1. Baseline Characterization of Tad Fa Watershed, Khon Kaen Province, Northeast Thailand

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Introduction

Agriculture is the main occupation in Thailand and it plays an important role in the economic development of the country. Thailand is located in the tropical monsoon climate region where the amount of rainfall is high but shortage of water occurs even in rainy season. Only 20% of total agricultural area is under irrigation, with rest constituting rainfed area, which has relatively lower crop yields. High soil erosion and reduced soil productivity are some of the problems in the rainfed area.

The northeastern part of Thailand occupies one-third of the whole country. The climate of the region is drier than that of other regions. Most of the soils in Northeast Thailand are infertile at present and liable to be further degraded. The empirical evidence shows that crop yields decreased over the years after the conversion of the area as agricultural land by deforestation. The soils have become infertile due to improper soil management. The soils are low in fertility and have low water-holding capacity (WHC), and soil erosion is a serious problem. The interventions by ICRISAT (International Crops Research Institute for the Semi-Arid Tropics) project aim to address these problems in the rainfed areas of Northeast Thailand. The watershed area in Phu Pa Man district in Khon Kaen province has been selected as benchmark site to address the above problems and increase agricultural productivity through a sustainable manner by adopting integrated soil, water and nutrient management (SWNM) and integrated crop management options.

Physical Resources

Location and Extent

Northeast Thailand is situated between 14^{O} to 19^{O} N latitude and 101^{O} to 106^{O} E longitude. The area is about 17 million ha or one-third of the whole country and is spread over 19 provinces: Kalasin, Khon Kaen, Chaiyaphum, Ysothon, Nakhon Phanom, Nakhon Ratchasima, Burirum, Maha Sarakham, Roi Et, Loei,

Sri Sa Ket, Sakon Nakon, Surin, Nong Khai, Udon Thani, Ubon Ratchathani, Mukdaharn, Nong Bua Lam Phu and Amnat Charoen. Location of the benchmark Tad Fa watershed is shown in Figure 1.

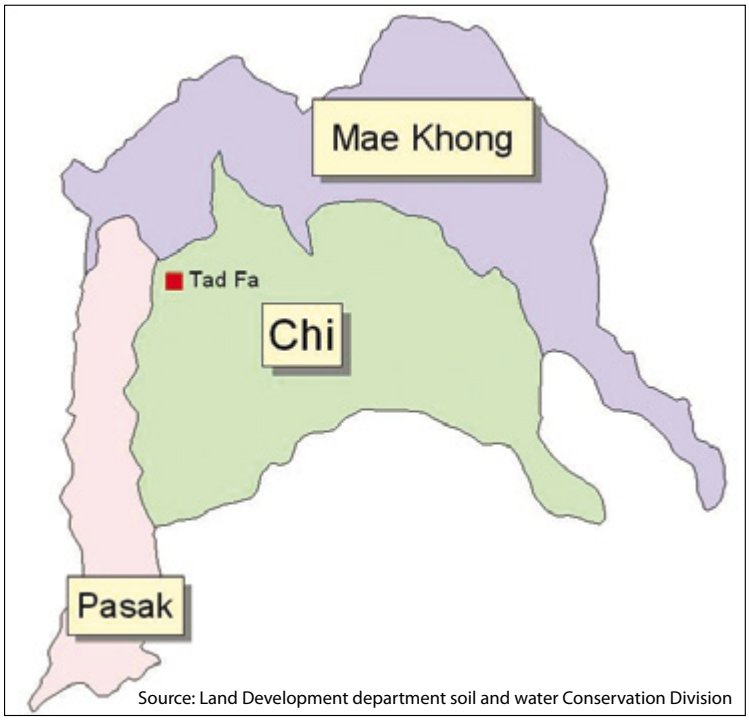

Figure 1. Location of Tad Fa watershed.

The topography of Northeast Thailand is generally characterized by high plateau with the ranges of Phetchabun and Dong Phayayen on the west, Phaya Dong Rak bordering Thailand with Cambodia on the South and Southeast, and Mae Khong river bordering with the Democratic Republic of Laos (LAOSPPR) on the north. On the middle, the range of Phu Pan divides the watershed area into two basins: Sakon Nakon basin on the upper part and Mun watershed on the lower part.

Despite similar amount of rainfall as in North and Central Thailand, Northeast Thailand is drier because of the shorter rainy season. Farming is the main occupation, with only 20% of total agricultural area under irrigation. Low crop productivity, soil salinity and soil erosion are some of the problems faced by the farmers.

Topography

Northeast Thailand, or the “Khorat Plateau”, is characterized by shallow basin (saucer-shaped basin). The plateau consists of flat-topped mountains and dissected peneplain surface with undulating features. The elevation varies from 200 m to 1000 m above mean sea level (amsl). Geologically, the region can be divided into six parts.

Western Highland

This area is distinct by hilly to mountainous topography, except the area close to northeastern part which is undulating to rolling topography. It covers the province of Loei and some part of Udon Thani, Khon Kaen, Chaiyaphum and Nakhon Ratchasima.

Northern Highland

This area is formed as thin strip on the northernmost region. The topography is rolling to hilly underlaid by lower and middle Khorat group. It covers some part of Nong Khai province and Nakhon Phanom province.

Sakon Nakon Basin

This basin is in the north of the region in which Sakon Nakon province is located in the middle. The basin covers the provinces of Nakhon Phanom, Sakon Nakon, Udon Thani, and Nong Khai. The topography is flat to undulating underneath by evaparite-bearing salt formation. The area is approximately 43,000 km^2 and the streams mainly flow to Nong Han, the biggest lagoon in Thailand with 170 km^2 size and then flow to Mae Khong river via Num Karn stream. Moreover, Songkram river, which originates in the north, joins with Mae hong river flowing through the northeastern part of the plateau.

Central Highland

This area is characterized by rolling to hilly topography. The range of Phu Pan is situated in southeastern part. It lies below the lower and middle Khorat group. Phu Pan range is extended to Mae Khong river.

Khorat Basin

The basin is located in the south of the region where Roi Et province and the north of Nakhon Ratchasima province are in the middle. It also covers

the provinces of Surin, Sri Saket, Nakhon Ratchasima, Ubon Ratchathani, Roi Et, Burirum, Maha Sarakham, Chaiyaphum, Yasothon, Khon Kaen and Kalasin. The topography is flat or almost flat or undulating. The area is about 137,000 km^2. The basin receives the water from Mun river which originates in the southeastern mountain and flows from east to the south. The watershed area is about 82,000 km^2. Chi river originates in the rim of the western part of the plateau, flows to the middle of the basin and joins with Mun river in Ubon Ratchathani province. The Chi river then flows to Mae Khong on the southeastern part of the plateau. Chi watershed is approximately 55,000 km^2.

Southern Lowland

This area is situated on the southernmost part of the region, where Phanom Dong Rak range is formed as a strip on the southernmost part. The topography is sloped northward towards Mun river and is characterized by flat to undulating land with some hilly topography in many areas especially the provinces of Surin, Burirum and the southeast of Nakhon Ratchasima. Basalt rock in tertiary area lies underneath. From the above characterization Northeast Thailand thus can be described in three areas: highland, upland and lowland.

Climate

The northeastern part of Thailand is located in the low latitude and is influenced by tropical low rainfall climate and wet-dry monsoonal or tropical Savannah climate. During November to February, the area is influenced by the northeast monsoon from the Eurasian continent resulting in a cooler and dry weather covering the whole region. The southwest monsoon lasting from May to September brings warm and moist weather from Indian Ocean to the area.

Seasons

The year can be divided into three seasons. Based on the climatic data for 10 years from 1988 to 1997 of many stations in Northeast Thailand, the climatological parameters are summarized.

Rainy season: The rainy season starts from May or the beginning of June to the beginning of October due to the effect of the southwest monsoon. Because the ranges of Phetchabun on the northeast and Dong Phayayen on the west, and the ranges of San Khampaeng and Phanom Dong Rak on the south are barriers, the rainfall due to the southwest monsoon is lower compared with the rainfall due the depression from the South China sea.

Winter season: The season starts from mid October to mid February caused by the northeast monsoon from China and brings a cool and dry climatic mass without vapor to the area. Thus the weather is very cool in the north while on the south it is warmer.

Hot season: The season starts from February to the end of May caused by the northeast monsoon from the South China sea and Gulf of Thailand. Because the northeast region is located far away from the Gulf of Thailand, the climate is hot and very dry.

Rainfall

The annual rainfall in Northeast Thailand is about 1,375 mm. In the west and the middle of the region including the provinces Chaiyaphum, Nakhon Ratchasima, Loei, Khon Kaen and Roi Et, the rainfall is lower than in the east and the north and is about 1,000–1,400 mm, occurring on 108 rainy days. In the east and north including the provinces Nakhon Phanom, Sakon Nakon, Nong Khai, Ubon Ratchathani, Udon Thani and Mukdahan, the annual rainfall is about 1,500–2,300 mm. Rainfall is highest in the Nakhon Phanom province (Table 1) and the number of rainy days is about 123 (Fig. 2).

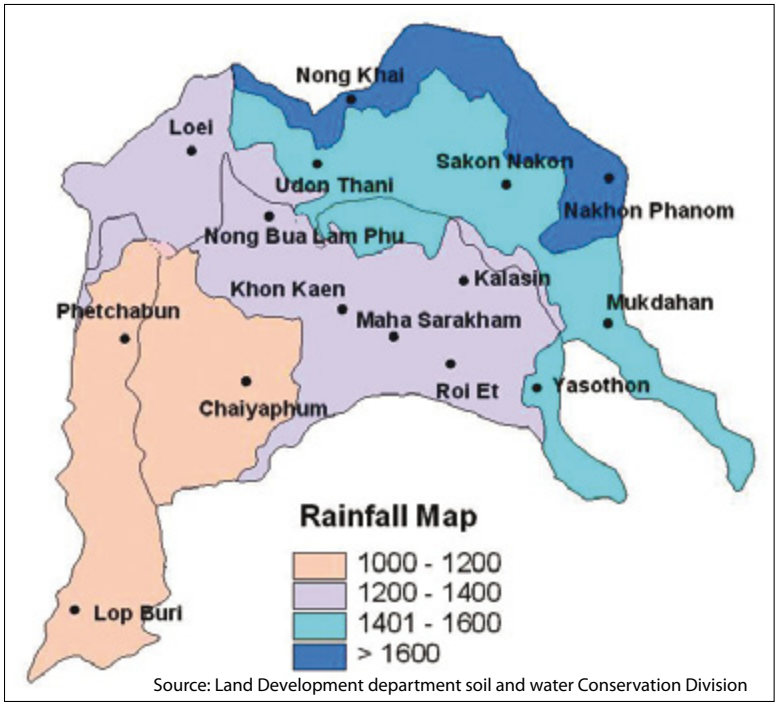

Figure 2. Rainfall distribution in different watersheds of Northeast Thailand.

Table 1. Mean annual rainfall (mm) in Northeast Thailand during 1988 to 1997.

Province	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	Average
Mukdahan	1206	1537	1762	1515	1438	1324	1490	1370	1751	1423	1482
Sakon Nakon	1623	1569	2078	1563	1513	1369	1686	1321	1614	1588	1593
Nong Khai	1878	1822	1566	1932	1626	1723	1992	1591	1372	1749	1755
Loei	1490	1131	1357	1252	1098	862	1318	1420	1289	969	1219
Udon Thani	1516	1399	1674	1281	1208	983	1932	1355	1845	1429	1462
Ubon Ratchathani	1270	1382	1734	1490	1597	1029	1956	1266	1470	1555	1475
Nong Bua Lam Phu	-	952	1041	457	-	865	1196	1344	1310	911	1009
Amnateharoen	1329	1595	1808	1724	1561	1167	1210	1038	1361	1306	1410
Chaiyaphum	1260	905	1193	1135	987	1026	1191	1147	1442	760	1104
Kalasin	1302	1022	1299	1361	1109	1087	1174	1023	889	1044	1131
Maha Sarakham	988	1011	1207	1381	1122	-	-	1374	1590	-	1382
Yasothon	1482	1253	1313	1345	1236	1152	1155	1203	1132	1195	1247
Nakhon Ratchasima	1446	974	914	8732	1039	1232	774	1292	1174	624	1034
Sri Sa Ket	1435	1135	1877	1387	1419	1187	1547	1448	1647	1489	1457
Khon Kaen	1255	1280	1449	1333	912	873	1252	1479	1293	898	1202
Roi Et	1477	1251	1351	1309	1257	957	1004	1194	1110	1197	1211
Nakhon Phanom	1977	2060	2975	2158	1920	2355	2326	1193	2371	2660	2324
Burirum	1360	1213	1314	1395	-	1260	-	2442	1269	-	1244
Surin	1422	1343	1567	1411	1041	1107	1439	895	1711	1480	1379

Temperature

The mean temperature during the 10-year period from 1988 to 1997 in Northeast Thailand was about 26.7^{O}C. Maximum temperature is about 27.4^{O}C in Nakhon Ratchasima province, while it is about 25.7^{O}C in Sakon Nakon (Fig. 3).

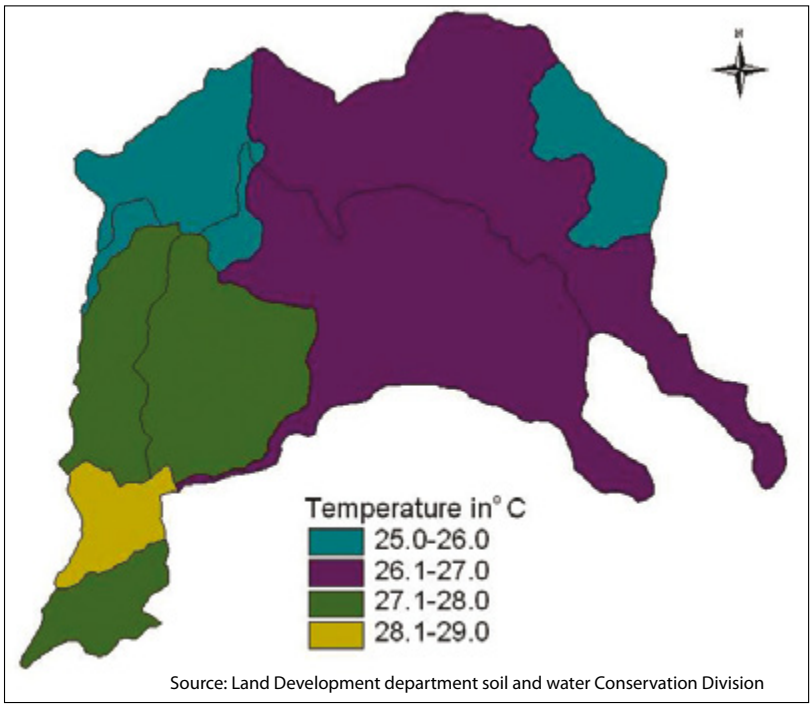

Figure 3. Temperature distribution in the watersheds of Northeast Thailand.

Irrigated area and water resources

The water resource in the northeast is surface water. The area consists of two basins: Khorat basin and Sakon Nakon basin. The Phu Pan range is the barrier between these basins.

Water Resources in Sakon Nakon Basin

The basin composes of Nong Khai, Sakon Nakon and Nakhon Phanom provinces. Their streams flow to the north and then to the east, finally joining the Mae Khong river. The important river is Song Khram, which originates in Phu Pan range. It flows through the province of Sakon Nakon and Nong Khai and joins the Mae Khong in Nakhon Phanom province. The other river is Huai

Luang. It joins the Song Khram river in Nakhon Phanom province and then flows into the Mae Khong. There are many other streams such as Num Pung that flow into the Nong Han in Sakon Nakon province.

Water Resources in Khorat Basin

The basin is located in the south of Phu Pan range and in the north of the provinces of Khon Kaen, Kalasin, Nakhon Ratchasima, Maha Sarakham, Roi Et, Yasothon and Ubon Ratchathani. The important rivers are Chi and Mun. The Mun river originates in the ranges on the southeast of the region. It flows eastwards through the provinces of Nakhon Ratchasima, Burirum, Surin, Sri Sa Ket to the Mae Khong in Ubon Ratchathani province. It has several tributaries including Lum Ta Khong, Lum Pra Pleong, Lum Plai Mat, Lum Dom Yai and Lum Dom Noi.

The Chi river originates in the ranges of the provinces of Loei, Chaiyaphum and Khon Kaen. There are three main tributaries which join the Chi river: Num Pang which originates in Loei province, Num Proom which originates in Chaiyaphum province and Num Pao or Lum Pao which originated in Kalasin. These rivers join the Chi river at Koengnai and Warinchumrap district in Ubon Ratchathani province, which then flows into the Mae Khong in the east. The Chi river has many tributaries such as Lum Se, Huai Se Bok and Lum Num young. The streams in the northeast normally have water only during some periods of the year and there is water shortage during the dry season, even in the main river like Chi, Mun and Song Khram. Water resources development is being promoted in approximately 4.64 million ha or about 20% of the agricultural land.

Soil

The Survey Division (1996) reported that the northeastern Thailand soils consist of nine sub-orders: Usterts, Aquepts, Tropepts, Ustolis, Aqualfs, Ustalfs, Aquults, Ustults and Udults (Fig. 4). The soil is characterized by sandy or sandy loam to sandy clay loam texture with low to medium fertility. Ustults area is the largest and mainly used for field crops; Aquults area is less than that of Ustults and is flat and mainly used for paddy rice (Fig. 4).

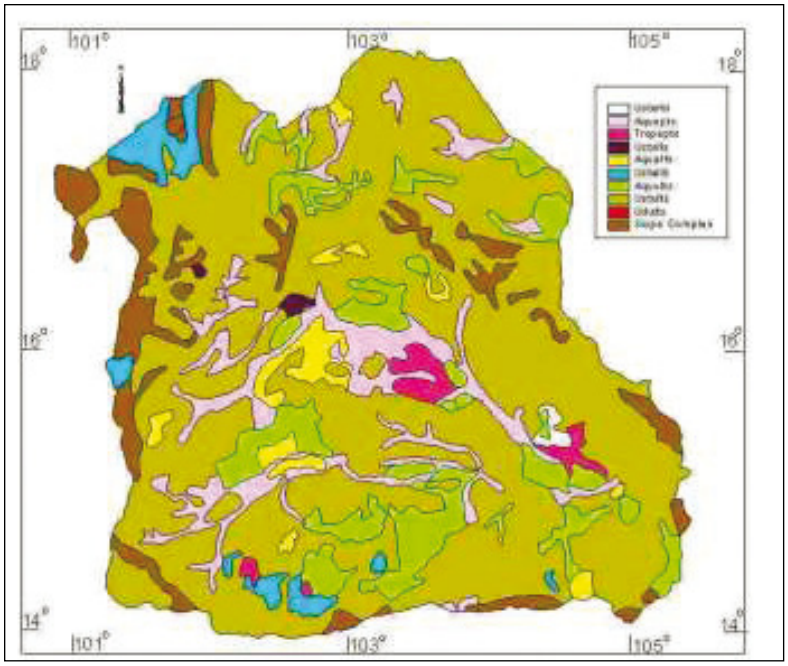

Figure 4. Soil distribution in northeastern Thailand.

Landuse

There are three kinds of forests as described below.

Dry Dipterocarp Forest

Dry dipterocarp forests exist in this region both in the flat plain and in highland. These forests are in the elevated area but below 1,000 m amsl. The area is characterized by sandy or lateritic soil, and is dry with low soil productivity.

Mixed Deciduous Forest

The mixed deciduous forest is composed of medium-size trees. These forests are found more in the provinces of Khon Kaen, Nong Khai and Nakhon Phanom.

Tropical Rain Forest

Large trees with high rainfall characterize these forests. Most of the area has been deforested with a greater proportion of the remaining area being present in the provinces of Loei and Nakhon Ratchanima.

Physical Characteristics of the Watershed

The Tad Fa Watershed is located within the three main watersheds namely, sub-system of Mae Khong watershed in the Northeast, Chi watershed in the East and Pasak watershed in the Southwest. In order to study the ecology of the watershed, the biophysical and socioeconomic data have been collected and analyzed. The related parameters of ecoregional database comprise the rainfall, evaporation, temperature, elevation, soil and land use.

The existing data concerning the biophysical and sociological data have been analyzed to present the important data in terms of watershed name, watershed code, location, latitude, longitude, area, length of main river, highest elevation, geomorphology, dam/reservoir, annual rainfall, runoff, population, province and land use. These data are the main characteristics of the whole watershed as shown in Tables 2-4.

Table 2. Basic data of Mae Khong sub-watershed.

Description
Name: Mae Khong River; Watershed code: 02
Location: Northeastern region
Latitude: 16^{O} 08' 55 – 18^{O} 28' 00 N
Longitude: 100^{O} 54' 10 – 106^{O} 04' 00 E
Area: 47,002 km^2; Length of main river: 3927 km
Head watershed: Nammailoei
Lower watershed: South China Sea
Geomorphology: Granite and Granodiolite, Kaeng Krachan Formation, Kanchanaburi Formation, Mafic and Ultramaific, Phu Pan and Phra Wihan Formation, Ratburi Formation, Mae Moh and Li Formation, Phu Kradung Formation, Alluvium, Marine Formation, Granite, Basalts and its equivalents, Phu Pan and Whian Formation salt and Khok Kruat Formation.
Important Dam/Reservoir: Nam Un dam 477 m.cu.m (constructed in 1974), Hui Luang Dam 108 m.cu.m (constructed in 1973)
Mean annual rainfall: 1,871 mm (1952-1996) at station 03023301 Amphur Mung, Sakon Nakon province
Runoff: 36.82 cu.m/sec (1984–1997) at Ban Ta Hui Lua, Ban Muang district, Sake Nakhon province
Population: 5,763,690 (1997)
Provinces involved: Loei, Nong Khai, Udon Thani, Sakon Nakon, Nakhon Phanom, Mudahan, Amnat Charoen, Ubon Ratchathani
Land use: Forest 2.7%; paddy 38.6%; upland crop 23.5%; fruit crops and perennial crops 5.1%; urban area 1.4%; and water area 2.8%

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Area of watershed

Watershed name	Area (km^2)	Watershed name	Area (km^2)
Second part of Nam Khong	508	Upper Part of Songkhram river	3299
Third part of Nam Khong	674	Lower part of Songkhram river	3030
Nam Un	622	Hui Klong	693
Nam Sai	876	Hui he	715
Fourth part of Nam Khong	808	Nam Yam	1733
Nam Puan	658	Hui Nam Un	3469
Lower Loei river	2902	Hui Tuay	788
Fifth part of Nam Khong	1823	Eighth part of Nam Khong	1186
Nam Sano	1056	Nam Phung	971
Nam Mong	2718	Nam Kam	2537
Sixth part of Nam Khong	540	Ninth part of Nam Khong	6444
Nam sui	1310	Hui Bangsai	1366
Hui Luang	3425	Hui Muk	552
Hui Dan	681	Hui Bung Ae	1590
Seventh part of Nam Khong	2704	Lower part of Nam Khong	3387

Table 3. Basic data of Chi watershed.

Description

Name: Chi River; Watershed code: 04

Location: Northeastern region

Latitude: 15^O 30’ 00 – 17^O 30’ 00 N

Longitude: 101^O 30’ 00 –104^O 30’ 00 E

Area: 49,476 km^2, Length of main river: 3015 km

Geomorphology: Kanchanaburi Formation, Phu Pan and Pha Wihan Formation, Ratburi Formation, Phu Kradung Formation, alluvium, salt and Krat formation.

Area of watershed

Watershed name	Area (km^2)	Watershed name	Area (km^2)
Upper Chi	2489	Nam Prom	2320
Lam Sapung	758	Nam Chern Chirn	2922
Kamkrajan	886	Lowerpart of Nam Phong	3286
Lam kanshu	1635	Hui Saibath	741

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Second part of Nam Chi	3808	Fourth part of Nam Chi	4510
Hui Sammo	729	Upper part of Lam Pao	3282
Third part of Nam Chi	3244	Lampanchard	657
Upper part of Nam Phong	4424	Lower part of Lam Pao	4264
Hui Pui	916	Nam Yang	4145
Lampaneang	1912	Lower part of Nam Chi	2548

Important Dam/Reservior: Ubolratana 1,854 m.cu.m (constructed in 1996); Chulaporn 144 m.cu.m (1972); Nam Pung 156 m.cu.m (1965); Lam Pae 35 m.cu.m (1968)

Mean rainfall: 1842 mm (1952-1996) at station 0140801 Amphur Muang, Khon Kaen province

1131 mm (1952–1996) at station 01041607 Amphur Kosum Pisai, Maha sarakham province

Runoff: 122.0 cu.m/sec. (1952-1996) at station 01041601 Wat Thai Kosum Amphur Kosum Pisai, Maha Sarakham province

Population: 6,709,329 (1998)

Provinces involved: Chaiyaphum, Nakon Ratchasima, Khon Kaen, Loei, Udon Thani, Nong Bua Lam Phu, Maha Sarakham, Roiet, Kalasin, Yasothon and Ubon Ratchathani

Land use: Forest 22.2%; paddy 47.5%; upland crops 23.5%; fruit crops and perennial crops 0.2%; urban 1.4%; water area 2.8%; swamp and natural grassland 2.4%

Table 4. Basic data of Pasak watershed.

Description

Name: Pasak River; Watershed Code: 12

Location: Eastern region

Latitude: 14° 21' 44 – 17° 16' 02 N

Longitude: 100° 34' 40 – 104° 104' 56 E

Area: 15,799 km^2; Length of main river: 1039 km

Head watershed: Phetchabum

Lower watershed: Mae Nam Chao Praya

Highest elevation: Dan Sai, Loei province

Lowest elevation: Uthai, Phra Nakhon, Si Ayuthaya

Geomorphology: Phu Kradung, Phu Pan and Phra Wihan Formation, Ratburi Formation, Marine Formation, Andesite-Rhyorite, Basalt and its equivalents, Granite, Diorite and quartz diorite

Important Dam/Reservoir: Pasak Chonlasit dam 746 m.cu.m. (constructed in 1999)

Mean annual rainfall: 1,180 mm (1952–96) at station 03120505 Wichian Buri, Phetchabun province

Runoff: 76.70 cu.m/sec (1956–96) at station 0112806 Kaeng Khoi, Saraburi province

Population: 1,785,424 (1998)

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Provinces involved: Phetchabum, Lop Buri, Saraburi, Phra Nakhon, and Si Ayuthaya

Land use: Forest 19.4%; Paddy 19.5%; upland crop 47.6%; fruit crop and perennial crop 2.6%; urban area 2.0%; water area 0.82%; swamp and natural grassland 8.7% (1998)

Area of watershed

Watershed name	Area (km^2)	Watershed name	Area (km^2)
Upper part of Nam Pasak	1465	Hui Kokaew	520
Hui Nam Phu	655	Lam sonti	1410
Second part of Nam Pasak	2205	Lower part of Nam Pasak	4152
Third part of Nam Pasak	4717	Hui Muak lek	655

The Ecoregional Data

Rainfall

The rainfall data, collected by Department of Meteorology was selected for 10-year period from 1988 to 1997. The average annual rainfall of the three main watersheds was analyzed based on rainfall data within the area of those watersheds:

- Mae Khong watershed: Data are from the provinces Loei, Nong Khai, Sakon Nakon, Nakhon Phanom, Mukdahan and Amnat Charoen.
- Chi watershed: Data are from the provinces Udon Thani, Khon Kaen, Nong Bua Lam Phu, Chayaphum, Kalasin, Maha Sarakham, Yasothon, Nakhon Ratchsima, Si Sa Ket, Roi Et and Ubon Ratchathani.
- Pasak watershed: Data are from the provinces Phetchabun, Lop Buri and Saraburi.

Evaporation

The evaporation data, collected by Department of Meteorology, was selected for 10-year period from 1988 to 1997. The average annual evaporation of the three main watersheds was analyzed based on evaporation data within the area of those three watersheds (Fig. 5).

Temperature

Temperature data, collected by the Department of Meteorology, was selected for 10-year period from 1988 to 1997. The average annual temperature of the three main watersheds was analyzed based on temperature data within the area of those watersheds.

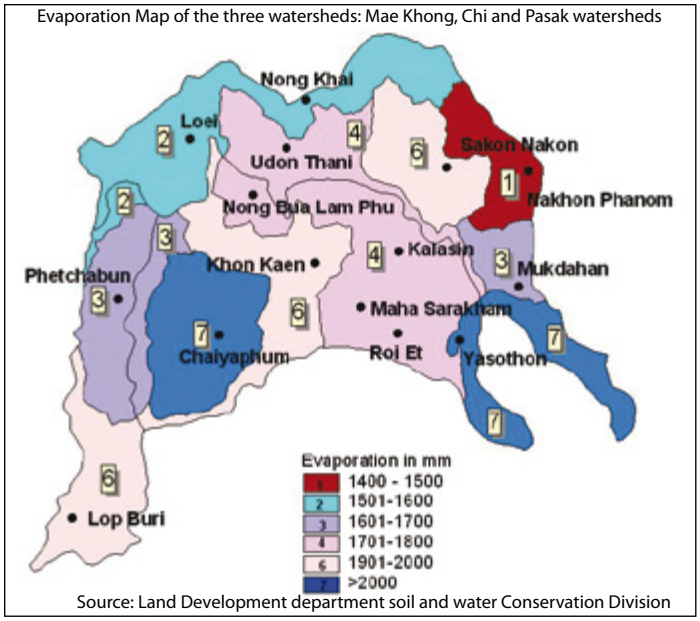

Figure 5. Evaporation map of the three watersheds: Mae Khong, Chi and Pasak.

Topography

Based on the analysis of landform and slope class, map of Tad Fa watershed prepared by DLD is presented (Fig. 6).

Elevation

The contour map of the Royal Thai Survey has been introduced and used as the base map for analysis of the contour intervals, which are grouped into five levels; 100–200 m, 200–500 m, 500–1000 m, 1000–2000 m and more than 2000 m.

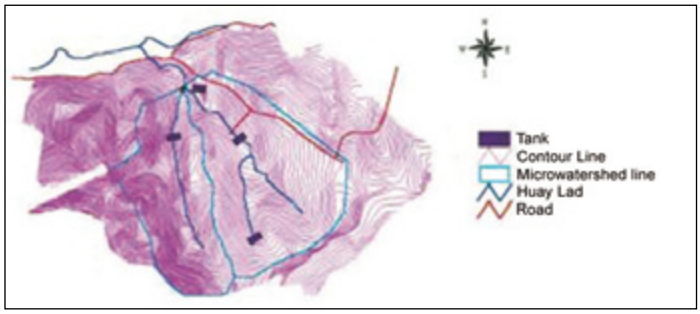

Figure 6. Topography and drainage lines map of Tad Fa micro-watershed.

Soil

The soil distribution has been discussed earlier (Fig. 4).

Land Use

The land use map is presented in Figure 7 (Source: DLD 1998).

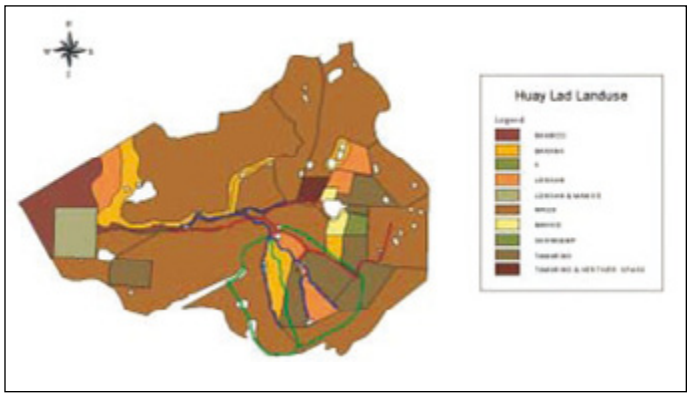

Figure 7. Land use map of Huay Lad Watershed.

Criteria Approach

The following criteria were chosen to analyze and group the data.

Rainfall: The data of mean annual rainfall are grouped into four classes: 1000–1200 mm, 1201–1400 mm, 1401–1600 mm and more than 1,600 mm (Table 5). The percentage area of each class is measured (Fig. 2).

Table 5. Rainfall range in the watershed.

Rainfall (mm)	Class
1,000–1,200	1
1,201–1,400	2
1,401–1,600	3
>1,600	4

Evaporation: The data of mean annual evaporation are grouped into seven classes (Table 6). The percentage area of each class is measured (Fig. 5).

Table 6. Evaporation range in the watershed.

Evaporation (mm)	Class
1,400–1,500	1
1,501–1,600	2
1,601–1,700	3
1,701–1,800	4
1,801–1,900	5
1,901–2,000	6
> 2,000	7

Temperature: The data of mean annual temperature (see Fig. 3) are grouped into four classes (Table 7).

Table 7. Temperature range in the watershed.

Temperature (°C)	Class
25.0-26.0	1
26.1-27.0	2
27.1-28.0	3
28.1-29.0	4

Topography: The topographic maps are introduced to analyze and subdivide into three levels (Table 8).

Table 8. Topography divisions in the watershed.

Topography	Class
Slope complex	S
Upland	U
Lowland	L

Hypsography: Based on the elevation, the region is grouped into five classes (Table 9 and Fig. 8).

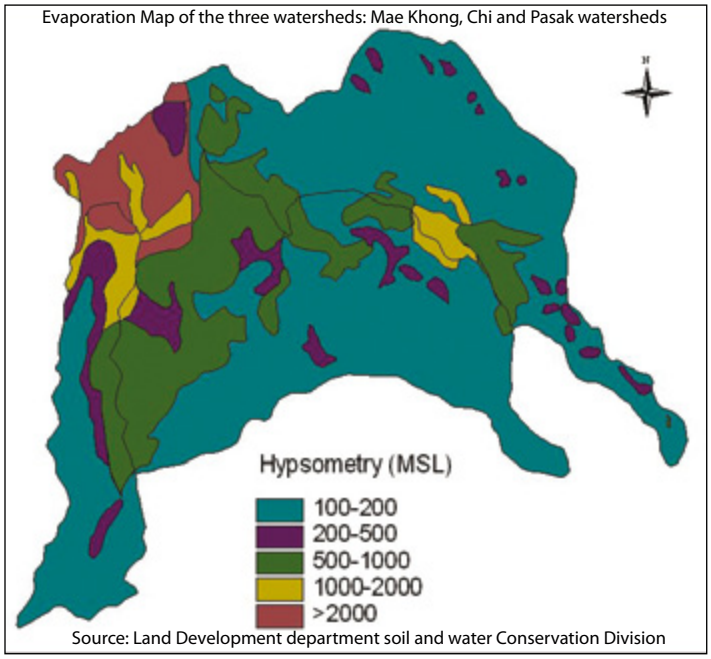

Figure 8. Hypsometry map of the three watersheds: Mae Khong, Chi and Pasak.

Table 9. Hypsographic classes.

Hypsometry (MSL)	Class
100–200	1
200–500	2
500–1,000	3
1,000–2,000	4
2,000 >	5

Soil: The soil distribution has been discussed earlier (Fig. 4).

Land use: The land use map of the watershed is presented in Figure 9 (Source: DLD 1998).

Agricultural Productivity – Yield Gap Analysis in Northeast Thailand

The amount of rainfall in the region is lower than other regions. So agriculture is based mainly on upland crops such as cassava, sugarcane, maize, upland rice,

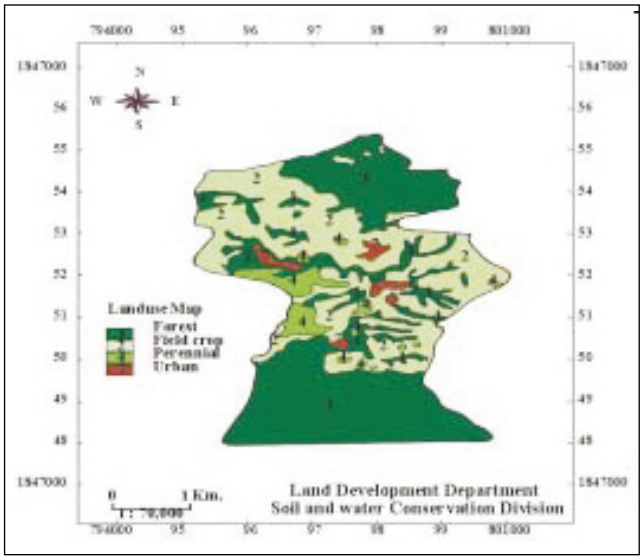

Figure 9. Land use map of Tad Fa watershed.

groundnut and soybean. A study was carried out on sustainable agriculture with crops, which minimize the use or destruction of natural resources and improve soil quality. The following five crops were selected for this study: rice, maize, soybean, groundnut and sunflower.

Rice

Rice is an economic crop important to Thai society. Since 1979, the export of rice has assumed increased importance. The total area of production and productivity are given in Table 10. Yield in the northeastern region is 50 per cent lower than that in research plots and 11 per cent lower than that of the whole country (Table 11). When considering the morphogeology of the northeast, yield in the highland and upland area is lower than that of the whole country and higher in plain flat lands.

Table 10. Rice production in Thailand in 1998[1].

Region	Planted area (rai)	Harvested area (rai)	Production (t)	Yield (kg rai^{-1})
Northeastern	31,040,327	28,543,360	8,009,659	281
Northern	12,526,986	11,217,283	4,975,721	444
Central Plain	9,886,193	9,406,367	4,289,886	456
Southern	2,919,666	2,677,407	885,449	331

1. 6.25 rai = 1 ha.

Table 11. Paddy yield gap in Northeast Thailand.

Description	Yield (kg rai^{-1})	Yield gap[1] (kg rai^{-1})	
		Research plots yield	Country yield
Research plots yield	566	-	-
Country yield	314	252 (44)	-
Northeastern yield	281	285 (50)	33 (11)
Northeastern on highland yield	195	371 (65)	199 (63)
Northeastern on upland yield	289	277 (48)	25 (7)
Northeastern on lowland yield	347	219 (38)	33 (10)

1. Percentage values are given in parentheses.

Upland rice is grown for household consumption. Farmers do not grow them for trading because seed quality is not good as required for the market. The yield of upland rice is 50 per cent lower than that of paddy. The upland rice yield in the northeast is 28 per cent lower than the research plots yield and about 18 per cent lower than the yield of the whole country (Table 12).

Table 12. Yield gap of upland rice in Northeast Thailand.

Description	Yield (kg rai^{-1})	Yield gap[1] (kg rai^{-1})	
		Research plots yield	Country yield
Research plots yield	238	-	-
Country yield	210	28 (11)	-
Northeastern on highland yield	195	43 (18)	15 (7)

1. Percentage values are given in parentheses.

Maize

In Thailand, maize is being grown for the past 40 years. During 1988–92, maize production decreased by 7 per cent, mainly due to frequent droughts during the crop season. This has resulted in farmers shifting to other crops such as sugarcane and cassava that are more tolerant to drought. Out of a total production area of 8.8 million rai, 2.3 million rai is in northeastern part of the country (Table 13). The yield is lower than the other regions.

Table 13. Maize production in Thailand in 1998.

Region	Planted area (rai)	Production (tons)	Yield (kg rai^{-1})
Northeastern	2,336,920	915,476	392
Northern	4,106,353	1,890,036	460
Central Plain	2,278,877	1,116,075	490
Southern	106,409	43,750	411

Maize yield in Northeast Thailand is 47% lower than that in the research plots, and 12% lower than that of the country (Table 14). Considering morphogeology, yield in the highland and upland area is lower than that of the whole country and higher in the lowland.

Table 14. Yield gap of maize in Northeast Thailand.

Description	Yield (kg rai^{-1})	Yield gap[1] (kg rai^{-1})	
		Research plots yield	Country yield
Research plots yield	753	-	-
Country yield	449	304 (40)	-
Northeastern yield	392	361 (47)	57 (12)
Northeastern on highland yield	244	509 (67)	205 (45)
Northeastern on upland yield	382	371 (49)	67 (15)
Northeastern on lowland yield	559	194 (25)	110 (24)

1. Percentage values are given in parentheses.

Soybean

In Thailand, soybean is being grown since 1936. In the northern part of the country, farmers were recommended to grow soybean after rice. However the seeds were imported from China and Japan, but were not suitable to the local conditions in Thailand. In 1960, varietal improvement were undertaken and many good varieties were produced. Due to the increase in the livestock population the requirement of soybean has reached 2 million t per year. From the total production area of 2.6 million rai, Thailand can produce 0.5 million t per year. In the northeastern part of the country soybean is grown on 349,613 rai but the yield is low (Table 15). The yield in the northeastern region is 37 per cent lower than that in the research plots, and 1 per cent lower than rest of the country (Table 16). Morphogeologically, yield in the highland and upland area is lower than that of the whole country and higher in lowland.

Table 15. Soybean production in Thailand region in 1998.

Region	Planted area (rai)	Production (t)	Yield (kg rai^{-1})
Northeastern	349,613	71,619	190
Northern	2,061,069	385,004	190
Central Plain	308,196	70,247	200
Southern	182	37	200

Table 16. Yield gap of soybean in Northeast Thailand.

Description	Yield (kg rai^{-1})	Yield gap[1] (kg rai^{-1})	
		Research plots yield	Country yield
Research plots yield	306	-	-
Country yield	194	112 (36)	-
Northeastern yield	192	114 (37)	2 (1)
Northeastern on highland yield	156	150 (49)	38 (19)
Northeastern on upland yield	180	126 (41)	14 (7)
Northeastern on lowland yield	206	100 (32)	12 (6)

1. Percentage values are given in parentheses.

Groundnut

Groundnut is an important crop in Thailand and was introduced by the Portuguese. Since 1962, the Department of Agriculture initiated research efforts to improve the varieties. Out of a total area of 4.5 million rai, the groundnut area in Northeast Thailand is 228,565 rai. The yield is low at 214 kg rai^{-1} (Table 17). The groundnut yield in the northeastern region is 23 per cent lower than that in the research plots, and 7 per cent lower than rest of the country (Table 18). Morphogeologically, the yield on the highland and upland area is lower than that of the whole country and it is higher in the lowland areas.

Table 17. Groundnut production in Thailand in 1998.

Region	Planted area (rai)	Production (t)	Yield (kg rai^{-1})
Northeastern	228,565	50,617	214
Northern	295,850	69,919	238
Central Plain	96,881	24,465	247
Southern	29,375	3,169	176

Table 18. Yield gap of groundnut in Northeast Thailand.

Description	Yield (kg rai^{-1})	Yield gap[1] (kg rai^{-1})	
		Research plots yield	Country yield
Research plots yield (Ey)	278	-	-
Country yield (Cy)	231	47 (16)	-
Northeastern yield (Ny)	214	64 (23)	17 (7)
Northeastern on highland yield (Nhy)	186	92 (33)	45 (19)
Northeastern on upland yield (Nuy)	211	67 (24)	20 (9)
Northeastern on lowland yield (Nly)	247	31 (11)	16 (7)

1. Percentage values are given in parentheses.

Sunflower

Sunflower, which originated in western USA was introduced in Thailand in 1973. But it was not successful because of its low yield and marketing problems. Since 1987, extension efforts have been directed to introduce it as the second crop in the central plain such as Saraburi and Lob Buri. In other areas, it is grown by a few farmers and still cannot be classified as an economic crop (Table 19). In the northeastern region the yield is lower than that of the research plots by 6 per cent and 0.4 per cent lower than that of the country (Table 20).

Table 19. Sunflower production in Thailand in 1993.

Region	Planted area (rai)	Production (t)	Yield (kg rai^{-1})
Northeastern	63,500	14,980	235
Northern	174,820	43,005	246
Central Plain	270	64	238

Table 20. Yield gap of sunflower in the Northeast Thailand.

Description	Yield (kg rai^{-1})	Yield gap[1] (kg rai^{-1})	
		Research plots yield	Country yield
Research plots yield	255	-	-
Country yield	239	16(6)	-
Northeastern on highland yield	238	17(6)	1 (0.4)

1. Percentage values are given in parentheses.

Productivity Constraints

It is apparent that in Thailand, few of the factors and constraints involved in agricultural productivity are nationwide. Mostly they have specific regional or provincial relevance. The constraints on productivity are discussed under the following headings:

- Physical constraints
- Technological constraints
- Institutional constraints
- Socioeconomic constraints

Physical Constraints

Physical constraints have a major impact on agricultural productivity. The main physical constraints are:

- Climatic, especially rainfall, relative humidity, and dry season temperatures
- Topography
- Drainage and flood hazards
- Soils
- Accelerated erosion and runoff

Climatic constraints: The major climatic constraint is low rainfall in the dry season. A less important climatic constraint is the high relative humidity in the wet season, which encourages pests and diseases in dryland crops such as maize and sugarcane. Temperatures fall in the dry season. As altitude increases in the mountains temperature restricts the range of introducing tropical perennial crops that can be grown, although at the same time there is possibility of introducing temperate crops. However, the area affected by this constraint is very limited in extent and is generally lacking in agricultural potential due to the topography and soil.

Topographic constraints: The steep and uneven slopes result in rapid runoff of rainfall, accompanied by sheet and gully erosion and thus make cultivation difficult.

Drainage and flood constraints: Flooding is the major factor resulting from intensive rainfall in the wet season causing rivers to rise and inundate large areas of lowland crops.

Soil constraints: The major soil constraint is low fertility, affecting most highland soils and the strongly leached soils on the slightly higher terrain of the older terraces in the lowlands. The other widespread soil limitation is shallow depth and lateritic gravel aggregates, which cause loss of applied nutrients during the wet season, especially on the steep slopes. In addition they reduce the total water-holding capacity of the soil profile, limit rooting depth and increase erosion. Soil depth may be limited by bedrock or by dense and/or compacted lateritic gravels.

Erosion and runoff constraints: The increase of cultivation and illegal logging in the past decades in marginal highland areas has resulted in acceleration of soil erosion and rainfall runoff.

Technological Constraints

The physical constraints can be mitigated by technological measures. Such measures include: irrigation; drainage flood control; system of highland agriculture and forest conservation; application of fertilizers and pesticides and weed control; improvement of seed supply and crop varieties.

Institutional Constraints

Institutional constraints on agricultural productivity such as inadequate research, training, and extension and availability of agricultural credit are found in most developing countries. But in Thailand, research and training programs are relatively well developed. The government operates numerous agricultural research bodies and research stations. The department of Agricultural Extension Service is established in each province in the capital and at district level and provides a reasonably effective and comprehensive service to farmers. The country has many agricultural training establishments at all levels, which provide the government with competent recruits for its various agricultural departments. The institutional credit to farmers is provided by Bank of Agricultural and Agricultural Cooperatives (BAAC), farmer's welfare funds and commercial banks.

Socioeconomic Constraints

Social constraints: There are few social constraints on agricultural productivity in Thailand: the Thai farmer is capable, adaptable, owns his land, and is generally free from restrictive Government control and direction. The main constraint is seen as the rapid population growth prior to 1975 and the consequent build-up of population pressure on the land. This in turn has led to the expansion of agricultural activity to less suitable lands.

Economic constraints: There are a few direct economic constraints on agricultural productivity in Thailand. In addition to the widespread institutional and infrastructure support that it provides to agriculture, the government also attempts to guarantee farmers' income by imposing minimum farm-gate prices for certain crops. At the same time the government avoids applying unnecessary restrictions on the farmers.

Analysis of the Productivity Constraints

The northeastern part of the country is an important agricultural area of the country and a significant proportion of the production of important crops is from the region. But there are productivity constraints due to droughts and floods; also low soil fertility reduces the yield (Tables 21-23).

Physical Constraints

Climate: Thailand has a tropical climate and there is not much variation in the weather. The limitation is the occurrence of dry period during the rainy season. The climatic constraints could be classified as low.

Soil: Soils in the recent past have been degraded due to degradation. The chemical and physical properties of soil in the agricultural area in the northeastern region indicated that the soils were strongly degraded when compared with the forest area. In the flat plain there is salinity. In the northeastern region, the area effected with salinity is 18 million rai or about 17 per cent of the region. So the Kong–Chi–Mun project encouraged cultivation of salt tolerant crops and increasing the forest area.

Application of fertilizer: Efforts have been initiated to encourage application of organic fertilizers due to high cost and toxicity of chemical fertilizers. The Soil and Water Conservation Department conducted an experiment in 1999 on the use of compost in rice fields at Roi Et province. Rice with compost gave 23 per cent higher yield than with chemical fertilizer. An experiment on the use of *Sesbania rostrata* before rice planting has shown that rice yield is only 3.6 per cent lower than that with 16-16-16 fertilizer at 20 kg rai^{-1}. The Land Development Department aims to decrease the usage of chemical fertilizers and promote the use of compost or green manure along with the promotion of soil and water conservation by the use of vetiver grass and prevention of soil erosion in 5 million rai in a year.

Improved seeds and varieties: This constraint is low as government and private sector are working actively to distribute and sell seeds to the farmers. The Department of Agriculture in 1994 has developed the following varieties:

upland rice variety Sew Mae Jan in Khon Kaen province yielding about 320 kg rai^{-1}, soybean variety Nakosawan yielding about 265 kg rai^{-1} and sunflower variety Pacific 33 yielding about 228 kg rai^{-1}.

Credit: Farmers owning larger land holdings have greater access to credit from government or commercial banks whereas the smaller farmers with marginal land holdings rent out their land and have access only to the costlier loans from private moneylenders.

Agricultural research: The Government has a technology transfer center in each sub-district. Therefore there is no technological constraint in the institutional mechanism for technology transfer.

Socioeconomic Constraints

There is shortage of agricultural labor and generally the farmers with marginal land holding prefer to lease-out their land. Another major problem is that some crops have a minimum support price while others do not.

Table 21. Production constraints of the lowland in the northeastern region[1].

Physical constraints			Technological constraints			Institutional constraints			Socioeconomic constrains		
Crops	Climate	Soils	Irrigation	Drainage and flood control	Fertilizers	Sustainable agriculture	Crop varieties	Financial	Technology/ Institutional	Social	Economic
Rice	L	M	M	M	M	M	L	M	M	M	M
Maize	L	M	M	M	M	M	L	M	M	M	M
Soybean	L	M	M	M	M	M	L	M	M	M	M
Mung bean	L	M	M	M	M	M	L	M	M	M	M
Sunflower	L	M	M	M	M	M	L	M	M	M	M

1. Level of constraint: L = Low; M = Moderate; H = High.

Table 22. Production constraints of the upland in the northeastern region[1].

Physical constraints			Technological constraints			Institutional constraints			Socioeconomic constraints		
Crops	Climate	Soils	Irrigation	Drainage and flood control	Fertilizers	Sustainable agriculture	Crop varieties	Financial	Technology/ Institutional	Social	Economic
Rice	L	M	M	M	M	M	L	M	M	M	M
Maize	L	M	M	M	M	M	L	M	M	M	M
Soybean	L	M	M	M	M	M	L	M	M	M	M
Mung bean	L	M	M	M	M	M	L	M	M	M	M
Sunflower	L	M	M	M	M	M	L	M	M	M	M

1. Level of constraint: L = Low; M = Moderate; H = High.

Table 23. Production constraints of the highland in the northeastern region[1].

Physical constraints			Technological constraints			Institutional constraints			Socioeconomic constraints		
Crops	Climate	Soils	Irrigation	Drainage and flood control	Fertilizers	Sustainable agriculture	Crop varieties	Financial	Technology/ Institutional	Social	Economic
Rice	L	M	M	M	M	M	L	M	M	M	M
Maize	L	M	M	M	M	M	L	M	M	M	M
Soybean	L	M	M	M	M	M	L	M	M	M	M
Mung bean	L	M	M	M	M	M	L	M	M	M	M
Sunflower	L	M	M	M	M	M	L	M	M	M	M

1. Level of constraint: L = Low; M = Moderate; H = High.

Conclusion

The constraint analysis of agriculture in Northeast Thailand reveals the existence of problems related to infertility of the soil, soil erosion and flooding due to the steep slopy nature of the land. The increasing pressure of the population, which has led to the conversion of forestland to agriculture land, has been a major reason for the above problem. The Department of Land Development in Thailand admits that the magnitude of the problem is large and realistically admits that tackling the problem in its totality requires huge budgetary support, which is a constraint. To address the budgetary constraint problem and to garner greater contribution from the farmers for soil and water conservation works, there is a need to effectively demonstrate that yield increase is possible and the gap between the potential yield in research plots and farmers' fields needs to be reduced. The differences in yields are currently relatively high particularly for rice (50 per cent lower), maize (47 per cent lower), soybean (37 per cent lower), and sunflower (6 per cent lower).

The intervention of the project should provide the scope to demonstrate that cost-effective solutions with farmers' participation (in program conceptualization and financial support) is a possible solution. The intervention process has the advantage of a decentralized agriculture extension system in the country, which can be effectively utilized.