University, independent of TAHAP, but relevant to TAHAP's objectives, were funded. The comprehensive programme carried out by the Soil Science Department which is detailed in Section 10 is an example of this.

3.3 Field Sites

TAHAP's main field research site was located near the Meo Village of Pa Kia on a granite derived, podzolic soil at an altitude of 1450 metres. All facilities at this site were provied by TAHAP. Other field sites used by TAHAP were established and run by other organizations (Chiangmai University, Department of Public Welfare, and United Nations Program for Drug Abuse Control). They varied in altitude from 800 to 1350 m and their locations and elevations are shown on the location map. Most highland soils are acidic and deficient in N, P and S; details of soil and climatic data for all sites are given in the body of the report where appropriate.

His Majesty King Bhumipol making presentations at Pa Kia, in February 1978, to the Meo Hilltribe farmers participating in the village cattle fund.

It is Government policy to eliminate opium poppy growing.

4 HIGHLAND FARMING SYSTEMS OF NORTHERN THAILAND

4.1 Introduction

Highland farmers in Northern Thailand occupy land at altitutdes above 600 m and total only about one per cent of the population of Thailand. However, their distribution along the mountainous borders with Laos and Burma in the watersheds of Thailand's major river system, the Chao Phya, and their opium production make them politically important.

The hilltribe population is now estimated to be nearly 400,000 comprising many ethnic groups (Table 1). In addition to the hilltribe population there is a highland population of Northern Thai ("Khon muang") estimated at over 40,000 people who produce a fermented tea product "miang", that is consumed only in the Northern Region of Thailand.

The Hilltribe Division of the Public Welfare Department (D.P.W.) provides Government service to about 950 hilltribe villages (42% of the total). The rural development work is implemented through mobile teams in remote areas where the mainline Thai Departments are not operating. The mobile teams at full strength consist of four members: a team leader who is usually the social worker, and agricultural extension officer, a paramedic and a teacher.

4.2 Social and Political Factors Affecting Highland Agriculture

4.2.1 Population pressure and Highland Farming Systems

The ethnic diversity of the highland population can be seen in Table 1. The largest number of households per village are found in Htin, Lua and Khamu villages which together wih the largest population group, the Karen, live in villages established for up to 200 years within the same land boundaries. They are traditionally subsistence rice farmers on a limited area of land. Areas of lesser slope are developed for highland paddy but most of the rice comes from highland rice grown after bush fallow on steep slopes with a fallow period from 4 to 12 years.

The upper population pressure limit for stability of the subsistence farm in a bush fallow farming systems as practised by the Karen and Lua, with dry season fire control, is about 20 persons km^{-2}. This gives a farm size of 16 ha, of which 94% is bush fallow, but increasing population pressure has halved the farm size to about 8 ha, with only 81% bush fallow. Resumption of land for reafforestation is further reducing farm size in some areas.

As the bush fallow period shortens under increasing population pressure, forest products for consumption and sale have declined, and minimal income and human nutrition levels can only be obtained by seeking off-farm income. At present

TABLE 1

Hilltribe Population by Ethnic Group DPW Tribal Research Centre Survey 1977

Ethnic Group	Population	Number of Villages	Number of Households	Average number of households per village	Average number of persons per household
Karen	184,650	1,545	35,634	23	5.2
Meo	34,480	148	4,743	32	7.3
Yao	22,650	105	3,056	29	7.4
Lahu	22,580	148	3,857	26	5.9
Htin	19,400	45	3,176	71	6.1
Akha	13,570	94	2,115	23	6.4
Lisu	12,550	82	1,980	24	6.3
Lua	11,250	42	1,986	47	5.7
Khamu	6,320	27	1,038	38	6.1
TOTALS	327,450	2,236	57,585	26	5.7

livestock raising is minimal and there is no substantial income from tree crops.

The opium-cultivating farmers are the Meo, Yao, Lahu and Lisu who have traditionally been more mobile, farming at lower population pressures of around 10 persons km^{-2}; but degradation of the highland vegetation base has resulted in a migration from these ethnic groups to upland areas where they are in competition with the lowland Northern Thai.

The extensive tea cultivation of the Northern Thai aimed at producing the fermented tea production "miang" supports population pressures of up to 100 persons km^{-2} without fertilizer inputs on some of the poorest granite-derived highland soils.

4.2.2 Land

In the nine provinces of Northern Thailand (Mae Hong Son, Tak, Chiangmai, Chiang Rai, Lampang, Lamphun, Nan, Phrae) the highlands make up 60% of the land area; the uplands and lowlands comprise 30% and 10% respectively.

The Royal Forestry Department (R.F.D.) retains residual land control over the Northern Highlands. Usufruct right to land is largely recognized by village people such as the Karen whose forebears cultivated environmentally stable extensive slash and burn systems for over 200 years. Usufruct rights are not recognized by R.F.D. with the recent increase in R.F.D. budget for reafforestation of watershed areas in Northern Thailand, thirty units were established in the highland areas of Chiangmai Province from 1977 to 1980, each replanting about 160 ha per year. Inevitably there are conflicts in some areas where R.F.D. resumes land.

4.2.3 Labour

Labour resources are a major determinant of highland wealth accumulation when land is not a limiting resource.

The Meo and Yao have polygamous households and the largest number of people per household (Table 1). The importance of labour resources in determining wealth accumulation with these ethnic groups is reflected in the high bride price. Labour resources of newly-wed Lahu families are shared with the bride's parents for 2 to 3 years and for a similar period with the husband's parents before they establish their own farm.

Hired labour for picking tea leaf in the wet season is a feature of the Highland Thai "miang" villages, and hired labour, often opium addicts, are commonly found in opium growing villages.

Most of the forest camp labourers of R.F.D. are Northern Thai drawn from the lowlands, but the off-farm income opportunities are increased for highland people during the first 5 years of tree establishment. Social and economic factors determine whether hilltribe people accept wage labour opportunities e.g. Karen at Mae Sariang make up about 30% of the camp labour; but at Chiang Dao none of the Meo in the neighbouring Pa Kia village work for R.F.D.

The steep slopes (up to 40°) necessitate the use of hand tools rather than ploughs for cultivation. Females are primarily responsible for farm tasks in the Meo and Yao groups, but for other ethnic groups there is relatively equal division of labour. However, some tasks are sex-related such as cutting timber for field preparation by males, and pig husbandry by females.

Some ethnic groups are recognized for particular farming skills such as the Lua for terrace construction, the Yao for hillrice, and the Karen for paddy rice production.

4.2.4 Capital

The capital investment is in seed, usually stored from the previous harvest, and in hand tools.

Capital accumulaion may be in livestock, particularly large ruminants; jewelry, particularly silverware; guns; in motor vehicles resulting from improved village road access; and improved housing.

4.2.5 Opium

Thai Government policy is to eliminate poppy growing and there are heavy penalties for trading opium and its derivatives. Hilltribe Division mobile teams are attempting to ameliorate the opium problem. The Tribal Research Survey in 1977 showed that, over 15 years, the rates of addiction as a percentage of the population ranged from 2.8% (Karen) to 30.4% (Akha) for males, and from 0.46% (Karen) to 15.63% (Lisu) for females. The Thai male rate of addiciton was given as 2% of the population.

4.3 Measurement of Highland Farming Systems

The methodology for rural development work, based on Australian experience in Papua New Guinea, was tested with TAHAP and DPW staff in the highlands of Northern Thailand in 1978. During 1979 and 1980 the farming systems in five villages were measured and a summary of the utilization of land and labour available for subsistence cropping is given in Tables 2 and 3. Rice is the dominant food crop providing from 70% to 90% of human energy and from 60% to 80% of dietary protein.

The subsistence farm model is based on the FAO standard requirement of energy and protein for a moderately active male. Using average yields of the main subsistence crops this translates into an area of about two rai needed for the energy and protein requirements of an adult male. The labour requirements to produce this food have peaks in

TABLE 2

SUBSISTENCE FARM MODEL — HILLTRIBES (1 rai = 1600 m^2)

(1 rai Garden)

Crop Grown	Percentage 1/ area of crop (5)	Average 1/ yield rai^{-1} yr^{-1} (kg)	Actual 1/ yield per 1 rai garden (kg)	Energy value (calories)	Equivalent 2/ protein (g)	CROPPING CALENDAR (MAN DAYS) 1/											
						Husbandry practices								Harvest period			
						J	F	M	A	M	J	J	A	S	O	N	D
Hill Rice	82	150 (rough)	123	419,439	7,134	0.2	5.1	0.1	2.4	5.6	3.9		0.1	1.0	1.1	3.5	1.0
Paddy rice	10	250 (paddy)	25	85,250	1,450					0.5	0.5	1.0				1.0	1.0
Corn	1	200 (seed)	2	6,980	182		0.2	0.1				0.2					
Concurbits	1	1500 (fresh weight)	15	2,000	120				0.1	0.1	0.1				0.1		0.1
Chilli	1	120 (fresh weight)	1.2	1,900	66												
Banana	1	1000 (fresh weight)	10	6,300	80			0.1					0.2		0.1		
Sesame	1	30 (seed)	3	17,460	516		0.2			0.1		0.1					
Grain legume (soy bean)	2	150 (seed)	3	12,000	1,053		0.2			0.1		0.1	0.2				
Sweet Potato	1	600 (fresh weight)	6	6,480	60		0.1			0.1		0.1					
TOTALS				**558,800**	**10,661**	**0.2**	**5.8**	**0.3**	**2.5**	**6.5**	**4.5**	**1.5**	**0.5**	**1.0**	**1.3**	**4.5**	**2.1**

Assumption

1 moderately active adult male (65 kg) consumes 3/

(a) 3000 cal/day, and @ = 1,095,000 cals/adult/year and)
(b) 1 g protein/1 kg bodyweight/day 23,725 g/adult/year) = Requirement of approximately 2 rai of average garden to meet energy and protein needs.

Source: 1/ TAHAP & Tribal Research Centre Data

2/ Food Composition Table for Use in East Asia; F.A.O. 1972

3/ F.A.O. Handbook on Human Nutritional Requirements, F.A.O. 1974.

TABLE 3

MAN DAY BUDGET assuming 2 Rai Subsistence for 1 Adult (Nutrition needs met)

Item	LABOUR CALENDAR (MAN DAYS)											
	J 31	F 28	M 31	A 30	M 31	J 30	J 31	A 31	S 30	O 31	N 30	D 26
Labour requirements for 2 rai garden	0.4	11.6	0.6	6.0	13.0	9.0	3.0	1.0	2.0	2.6	9.0	4.2
Surplus Garden	30.6	16.4	30.4	25.0	18.0	21.0	28.0	30.0	29.0	28.4	21.0	21.8
Discount 20% for Household Chores	6.1	3.2	6.1	5.0	3.6	4.2	5.6	6.0	5.8	5.7	4.2	4.4
Surplus for other enterprises	25.0	13.0	24.0	20.0	14.0	16.0	22.0	24.0	23.0	23.0	17.0	17.0

Source: TAHAP and Tribal Research data.

February when new fields are slashed (5.8 days), in May at planting time (6.5 days) and in November for harvest (4.5 days). These peak labour demands limit agricultural productivity with the present technology, so that one active agricultural worker is capable of feeding only two people.

However, the labour budget shows that for 20 to 25 days per month for 7 months of the year there is considerable labour surplus that could be employed in stabilizing the subsistence sector through improved conservation practices such as terrace construction and in raising farm income by incorporation of permanent tree crops.

Figures 2 summarizes the utilization of household resources and returns to labour in a traditional Red Lahu village (Pahlo) and in a highland Thai village (Pang Ma-O). The importance of tree crop in stabilizing the highland farming systems is shown as the highest return to labour for both 1979 and 1980.

Figure 2 shows the allocation of household labour resources for Pahlo Red Lahu village where the total gross value of the main crops produced by the 13 households were:- hill rice 107,450 Baht (31%), corn 11,910 Baht (3%), potatoes first crop 33,770 Baht (6%) and opium 110,700 Baht (32%). Average gross family farm income of 26,500 Baht was about double the absolute poverty level.

The peaks in the graph of family labour in January-February represent harvesting of opium and clearing new swiddens for hill rice, in June weeding of rice, and in November-December harvesting rice, potatoes and weeding opium. The peak in the hired labour graph is for preparing fields for opium planting in August.

Although cash crops of opium, potatoes and native peach return high incomes, farmers still grow subsistence rice as shown by the allocation of an average of 180 man days per household of labour with a return of 35 Baht per worker day, equal to the minimum regional wage rate. This return to labour for rice was much better than that found in most Karen and Akha villages, where swiddens are cleared from secondary forest.

Native peach with minimal inputs of labour provided the best return of 296 Baht per worker day.

In Figure 3 the "miang" farming system is summarized. Pang Ma-O village consists of 20 households. The average area of rented and owned gardens per household was 15 rai and average gross farm income was 19,870 Baht per household. Labour is used for cutting firewood and bamboo ties in the dry season. From April to December labour is used only for picking tea leaf and the labour graph indicates the yield distribution of the tea leaf. Contract labour is employed during this period to help with the picking. In 1979 the return to family labour was 20 to 106 Baht per worker day.

4.4 Highland Livestock

Highland ruminants and pigs are covered in Chapter 9 through the highland ruminant and pig surveys.

Poultry are raised by most households and unhusked rice in hilltribe villages, and milled rice in highland Thai villages is fed at the rate of ½ to 1 litre per household per day as a supplement to foraging. The food consumption survey data shows that poultry provide less than 5% of the human dietary protein in villages. In Pang Ma-O village in 1979 all 20 households raised chickens, but there was a substantial loss due to deaths from endemic diseases. An average of 2.5kg of rice protein was fed per household for a return of 250g of meat protein.

FIGURE 2 SAMPLE HOUSEHOLD RESOURCE UTILIZATION – MR JA ER WEDA VILLAGE – PAHLO – RED LAHU (ALTITUDE 1200 metres a.s.l.) 1979.

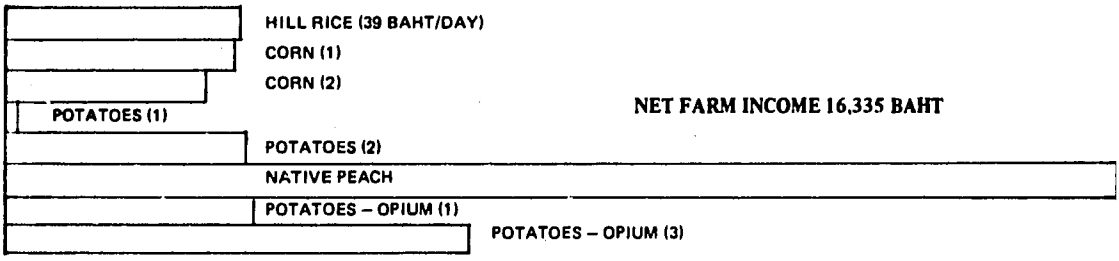


Figure 2(a) Return to Household labour (BAHT/day).

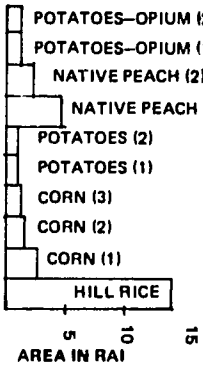


Figure 2(d) Allocation of Land by Crop

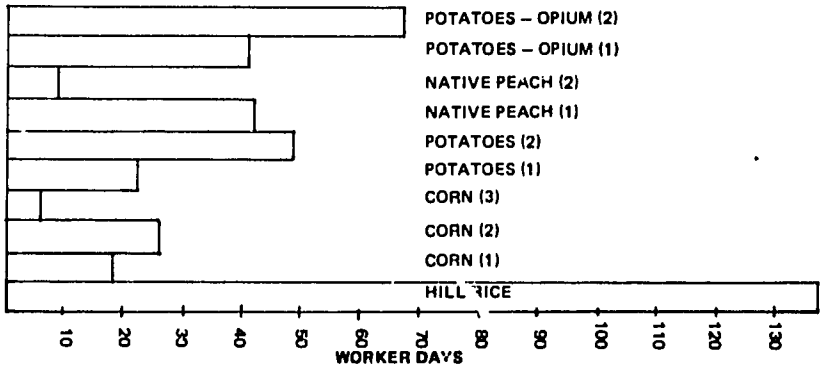
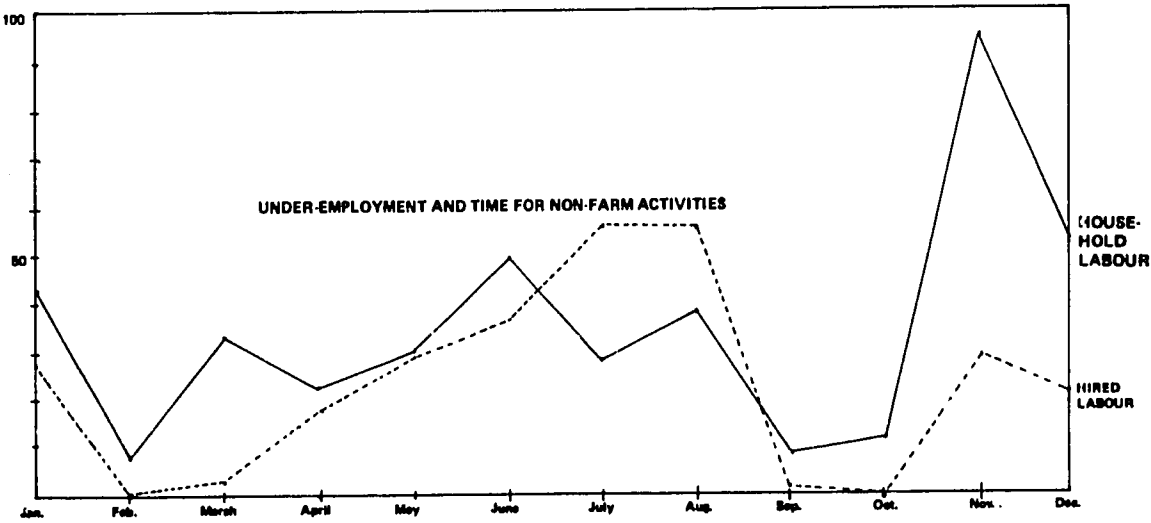


Figure 2(c) Household allocation of labour by crop.

Figure 2(b) Labour Utilization – Total household labour available (3.8 worker units)

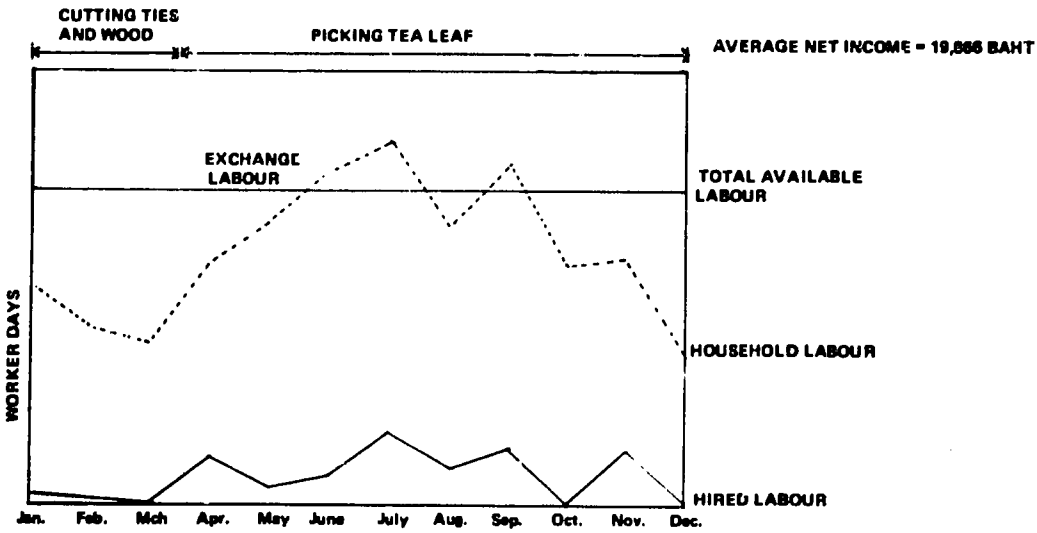


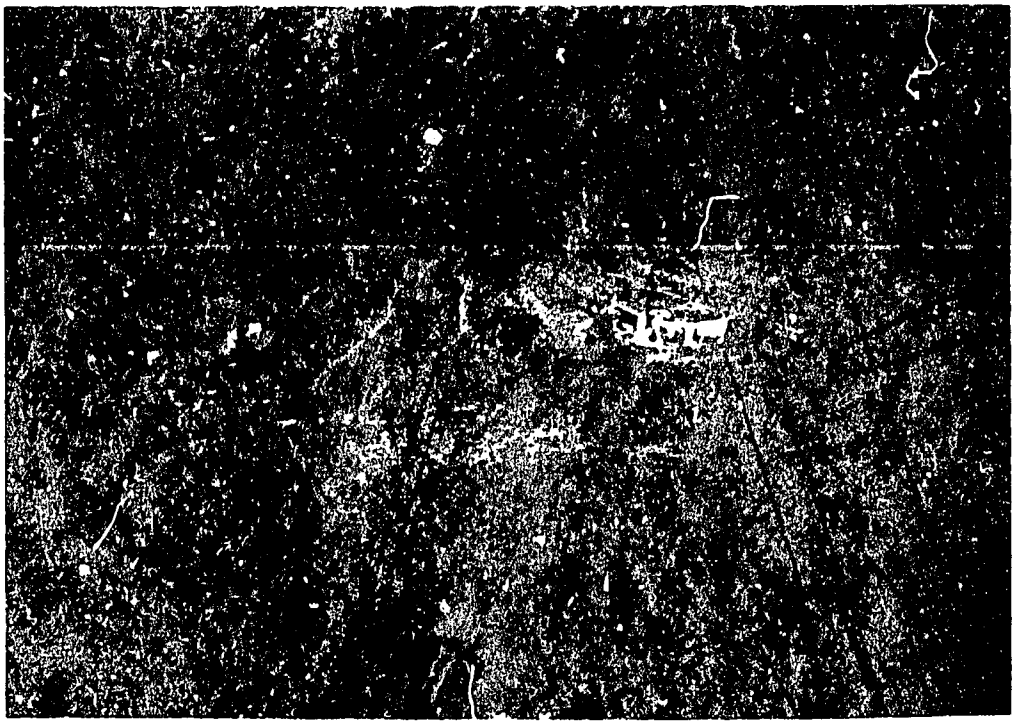
4.5 Conclusion

The analysis of highland farming systems demonstrates clearly the importance of subsistence rice production. Although returns to labour are low compared to many cash crop alternatives, hilltribe farmers divert a substantial proportion of their labour and land resources to the production of rice for home consumption. Our examination of the yearly labour calendar indicates periods of the year when surplus labour would be available for the establishment of permanent tree crops, an activity which would both stabilize steep, erodable land and increase cash returns to farmers.

Traditional Lahu house at Pahlo Red Lahu Village.

FIGURE 3 — Miang labour requirements — Pang Ma-O Village 1978 — Average of 20 households





In addition to the upland rice fields many highland pocket valleys are terraced and planted to paddy rice. Highland paddy rice yields are about double the upland rice yields.

Planting hill rice at Lahu hilltribe village of Huey Tadt after 7 years bush fallow. The rice crop is followed in the succeeding year by corn or sesame on about half the area before reverting to bush fallow.

A highland Thai farmer picking tea leaf to make the fermented tea product "miang". About 2 hectares per household is the average "miang" garden.

5 HIGHLAND RICE

5.1 Introduction

5.1.1 Nutritional importance

Rice is the basic subsistence crop of the highland people. TAHAP surveys of four households from different ethnic groups showed that rice provides approximately 80-90% of dietary energy and 60-80% of the protein intake. The sample was small, but thought to be representative of highland populations.

5.1.2 Source of rice

About half the rice consumed by the hilltribe people is supplied from rainfed hillrice grown in swiddens under the shifting agricultural systems. About one third is imported from the lowlands, and the remainder comes from paddy rice grown by the hilltribe people on valley floors.

Swidden yields are often less than 1 t ha^{-1}, but may be almost twice this in a good season and after a long fallow. The length of the fallow is declining and yields can be expected to decline, but no reliable data on yield stability are available. Paddy yields are higher, but the available area is limited and is not expected to increase significantly. The lower elevation and distance of paddy areas from the village can result in considerable work to carry the crop to the village. It is expected that rain-fed hill rice will remain the most important source of food for the hilltribe people.

5.1.3 Altitude and rice production

Villages of the opium producing hilltribes are often located at up to 1300 m altitude, but most hill rice is grown below 1000 m. One of the reasons for this is a lack of varieties suitable for high altitudes. Hilltribe people have preferences based on taste and cooking volume but yield is the major criterion in their varietal selection. Some early maturing varieties may be required to overcome food shortages before the main crop is harvested. The availability of varieties that would yield well at altitudes above 1000 m could make a significant contribution to hillrice production.

5.1.4 Calendar of hillrice activities

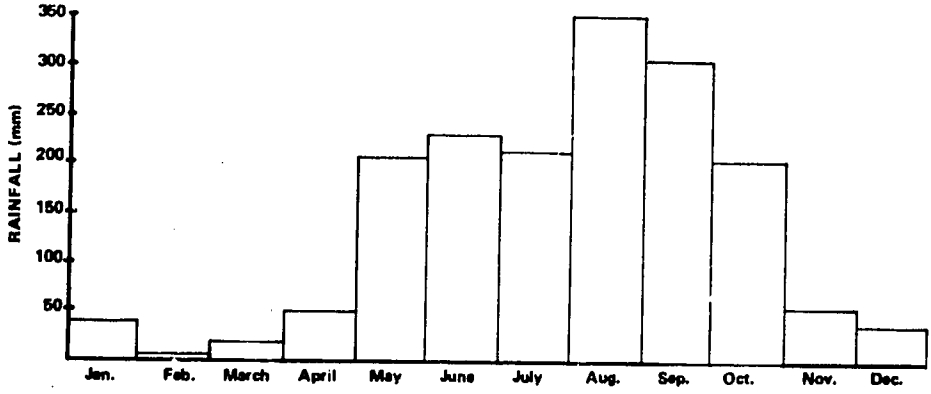
A survey of hillrice production in the highlands has shown that labour input is spread over a period of 9 to 15 months depending on the vegetative cover and the maturity date of the rice. Where the vegetation base is forest or a bush fallow the cutting o timber begins in January-February. Burning in March is followed by stick gathering and the construction of a field hut. Planting and weeding are done by hand, the latter in one or two operations or continuously from late June to August. The harvest of early varieties begins in August-September depending on altitude and tribal group, with the main harvest in October-November. Stooking, threshing and transport of grain to storage are completed in December.

Where the vegetative base is Savannah grassland as with the Akha in Chiang Rai the labour input into hill rice may commence in the late wet season (September-October) of the year preceding the planting of hill rice. The grass cover (2 to 3 m high) is slashed, burnt in October, and the cleared area cultivated by chipping hoe after the rains cease. These operations weaken the stoloniferous grasses and result in a lower labour input in land preparation in the January-March period.

5.2 Research

The initial aim of the TAHAP rice research programme was to define the major causes of low yields of hillrice at high altitudes, and following this, to screen local and exotic varieties for adaptation to the highlands.

FIGURE 4. Rainfall distribution at Pa Kia for the period 1973 — 1979



5.2.1 *Sites and varieties*

Three sites were selected:

(i) Pa Kia, a granite derived soil at 1450 m altitude;
(ii) Chang Khian, a granite derived soil at 1200 m altitude;
(iii) Phabujom, a limestone derived soil at 800 m altitude.

The growing season at these sites is defined largely by the rainfall pattern. The wet season commences in April/May and usually lasts until October/November. The average rainfall at Pa Kia is 1620 mm per year, and at Chiang Khian, 1720 mm. There are no reliable records for Phabujom. Figure 4 shows the monthly rainfall distribution at Pa Kia. The approximate average daily temperatures over the growing season are: Pa Kia, 18°C; Chang Khian 20°C; and Phabujom 23°C. No measurements of solar radiation were possible during the period when most of the work reported here was carried out.

The varieties used initially in this work were:

(i) Kichang, a cold tolerant variety from the Shan states of Burma;
(ii) Kichang X RD 1, F_9 generation (RD 1 is successful lowland paddy variety);
(iii) a variety from a Meo hilltribe village;
(iv) a variety from a Lahu hilltribe village;
(v) CMU 1 and
(vi) CMU 3, both selected by Agronomy Department, Chiangmai University from a collection made in Nan province, Thailand.

5.2.2 *Yields*

Table 4 gives some of the results of the first year's work (1978). Yields of most varieties of Phabujom were good, several varieties yielding about 5 t ha^{-1}. Lodging and spikelet sterility were major yield constraints. Lodging was severe with the Lahu and Khichang varieties at Phabujom and Chang Khian even though at Phabujom only 30 kg N ha^{-1} was applied.

5.2.3 *Spikelet sterility*

The panicle of the rice plant consists of a group of spikelets, each one potentially capable of producing a grain. The low yields at Chang Khian and Pa Kia resulted primarily from high spikelet sterility. In general, sterility was more severe at higher altitudes, although there were considerable differences among varieties. It probably resulted from the low air temperatures. Temperatures less than about 15°C have frequently been reported to induce serious sterility in rice and the most sensitive stage is during pollen formation. Degeneration of floral parts can also occur, and this was observed at Pa Kia where minimum temperatures of 15°C were relatively common. At this site, where there was no lodging, Khichang had the lowest percentage of sterile spikelets (40%). Some varieties were completely sterile at both Pa Kia and Chang Khian.

5.2.4 *Screening for spikelet sterility*

Genotype variability in sterility was examined more extensively at Pa Kia and Chang Khian in screening trials at these sites in 1979. Thirty-five varieties were grown; some from a collection of local highland varieties made by TAHAP staff, and some cold tolerant lines from the International Rice Research Institute (IRRI). At Chang Khian, the varieties Khichang and Silewah had the lowest spikelet sterility (20%); five varieties were completely sterile. At Pa Kia, Khichang and Silewah were also the best varieties, but were 40% sterile; twenty-five varieties were completely sterile. Unfortunately, at both sites the varieties with the

TABLE 4

Grain yields and per cent spikelet sterility in trials at Phabujom, Chang Khian and Pa Kia, 1978

VARIETY	PHABUJOM		CHANG KHIAN		PA KIA	
	Yield (t ha^{-1})	% spikelet sterility	Yield (t ha^{-1})	% spikelet sterility	Yield (t ha^{-1})	% spikelet sterility
Khichang	100% lodging	–	100% lodging	–	2.7	38
Khichang X RD 1	3.4	24	1.6	60	0	100
CMU 1	5.4	10	0	100	0	100
CMU 3	5.0	6	1.2	80	0	100
Lahu	100% lodging	–	1.5	67	1.3	66
Meo	5.3	9	0	100	0	100

lowest sterility tended to lodge. This is in contrast to the experimental work in 1978 (on bench terraces previously cropped for one year) where there was no lodging at Pa Kia even with the addition of 60 kg N ha^{-1}. In 1979, land was used which had been fallow for several years, and only 25 kg N ha^{-1} was applied. Total dry matter production of Khichang by heading, however, was 30% higher than in the first season, and this was probably a result of better soil fertility.

5.2.5 *Effect of altitude on other components of yield*

While per cent spikelet sterility is obviously an important varietal characteristic, it must be considered in conjunction with total spikelet number. A yield of 2.7 t ha^{-1} was obtained from Khichang at Pa Kia even though 40% of its spikelets were sterile. In most cases results have shown a trend of increasing spikelet number with increasing altitude. This trend, however, was not consistent for all varieties. It would be expected that soil fertility, temperature, and solar radiation (environmental factors varying with site) would interact to determine the number of spikelets developed on any variety.

The average grain weight was the lowest at Pa Kia and highest at Phabujom. The reduction was approximately 15% and this resulted in a further reduction in grain yield.

5.2.6 *Rate of development*

At Phabujom the average time to heading was 102 days, and to maturity, 134 days. At higher altitudes the lower temperatures extended the growth duration of all varieties, and the vegetative, reproductive and grain filling phases were all affected. Heading at Chang Khian was approximately three weeks later than at Phabujom, and at Pa Kia, about five weeks later. As very little rain falls after October, late maturing varieties at high altitudes may sufer from water stress during grain filling. In the screening trial at Chang Khian all except one of the best six varieties i.e., with lowest spikelet sterility, had headed by the beginning of October when rainfall may be expected to ensure grain filling.

5.2.7 *Yield potential at high altitudes*

Growth rate was highest at Phabujom and lowest at Pa Kia, but because of the effect of altitude on rate of development, total dry matter production at the three sites was similar. The term "Harvest Index" gives a measure of the efficiency of grain production. It is defined as the ratio of grain dry weight to total above ground dry weight. At Phabujom all varieties had similar harvest indices of approximately 0.4. All varieties at Chang Khian and Pa Kia which did not lodge had harvest indices considerably less than this, with the exception of Khichang which had a harvest indix of 0.3 at Pa Kia. If varieties with low sterility could be selected under the cool conditions of Pa Kia with a harvest index of 0.4, then grain yields of the order of 4 t ha^{-1} could be expected.

5.2.8 *Seasonal variations in yield at lower altitudes*

In an attempt to substantiate the findings of the first season's work at Phabujom, the varieties CMU 1, CMU 3 and the Meo variety were grown for a second season at that site. Yields in 1979 were approximately 20% lower than in 1978, probably due to poorer soil fertility. Growth of CMU 3 was visibly poorer than in the previous season and all varieties therefore received additional nitrogen fertilizer at head (20 kg N ha^{-1} in additional to 30 kg N ha^{-1} applied a month after emergence). Total production, grain yield, spikelet number and average grain weight of CMU 3 were all reduced. However, with CMU 1 and the Meo variety, grain yield and average grain weight were reduced, but not total yield or growth after heading. Good growth after heading is particularly important for high cereal crop yields as most grain production is a direct result of photosynthesis during this period. The yield potential for these two varieties was therefore the same in each season, but there appears to have been some restriction on grain growth in the second year. Measurements of hull size gave no evidence of a physical restriction. A proportion of final grain yield of rice (about 20%) usually comes from carbohydrates stored before heading and translocated to the grain during grain filling. The data indicate that the restriction on growth may have been an indirect one through some effect on retranslocation of stored reserves, which occurred to a much greater extent in 1978 than in 1979.

5.2.9 *Screening for yield and harvest index at lower altitudes*

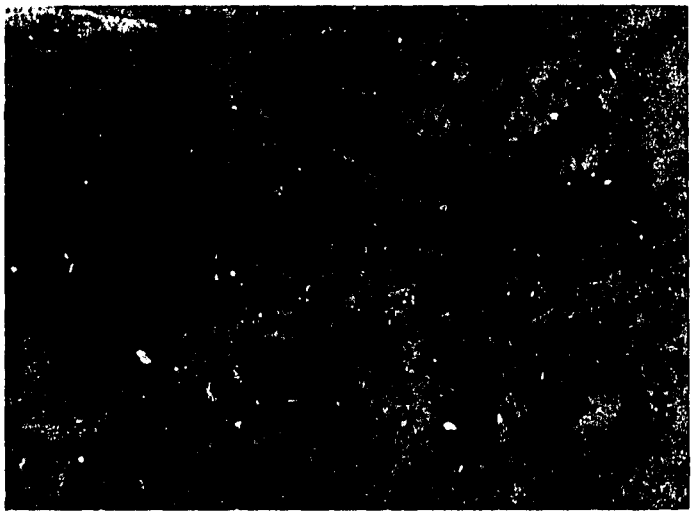
Thirty-five additional varieties were screened in small plots for adaptability to the Phabujom environment during 1979. Sixteen of these were upland breeding lines from IRRI and the remainder were from local collections. Fourteen varieties yielded over 4 t ha^{-1} and harvest indices ranged from 0.27 to 0.40. The higher the harvest index of a variety the better the chance that it will respond to improved fertility. In areas of altitude similar to Phabujom and where slope is not too great, fertilizer response trials with varieties selected on the basis of harvest index and yield would be warranted. Many of the varieties with higher values of harvest index are shorter than the traditional varieties (90-120 cm compared with 140-150 cm) and their success may depend on the efficiency of weed control. Upland rice yields are often severely reduced by weed competition and the taller leafy varieties are better competitiors.

5.3 Conclusions

On the basis of a descriptive analysis of growth of a number of rice varieties in the highland and some supplementary screening trials, it appears that initial improvement in subsistence agriculture on steep slopes at high altitudes will be mainly through varietal improvement. Evaluation of varieties collected from highland areas is continuing.

If the present practices of burning and minimum tillage continue, fertilizer would be of little benefit since storm rains would wash a substantial amount to the bottom of the slopes. In addition, the lack of soil conservation practices results in loss of topsoil containing essential nutrients released after burning. If population and land pressures become so severe that some form of stable agriculture is required, permanent soil conservation measures (possibly as bench terraces), will be necessary, and fertilizer inputs will be essential to maintain yield. This is most likely to commence in areas of lower altitude and slope and as mentioned previously, research on fertilizer use in these areas would be beneficial. At higher altitudes and on steeper slopes techniques for minimizing loss of soil fertility should be encouarged. The growing of legumes such as pigeon pea would be beneficial, and this is discussed in the section on grain legumes. There is considerable evidence to show that chemical weed control is technically possible, but relatively little information on the economics of this form of control in the highlands or its acceptance by hilltribe farmers is available. A combination of chemical and hand weeding may be more acceptable, and should be investigated.

TAHAP pioneered the use of commercial bank agricultural credit by Hilltribe farmers. The Headman of Pakia (left) and Mr. Seksak Wiboonjag of TAHAP (right) are checking credit accounts at the Mae Rim branch of the Bangkok Bank. The Pakia Meo villagers have repaid 100% of the credit in the first 3 years of operation.



TAHAP dry rice trials in the highlands.

6. GRAIN LEGUMES

6.1 Herbaceous Annual Legumes

6.1.1 Introduction

Surveys have indicated that the diet of highland people which is based on rice with small amounts of corn, vegetables and forest products is frequently deficient in protein. High protein feeds such as meat and legumes make up a very minor proportion of their total diet. Thus there appears to be considerable potential to use grain legumes in the highlands as a source of protein for humans or livestock. As numerous grain legumes are traded in the lowland markets, they could also be grown as cash crops.

In addition, grain legumes, because of their nitrogen fixing properties, may help to maintain soil fertility. One comprehensive study of grain legumes in the highlands has already been completed by Tiyawalee (1978) but it is essential to assess these legumes over several years at different altitudes and on varying soil types before reliable recommendations can be made.

6.1.2 Experimental Approach

Trials were conducted at Pa Kia at an elevation of 1450 m. They were conducted on bench terraces which were constructed by hand in early 1976. Standard experimental designs were used with three to four replications.

In both 1976 and 1977 a series of species adaptation trials were conducted to study such factors as variety, planting date and fertilizer input. Over the two years the following species were tested:– common bean *(Phaseolus vulgaris)*, lab lab bean *(Lab lab purpureus)*, cow pea *(Vigna unguiculata)*, soy bean *(Glycine max)*, rice bean *(Vigna umbellata)*, mung bean *(Vigna Radiata)*, black gram *(Vigna mungo)*, adzuki bean *(Vigna angularis)*, winged bean *(Psophocarpus tetragonobolus)*, chick pea *(Cicer arietinum)* and broad bean *(Vicia faba)*. Most species were planted in June, August and October; exceptions to this were chick pea and broad bean which were tested as cool season legumes and were planted in October or November. In 1976, the effect of fertilizer application (triple super phosphate and gypsum equivalent to 20 kg P ha^{-1} and 15 kg S ha^{-1}) was studied, but in 1977 the fertilizer was applied to all plots to reduce variability between plots. The cheap granular insecticide "furadan" was broadcast on all plots at planting but no other insecticides or fungicides were used because their use was not appropriate for subsistence agriculture in the highlands.

6.1.3 Results

Some of the yields are presented in Table 5. In 1976, the average yields (mean of plus and minus fertilizer) of lab lab, common bean and cow pea were 780, 498 and 189 kg ha^{-1} respectively for the June planting date. The corresponding yields of all three species were lower from an October planting with the overall average being only 57 kg ha^{-1}. Fertilizer increased the yields of common bean, lab lab bean and cow pea by 80, 18 and 18 per cent respectively. However, the use of fertilizer would not have been economic except on common bean planted in June. Mung bean and winged bean failed to produce any grain yields.

TABLE 5

The seed yield (kg ha^{-1}) of the leading variety of each grain legume tested at Pa Kia in 1976 and 1977. The results (corrected to 20% moisture content) are for a June planting date with an application of 100 kg ha^{-1} of triple super phoshate (20%P) and 60 kg gypsum (20%S). An exception is chick pea which was planted in November.

Scientific Name	Common Name	Year	Variety	Yield (kg ha^{-1})	Days to Maturity
Lab lab purpureus	lab lab bean	1976	Payee	843	300
Phaseolus vulgaris	common bean	1976	Red Kidney	646	80
Vigna unguiculata	cow pea	1976	TVU 37	202	150
Glycine max	soy bean	1977	Orba	1129	110
Lab lab purpureus	lab lab bean	1977	Rongai	810	240
Phaseolus vulgaris	common bean	1977	Rajung	897	90
		1977	Red Kidney	573	75
Vigna umbellata	rice bean	1977	Nepalese	656	120
Vigna angularis	adzuki bean	1977	Chien Chien	320	85
Vigna cambiens	cow pea	1977	Nepalese	318	120
Cicer arietinum	chick pea	1977	JG 62	610	136
		1977	L 550	540	136

In 1977, satisfactory yields were achieved from soy beans, lab lab, rice bean and common bean planted in June and from chick pea planted in November (Table 5). However, yields of adzuki bean, cow pea and black gram were low and mung bean again produced no crop at all. For the August planting date soy bean and lab lab produced 393 and 550 kg ha^{-1} respectively but other species failed to produce a crop.

6.1.4 *Conclusions*

Fungal diseases have been a major constraint on grain legume production at Pa Kia. Relatively infertile soils and a high incidence of cloud cover may also have contributed to low yields. Most of the legumes which appeared promising in these trials have been used in cropping systems at Pa Kia (see later section) and only the lab lab variety Rongai has proved reliable. At elevations similar to Pa Kia, Rongai is the only legume suitable for later plantings and hence the only one which can be used for following a corn crop. The early plantings have given the highest yields and perhaps soybean or common bean planted in May followed by potatoes in July would be a feasible system. Generally however, it would be safer to plant the herbaceous grain legumes at lower elevations where radiation is higher, fungal diseases less prevalent and the growth of plants more vigorous.

6.2 Agronomy of Pigeon Pea

6.2.1 *Introduction*

Cajanus cajan, commonly known as pigeon pea or red gram is grown primarily as a subsistence food crop in India, parts of Africa and the Caribbean. In various parts of the world it is also used for animal feed, erosion control, shading of coffee and tea plantations, green manure, windbreaks and fuel. In Northern Thailand, it is grown by some hilltribe groups for pig feed and is also eaten in small amounts as a green vegetables in the lowlands. Early trials by TAHAP indicated that pigeon pea was susceptible to insect attack but was not usually affected by fungal diseases. This was in marked contrast to most other grain legumes tested and was one of the main reasons for the intensification of research into the agronomy and varietal selection of this species.

6.2.2 *Experimental Approach*

The research program has given considerable emphasis to varietal selection. Most of the work has been carried out at Chang Khian (1100m) with secondary sites at Phabujom (800m), Nong Hoi (900m), Khun Wang (1300m) and Pa Kia (1450m). The program started in 1977 with 30 cultivars originating from the research institutions ICRISAT, IITA, and University of Queensland. These were reduced to 18 in 1978 and 10 in 1979. Three new varieties were also tested in 1979. In the first two years, plots consisted of single rows and varieties were assessed in terms of days to maturity, yield per plant and harvest index. In 1979 with fewer treatments and more seed, the varieties were tested in plots at low and moderate plant densities so that yields ha^{-1} could be estimated. No attempt was made to select one particular type because different types may be suited to different subsistence and cash crop situations.

Aspects of agronomy which were also investigated include fertilizer responses (P and S), plant density and planting date. Initially no crop protection measures were used but this produced highly variable results which were difficult to interpret. Consequently insecticides were used to control pod borers in 1978 and 1979. In all trials, pigeon peas were planted by hand, into chipped plots, with 100kg triple superphosphate and 100kg gypsum ha^{-1} applied at sowing. The crops were sprayed two to three times from early flowering onwards, to control insects, particularly pod borers. Crops were harvested by hand picking every 3 weeks. This involed 2 – 4 pickings depending on the variety and the planting date.

6.2.3 *Yields*

Table 6 gives yield and yield components for eleven of the twenty cultivars tested in rows. Varieties ranged from short early types (100cm), such as 4F-38, to tall late maturing cultivars (200cm), such as UQ68 and Lahu. There were significant differences in pods per plant and seed size. The local Lahu variety had more pods per plant than any other but its seed yield was only average, due mainly to a very small seed size. The Lahu variety also had a low harvest index. Virtually no rain fell after early October in 1978 but moderately good yields were achieved on poor stoney terraces and the high harvest indices demonstrated the efficiency of these plants under stress conditions.

Some good to excellent yields were recorded in the variety trials in 1979 (Table 7) although no rain fell after early October as in the previous year. Highest yields in the main trial were recorded by UQ34, a tall mid-season variety, with the second highest yields from the short early variety 4F 38. Yields from a density of 6 plants m^{-2} were on average 37 percent higher than those with 2 plants m^{-2}, but the magnitude of this difference varied between the varieties, UQ68, the highest per plant yielder in 1978, produced less than one third of UQ34 in 1979. UQ68 matured about one month after UQ34 and apparently the seed yield of UQ68 in 1979 was affected by moisture stress. There was

TABLE 6

The yield characteristics of some varieties of pigeon pea grown in single replicated spaced rows at Chiang Khian
Section (a) — 10 cultivars — was grown in 1978 — 79; and
Section (b) — 2 cultivars — was grown in the 1979 — 80 season

Cultivar	Height (cm)	Dry Matter (g plant^{-1})	Days to 50% flowering	Seed Yield (g plant^{-1})	No. of Pods	Seed Wt. (mg)	Harvest Index
(a) 1978 – 79							
UQ 1	172	127	173	68	208	104	0.35
UQ 17	124	43	143	36	118	82	0.46
UQ 34	126	45	135	38	100	120	0.45
UQ 50	113	84	150	58	182	124	0.41
UQ 55	126	99	165	50	109	120	0.33
UQ 68	204	181	195	86	300	110	0.32
UQ 70	107	67	165	54	259	74	0.45
4F-38	100	34	135	26	101	84	0.43
I-7182	125	44	143	39	131	102	0.47
Lahu	198	151	203	46	348	40	0.23
Mean	133	81	154	45	162	101	0.36
LSD (P < 0.05)	18.4	26.3	25	15.6	58.5	13	0.08
(b) 1979 - 80							
UQ 50	144	234	125	94	225	143	0.28
ICP 7035	177	272	132	89	104	292	0.25

a substantial increase in yield from F1 hybrid (I-C11 x MS) as compared to its parent. However, unless the crop becomes a commercial cash crop it is doubtful if hybrid varieties are warranted for this area. Nitrogen yields in the vicinity of 200kg N ha^{-1} (in the above ground vegetative portion) were recorded in one trial. On average, 45% of the nitrogen was in the stem and 55% in the leaf. These high nitrogen yields suggest that the plant has potential as a species for a cereal-legume rotation system.

6.2.4 *Plant Spacing*

Table 8 presents the results of a spacing trial with a dwarf variety which was selected at the University of Queensland and which has the rare characteristic of being insensitive to day length. At Chang Khian this variety, planted in early July, flowered after 50 days and final harvests were completed 4 months after planting. Maximum height was 60 cm. Yield per unit area increased with plant density although the difference in yield between 30 and 60 plants m^{-2} was not significant. There was a decline in both yield per plant and pods per plant as well as a slight reduction in seeds per pod and seed size with increasing plant density. However these reductions were more than compensated by the higher plant population. The ratoon crop produced very low yields because moisture stress in October and November restricted plant regrowth. This variety is a useful addition to the range of cultivars, since its short maturity time means that it could be used in a multiple cropping situation in relay with other crops, where as other pigeon pea varieties can only be used in mixed cropping or as a pure stand for an entire season.

6.2.5 *Hedge Row Plantings*

Another series of trials attempted to determine the optimum plant spacing when pigeon peas were grown in widely spaced rows. The results, summarised in Table 9, showed that plant size increased as the spacing between plants increased. Seed yield per metre of row was similar for 12.5 and 25 cm spacings (with the exception of UQ1 at Nong Hoi) but yields dropped considerably as the spacing was widened to 50 and 75cm. Plants were generally bigger at Chang Khian, the result of both site and planting date effects.

6.2.6 *Time of Planting*

Table 10 and Table 11 summarise the planting date experiments which indicate that earlier plantings (June) gave highest yields. Later planting resulted in smaller plants and larger differences in yield per unit area between the high and low plant density treatments. This effect was more apparent for the smaller 4F 38 variety than the tall types, Lahu or UQ 68.

The final experiment at Pa Kia, looked at the interaction of plant density and fertilizer using the

TABLE 7

Results from varietal trials at Chang Khian in 1979-80
(a) Main trial (b) Supplementary trial
The experiments were separated by a distance of about 100m.

Variety	Days to Flowering	Height at maturity (cm)	Seed Size (mg)	Yield at 2 plants m^{-2} (kg ha^{-1})	Yield at 6 plants m^{-2} (kg ha^{-1})
(a) Main Trial					
4f 38	110	110	94	735	1104
I 7182	130	200	114	634	952
UQ 34	134	225	123	1492	1850
UQ 50	134	140	125	420	473
UQ 55	153	213	126	186	422
UQ 1	153	229	112	684	964
UQ 70 R	160	150	88	742	878
UQ 68	174	243	111	403	506
Lahu	192	212	56	321	488
Mean	149	191	105	619	849

Variety	Days to Flowering	Height at maturity (cm)	Seed Size (mg)	Yield at 2 plants m^{-2} (kg ha^{-1})	Nitrogen Yield (kg N ha^{-1})
(b) Supplementary trial					
UQ 17	117	213	101	2043	145
UQ 34	130	219	123	2603	190
I-C11	142	197	119	1947	187
I-C11xMS	134	217	104	3007	215
UQ 70B	152	162	83	1027	175
UQ 70R	151	146	87	910	226
UQ 70Y	150	151	89	1417	222
Mean	139	186	101	1851	194

N.B. UQ 70R, B and Y refer to red, black and yellow seeded types of UQ 70 respectively.
I-C11 and I-C11xMS are a line from ICRISAT and the F1 hybrid of this line and another parent which was male sterile.
Nitrogen yield is the nitrogen yield held in the leaf and stem at flowering time.

TABLE 8

The effect of plant density on yield and yield components of the 'UQ insensitive dwarf' pigeon pea at Chang Khian in 1979

Density Plants m^{-2}	Yield (kg ha^{-1})	Yield per Plant (g)	Pods per Plant	Seeds per Pod	Seed Size (mg)	Harvest Index
7.5	445 c*	5.93	33.9	2.7	64	0.18
15	617 b	4.11	25.0	2.6	63	0.17
30	791 a	2.64	19.9	2.2	63	0.20
60	911 a	1.52	25.2	2.2	60	0.18
Mean	691	3.55	23.5	2.4	63	0.18

Ratoon Yields: 30 plants m^{-2} – 80 kg ha^{-1}
60 plants m^{-2} – 89 kg ha^{-1}

*Treatments sharing a common letter are not significantly different ($P < 0.05$).

local Lahu variety (Table 12). Grain yield increased as the plant density was increased from 1 - 8 plants m^{-2}. Yield of both pods and seed per plant gradually declined as the plant density increased but this was more than compensated by the increased number of plants. Thus for high altitude sites like Pa Kia, plant densities of at least 8 plants m^{-2} are required for maximum yields per unit area of the native variety is used.

TABLE 9

Effect of plant spacing within a row on (a) seed yield (g m^{-1} of row) of pigeon pea varieties 4F 38 and UQ 1 at Chang Khian and Nong Hoi.

Plant Spacing (cm)	Chang Khian 4F 38	Chang Khian UQ 1	Nong Hoi 4F 38	Nong Hoi UQ 1	Mean 4F 38	Mean UQ 1
12.5	213	267	154	299	183	283
25	238	262	175	253	206	258
50	171	226	108	191	140	208
75	136	183	94	180	115	181
Mean	190	235	133	231	161	233

(b) vegetative yield (g $plant^{-1}$)

Plant Spacing (cm)	Chang Khian 4F 38	Chang Khian UQ 1	Nong Hoi 4F 38	Nong Hoi UQ 1	Mean 4F 38	Mean UQ 1
12.5	63	188	47	132	55	160
25	93	306	64	150	79	228
50	102	424	69	173	86	299
75	111	433	79	207	95	320
Mean	92	338	65	165	79	252

6.2.7 *Conclusions*

Four types of varieties were selected for suitability for the highlands. These are:

(i) Dwarf short season - UQ insensitive dwarf;
(ii) Medium height, mid season - 4F 38;
(iii) Tall late maturing - UQ34, UQ1, UQ68; (of these three, UQ34 is preferred)
(iv) Medium height late maturing - UQ70 (yellow seed).

The most appropriate variety will vary with different situations. The UQ dwarf line is recommended as a relay crop sown either before or after other crops such as corn or sesame or potatoes. 4F 38 and UQ70 are recommended if crops are grown in pure stands for a full growing season (single crop) as a crash crop. The tall varieties are appropriate for subsistence cropping fields planted in rows or widely spaced single plants and they could also be used as shade in coffee plantations. UQ70, because of its leafy habit, is perhaps the best variety for soil fertility improvement.

Highest seed yields are obtained from early (May-June) plantings. The suggested plant densities for a June planting of UQ dwarf, 4F 38 and UQ34 are 30, 6 and 3 plants m^{-2} respectively, but for a July planting, these densities should be doubled. Insufficient data is available to make definite conclusions with regard to fertilizer. Moderate yields can be achieved without fertilizer and fertilizer probably would not be used for a subsistence crop. For a cash crop, fertilizer may be warranted, but to be economical, it would be necessary to achieve optimum planting dates and plant density. Insect damage can be severe in the grain filling stage and spraying to control pod borers is recommended for cash crops.

TABLE 10

Effect of planting date and plant population on yield and days to flowering of 4F 38 and Lahu at Chang Khian (kg ha^{-1})

Planting Date	4F 38 6 pl.m^{-2} (kg ha^{-1})	4F 38 12 pl.m^{-2} (kg ha^{-1})	Days to first flower	LAHU 6 pl.m^{-2} (kg ha^{-1})	LAHU 12 pl.m^{-2} (kg ha^{-1})	Days to first flower	Mean
19 June	2180	2310	106	1240	1120	173	1712
20 July	1330	1670	98	490	553	157	1011
20 August	290	560	104	70	110	151	257
Mean	1267	1513	103	600	594	160	993

TABLE 11

The effect of planting date and plant population on yield (kg ha^{-1}) of 4F 38 and UQ 68 varieties at Nong Hoi. Plant populations were 1.8 and 4 plants m^{-2}.

Planting Date	4F 38 1.8 pl. m^{-2}	4F 38 4 pl. m^{-2}	UQ 68 1.8 pl. m^{-2}	UQ 68 4 pl.m^{-2}	Mean
7 June	1650	2150	1980	1820	1877
19 July	320	560	910	1020	702
Mean	985	1350	1400	1410	1290

TABLE 12

The effects of plant spacing and phosphorus (P) (400kg rock phosphate ha^{-1}) and sulphur (S) (100kg gypsum ha^{-1}) fertilizers on the grain yield (kg ha^{-1}) of pigeon pea at Pa Kia in 1976 and 1977

Plant Spacing (cm)	O	S	P	S+P	Spacing Mean
100 x 100*	166	314	341	444	316
100 x 100	223	207	307	283	255
100 x 50	236	467	418	582	426
50 x 50	418	727	865	1124	784
50 x 25	657	1131	1041	1469	940
Fert. Mean	315	545	574	765	547

*Hills spaced 1 m x 1 m with 4 plants $hill^{-1}$

6.3 Mixed Cropping of Pigeon Pea and Upland Rice

6.3.1 Introduction

In the highlands, upland rice does not mature until early November when low temperatures and declining soil moisture make it virtually impossible to then plant another crop. Mixed cropping appears to be the only way to incorporate a legume into an annual cropping system involving rice. The possibility of growing rice with pigeon pea was investigated firstly because pigeon pea is already grown with cereal crops such as corn and sorghum in other countries, and secondly, some of the local farmers, particularly the Lahu, currently do grow pigeon pea mixed with rice. Where this is done however, the pigeon pea is planted at very low densities (1 plant to 10 m^2) and there appears to be scope for intensifying this system. An early experiment in a Karen rice field indicated that pigeon pea, at a density of 4 plants m^{-2}, planted six weeks after rice, grew satisfactorily without affecting rice yields. It was then decided to investigate the rice-pigeon pea relationship when rice was grown under moderately intensive management.

6.3.2 Experimental approach

The rice crops were planted either on terraces or on relatively flat land with a spacing of 25 cm between hills. Nitrogen (30kg N ha^{-2}), phosphorus (20kg P ha^{-1}) and sulphur (20kg S ha^{-1}) fertilizers were applied. The trials were carried out in 1978-79 at three locations covering a range of elevations, Nong Hoi (900m), Chang Khian (1100m) and Khun Wang (1300m). Three factors were investigated: variety and plant density of pigeon pea, and planting date of pigeon pea relative to that of rice. Pigeon pea varieties used were the short midseason type 4F 38 and the tall late types UQ1 or UQ68. These were planted at densities ranging from 1–8 plants m^{-2}, at the same time as rice, and 2, 5 or 7 weeks after rice planting.

6.3.3. Findings

At Khun Wang yields of pigeon pea planted 2 weeks after rice ranged from 70 to 570kg ha^{-1}. Yield increased with pigeon pea plant density and were higher for variety 4F 38 and UQ1. The pigeon pea treatments in this trial had no effect on rice yields, which averaged 1475 kg ha^{-1}. Some of the results from Nong Hoi are given in Table 13. At Nong Hoi, pigeon pea planted at the same time as rice, produced about half as much pigeon pea seed as the pure stand control and reduced rice yields to 45 percent of the control Pigeon pea planted two and seven weeks after rice had no effect on rice yields, but pigeon pea yields from the two week treatment were low and those from the seven week treatment negligible.

The results for Chang Khian are given in Table 14. The depression of rice yields increased as the density of pigeon pea increased, and the taller variety UQ68 had a greater depressive effect than 4F 38. Pigeon pea yields increased as the plant density increased and those planted in rice produced yields ranging from 55 to 100% of the controls. However, for equivalent plant densities, yields were 70 and 55% of the control for 4F 38 and UQ68 respectively. Pigeon pea yields from the 5 week planting date were negligible.

TABLE 13

The effect of pigeon pea planted with rice (Time O) and two weeks after rice (Time 2 wk) on rice and pigeon pea yields.The controls are pure stands of pigeon pea and rice.

Treatment	Rice Yield (kg ha^{-1})	Pigeon Pea Yield (kg ha^{-1})	Pigeon Pea % Establishment
Time O	1390	670	75
Tine 2 wk	3290	160	44
Rice Control	3050	-	–
Pigeon Pea Control	–	1390	94

TABLE 14

The effect of pigeon pea plant density on yield of rice and pigeon pea at Chang Khian in 1979-80. The pigeon pea controls for 4F 38 and UQ 68 were planted at 4 and 1.8 plants m^{-2} respectively.

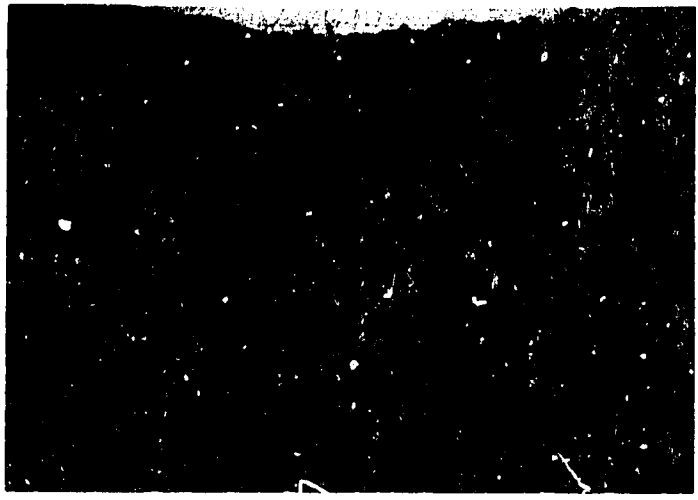
Pigeon Pea Plant Density (plants m^{-2})	Rice Yield (kg ha^{-1})		Pigeon Pea Yield (kg ha^{-1})	
	4F 38	UQ 68	4F 38	UQ 68
1.8	2309	1762	538	260
4	1620	1239	677	338
8	1288	277	932	381
Rice Control	2860	2860	–	–
Pigeon Pea Control	–	–	936	490

6.3.4 Conclusion

Overall, the results suggest that it will be difficult for farmers to obtain good yields of both rice and pigeon pea if the two crops are grown together. If pigeon peas are planted at the same time as rice (at a plant density sufficient to give reasonable pigeon pea yields), then rice yields will be severely depressed. If pigeon pea planting is delayed, even by as little as two weeks, rice yields will be unaffected, but pigeon pea yields are likely to be poor. The results at Khun Wang are to some extent, an exception to this trend, but at Khun Wang, the rice vegetative growth and subsequent rice yields were lower than the other two sites. Thus competition from the rice during the vegetative phase was less severe.

An alternative approach might be to plant pigeon peas at the same time as rice but in widely spaced rows (say 2m apart with 20cm between plants in the row). Cultural practices such as weeding and harvesting of rice would also be easier using this system. Some highland farmers, notably the Lahu, grow pigeon pea mixed with rice at very low densities, and it may be possible to increase output from this system by replacing the native Lahu variety with UQ34. However, if insect activity is high and the crops are not sprayed, then the greater yield potential of UQ34 may not be realised.

Contrasting varieties of pigeon pea (Cajanus cajan). On the left is the tall native Lahu variety which is used as a shade for coffee. On the right is the day length insensitive dwarf variety selected at the University of Queensland.



Mixed cropping of upland rice and pigeon pea (variety 4F 38) at Khun Wang in 1979.

Construction of bench terraces at Pa Kia. The project demonstrated that these terraces could be constructed using simple tools with a labour input of 50 man days per rai.

7. MULTIPLE CROPPING SYSTEMS AT PA KIA

With rising population and decreasing availability of agricultural land in the highlands, there is a need to investigate the possible introduction of some stable agricultural system to replace the current practice of shifting agriculture. Maize and rice are the major subsistence crops in the highlands and potatoes are sometimes grown as a cash crop. Accordingly, these crops were included in an investigation of a number of multiple cropping systems which are shown in Figure 5. The grain legume included had shown promise in previous trials at Pa Kia. The objectives of the study were (i) to assess the suitability of particular crop combinations and (ii) to examine the stability of yields with time.

There were four fertilizer treatments (a) nil; (b) mixed commercial (rock phosphate, gypsum, urea); (c) cow manure; (d) mixed commercial plus cow manure. Fertilizer was applied annually at the start of the growing season.

The experiment was marred by high variability, particularly after the first year. This was due to washing of topsoil along terraces and waterlogging in some areas. There were only two replications and very few conclusions can be drawn from the data.

In general, maize showed promise, and yields of 2.5 to 3 t ha^{-1} were obtained with the addition of fertilizer. It matures earlier than rice and can be harvested before the beginning of October. A second crop can often be sown before the maize matures and be well established before the dry season. However, water stress can still seriously affect the second crop and some work has begun on selection of earlier maturing maize varieties at Pa Kia.

The only variety of rice so far grown with any success at Pa Kia is Khichang, which matures about 170 days after sowing. Time of maturity often coincides with the end of the wet season and attempts to grow a second crop after rice (chick pea and broad bean) were unsuccessful.

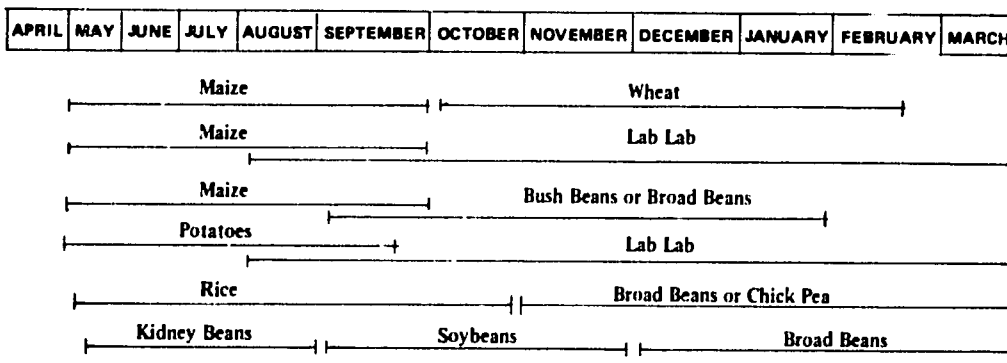
Many of the legumes suffered from fungal disease attacks and yields were poor, although the lab lab variety Rongai was grown for two years without disease with yields up to 1 t ha^{-1}.

There is insufficient information to draw any conclusions on yield trends with time, although the yield of crops not diseased showed no decline over the period of the study.

The growth duration of all crops at Pa Kia is considerably longer than at lower elevations and opportunities for successful multiple cropping in this area are therefore restricted. Systems with maize as a first crop appear most successful although disease and water shortage in subsequent crops pose major problems.

FIGURE 5

The yearly calendar showing planting, growth and harvest times of the crop combinations at Pa Ki.



8. IMPROVED PASTURES

8.1 Agronomy

8.1.1 Introduction

In the highlands of Northern Thailand, the exploitative nature of the shifting cultivation practices of opium growing hilltribes has resulted in a proportion of the natural forest being converted to savannah grassland. This grassland, dominated by *Imperata cylindrica*, is maintained by dry season wild fires which are a regular feature of the environment. When TAHAP commenced in 1972, it was believed that *Imperata* was a weed of little value which covered a large proportion of the highlands. However, it is now estimated that c. 4% of the forest cover has been converted to grassland. *Imperata* is a fire hazard in the dry season when young forestry plantations may be destroyed, and an erosion hazard during the early wet season when grassland is burnt. Despite these hazards, *Imperata* forms the basis of the cattle industry that exists today. The productivity of these grasslands is low however, and they support a stocking rate of less than 0.1 beasts ha^{-1}. Continuous grazing at higher stocking rates leads to a decline in the vigour of *Imperata* and invasion by unpalatable weeds.

In 1972 TAHAP began a series of experiments to determine the feasibility of rehabilitating the grasslands by the introduction of improved pasture species. It was envisaged that cattle raising on fenced grazed pastures would be a viable enterprise and a substitute for the current main cash crop of opium. By 1976, it became clear that some features of the existing cattle industry created obstacles to the introduction of fenced grazed improved pastures. While it was felt that interested farmer groups and development project personnel could be trained in the management of improved pastures, research was directed to alternative uses of pasture legumes for commercial seed production, orchard cover crops, ley rotations with rice and corn, and cut and carry supplementation of cattle grazing native rangeland.

8.1.2 Experimental Procedure

In the period from 1972 to 1975 TAHAP personnel obtained basic information required for the development of improved pastures in the 1200 to 1500 m elevation belt where most of the grasslands exist. Species were assessed in field plot trials in which data was initially collected for seedling development and first season growth where livestock were excluded by fencing. In second and third years, the species were alternately grazed and rested and dry matter yields were measured on several occasions after the plots had been rested for 10-12 weeks.

Fertilizer requirements of the successful species were also determined in this period (1972-75) by glasshouse pot trials and then field plot experiments to determine the appropriate application rates for those nutrients. Further trials determined the establishment methods and pasture and grazing management procedures necessary to maintain broad scale grass/legume pastures.

Pasture research in the period from 1976 to 1980 can be divided into four categories:–

1. Consolidation and completion of the species adaptation trials with emphasis on selection of grass and legume species for lower altitudes (below 1000 m);

2. Evaluation of improved pastures for cut and carry supplementation of livestock. This involved cut and regrowth studies of several grass legume mixtures to assess annual and seasonal drymatter production and protein content. The legume-grass balance of these mixtures was monitored over several years. A feeding trial with cattle was also carried out.

3. Assessment of low cost methods of establishment of improved pastures.

4. Measurement of the animal production from improved pastures and assessment of management to keep them stable and productive. This involved grazing trials at different stocking rates and agronomic studies of weed control.

8.1.3 Results

Species adaptation (a) above 1200 metres

In the zone above 1200 m Greenleaf desmodium *(D. intortum)*, Silverleaf desmodium *(D. uncinatum)*, Schofield stylo *(Stylosanthes guianensis)*, *Macrotyloma axillare*, white clover *(Trifolium repens)*, Kenya white clover *(T. semi-pilosum)* and lotononis *(L. bainesii)* were the best legumes but the last three were not persistent and did not thrive at all sites. With the exception of Schofield stylo, all legumes responded to fertilizer and the clovers and lotononis did not make satisfactory growth unless fertilizer was applied. Fertilized Greenleaf desmodium was favoured because of its persistence, palatability, high production, ease of establishment, long growing season and ability to compete with weeds and native grasses. Some selected legume yield data are shown in Tables 15 and 16. Of the grasses the most favoured species were setaria (*S. sphacelata* var. *sericea*), Hamil *(Panicum maximum)*, plicatulum *(Paspalum plicatulum)* and signal grass *(Brachiaria decumbens)*, the last species having the best dry season performance. The grasses generally showed a much smaller response to fertilizer than the legumes. Annual

TABLE 15

The annual dry matter yields (t ha^{-1}) of Greenleaf desmodium, Schofield stylo, Kenya white clover cv. Safari and white clover cv. Ladino, at Pa Kia (Elev. 1450m).

Treatment		1976	1977	1978	Mean
Greenleaf	–F	0.3	1.9	1.6	1.3
	+F	1.3	7.1	3.6	4.0
Schofield	–F	0.6	1.9	0.9	1.1
	+F	1.1	2.5	1.4	1.7
Safari	–F	0.2	0.3	0.1	0.2
	+F	1.1	1.9	0.4	1.1
Ladino	–F	0.1	0.1	0.04	0.08
	+F	0.8	0.3	0.1	0.4

–F = Nil fertilizer
+F = An initial application of 24 kg S ha^{-1} plus 40 kg P ha^{-1}

yields of Greenleaf desmodium and Nandi setaria were about 8 and 9 t ha^{-1} respectively.

Paspalum *(Paspalum dilatatum)* and Kikuyu *(Pennisetum clandestimum)* consistently had higher protein content than the other grasses, but their yield potential is much less than setaria or signal grasses. Kikuyu in particular has not thrived except in special places such as in drains and around cattle yards where fertility is high.

Species adaptation (b) 600 – 1000 m

In 1976, a series of legume yield experiments commenced at Phabujom (Elev. 800 m) and results are presented in Table 16. In contrast to results obtained at higher altitudes, Schofield stylo out-yielded Greenleaf in the first two years, but Greenleaf was again more persistent. Fertilizer increased the yields of Greenleaf by 60% compared to an average of only 10% for stylo, but stylo yielded relatively well without fertilizer.

Grass species were evaluated at Phabujom in 1977 in plots receiving split applications of nitrogen fertilizer totalling 150 kg N ha^{-1} yr^{-1}. The yields of some species are shown in Table 17. Signal grass gave the highest yields with setaria next. Kikuyu again performed poorly despite higher soil fertility and the fact that it was planted from cuttings.

TABLE 17

The total dry matter yield of protein content of four grass species in 1978. The grasses received 150 kg N ha^{-1} yr^{-1} but no other fertilizer.

Species	Dry matter yield (tonnes ha^{-1})	Protein Content %
Signal grass	10.6	8.7
Nandi Setaria	7.1	9.9
Paspalum dilatatum	6.2	10.6
Kikuyu	0.7	10.2

A third trial planted in 1977, measured the yield of several grass legume mixtures. These plots were chipped before sowing and given an initial application of phosphorus and sulphur fertilizers. The results are shown in Table 18. Cook and Endeavour stylos were associated with highest legume and total yields. The mean protein content of the legume and grass components were 17.2% and 9.6% respectively. The yield of Greenleaf was lower than the adjacent species adaptation trial and this was probably due to competition from the

TABLE 16

The productivity (t ha^{-1}) of Greenleaf desmodium and Cook stylo at Phabujom (800 metres) with (+F) and without (–F) fertilizer consisting of 100 kg gypsum and 400 kg rock phosphate ha^{-1}.

Treatment		1976	1977	1978	Crude Protein %
Greenleaf desmodium	–F	0.2	4.4	3.0	14.5
	+F	1.8	6.4	4.5	15.1
Cook stylo	–F	0.7	5.0	1.4	12.9
	+F	2.2	7.3	1.5	13.6

TABLE 18

The yield (t ha^{-1}) and proportion of legume of eight legume – grass mixtures at Phabujom.

Mixture	Total Yield 1978	% legume Oct. '77	% legume Oct. '78
Endeavour – Signal	7.5	92	42
Endeavour – Setaria	7.1	73	28
Cook - Setaria	7.0	82	42
Schofield – Setaria	5.8	64	29
Verano –	4.4	44	50
Greenleaf – Setaria	5.8	68	32
Centro – Setaria	5.1	30	32
Siratro – Setaria	4.1	42	22
Mean	5.8	62	35

companion grass Setaria. There was a general trend from legume dominance in the first year to grass dominance by the end of the second year. In large scale grazing situations where the pastures are established on cultivated fields, grass dominance is not usually a problem because germination of the grass is usually low and cattle selectively graze the grass. However, the results of this trial suggest that grass dominance could be a problem for cut and carry systems.

The productivity of four varieties of the shrub legume Leucaena *(L. leucocephala)* was studied in rows 2 m apart with 50 cm between plans in the row. They were cut at a height of 60 cm every 3 months, commencing in February 1978. Yields were lower in the first year because the plants were not fully established when cutting began. The variety Peru produced 5.12 t ha^{-1} of leaf in the second year, more than double that of the local variety. Average protein content of the leaf was 23% with little difference between varieties. The growth of Leucaena in this trial greatly exceeded that of earlier trials at higher altitudes with lower temperatures and less fertile soils.

Two other small trials were also carried out at Phabujom. One trial concerned the forage peanut *Arachis galbrata*. The variety Arblick produced 1.1 t DM ha^{-1} in the second year with average protein content of 18%. It spread from 20% of the plot area in the first year to 70% after two years. Another trial evaluated several lines of *Stylosanthes* species and one prostrate *S. guianensis* line, 32704A, produced higher yields and was more persistent than cv. Cook. Both Arblick and 32704A are promising enough to warrant further study but insufficient data are available to recommend them at this stage.

Fertilizer Experiments

Early glasshouse trials showed that the highland soils were generally deficient in phosphorus and sulphur and there were smaller responses (by Greenleaf) to the trace elements zinc, copper and molybdenum. In a subsequent field trial at Pa Kia (1974-76), Greenleaf showed a marked response to triple superphosphate up to 80 kg P ha^{-1} in the first year but in the third year there was no response. Sulphur at 15 kg S ha^{-1} increased yields by 70% but there was no further response to higher applications. This response was still evident after 3 years. In the first year there was also a marked response to trace elements but this response was not evident in the second year. As a result of these experiments, and because fertilizer proved to be vital for legume establishment in the absence of cultivation (see next section), it was recommended that for Greenleaf based pastures, 40 kg P ha^{-1} (as triple superphosphate) and 15 kg S ha^{-1} (as gypsum) should be applied at sowing time. This represented an outlay of $75 per hectare.

A cheaper source of phosphorus, rock phosphate (16% P), is available in Chiangmai and this was tested in a factorial experiment at Pa Kia with two levels of gypsum and four levels of rock phosphate (RP). Several species were involved and triple superphosphate was included to compare the relative efficiency of the two sources of phosphorus. In the first two years, there were large responses to P and 600 kg RP ha^{-1} doubled legume yields, but in the third year, yields were generally lower, and there was a positive response up to 200 kg RP ha^{-1} but no additional response to higher applications. An application of 100 kg gypsum ha^{-1} doubled yields in the first two years but there was only a 10% increased in the third year. Rock phosphate was more efficient, and the response to phosphorus

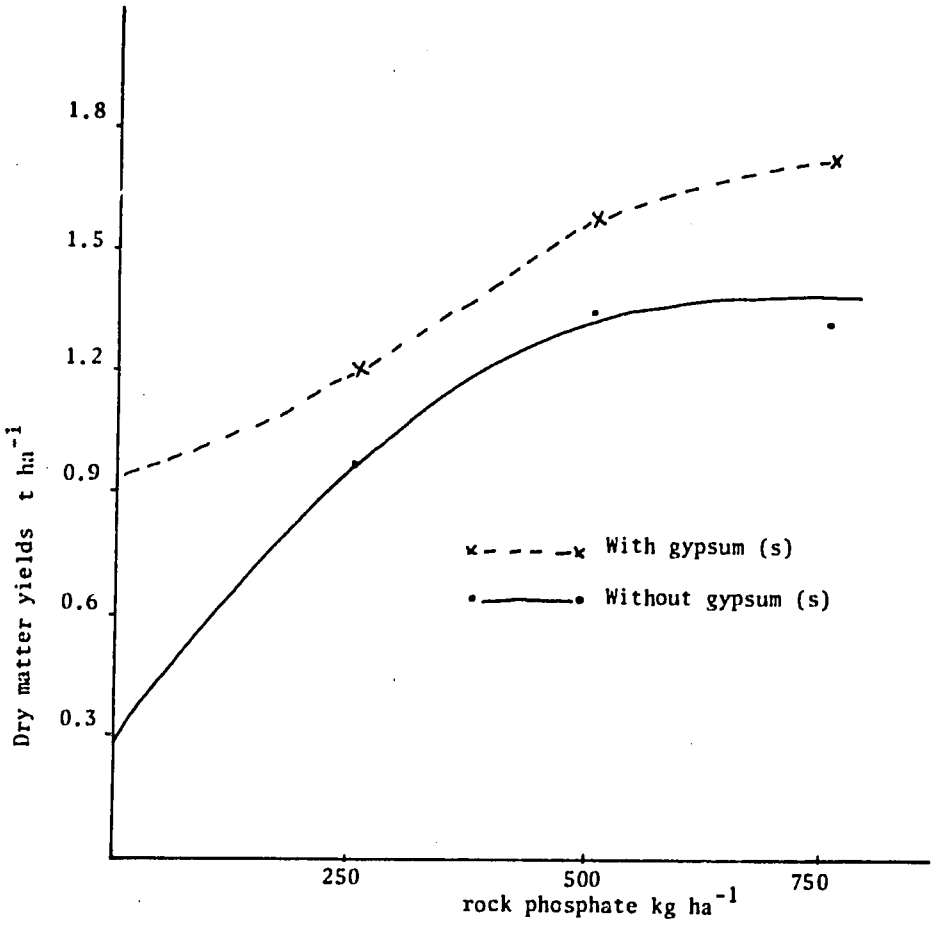


FIGURE 6. The effect of rock phosphate (16% P) on dry matter yields of Greenleaf desmodium when plots were harvested in January 1979. The results are the mean of two sites, Pa Kia and Phabujom.

was greater when sulphur was applied than when it was not. In the presence of gypsum, rock phosphate was half as efficient as triple superphosphate and one fifth of the cost. Gypsum had no effect on the phosphorus content of herbage, suggesting that the gypsum effect was a direct sulphur response rather than an effect on solubility, and hence availability, of phosphorus.

A second trial, planted in 1977 and conducted at Pa Kia and Phabujom, measured the effects of rock phosphate on both dry matter yields of Greenleaf. The results are presented in Figure 6. Dry matter yields increased with rock phosphate applications up to 750 kg RP ha^{-1}. Sulphur again substantially increased yields but in this trial there was no P x S interaction. Trends in seed yield were similar to those for dry matter yield and the linear correlations between seed and dry matter were highly significant.

As a result of these two trials, the fertilizer recommendation for establishing Greenleaf pastures was changed to 100 kg gypsum (18 kg S) ha^{-1} and 500 kg rock phosphate (80 P) ha^{-1}, which would reduce fertilizer costs (excluding transport) from $75 to $40 per hectare.

Establishment

A number of experiments were conducted to determine the methods necessary to establish legume pastures on a broad scale from seed. The effect of variation of the following factors was investigated:–

(a) fertilization
(b) grazing before sowing
(c) cultivation
(d) slashing after sowing

(e) fencing
(f) grazing pressure
(g) sowing into chipped contour strips.

Legumes studied included Greenleaf and Silverleaf desmodium, axillare, Schofield stylo, Lotonis and Safari (kenya) and Ladino (white) clovers. Establishment was assessed one year after planting.

Fertilization generally increased legume yields two to three fold and was particularly important in a weedy site. Grazing for several months prior to sowing doubled legume yields and reduced *Imperata*. Slashing regrowth after sowing reduced weeds and hastened legume dominance but did not affect legume yields.

The effect of cultivation was variable. At one site with good soils, *Imperata* was particularly vigorous and cultivation doubled legume yields. Cultivation also increased legume yields at an overgrazed weedy site. Generally however, cultivation has reduced *Imperata* yields and hastened legume dominance but had little or no effect on legume yield.

Fencing in this context is synonymous with exclusion of livestock and thus its effects have been influenced by the grazing pressure (i.e., number of livestock). At one site where the grazing pressure was light, fencing reduced the establishment of ladino clover. Generally however, fencing has increased the establishment yields of the tropical legumes, increased *Imperata* grass yields and reduced weeds. Heavy grazing pressure reduced legume yields and this was associated with greater weed competition particularly from *Eupatorium* species.

Legume establishment in chipped contour strips was investigated using six species. The strips, 60 cm wide were fertilized with rock phosphate (400 kg ha^{-1}) and gypsum (100 kg ha^{-1}). Cattle were excluded in the first year but the experimental areas was grazed at an average of 1 beast ha^{-1} for the next two years. Some of the results are presented in Table 19. Ladino cover and spread was poor despite excellent establishment in the first year. Axillare had the greatest spread (264cm) but differences in both spread and percentage cover between legumes apart from Ladino were not large. Greenleaf was attacked by leaf eating insects and its performance in this trial was much poorer than in other experiments. The sptread of the legumes was checked in the third year by *Eupatorium* which invaded the grassland between the strips.

The establishment of grasses sown into uncultivated grassland has often been poor. One experiment looked at the possibility of establishing grasses into established swards of either Greenleaf desmodium of white clover. Grasses were sown with both seed and cuttings. Establishment from seed was very low for setaria and zero for other species. However, from cuttings establishment was good (>70%) for setaria and signal, satisfactory (30% – 70%) for Hamil grass and Kikuyu, and unsatisfactory (<30%) for paspalum and *Paspalum plicatulum* cv. Hartley. Establishment and spread of the grasses was slightly greater in the clover sward than in Greenleaf.

TABLE 19

The spread and percentage cover (from a 2m strip) of six legumes planted into cultivated 60cm wide strips at Pa Kia. The measurements were taken 2½ years after planting.

Species	Width of row (cm)	Cover %
Greenleaf desmodium	182	28
Silverleaf desmodium	213	33
M. axillare cv. Archer	264	34
Schofield stylo	222	36
Kenya white clover	201	33
Ladino white clover	47	5
Mean	188	25

Cutting trials for supplementary feeding

A series of four experiments assessed the production of improved pastures at higher elevation for supplementation of cattle grazing range. Several grass species were transplanted from cuttings (4 cuttings m^{-2}) swards of Greenleaf, Ladino and Safari swards. Another trial assessed the production of Nandi Setaria – Greenleaf desmodium swards with 0, 1, 2 and 4 grass sprigs m^{-2}. Some of the results are presented in Figures 7 and 8. All swards received a topdressing of 20 kg ha^{-1} of rock phosphate and 100 kg ha^{-1} of gypsum in 1977 and 1979.

Total edible yields in all trials (and all years) were highest in the Nandi plots. In the Greenleaf experiment, Nandi increased total production by about 50% (mean of 4 years) compared to the pure legume control. However, there was a gradual decline in the proportion of legume in the Nandi swards which lowered the mean protein of the forage. Consequently nitrogen yields from the plots containing Nandi were only about 20% more than the control. Caterpillars and other leaf eating insects reduced Greenleaf yields in the last year. In the clover experiments, grass yields were equal to or greater than those in the Greenleaf trial, but legume yields were less, so that total dry matter and nitrogen yields were lower. Of other grass species tested, total yields from Kikuyu, paspalum and Hartley plots were only slightly greater than the control while Hamil and signal were intermediate between Nandi and the control.

In the grass density trial, grass yields increased and legume decreased as the grass density became

higher. Maximum nitrogen yields occurred in the treatment with 4 plants m^{-2} in the first year, but in the second and third years when legume suppression was more apparent, maximum nitrogen yields were obtained from 2 grass sprigs m^{-2}. After 3 years, the tillering setaria clumps planted at 4 sprigs m^{-2} had covered most of plot area, whereas the plots with 2 plants m^{-2} consisted of rows of setaria interspersed with rows of Greenleaf.

Weed Control

Weed control is the major technical problem of broad area fenced pastures. It is less of a problem in a cut and carry system where weeds are cut at the same time as the pasture. The main weeds are *Eupatorium* species, bracken fern and broad leaf annuals. Surveys in the highlands have shown that the incidence of *Eupatorium* is directly related to stocking pressure, i.e., the stocking rate and the length of time that the stocking rate is maintained. Thus the incidence of *Eupatorium* usually decreases with distance from the camp.

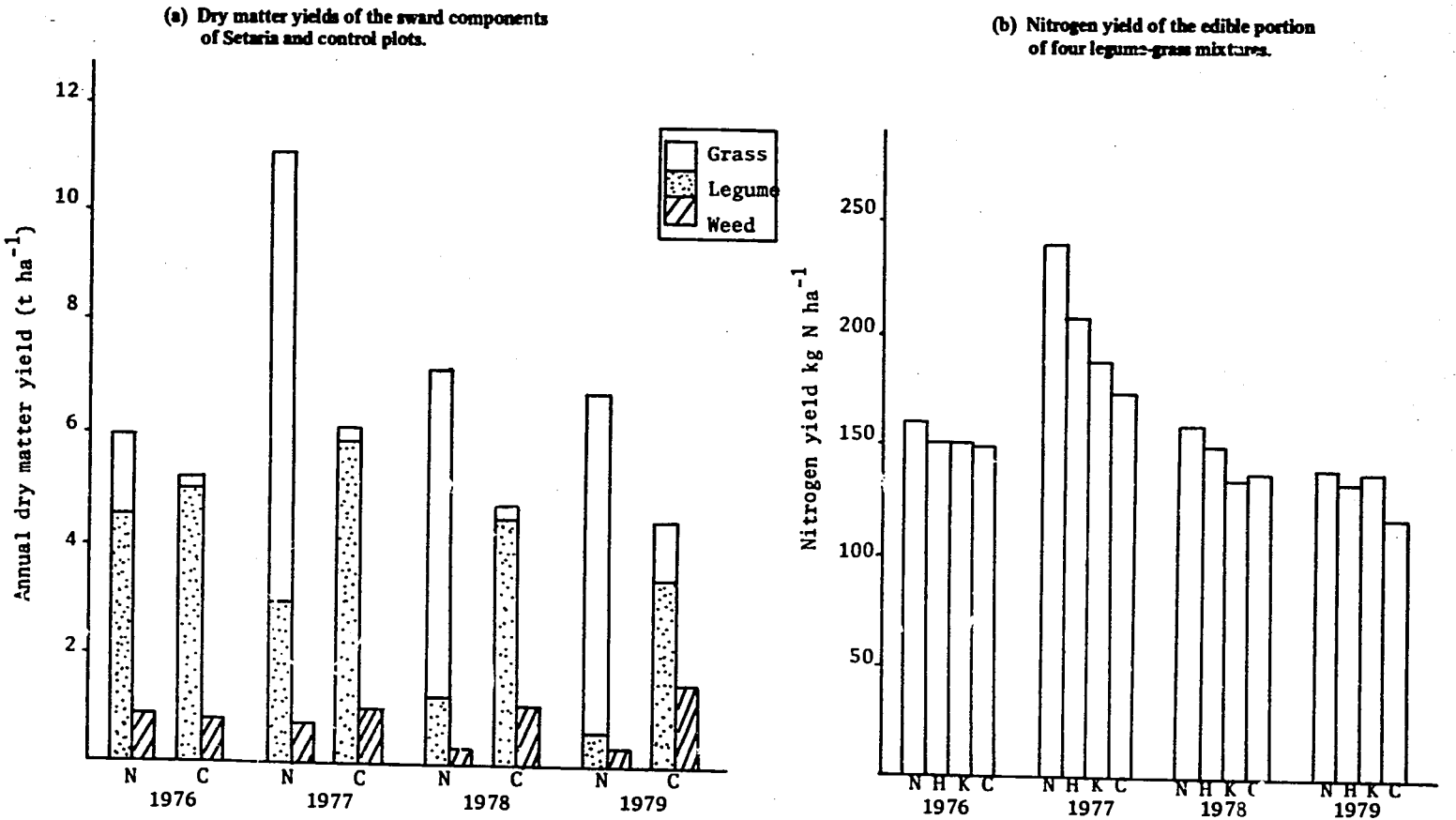
One experiment at Pa Kia looked at possible ways to rehabilitate a legume pasture which had become weed infested following 2 years continuous grazing. Weeds were depressed by the exclusion of livestock (fencing) and by 3 monthly slashing, but fertilizer and chipping of weeds in the dry season (without subsequent slashing) had no effect on weed yields at the end of the next wet season. Exclusion of livestock increased grass yields but suppressed legume yields especially in the absence of the slashing treatment, due mainly to excessive competiton from improved grasses.

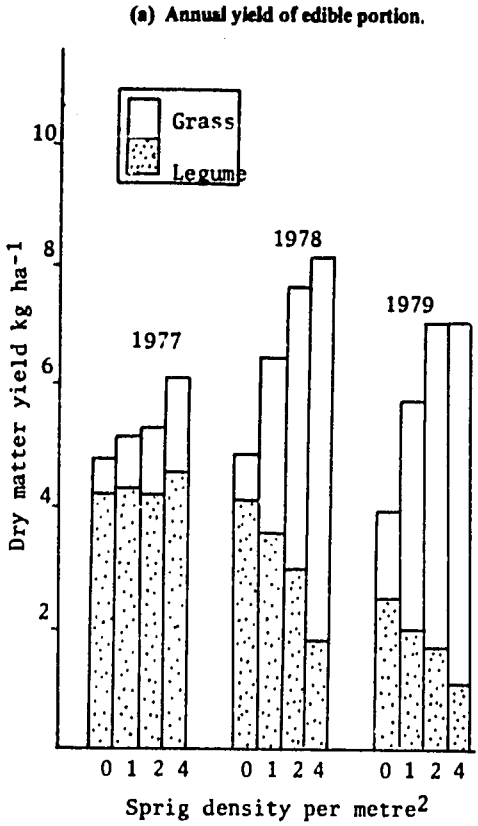
Other experiments have not looked at weed control specifically but the weed component was measured so that it was possible to make some estimate of treatment effects on weed growth. The data in Figures 8 and 9 show that weed yield is inversely proportional to improved grass yields. In 1978, the negative linear correlation between grass and weed yields in the grass density experiment was highly significant ($r^2 = 0.96$). In one fertilizer trial Greenleaf responded to both P and S in terms of legume dry matter yields, and there was a corresponding drop in weed yields. The negative correlation between legume and weed yields was also highly significant ($r^2 = 0.87$).

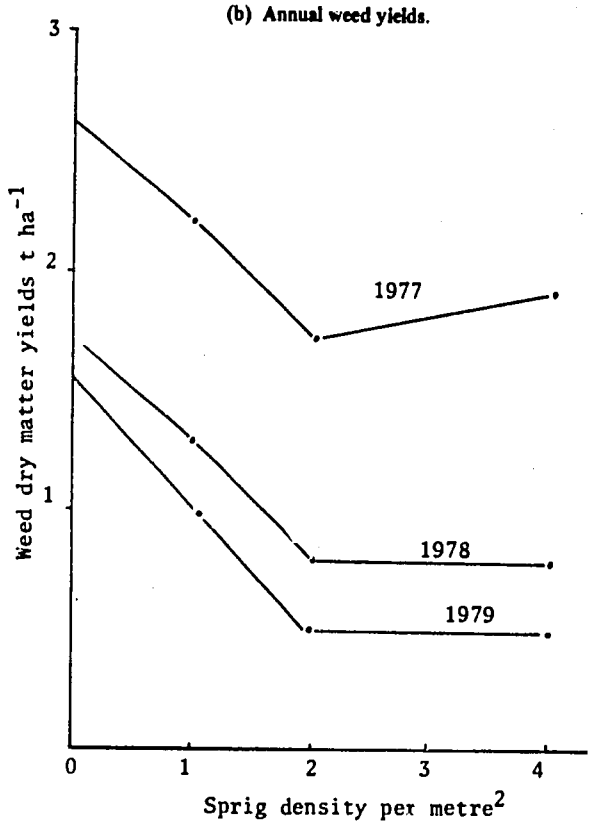
Conclusion

1. For grazed pastures, the best legume species are Greenleaf desmodium and *Macrotyloma axillare* at elevations above 1000 m and *S. guianensis* and Greenleaf desmodium below 1000 m. The best grasses are setaria and signal grass.
2. Phosphorus and sulphur fertilizers promote the growth of all legume species and are essential for Greenleaf based pastures. The recommended rates are 500 kg rock phosphate (80 kg P) ha^{-1} and 100 kg gypsum (20 kg S) ha^{-1}, at sowing time. Maintenance dressings at half these rates should be applied every two years thereafter.
3. Successful establishment into grassland requires a dry season burn (February), grazing of regrowth for several months, and oversowing of inoculated legume and of grass seed at the start of the wet season (June). Cultivation is not necessary but slashing of regrowth (grass and weeds) during the first wet season is desirable. Fencing is essential to exclude livestock in the first year unless the grazing pressure is very light.
4. For cut and carry forage, the recommended species are Greenleaf desmodium and setaria. Greenleaf should be sown in year 1 (as per points 2 and 3 above) and in the second year cuttings of setaria planted into the Greenleaf sward at a spacing of 100cm x 50cm. One rai (0.16 ha) of pasture will produce 1 tonne of dry matter per annum with a protein content of 12%, sufficient to supplement two head of cattle with 1 kg of dry matter per day.
5. The incidence of weeds in grazed pastures is reduced by the presence of sown grasses, fertilization to maintain a vigorous legume sward, regular (3-4 months) slashing, and control of grazing pressure so that a complete ground cover is maintained.

FIGURE 7. The yields of mixed swards of Greenleaf desmodium with Nandi setaria (N), Hamil grass (H), Kikuyu (K) or control (C) containing only the native grasses.







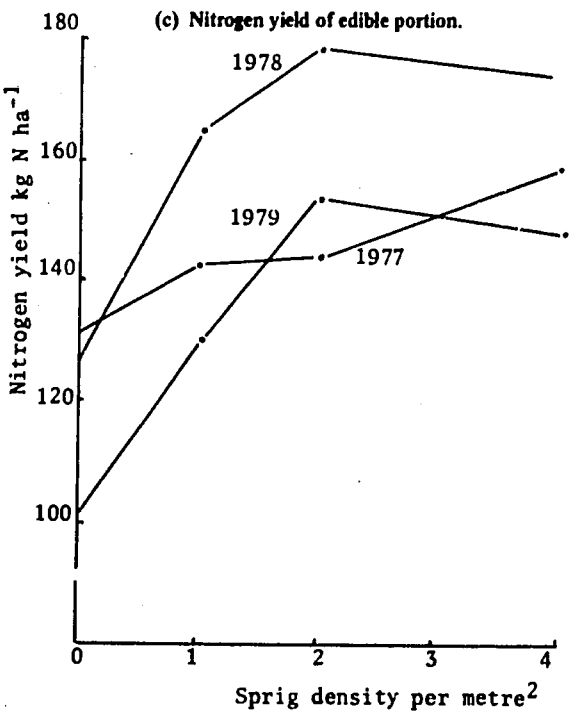


FIGURE 8. The effect of density of sprigs of Nandi setaria planted in June 1977 on yield components of a sward of Greenleaf desmodium.

8.2 Animal Production from Improved Pastures

8.2.1 Introduction

Following the early species adaptation and fertilizer experiments (1972-76) a series of grazing trials were commenced. The purposes of these trials were:

(i) to study botanical changes in the pastures under grazing and to assess pasture stability in a grazing situation;

(ii) to obtain information on animal production from improved pastures and hence assess their economic potential;

(iii) to assess the management requirements needed to maintain the pastures in a productive form for several years.

8.2.2 Experimental Approach

The first trial conducted at Pa Kia compared the productivity of cattle grazing improved pastures at a stocking rate of 1.04 beasts ha^{-1} with others grazing native range (based on *Imperata cylindrica*) at an estimated 0.06 beasts ha^{-1}. Paddocks were sown in 1974 and 1976 to a mixture of Greenleaf desmodium, Schofield stylo, axillare, white clover, setaria and signal grass. The pastures were fertilized with phosphorus and sulphur and weeds were cut twice annually.

In the second study also at Pa Kia, pastures were grazed at stocking rates of 1.5 and 3.0 beasts ha^{-1}. Within each stocking rate treatment, there were four pasture mixtures; (i) axillare-signal grass; (ii) Greenleaf-signal grass; (iii) Greenleaf-setaria; (iv) Greenleaf-*Paspalum dilatatum*-*Paspalum plicatulum*. Phosphorus and sulphur fertilizers were again used and weeds were slashed four times per year. The animals within each stocking rate treatment were subdivided into two groups one of which received an anthelmintic treatment to control internal parasites. Pasture yields were estimated from cut quadrats in the first trial and from a visual ranking technique in the second trial.

A further study was conducted at Khun Wang where a breeding herd grazing a sward dominant in *Desmodium intortum* cv. Greenleaf was divided into two groups, one of which received a monthly supplement containing all important minerals except nitrogen.

8.2.3 Results

In the first experiment, there was a rapid decline in perennial stylo and white clover, and a more gradual decline in the amount of grass and Greenleaf desmodium. The axillare component increased. The decline in the grass component was due to a reduction in native grasses. The sown improved grasses increased but were always a very minor component of the total production. There was a marked increase in weeds (mostly *Eupatorium adenophorum*) in this trial to the extent that weeds accounted for over half the total dry matter in the last year. Live weight gains of cattle grazing improved pasture significantly ($P<0.05$) exceeded those of cattle grazing native rangeland (173 cf. 39 g hd^{-1} day^{-1}). The primary difference between the two pastures occurred during the wet season.

The second trial was affected by fire and some sections had to be withdrawn from the experiment. In the paddocks which were not burnt, the legume component increased from 25 to 35% of the total while the native grass decreased from 50% to 30%.

Most of these changes occurred in the first six months after grazing commenced. The sown grass component gradually increased over the duration of the trial (18 months) from 5% at the start to 20% at the end. The weed component accounted for about 20% of the total and was stable at this figure throughout the trial. The stocking rate had no effect on the proportion of each component although total yields of the lower stocking rate were roughly 40% more than the higher stocking rate treatment. Total yields were lowest in the late dry season and gradually increased to reach a maximum in the late wet season. The average nitrogen content of the legume, sown grass and native grass components were 2.2, 1.2 and 0.8 respectively. Average nitrogen content of edible forage in the early dry, late dry and wet seasons was 1.1, 0.8 and 1.7% respectively.

There were no significant differences in liveweight gains in the four treatments over the duration of the experiment, but this was probably in part a consequence of the fire. During the mid and late wet season, animals receiving anthelmintic treatment gained significantly ($P<0.05$) more weight but this difference subsequently disappeared. Over the first year, cattle receiving anthelmintic gained 60% more weight than those that did not, and animals stocked at 1.5 beasts ha^{-1} also gained 60% more than those at 3.0 beasts ha^{-1}.

In the third trial, mineral supplement had no significant effect on liveweight gains. These gains were of a similar order to those recorded for breeding animals in studies conducted elsewhere and the mean liveweight gain of young animals was higher than that recorded in any other studies with improved pastures. It was concluded therefore, that mineral deficiencies were not restricting the productivity of cattle on this pasture.

8.2.4 Economics

The capital outlay for a fenced improved pasture in the highlands is about ฿ 1000 per rai. Approximately half of this investment is for cattle and the balance for fertilizer, seed, fencing materials and transport. Animal production from the

second year onwards should be 25kg liveweight rai^{-1} $year^{-1}$ worth at least ฿ 200 rai^{-1} $year^{-1}$. Considerable cash income could also be derived from Greenleaf seed sales each year provided a market is available. However, it is clear that if charges are made for interest and labour, then the enterprise will not be economically viable to a farming group at current prices. Farmers in many villages already own cattle however, and if cattle are not costed, then a farmer could recoup his investment in improved pastures in three years.

However, social constraints such as the farmers' non-commercial attitudes to cattle production, and the problem of land tenure and limited labour availability, work against rapid acceptance of this technology. In addition, budgets based on costs and returns per unit area may not be valid until land becomes more limiting. On the basis of returns to capital, utilization of improved pasture as a cut and carry supplement fed to cattle grazing native pastures is the most economic proposition. This system reduces the inputs for weed control and there are opportunities to reduce costs of fencing and maintenance fertilizer (e.g., manure from nearby cattle yards). The free resource of native rangeland is used in conjunction with the improved pastures and farmers would be able to recoup their investment in improved pastures within two years.

8.2.5 Conclusions

In the highlands, conventional improved pastures are technically feasible and economically viable in some circumstances but they are not yet socially acceptable, except perhaps in the form of a cut and carry supplement to cattle managed under the traditional system. In spite of this it is conceivable that development projects will sponsor improvement pasture projects and for them, site selection, stocking rate and weed control will be the main problems of pasture management. The following recommendations are based on experience of other sites as well as on the three trials described here.

1. Sites should have relatively gentle slope. Steep sites cannot be grazed efficiently and bare areas caused by cattle slipping down steep slopes are susceptible to weed invasion. The site should have a low incidence of weeds, especially *Eupatorium adenophorum*.

2. A stocking rate of 1.5 beasts ha^{-1} is recommended. Pastures will support higher stocking rates during the wet season but there must be sufficient carry over for the dry season. Overgrazing leads to bare areas of ground which will allow weed invasion.

3. If areas of native pastures are available these should be used in conjunction with the improved pastures during the dry season.

4. Weed control is vital and it is recommended that weeds should be slashed at least three times per year. Improved grasses such as setaria, and fertilization to maintain a vigorous legume stand, will also help control weeds.

5. Drenching with anthelmintics is desirable.

8.3 Cattle grazing in forest plantations

8.3.1 Introduction

Imperata grassland has some unfavourable watershed characteristics and it is the policy of the Thai government to plant trees in areas of grassland that occur at high elevations. This reafforestation program will reduce the area of native pastures available to highland cattle. Experiments in other countries have shown that livestock can be grazed in forestry plantations without damaging the trees and this technique may also be applicable in the highlands of Thailand.

8.3.2 Procedure

Species of *Eucalyptus* and *Pinus* were planted in 1976 without and with fertilizer containing nitrogen, phosphorus, potassium and sulphur. There were three grazing treatments. Cattle were introduced either one or two years after planting of the trees and the third treatment was an ungrazed control. The areas with cattle were grazed on a rotational basis at an average stocking rate of one beast per hectare.

8.3.3 Findings

The results are summarised in Table 20 and Figure 10. Initially, the growth of the Eucalypts, especially *E. camaldulensis* was faster than the pines but after 3½ years, the pines outstripped the eucalypts in both percent survival and height. The slow initial growth of the pines was a consequence of their greater branching habit (this was also true to a lesser extent for *E. grandis*) and height was therefore not a good indication of early seedling vigour. Fertilizer appreciably increased the growth of eucalypts in the first year and this differnece was maintained in subsequent years. However, fertilizer had no effect on the growth of *Pinus* species (Fig. 9). There was no clear pattern to the effects of grazing (Table 20). The height of the trees (especially the pines) was lowest in the plots where cattle were introduced after twelve months but the differences were small and the grazing treatments had no effect on percent survival of the trees.

The results suggest that forestry and livestock industries can coexist at least until the growth of

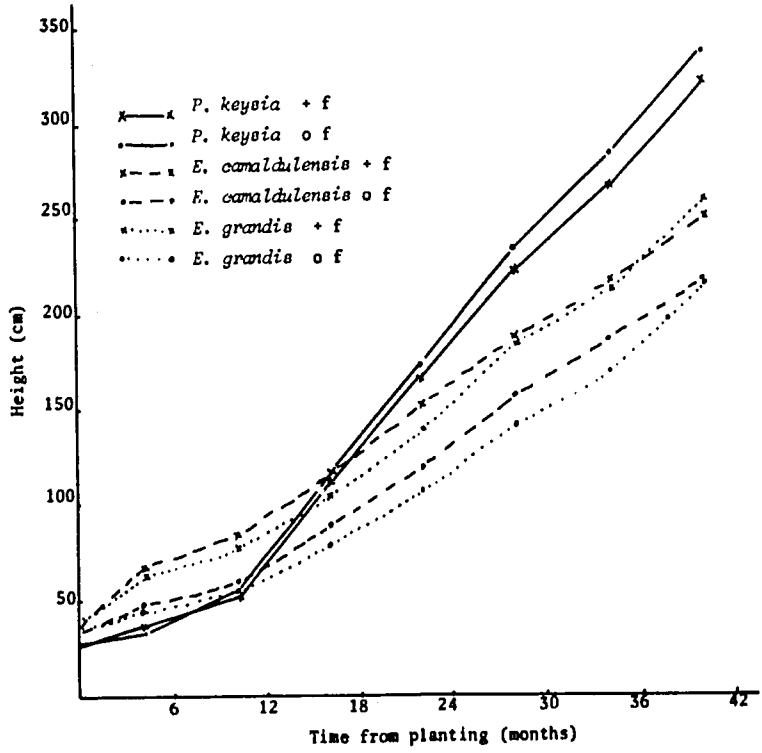
the trees produces a closed canopy. The system in native rangeland is limited by the fact that the grassland is invaded by *Eupatorium* weeds unless the grazing pressure is very light.

TABLE 20

The effects of grazing on growth of *Eucalyptus camaldulensis, Eucalyptus grandis* and *Pinus keysia*, three and a half years after planting at Pa Kia.

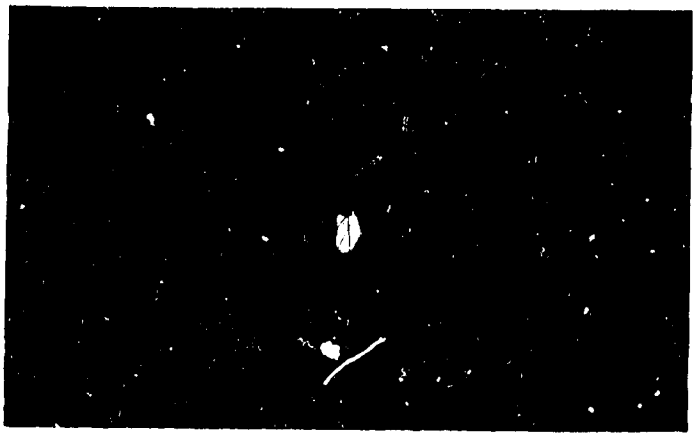
Species	Cattle Introduced After 12 months	24 months	control	Species Mean
(a) Tree Height (cm)				
E. camaldulensis	226	248	232	235
E. grandis	214	262	243	239
P. keysia	312	339	335	329
Grazing Mean	251	283	270	268
(b) Survival (%)				
E. camaldulensis	68	55	55	59
E. grandis	51	59	56	55
P. keysia	96	92	95	94
Grazing Mean	72	69	69	70

FIGURE 9. The effect of fertilizer on the growth of *Eucalyptus* and *Pinus* species.



Cattle grazing Greenleaf desmodium pastures at Pa Kia.

Weeds were a major problem in improved pastures. Photograph shows Eupatorium and bracken fern invasion of Greenleaf desmodium pastures following grazing and Doi Chiang Dao in the background.



A group of cattle grazing native pastures (Imperata cylindrica) under reafforestation with pine trees at Khun Wang, a key village of UNPDAC.

9. ANIMAL PRODUCTION RESEARCH

Research was mainly directed at large ruminants but sheep and pig research was also conducted. The animal production research program began in 1976 with an intensive survey of the ruminant industries of the northern highlands to determine the problems of the ruminant industry and to define its operation in biological, sociological and economic terms before commencing a large scale research program. The survey and the subsequent nutrition program were the first research projects concerning animals in the region.

9.1 The Initial Survey

9.1.1 Ownership

A total of 42 villages comprising 1180 households representing the seven major ethnic groups of the region were visited and questioned about many aspects of ruminant production.

Ruminant livestock, mainly cattle and buffalo, occupied an important position in the culture of some tribal groups but they were not usually raised specifically for economic profit. Hilltribe farmers obtained cattle by purchase, payment of agistment fees, as a gift or by inheritance. They were raised primarily as an insurance against crop failure, an attitude that prevented sale of stock even when herds exceeded optimal sizes. Use of stock for draught was a minor activity restricted to those highland areas with favourable terrain; some pack cattle were used to transport miang (fermented tea).

It was found that the largest herds of cattle were kept by the Lisu and the proportion of households owning cattle or buffalo in a village varied from about 33% for the Yao to 88% for the Karen. The most common number of cattle and buffalo owned per household over all ethnic groups was two. In some cases this comprised a pair of draught animals although more commonly it was a cow and calf. The survey demonstrated that the ethnic groups had different attitudes to livestock and agriculture; for example, the Yao were seen to be striving to enter lowland areas and large numbers of ruminants are not easily accommodated in that system. The Meo sacrifice cattle as a necessary part of funeral celebrations while the Akha use buffalo to a lesser extent in a similar role. The Khon muang and Karen keep buffalo to cultivate paddy fields while most other ethnic groups do not have access to paddy lands. Attitudes toward large ruminants varied among ethnic groups although these differences were diminishing as contacts among the ethnic groups and between them and the lowlands increased.

9.1.2 Management

Management inputs for cattle and buffalo were universally low. No additional feed was offered and in all cases villagers required their animals to survive and produce under these conditions. Feed quality was not recognized by villagers as a problem although they did consider they dry season to be the most difficult period of the year. Veterinary treatment was provided occasionally, usually at the instigation of the owner of agisted stock in the case of injectable drugs, or by owners themselves where native remedies were utilized.

Cattle and buffalo returned to the village or a camp each evening, thereby restricting grazing to a maximum of twelve hours per day. This practice is dictated by topography, because cattle cannot graze comfortably on steep slopes in the dark, and by the need to minimize theft of stock. Tending of stock during grazing was practised occasionally to minimize theft and losses to predators especially where stock were tethered near paddy lands at lower altitudes. Cattle and buffalo grazed natural pastures at stocking rates that varied between seven and twenty-five hectares per beast. Weaning and castration were not regular management practices. Bull to breeding cow ratios averaged 1:4.3 for cattle and 1:2.0 for buffalo which, together with the low total management input, precluded any selective breeding.

9.1.3 Income

Income was derived through sales, agistment, leasing of working animals and use as pack animals. Sales and purchases seemed to follow an annual pattern in some villages; cattle were bought at a time of the year when villages had surplus cash and sold when reserves were exhausted. Another cycle involved the sale of stock to lowland farmers for paddy cultivation followed by repurchase at the end of the rice season at a lower price. Prices for cattle and buffalo in the highlands were found to be lower than those in the lowlands and a general upward trend in prices over twenty years to 1976, and particularly the years 1970 to 1976 was recorded. Agistment of cattle owned by lowlanders was practised in 30% of the villages surveyed. Usually the progeny were divided between the agister and agistee in an unwritten agreement although occasionally contract agreements were employed. Leasing of working buffalo was practised primarily by the Akha ethnic group residing in close proximity to the lowlands. Rental charges varied from 15 to 150 tang (= 10 kg) of rice. Pack animals are used by some miang producers in isolated areas to transport their product to roads serviced by motor transport. An owner of pack cattle charges fellow producers a small fee for transport to produce a total estimated income of 350 Baht per year.

9.1.4 *Regional movements of ruminants*

The net movement of cattle out of northern Thailand to elsewhere in Thailand was supported by illegal movement of cattle across borders, primarily between Thailand and Burma. Disease control measures exist for cattle imported legally and a similar check is maintained by the Karen and Shan persons controlling the border areas where illegal imports probably occur.

9.1.5 *Productivity*

Productivity data such as age at first calving, length of calving interval and age of maximum liveweight obtained from the survey were variable and were subsequently tested as part of the definition studies. In general, it seemed that productivity was low. The principal problems of the highland cattle and buffalo industries indicated by the survey were: disease, theft, predators and nutrition. Diseases of importance were foot and mouth and haemorhagic septicemia; vaccines against both diseases are produced and are readily available in Thailand. The problems of theft and predators were related to the low management input levels but improvements in management were unlikely unless significant increases in productivity could be demonstrated. It was concluded that nutrition was the principal limiting factor in the technical sense.

One interesting conclusion from the survey was the apparent economic superiority of the buffalo in the highlands. However, the areas to which the buffalo was adapted were far more limited than those areas in the highlands to which cattle were adapted. Other ruminant species were included in the survey but they were not of great significance. Sheep were not raised in any villages as a result of the initiative or preference of their owners. Low productivity and high mortality restricted productivity. Goats raised by highlanders were politically unpopular in development projects unless well controlled. As villagers seemed to prefer to sell all of their goats rather than increase management inputs, little further work concerning goats was conducted by TAHAP.

9.2 Results of Cattle Production Research

9.2.1 *Definition Studies*

The survey provided valuable sociological, economic and biological information, but little data concerning the productivity of highland cattle. A series of studies designed to provide further insight into the productivity of cattle in the highlands were therefore initiated.

9.2.2 *Estimation of liveweight*

Lack of sophisticated equipment and difficult access to remote villages made it necessary to develop relationships between various body measurements and liveweight so that liveweight could be estimated where scales were not available. One hundred and fifty-one sets of data concerning girth circumference, height, age and liveweight were collected and the data analysed by regression and bivariate curvilinear analysis. The most useful predictive relationship was between liveweight (W) in kg and girth circumference (g) in cm of the form:

$$W = 0.0102g^2 - 0.0120g - 6.45$$

A further relationship between liveweight (W) and age (1) in months, was also calculated of the form:

$$W = -0.335a^2 + 5.068a + 31.33$$

This relationship provided the first description of the growth rate of cows in the highlands and it indicated a mature liveweight of less than 250kg at about six years of age.

9.2.3 *Grazing behaviour and animal productivity*

A study of the grazing behaviour of cattle under field conditions was conducted. It was found that grazing was commonly observed early in the morning after cattle were released from their nightyard and immediately before returning to the yard. Resting largely complemented grazing frequency while rumination occurred during the yarding period.

More information concerning the productivity of cattle under natural conditions was obtained from a group of thirteen cattle studied over a period of 25 months. A liveweight gain of 32.5 kg over the period of the study was recorded for non-reproducing animals. Liveweight losses in the month of August and in the dry season were associated with heavy rainfall and poor quality pastures respectively. Liveweight gains began within three weeks of the burning of native pastures before the beginning of the wet season. Data obtained at Pa Kia research site included mean birth weights (13.8 kg), mean rate of calf mortality (21.4%), mean birth weight of calves that died before six months of age (11.9 kg), mean birth weight of calves that survived (14.3 kg), mean pre-weaning liveweight gain (291 g day^{-1}), period of greatest incidence of conception (late wet season), mean liveweight of cows at conception (190 kg), mean period between calvings (480 days), mean calving percentage (76) and mean weaning percentage (60).

9.2.4 *Carcass appraisals*

Carcass appraisals indicated dressing percentages of 40.4 to 55.2 (50.1 to 60.5 on an empty body-weight basis) and meat to bone ratios of 1.3:1 to 4.1:1. Under the marketing structure of Thailand however, the total percentage of edible liveweight is more relevant and this varied from 34.5% to 58.2%.

9.2.5 *Productivity and nutritive value of native pastures*

The productivity and nutritive value of *Imperata cylindrica* the principal native grassland species, was studied following cutting every three weeks throughout the wet season and every six weeks throughout the dry season. Dry matter production (green leaves) reached a peak of 3900 kg ha^{-1} in the month of January while the dry matter production of a sward that had not been burned or grazed for five years was 4200 kg ha^{-1}. Nitrogen content of the samples varied from 2.9 – 0.61% of dry matter (DM) while phosphorus content varied from 0.4 – 0.09% of DM. *In vitro* digestibility varied from 71.4% to 57.4%. Dry matter production rates were much lower than those reported for *Imperata cylindrica* elsewhere in the world, and nitrogen contents and *in vitro* digestibility remained at acceptable levels for a correspondingly longer period. These differences were attributed to the poor soils and the cooler climate of the highlands. It was concluded that *Imperata cylindrica* could provide an above maintenance diet with a nitrogen content above 1.1% of DM and an *in vitro* digestibility above 40% for up to six months of the year.

9.2.6 *Mineral content of native species*

In a further study, the nitrogen, phosphorus, and sodium contents and the *in vitro* digestibility of the species selectively grazed by cattle were determined every six weeks. A total of 41 species selected by cattle were identified and the ten most commonly selected were harvested for analysis. In most cases, nitrogen levels were found to be above the critical level of 1.1% of DM and phosphorus levels were above the critical level of 0.15% of DM. However, sodium levels were seldom above the critical level of 0.1% of DM while *in vitro* digestibility was usually greater than 50%. Oesophageally fistulated animals showed that cattle selected diets from native and improved pasture that declined in *in vitro* digestibility and crude protein content during the dry season.

A study of the faecal nitrogen and phosphorus contents of highland cattle in different locations supported the results that the diets selected were probably adequate in both nitrogen and phosphorus.

9.2.7 *Nutrient Supplementation Studies*

Five studies were conducted to determine the potential for improving cattle productivity by supplementary feeding, and the specific nutrients that limit productivity on native pastures. The first supplementary feeding studies established that responses could be obtained and suggested that phosphorus, nitrogen, sodium and energy may be limiting. All nutrients were subsequently investigated.

Cattle grazing improved pasture (consisted mainly of Desmodium intortum) at Pa Kia with Imperata cylindrica in the background.

Phosphorus

No response to phosphorus was recorded in an extended supplementary feeding experiment with cattle. Serum, faecal, salivary, ruminal and rib bone samples indicated no significant differences between supplemented and unsupplemented cattle. A liveweight and reproduction rate response was attributed solely to the sodium component of the supplement, sodium dihydrogen phosphate. Similar results in other experiments suggested that low phosphorus levels are not limiting cattle productivity from native pastures. Low levels of phosphorus occur in pasture during the dry season but this coincides with low levels of nitrogen and low digestibility, both of which probably limit productivity before phosphorus does.

Nitrogen

Urea was included in most supplementary feeding experiments, although no direct evidence of a response to additional nitrogen was recorded. Low levels of nitrogen in pasture during the dry season suggest that a response would be expected and it was possible that the rumen fluid samples which failed to indicate any response, were collected too long after administration of the supplement.

Method of Urea Administration

Two experiments were conducted in metabolism pens to determine the benefit of administering urea in single or split daily applications. Under a regime of daytime feeding which is common in the highlands, urea supplementation twice daily maintained rumen fluid ammonia levels higher than in unsupplemented animals and for a longer period than once daily supplementation. Single daily supplementation raised serum urea to levels significantly higher than unsupplemented cattle for a period of at least ten hours. It was concluded that urea was not efficiently utilized by administration of infrequent large doses. However, in situations such as the highlands where this is the only practical alternative, such supplementation should be of benefit for about eight out of twenty-four hours.

Sodium

A response in terms of liveweight gain, reproductive rate and reduced calf mortality in the experiment in which the supplement, sodium dihydrogen phosphate was administered, was attributed to sodium. Significant differences were recorded between supplemented and unsupplemented cattle for sodium to potassium ratios in faeces, saliva, rumen fluid and serium. A subsequent experiment showed a liveweight response to a supplement containing nitrogen, phosphorus, sodium and sulphur; the response was attributed to the sodium component of the supplement. An additional treatment included the regular administration of trace elements including sodium. No response was recorded to this treatment, probably because the levels of sodium fed were very much lower than those fed in the other treatments. It was concluded that a sodium deficiency limits cattle productivity on native highland pastures and supplementation with sodium can increase liveweight gains by 30% and lead to improvement in reproductive rate and a decrease in calf mortality.

Trace elements

A mixture of trace elements was administered in three experiments. However, responses to trace elements *per se* were not recorded with the exception of sodium. It was therefore concluded that trace elements are probably not restricting productivity under natural conditions or when supplementary nitrogen, sodium or phosphorus is provided.

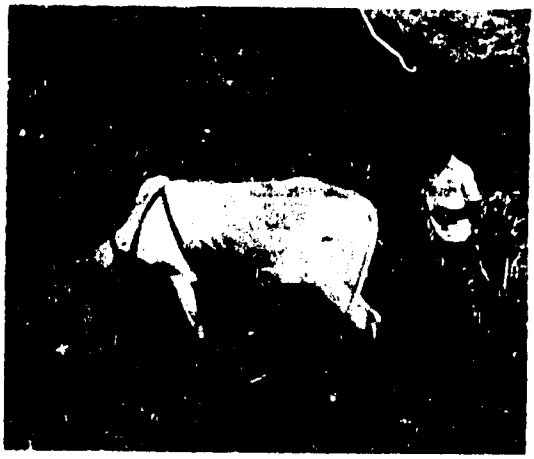
Energy

Limited grazing times, difficult terrain and poor quality pastures limit the intake of cattle in the highlands. Oesophageally fistulated cattle and chromium sesquioxide capsules were employed to estimate the quality and quantity of pasture ingested by cattle. It was determined that feed intake was restricted and was 2% of bodyweight per day. A treatment of nightly supplementary feeding of cut improved pasture to cattle that had grazed native pasture during the day indicated liveweight responses that were attributed to increased feed intake rather than increased protein in the diet.

Conclusion

An inherent sodium deficiency limits cattle production from native pastures in the highlands; this can be easily remedied by supplementation with common salt. An energy deficiency due to limited feed intake also restricts productivity; this can be remedied by the feeding of supplementary forage. Increases in productivity from either supplement would be expected to exceed 30%.

An oesophageally fistulated steer used for collecting samples of the pasture. The rubber enclosure plug has been removed from the fistula.



Herbage sampling by fistulated steer. The collection bag has been attached, the man on the right hand side recorded the number of bites and the period of grazing.

9.3 Results of Pig Research

The pig research programme was conducted over two years and followed the same approach employed for the ruminant programme, viz; an initial survey followed by problem orientated research leading to practical recommendation.

9.3.1 The Survey

Pigs were owned by 90% of the ho seholds surveyed. Variations between ethnic groups and reasons for those differences were obtained, together with information about the use of pig products, management systems, productivity and the economics and problems of the industry. Some of the pertinent results from the survey were: productivity is very low and appeared to be correlated with nutritional level except where disease epidemics occur; hilltribe people prefer black coloured pigs for religious reasons and regard fat as highly as meat because it is more easily stored; raising of pigs on a scavenging management system encourages disease and parasite cycles and restricts village development; management inputs were disproportionately low compared to the value placed on pigs by hilltribes. A carcass study of highland pigs confirmed their extremely high fat content and correlations between various carcass characteristics suggested that the breed had been selected for high fat deposition.

The subsequent research programme was therefor based on the treatment of native pigs with an anthelmintic and swine fever vaccination and raising them in floored pens to prevent parasite reinfestation. Native pigs were utilized to accommodate the preference for a black pig that produced a fat carcass. Nutrition was researched using locally grown products in keeping with the semi-subsistence orientation of the industry.

9.3.2 Supplementation using local feedstuffs

In the initial study, pigs treated with an anthelmintic and raised in pens in villages on a diet containing a grain legume, were compared with pigs raised under traditional conditions. The superior liveweight gains of the treated pigs indicated the potential of this approach and a controlled programme at the project research site was therefore initiated. In a comparison of local feedstuffs, it was found that highland pigs fed chopped banana stalk and rice bran gave higher liveweight gains than pigs fed chopped banana stalk and corn. Subsequent research utilized rice bran and banana stalk as the basal ration and determined that the principal nutritional deficiency of pigs was protein. Grain legumes viz, pigeon pea *(Cajanus cajan)* and red kidney bean *(Phaseolus vulgaris)*, added to the basal ration increased liveweight gains significantly. A concurrent treatment demonstrated the genetic potential of the native pig to make high liveweight gains when fed a high quality diet. The resultant very high fat content of the cracass was on average 70% higher than for native pigs of similar weights raised under traditional conditions.

Pigeon pea produced slightly higher liveweight gains then red kidney bean despite a lower digestibility. An experiment to investigate the effect on weight gains of different means of preparation of pigeon pea grain showed no significant differences in either digestibility or liveweight. Boiling was adopted as the most convenient method of preparation.

Quality and quantity of carbohydrate in the ration may reduce the utilization of protein below maximum efficiency. Two alternative basal rations were investigated, viz. sweet potato *(Ipomoea batatas)* and unsaleable potato *(Solanum tubero-*

A typical way of raising pigs in the highland is an open range.

Pigs in the slatted floor of cheaply constructed and yet sanitary pen, are being fed with traditional diet of chopped banana stalk and rice bran, supplemented with pigeon pea for their source of protein (Pa Kia).

sum). Sweet potato produced significantly higher liveweight gains than potato with or without pigeon pea. Both carbohydrate sources were superior to the traditional rice bran and banana stalk diet.

The final two experiments examined the effect on liveweight of various levels of supplementary pigeon pea grain to both sweet potato and rice bran banana stalk diets. Pigeon pea fed at about 1% of the liveweight of the pig per day was determined to be practical on either diet. In the case of the sweet potato diet a response to a vitamin and mineral supplement was also recorded.

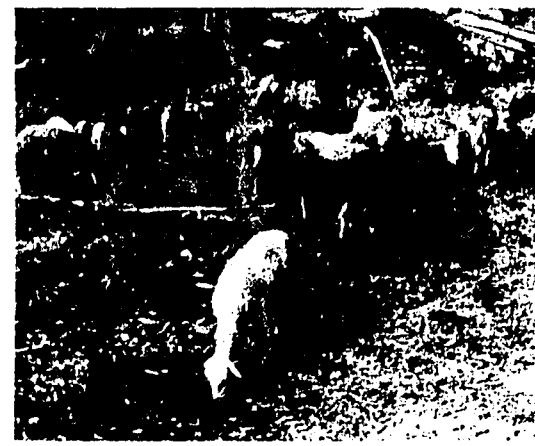
It was concluded from this programme that significant improvements in the highland pig industry are possible. It is recommended that the diet of native pigs raised in floored pens and treated with an anthelmintic and swine fever vaccination, be supplemented with pigeon pea at a daily rate of 1% of bodyweight. Sweet potato may be used in areas where it is available, and to utilize the pigeon pea grain more efficiently, a vitamin-mineral supplement may also be recommended.

9.4 Results of Sheep Research

Sheep were first introduced to the highlands by some developmental agencies. In most instances, production was poor and many of those introduced died. A two year research programme was conducted to determine the technical inputs necessary to raise productive sheep in the highlands.

A survey of villages where sheep were raised was carried out and three experiments were conducted. The survey indicated that management inputs were extremely low and that villagers had equated sheep with goats in terms of management inputs. The first experiment compared productivity of three sheep breeds raised in the highlands, viz, native, Bangladesh-Burmese and German Merino x native. The crossbred sheep showed significantly higher liveweight gains than either of the other breeds which did not differ significantly from each other. Liveweight gains of the progeny sired by German Merino x native rams were higher for lambs born to the crossbred ewes. Mature liveweights, birth weights, lamb survival rates and greasy fleece yield were also higher in the crossbred group while the other two breeds were similar. Carcass evaluations of the above three breed types and Polwarth x native crossbred indicated a higher total edible portion for the German Merino x native crossbreds although yields of all marketable fractions were low for all breed types. A third study investigated the role of internal parasites in the raising of sheep in the highlands. It was found that anthelmintic treatment resulted in significantly higher liveweight gains and lower mortality rates.

It was concluded that productive sheep can be raised in the highlands with adequate management inputs which include clean ventilated housing and drenching for worms. It is recommended that sheep should not be promoted for the highlands due to the very limited markets for the inferior products of these sheep. In those villages where sheep will continue to be raised, the recommendations of anthelmintic treatment and higher management inputs apply.



Sheep of two breeds (50% German Merino, indigenous) grazing native pasture around the field sites at Pa Kia.

10. HIGHLAND RURAL DEVELOPMENT – EXTENSION STRATEGIES

10.1 Introduction

The Hilltribe Division of the Department of Public Welfare (D.P.W.) has about 800 field staff servicing a total of 950 hilltribe villages. The field staff work in mobile teams providing the multiple services of health, education and agriculture in remote areas where the mainline Departments are not operating.

The mobile teams have four members. A social worker is team leader. He is usually a graduate in the social sciences; the agricultural extension officer is a technical college graduate; the paramedic has three years high school education followed by short course-training by the Ministry of Public Health. Finally the fourth member is an assistant teacher who is usually a hilltribe person with primary education and short-course training.

D.P.W. policy is to service all of the over 2,000 hilltribe villages within the next 5 years. For this policy to be implemented, increased staffing and increased staff mobility with scheduled patrol duty will be needed. Currently, the average ratio of farm families to extension officers is 150:1 covering about four hilltribe villages. An average of 20 days per month are scheduled for field work.

The present agricultural extension practice is to establish a demonstration garden near the quarters of the mobile team to promote coffee. A budget is usually provided to hire hilltribe labour to work in the garden.

Most of the extension officer's time is spent in the one village and there is usually frequent communication with a limited number of hilltribe households with an effective farm family to extension officer ratio of less than 50:1. Despite this low ratio the coffee promotion has achieved limited success due to poor quality seedlings produced in the coffee nurseries and inadequate supporting educational and credit programmes.

10.2 Differences between Highland and Lowland Areas

There are essential differences between the highlands and the lowlands which affect agricultural extension activities:

(a) Lack of pre-service training of personnel since no Thai institutions offer specialised training in highland agriculture.

(b) Lack of in-service training; there are insufficient subject matter specialists on the major highland crops to service ten provincial hilltribe centres which administer the DPW mobile development teams.

(c) For the staple food crops and traditional cash crops, farmers' knowledge may be superior to institutional knowledge and farmers' yields superior to demonstration plot yields.

(d) The farm family to extension officer ratio is only 150:1 to service 4 to 5 villages in contrast to the IBRD extension project for Thailand with a ratio of 1000:1 in the lowlands and uplands.

(e) Communication difficulties, physiography, scattered fields, heavier rainfall, unmeasured fields etc., make understanding of the highland farming systems more difficult;

(f) As is common throughout Thailand, too few extension officers are trained in extension principles and practice, extension methods and behavioural science principles relevant to extension work.

For these various reasons the highlands can be considered as atypical. Nevertheless, these differences need not be construed as a major barrier to effective work. It highlights the need to develop an extension strategy tailored to the needs of the highlands and its people.

The major problem of extension strategies which have had their origin in developed countries is that they are based on a "progressive farmer" approach. This is, extension activities are geared to the top 5 – 10% of farmers, providing no component for other farmers. Although the approach has only limited success, in Thailand it would favour commercial rather than subsistence farmers. More recent attempts to offset this problem are discussed below.

10.3 The Training and Visit System

The World Bank has proposed the Training and Visit System as the extension method to be used in the highlands of Northern Thailand through the Highland Agricultural and Social Development Project (HASD).

The mainline Department of Agricultural Extension in the Ministry of Agriculture and Cooperatives in Thailand, Malaysia and Indonesia have accepted World Bank (IBRD) loans over the past three years to implement the "Training and Visit System" (T & V) as the basis for extension operations. The application of the T & V system has achieved notable yield increases with monoculture systems where adequate institutional inputs are available, such as the paddy rice programmes in Malaysia and Indonesia. The T & V system has been used in four World Bank projects in Thailand and currently is an essential component of the National Extension Project administered by the DDAE. Monitoring the evaluation of the T & V

system has only recently been incorporated and it is too early to know the relative effectiveness of this extension strategy in Thailand.

Briefly, the main objective of the T & V system is to transmit simple improvements in low cost agricultural management programmes to farmers. It is based on an organizational arrangement by which extension workers are committed to meet with farmers in a village once a week or once a fortnight. One day a fortnight the extension worker is instructed by subject specialists as to which practice or package of practices will be recommended to farmers in the subsequent two weeks.

Several of the problems associated with the T & V system are:

1. Fortnightly meetings between extension workers do not involve farmers.
2. No provision is made for farmer problems which are inconsistent with the extension workers' programme.
3. There is essentially a one way flow of information from subject specialist to extension worker and from him to farmers. It is assumed that the institutional knowledge is superior to that of the farmer and relevant to the farmer's present level of farm development.
4. The system is sessentially geared to the progressive, motivated farmer.
5. The formalization of meeting between extension workers and farmers is no guarantee of more effective extension work.

10.4 An Alternative Extension Strategy

Because of the proposed World Bank involvement in future highland programmes it is expected that the T & V system will be incorporated. However, it is possible to build into this system additional extension activities and methods which will be of benefit to the highland village people.

In consultation with IBRD officers, the Thai Australian World Bank Land Development Project (TAWLD) and the Extension Department it was decided that TAHAP investigate a suitable highland rural development extension strategy incorporating the favourable features of the T & V system.

The techniques developed are based on the premise that the information and knowledge gained today from village people is the starting point for rural development work. That is, any effective extension work has its beginning at the present level of development of farms and any technical inputs incorporated into the farm system are only one step removed from that level of development. Too often research and its application on farms has its origin in institutional agriculture and is too far removed from present farm development to be comprehended and understood by the farmer. It is thus not necessary to make institutional knowledge the starting point for village development.

The extension agent is trained to work with farmer groups, and obtain a situational analysis of the farm system through formal research and on-farm visits. The so termed situation analysis represents the documentation of baseline data from farms and farm families. Such data includes the present utilization of household resources of land, labour, cash flow budgeting and capital; group work structured to initiate a farmer centred problem solving programme; and understanding of the communication structure in the village. The methodology was field tested on Thai highland villages with mobile teams and DPW agreed in July 1980 for in-service training programmes to be based on this methodology which incorporates the following steps: -

1. Measurement of present utilization of household resources of land, labour and capital which takes about 2 hours per household with about 4 hours for survey of fields. This is followed by preparation of a household labour budget.

During this procedure a baseline is established which can be used for continuous project monitoring, indigenous technical knowledge and yield gaps are identified within the village, and better community level statistics are available for macro-planning.

2. The felt needs of village people and their major problem areas are identified by monitoring them in structured group discussions which also involves an extension worker. The field data from farm calendars, yield gaps, level of technical knowledge etc. are essential baseline data to be incorporated into these group discussions.
3. The village communication structure is identified. This is essential since most information about agriculture is communicated among village members. It is only the most progressive farmers who rely on outside institutional sources of information rather than on other farmers or "ancestors". For this reason identification of informal social networks of extended family groups, friendship cliques etc. is one of the essential first steps in developing an effective extension strategy.
4. Cash flow budgets are preapred, with the help of village people, for the major farm enterprises and new crops that may fit the system.

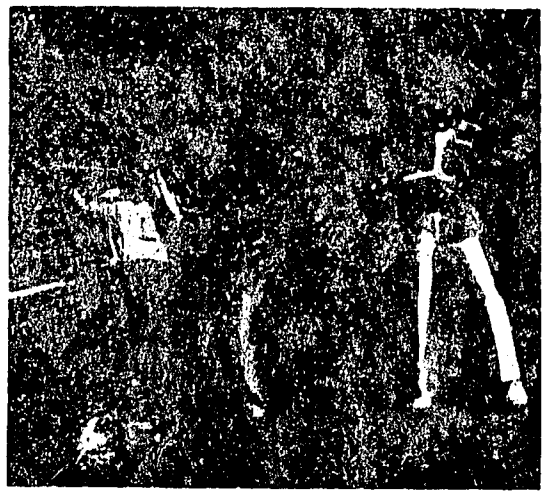
5. Farm development planning is carried out to utilize surplus household resources of labour, land and capital.

6. Any identified problems relating to research workers to help make agricultural research more relevant to the farmers' needs.

Thai agricultural research staff trained in Western countries usually receive little training in problem identification. This communication gap between the farmer and research officer is usually greater in Thailand than in Western countries. In the absence of information on farmers' real problems, agricultural research tends to become institution-centred and may not be oriented towards the most pressing agricultural problems. The logical outcome is that research and extension are based on organizational goals and orientations. In reality they should be farmer-oriented and farmer-centred.

Although only briefly documented, the above strategy and its accompanying methodology ensures farmer involvement and an orientation to his problems. This increases his interest. The consequent effect on research is that work will be done which is relevant to an ongoing farm situation in which farmers are motivated to adopt new technology. The essential difference between traditional extension strategies and the one proposed is that by sharing in the problem-solving exercise, farmers become involved, gain ample understanding of all the factors needed to solve the problem and thus become central to decision-making. With the extension officer working with small groups from the village, natural group processes ensure that group decisions made as a result of problem solving exercises involve and commit each farmer.

Groups of extension officers of DPW have now been trained in this approach.



Field measurement by technicians Udom Satit, Mobile Team Leader, Songtong Hasarpaya, and Sakda Aeimteng. As swidden fields change from year to year it is necessary to survey to measure the area.

Farm calendar interview with a Lisu coffee plantation foreman in Chiang Rai Province during the TAHAP training courses. Recommended cultural practices were being followed, except for pruning. A training course was arranged to impart this skill.

11. REPORT ON FERTILITY, MICROBIAL POPULATIONS, EROSION HAZARD AND PHYSICAL PROPERTIES OF SOILS IN KAREN SWIDDEN AGRICULTURE

11.1 Introduction

As part of a programme to promote the Faculty of Agriculture, Chiangmai University as a research centre for the highland and upland area, the Department of Soil Science was invited in 1979 to submit a research proposal for inclusion in the TAHAP project. Over the past two years a number of small projects have been carried out by staff members of the Department and some useful data have been obtained. It is obvious that only limited data are available on the fertility status of highland and upland soils, and further experiments are being initiated in 1980 to identify specific nutrient deficiencies.

An experimental area was chosen at Mae Muang Luang village in Mae Hong Son province. It is located 100 km north west of Chiangmai.

The Karen population practise shifting cultivation at elevations of 400 m – 1000 m above sea level. The village is inhabited by 150-200 Karen people and the experimental area has an average elevation of 950m and a slope of 10 - 15%. Experimental sites were selected to represent the following stages in the Karen cycle: recently slashed and burnt; deserted one year, two years, five years and ten years; undisturbed virgin forest area.

Measurements were made on a number of soil properties and a glasshouse trial was conducted to identify nutrient deficiencies. The following experiments were carried out by staff of the Soil Science Department, Chiangmai University.

11.2 Chemical Analysis of Soils

11.2.1 Sampling Method

Soil samples were collected for analysis at three times viz. during the hot period (April 1979), in the rainy season (July 1979) and in the cool season (January 1980). Soils were sampled at five depths down to 120 cm at each of the experimental sites and chemically analysed. The results are as follows.

11.2.2 Soil pH

The pH of most samples was in the range 5.3 – 5.7 except for those from the recently slashed and burnt area, which were between 6.1. and 6.9 early in 1979, falling to 5.9 – 6.4 by January of the following year. The effect of forest burning was particularly evident in the 0 – 5 cm layer, reflecting the accumulationg of basic cations in this part of the profile.

The amount of lime required to rise soil pH to neutral was least for the recently slashed and burnt area but for all sites the 0 – 15 cm layer had a higher buffer capacity than the subsoil, probably because of the higher organic matter content in the upper part of the profile.

11.2.3 Organic Matter

There was an accumulation of organic matter in the 0 - 5 cm layer of the recently slashed and burnt area. This part of the profile contained 6.06% organic matter in April 1979, before the onset of the rain, and there was little change during the wet season. However, by January 1980, well into the dry season, the figure had dropped to 5.4% in the surface layer.

There was a trend towards a higher organic matter content in the 1 year deserted area at the end of the wet season, which may be due to the cropping phase following burning. Evidence of any accumulation in the revegetated area during this early period appears to have disappeared after 2 years.

It could be concluded from the data that the Karen cultivation practice did not have any significant effect on organic matter content of the soil over the ten year period.

11.2.4 Available Phosphorus

In general, available phosphorus contents were low except after burning, which resulted in a significant increase in the 0 - 5 cm layer. Phosphorus extracted by Bray No. 2 solution was approximately 160 ppm P in this layer compared with 16 ppm in the virgin forest area and 14 ppm in the 10 year deserted area. This declined rapidly during the wet season and had dropped to 35 ppm P by January 1980. The effect of burning was apparent even after 5 years when the available phosphorus figure was still significantly higher than in the 10 year deserted soil. The effect was confined to the surface layer (0 - 30 cm), indicating the low mobility of phosphorus in these soils. The rapid decline in available phosphorus following burning is consistent with the high reactivity of phosphorus in soil. The high content of iron and aluminium in these soils would result in the formation of insoluble phosphates, and there is also the likelihood of calcium and magnesium oxides formed in the burning operation chemically combining with phosphorus released at the same time.

11.2.5 Potassium

Potassium content was higher in the recently slashed and burnt area to a depth of 120 cm. This is consistent with the release of potassium by burning and its susceptibility to leaching. During the wet season movement of potassium occurred from the surface horizon to lower depths. There was little change during the 10 year cycle, but the

virgin forest soil had a significantly higher potassium content throughout the profile.

11.2.6 Sulphate

Burning of the forest released sulphate sulphur to the surface soil but there was evidence of leaching during the wet season and the effect of burning had disappeared after 1 year. There was evidence of mineralization of sulphur during the wet season in the virgin forest soil.

11.2.7 Calcium and Magnesium

Calcium extractable in normal ammonium acetate solution was higher following burning in the topsoil, and leaching occurred during the wet season to a depth of about 45 cm. The higher calcium was not evident in the one year deserted area, nor in any of the other areas except the virgin forest where levels were above those of the one, two, five and ten year deserted areas. It is not certain whether this was a natural variation or whether the dense vegetation on the virgin forest protected the soil against leaching in the relatively dry year.

Accumulation of magnesium was less evident as a result of burning and the virgin forest land was only marginally different from the 10 year deserted area. There was evidence of a slight build up of magnesium content towards the latter part of the cycle. Generally speaking, magnesium levels were low and deficiencies of this element could occur with faulty soil management.

11.2.8 Zinc

Zinc values were low in all soils and there were no differences between the different areas. Zinc deficiency has been reported in many highland areas with a variety of crops, and there is need for research on zinc nutrition of highland crops.

11.2.9 Conclusion

Slashing and burning resulted in an increased in pH and organic matter and the release of several essential nutrients. In general, the effect of burning did not persist long and there was no evidence of fertility decline as a result of the Karen cultivation practices.

11.3 Omission Trial

A glasshouse experiment was carried out in 1979 on a reddish brown lateritic soil from Mae Muang Luang to identify nutrient deficiencies and to determine the effect of liming. The test crops were mungbean and rice and a comparison was made between soil from a recently burnt area and one that had been deserted for one year. Mungbeans were grown as a first crop, after which rice was sown into the same plots.

There were no detectable nutrient deficiencies on soil from the recently burnt area, reflecting the high fertility level as a result of burning, which persisted during the growing of the rice crop. Lime gave a trend towards lower yields, which had been reported in other work with soybeans and corn in the previous year.

Yields of both mungbean and rice were lower on the 1 year deserted soil regardless of treatment, but nutrient deficiencies were also apparent. Mungbean yield was particularly low in the absence of phosphorus, and liming caused a significant depression with both crops. The reason for the lack of a phosphorus response with rice is probably its lower fertility requirement. The very marked depresssion in yield as a result of liming suggests an induced deficiency of one or more micronutrients and this should be further investigated on highland soils. There have been numerous reports of responses to both zinc and boron on many of these soils.

11.4 Studies of Microbial Population of Highland soils under Karen Cultivation Practices.

11.4.1 Method

Top soils from 0 - 5 cm depth were collected in May 1979, June-July 1979 and in January 1980 for determination of microbial numbers. The population of bacteria plus actinomycetes and fungi were determined by plate counting and the nitrogen fixing blue-green algae were determined by the most probable number method in a nitrogen free medium.

11.4.2 Results

The population of soil micro-organisms from each location and each period are shown in Figure 10.

In May, differences in bacterial plus actinomycete population among soils from different locations enabled soils to be placed into three groups. The first group from the slashed and burnt area contained the highest number, with those from one and two year deserted area in a second group containing a lower number of cells/g. The third group and lowest count was from virgin forest area, 5 year deserted area and 10 year deserted area. It has been reported that heat from burning can cause immediate reduction in bacterial population, but the population decline may last only until the first postfire rainfall. After a few months, population in the upper 4 cm of soil on burnt land may be higher than on the unburnt area. The results in Figure 1 for the May count sup-

port this view, since the samples were collected not later than 2 weeks after burning, and the bacteria population in burnt soil had increased very rapidly. The favourable soil pH (6.9) and high availability of nutrients resulting from burning were considered as factors promoting growth of bacteria from the slashed and burnt area.

In contrast with the bacterial population, each location had approximately equal numbers of fungi.

In June and July, the population of bacteria plus actinomycetes from every location decreased. Since the microbial counts in June and July were not determined by the same person as in May, differences from the May figures may be due to different techniques in determination.

Variation in number of nitrogen fixing blue-green algae from different locations was also observed both in May and in June-July, but no explanation for the differences is apparent.

In January 1980, soil microbial population declined due to low temperatures in the cold season and to the limitation of soil moisture. No variations among different locations were observed for this period.

11.4.3 Incubation Study

A short term incubation study was conducted to observe the N mineralization of soil organic matter from different locations. Most soil samples from each site were incubated at room temperature for 8 weeks and analysed for NH^+_4 and (NO^-_2 + NO^-_3). The results are given in Figures 11 – 13.

The pattern of release of organic nitrogen varies among different soils. The mineralizing patterns of soil from the 10 year deserted area and the virgin forest soil are similar. The NH^+_4 accumulation of these two soils increased with time until the end of the incubation period, whereas the other soils decreased after 1 – 2 weeks.

The mineralizing pattern of the slashed and burnt area, and the one, two and five year deserted area are similar and the rates of mineralization do not change much after the second week of incubation. The mineralization of nitrogen from virgin forest soil and the 10 year deserted area increased continuously throughout 8 weeks of incubation. Virgin forest soil produced more inorganic N than soil from the 10 year deserted area.

11.5 Soil Erosion Studies

Soil lost through water erosion removes fertile soil containing organic matter, plant nutrients and fertilizer residues. Much of the highlands is subject to severe erosion as a result of shifting cultivation methods as practised by the Karen hilltribe people. Large quantities of surface soil are lost each year during the wet season and this loss contributes significantly to declining productivity levels in the region.

Erosion studies were conducted during the 1979 wet season (June-October) in an effort to estimate soil losses under different land use conditions. Because of limitations of finance and manpower for construction of runoff plots, stake erosion studies were conducted to enable a rough estimation of soil loss in 1979 which was a relatively dry year with annual precipitation only about 57% of normal.

The experiment was conducted at Mae Muang Luang village where the June-October rainfall was 940 mm compared with 1582 mm average for the same period in 1965-1974. The average rainfall distribution pattern is given in Figure I.

Table 21 summarises the results of the experiment.

The data were very variable and no reliable conclusion can be drawn, but erosion losses were large, even from the virgin forest area despite the fact that 1979 was a drought year.

It is obvious that further studies are necessary to accurately assess erosion losses under different cultivation practices. Appropriately investigated conservation measures should be undertaken.

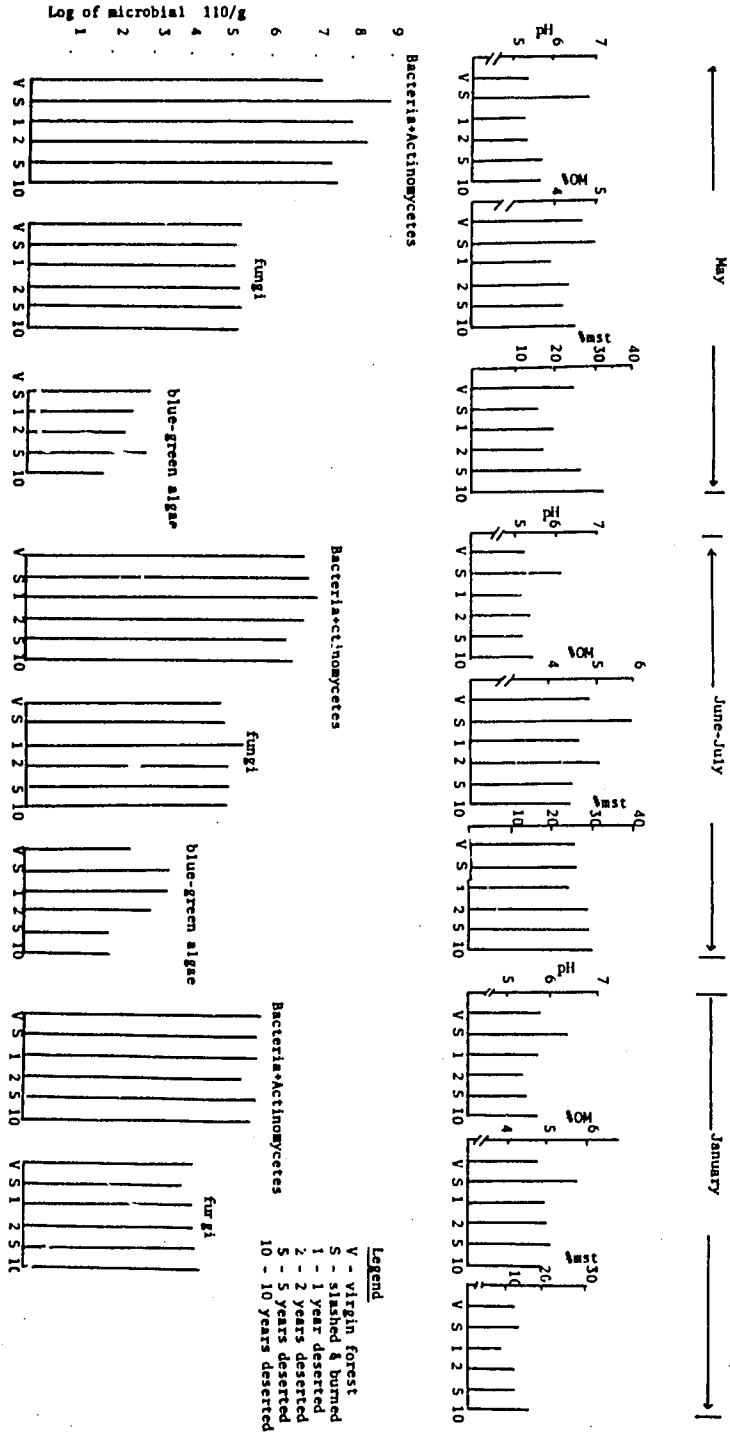
11.6 Changes in Soil Physical Properties

A number of soil physical properties as well as moisture characteristics have been determined and compared from the various locations representing stages in the Karen cycle. The initial measurements were commenced in 1978-79. Further work carried out in 1979-80 is summarised in Table 22 and Table 23.

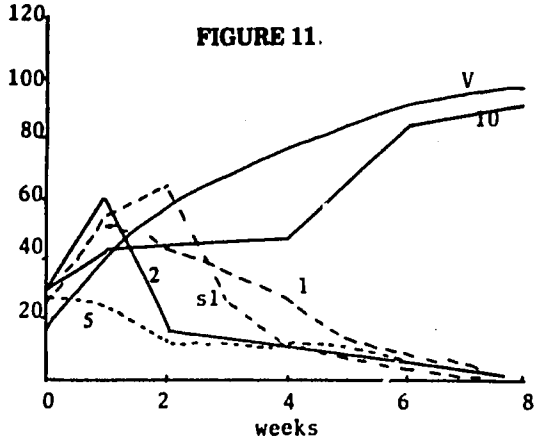
The data in Table 22 show only small variations at different sites and different depths. Total porosity in every area is much the same and in the optimal range for plant growth. The soils are well aerated with field capacities of 22% – 38% and available water levels from 9% – 19%. There was considerable variation in hydraulic conductivity from one area to another, but it is not certain if this is due to cultivation history.

Table 23 indiciates that the pattern of moisture distribution within the profile of the virgin soil is similar to the 10 year deserted area. The 1 year and 5 year samples were similar with a slightly narrower moisture range than the others.

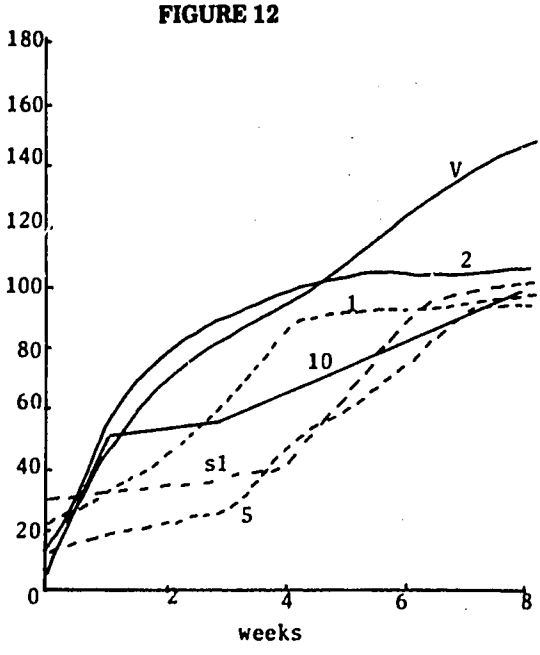
FIGURE 10. Microbial population of soils under Karen cultivation practice.



FIGURES 11 – 13 Nitrogen mineralized from soil organic matter (PPM NH_4^+, NO_2^-, NO_3^-)



Virgin forest soil (v)
Slashed and burned soil (sl)
2 year deserted area (2)
1 year deserted area (1)
5 year deserted area (5)
10 year deserted area (10)



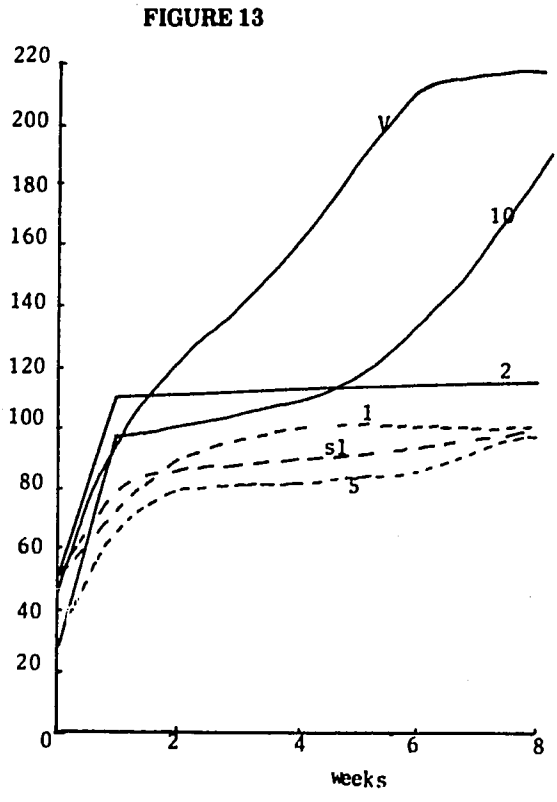


TABLE 21

Average soil loss from the Mae Muang Luang highland soil for a 4 month period (June—November 1979).

Location	% Slope	Depth of soil loss (mm)	Soil Loss ($t\ ha^{-1}$)	Adjusted to 30% slope ($t\ ha^{-1}$)
Slash and burnt area	15	3.1	32.8	82.0
1 year deserted area	10	3.3	34.9	131.0
2 year deserted area	10	5.5	58.3	281.4
5 year deserted area	10	4.7	49.8	186.8
8 year deserted area	28	9.5	100.7	133.9
10 year deserted area	31	6.2	65.7	63.1
Virgin forest area	16	5.4	57.2	129.2

TABLE 22

Physical properties of soils in Mae Muang Luang.

Soil Description & Depth (cm)	Particle Density ($g\ cm^{-3}$)	Total Porosity (%v/v)	Aeration Porosity (%v/v)	Total Available Moisture (%v/v)	Saturated Hydraulic Conductivity ($cm\ hr^{-1}$)
Virgin soil					
0 – 20	2.60	53.85	30.89	9.02	12.01
20 – 40	2.68	54.10	26.88	11.26	–
40 – 60	2.72	50.37	22.36	11.47	–
60 – 90	2.65	46.04	11.21	11.99	–
1 year deserted area					
0 – 20	2.56	55.86	28.82	11.99	26.07
20 – 40	2.56	51.56	24.16	7.60	–
40 – 60	2.62	56.87	28.11	11.45	–
60 – 90	2.60	55.77	25.49	12.08	–
5 year deserted area					
0 – 20	2.47	57.89	28.00	13.00	8.31
20 – 40	2.57	59.14	30.10	9.37	–
40 – 60	2.55	56.08	26.51	8.01	–
60 – 90	2.62	59.54	28.90	13.80	–
10 year deserted area					
0 – 20	2.48	57.26	28.44	14.18	20.09
20 – 40	2.61	59.39	34.14	9.77	–
40 – 60	2.60	59.23	20.43	8.75	–
60 – 90	2.62	57.63	18.83	19.16	–

TABLE 23

Soil moisture characteristics of soils from Mae Muang Luang

Soil Description & Depth (cm)	% Moisture at Soil Water Tension (centibar)					
	33	100	300	500	1,000	1,500
Virgin soil						
0 – 20	23.0	18.6	16.1	15.6	15.2	13.9
20 – 40	27.2	25.2	23.8	23.4	22.3	16.0
40 – 60	28.0	20.2	19.9	17.4	16.6	16.5
60 – 90	34.8	31.4	29.2	28.7	23.7	22.8
1 year deserted area						
0 – 20	27.1	22.7	19.8	17.2	16.8	15.1
20 – 40	27.4	25.7	23.8	21.6	20.7	19.8
40 – 60	28.8	22.9	19.7	19.8	18.7	17.3
60 – 90	30.3	26.6	20.6	20.5	19.3	18.2
5 year deserted area						
0 – 20	29.9	26.5	22.6	22.0	19.3	16.9
20 – 40	29.0	25.2	25.0	26.8	21.7	19.7
40 – 60	29.6	27.6	26.3	24.6	22.5	21.6
60 – 90	30.6	25.4	23.2	22.1	18.7	16.8
10 year deserted area						
0 – 20	27.6	20.2	19.3	19.9	18.3	13.4
20 – 40	28.8	22.7	21.5	20.8	19.1	19.1
40 – 60	25.3	22.9	18.9	17.7	17.6	16.5
60 – 90	38.8	30.8	25.7	24.7	22.3	19.6

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Bangkok Bank
Mr. Chusak HimathongKum, The Vice-president of Bangkok Bank Ltd. and Head of the Agricultural Credit Division.

Australian Embassy
Mr. G.A. Jockel, Australian Embassador
Mr. M.L. Johnston, Former Australian Ambassador
Mr. R.D. Peacock, First Secretary (Development Assistance)
Mrs. M. Jackson, Second Secretary (Development Assistance)
Former First Secretaries (D.A.) – Mr. J.J. Casey and Mr. G.C. Martin
Former Second Secretaries (D.A.) – Mr. P. Malone Ms. H. Hughes and Ms. M. Rayner
Mr. T. Commins, former Attache (D.A.)
Mr. T. Morton

Sydney University
Professor M.J.T. Norman, Head Department of Agronomy and Horticultural Science.

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Mr. R.C.G. Martin, Former First Secretary (Development Assistance)
Mr. B. Mortensen, Former Attache (D.A.)

APPENDIX I – PROJECT PERSONNEL

A. THAI PERSONNEL

Faculty of Agriculture, Chiangmai University

Dr. Dumrong Tiyawalee, Dean, Faculty of Agriculture.
Dr. Manu Seetisarn & Dr. Boonyawart Lumpoopong, previous Deans, Faculty of Agriculture
Ajan Sangwein Posri, Head, Animal Science Department.
*Ajan Songchao Insomphun, Crop Agronomist.
*Ajan Theera Visitpanich, Livestock Specialist.
*Ajan Anand Isarasanee, Agronomist.
*Ajan Chalermpon Sampet, Plant Nutrition.
*Ajan Choke Mikled, Livestock Specialist.
*Ajan Dumnern Karladee, Plant Breeder.
*Ajan Dusit Manajuti, Soil Scientist.

And many co-operating scientists from Chiangmai University.

* Personnel undergoing or completed postgraduate training in Australia.

Department of Public Welfare; Hilltribe Welfare Division and Tribal Research Centre

Mr. Warat Bhruksasri, Director, Tribal Research Centre.
Mr. Banyart Visesri, Chief, Chiangmai Hilltribe Development & Welfare Centre.
Mr. Egachai Thanyalappitak, Livestock Specialist.
*Mr. Prakob Hengmichai, Livestock Specialist.
*Mr. Seksak Wiboonjag, Extension Agronomist.
*Mr. Yuthapong Comudom, Crop Agronomist.
*Miss Ralana Piriyamasakul, Community Nutrition.

* Personnel undergoing or completed postgraduate training in Australia.

Royal Forestry Department

*Mr. Somyos Kwaengsopha, Rangeland Management.

Northern Region Agricultural Development Centre, M.O.A.C.

Mr. Pairoj Pholprasit, Director, Northern Region Agricultural Development Centre.

* Personnel undergoing or completing postgraduate training in Australia.

B. AUSTRALIAN PERSONNEL

Thailand Based – Faculty of Agriculture, Chiangmai

Mr. P. Hoare, Highland Extension Adviser and Project Manager.
Mr. L. Falvey, Livestock Adviser.
Dr. A. Andrews, Pasture Agronomy Adviser.
Dr. R.J. Chamberlin, Crop Agronomy Adviser.

Australia Based – Department of Agriculture, University of Queensland

Dr. L.R. Humphreys, Head, Department of Agriculture, Technical Adviser, T.A.H.A.P.
Dr. H.M. Shelton, Executive Officer.
Dr. J.D. Hughes, Short Term Soils Adviser.
Dr. B.R. Crouch, Short Term Extension Adviser.
Dr. B.W. Norton, Short Term Livestock Adviser.
Mr. J.C. Lamrock, Short Term Extension Adviser.
Dr. D.G. Edwards, Short Term Soil Fertility Adviser.
Dr. D.F. Cameron, Short Term Pasture Adviser.
Miss S. de Haas, Project Clerk.
Miss J. Dobinson, Project Clerk.

APPENDIX II – PROJECT PUBLICATIONS

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