THE KINGDOM OF THAILAND
MINISTRY OF AGRICULTURE AND COOPERATIVES
DEPARTMENT OF LAND DEVELOPMENT

THE STUDY ON AGRICULTURAL LAND CONSERVATION FOR INTEGRATED RURAL DEVELOPMENT IN THE EAST

Vol. II BASIC PLAN FOR LAND AND WATER CONSERVATION IN THE 4 PROVINCES OF THE EAST

SEPTEMBER 1988

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

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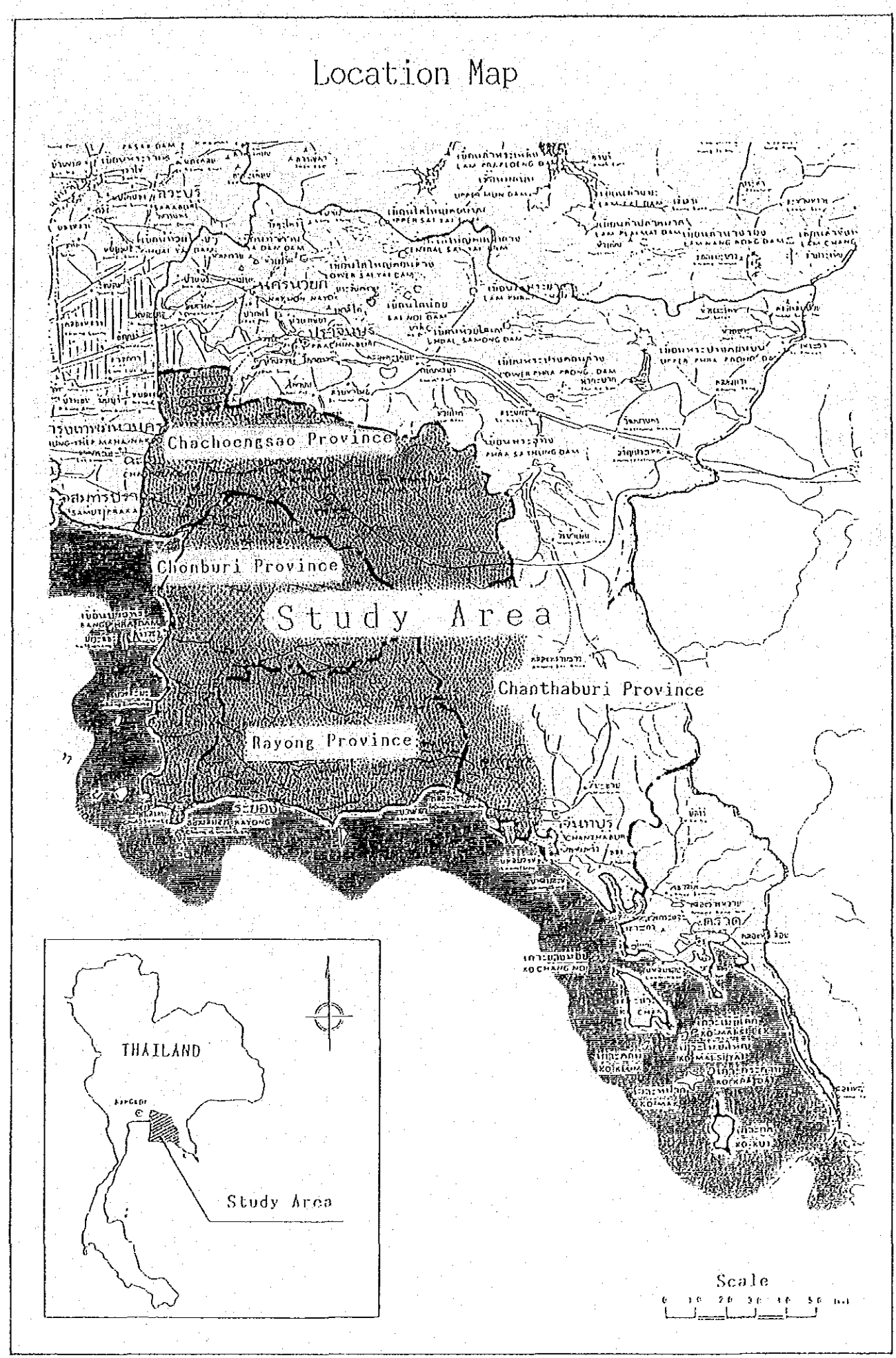
Location Map



SUMMARY

Volume II, Basic Plan for Land and Water Conservation in the 4 Provinces of the East, is composed of 7 chapters. The outlines of each chapter are as follows;

Chapter 1 Introduction

The process, necessity and purpose of "the Study on Agricultural Land Conservation for Integrated Rural Development in the East" were explained at first.

Then, it was stressed that the policy for the development should follow the objectives of the Sixth National Economic and Social Development Plan (1987-1991) established by NESDB.

Agricultural conditions of Thailand and the East were briefly summarized and the importance of soil conservation was specially mentioned from the view points of economy and environmental protection.

The features of the basic plan were also explained and 4 major objectives and 8 strategies for the said plan were suggested.

Chapter 2 Background

The natural, agricultural and social environment of the study area were briefed stressing the importance of soil and water conservation.

Chapter 3 Study Area

The terminology of study-, project- and planning-areas was explained. Then the planning area in the 4 provinces was clearly shown in tables. Classification of the erodible area in each province was also carried out.

Study Area

(Km²)

Province	Study Area	Project Area	Planning Area
Chachoengsao	5,351	5,351	2,200
Chonburi	4,363	4,363	3,041
Rayong	3,552	3,552	2,634
Chanthaburi	6,338	1,981	965
Total	19,604	15,247	8,840

Erodible Area

(km²)

Classification		Chachoengsao	Chonburi	Rayong	Chanthaburi	Total
	ton/ha/yr.					
1. Top Urgent	(50 <)	388	1,245	923	331	2,887
2. Urgent	(50 – 30)	553	521	170	268	1,512
3. Necessary	(30 – 20)	523	439	864	328	2,154
4. Normal	(20 – 5)	351	23	223	12	609
1 – 4 Total (Erodible Area)		1,815	2,228	2,180	939	7,162
5. Not Necessary (5 >)		385	813	454	26	1,678
1 – 5 Total (Planning Area)		2,200	3,041	2,634	965	8,840

Chapter 4 Soil Conservation Measures

Four approaches to soil conservation were suggested, viz., agricultural measures, mechanical measures and irrigation facilities from the technical point of view and supporting measures from the socio-economical point of view.

In the technical approaches, out of several countermeasures crop diversification and contour strip cultivation with graded terrace and drainage system were strongly suggested. The outlines of these proposals were shown by tables and figures in detail. The four components of the supporting measures; infrastructure, agro-industry, farmers' education and institutional cooperation were mentioned and discussed.

The outlines of these proposals are shown below.

Agricultural Measures

1. Mulching	1) Live mulching
	2) Non-live mulching
2. Cropping Method	
3. Cultivation method	1) Contour ploughing
	2) Contour ridging
	3) Contour strip cultivation
4. Canopy improvement	
5. Soil management	1) Tillage
	2) Soil property improvement

Mechanical Measures

1. Soil management system
2. Terracing system
3. Drainage system
4. Farm road system
5. Farm pond or reservoir
6. Check dam (sediment pond)
7. Slope protection
8. Others

Chapter 5 Implementation and Project Cost

Several proposals such as establishment of the "Board of Land and Water Conservation" were made for implementation of the proposed project. 10 year plan (1987~1996), 30 year long term time schedule (1991~2020) and three grades (high, medium and common) of alternative plans were recommended for the implementation of the project as well.

As for the cost estimation, unit project cost was fixed at 12,825 Baht/rai then total cost of each province depends on the planning areas. The total amount of the project cost in the four provinces was estimated to be 70,851 million Baht.

Two modes of construction, force account under DLD and contract basis, were also discussed for project execution.

Project Cost for B/P

Province	Area	Plan	Unit Project Cost	Total Project Cost
	(km^2)		(Baht/rai)	(10^6 Baht)
Chachoengsao	2,200	II	12,825	17,633
Chonburi	3,041	II	"	24,373
Rayong	2,634	II	"	21,111
Chanthaburi	965	II	"	7,734
Total	8,840			70,851

Chapter 6 Project Evaluation

The evaluation of the proposed project was made applying the following three aspects.

1) Economic Evaluation
2) Financial Analysis
3) Socio-economic and Environmental Impacts

Providing reasonable parameters for the economic evaluation, the project benefit and economic cost were calculated, and the economic internal rate of return (EIRR) was calculated for each of the four provinces. The estimated EIRR's range from 8.9% to 12.3% and their average is 10.8%. There are two provinces whose EIRR's are less than 10%, which is assumed to be the minimum acceptable rate of return, but they should be judged not only by monetary terms but also by other aspects such as socio-economic and environmental conservation factors as mentioned later on.

The financial analysis was made by the comparison between the willingness and ability-to-pay of the farmers and cost-recovering charges of the project cost.

Through analysis, it can be said that the appropriate cost recovery by farmers is considered to be 20~40% and the remaining 60~80%, which corresponds to 48,000-64,000 Baht per hectare, is expected to be supplied by government subsidy.

As for socio-economic and environmental impacts of the proposed Project, these were discussed from the view points of 1) creation of employment opportunities 2) reduction of regional disparity 3) saving and earning of foreign exchange by preventing nutrient loss from soil erosion and getting high yield of agricultural products 4) enhancement of cooperation among farmers and 5) conservation of the environment.

If these unaccountable benefits could be included in the evaluation, the EIRR's would certainly be much higher. Since there is such a great potential for these benefits, government should subsidize the Project.

(%)

Items \ Province		CS	CN	RY	CT	Overall
1. EIRR		8.9	12.3	9.8	11.9	10.8
2. B/C Ratio						
a) discount rate	8	1.09	1.42	1.19	1.34	1.27
b) discount rate	10	0.90	1.20	0.98	1.15	1.07
c) discount rate	12	0.74	1.02	0.82	0.99	0.90

Chapter 7 Project Implementation Program

It is stressed that the target of this project is completely in line with the Sixth National Economic and Social Development Plan, which places significant importance on Natural Resources and Environmental Development and Rural Development.

DLD is recommended as the responsible agency for implementation of the proposed project judging from the view point of capacity, experience and assigned duty. To successfully carry out this role, institutional strengthening of DLD by setting up a new division composed as follows is strongly recommended.

Technology Introducing Center (TIC)	1 place
Land and Water conservation Center (LWCC)	1 place
Land and Water Conservation Station (LWCS)	5 places
Pilot Area	16 places

Their roles, activities and relationship to the existing organization are explained.

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ABBREVIATIONS AND UNIT

Agencies

AC	Agricultural Cooperative
ADB	Asian Development Bank
ALRO	Agricultural Land Reform Office, MOAC
ARDO	Accelerated Rural Development Office, MOI
BMA	Bangkok Metropolitan Administration, MOI
DA	Department of Agriculture, MOAC
DH	Department of Health, MPH
DLD	Department of Land Development, MOAC
DMR	Department of Mineral Resources, MI
DOAE	Department of Agricultural Extension, MOAC
DTEC	Department of Technical and Economic Cooperation
EGAT	Electricity Generating Authority of Thailand
FAO	Food and Agriculture Organization of the United Nation
JICA	Japan International Cooperation Agency
LWCB	Land and Water Conservation Board
MD	Meteorology Department
MI	Ministry of Industry
MOAC	Ministry of Agriculture and Cooperative
MOI	Ministry of Interior
MPH	Ministry of Public Health
MWWA	Metropolitan Water Works Authority
NESDB	National Economic and Social Development Board, PMO
PMO	Prime Minister's Office
PWD	Public Welfare Department, MOI
RFD	Royal Forestry Department, MOAC
RID	Royal Irrigation Department, MOAC

Other abbreviations

CS	Chachoengsao
CN	Chonburi
RY	Rayong
CT	Chanthaburi
B/P	Basic Plan
F/S	Feasibility Study
GDP	Gross Domestic Product
GRP	Gross Regional Product
GPP	Gross Provincial Product
HYV	High Yield Varieties
LV	Local Varieties
EIRR	Economic Internal Rate of Return
NPV	Net Present Value / Net Production Value
B/C	Benefit Cost Ratio
GPV	Gross Production Value
F. C	Foreign Currency
L. C	Local Currency
C. I. F	Cost, Insurance and Freight
F. O. B	Free on Board
O & M	Operation and Maintenance
H. W. S	High Water Surface
N. W. S	Normal Water Surface
L. W. S	Low Water Surface

Glossary

Park	Region
Changwat	Province
Muang	Capital of Province
Amphoe	District
Tambon	Sub-district
Muban	Village
Mae Nam	Large river
Nam	A medium-size river
Lam	A small river
Kwae	A tributary of a river
Huai	A rivulet

Unit

Rai	Unit of land measurement
Baht	Unit of Thai Currency
mm	Millimeter
cm	Centimeter
m	Meter
cu. m	Cubic meter
MCM	Million Cubic Meter
cu. m/s	Cubic meter per second
km	Kilometer
sq. km	Square kilometer
g	Gram
kg	Kilogram
ton	Metric ton
ha	Hectare
El	Elevation above mean sea level
MSL	Mean Sea Level
°C	Degree Centigrade
mmho/cm	Millimho per centimeter
HP	Horsepower
ppm	Parts per million

Units of Measurement

Rai	=	0.16 hectares = 1,600 sq.m
Hectare	=	6.25 rais = 10,000 sq.m

Currency Equivalents (Average of March. 1988)

US Dollar	US$ 1.00 = 25.52 Baht = ¥ 128.92

Definition of Words

The Sixth Plan or the Sixth NESD Plan	The Sixth National Economic and Social Development Plan (1987~1991) published by NESDB
Survey area or Study area	19,604 km^2 (12,252,500 rais) covering the whole area of 4 provinces (Chachoengsao, Chonburi, Rayong and Chanthaburi)
Project area	15,248 km^2 (9,530,000 rais) covering 3 whole provinces (Chachoengasao, Chonburi and Rayong) and a part of Chanthaburi province (approximately one third of the western side of the province)
Planning area	The net area of 8,840 km^2 (5,525,000 rais) out of the Project area excluding paddy and forest land, residential and industrial area, etc.

Chapter 1.

INTRODUCTION

CHAPTER 1 INTRODUCTION

1-1 General

The agreement for "the Study on Agricultural Land Conservation for Integrated Rural Development in the East" was concluded between the Japan International Cooperation Agency (JICA) and the Department of Land Development (DLD), Ministry of Agriculture and Cooperatives (MOAC) of Thailand on February 17, 1987. The Study was divided into two phases, Phase I and II, with each respective phase consisting of field survey works and home analysis works.

The Phase I field survey and home analysis works were carried out from September 24 to November 23, 1987 and from December 18 to January 13, 1988 respectively. The Phase II field survey and home analysis works were carried out from December 24, 1987 to March 28, 1988 and from May 14 to July 12, 1988 respectively.

For the survey and study JICA assigned and dispatched a study team composed of twelve experts.

The purpose of the study was to formulate the Basic Plan for the 4 provinces in the Eastern Region and to carry out a Feasibility Study on the 16 pilot areas for agricultural land and water conservation.

As for the basic plan, the policy of rural development in the East is understood to be as follows;

- To prevent destruction of natural resources, particularly land affected by disorderly development, through introduction of land and water conservation projects.
- To supply food and raw material to the industrial sector, especially the Eastern Seaboard, from the rural area which will also stabilize the farmers income and improve living standards.
- To reduce the disparity in income between the people living in the industrial and rural area.
- To protect national security particularly in the area near the border between Cambodia and Thailand.

The development policy mentioned above follows the objectives of "the Sixth National Economic and Social Development Plan (1987-1991)" established by NESDB.

The Report on the Study consists of seven volumes as follows;

Vol. I. Main Report (As the Project Summary)

Vol. II. Basic Plan for Land and Water Conservation in the 4 Provinces of the East

Vol. III. Feasibility Study of 16 Pilot Areas

Vol. IV. Appendix for B/P

Vol. V. Appendix for F/S

Vol. VI. Guideline for Planning, Design and Construction of Land and Water Conservation

Vol. VII. Drawings

Vol. I is a summary of the Basic Plan (Vol. II) and the Feasibility Study (Vol. III).

Both Vol. II and Vol. III shall be independent and complete in itself.

1-2 Agriculture in Thailand and the East

1) Area for agriculture

The total area of Thailand is 51,300 thousand hectares (513,000 km^2). Out of this total, farm land accounted for 18,098 thousand hectares (35.3%) in 1976 increased to 20,576 thousand hectares (40.1%) in 1985.

On the contrary, the forest area was 19,842 thousand hectares (38.7%) in 1976 and since than has been extremely reduced to 14,905 thousand hectares (29.1%) by 1985.

The farm land is divided into two categories; paddy field and, upland crops and tree crops such as fruit trees, Para rubber. The area of paddy was 11,411 thousand hectares in 1976 and 11,824 thousand hectares in 1985. This figure has not changed much during the last ten years.

On the other hand, the area of upland crops and tree crops was 5,064 thousand hectares in 1976 and increased to 7,211 thousand hectares in 1985, 42 percent more than that of ten years ago. This means that most of the encroached forest area has been converted to upland crops and tree crops.

As for the study area in the East in 1985, the total area was 1,960 thousand hectares, the forest area was 378.6 thousand hectares (19.3%) and farm land was 976.4 thousand hectares (49.8%).

Farm land consists of 278.1 thousand hectares (14.2%) of paddy field and 451.1 thousand hectares (23.0%) of upland crops. This means that upland crops such as cassava, sugarcane and maize are the main crops in the area.

Forest encroachment in the East has accelerated so rapidly reducing the forest area from 2,116 thousand hectares (58.0%) in 1961 to 799 thousand hectares (21.9%) in 1985. This means that 62.2% or 1,317 thousand hectares of forest were encroached and converted to farm land during the last 25 years.

2) Position and weight of agriculture in Thailand and the East

The share of Agricultural Production in the GDP of Thailand was 22.3% in 1982 and 16.6% in 1986.

As for exports, the share of agricultural production was 67.5% in 1982 and 57.1% in 1986, maintaining the most important position in the Thai economy.

Thai agriculture has concentrated on rice cultivation but recently upland crops have been promoted with the policy of crop diversification. Details of production in recent years are mentioned in Vol. Ⅳ, appendix for B/P.

The share of agricultural production in the GRP of the East was 30.4% in 1981 and became 22.55% in 1985 and still ranked as number one among other sectors such as manufacturing (22.2% in 1985) and wholesale and retail trade.

Condition of agricultural production in the East is stated in section 2-3, Vol. Ⅳ in detail.

The agricultural feature of the region will be summarized as follows.

- Cassava is the main upland crop and 26% of the country's total production comes from the East following 60% from the North East. No other dominant upland crops are observed.
- Rice is not a main crop in the East since water resources for it are very limited except for in Chachoengsao Province.
- Fruit trees such as durian, mangosteen, rambutan and mango have a high share in the country and a high priority in the region.
- Industrial crops such as pineapple, sugarcane and coconut are also important crops which characterize the East, though not all of their shares in Thailand are high. In the above three crops pineapple is supposed to be the most hopeful, judging from an agro-industrial view point.
- No specific vegetable crops are observed at present but prospects in future are bright with the progress of the Eastern Seaboard Development Program.
- Para rubber is one of the most promising crops judging from the climatical view point though the majority of the present production of Thailand is from the South. Para rubber will be one of the main substitutes for cassava.

- Being located inland of the Eastern Seaboard, the Eastern Region has a big advantage as a supplying base of agricultural products to the people and to agro-industry there.

But limitations to production will come from lack of water resources and poor soil conditions such as erosion and low fertility.

How to utilize natural water resources efficiently and how to increase soil fertility by preventing erosion and applying organic matter or fertilizer will be the key points of agricultural production in the East.

1-3 Necessity and Importance of Soil Conservation Works

1) Soil erosion in the East

Soil erosion in the East is very severe due to the 62.2% of forest area which has been encroached during the last 25 years.

The predicted soil loss in the planning area (880,000 ha) is estimated as 34 ton/ha/year (1.8 mm) and approximately 30 million tons in total.

The value of such soil loss is estimated to be equivalent to 4,260 million Baht consisting of 2,760 million Baht of nutrient loss and 1,500 million Baht of dredging costs.

Agricultural production is 13,839 million Baht (GPP in 1985) in the Study Area. Therefore, the estimated damage from soil loss is 30.7% of the total agricultural product.

Moreover, the number of farms in the Area is 171,159. Therefore, monetary loss can be estimated as 24.9 thousand Baht per farm and 4.5 thousand Baht per capita (one farm family is 5.5 persons on average).

2) Relationship between soil degradation and decrease of crop yield in the unit area

The rapid encroachment of the forest area has accelerated soil degradation.

The predicted soil loss can be calculated from the five factors of the Universal Soil Loss Equation (USLE);

- Rainfall factor
- Soil factor
- Crop management factor
- Land slope and slope length factor
- Soil conservation practice factor

Under present farm land conditions every factor mentioned is relevant in the East particularly for sandy soil, extensive crop farming represented by cassava and more then 300 meters of slope length. In spite of the fact that the average slope of farm land is not very steep, 2~5% , soil erosion occurs because of its length caused by no farm road, no terrace, no drainage system, etc.

Soil erosion causes the removal of surface soil from the farm land, this causes nutrient loss consisting mainly of nitrogen (N), phosphorous (P) and potassium (K).

Therefore, without fertilizing the yield of unit area shall decrease year by year.

In the case of cassava, unit yield has decreased from 29 tons per hectare to 16 tons per hectare during the 16 years from 1955 to 1971 as shown in Figure 1.2-2. The average ratio of declining yield is estimated to be 3.85%. This trend is almost the same in all areas and soil conditions in the East.

If it is supposed that cassava is planted on all farm land, annual income shall be reduced 3,431 Baht per farm on average in the Study Area based on the following figures:

Average farm size = 6.24 ha

Price of cassava = 950 Baht/ton in 1987

Unit yield of cassava = 15 ton/ha in 1987

Data : Agricultural Statistics 1986/1987

In the coastal area of the East, there are many scenic places along the Gulf of Thailand represented by Pattaya in Chonburi. It was reported that more than one million people visited Pattaya in 1987.

On the contrary, a huge volume of eroded soil is flowing into the Gulf of Thailand. It was reported that approximately 48 million tons per year was estimated as annual sediment yield in the Gulf of Thailand (Natural Resources Profile 1987).

This soil shall be suspended and then accumulated as bedload at the bottom of the sea. This phenomenon pollutes the sea and changes its ecology. This destruction is progressing rapidly in a steady and invisible manner.

Furthermore, the estimated sediment volume is equivalent to a loss of 13,500 ha/year of farm land when the top soil of the farm land is presumed to be 20 cm.

3) Necessity and importance of soil conservation in the East

From the above mentioned matters, it is strongly recognized that soil conservation work is indispensable and the most fundamental work for

protecting natural resources such as farm land, water, sea products and the human environment.

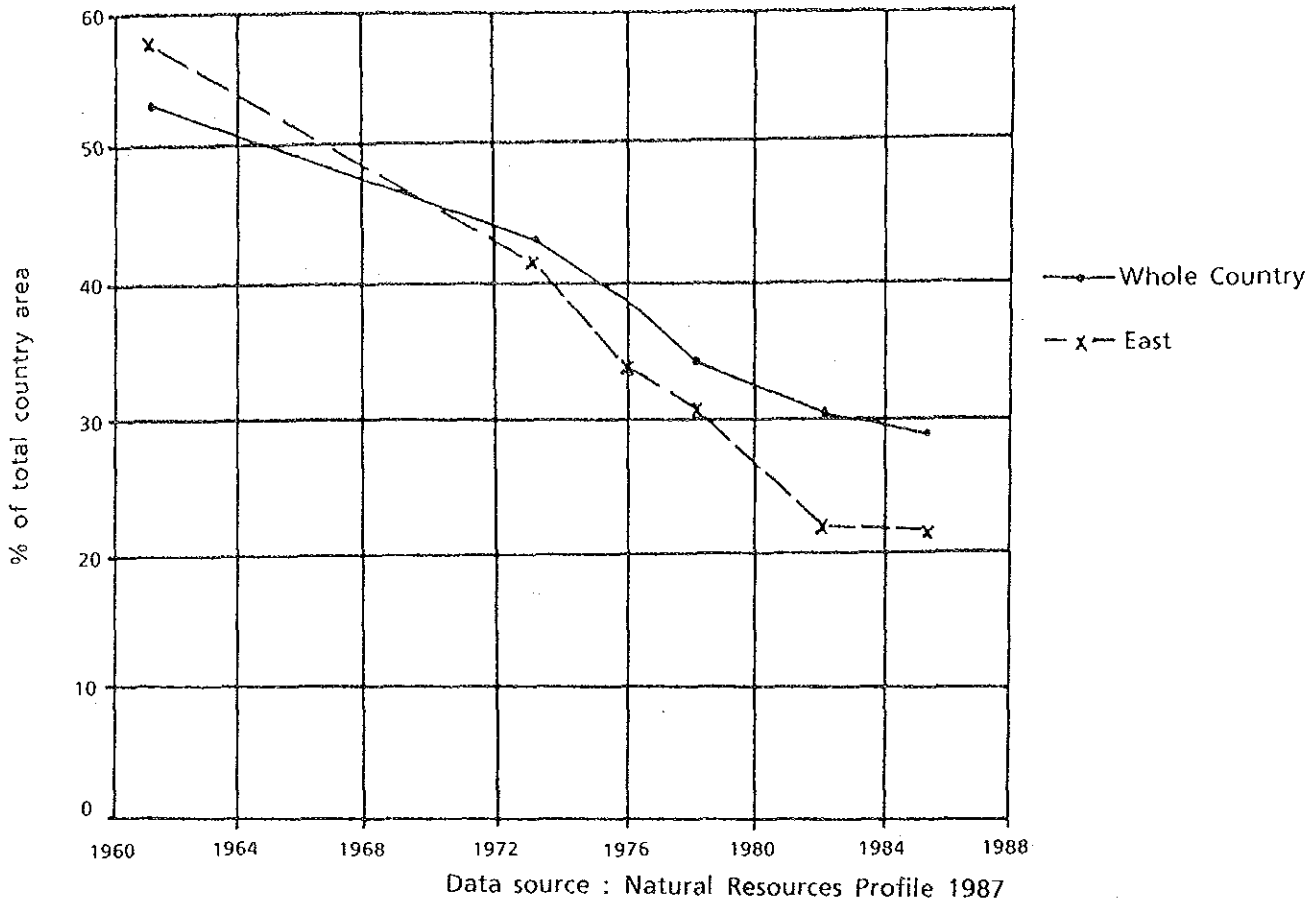


Figure 1.2-1 Forest Area in Thailand, 1961 - 1985

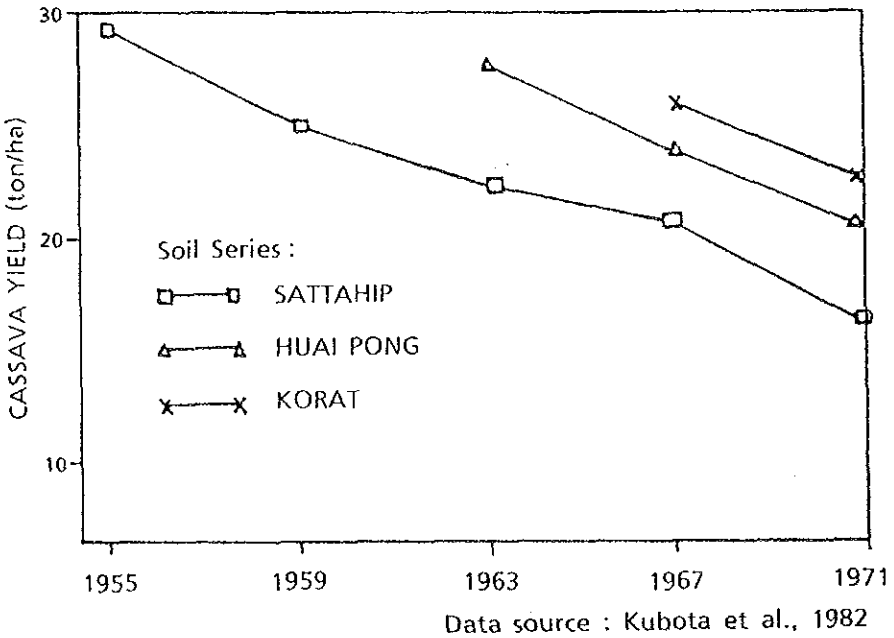


Figure 1.2-2 Tendency of Cassava Yield

1-4 Characteristics and Necessity of the B/P

The B/P will lay down the long-term integrated rural development plan centering on agricultural land conservation for the four provinces located in the Eastern Region. Integrated rural development has two aspects, improvement in both the productivity of agriculture and agricultural land, and the living conditions of the rural community and farmers.

In the case of this project, the most important method for improvement in productivity of agricultural land is the prevention of soil erosion. There are many reasons for soil erosion in the East such as undulating topography, high rainfall intensity, improper land-use and cultivation practices such as up down tillage which is common in that area.

Basically, surface soil of the area is shallow and sandy derived from granite. Humus content of the soil is low and its water holding capacity is poor. Occasionally there are hard layers under the surface soil which prevent water percolation into the soil and eventually cause soil erosion by rapid water stream on the land surface.

Since the Study Area is located near to Bangkok, and includes the Eastern Seaboard Industrial Zone and the Pattaya resort area the marketability of products and the opportunities for employment are considered to be very high.

After thoroughly investigating the circumstances in the surrounding area, an integrated type basic plan was found to be indispensable in carrying out future development as well as land conservation.

1-5 Target and Objectives of the B/P

The B/P has set forth 4 major objectives. They are;

1) to clarify the actual condition of soil erosion and to prepare the agricultural land and water conservation plan in the 4 provinces,

2) to survey the actual condition of rural facilities and farmers' living conditions, and to prepare the rural development plan, as a supporting measure for soil conservation,

3) to determine the measures for land and water conservation, and

4) to formulate the project implementation program

To achieve the above-mentioned 4 major objectives and targets, 8 strategies were set down for the project establishment. They are discussed later in detail.

1) to adopt the appropriate methods for the survey of erosion and farmers' needs,

2) to consider the agricultural (soft) measures for land conservation,

3) to consider the mechanical (hard) measures for land conservation also,

4) to consider the introduction of an irrigation system together with the mechanical measures,

5) to consider the establishment of the Land and Water Conservation Center (LWCC) and related organization for the successful completion of land conservation projects,

6) to recommend the introduction of rural development works into the project,

7) to recommend the establishment of the Board of Land and Water Conservation and the Committee of Land and Water Conservation for coordination of the many agencies concerned, and

8) to consider the organization and training of farmers.

Chapter 2.

BACKGROUND

CHAPTER 2 BACKGROUND

The 4 provinces of Chachoengsao, Chonburi, Rayong and Chanthaburi in the Eastern Region of Thailand are rural areas centering around upland crop farming, however, over the past several decades forest areas have been reclaimed for the production of cash crops such as cassava, sugarcane, etc. creating a soil erosion problem.

Furthermore, many peasants have moved to the area from the central and northern provinces and are carrying out extensive cultivation of cassava, etc. without countermeasures for land conservation which has recently caused the intensification of the soil erosion problem. Moreover, succession of cassava cultivation is considered as a major cause of the depletion of soil fertility.

At present, the Government of Thailand is carrying out the Eastern Seaboard Development Programme under the Sixth NESD Plan and the 4 provinces in the Eastern Region are, therefore, expected to fulfil the role of the food supply base for the zone.

The Department of Land Development, MOAC has carried out land and water conservation projects in the East under its own budget with the technical cooperation of FAO, from 1983 to 1986.

Details concerned with the background and present conditions for the B/P are given in Vol. Ⅳ. Therefore, they have been omitted from this volume.

Chapter 3.

STUDY AREA

CHAPTER 3 STUDY AREA

3-1 Definition of Terms and Acreage

In the Report terms which express area are defined and their acreage is as follows;

(1) Study Area

Study area which can also be called survey area means the whole area of the 4 provinces namely Chachoengsao, Chonburi, Rayong and Chanthaburi. In the study area, data and information collection, and reconnaissance surveys were carried out and the acreage in each province is as follows;

Chachoengsao	5,351 km²	(3,344,375 rai)
Chonburi	4,363 km²	(2,726,875 rai)
Rayong	3,553 km²	(2,220,000 rai)
Chanthaburi	6,338 km²	(3,961,250 rai)
Total	19,604 km²	(12,252,500 rai)

(2) Project Area

Project area means the gross area including the planning area and other existing areas such as roads, forest, villages, etc., in the case of this Study the whole area of the 3 provinces of Chachoengsao, Chonburi and Rayong and for Chanthaburi 1,981 km² or 1,238,125 rai (31.3%) which is approximately one third of the western side of the province.

(3) Planning Area

Planning area means the area of actual planning or design and implementation. In the case of this project upland farms requiring land conservation are defined as the planning area. From the results of the surveys, etc., the planning areas in each province are as follows;

Chachoengsao	2,200 km²
Chonburi	3,041 km²
Rayong	2,634 km²
Chanthaburi	965 km²
Total	8,840 km²

3-2 Methodology

The planning area of each province is based on the following items and is shown in Table 3.1-1~3.1-4.

- Land classes include 8 items namely rice, upland, tree, grass, forest, reservoir, unused land and others.
- Planning area includes the 3 items of upland, tree and grass.
- Present land-use is according to the land-use maps on a scale of 1 to 500,000 which were compiled by DLD in 1987.
- Concerning figures for the land-use plan, upland and tree apply the present acreage, and for grass maps of the land-use plan which were compiled by DLD in 1984 are applied.
- Rice and forest are excluded from the planning area.
- Reservoirs, unused land and others are based on the DLD plan which was compiled in 1984.

3-3 Classification of Erodible Area

Classification of the erodible area in each province is shown in Table 3.1-5 which is derived from Vol. Ⅳ Annex 3, 3-2.

Table 3.1-1 Present and Plan of Land-use in Chachoengsao

(Km²)

Land Classes		Present Land-use (In 1985)			Land-use Plan	Description
		Non-Forest Reserve	Forest Reserve	Total		
Rice field		1,983.2		1,983.2	1,409.4	
Upland	Surgarcane					
	Cassava					
	Other crops					
	(Sub total)	941.8	1,032.4	1,974.2	1,974.2	
Tree	Fruit trees	5.4		5.4		Planning Area
	Para-rubber	10.7	14.3	25.0		2,200.1 Km²
	(Sub total)				30.4	
Grass field					195.5	DLD Land-use plan
Forest		13.3	1,007.6	1,020.9	1,020.9	
Reservoir					135.5	DLD Land-use plan
Unused land		0.6	341.7	342.3	342.3	
Others					242.8	DLD Land-use plan
Total		2,955.0	2,396.0	5,351.0	5,351.0	

Table 3.1-2 Present and Plan of Land-use in Chonburi

(Km²)

Land Classes		Present Land-use (In 1985)			Land-use Plan	Description
		Non-Forest Reserve	Forest Reserve	Total		
Rice field		660.3	7.4	667.7	667.7	
Upland	Surgarcane					
	Cassava					
	Other crops					
	(Sub total)	2,007.3	1,131.8	3,139.1	2,356.5	
Tree	Fruit trees	158.0	18.5	176.5		Planning Area
	Para-rubber	3.2		3.2		3,041.3 Km²
	(Sub total)				179.7	
Grass field					505.1	DLD Land-use plan
Forest		32.2	319.6	351.8	351.8	
Reservoir		14.7	1.2	15.9	97.8	DLD Land-use plan
Unused land		7.7		7.7	7.7	
Others		1.2		1.2	196.8	DLD Land-use plan
Total		2,884.6	1,478.5	4,363.1	4,363.1	

Table 3.1-3 Present and Plan of Land-use in Rayong

(Km²)

Land Classes		Present Land-use (In 1985)			Land-use Plan	Description
		Non-Forest Reserve	Forest Reserve	Total		
Rice field		284.0	13.2	297.2	297.2	
Upland	Surgar cane					
	Cassava					
	Other crops					
	(Sub total)	1,616.0	616.6	2,233.2	1,614.3	
Tree	Fruit trees	90.9	38.0	128.9		Planning Area
	Para-rubber	513.8	3.1	516.9		2,633.9 Km²
	(Sub total)				645.8	
Grass field					373.8	DLD Land-use plan
Forest		129.7	184.3	314.0	314.0	
Reservoir		12.9		12.9	37.7	DLD Land-use plan
Unused land		27.8	3.0	30.8	30.8	
Others		18.1		18.1	238.4	DLD Land-use plan
Total		2,693.8	858.2	3,552.0	3,552.0	

Table 3.1-4 Present and Plan of Land-use in Chanthaburi

(Km²)

Land Classes		Present Land-use (In 1985)			Land-use Plan	Description
		Non-Forest Reserve	Forest Reserve	Total		
Rice field		106.1		106.1	106.1	
Upland	Surgarcane					
	Cassava					
	Other crops					
	(Sub total)	377.4	340.5	717.9	572.6	
Tree	Fruit trees	18.4		18.4		Planning Area
	Para-rubber	242.7	131.3	374.0		965.0 Km²
	(Sub total)				392.4	
Grass field						DLD Land-use plan
Forest		58.2	706.4	764.6	764.6	
Reservoir					43.6	DLD Land-use plan
Unused land					43.5	
Others					58.2	DLD Land-use plan
Total		802.8	1,178.2	1,981.0	1,981.0	

Table 3.1-5 Erodible Area in the Planning Areas of the 4 Provinces

(Km²)

Classification	Chachoengsao	Chonburi	Rayong	Chanthaburi	Total
Ton/ha/yr.					
1. Top Urgent (50 <)	388	1,245	923	331	2,887
2. Urgent (50 - 30)	553	521	170	268	1,512
3. Necessary (30 - 20)	523	439	864	328	2,154
4. Normal (20 - 5)	351	23	223	12	609
5. Not Necessary (5 >)	385	813	454	26	1,678
Total (Planning Area)	2,200	3,041	2,634	965	8,840
1 - 4 Total (Erodible Area)	1,815	2,228	2,180	939	7,162

Note: a. Method and calculation details are shown in Vol. IV Annex 3, 3-2.

b. Soil erosion maps (S = 1/250,000) are attached in Vol. VII Drawings.

Chapter 4.

SOIL AND WATER CONSERVATION MEASURES

CHAPTER 4 SOIL AND WATER CONSERVATION MEASURES

4-1 General

Four approaches to soil and water conservation are selected in this report as follows;

1) Agricultural measures
2) Mechanical measures
3) Irrigation facilities
4) Supporting measures

Agricultural measures mean how to prevent soil erosion and how to keep and utilize natural water resources agronomically, mechanical measures mean applying civil engineering techniques such as terrace making, etc.

Irrigation facilities mean how to save the water resources and utilize them.

All of these three measures are directly connected with the topic but 4) supporting measures, has a rather indirect relation with it. It has very wide fields to discuss but since the topic is under the scope of integrated rural development, the next four items have been selected.

- Infrastructure
- Agro-industry
- Education of farmers
- Institutional cooperation

Focussing on the direct relation between soil and water conservation, and its measures, crop diversification and contour strip cultivation in the agricultural sector and establishment of a drainage system, graded terrace and irrigation facilities in the mechanical sector should be emphasized.

These should be the four main measures in the East in future and their priority will depend on the physical and economical conditions of each area.

4-2 Agricultural Measures

(1) Basic concept and consideration

Figure 4.2-1 shows the position and role of agricultural measures against erosion in the cycle of natural water resources based on soil, the main objective of DLD. All the activities mentioned in the legend of the figure are directly and closely connected with agricultural soil and water conservation. They are protection of soil, prevention of evaporation, blocking of run-off water and stopping of percolation.

The outline of the measures for the activities mentioned above are classified as follows;

1) Mulching	• Live mulching
	• Non-live mulching
2) Cropping method	
3) Cultivation method	• Contour ploughing
	• Contour ridging
	• Contour strip cultivation
4) Canopy improvement	
5) Soil management	• Tillage
	• Soil property improvement

1) Mulching

Mulching for protection of soil and prevention of evaporation has been recognized as the best measure by experience and experiment all over the world. Practically, how to prepare materials for mulching is the problem on farms. In the Eastern upland area, some suitable cover crops as live mulching have been recommended by DLD but no appreciate non-live material is found except compost which is available at sugarcane factories.

Rice straw is the most suitable for the purpose according to past experience but transportation from rice cultivation areas is the major obstacle.

Upland rice cultivation or intercropping with tree crops would be another source of the material. In that case, the rice

cultivation area should be large enough to scatter the damage of insects or birds, especially the latter. Where rice straw is presently available, it is recommended to utilize 4 t ~ 5 t/ha for mulching.

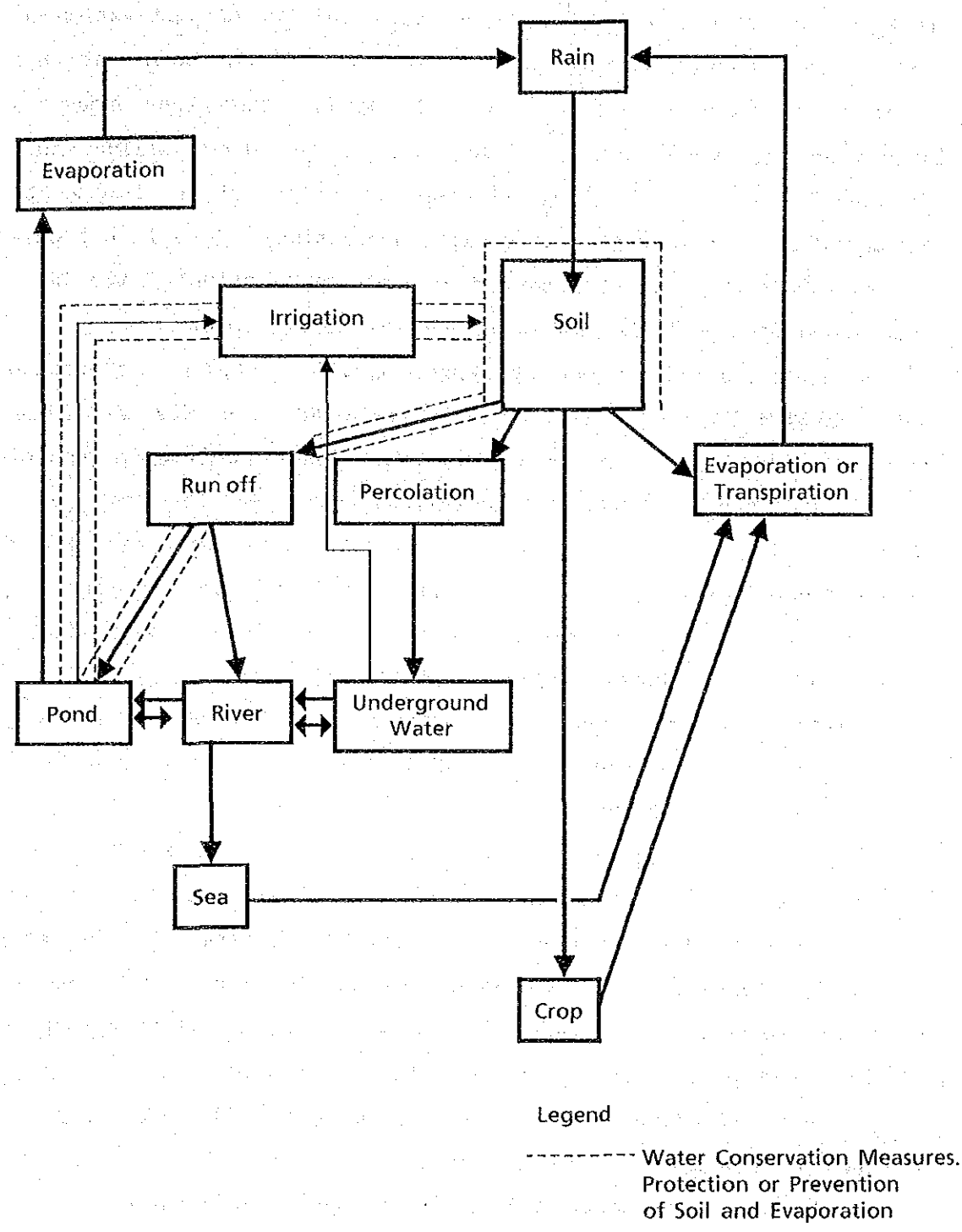


Figure 4.2-1 Soil and Water Conservation Activities in Water Cycling

2) Cropping method

Cropping method means continuous cropping of a certain crop, rotation of crops and intercropping etc. Successive cultivation of cassava is so popular in the Eastern Region and it has been said that it is the main reason of erosion there. Tree and fruit tree crops are suggested for cassava among so many alternative crops. Since they are perennial, intercropping at the beginning stage is to be recommended for the purpose of erosion prevention. This is not only for soil conservation but also for economic utilization of the land. Intercropping cassava is also beneficial in this respect.

A technical and economical survey on intercropping was carried out from 1973~77 by the Field Crop Reserch Insutitute, DOA. According to the report, the percentage of the total income, selling prices of cassava and intercropping, were as follows;

Cassava (Only)			100%
-do-	+	Sweet corn	231%
-do-	+	Mungbean	134%
-do-	+	Soybean	125%
-do-	+	Peanut	121%
-do-	+	Maize	103%

Changing from a familiar crop e.g., cassava, to another economical crop will be one of the biggest problems in the crop diversification policy for farmers. Because they are not familiar with the new crop, new investment will be necessary and the prospect of the new crop is not always sure.

To cope with this problem, the following will be necessary for the authorities concerned to support them.

- Discussion in detail with related farmers and people
- Suggestion of new crop(s) should be on the basis of financial prospects
- Helping them receive financial support from outside

- Giving them conveniences, such as technical know-how, administrative arrangement etc. as much as possible for a definite period.

It is advisable to set up a new organization of related farmers themselves with the help of a DLD officer. These items are also necessary in order to adopt the cultivation method as mentioned in 3).

3) Cultivation method

As for cultivation method, contour cultivation is now common practice for cultivation on any sloping land. Judging from the present condition in the Eastern Region, contour cultivation with graded terrace will be the most adaptable and practical method. It may be sufficient enough to cope with the erosion problem if it is enforced with some modification such as ridge making or tree crop planting along the ridges for fixing soil and preventing up and down tillage operation in future. A consensus of the related farmers is essential for carrying out such a measure and this might be the biggest constraint for implementation of soil and water conservation measures.

4) Canopy improvement

Leaf canopy improvement is the same as mulching in the sense of soil protection. The purpose of the leaf canopy is to prevent rain drops which degenerate soil character from falling directly on the ground. In case of cassava monoculture, it takes roughly three months from planting to make a canopy. For planting at the beginning of the raining season, the situation of erosion is very serious because the soil surface is almost bare. If a canopy is established as soon as possible a better situation is expected. For that purpose, the following will be emphasized;

a) Sufficient fertilization at early stage of cassava cultivation
b) Consideration of planting density from erosion aspect

c) Breeding a variety of early canopy developing characteristic

d) Planting cassava at the end of the rainy season

5) Soil management

Soil management is another very important factor in soil and water conservation. So far, almost all information regarding the relationship between tillage operation and erosion reveal that no tillage or minimum tillage is better than conventional methods.

For instance, in the Fifth International Soil Conservation Conference which was held in Bangkok in January 1988, Mr. S. Boonchee and others, Region 6, DLD, presented the paper "Effects of Land Development and Management on Soil Conservation in Northern Thailand" explaining the effectiveness of the no-tillage system on soil loss and water run-off and advantages in yield, although there were some problems such as weed control.

To the contrary, according to the results in a cassava cultivation trial carried out at Kasetsart University's Farm, Sri Racha, Chonburi Province in 1987, by CIAT and the University, no-tillage operation is the worst method in terms of sediment.

The trial was carried out on a field of 5%~10% slope on which cassava was planted. According to the information of Dr. R. H. Howeler, CIAT, out of thirteen soil preparation operations "ploughing and disking followed by contour ridging" is the best method from the viewpoint of sediment. Second best is "subsoiling at 40 cm depth and 80 cm rows with planting at 80 cm × 125 cm", and the worst method is "no land preparation, pre-plant application of Gramoxon, weedicide", for which the amount of sediment is more than ten times that of the best.

The two results mentioned above show that soil condition and other environmental factors of each locality are closely connected with soil and conservation, showing different reaction to rain.

Though no-tillage operation is not conventional in the Eastern Region, it is suggested to re-check the effect of tillage operation.

It is not necessary to elaborate on the importance of soil property improvement. Soil fertility and the water retaining capacity of soil will be increased by soil improvement and their effects are directly connected with soil erosion and crop yield.

Generally speaking, soils in the East are very poor in fertility and that is one of the reasons why monoculture of limited crops is prevailing in the region.

For increasing soil fertility, incorporation of organic materials is essential but tropical conditions are not favorable for accumulating organic substances in soil due to high temperatures. Though there is some data of the Department of Agriculture that application of organic materials for a certain period is effective in increasing soil fertility, it might not be practical on a large scale in the area for the time being judging from availability of the materials.

In case of mulching, the remains of the plant materials are to be incorporated in the soil in the next season and nutrient, especially nitrogen, which is produced during the initial process of decay will be utilized by plants. This nutritions effect of organic matter is expected especially when legume plants are intercropped with other crops. Their nitrogen fixing ability at roots has a good effect in the same way to other crops and many trials support this fact.

Choosing proper leguminous crops from a biological and economical view point will be one of the problems in the region.

Of course, utilizing composts made of plant residues or agro-industrial waste and city compost in a limited area, e.g., pit for tree planting, is strongly recommended, since it is technically possible and economically rewarding. Farmers in the East have been following such advise from DLD officers for the past several years.

(2) Cropping pattern

Cropping patterns in the Eastern Region look rather simple because 1) perennial crops such as Para rubber and fruit tree crops are popular 2)

water resources are very limited and the number of crops is limited and 3) cassava has been the dominant crop due to environmental conditions.

A comprehensive cropping pattern on upland in the region is suggested in Figure 4.2-2. This is based on the present pattern of the Eastern Region with some modification.

In the figure, water conditions are divided into rainfed and semi-irrigable. Semi-irrigable means that a limited amount of irrigation water is available in dry season.

Three kinds of crop, cassava, Para rubber and fruit tree are specially selected to be the main crops in the cropping patterns.

The growth period of cassava is divided into two, 8 month and 12 month for the time being and tree crops are classified into two groups, water consuming and others.

Intercrops of the above mentioned basic crops are suggested in Table 4.2-1. It is necessary to modify the suggested pattern in case of making a practical plan for a specific project area and it is indispensable to get information concerning the experience of farmers in the area.

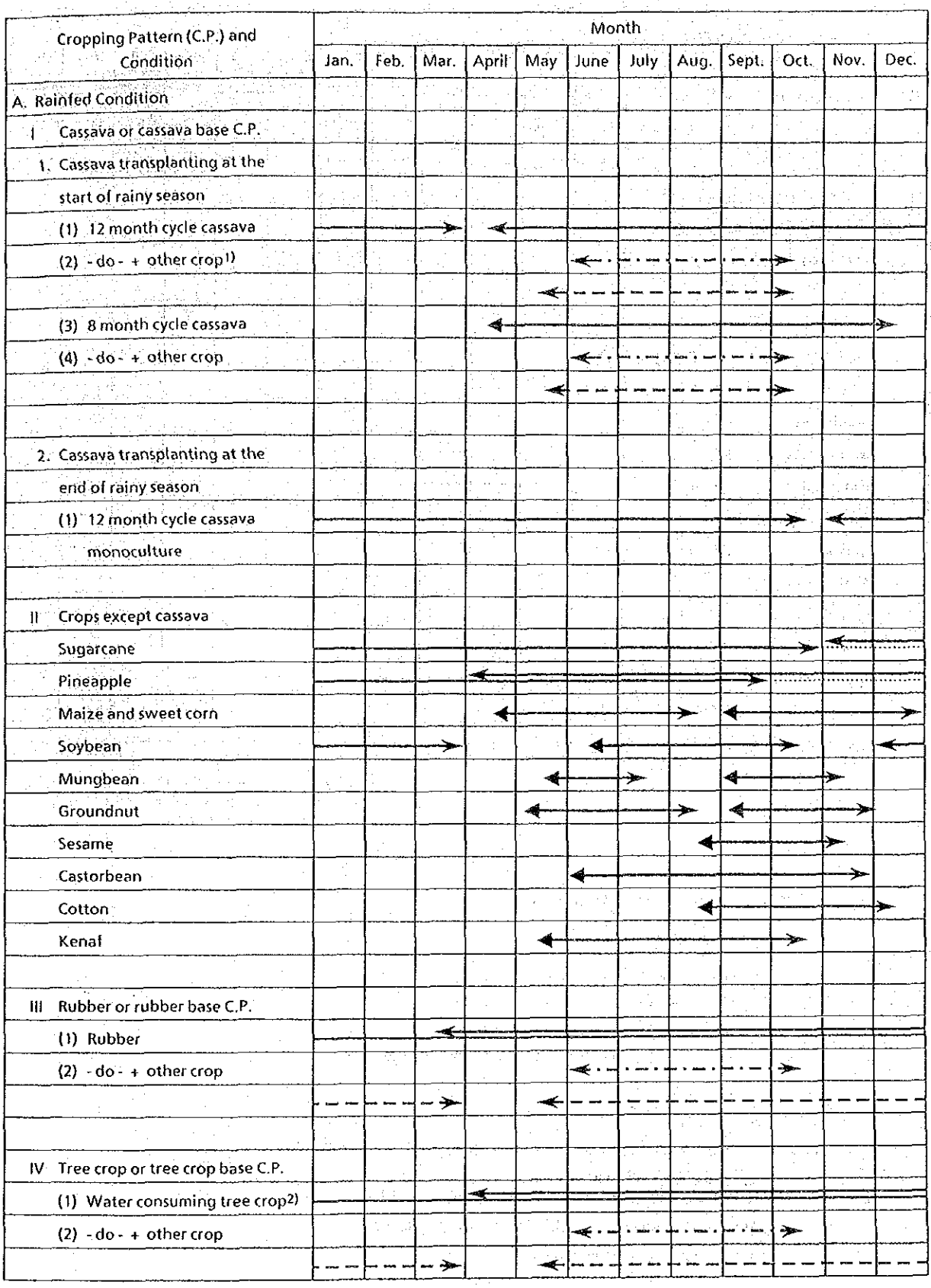
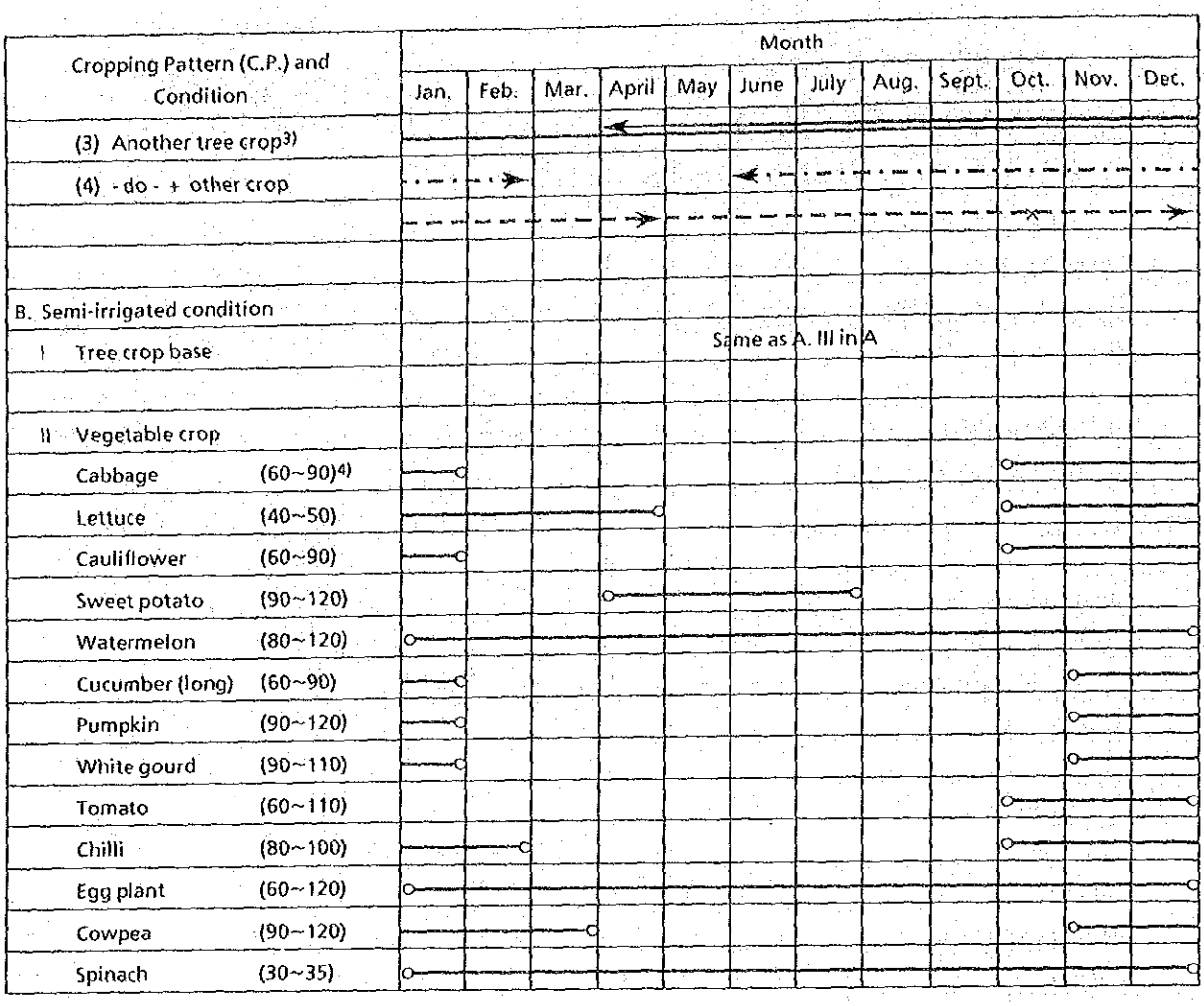


Figure 4.2-2 Cropping Pattern in the Eastern Region, Thailand



Source: Annual Report (1987), Chonburi LDS, "Vegetable growing" DOAE, and Information in DOA.

Legend:
- Cultivation
- Planting
- Harvesting
- Intercropping cultivation
- Cover or manure crop cultivation
- Ratoon cropping
- Best planting time of vegetable

Note:
1) Inter, cover and manure crops as suggested in Table 4.2-1.
2) Water consuming tree crop
Durian, Rambutan, Coconut, Mangosteen and Lansium, etc.
3) Mango, Cashewnut, Jackfruit and Tamarind, etc.
4) Harvesting day after planting.

Figure 4.2-2 Cropping Pattern in the Eastern Region, Thailand (Cont'd)

Table 4.2-1 Suggested Inter and Cover Crops for the Cropping Pattern in the Eastern Region

Base Crop	Intercrop	Cover Crop
I Cassava	Groundnut, Black bean Mungbean, Cow pea Sweet corn, Maize, Sorghum Upland rice, etc.	Kudzu, Kalapogonium Centrosema, Stylosanthes Seratoro, Sesbania, etc.
II Crops except cassava	no intercrop	no cover crop
III Rubber	Cassava, Pineapple Corn, Maize, Groundnut Mungbean, Pigeon pea Sweet potato, Upland rice, etc.	Native grasses Bermuga grass, Pangora grass Love grass, etc.
IV Tree Crops		
1. Water consuming tree crop	same as the above for initial few years	same as the above
2. Another tree crop	same as I and III	same as the above

(3) Basic cropping plan in the target areas in the Eastern Region

In accordance with the Sixth NESD Plan and its extension plan in the target provinces, and from the trend in crop production, the future of agricultural acreage in the area is suggested as shown in Table 4.2-2, based on the points mentioned bellow.

1) Following the national policy of crop diversification, cassava is to be replaced mainly with fruit tree crops and Para-rubber

2) However, cassava will still be the most popular crop in the region in future

3) Pineapple may be one of the most stable cash crops in the region though not being emphasized in the Plan

4) A certain fixed percent of the target area will be allocated to road, river and irrigation facilities

5) Intercropping area is not counted in the table.

Table 4.2-2 Present and Suggested Land-use for Upland Crops in the Eastern Region

(Km²)

Province	Study Area	Project Area	Present & Suggested	Upland				Rubber & Tree Crop	Grassland	Others
				Cassava	Sugarcane	Pineapple	Others			
Chachoengsao	5,351	2,200 (100%)	Present	710 (32)	68 (3)	13 (1)	177 (8)	223 (10)	569 (26)	440 (20)
			Suggested	462 (21)	66 (3)	22 (1)	177 (8)	462 (21)	462 (21)	550 (25)
Chonburi	4,363	3,041 (100%)	Present	900 (30)	596 (20)	58 (2)	431 (14)	303 (10)	145 (5)	608 (20)
			Suggested	456 (15)	608 (20)	61 (2)	426 (14)	608 (20)	152 (5)	760 (25)
Rayong	3,552	2,634 (100%)	Present	1,130 (43)	253 (10)	116 (4)	92 (3)	391 (15)	75 (3)	527 (20)
			Suggested	580 (22)	184 (7)	105 (4)	79 (3)	948 (36)	79 (3)	658 (25)
Chanthaburi (Amphoe Tha Mai)	1,981	965 (100%)	Present	192 (20)	1 (0)	– (0)	53 (5)	430 (45)	96 (10)	193 (20)
			Suggested	68 (7)	– (0)	– (0)	68 (7)	492 (51)	97 (10)	241 (25)
Total	15,247	8,840 (100%)	Present	2,932 (33)	918 (10)	187 (2)	753 (9)	1,347 (15)	885 (10)	1,768 (20)
			Suggested	1,566 (18)	858 (10)	188 (2)	750 (9)	2,510 (28)	790 (9)	2,209 (25)

Agricultural Statistics of Thailand, Crop Year 1986/87 and Extension Plan 1987~1991, four provinces of the East were referred.

4-3 Mechanical Measures

(1) General

The role of the mechanical measures shall be considered as supporting practices of the agricultural measures. There is a possibility that mechanical measures are able to completely prevent soil erosion. Namely, to make the farm level flat as same as a paddy field, to establish a perfect drainage system, to construct a road network and prevent siltation downstream by making a sediment pond and filtration system at the effluent place of each farm. Concrete structures and asphalt pavement of all farm roads will also be necessary for complete prevention.

However, such measures require a huge investment for initial construction and, operation and maintenance costs are enormous. In actuality, such measures are not practical and could never be provided by farmers.

Mechanical measures should be considered on the balance of input and output of the Project and it will be appropriate to assume a Project life of 30 years for calculation purposes.

(2) Basic concept of mechanical countermeasures for soil conservation

Basic countermeasures for soil conservation are given as follows in order of their priority.

1) Establishment of drainage system

Top priority of mechanical measures is establishment of a drainage system. Although a complete drainage system should cover from the top of the mountain to the sea, in this report, topics related only to farm level shall be mentioned due to the scope of the project.

For soil conservation, excess water should be immediately carried away from farm land to natural stream and sea through a drainage canal. Construction of a drainage system up-stream sometimes causes flooding down-stream by shortening the flood concentration time. Therefore, improvement of the drainage system down-stream should be done first. As temporary measures, flood

control shall be carried out by using a farm pond.

Classification of drainage canals is as follows;

- Catching ditch

  to catch surface run-off water, normally constructed in the direction of the contour

- Collecting ditch

  to collect discharges from catching ditches, constructed at a right angle to contour direction, discharge increases gradually

- Draining ditch

  to collect discharges from collecting ditches, there are trunk ditches and branch ditches

Velocity of the surface flow (surface laminar flow) on the soil is variable depending on slope, roughness coefficient and length. To reduce the capacity of soil transportation by flow (tractive force) shortening the water way, reducing the slope and increasing surface roughness shall be adopted. Therefore, contour cultivation (contour stripe) is effective for soil conservation. However, if the collecting ditch is not strong enough, damage to farm land shall occur, therefore, the structure and materials of collecting canals should be selected carefully. Figure 4.3-1 shows an illustration of the drainage system.

In Japan, soil erosion causes land slides and disasters on farm land areas, therefore, the establishment of a drainage system is the most important work of a farm land development project and land consolidation project, and requires sufficient investment. In other words, the main construction work of such a project is the establishment of a drainage system.

2) Terrace construction

As a supporting method of agricultural measures, terrace construction is one of the most effective methods for making drainage systems more complete.

To realize cultivation methods such as contour ploughing, contour ridging and contour strip by farmers, terrace construction shall be indispensable because of the shape of each farm lot

constructed along the contour direction (refer to Figure 4.3-2).

Up-down farming against the contour line can not be carried out by farmers without breaking the terrace.

From the aspects mentioned above, the following terracing method shall be introduced to the project in order of priority;

① Graded Terrace

② Contour Terrace

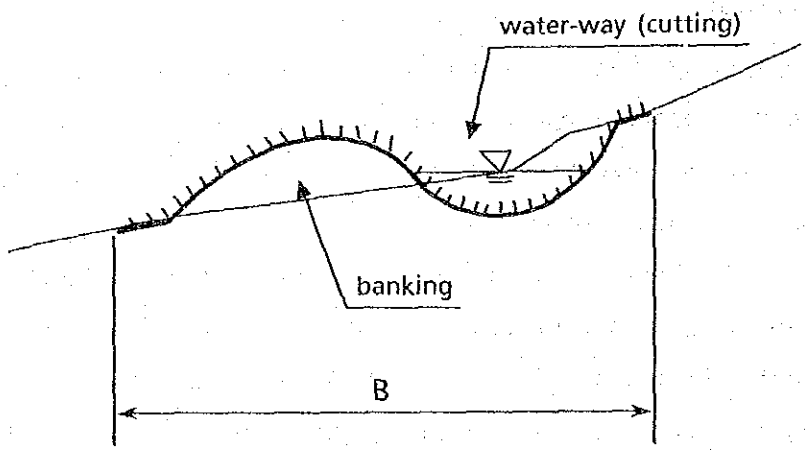
③ Bench Terrace

In this report, contour terrace shall be included under graded terrace, and Zing terrace shall be omitted since it is applied to paddy fields.

- Graded Terrace (including Contour Terrace)

  Considering natural conditions such as topography and soil in the East, graded terrace method shall be the most effective from the view points of construction and cost.

  Graded terrace consists of banking and water-way.



To receive farmer's agreement, useless land (non cultivable area) should be minimized e.g., within 6% of project area. Therefore, B (total width) and the interval of the terrace shall be decided in line with farm width.

Surface of banking and cutting shall be covered by grass as protection and also banking shall be well compacted by mixing water with clayey soil.

- Bench Terrace

  For the steep land slope area, more than 27% (= 15 degrees), bench terrace shall be very effective for making farm land and soil conservation. In the East, however, such steep areas shall be planned for reforestation. For tree plantations, contour ridging or hole method shall be introduced since they are easy to construct and low in cost.

  Therefore, in this report, bench terrace method shall not be selected.

3) Farm road construction

Farm roads have functions for both farm management and soil conservation.

Farm roads are classified into several grades from footpath to trunk agricultural roads, the same as for the drainage system. Normally, drainage ditches shall be constructed beside farm roads. In the case of Japan, farm roads are sometimes used as both roads and drainage ditches so as to intensify the land-use.

The condition of farm road construction in the East of Thailand is not so limited owing to large land holding areas per farm of 50 rai (8 ha) and a slope gradient of less than 10%. Therefore, not how to make the plan but how to minimize the construction cost of farm roads shall be very important.

4) Farm pond (Tameike) construction

The functions and effectiveness of Farm Ponds are as follows;

- To deposit soil in the drainage system (soil conservation).
- To be able to use storage water for irrigation and domestic use.
- To control flooding discharges.
- To make soil downstream of the pond moist.

In particular, to supply water to parched soil is very useful for soil conservation.

The most important merit of the farm pond is to use storage water for irrigation. Crop diversification and crop conversion from

cassava to orchard can be realized by irrigation without failure or risk.

5) Standard farm lot and farm land block

Farm land consists of farm land blocks and farm lots. Farm land blocks are enclosed by farm roads and divided into several farm lots. It is presumed that farm lots shall be 100 m (length) × 20 m (width) at this time and the length shall lie in the contour direction and the width at a right angle to the contour direction.

In general the shape of farm lots and arrangement of farm roads shall be decided from crops, coefficient of farming machinery and arrangement of the drainage system for soil conservation. In this chapter, the plan of farm lots and farm land blocks mainly for soil conservation shall be mentioned. Figure 4.3-2 shows that there are many arrangements of farm roads. In general, for erodible areas, the interval of vertical roads (at a right angle to the contour direction) is shorter than the horizontal road (contour direction) in order to drain excess water from the farm land as soon as possible.

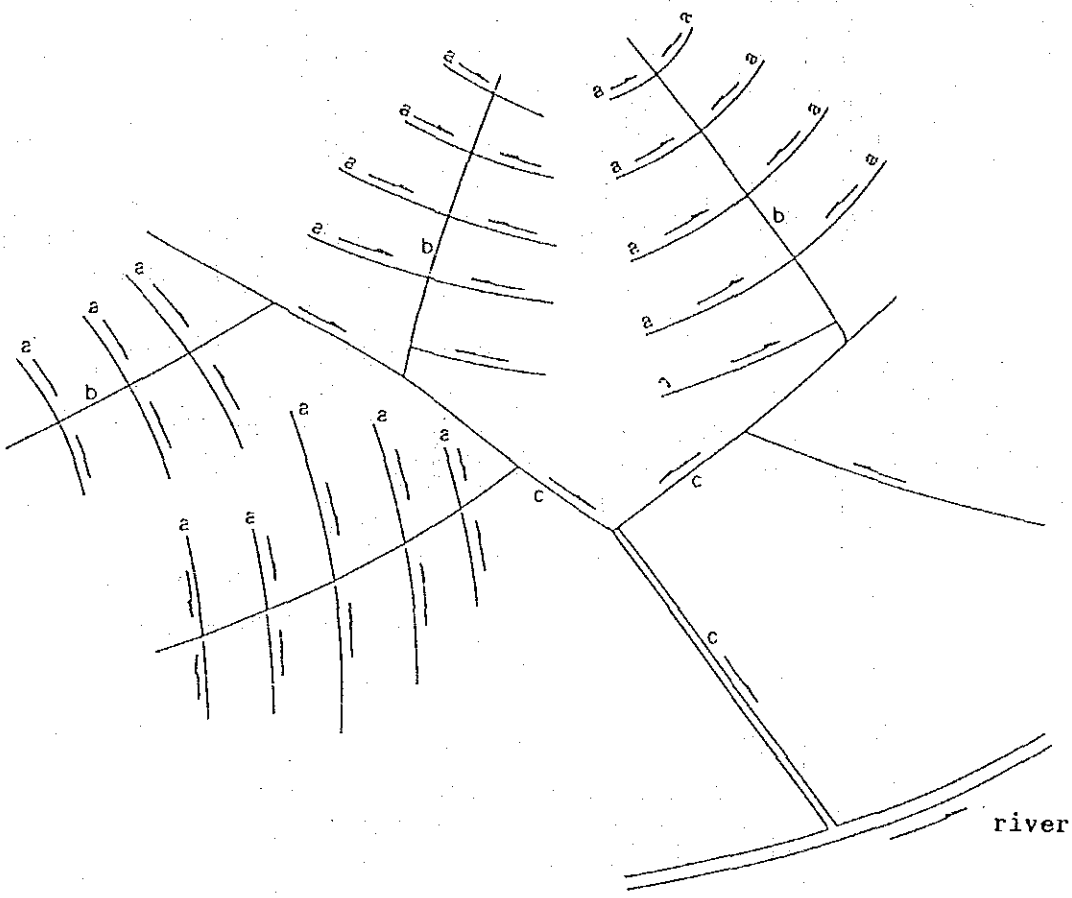
The preliminary basic plan is as follows.

- Interval of vertical roads shall be 100 m ~ 200 m.
- Interval of horizontal roads shall be 200 m ~ 500 m.
- Drainage of the farm land shall be done using natural topographic slope to the contour direction.
- Drainage system shall be constructed beside farm roads in principle.
- Vertical roads and horizontal roads cross at right angles in principle.

For soil conservation, road arrangement should be high in density as much as possible.

6) Land grading

The topographic condition in the East is comparatively flat with 3 ~ 10% slope gradient and rolling. Therefore, land grading shall be carried out according to natural slope without earthwork on a large scale.



a : Catching ditch

b : Collecting ditch

c : Draining ditch

Figure 4.3-1 Drainage System Diagram

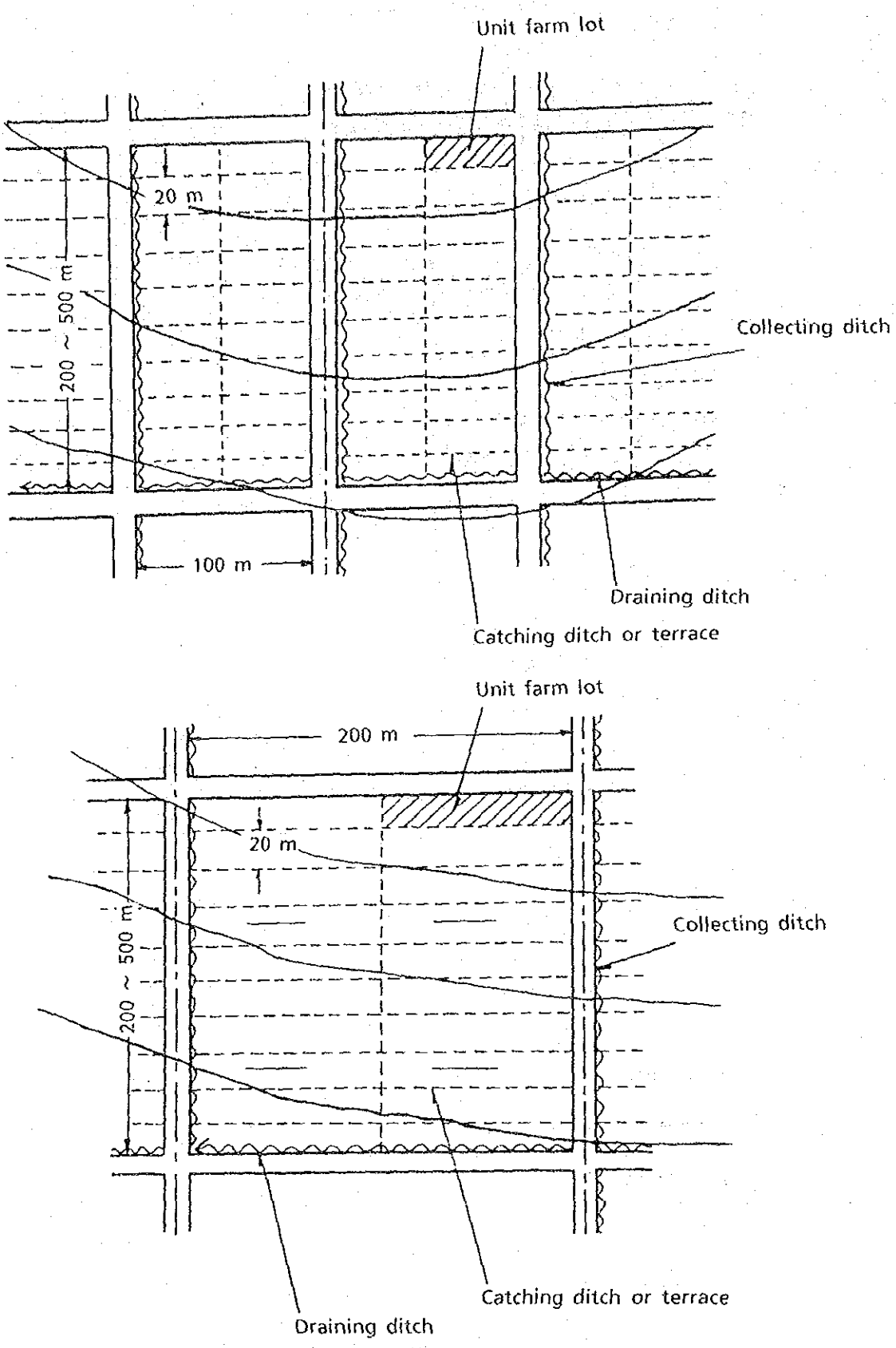


Figure 4.3-2 Plan of Farm Land Consolidation

(3) Items and types of mechanical measures

Mechanical measures shall be classified as follows;

category	items
a) Soil management system	· Sub soiling
b) Terracing system	· Contour terrace
	· Graded terrace
	· Bench terrace
	· Zing terrace
c) Drainage system	· Catching ditch
	· Collecting ditch
	· Draining ditch
	· Appurtenance
	drops
	sediment trap
	connecting pit
	rectifying pit
d) Farm road system	· lateral road, vertical and horizontal
	· trunk road (main road)
e) Farm pond (Tameike)	
f) Check dam (Sediment pond)	· Woven-wire dam
	· Brush-wood dam
	· Loose-rock dam
	· Plank or slab dam
	· Masonry dam
	· Concrete dam
	· Earth dam
g) Slope protection	· Spray method
	· Sodding
	· Concrete wall
	· Wooden wall
h) Others	· Sand bag
	· Woven-wire mat

Each measure shall be selected depending on actual site conditions of the Project.

(4) Specification and application criteria

Specification and application of measures are explained in Table 4.3-1. In the table, Contour Terrace shall be included in the Graded Terrace and Zing Terrace shall be omitted to avoid large earth movement.

Table 4.3-1 Specification and Application of Measures (1/4)

Measure	Specification	Application
1. Sub-Soiling	a. To break hard subsoil b. Proposed depth = 0.60 m	· Slope : 3 % ~ 10 % · Soil : any type · Crop : any crop
2. Contour Ridging	a. To make ridge for planting b. Proposed height = 0.30 m	· Slope : 3 % ~ 10 % · Soil : any type · Crop : field crop; vegetable
3. Graded Terrace	a. To make contour bank and grass water-way b. Allowable ditch slope of water-way is 2% c. Horizontal interval = 40 m ~ 60 m	· Slope : 3 % ~ 15 % (1.70 ~ 9.10) · Soil : any type · Crop : any crop
4. Bench Terrace	a. To make bench farm and catching ditch b. Surface slope 2% inversely c. Hmax = 2.0 m d. Slope protection = Sodding e. Slope = 1 : 2.0 f. All cutting method g. Farm length = 6.0 ~ 12.0 m	· Slope : more than 27% · Soil : any type · Crops : Fruit, vegetable (Note) To avoid large scale earth movement and slope protection, Hmax shall be decided as 2.0 m.
5. Grass Water-way	a. Vmax = 1.0 m/s (n = 0.04) b. I max = 3 % < 0.1 m^3/s 2% > 0.1 m^3/s c. Bottom W = 0.30 ~ 0.50 m H = 0.40 ~ 0.80 m Z = 1 : 1.5 ~ 2.0 d. Grass = Pangola, Bermuda	· Side ditch of farm road · Graded Terrace · Collecting ditch · Catching ditch
6. Masonry Ditch	a. Vmax = 2.5 m/s (n = 0.032) b. I max = 4% < 1.0 m^3/s 2% > 1.0 m^3/s c. Bottom W = 0.30 ~ 0.70 m H = 0.50 ~ 1.00 m Z = 1 : 1.0	· Side ditch of farm road · Collecting ditch · Draining ditch

Table 4.3-1 Specification and Application of Measures (2/4)

Measure	Specification	Application
7. Drop	a. dHmax = 1.00 m in Grass water-way and Masonry water-way b. B = 1.0 ~ 1.5 m c. L = 1.0 ~1.5 m d. H = 1.5 ~ 2.0 m e. Structure = Concrete Block + mortar f. Side protection = Sand bag	· Grass water-way (dH = 1.0 m) 4 % : 50 m interval 5 % : 34 m interval 6 % : 26 m interval · Masonry canal (dH = 1.0 m) 4 % : no need 5 % : 100 m interval 6 % : 50 m interval (Note) Interval of drops shall be decided by hydraulic calculation considering slope of land and run-off discharge.
8. Check dam (Sediment Pond)	a. H = 1.0 ~ 2.0 m b. Qmax = 3.0 m^3/s (1/10) c. Structure · Earth + Riprap · Woven-wire dam · Loose rock dam · Wood and rock · Sand bag · Others	
9. Farm Road	a. Effective width · Main = 5.0 m · Lateral = 3.0 m b. Total Width · Main = 6.0 m · Lateral = 4.0 m c. Laterite thickness = 0.2 m d. Banking = 0.10 ~ 0.30 m e. Stripping of original ground = 0.15 m	· Pavement type by slope Laterite < 10 % Gravel = 10 ~ 15 % Concrete > 15 % · Surface slope of road CS = 3 % CN. RY = 4% CT = 5 % (Note) Surface slope shall be decided depending on rainfall intensity at the site.

Table 4.3-1 Specification and Application of Measures (3/4)

Measure	Specification	Application
10. Canal Crossing	a. Structure	
	· Concrete slab bridge	Q > 10 m³/s (1/10 Probability)
	· Concrete paved road	Q = 3 ~ 10 m³/s (1/10 Probability)
	· Concrete pipe	Q < 3 m³/s (1/10 Probability)
11. Farm Pond Large Scale	a. Earth Dam	
	· Height max = 6.0 m · Cut off trench = 5.0 m · Crest width = 5.0 m · Freeboard = 1.0 m · Slope : Upst. = 1 : 3.0 Downst. = 1 : 2.5 · Slope protection = Riprap and Sodding · Spillway (1/50) = Chute type (Concrete) · Outlet = Bottom type (steel pipe)	· Effective storage capacity (Ve) Ve > 100,000 m³ · Not to make farmer's house submerge
Small Scale	a. Earth Dam	
	· Height max = 4.0 m · Cut off trench = 4.0 m · Crest width = 5.0 m · Freeboard = 1.0 m · Slope : Upst. = 1 : 3.0 Downst. = 1 : 2.5 · Slope protection = Riprap and Sodding · Spillway (1/50) = Chute type (Masonry) · Outlet = Bottom type (steel pipe)	· Effective storage capacity (Ve) Ve > 10,000 m³ · Not to make farmer's house submerge
	(Note) · Type of earth dam shall be inclined one in principle because of lack of core type dam materials. · To stop the water loss by seepage under the dam, the depth of cut off trench shall be carefully decided at detailed design stage.	

Table 4.3-1 Specification and Application of Measures (4/4)

Measure	Specification	Application
12. Slope Protection	a. Spray method · Sodding · Concrete mortar · Asphalt emulsion b. Sodding c. Stripped sodding	· Sprayed sodding terrace bank in the reservoir ditch · Concrete mortar slope of the road · Asphalt emulsion catching canal
13. Gully Protection	a. Brush wood method b. Wooden pile and stem or branch of tree or bamboo shall be used. c. Sand bag (50~60 kg) cloth or vinyl bag and soil shall be used. d. Woven-wire method (T×B×L = 0.60 m × 1.20 m × 2.4 m) woven wire and stone or rock (dia. > 10 cm) shall be used. e. Wood and rock	(Note) This method shall be used as temporary countermeasure for disaster. However, woven-wire method shall be used as a permanent measure to save cost sometimes.