4. Improved Crops and Cropping Systems for Rainfed Northeast Thailand

Somsak Idhipong, Adul Pong-sed,Thewa Maolanont, Suhas P Wani, TJ Rego and Prabhakar Pathak

Farm Resources

Northeast Thailand has a population of about 14.5 million and covers an area of 170,000 km^2. The region accounts for about one-third of Thailand's population and area. The region is characterized by a relatively poor endowment of natural resources and low living standard of the people. Per capita income of the rural family is about 40 per cent of the country's average and only 30 per cent of the central region (excludes Bangkok). Over 85 per cent of the total population is engaged in agriculture. Family farming is the major characteristic of agricultural production. Farming is done on small scale and crop yield is generally low due to poor soil productivity and erratic rainfall. Farm work is heavily concentrated in May to July and October to November.

The majority of soil types in the Northeast are alluvial, low-humic gley, gray podzolic and red-yellow podzolic soils. These soils are characterized by sandy texture, acid reaction, low organic matter content, low cation exchange capacity, low level of plant nutrients and low water-holding capacity. Continuous cultivation on these soils usually results in rapid decline in fertility level and becomes a major problem for crop production.

The Northeast climate is usually described as semi-arid tropics. The calendar year can be divided into a six-month rainy season (mid-April to mid-October) and six-month dry season (mid-October to mid-April). During the rainy season, most of the rainfall occurs at irregular intervals and at variable intensities. Periods of flooding are interspersed by periods of drought during the season. Rainfall occurs only occasionally in the dry season, and the crop production is feasible only with irrigation. The potential irrigation service area in the Northeast region is relatively small as compared to rainfed area. Irrigation water is not available or will not be available to most of the farms in the foreseeable future. Therefore, rainfed agriculture will still have to play a major role in agricultural production for many years to come.

Temperature is relatively high all year round. Soil and air temperatures during the early rainy season are too high for optimum growth of most crops. The second half of the rainy season is more ideal for crop growth in terms of soil and air temperatures.

Current Cropping Systems

The present cropping system in the Northeast is monocropping of rice, kenaf and cassava during the rainy season. Rice is the subsistence crop that occupies more than two-thirds of the crop acreage. The region is mostly into production of paddy rice that uses photosensitive varieties. The first half of rainy season is used in soil preparation and growing seedbeds. Only the last half of the wet season is used for crop production. A review on the distribution of paddy and upland fields revealed that more than half of paddy areas are located on soils that are generally suitable for upland crops. This may be due to the fact that farmers have to produce all the rice they need for family consumption and sell only the surplus product. As a result of unfavorable land use conditions, low yields are generally obtained.

Due to rolling topography of the land, paddy fields in the Northeast could be roughly divided into middle and low terraces. The low-terrace (lowland) fields generally have alluvial soils which are suitable for rice growing, and water is usually sufficient for rice crop. On the contrary, soils in the middle-terrace (upper) fields are more coarse in texture with low water-holding capacity and are more suitable for field crops than for rice. A substantially large portion of the upper paddy fields are left fallow most of the years due to insufficient rainfall or delayed onset of the southwest monsoon. Productivity of this type of paddy field could be improved by using the land for production of suitable upland crops.

About one-fifth of the cultivated area is devoted to upland crops. Kenaf and cassava occupy the major portion of the upland areas where soils are generally infertile. Maize and sorghum are grown on fertile soils, which constitute only a small percentage of upland areas. Groundnut is the major food legume grown in the Northeast, while a small acreage is planted with soybean and mung bean. Areas devoted to some other crops are insignificant.

Need for More Efficient Cropping Systems

Under the present cropping systems where monoculture is the rule, farmers do not utilize the farm resources efficiently. The farming practices in which the same crop is repeated year after year and almost no fertilizer is applied, have resulted in progressive depletion of soil fertility and declining crop yield. Thus, there is a great need for potential cropping systems that would increase productivity of land through better use of natural and human resources. The most suitable cropping systems that fit the farming conditions would be crop intensification or multiple cropping. The need is to develop cropping patterns that fit the local physical and socioeconomic conditions. The cropping patterns to be developed should result in better use of land, water, labor resources, better maintenance of soil fertility, and prolong soil productivity.

A major constraint in developing cropping systems is the lack of adequate research. Most of the research in the past has been focused on improving production of individual crops and not directed towards improving the efficiency of land utilization to maximize return per unit area per unit time. Little attention has been paid to integrate research findings into technological packages and test them at the farmer level. Although considerable research has been done on cropping systems in Thailand, all of them are directed towards developing cropping systems for irrigated areas. There is very little research aimed at developing cropping systems for rainfed conditions. Since irrigation water is not available to 90% of cropped land, research directed towards developing cropping systems for rainfed areas would make a great contribution to agricultural development of the region. Therefore, this project was proposed to fulfill the need of research for more efficient cropping systems.

The Participatory Watershed Management Project for Reducing Poverty and Land Degradation in Thailand has been implemented at Tad Fa watershed, Wang Sawaap Sub-district, District of Phu Pha Man, Khon Kaen since 1999 in partnership with International Crops Research Institute for the Semi-Arid Tropics (ICRISAT). Research at Wang Chai watershed, Din Dam Sub-district, District of Phu Wiang, Khon Kaen started in 2003. These watersheds have been characterized by topographical conditions. The Tad Fa watershed has sloping mountainous areas with Vertisol soil while the Wang Chai watershed has undulating areas with light red loamy to sandy loam soils. The improved crops and cropping systems are important components of this integrated watershed project.

The major objective of the cropping systems research was to develop cropping systems suitable for rainfed cultivated areas of Northeast Thailand, which will increase the productivity of land through better use of farm resources. In this paper, work done on improved high-yielding varieties and cropping systems evaluated in the two watersheds are discussed in detail.

Tad Fa Watershed

The Tad Fa watershed is sloping mountainous area under rainfed condition and is characterized by erratic and low rainfall. Loamy to clayey texture soils are common in the watershed. The major constraints to crop production are high soil erosion and severe water scarcity, resulting in low yields of all crops, particularly maize (Fig. 1). The soil chemical properties (0–15 cm depth) determined in 1999 reveal that the soils are extremely low in available phosphorus (P) along the

Figure 1. Maize cultivation at Tad Fa Watershed: (a) planting in sloping areas, (b) emerging of rock on sloping areas, and (c) wilting due to severe drought late in the rainy season.

toposequence, mostly due to continuous maize cultivation over a long period without the application of P fertilizer (Table 1). The agronomical interventions at Tad Fa watershed during 2000/01 to 2005/06 consisted of the evaluation of (1) suitable crops and improved crop varieties; and (2) performance of improved cropping systems under various cultural practices. Crop cultivation in Tad Fa watershed can be classified into two categories: fruit trees and annual crops.

Table 1. Analysis of soil samples taken from 0–15 cm depth at different positions along the toposequence in Tad Fa watershed in 1999.

Toposequence	Slope	pH	Organic matter (%)	Available P (mg kg^{-1} soil)	Extractable K (mg kg^{-1} soil)
Upper	Steep	5.65	2.55	2.4	237
Middle	Moderate	5.50	2.17	2.2	259
Lower	Mild	5.67	2.67	2.2	313
Normal limit		6.5–8.5	0.5–0.75	5–10	50–125

Fruit Tree Cultivation

Tad Fa watershed farmers were encouraged to grow fruit trees to reduce erosion on the slopy lands. However, there were some orchards in Tad Fa watershed before 1999 and some fruit trees were planted during ADB-ICRISAT project (1999–2005). Normally, most fruit trees in Tad Fa watershed have been grown in the watershed under rainfed condition in the lower portion on the toposeqence (Fig. 2). Due to better moisture regime in the lower portion of the watershed, the survival of fruit trees was higher.

Four major species of fruit trees, viz, sweet tamarind (*Tamarindus indica*), mango (*Mangifera indica*), longan (*Euphoria longana*) and banana (*Musa* spp) existed in large areas in Tad Fa watershed. These species were grown both as sole and mixed crops (Table 2 and Fig. 3). Besides these species, jackfruit (*Artocarpus* spp), santol (*Sandoricum indicum*), custard apple (*Annona squamosa*) etc were also grown for household consumption.

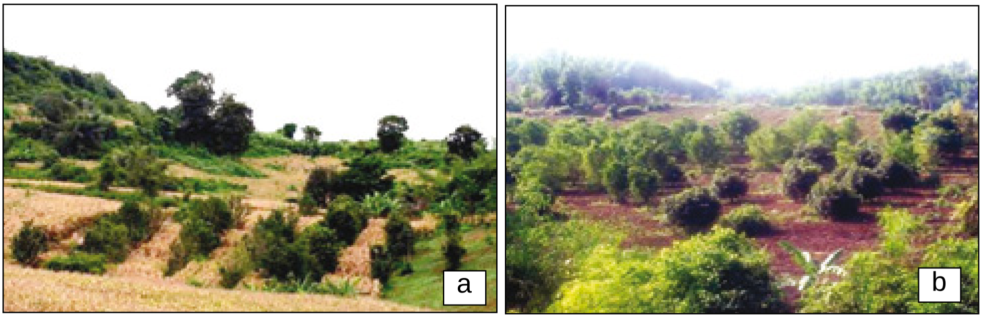

Figure 2. Fruit tree orchards (a) with maize intercropping between fruit tree rows in lower topography; and (b) sole maize in upper topography at Tad Fa watershed.

Table 2. Fruit tree cultivation at Tad Fa watershed before and during project.

	Before project (1999)		Additional planting during project (1999–2005)	
Fruit tree	No. of households	Area (ha)	No. of households	Area[1] (ha)
Sweet tamarind	14	14.72	0	0
Mango	4	5.6	0	0
Longan	2	2.88	7	3.84
Banana	3	6.4	5	2.08
Mixed orchard[2]	8	13.92	0	0
Litchi	0	0	5	2.08
Longkong	0	0	2	0.64
Plum	0	0	25 (approx.)	3 plants hh^{-1}
Chinese chestnut	0	0		3 plants hh^{-1}
Chinese persimmon	0	0		3 plants hh^{-1}
Peach	0	0		2 plants hh^{-1}
Macadamia	0	0		2 plants hh^{-1}
Total	31	43.52	48	8.64

1. hh = household.

2. Sweet tamarind, mango and longan.

The area under sweet tamarind did not increase due to the following problems: (1) production affected by unreliable seedling, (2) labor shortage for harvesting, and (3) fruit damaged by rains. However, the crop still is a good source of income to the farmers. Some farmers even made 17,800 bahts ha^{-1} in 2005. Similarly,

Figure 3. Four major fruit trees at Tad Fa watershed before 1999.

mango production was influenced by (1) seasonal fluctuation in flowering and yield during different years, (2) low price of the fruit, (3) falling of young fruits by storms, (4) fruit fly damage, and (5) labor shortage for harvesting.

About 19 farmers planted longan, litchi (*Litchi chinensis*), mango and banana. Also, new fruit trees including longkong (*Lansium domesticum*), Chinese chestnut (*Castanea* spp), Chinese persimmon (*Prunus domestica*), peach (*Prunus persica*) and macadamia (*Macadamia tetraphylla*) were introduced for preliminary evaluation (Table 2). In 2005, among these crops banana gave satisfactory income of about 12,000 bahts ha^{-1}, but longan and litchi gave lower yield.

Evaluation of Improved Cultivars of Annual Crops

Maize (*Zea mays*) commercial hybrid variety was grown as a major crop in Tad Fa watershed while other crops grown were ricebean *(Vigna umbellata),* cowpea (*Vigna unguiculata*) (black testa) and groundnut (*Arachis hypogaea*). Prior to the project, local cultivars of these three legumes were widely grown but their yield potential was low. Therefore, during 2002/03 to 2005/06, emphasis was on the evaluation of new high-yielding improved cultivars of groundnut, ricebean and black testa cowpea to improve the crop yield and water use efficiency. Groundnut is grown in Thailand in small areas in early rainy season for both local consumption and external markets. Ricebean and black testa cowpea were alternative crops grown late in the rainy season as the second crop in maize-based cropping systems. Most of the produce was usually sold in the market, but the prices always fluctuated over time.

Groundnut: Although groundnut is more important in Thailand than ricebean and black testa cowpea, it was planted in small areas in Tad Fa watershed during the first few years of project. The North and Northeast are two major groundnut-growing areas in Thailand. Some provinces of the North such as Lampang, Nan, Chiang Rai, Prayao, Chiang Mai and Phrae and in the Northeast as Loei, Kalasin, Nakhon Ratchasima, Udon Thani and Ubon Ratchathani are principal provinces for groundnut production (Table 3) (Field Crops Research Institute 2001).

Baseline survey at Tad Fa watershed in rainy season 1999 indicated that groundnut, normally, was sown in early rainy season in small areas by a small number of farmers. The local cultivar with red testa (valencia type) was sown and gave rather low pod yield with small seed size.

However, field evaluation of KK 5 with pink testa (Spanish type) from Khon Kaen Field Crops Research Center (KKFCRC) (1996) was taken up to compare with the local cultivar with red testa (valencia type) in June 2001 under no fertilizer application and hand weeding done only once. KK 5 gave 16 per cent higher pod yield and with larger seed size than the local cultivar, even though its shelling out-turn was lower than local variety. The duration of improved variety was also one week earlier (Table 4).

Table 3. Groundnut production in Thailand during 2002/03–2004/05[1].

	Planted area ('000ha)			Production ('000 t)			Pod yield (kg ha^{-1})		
Region	2002/03	2003/04	2004/05	2002/03	2003/04	2004/05	2002/03	2003/04	2004/05
North	32.38	21.09	19.83	51.76	34.88	33.14	1,660	1,690	1,725
Northeast	27.39	19.82	18.71	41.08	31.17	29.02	1,570	1,630	1,610
Central	10.08	5.01	4.84	16.88	7.98	8.41	1,760	1,640	1,825
South	1.86	1.49	1.63	2.43	2.03	2.24	1,360	1,450	1,640
Whole country	71.72	47.42	45.01	112.1	76.1	72.8	1,630	1,650	1,675

1. Source: Office of Agricultural Economics (2004).

Table 4. Groundnut cultivar yields and other yield attributes during rainy season in 1999 and 2001 at Tad Fa watershed.

Year	Cultivar	Harvested population ('000 plants ha^{-1})	Pods $plant^{-1}$	Dry pod yield (kg ha^{-1})	Shelling (%)	100-seed weight (g)
1999	Local	152.8±7.6	7.1±0.11	1,710±390	61.8±3.03	27.25±2.28
2001	Local	182.4±32.2	14.3±2.80	1,980±370	60.0±0	37.03±0.74
	KK 5	171.3±32.6	14.7±2.23	2,000±255	57.3±2.31	46.90±1.14

Ricebean: Ricebean is an important legume crop that is grown in the northwestern part of the Northeast region. About 90 per cent production is exported to Japan, Taiwan and Korea and about 10% is consumed in Thailand as ingredient for some Thai sweets through direct and modified cooking and also for some western foods such as dressing bun. The composition of ricebean grain is shown in Table 5.

Table 5. Composition of ricebean grain[1].

Constituent of dry grain	Amount (per 100 g of grain)
Protein	20.9 g
Fat	0.9 g
Carbohydrate	60.7 g
Fiber	4.8 g
Ash	4.2 g
Calcium	200 mg
Phosphorus	390 mg
Iron	10.9 mg
Thiamin	0.49 mg
Riboflavin	0.21 mg
Niacin	2.4 mg

1. Source: Na Lampang (1990), Bhag Mal (1994), Toomsaen (1996).

Most ricebean growing areas are in Loei Province and small areas are in the provinces of the Northeast including Khon Kaen, Chaiyaphum and Udon Thani (Nongbua Lamphu) and in the North including Phitsanuloke, Tak, Petchabun and Chiang Rai. During 1999–2001, the areas under ricebean cultivation in Thailand was 3,568, 5,595 and 3,741 ha and production was 4,444, 6,209 and 3,726 t, respectively. Ricebean is a photosensitive crop and starts flowering in October and hence the crop should be planted not later than mid-August. Early sowing of the crop is preferred for better vegetative growth and yield.

Trials for the evaluation of L 28-0395 variety of ricebean to improve grain yield, were conducted in late rainy season during 2002/03 to 2004/05 under two cropping systems: sequential and relay. In sequential system, the sowing of ricebean was done after the maize was harvested in 2002/03 and 2003/04; and in relay system, the sowing of ricebean was done prior to the maturity of the maize crop in 2004/05. The L 28-0395 variety performed better compared to local cultivars at Tad Fa watershed. It gave 122 per cent, 124 per cent and 13 per cent higher grain yield compared to the local cultivar each year (2002/03 to 2005/06), respectively with larger seed size than the local cultivars (Table 6) and also its pods had delayed shattering.

In late rainy season 2005/06, at least 27 farmers grew L 28-0395 both as relay and sequential crops in maize-based cropping systems, and they achieved significantly higher grain yield (20 per cent) than late rainy season 2004/05 due to rainy season delay until November 2005. After harvest of the crops approximately 223 kg seeds of L 28-0395 were returned to the community as common seed stock for the next growing season in 2006.

Black testa cowpea: Black testa cowpea is another important leguminous crop grown in a small area of 1,488 ha in Thailand, mostly in North and the Northeast. A large amount of product is consumed in Thailand while a small proportion is exported to Japan, Malaysia, USA and England. In Thailand, grain cowpea (black testa only) is widely used. The composition of black testa cowpea grain is shown in Table 7.

Table 6. Grain yield and 100-seed weight of two ricebean cultivars as the succeeding crop in maize-based cropping system at Tad Fa watershed in late rainy season during 2002/03-2005/06.

Crop year	Cropping System	Grain yield (kg ha^{-1})		100-seed wt (g)	
		Local	L28-0395	Local	L28-0395
2002/03	Sequential	310	680	NA[1]	NA
2003/04	Sequential	160	370	NA	NA
2004/05	Relay	460	520	9.60	10.50
2005/06	Relay and sequential	890	1,070	10.12	10.77

1. NA = Data not available.

Prior to the project, the local cultivars of three legumes were widely grown but their yield potential was low. In order to increase productivity and to improve water use efficiency, high-yielding improved cultivars of these three legume crops were introduced and evaluated during the project 2001/02 to 2004/05 (Fig. 4).

Table 7. Composition of black testa cowpea grain.

Constituent of dry grain	Weight (per 100g of grain)
Protein	23.4 g
Carbohydrate	56.8 g
Fat	1.3 g
Fiber	3.9 g
Ash	3.6 g
Lysine	6.6 mg
Cysteine	0.9 mg
Methionine	0.9 mg
Histidine	3.3 mg
Threonine	4.1 mg
Tryptophan	0.9 mg

Source: Ubon Ratchathani Field Crops Research Institute (2000).

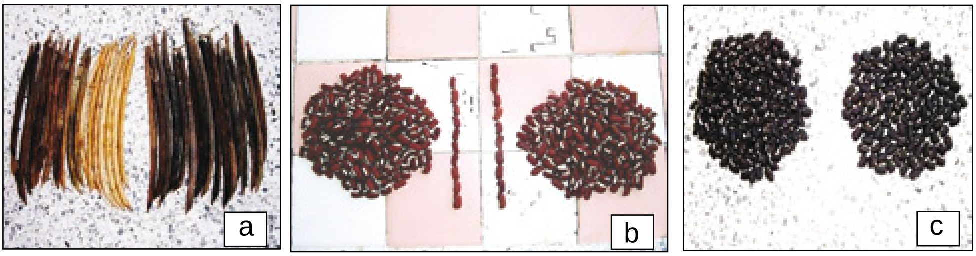

Figure 4. Pod and seed performance of two legumes: (a) and (b) ricebean cultivars as Local (left) and L 28-0395 (right); and (c) black testa cowpea cultivars as Local (left) and KKU 305 (right).

The trials for the evaluation of KKU 305 variety of black testa cowpea to improve grain yield were conducted in late rainy season during 2002/03 to 2004/05 and CP 4-2-3-1 variety from International Rice Research Institute (IRRI) and IT 82E-9 from International Institute of Tropical Agriculture (IITA) were also included in the evaluation in 2004/05. They were grown as sequential crops after maize in mildly slopy areas. Low and erratic rainfall and rapid soil water depletion resulted in poor growth and grain yield of ricebean and black testa cowpea; however, the results indicated that KKU 305 was a superior cultivar compared to the local cultivar. KKU 305 variety gave 79 per cent, 142 per cent and 34 per cent of grain yield, respectively during 2002/03, 2003/04 and 2004/05 compared to the local cultivars. CP 4-2-3-1 and IT 82E 9 varieties gave lower grain yield than the local cultivar in 2004/05 (Table 8). Besides higher grain yield, KKU 305 variety had larger seeds than the local cultivar, and also showed delayed shattering of the pods.

Table 8. Grain yield and 100-seed weight of four black testa cowpea cultivars as the sequential crop in maize-based cropping system at Tad Fa watershed in late rainy season 2002/03-2005/06.

	Grain yield (kg ha^{-1})				100-seed weight (g)			
Year	Local	KKU 305	CP 4-2-3-1	IT 82E-9	Local	KKU 305	CP 4-2-3-1	IT 82E-9
2002/03	440	790	NA[1]	NA	NA	NA	NA	NA
2003/04	180	440	NA	NA	NA	NA	NA	NA
2004/05	280	370	171	230	11.78	16.08	9.68	13.72
2005/06	800	960	NA	NA	15.34	19.42	NA	NA

1. NA = Data not available.

In late rainy season 2005/06, at least 17 farmers grew KKU 305 as sequential crop after maize in mildly slopy areas and achieved significantly higher grain yield (20%) than late rainy season 2004/05 due to the late withdrawal of rainy season until November 2005.

After harvesting, approximately 110 kg seeds of KKU 305 were returned back to the community as common seed stock for the next growing season in 2006. Some of the characteristics of the three cultivars of black testa cowpea are:

KKU 305: Promising line from Khon Kaen University, large seed, drought tolerant, 50% flowering at 33-37 DAE, pod length $\simeq$ 15-20 cm, seeds pod^{-1} $\simeq$ 10-12 seeds, 1st harvesting $\simeq$ 65-72 DAE, 100-seed wt $\simeq$ 17.7g, dry grain yield ~ 1,125-1,250 kg ha^{-1}, shelling $\simeq$ 78%.

CP 4-2-3-1: Introduced cultivar from International Rice Research Institute (IRRI), The Philippines, semi-indeterminate, 50% flowering at 35-38 DAE, pod length $\simeq$ 15-20 cm, 1st harvesting $\simeq$ 70-75 DAE, 100-seed wt $\simeq$ 14.5-15.5 g, dry grain yield ~ 750-937.5 kg ha^{-1}.

IT 82E-9: Introduced cultivar from International Institute of Tropical Agriculture (IITA), Nigeria, 50% flowering at 33-37 DAE, pod length $\simeq$ 15-20 cm, 1st harvesting $\simeq$ 65-72 DAE, 100-seed wt $\simeq$ 13.5-15.0 g, dry grain yield $\simeq$ 937-1,250 kg ha^{-1}.

Improved Cultivation Practice

Maize-based cropping system is predominant at Tad Fa watershed and maize is grown both in early rainy season as preceding crop and in the late rainy season as the succeeding crop. Maize planting in the early part of rainy season is a common feature in order to harness maximum benefit from the succeeding crops grown preceding maize cultivation due to better moisture availability in the soil that allows cultivation of two crops. Generally, maize yield has been showing a declining trend due to continuous cultivation compounded with declining soil fertility and decreased water-holding capacity of soil as a result of severe soil erosion. To address some of these problems, an improved cultural practice of planting maize across the slope and incorporation of maize stover into soil to improve soil organic matter and other soil properties was adopted.

Cultivation of Maize Across Slope/on Contour

Generally, cultivation of maize in slopy areas by using heavy machinery induces severe erosion and also land slides (Fig. 5). Cultivation of maize across the slope gave a marginal increase (3%) over sowing along the slope, while it responded significantly (average of 48% along the toposequence) with fertilizer application (141 kg ha^{-1} of 16-20-0 as basal dose) (Table 9). The grain yield of maize in lower toposequence was higher compared to upper and middle fields on toposequence (Table 10).

Figure 5. Sloping areas used for maize cultivation: (a) evident land slide and high soil erosion after soil tillage by heavy machinery; and (b) small area of maize in no-tillage soil nearby Tad Fa watershed in early rainy season 2006.

Table 9. Effects of two sowing methods on the performance of maize at Tad Fa watershed in early rainy season 2000.

Sowing method[1]	Harvested pop. ('000 plants ha^{-1})	Plant height (cm)	Ears plant^{-1}	Grain yield (kg ha $^{-1}$)
Across slope	30.2+4.7	204.6+21.1	1.3+0.20	5,030.2+1,186.5
Up-down	32.8+5.9	196.4+7.8	1.2+0.18	4,870.8+600.0

1. Sown by machines.

Table 10. Average effects of fertilizer application on three toposequence positions on maize performance at Tad Fa watershed in early rainy season 2004[1].

Topo-sequence	Fertilizer application	Harvested population ('000 plants ha^{-1})	Plant height (cm)	Ears plant $^{-1}$	Threshing (%)	Grain yield (kg ha^{-1})
Upper	No fertilizer + up-down cultivation	49.94±16.62	89.8±25.7	0.66±0.25	77.37±12.05	1,120.1±956.8
	Fertilizer + across slope cultivation	53.89±13.96	127.1±18.7	0.72±0.25	84.2±0.36	2,370.2±574.3
Middle	No fertilizer + up-down cultivation	64.80±28.16	99.0±13.2	0.72±0.17	82.77±2.38	1,480.0±510.1
	Fertilizer + across slope cultivation	62.00±9.10	145.4±19.2	0.83±0.11	83.47±0.67	2,940.3±208.0
Lower	No fertilizer + up-down cultivation	62.39±28.17	104.0±16.2	0.68±0.09	83.60±0.30	1,390.2±548.1
	Fertilizer + across slope cultivation	61.85±15.20	144.2±8.2	0.85±0.11	83.87±1.17	3,410.8±1,104.7

1. Average from three farmers' fields that were sown manually in mid May 2004. About 140.6 kg of 16-20-0 fertilizer was applied basally.

Some of the beneficial cultivation practices were contour planting and incorporation of maize stover (Fig. 6).

Ricebean as a Relay or Sequential Crop with Maize

Ricebean is a popular legume crop grown in sloping land ecologies of Northeast Thailand. In about 40% of the maize growing area, ricebean is relay planted

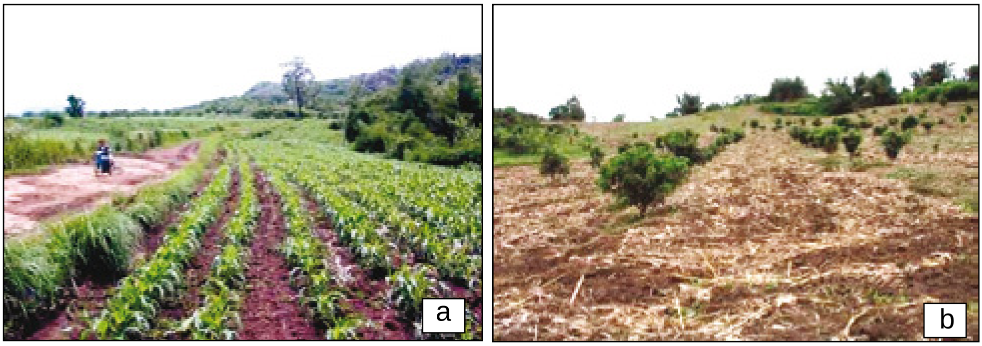

Figure 6. Beneficial practices of soil-water conservation: (a) contour planting; and (b) incorporating maize stovers.

during July to August. It is sown in the standing crop of maize at the time of flowering. Since it is sown without any land preparation (unlike sequential planting), relay planting is a soil conservation efficient system. Ricebean is a shade tolerant, climbing type, and a photosensitive crop (Fig. 7). On steeper slope (>15 per cent), the yield (970 kg ha^{-1}) is 25–30 per cent less compared to moderate slope (5–15 per cent) (1270 kg ha^{-1}) or mild slope (2–5 per cent) (1360 kg ha^{-1}). Poor soil as well as less amount of soil moisture may be responsible for low yields on steep slopes. Relay cropping system has to be popularized with most of the maize farmers who sometimes try a second crop of maize, which suffers due to terminal drought. Sometimes they are not able to plant the second crop due to late onset of monsoon and late planting of first maize crop.

Ricebean can also be grown as a sequential crop after harvesting of maize in August to September. Flowering in ricebean starts in October and the crop matures in late December as it is photosensitive. So ricebean should not be

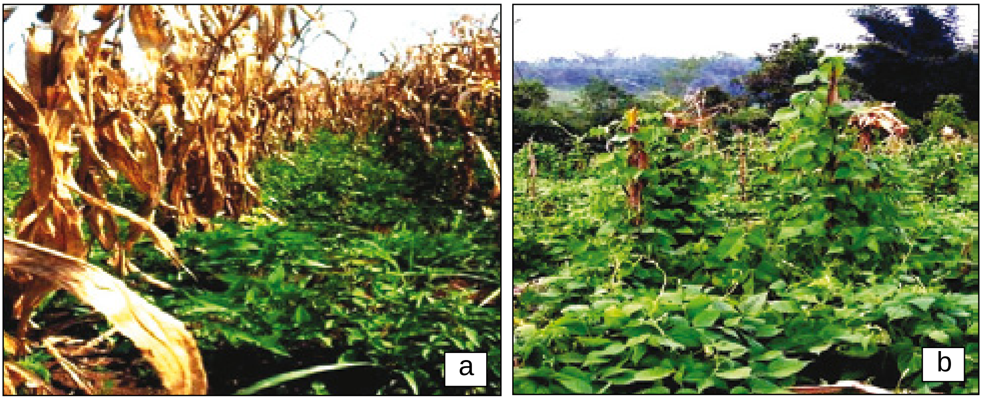

Figure 7. Characteristics of ricebean: (a) shade tolerant; and (b) climbing type.

sown later than mid August. Sowing ricebean as relay crop with maize showed better results than as a sequential crop. The farmers are convinced to sow ricebean on steep slopy areas between maize rows without tillage of the soil and use the maize stover for mulching (Fig. 8 and Table 11).

Figure 8. Relay cropping of ricebean after cutting down maize stover in moderate slope area.

Ricebean as relay crop in maize crop rows gets longer duration of growth than in sequential system. Trials on relay and sequential cropping were conducted in Tad Fa watershed. The local ricebean cultivar gave higher grain yield (77 per cent increase) in relay system than in sequential system in late rainy season 2003/04 (Table 12). During early rainy season of 2002, improved variety of ricebean (L 28-0395) in relay system gave 110% higher yield than under the sequential system, while during 2003 with local variety, the increase in crop yield in relay system was 67% compared to the sequential system (Table 12). However, sowing ricebean as relay crop with maize had some limitations like increased requirement for labor for seeding and cutting down the maize stover.

Table 11. Local cultivar of ricebean sown as relay crop with maize and as sequential crop after maize in Tad Fa Watershed in late rainy season 2003/04.

Component	Relay crop	Sequential crop
No. of farms	7	12
Planted area (ha)	22	16
Average grain yield (kg ha^{-1})	380±251.5	220±226.9

Table 12. Improved method of cultivation of ricebean at Tad Fa watershed in early rainy season 2002 and 2003.

Year	No. of plots	Treatment	Grain yield (kg ha^{-1})
2002	2[1]	Relay (L 28-0395)	1,370.0±486.2
		After maize (L 28-0395)	650.1±490.6
2003	7[2]	Relay (Local cultivar)	380.0±251.5
	8[2]	After maize (Local cultivar)	180.9±228.3

1. Field evaluation under farmers' conditions.
2. Yield evaluation by sampling crop cut individually.

Black Testa Cowpea as Sequential Crop with Maize and Incorporation of Maize Stover as Mulch

Black testa cowpea is a photo-insensitive, short-duration crop, which matures in less than three months. At Tad Fa watershed, it is usually grown as sequential crop after harvest of maize and the maize stover is incorporated (Fig. 9). Cowpea is sown by broadcasting the seed without tillage. This system of cultivation is suitable for the short period of the remaining crop season under limited residual soil moisture. However, it is recommended only on mild slopy areas where soil erosion is not a serious problem.

Recommendation for Better Cropping System

Even with moderately sloped lands in Tad Fa watershed, soil is prone to erosion under high intensity of crop cultivation. Maize is still a major crop grown in the early rainy season by using heavy machines that induces severe erosion. However, erosion could be reduced through effective cultivation practices and crop management. Under the Participatory Watershed Management for Reducing Poverty and Land Degradation Project in Thailand at Tad Fa watershed, research activities were undertaken on the improvement of groundnut, ricebean and black testa cowpea and maize-based crop management systems were quite effective for increasing the productivity and maintaining soil fertility, while reducing the degradation of soil and water resources. Some recommendations for improved cropping systems are given below:

- **Improved cultivars and their characteristics of groundnut, ricebean and black testa cowpea**

Some of the promising improved cultivars of groundnut, ricebean and black testa cowpea recommended for Tad Fa watershed are given in Table 13.

Figure 9. Black testa cowpea grown as sequential crop: (a) after maize in mild slope areas; (b) after maize between fruit tree rows; and (c) after maize between fruit tree rows (maturing stage).

- **Improved cropping systems through maize-based systems**

Plantation of fruit trees is a long-lasting suitable technology for erosion control, while sowing groundnut, ricebean and black testa cowpea through suitable cultivation is effective in reducing erosion on any degree of slope as shown in the flow chart of cropping systems (Fig. 10).

Moderate to steep slope areas: Severe erosion is a common occurrence after heavy rainfall in tilled soil of moderate to steep slopes. Therefore, alternatives to be used in decreasing erosion in this area are: (1) zero tillage after planting fruit trees; and (2) manually relay sowing of ricebean between maize rows prior to its maturity in late rainy season. However, maize sowing in early rainy season, if possible, should be done under no-tillage condition.

Table 13. Improved cultivars of groundnut, ricebean and black testa cowpea recommended for Tad Fa watershed.

Crop	Cultivar	Characteristics
Groundnut	KK 5	Higher yield, pink testa for both fresh and dry pod utilization and larger seed
Ricebean	L 28-0395	Higher yield, delayed shattering and larger seed
Black testa cowpea	KKU 305	Higher yield, delayed shattering, larger seed and tolerance to mosaic virus

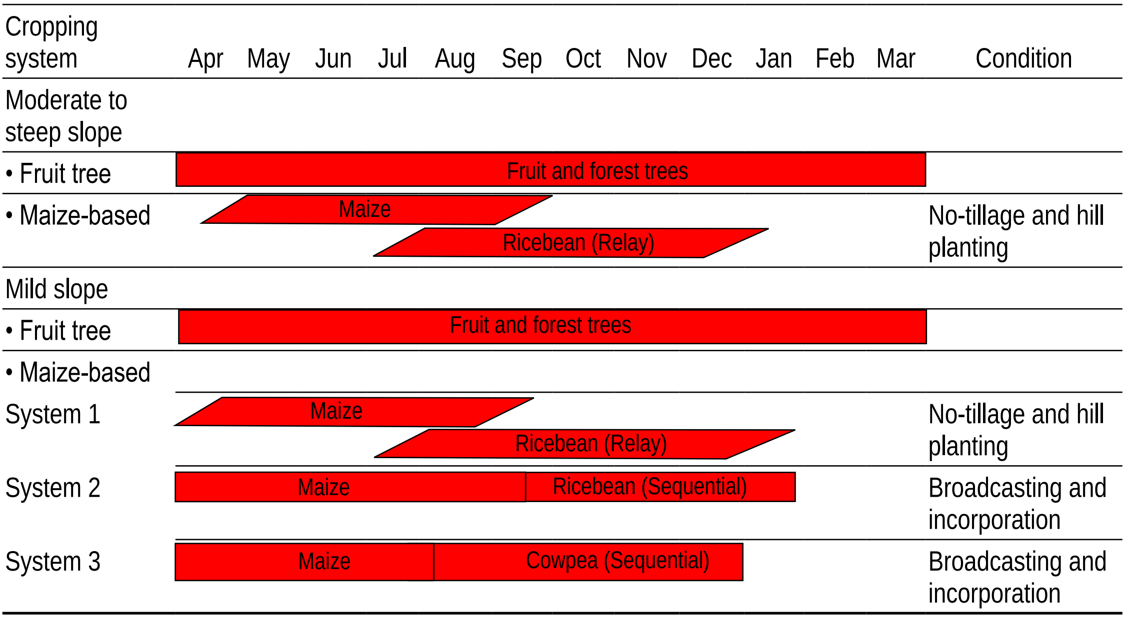

Figure 10. Flow chart of improved cropping systems at Tad Fa watershed and recommendation for legumes.

Mild slope areas: Erosion also can occur after heavy rainfall in tilled soil of mild slope areas. Therefore, alternatives in decreasing erosion in this area are: (1) sowing maize across slope in early rainy season; and (2) sequential sowing of ricebean or black testa cowpea by broadcasting prior to incorporation of maize stover in late rainy season.

Wang Chai Watershed

Wang Chai watershed has undulating areas that can be classified into: (1) upper upland, (2) lower upland, (3) upper paddy fields, and (4) lower paddy fields (Fig. 11).

Figure 11. Cross section of undulating topography at Wang Chai watershed.

Paddy is a major crop grown under rainfed and partially irrigated conditions. The paddy fields may be classified into two zones: downstream and upstream. Downstream covers lower toposequence of the watershed including the areas along Lam Huay Bong stream where soils are sandy loam to loam and irrigation is available. Upstream covers the upper toposequence of the watershed with sandy loam soils and this upstream area is rainfed. Most soils are loamy sand to sandy loam. The soils in downstream are more fertile than the soils in upstream (Table 14).

Table 14. Soil properties on toposequence at Wang Chai watershed, 2004/05[1].

Location on toposequence[1]	Texture class	pH	Organic matter (%)	Available P (mg kg^{-1} soil)	Extractable K (mg kg^{-1} soil)	Extractable Ca (mg kg^{-1} soil)
Downstream	Sandy loam to loam	5.2	0.95	12.8	110.0	373.3
Upstream	Sandy loam	6.4	0.66	9.6	48.4	489.9

1. Average of data from six sites in downstream and from four sites in upstream.

Normally, rice is cultivated in the rainy season and soybean is grown under irrigated conditions along the Lam Huai Bong stream in the dry season. Most rainfed areas are left fallow in dry season due to scarcity of water and low soil fertility in the upstream areas. Crop growth and yield in the dry season are affected by water shortage (Fig. 12). The agronomic interventions at Wang Chai watershed during 2003/04-2005/06 were improved crop varieties and improved cropping systems with better cultural practices.

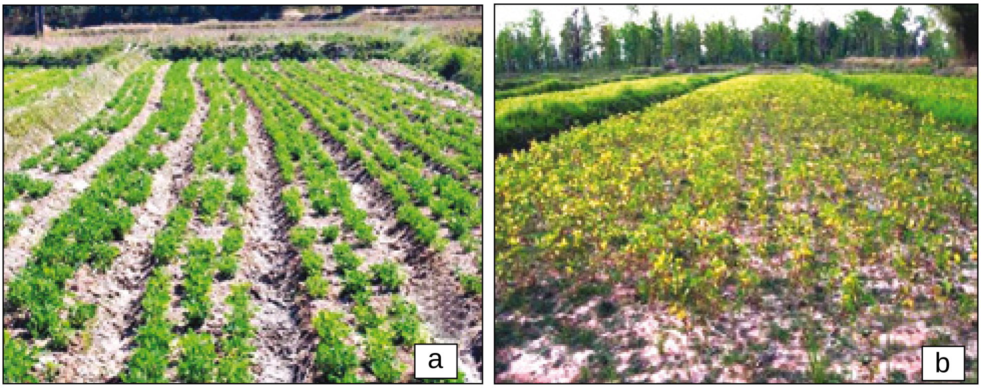

Figure 12. Performance of crops under harsh condition: (a) low fertile sandy soil in groundnut plot; and (b) water shortage in soybean plot.

Improved Crop Cultivars

The existing field crops in Wang Chai watershed are soybean, groundnut and maize. Normally, local cultivars of these crops are grown. The local cultivars usually give low yield. However, during 2003/04 to 2005/06 project period, the focus was on improved cultivars of soybean, groundnut and black testa cowpea.

Soybean: Soybean is an important leguminous crop in Thailand and the area planted to the crop was 422,000 ha and production was about 539,000 t during 1988–1991. However, after 1999, the area under soybean decreased due to low profits and erratic rainfall at the crop harvesting stage (Table 15). About 85% of annual production is used for vegetable oil extraction and soybean cake is used as animal feed. Twelve per cent soybean is used as source of protein in the diet of Thai people and 3% is used as seed. Annual production at the end of the 20th century was only 20–30% of domestic demand and Thailand imported about 1.0–1.5 million t of soybean cake during 1978–1998.

Soybean is a major crop in Wang Chai watershed in dry season and SJ 5 was the most extensively sown variety. Normally, soybean is widely grown in the irrigated areas on both sides of Lam Huai Bong stream where full irrigation (4–5 times) by pumping water is done. The evaluation of high-yielding cultivar of soybean “Khon Kaen (KK)” from KKFCRC was taken up in 2004/05. The trial plots were laid out in randomized complete block design (RCBD) with three replications. Soybean was sown in mid December 2004. Seeds were treated with *Rhizobium* and 93.75 kg ha^{-1} of complex fertilizer (16:16:8) was applied. KK gave higher grain yield (19%) and larger seed compared to SJ 5 in the dry season 2004/05 (Table 16 and Fig. 13). The data showed that KK is profitable, and farmers, particularly in downstream areas with irrigation facility, cultivated it on more than 16 ha during dry season of 2005/06.

Groundnut: Normally, only a few farmers grow groundnut in the dry season and common cultivars are local cultivars and Tainan 9. Field evaluation of four groundnut cultivars in farmers' fields under full irrigation (four to five times) along the Lam Huai Bong stream was conducted in the dry season 2004/05. New introduced cultivars Khon Kaen 5 (KK 5), Khon Kaen 6 (KK 6) and Khon Kaen (KK) from KKFCRC were compared with the local cultivar Tainan 9 for their performances (Fig. 14).

Table 15. Soybean production in Thailand during 2002/03–2004/05[1].

	Planted area ('000 ha)			Production ('000 t)			Grain yield (kg ha^{-1})		
Region	2002/03	2003/04	2004/05	2002/03	2003/04	2004/05	2002/03	2003/04	2004/05
North	127	104	110	178	154	162	1,450	1,510	1,490
Northeast	35	320	35	48	48	48	1,406	1,510	1,410
Central	18	16	16	34	29	29	1,360	1,450	1,480
Country average	180	153	162	260	230	240	1,490	1,540	1,510

1. Source: Office of Agricultural Economics (2004).

Figure 13. Comparison of two soybean cultivars: (a) field performance of KK (left) and SJ 5 (right); and (b) seed of SJ 5 (left) and KK (right).

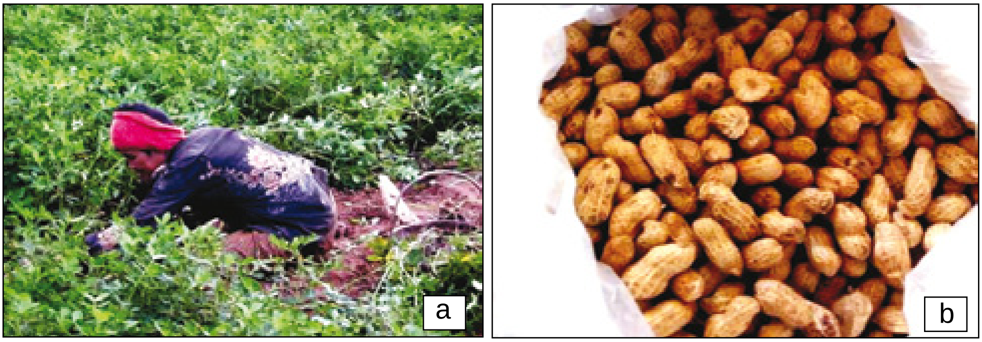

Figure 14. Performance of two suitable groundnut cultivars for Wang Chai watershed: (a) KK 6 at harvest; and (b) dry pods of KK 5.

Table 16. Yield and agronomic traits of two soybean cultivars in paddy fields in Wang Chai watershed[1].

Cultivar	Duration (days)	Harvested population ('000 plants ha^{-1})	Height (cm)	Nodes $plant^{-1}$	Pods $plant^{-1}$	Seeds $plant^{-1}$	Grain yield (kg ha^{-1})	100-seed weight (g)
KK	100	502.8[b]	55.6	11.9[a]	18.7[a]	43.9[b]	1,960[a]	14.75[a]
SJ 5	95	997.4[a]	55.2	9.8[b]	13.0[b]	27.4[b]	1,640[b]	12.80[b]
F-test		**	NS	**	*	**	**	*
CV (%)		24.91	6.20	4.96	23.04	20.99	9.42	9.27

1. NS = Not significant; * = Significant at *P* <0.05; ** = Significant at *P* <0.01; figures followed by the same letter in a column are not significantly different.

The cultivars KK 5 and KK 6 performed better in terms of pod yield (26% and 30% respectively) and shelling out-turn over local variety (Table 17). KK did not show encouraging results even when compared with local cultivar. Farmers gained about 48.8% and 31.5% by selling fresh pods (11.11 bahts kg^{-1}) of KK 5 and KK 6 respectively, ie, about 20,554 and 13,254 bahts ha^{-1} higher compared to the local cultivar. The total return from the local cultivar was 42,107 bahts ha^{-1}. The soil properties of trial fields are given in Table 18. Some of the major characteristics of KK 5 and KK 6 are given in Table 19.

Table 17. Comparison of three groundnut cultivars with the local cultivar at five sites in Wang Chai watershed in the dry season 2004/05[1].

Cultivar[2]	Duration (days)	Harvested population ('000 plants ha^{-1})	Pod yield (kg ha^{-1})		Shelling out-turn (%)	100-seed weight (g)	Bud necrosis virus[3] (%)
			Fresh	Dry			
KK 5	110	247.9[b]	4,480[ab]	1,959[ab]	67[a]	51.0[b]	17[a]
KK 6	120	231.5[b]	5,180[a]	2,017[a]	67[a]	84.4[a]	2[b]
KK	100	266.9[a]	3,510[b]	1,426[c]	62[b]	39.9[b]	22[a]
Local	110	180.0[c]	3,570[b]	1,554[bc]	66[a]	43.7[b]	23[a]
CV (%)		13.09	14.79	18.39	3.83	10.8	43
F-test		**	**	*	**	**	**

1. * = Significant at *P* <0.05; ** = Significant at *P* <0.01; figures followed by the same letter in a column are not significantly different.
2. Sowing date: December 2004; Fertilizer: Side dressing of 12-24-12 ~ 162.5 kg ha^{-1} at 1st flowering; Irrigation: (4–5 times).
3. Observations recorded at harvest.

Table 18. Soil properties of experimental fields at Wang Chai watershed.

Site	Farmers	Texture	pH	Organic matter (%)	Available P (mg kg^{-1} soil)	Extractable K (mg kg^{-1} soil)	Extractable Ca (mg kg^{-1} soil)
1	Mr. Somjit	Loam	5.1	1.039	12.5	83.85	431.7
2	Mr. Boonhom	Sandy	5.1	0.863	21.9	144.9	360.6
3	Mr. Wichian	Loam	5.1	1.175	8.2	96.13	262.0
4	Mrs. Sa-Ngat	Loam	6.1	0.772	8.8	87.02	461.3

Table 19. Positive and negative attributes of the two newly introduced groundnut cultivars as compared to the local cultivars.

Cultivar	Advantage	Disadvantage
KK 5	Large seed	-
KK 6	Large seed	Duration 10 days more than KK 5
	Resistant to bud necrosis virus (more than KK 5)	About 2 months of seed dormancy

Black testa cowpea: Black testa cowpea was introduced as a new crop in Wang Chai watershed. Three black testa cowpea cultivars, viz, CP 4-2-3-1, IT 82E-9 and KKU 305 were evaluated under both residual soil moisture and partially irrigated condition. The three cultivars were grown after paddy rice in the dry season 2004/05. Table 20 reveals that IT 82E-9 performed better than the other two cultivars (CP 4-2-3-1 and KKU 305) grown under residual moisture condition, while under partial irrigated condition, no specific advantage was found with all the three cultivars (Fig. 15).

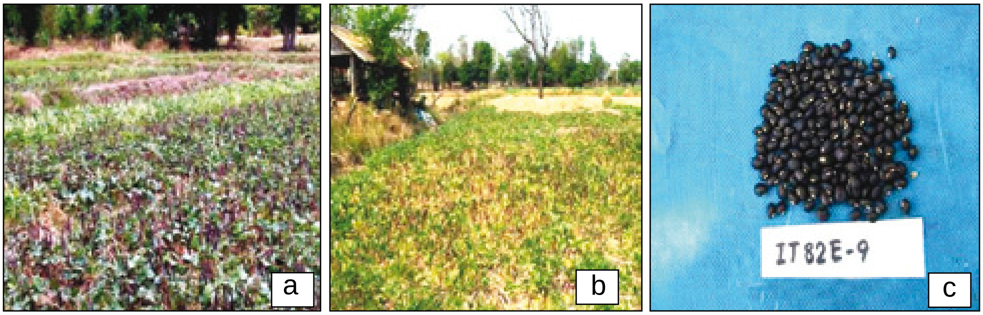

Figure 15. Performance of black testa cowpea IT 82E-9 at Wang Chai watershed in dry season: (a) under partial irrigation (2–3 times); (b) seed under residual soil moisture; and (c) seed.

Table 20. Grain yield of three black testa cowpea cultivars under two different conditions in paddy fields in Wang Chai watershed in dry season 2004/05[1].

Cultivar	Duration (days)	Residual soil moisture: Harvested population ('000 plants ha^{-1})	Residual soil moisture: Grain yield (kg ha^{-1})	Residual soil moisture: 100-seed weight (g)	Partial irrigation (2-3 times): Harvested population ('000 plants ha^{-1})	Partial irrigation (2-3 times): Grain yield (kg ha^{-1})	Partial irrigation (2-3 times): 100-seed weight (g)
CP 4-2-3-1	76–84	179.6±117.9	460±10.7	12.8±1.24	162.0±104.6	520±21.9	13.8±1.20
IT 82E-9	76–84	122.3±18.7	570±162.0	15.1±0.28	145.3±17.9	490±53.0	13.9±1.65
KKU 305	76–89	180.4±20.8	490±6.1	19.0±1.90	176.2±22.4	480±22.7	19.8±1.73

1. Fertilizer: Basal of 12-24-12 ~ 125 kg ha^{-1}.

Improved Cropping Systems

The improved cropping systems were focused on the evaluation and expansion of the three legume crops soybean, groundnut and black testa cowpea in: (1) paddy fields in dry season under rainfed and partial irrigation; and (2) uplands in dry season.

Responses of Three Soybean Cultivars with Supplemental Irrigation

Three soybean cultivars (viz, KK, SJ 5 and CM 2) in paddy fields in dry season with 1–2 irrigations at monthly interval after sowing were evaluated. With one irrigation, CM 2 gave the highest grain yield (13.7% more compared to KK and 20.0% higher compared to SJ 5). Mean grain yield was higher in treatment with two irrigations than in treatment one irrigation (Table 21). More frequency of irrigation increased plant height, nodes and seed weight but decreased green seed percentage (Table 22). The soil properties of trial fields are shown in Table 23.

Table 21. Effect of irrigation on yield of three cultivars of soybean in paddy field during the dry season 2004/05.

Cultivar	Crop duration (days after sowing)	Yield (kg ha^{-1}): One irrigation	Yield (kg ha^{-1}): Two irrigations	Yield increase (%)
CM 2	83	660	870	31.3
KK	95	580	860	47.5
SJ 5	91	550	870	57.5
Average		600	870	44.6

Table 22. Comparison of two levels of water application treatments to soybean crop[1].

Irrigation[2]	Harvested population ('000 plants ha^{-1})	Height (cm)	Nodes plant^{-1}	Pods plant^{-1}	Grain yield (kg ha^{-1})	100-seed weight (g)	Green seed[3] (%)
One	230.5±51.3	35.8±3.6	10.4±0.2	16.0±3.4	600±57.2	10.8±0.52	17.9±10.4
Two	241.1±66.9	38.6±4.5	10.7±0.5	20.0±3.3	870.7±5.5	12.2±0.51	10.7±8.6

1. Fertilizer: Basal of 12-24-12 at 156.25 kg ha^{-1}.
2. One month interval after sowing.
3. By weight (visual separation).

Table 23. Soil properties of trial fields.

Texture	pH	Organic matter (%)	Available P (mg kg^{-1} soil)	Extractable K (mg kg^{-1} soil)	Extractable Ca (mg kg^{-1} soil)
Sandy loam	6.3	0.737	8.8	28.51	310.7

Rice Stubble Management in Soybean Cultivation in Paddy Fields

Two experiments with soybean were conducted at two different sites during dry season of 2003/04 and 2004/05. The details of the experiments were as follows:

Evaluation of soybean cultivation in the dry season after rice: This experiment was conducted in paddy fields in Phu Kiew District, Chaiyaphum province in dry season 2003/04. The trial consisted of two sub-experiments with two sowing dates (9 and 25 December 2003) in nine lateral areas.

Experiment design for each sub-experiment: Split plot in RCB with three replications

Main plots: Three soybean cultivars [Chiang Mai 2 (CM 2), Khon Kaen (KK) and SJ 5]

Sub-plots: Soybean stand within 1 m row (9, 12, 15, 18, and 21 plants after thinning)

General practices: Broadcasted urea (46% N) 62.5 kg ha^{-1} then incorporated rice stubble before sowing

Fertilizer: Seed inoculation with *Bradyrhizobium japonicum* and basal application of fertilizer 12-24-12 (156.25kg ha^{-1}) at sowing

Non-irrigated (residual soil moisture)

Stubble of rice cultivar RD 6 (sticky rice) was incorporated in rainy season before sowing soybean cultivar: 3,226 kg and 5,920 kg of stubble dry weight (sun-dried) ha^{-1} before sowing date 1 and date 2, respectively. Soil properties are given in Table 24. Soil moisture trends in the trials are shown in Figure 16. Sowing date had a significant effect on crop yield (about 100% in date 1 vs date 2), and yield variation was not significantly different among the three cultivars and five levels of plant populations (Tables 25 and 26).

Table 24. Soil analysis of surface soil (0–15 cm) in Phu Kiew in dry season 2003/04.

Sowing	pH	Organic matter (%)	Available P (mg kg^{-1} soil)	Extractable K (mg kg^{-1} soil)	Extractable Ca (mg kg^{-1} soil)
Date 1	4.9	0.62	1.8	21.0	117.0
Date 2	5.1	0.58	1.7	21.0	147.0

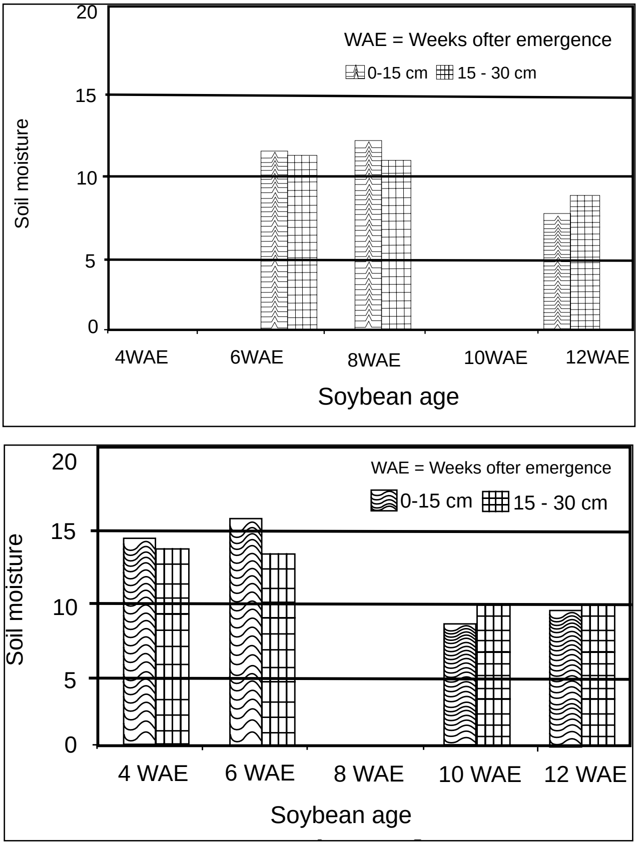

Figure 16. Soil moisture (%) at 0–15 cm and 15–30 cm in dry season 2003/04: (top) experiment 1; and (bottom) experiment 2.

Table 25. Effect of three soybean cultivars and five population densities on grain yield and seed characters in two sowing dates at Phu Kiew district in dry season 2003/04[1].

	Sowing date 1				Sowing date 2			
	Harvested population	Yield			Harvested population	Yield		
Treatment	('000 plants ha^{-1})	(kg ha^{-1})	Green seed[2] (%)	Hard seed[3] (%)	('000 plants ha^{-1})	(kg ha^{-1})	Green seed[2] (%)	Hard seed[3] (%)
Cultivar (A)								
SJ 5	492.7	600	5.3	14.9[b]	504.9	350[b]	20.9[a]	44.3[a]
KK	470.1	580	1.1	19.2[a]	467.9	390[a]	1.1[c]	37.8[a]
CM 2	518.7	630	2.4	0.7[c]	480.6	240[c]	5.0[b]	7.3[b]
Plants m^{-1} row (B)								
9	315.2[e]	580	3.1	8.0	314.8[d]	320	9.4	25.6
12	404.4[d]	610	2.8	12.8	414.5[c]	340	10.2	26.1
15	507.6[c]	660	2.9	11.0	454.3[c]	320	8.3	29.9
18	566.5[b]	530	2.8	12.6	581.0[b]	290	8.5	33.6
21	675.4[a]	640	3.0	13.7	640.0[a]	350	8.6	33.8
CV (%)	7.2	16.2	27.3	49.2	8.5	32.4	63.9	30.5
F-test: A	NS	NS	NS	**	NS	**	**	**
B	**	NS	NS	NS	**	NS	NS	NS
AxB	NS	NS	NS	NS	NS	NS	NS	NS

1. NS = Not significant; ** = significant at $P < 0.01$; figures followed by the same letter in a column are not significantly different.

2. By weight (visual separation).

3. By counting ofter seed germination test.

Table 26. Combined analysis of soybean yield, yield components and agronomic traits under two sowing dates, three cultivars and five population densities in Phu Kiew in dry season 2003/04[1].

Treatment	Harvested population ('000 plants ha^{-1})	Plant height (cm)	TDW[2] (g plant^{-1})	Pods plant^{-1}	Seeds plant^{-1}	Yield (kg ha^{-1})	100-seed weight (g)	Green seed (%)[3]	Hard seed (%)[4]
Sowing date (D)									
Date 1	493.8	50.1	1.10	8.7[a]	14.9[a]	600[a]	11.9	2.90[b]	11.60[b]
Date 2	484.5	49.3	1.16	6.9[b]	11.2[b]	320[b]	12.3	9.00[a]	29.78[a]
Cultivar (A)									
SJ 5	498.8[a]	56.1[a]	1.01[b]	8.9[a]	14.2	470	11.6	13.1[a]	29.57[a]
KK	469.0[b]	54.6[a]	1.31[a]	7.2[b]	12.6	480	12.3	1.11[b]	28.50[a]
CM 2	499.6[a]	38.3[b]	1.00[b]	7.3[b]	12.3	440	12.6	3.70[b]	4.00[b]
Plants m^{-1} row (B)									
9	315.0[a]	48.4[b]	1.10[ab]	9.2[a]	15.3[a]	450	12.4[a]	6.3	16.78
12	409.5[b]	49.7[ab]	1.13[ab]	8.3[a]	14.1[ab]	480	12.1[ab]	6.5	19.44
15	481.0[c]	50.8[a]	1.22[a]	7.8[ab]	13.0[bc]	490	12.3[a]	5.6	20.44
18	573.7[d]	48.3[b]	1.01[b]	6.7[b]	11.3[c]	410	11.8[b]	5.7	23.06
21	666.6[e]	51.2[a]	1.20[a]	6.8[b]	11.4[c]	500	12.0[ab]	5.8	23.72
CV (%)	7.9	6.5	17.6	19.4	19.1	21.8	4.6	68.7	36.6
F-test: D	NS	NS	NS	**	**	**	NS	**	**
A	*	**	*	*	NS	NS	NS	**	**
DxA	NS	NS	NS	NS	NS	*	NS	**	**
B	**	*	*	**	**	NS	*	NS	NS
DxB	NS	NS	NS	NS	NS	NS	NS	NS	NS
AxB	NS	NS	NS	NS	NS	NS	NS	NS	NS
DxAxB	NS	NS	**	NS	NS	NS	NS	NS	NS

1. NS = Not significant; * = Significant at *P* <0.05; ** = Significant at *P* <0.01; figures followed by the same letter(s) in a column are not significantly different.
2. Top growth (stalks, pods and seeds) dry weight (sun-dried) at harvest.
3. By weight (visual separation).
4. By counting after seed germination test.

Response of Three Soybean Cultivars Under Three Management Methods of Rice Stubble

During 2004/05 dry season, a farmers' participatory field trial was conducted with three cultivars of soybean under three methods of rice stubble management in paddy fields in Wang Chai watershed, Phu Wiang district, Khon Kaen province (Fig. 17) and details of the experiment are given below:

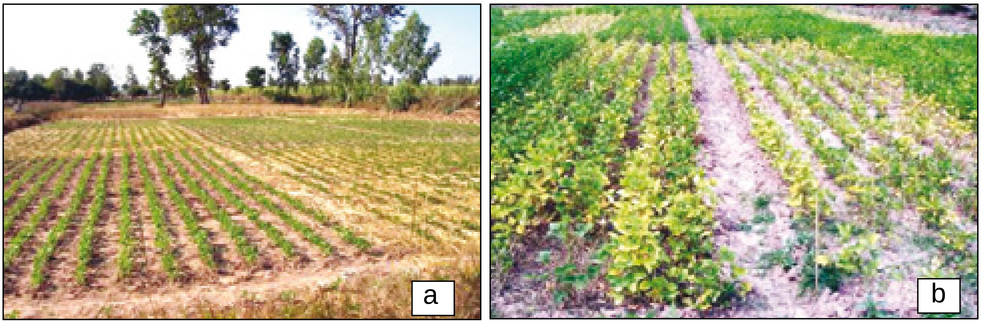

Figure 17. Rice stubble treatment before sowing soybean cultivar CM 2 (a) pre-flowering stage of crop with mulching; and (b) pre-harvest stage of crop with mulching (left) and incorporation (right) of rice stubble.

Sowing date: 17 December 2004

Experiment design: Split plot in RCB with three replications

Main plots: Three management methods of rice stubble (mulching, incorporating and burning); rice stubble used in each plot was collected or treated in in-situ areas

Sub-plots: Three soybean cultivars [Chiang Mai 2 (CM 2), Khon Kaen (KK) and SJ 5]

General practices: Conventionally plowed the soil

Fertilizer: Seed inoculation with *Bradyrhizobium japonicum* and basal application of fertilizer 12-24-12 (156 kg ha^{-1}) at sowing

Partially irrigated (if necessary)

About 4,150 kg ha^{-1} (dry weight, sun-dried) of stubble of rice cultivar RD 6 was applied before sowing soybean. Soil analysis of surface soil (0 to 15 cm) in Phu Wiang in dry season 2004/05 is shown in Table 27. Soil moisture contents in mulching, incorporation and burning methods are shown in Figure 18.

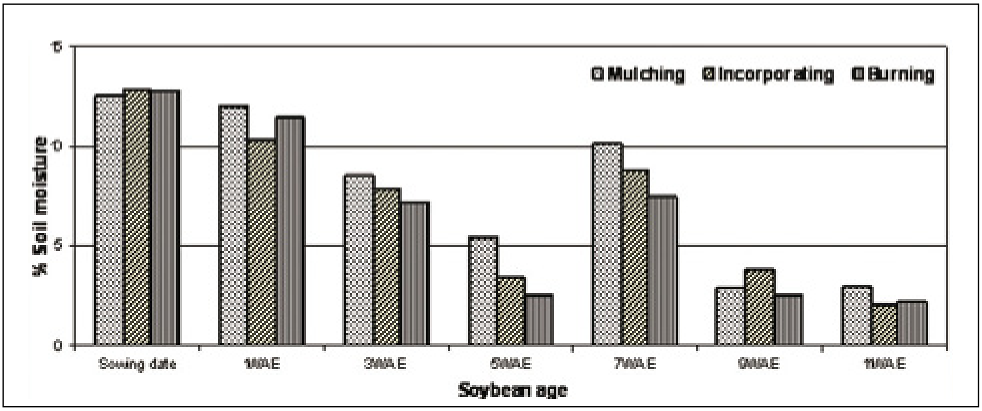

Figure 18. Soil moisture in surface (0 to15 cm) and subsoil (15 to 30 cm) under different rice stubble management treatments in soybean crop in dry season 2004/05 (Note: WAE = Weeks after emergence).

Table 27. Soil analysis of surface soil (0-15 cm) in Phu Wiang in dry season 2004/05.

Management	pH	Organic matter (%)	Available P (mg kg^{-1} soil)	Extractable K (mg kg^{-1} soil)	Extractable Ca (mg kg^{-1} soil)
Before tillage	7.2	0.41	12.7	35.0	178.0
After sowing					
Mulching by rice stubble	5.5	0.36	15.4	43.8	90.4
Incorporating rice stubble	5.2	0.22	10.7	38.6	58.1
Burning rice stubble	7.0	0.09	14.0	100.0	439.7

Table 28 shows the detailed statistical analysis of the effect of three methods of rice stubble management on three soybean cultivars on various agronomic traits like grain yield, yield component and other characters. The analysis showed that both the cultivars and rice stubble management system had significant effect on grain yields.

Response of Groundnut Cultivar KK 5 Under Three Levels of Supplemental Irrigation

Groundnut cultivar KK 5 was grown on loamy sand soil after paddy in the 2004/05 dry season under three levels (1, 2 and 3 times) of irrigation applied at one month interval after sowing. The results showed that one irrigation gave very low yield and shelling out-turn and the application of two and three irrigations gave an increase in pod yield of 238% and 313% compared to yield under one irrigation treatment (Table 29). The frequencies of irrigation also affected growth of groundnut (dry weight, sun-dried) at harvest. The results indicated that application of irrigation had significant effect on yields and other yield attributes. Three irrigations at monthly interval after sowing enhanced crop growth and yield compared to one and two irrigations (Fig. 19).

Figure 19. Plant growth and pod yield of groundnut cultivar KK 5 after number of irrigations: one (right); two (middle); and three (left).

Table 28. Effects of three rice stubble management practices on soybean on grain yield, yield components and agronomic characters at Phu Wiang district in dry season 2004/05[1].

Treatment	Harvested population ('000 plants ha^{-1})	TDW[2] (g $plant^{-1}$)	Pods $plant^{-1}$	Seeds $plant^{-1}$	Yield (kg ha^{-1})	100-seed weight (g)	Seed performance: Green seed (%)[3]	Seed performance: Green seed germination (%)[4]	Seed performance: Germination (%)[5]
Rice stubble management (A)									
Mulching	466.7	168.6	12.6	23.4	580	10.9	6.7	10.9	81.6
Incorporating	461.1	117.4	9.5	15.8	430	10.3	5.3	11.3	79.6
Burning	463.5	163.0	11.2	20.0	590	11.0	5.2	5.9	85.7
Cultivar (B)									
SJ 5	515.7[a]	157.6[a]	11.4[ab]	20.7[a]	540[a]	10.1[b]	12.1[a]	19.2[a]	67.6[c]
KK	410.8[c]	172.4[a]	12.3[a]	22.3[a]	570[a]	10.5[ab]	2.6[b]	8.2[b]	84.9[b]
CM 2	464.8[b]	118.9[b]	9.6[b]	16.2[b]	480[b]	11.5[a]	2.5[b]	0.7[c]	94.3[a]
CV (%)	6.6	13.5	13.0	17.8	9.7	6.7	38.2	50.3	6.5
F-test: A	NS	NS	NS	NS	NS	NS	NS	NS	NS
B	**	**	**	**	*	**	**	**	**
AxB	NS	NS	NS	NS	NS	NS	NS	NS	NS

1. NS = Not significant; * Significant at *P* <0.05; ** = Significant at *P* <0.01; figures followed by the same letter in a column are not significantly different.
2. Top growth (stalks, pods and seeds) dry weight (sun-dried) at harvest time.
3. By weight (visual separation).
4. By counting after seed germination test.
5. By counting; germination test 4 months after storing seed under room temperature.

Table 29. Performance of groundnut cultivar KK 5 under different levels of irrigation in paddy field in Wang Chai watershed in dry season 2004/05.

No. of irrigations[1]	Population ('000 plants ha^{-1})	Top growth[2]: Dry weight (kg ha^{-1})	Top growth[2]: Rel. (%)	Pods $plant^{-1}$	Dry pod yield (kg ha^{-1})	Yield increase (%)	Shelling out-turn (%)	100-seed weight (g)
One	200,556	3,187±93	100	1.40±0.01	310±62.9	0	44.6±4.8	48.4±1.92
Two	212,778	4,148±637	130.7	4.16±1.48	1,050.0±149.3	+237.6	64.0±3.9	55.0±0.64
Three	223,333	5,625±748	177.2	8.44±0.05	1,280.3±7.9	+312.5	61.4±2.2	48.7±1.47

1. One month interval after sowing.
2. After detachment of pods.

Response of Black Testa Cowpea Cultivars with Supplemental Irrigation

Two black testa cowpea cultivars (CP 4-2-3-1 and IT 82E-9) were sown in paddy field after rice in the dry season and two treatments of no irrigation (residual soil moisture) and one irrigation at one month after sowing were compared. Crop yield increased significantly with one supplemental irrigation compared to the non-irrigated crop; however, crop yield variations between the two varieties was not significant (Table 30).

Table 30. Grain yield of two black testa cowpea cultivars in paddy fields under different water regimes in Wang Chai watershed in dry season 2004/05.

	Grain yield (kg ha^{-1})		
Cultivar	Residual soil moisture	One irrigation[1]	Yield increase (%)
CP 4-2-3-1	470	670	+42.0
IT 82E-9	460	660	+45.0
Average	470	670	+43.3

1. At 30 days after sowing.

Normally, sugarcane is grown in both upper and lower uplands for two to three years. The harvesting of the last ratoon is in March and the fields are left fallow during April up to October, prior to growing next sugarcane crop. During this period some short-duration crops like soybean, groundnut and black testa cowpea can be grown.

Evaluation of Three Legumes in Rainy Season in 2004

Soybean (KK and SJ 5), groundnut (KK 5, KK 6 and local) and black testa cowpea (IT 82E-9 and CP 4-2-31) were planted in upland (loamy sandy) in Wang Chai watershed in early August 2004 (Fig. 20). Due to low soil fertility, waterlogging after heavy rainfall during late August to early September and early withdrawal of rain in September, growth of all crops was affected but black testa cowpea gave reasonable grain yield. CP 4-2-3-1 gave higher grain yield than IT 82E-9 by 16.6%, but its seeds were smaller. Groundnut and soybean gave very low yield. But the large-seeded groundnut Virginia type KK 6 had high shelling out-turn (46%) (Table 31).

Figure 20. Legumes sown in upland in Wang Chai watershed in rainy season 2004: (a) groundnut with good vegetative growth but low pod yield; (b) soybean with poor performance; and (c) good crop performance of black testa cowpea.

Table 31. Effect of growing black testa cowpea in upland in Wang Chai watershed in rainy season 2004.

Crop	Cultivar	Yield (kg ha^{-1})	Shelling (%)	100-seed weight (g)
Groundnut	KK 5	490 (dry pod)	35.9	29.5
	KK 6	140 (dry pod)	46.3	31.1
	Local	6010 (dry pod)	15.0	29.0
Soybean	KK	143 (grain)	-	8.2
	SJ 5	100 (grain)	-	8.2
Black testa cowpea	IT 82E-9[1]	750 (grain)	62.5	13.1
	CP 4-2-3-1	880 (grain)	66.8	11.6

1. Susceptible to leaf blight (Ubon Ratchathani Field Crops Research Center 2000).

Evaluation of Legumes in Rainy Season in 2005

After we found in the dry season 2005 that KK is a suitable soybean cultivar, farmers in Wang Chai watershed adopted it. The evaluation of seed multiplication of KK was conducted in the upper and lower upland in Wang Chai watershed in rainy season 2005. Due to more variation in soil fertility, large variation in soybean performance was found (Table 32 and Fig. 21). Grain yield was higher (202 per cent) in the lower part of upland area than in the upper area. Also harvest index, seed size and seed germination percentage were greater in the lower area than in the upper area (Table 33).

Figure 21. Performance of soybean cultivar KK in upland in Wang Chai watershed in rainy season 2005: (a) upper upland; and (b) lower upland.

Table 32. Soil analysis of different plots in Wang Chai watershed in rainy season 2005.

Area	Texture class[1]	pH	Organic matter (%)	Available P (mg kg^{-1} soil)	Extractable K (mg kg^{-1} soil)	Extractable Ca (mg kg^{-1} soil)
Upper upland[2]	SL	5.1	0.45	35.0	86.8	102.2
Lower upland[2]	LS	6.9	0.38	175.5	81.0	269.0
Upper paddy	SL	5.5	0.17	90.5	89.0	83.5

1. SL = Sandy loam; LS = Loamy sand.
2. Common soil analysis for evaluations of both groundnut and soybean.

Table 33. Effect of growing soybean in upland in Wang Chai watershed in rainy season 2005 on yield and yield components of cultivar KK[1].

Area	Harvested population ('000 ha^{-1})	Grain yield[2] (kg ha^{-1})	SW/TDW[3] (%)	Good seed by weight (%)	100-seed weight (g)	Seed germination (%)
Upper upland	385.0	490	21.5	75.0	14.2	70.0
Lower upland	382.8	1490	46.0	95.0	15.0	90.3

1. Sowing date: Early July 2005.
2. Sun-dried.
3. SW/TDW = Seed weight/top growth dry weight.

Groundnut cultivar KK 5 was grown for seed multiplication in three positions on used toposequence (upper upland, lower upland and upper paddy) and three planting dates in Wang Chai watershed in the rainy season 2005 (Figs. 22 and 23). Monthly rainfall during 2005 in Wang Chai watershed is given in Table 34. The results indicated that even though Ca concentration in the upper paddy field seemed to be lower than the lower upland, water deficit throughout the growing season was more serious in the upper upland. Under same amount of rainfall, groundnut sown in the upper paddy field and lower upland had shown better performance than the upper upland (Table 35). Planting in early May to early June was also advantageous (343% increase) than planting during late June to early July (Table 36).

Table 34. Monthly rainfall and rainy days in Wang Chai watershed in rainy season 2005[1].

	Apr		May		Jun		Jul		Aug		Sep		Oct		Nov	
Month	E	L	E	L	E	L	E	L	E	L	E	L	E	L	E	L
Rainfall (mm)	0	0	40	139	16	103	97	53	31	95	166	76	43	10	40	0
Rainy days	0	0	4	7	2	10	4	7	5	8	8	5	3	1	3	0
Total rainfall (mm)	0		179		119		150		126		242		53		40	
Total rainy days	0		11		12		11		13		13		4		3	

1. E = Early; L = Late.

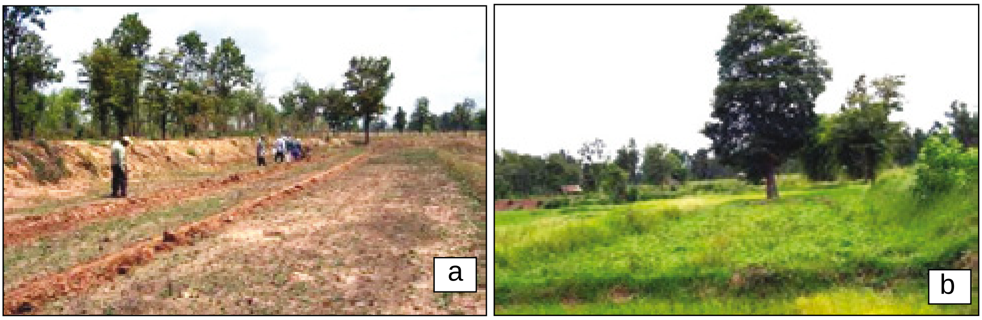

Figure 22. Groundnut in upper paddy field in Wang Chai watershed in May 2005: (a) sowing; and (b) at harvest.

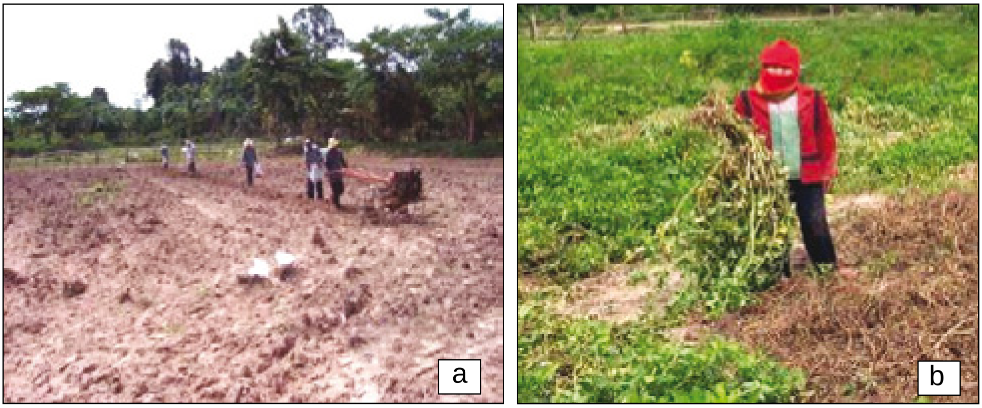

Figure 23. Groundnut in lower upland in Wang Chai watershed in May 2005: (a) sowing; and (b) at harvest.

Table 35. Yield and yield components of groundnut cultivar KK 5 sown in different areas at Wang Chai watershed in rainy season 2005.

Area	Harvested population ('000 plants ha^{-1})	Top growth dry weight[1] (kg ha^{-1})	Pods plant^{-1}	Dry pod yield[1] (kg ha^{-1})	Shelling out-turn (%)	100-seed weight (g)
Upper upland[2]	184.4±12.6	5,070±516	6.8±0.2	730±134	54.5±12.0	38.16±5.26
Lower upland[2]	258.9±2.2	6,960±582	6.4±1.7	1,640±42	74.0±2.0	55.46±1.79
Upper paddy[3]	349.4±17.5	4,510±1044	7.3±0.7	1,730±369	72.0±2.8	41.60±6.46

1. Sun-dried.
2. Conventional tillage.
3. No tillage.

Table 36. Effect of sowing date on groundnut yield and other growth components in uplands.

Sowing time	Harvested population ('000 plants ha^{-1})	Top growth dry weight[1] (kg ha^{-1})	Pods plant^{-1}	Dry pod yield[1] (kg ha^{-1})	Shelling out-turn (%)	100-seed weight (g)
Early–late May	201.7±50.9	5,822±1,239	7.2±1.3	1,160±488	66.6±8.1	45.2±10.52
Early June	171.0±61.2	5,210±1,195	7.7±2.6	1,170±875	60.6±16.9	46.5±11.01
Late June–early July	173.8±39.7	2,172±701	2.7±2.2	260±330	48.2±35.9	33.2±9.40

1. Sun-dried.

Conclusion

As mentioned in the introduction the areas in Wang Chai watershed can be classified into four categories for the purpose of different cropping systems: upper upland, lower upland, upper paddy fields and lower paddy fields. The traditional cropping systems are given in Figure 24 and some improved cropping systems are recommended in Figure 25.

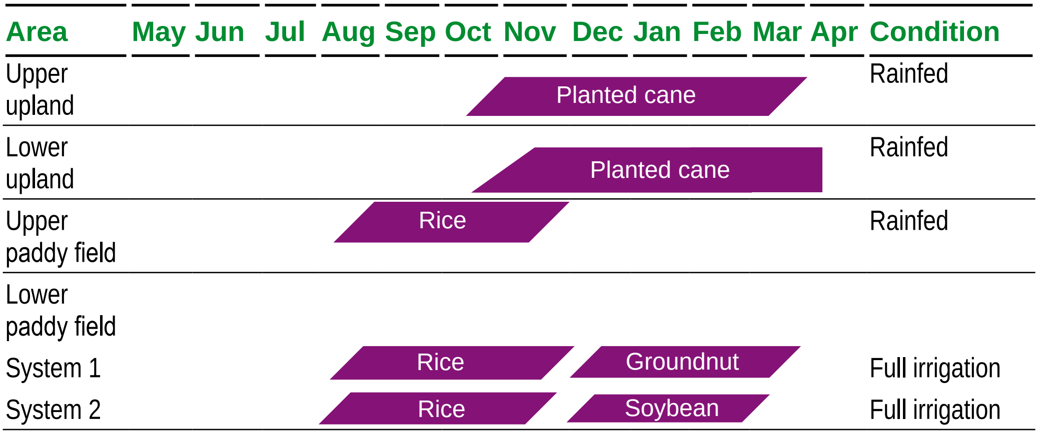

Figure 24. Flow chart of traditional cropping systems in Wang Chai watershed before 1999.

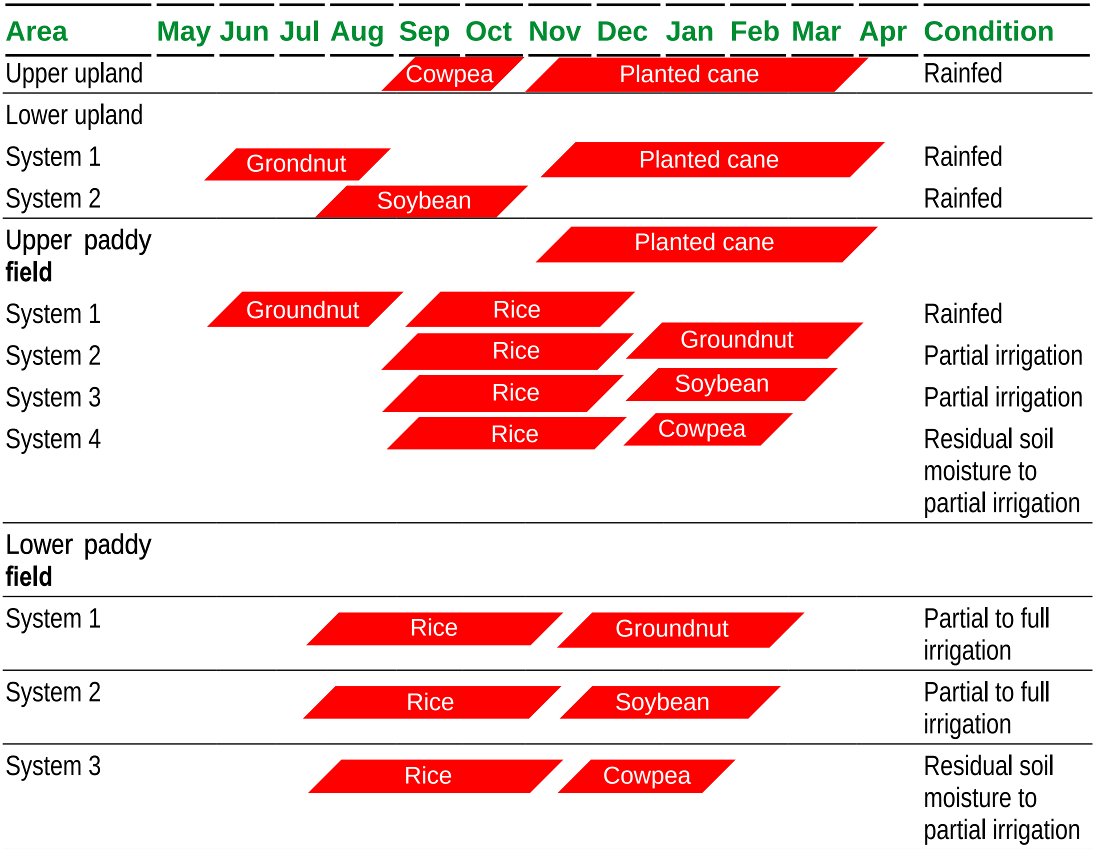

Figure 25. Flow chart of improved cropping system at Wang Chai watershed after ADB-ICRISAT Project during 1999-2005 and recommendation for legumes.

Sowing Legumes in Upper and Lower Uplands

Normally, both areas are occupied by sugarcane and the fields are left fallow for 6–10 months after harvest of the last ratoon. The fallow areas can be used for sowing some short-duration legumes. Therefore, recommendations for sowing short-duration legumes in sugarcane-based cropping systems in the upper and lower upland areas are different.

- **Recommendation for the upper upland in rainy season:** Moreover, soil fertility in the upper upland is low and most areas are rainfed. Often water shortage occurs in the early rainy season and waterlogging occurs in middle rainy season. This can affect crop growth and yield. However, black testa cowpea as a shorter duration crop can be sown but it should be sown in late rainy season. The cultivar CP 4-2-3-1 is suitable.
- **Recommendation for the lower upland in rainy season:** Soil fertility in the lower upland is higher than in the upper upland and water movement downward to the lower area induces sufficient water for crop growth for a longer period. Soybean and groundnut are well-adapted crops to this situation. For groundnut, sowing should be started earlier in early rainy season during May to early June.

Sowing Legumes in Upper Paddy Fields

Normally, most upper paddy fields are under rainfed condition with small water supplies from farm ponds. Rice can be sown only in rainy season and the fields are left fallow in dry season. However, some legumes can be sown in these areas.

- **Recommendation for rainy season:** Groundnut can be sown in late April to early May, and the crop can be harvested in early August under rainfed condition, prior to transplanting rice.
- **Recommendation for dry season:** Soybean, groundnut and black testa cowpea can be sown after rice but partial irrigation should be applied for good yields, ie, at least two irrigations for soybean, three irrigations for groundnut and one irrigation for cowpea. The results indicated that soybean cultivars CM 2, KK and SJ 5, groundnut cultivar KK 5 and IT 82E-9 and CP 4-2-3-1 can be recommended.

Sowing Legumes in Lower Paddy Fields in Dry Season

Normally, lower paddy fields are under both rainfed and irrigated conditions and rice is sown in rainy season but extended soybean areas and small areas of groundnut are common practices. However, some of the recommendations for irrigated and rainfed areas are:

- **For irrigated areas:** Soybean, groundnut and cowpea can be sown under both partial and full irrigation. The cultivars of the three legumes, mentioned earlier are recommended for the upper paddy fields in the dry season.
- **For non-irrigated areas:** Black testa cowpea can be sown without irrigation and IT 82E-9 is a suitable cultivar.

In conclusion the improved crops and cropping systems can play a very important role in increasing agricultural productivity and income of farmers and reducing land degradation in Northeast Thailand. Several improved crops and cropping systems were identified for the different toposequence positions of the landscape.

References

Bhag Mal. 1994. Grain legumes. Pages 43–52 *in* Underutilized grain legumes and pseudocereal – their potentials in Asia. Bangkok, Thailand: Regional Office for Asia and the Pacific (RAPA), Food and Agriculture Organization of the United Nations.

Field Crops Research Institute. 2001. A guide book for field crops production in Thailand. Khon Kaen, Thailand: Field Crops Research Institute. 194 pp.

Khon Kaen Field Crops Research Center. 1996. Rice bean. Khon Kaen, Thailand: Khon Kaen Field Crops Research Center, Field Crops Research Institute, Department of Agriculture. 24 pp.

Na Lampang A. 1990. Rice bean. Presented at the workshop on Unexploited and Potential Food Legumes in Asia, Chiang Mai Field Crops Research Center, Chiang Mai, Thailand, 27 Oct–3 Nov 1990.

Office of Agricultural Economics. 2004. Agricultural statistics of Thailand 2004. Bangkok, Thailand: Ministry of Agriculture and Co-operatives. (http://www.oae.go.th.statistic/yearbook47/index.html)

Toomsaen S. 1996. Rice bean. Khon Kaen, Thailand: Khon Kaen Field Crops Research Center, Field Crops Research Institute, Department of Agriculture. Khon Kaen. 24 pp.

Ubon Ratchathani Field Crops Research Center. 2000. Cowpea. 1st edition. Ubon Ratchathani, Thailand: Ubon Ratchathani Field Crops Research Institute, Department of Agriculture. 38 pp.