Government of the People's Republic of Bangladesh
Bangladesh Water Development Board
Water Resource Planning Organisation

NORTHEAST REGIONAL WATER MANAGEMENT PROJECT (FAP 6)

DAMPARA WATER MANAGEMENT PROJECT

FEASIBILITY STUDY
ANNEX B: AGRICULTURE
FINAL REPORT

March 1997

SNC ♦ LAVALIN International
Northwest Hydraulic Consultants

in association with

Engineering and Planning Consultants Ltd.
Bangladesh Engineering and Technological Services

Canadian International Development Agency

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COVER PHOTO: A typical village in the deeply flooded area of the Northeast Region. The earthen village platform is created to keep the houses above water during the flood season which lasts for five to seven months of the year. The platform is threatened by erosion from wave action; bamboo fencing is used as bank protection but often proves ineffective. The single *hijal* tree in front of the village is all that remains of the past lowland forest. The houses on the platform are squeezed together leaving no space for courtyards, gardens or livestock. Water surrounding the platform is used as a source of drinking water and for waste disposal by the hanging latrines. Life in these crowded villages can become very stressful especially for the women, because of the isolation during the flood season. The only form of transport from the village is by small country boats seen in the picture. The Northeast Regional Water Management Plan aims to improve the quality of life for these people.

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FLOOD ACTION PLAN

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ACRONYMS AND ABBREVIATIONS

AEZ	agroecological zone
ASP	ammonium sulphate
BADC	Bangladesh Agricultural Development Corporation
BARC	Bangladesh Agriculture Research Council
BARI	Bangladesh Agriculture Research Institute
BBS	Bangladesh Bureau of Statistics
BRRI	Bangladesh Rice Research Institute
Ca	calcium
CEC	cation exchange capacity
CERDI	Central Extension Resource Development Institute
DAE	Department of Agricultural Extension
DTW	deep tube well
DAP	diammonium phosphate
FAO	Food and Agriculture Organization
FCDI	flood control, drainage, and irrigation
FW	future with
FWO	future without
ha	hectare
HTW	hand tube well
HYV	high yielding variety
IFDC	International Fertilizer Development Centre
K	potassium
LLP	low lift pump
m	metre
MP	murate of potash
MPO	Master Plan Organisation
N	nitrogen
P	phosphorus
PET	potential evapotranspiration
S	sulphur
SOP	sulphate of potash
SRDI	Soil Resources Development Institute
SSP	single super phosphate
STW	shallow tube well
t	metric ton
TSP	triple super phosphate
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNDP	United Nations Development Programme
USDA	United States Department of Agriculture
WARPO	Water Resources Planning Organization
Zn	zinc

GLOSSARY OF TERMS

Alluvium	Mineral material (sand, silt and clays) deposited by rivers.
Aus	Pre-monsoon rice or rice grown in Kharif I season.
B. aman	Broadcast or deepwater aman rice sown in Kharif I and harvest in Kharif II or in early rabi season.
Beel	Floodplain lake, which may hold water permanently or dry up during the winter season.
Boro	Winter rice or rice grown in Rabi season.
Bundh	Earthen dam or enclosure.
C	Carbon.
Calcareous	Soil containing lime.
Char	Islets in the rivers.
Clay	Mineral particles less than 0.002 mm in diameter.
Cropping Intensity	Ratio of total cropped area to the net cultivated area.
Danta	Vegetable crop (amaranths).
Deep Soil	A soil without a layer which impedes root or water penetration within about 90 cm from the surface.
Dissected	Landscape cut into by valleys.
F0	Highlands where seasonal flooding ranges from 0 to 30 cm.
F1	Medium highlands where seasonal flooding ranges from 30 to 90 cm.
F2	Medium lowlands where the seasonal flooding ranges from 90 to 180 cm.
F3	Lowlands where seasonal flooding depth is more than 180 cm during the monsoon.
FCD	Flood control and drainage.
Floodplain	Land made by deposition of river alluvium and subject to seasonal flooding.
Friable	Easily broken between the fingers (or by ploughing) when moist.
Haor	Depression in the floodplain located between two or more rivers, which functions as a small internal drainage basin
Khal	Canal.
Kharif	The crop growing period (March to October) when the moisture supply from rainfall plus soil storage is sufficient to support unirrigated crops. The period begins on the date from which precipitation continuously exceeds 0.5 PET and ends on the date when the combination of precipitation plus assumed 100 mm of soil moisture storage after the rainy season falls below 0.5 PET.
Kharif I	Pre-monsoon season (March to June).
Kharif II	Monsoon season (July to October).
Large Farm	A farm household owning more than 3 ha of cultivated land.
Mg	Magnesium.
Medium Farm	A farm household owning 1 to 3 ha of cultivated land.
Mottled	Patches of different colour occur in the soil.
Na	Sodium.
Noncalcareous	Soil without lime.
Non-farm	A farm households owning less than 0.2 ha of cultivated land.
Ploughpan	A compact layer of soil, usually about 5 cm thick, occurs immediately below the cultivation layer in some areas.

Pre-kharif	The period which is characterized by unreliable rainfall, varying in timing, frequency and intensity from year to year, and providing only an intermittently supply of moisture for growing crops during this period. The period is considered to start on the first date after end-February when precipitation first exceeds 0.5 PET. The period ends on the date from which precipitation continuously exceeds 0.5 PET (i.e., the beginning date of kharif growing period).
Rabi	The crop growing period between the end of the humid period (when rainfall exceeds PET) and the time when 250 mm soil moisture have been exhausted by evapotranspiration (i.e., between the end of kharif humid moisture period and the end of rabi humid moisture period with 250 mm soil moisture supply).
Rabi crops	Non-rice crops grown in Rabi season (winter). These include wheat, oilseeds and vegetables.
Shallow Soil	Soil in which substratum occurs within 60-90 cm from the surface.
Small Farm	A farm household owning 0.02 to 1 ha of cultivated land.
Substratum	The layer below the soil (topsoil or subsoil) which has not been altered by soil forming process.
T. aman	Transplanted aman rice grown in Kharif II season or monsoon season
Thana	An administrative unit. Several thanas make a district.

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1. INTRODUCTION

1.1 Background

This study provides an overview analysis of the present status of agricultural production system, production constraints and potential in the Dampara Project area. This report was used by the Northeast Regional Water Management Project (NERP) for the preparation of the Dampara Water Management Project Plan.

Agriculture in the project area is subsistence oriented, due to the ever present risk of flooding. Cropping is the chief component of the present agricultural production system. Crops occupy almost the total agricultural land. Livestock forms only a small component of the agricultural production system. Most of the livestock are kept by the farm household in small numbers to meet mainly local requirements for draught power.

1.2 Objectives

The specific objectives of this study are: to provide information on the agricultural production system, to address limitations to agricultural production, to consider opportunities for agricultural improvement, to develop preliminary intervention strategies involving both physical and nonphysical measures, and to assess impacts of flood control and drainage improvement on agricultural production in the project area.

1.3 Methodology

Primary data sources for this study include land use surveys, input use monitoring, crop cut, field interviews, group discussions, meetings and seminars. A full-scale land use survey was undertaken in 1995 to determine land utilization, crop area and patterns, irrigated area and method, crop plantation and harvest time, land use intensity, flooding period and crop damage in the project area. The information was recorded in the field at a scale of 1:3,960 on *mauza* maps comprising 164 sheets. Input use and crop yield levels were determined from farm monitoring and crop cut. Information on farming characteristics, cultivation practices, agricultural extension activities, marketing and limitations to agricultural production and suggestions as to the nature of interventions which would solve current problems were obtained from field interviews, group discussion, meetings and seminars.

Secondary data sources include the Soil Resources Development Institute (SRDI), the FAO/UNDP *Land Resource Appraisal Of Bangladesh,* the Water Resources Planning Organisation (WARPO), the Bangladesh Agricultural Development Corporation (BADC), the Bangladesh Agricultural Research Institute (BARI), the Bangladesh Rice Research Institute (BRRI), the Department of Agricultural Extension (DAE), the Central Extension Resources Development Institute (CERDI), and the Bangladesh Bureau of Statistics (BBS). The views and findings of other studies have been used where applicable. The secondary sources provided information on physiography, characteristics of agroecological zone, agroclimate, land capability according to the soil properties, agriculture extension services, and previous data on crop area and production.

1.4 Outline

The report is divided into seven chapters. Chapter 2 presents a brief description of basic components of the local agroecosystem and includes the quality and limitations of the land, the soil characteristics and the agroclimate. The present crop production system and the influence of the agroecosystem on crop production are described in Chapter 3. Chapter 4 describes trends in crop production system. Chapter 5 deals with physical constraints to crop production. Opportunities for increasing crop production are described in Chapter 6; and finally impacts of flood control and drainage improvements on agricultural production are assessed in Chapter 7.

2. PHYSICAL ENDOWMENT

2.1 Land Use Patterns

The project area covers a gross area of 15,000 ha. The net cultivated area accounts for 84 percent of the project area. Land which is not available for cultivation, such as homesteads, roads, market places, rivers, channels, and so on, accounts for 16 percent. Present land use patterns in the project area are shown in Table 2.1.

Table 2.1: Present Land Use

Land Use	Area (ha)	Percent of Total Area
Net Cultivated Land	12525	83.5
Homesteads	470	3.1
Ponds	120	0.8
Agro-forestry and Homestead Plantation	810	5.4
Infrastructure	485	3.2
Channel	415	2.8
Beel	175	1.2
Total	**15000**	**100.0**

2.2 Land Classification

The use of the land in the project area is largely determined by the depth, timing, rate and duration of flooding. According to the WARPO (former Master Plan Coordination Organisation) land classification system, which is based upon depth and period of flooding (flood phase), the net cultivated area within the project area can be divided into four land types: highlands (F0), medium highlands (F1), medium lowlands (F2) and lowlands (F3).

Analysis of land elevation and 1:5 year flood levels in the project area shows that the cultivated land is predominately occupied by lowlands (F3) where flooding depth is more than 180 cm during the monsoon season. These lands constitute 46 percent of the net cultivated area (Table 2.2). About 38 percent of the net cultivated area is occupied by medium lowlands (F2), where seasonal flooding ranges from 90 to 180 cm. Medium highlands (F1), where seasonal flooding ranges from 30 to 90 cm, account for 10 percent. The remaining 6 percent of the net cultivated area is occupied by highlands (F0), where seasonal flooding ranges from 0 to 30 cm.

Table 2.2: Present Land Type on the Basis of Monsoon Flooding Depth

Land Type	Flood Depth (m)	Cultivated Area (ha)	Percent of Total Cultivated Area
F0	0.0 - 0.30	777	6.2
F1	0.30 - 0.90	1319	10.5
F2	0.90 - 1.80	4708	37.6
F3	>1.80	5721	45.7
Total		**12525**	**100.0**

2.3 Physiography

The landform unit in the project area is Lowland Floodplains (Old Brahmaputra Floodplain). Land elevations typically range between 13.0 and 6.5 m. Levees are wedge-shaped ridges formed by the deposition of sediment when flood waters overtop the river banks. These are highly developed on the outer side of river meanders and often the highest points of land on the floodplain.

2.4 Agroecological Zone

Sub-zones of two agroecological zones (AEZs) occur in the project area (Figure 1). These are sub-zone 9b of AEZ 9 (Old Brahmaputra Floodplain) and sub-zone 22b (Northern and Eastern plains and basin) of AEZ 22 (Northern and Eastern Piedmont Plains). They cover 79.7 and 20.3 percent of the project area, respectively. The AEZ 9b extends from the west to the southeast of the project area. The AEZ 22b occupies the northeast section of the project area. The sub-zones are differentiated by details of relief and flooding characteristics.

2.5 Drainage

In AEZ 9b, the highest ridge soils stand above normal flood level. However, they become wet during periods of heavy monsoon rainfall. Lower ridges and depressions are flooded seasonally. Some Areas in depressions are deeply flooded, and stay wet for most or all of the dry season. The sub-zone AEZ 22b is subject to flash floods and rainwater is retained on the surface within field. Lower levels are deeply flooded in the rainy season.

2.6 Agroclimate

Mean annual rainfall is more than 2,800 mm in the west of the project area. The rainfall increases toward the east where it exceeds 3,200 mm. The mean date when minimum temperatures start to fall below 20° C is in the beginning of November. It occurs a little earlier in the north. The mean length of the cool winter period is 50-90 days with minimum temperatures below 15° C. The project area has an average of 0.5-5 days with maximum summer temperatures above 40° C.

The mean starting date of the pre-*Kharif* transition period is around mid-March. The mean length of the period increases from east to west. The mean beginning date of the *Kharif* growing period is April 20. It increases from mid April in the east to late April in the west. The mean end date is mid-December: earlier in the west and later in the east.

The *Rabi* growing period (assuming 250 mm soil moisture supply) extends from late October to late February. In the east, the *Rabi* growing period extends beyond the starting date of the following pre-*Kharif* moisture period in more than half the years. In general, conditions are wettest in the northeast and become less wet toward the west and south.

2.7 Soil

Physical and Chemical Properties

The project has a large area of Brahmaputra sediments. Silt loams and silty clay loams predominate, especially in the highest ridge sites. Clay predominates in depressions. The AEZ 22b has the most complex relief and soil patterns. Deposits in this sub-zone range from sand to clay.

Organic matter content in the cultivated layer ranges from 1.0-1.5 percent in ridge soils to 2.0-5.0 percent in clays. It is less than 1.0 percent in recent alluvium. In clay soils, organic matter is more deeply distributed down the profile. General soil fertility level is low in AEZ 9b, and low to medium in AEZ 22b.

Topsoil is moderately acidic. The cultivated layer is usually medium to very strongly acidic: higher in permeable ridge soils and lower in depression soils and in soils puddled for transplanted rice cultivation. Lower layers are between slightly acidic and slightly alkaline, but some heavy depression clays have medium or strongly acidic subsoils. The status of phosphorus and cation exchange capacity (CEC) is medium and potassium status is low in highlands and medium in lowlands.

Moisture holding capacity of the cultivated soil is high in the deep silt loams on the ridge. It is moderate or low in more sandy or shallow ridge soils, in soils puddled for transplanted rice cultivation and especially in depression clays. The highest ridge soils are rapidly permeable. Lower ridge soils used for transplanted rice cultivation are slowly permeable, so are depression clays.

Thirteen General Soil Types occur in the project area. Predominant soil types are Noncalcareous Dark Grey Floodplain, Noncalcareous Grey Floodplain Soils and Acid Basin Clays. The other General Soil Types which occupy minor areas are Noncalcareous Alluvium, Grey Piedmont Soils, Shallow Red-Brown Terrace Soils, Deep Red-Brown Terrace Soils, Brown Mottled Terrace Soils, Deep Grey Terrace Soils, Grey Valley Soils, Noncalcareous Brown Floodplain Soils, Brown Hill Soils and Peat. A correlation between these soil types and major international soil units is provided in Table 2.3. The physical and chemical properties of these soil types are given in Table 2.4.

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Table 2.3: Correlation between General Soil Types of Bangladesh and International Soil Units

General Soil Type	FAO-UNESCO Soil Unit	USDA Soil Taxonomy
Noncalcareous Alluvium	Mainly Eutric Fluvisol, Some Cambic Arenosol	Mainly Fluvaquent; Some Hydraquent, Psammaquent, Haplaquent, Ustipsamment and Udifluvent
Noncalcareous Brown Floodplain	Mainly Eutric Gleysol; Some Dystric, Gleyic and Eutric Cambisol; Dystric Gleysol; Cambic Arenosol; and Haplic Alisol	Mainly Eutrochrept; Some Ustochrept, Ustipsamment, Dystrochrept and Haplustult
Noncalcareous Grey Floodplain	Mainly Eutric Gleysol, Some Dystric Gleysol	Haplaquept
Noncalcareous Dark Grey Floodplain	Mainly Eutric Gleysol; Some Dystric, Mollic and Umbric Gleysol; and Umbric Cambisol	Mainly Haplaquept; Some Fluvaquent, Eutrochrept and Haplaquoll
Acid Basin Clays	Eutric Gleysol, Dystric and Mollic Gleysol	Mainly Haplaquept; Some Fluvaquent and Humaquept
Grey Piedmont	Eutric, Dystric and Albic Gleysol	Haplaquept
Shallow Red-Brown Terrace	Calcaric, Dystric, Regic and Eutric Gleysol; and Gleyic and Haplic Alisol	Ustochrept, Haplaquept, Haplaquent, Haplustult and Paleustult
Deep Grey Terrace	Albic Gleysol, Eutric Planosol	Albaquept, Haplaquent and Haplaquept
Deep Red-Brown Terrace	Ferric Alisol, Dystric Gleysol	Paleustult, Haplustalf, Dystrochrept
Brown Mottled Terrace	Ferric Luvisol, Gleyic Alisol	Paleustult
Grey Valley	Albic and Eutric Gleysol	Albaquept and Haplaquept
Brown Hills	Dystric Cambisol, Ferric Alisol, Dystric Leptosol, Haplic Luvisol	Haplustult, Ustochrept, Dystrochrept, Eutrochrept, Ustorthent, Haplaquept
Peat	Dystric Histosol	Histosol, Haplaquept, Madisaprist

Source: Agroecological Regions of Bangladesh, UNDP/FAO, 1988.

Table 2.4: Physical and Chemical Properties of General Soil Types

General Soil Type	Tex-ture	pH	C%	Top-soil N%	P_2O_5 ppm	S ppm	Zn ppm	Exchangeable Cations (me/100g)				
								CEC	Ca	Mg	K	Na
Noncalcareous Alluvium	SL	6.5	0.4	0.05	72	1.1	2.1	7.36	3.13	1.10	0.14	0.11
Noncalcareous Brown FP	SL	5.3	0.6	0.06	54	13.8	1.9	6.59	1.52	0.44	0.21	0.35
Noncalcareous Dark Grey FP	SiCL	5.2	2.3	0.22	36	45.7	1.0	15.30	10.30	2.19	0.32	0.37
Acid Basin Clays	C	4.5	2.4	0.23	32	32.2	6.4	31.90	8.52	3.39	0.51	0.20
Grey Piedmont	L	5.0	1.2	0.14	77	4.1	1.7	4.49	1.91	0.37	0.13	0.05
Shallow Red-Brown Terrace	SiCL	4.9	1.3	0.11	19	4.5	1.4	9.67	3.72	1.36	0.25	0.40
Grey Valley	SiL	5.8	1.2	0.13	54	1.0	2.6	7.36	4.44	0.99	0.19	0.75
Deep Red-Brown Terrace	SL	5.6	0.8	0.08	16	5.8	1.4	8.04	1.89	0.51	0.14	0.23
Brown Mottled Terrace	L	5.2	0.8	0.08	14	5.2	2.3	11.40	3.15	0.85	0.20	0.31
Brown Hills	SL	4.4	0.8	0.09	30	1.8	1.2	9.29	0.52	0.21	0.16	0.02
Peat	SiC	6.2	2.5	0.22	45	283.0	4.1	31.20	16.6	3.52	0.30	1.00

SL: Sandy Loam, C: Clay, L: Loam, SiCL: Silty Clay Loam, SiL: Silt Loam, SiC: Silty Clay.
Source: Soil Of Bangladesh, CERDI, 1983.

2.8 Soil Association

The soil associations presented below are from the SRDI's Reconnaissance Soil Survey Report of Netrokona and Sadar North subdivisions, 1968. The project area includes six soil associations (Figure 2). The extent of each soil association and the name of the series in it are provided in the following table.

Table 2.5: Soil Association and Series

Name of Soil Association	AEZ No.	Area (sqkm)	Percent of Project Area	Name of Series (Percent of Soil Association)
Lokdeo-Silmandi-Ghatail	9b	44.0	29.3	Lokdeo (30), Silmandi (25), Ghatail (15), Sonatala (10), Kendua (5), Homestead (15)
Ghatail-Lokdeo	9b 22b	39.4	26.3	Ghatail (60), Lokdeo (20), Balina (5), Sonatala (5), Kendua (5), *Beels* (1), Homestead (4)
Lokdeo-Ghatail (medium lowland phase)	9b 22b	38.5	25.7	Lokdeo (40), Ghatail (20), Sonatala (5), Kendua (5), Silmandi (5), Balina (5), Nandail (5), Susang (5), Homestead (10)
Susang-Chinakuri (normal phase)	9b 22b	19.7	13.1	Susang (75), Chinakuri (15), Kangsha (5), *Beels* (5)
Ghatail-Mohanganj (normal phase)	9b	4.4	2.9	Ghatail (60), Mohanganj (20), Lokdeo (5), Kendua (5), Barhatta (5), *Beels* (1), Homestead (4)
Silmandi-Sherpur	9b	4.0	2.7	Silmandi (30), Sherpur (20), Sonatala (10), Nakla (10), Phulpur (5), Nandail (5), Tarakanda (5), Homestead (15)

Source: SRDI, 1968.

2.9 Soil Series

Sixteen soil series have been identified in the project area. The description of these soil series are as follows.

Balina Series
This series is comprised of seasonally flooded, very poorly drained, fine textured soils developed in Brahmaputra deposits. These soils occur throughout the oldest Brahmaputra floodplain. They occupy about 3 percent of the project area. The colour ranges from dark grey to very dark grey. The topsoil texture is usually silty clay to clay. The subsoil is usually sticky and plastic. The General Soil Type of this series is Noncalcareous Dark Grey Floodplain. Seasonal flooding, rapid rise of flood water, poorly drained soils and wetness during most of the dry season are the major limitations for cropping in these soils.

Barhatta Series

This series includes seasonally flooded and poorly drained soils. These soils occur in few areas. They are found in depressions of the oldest Brahmaputra floodplain. The topsoil colour is usually dark grey to black and, occasionally, grey. The texture of the topsoil is usually clay. The structure of the subsoil is moderate to strong coarse to very coarse prismatic. The consistence is friable to firm. Acid Basin Clay is the General Soil Type. Seasonal flooding and very poorly drained soils are the agricultural limitations.

Chinakuri Series

This series comprises seasonally deeply flooded, very poorly drained, fine textured soils developed in relatively young Piedmont alluvium. These soils cover about 2 percent of the project area. The topsoil colour is neutral grey to dark grey. The texture is clay. The topsoil underlain by a neutral grey, clay subsoil. Mottles are common: comprising strong brown to yellowish red and, occasionally, yellowish brown colours. A buried topsoil is often found between 45 and 125 cm. General Soil Type is Acid Basin Clay. Seasonal deep flooding, sudden rises in flood water and wetness for most of the dry season are the limitations in cropping in these soils.

Ghatail Series

This series consists of seasonally, deeply flooded, poorly drained soils developed in fine textured alluvium on the oldest Brahmaputra floodplain. These soils occur extensively, occupying 27 percent of the project area. They occupy middle to lower slopes of ridges. The topsoil colour is grey to dark grey, and texture ranges from silty clay loam to silty clay. In the subsoil, the oxidation colour is olive-brown to yellowish brown, rarely dark yellowish brown. Texture of the subsoil is clay to silty clay. General Soil Type is Noncalcareous Dark Grey Floodplain. The soils in this series have been grouped into medium highland phase, medium lowland phase and lowland phase. They occupy 50 percent, 48 percent and 3 percent of the soils in the series, respectively. The medium highland phase is flooded up to 1 m for about one to five months in the monsoon and becomes draughty in the dry season. The medium lowland and lowland phases are flooded more than one metre for more than four months. They are wet early and draughty late in the dry season.

Kangsha Series

This series is comprised of intermittently and seasonally flooded, poorly drained, moderately textured soils developed in piedmont alluvium. These soils occur mainly in small areas on upper to lower slopes of very gently undulating ridges. They occupy less than 1 percent of the project area. The topsoil is grey to olive grey in colour. It ranges from silt loam to clay loam in texture. The subsoil is yellowish brown, strong brown and yellowish red, rarely olive-brown or olive in colour. The structure of the subsoil is mostly strong coarse prismatic and or moderate to strong medium to coarse block. Grey Piedmont is the General Soil Type. Flooding and rapid rise in flood level cause damage or loss of rice in the pre-monsoon and monsoon seasons. Droughtiness late in the dry season is also a limitation to crop production in these soils.

Kendua Series

This series comprises intermittently and seasonally flooded, imperfectly to poorly drained, medium textured soils developed in the oldest Brahmaputra floodplain. These soils occur on summits and upper slopes of ridges. They cover 4 percent of the project area. The topsoil ranges in colour from grey or dark grey to olive grey. It is silty loam to silty clay loam in texture. In the subsoil the oxidation colour ranges from olive to yellowish brown. The subsoil texture ranges from silt loam to loam. General Soil Type is Noncalcareous Dark Grey Floodplain. The soils are intermittently flooded between the field *bundhs* or seasonally flooded up to 1 m for one to five months. They usually remain moist for most or all of the dry season. Droughtiness late in the dry season and wetness or annual flooding in the monsoon season are the limitations to cropping. In some areas rapid rise of flood levels causes damage or loss of rice in the pre-monsoon season.

Lokdeo Series

This series consists of intermittently and seasonally flooded, poorly drained, mainly moderately fine textured soils developed in alluvium of the oldest Brahmaputra floodplain. These soils occur widely on upper to lower slopes of very gently undulating ridges. They occupy almost one-fourth (24.5 percent) of the project area. The topsoil is usually grey to olive-grey, occasionally grayish brown to olive. It ranges from loam to silty clay loam in texture. In the subsoil the oxidation colour is yellowish brown to olive-brown, occasionally dark yellowish brown or light olive-brown. The subsoil is clay loam to silty clay loam in texture and usually friable to slightly firm in consistence. Noncalcareous Dark Grey Floodplain is the General Soil Type. Droughtiness in the later part of the dry season and wetness or annual flooding in the monsoon season are the limitations in cropping. Rapid rise of flood level causes damage or loss of rice in the pre-monsoon season in some areas.

Mohanganj Series

This series includes seasonally flooded, very poorly drained, unripened, mucky clay soils with low bearing capacity. These soils occupy less than 1 percent of the project area. The thickness of the mucky layers ranges from 60 to 120 cm. The sub-surface is generally mucky clay and occasionally mucky clay loam. Acid Basin Clay is the General Soil Type. These soils are flooded up to 1 to 3 m in the monsoon season. Seasonal flooding, rapid rise of flood water, wetness for most of the dry season and low bearing capacity provide severe limitations for crop production. Slow drainage in some of these soils also prevents cultivation of *boro* rice in the winter season.

Nakla Series

This series is comprised of moderately well drained, very weakly to moderately structured soils developed in old Brahmaputra alluvium. These soils occur in Phulpur *thana*. They occupy less than 1 percent of the project area. Topsoil colour is usually grey to light grey, occasionally dark yellowish brown. The subsoil colour is olive brown. The texture of the topsoil and subsoil is loam to sandy loam. General Soil Type of this series is Noncalcareous Brown Floodplain. These soils occupy summits and upper slopes of very gently undulating ridge complexes. They are above normal flood level. Droughtiness in the dry season and low fertility are the limitations to cropping.

Nandail Series

This series comprises seasonally flooded, poorly drained, moderately fine to fine textured soils developed in Old Brahmaputra alluvium. These soils occupy a small area (1.4 percent) in inter-ridge depressions. The topsoil colour is grey to dark grey, occasionally light brownish grey to grayish brown. Texture of the topsoil ranges from loam to silty clay. In the subsoil the oxidation colour ranges from dark yellowish brown to olive brown. The subsoil texture is silty clay to silt loam. Noncalcareous Grey Floodplain is the General Soil Type. These soils are seasonally flooded up to 1.5 m for more than four months and become draughty in the middle or later part of the dry season. Seasonal flooding, accompanied by rapid rise of flood water causing loss of or damage to crops in the pre-monsoon and monsoon season and droughtiness in the dry season are the limitations for cropping.

Phulpur Series

This series consists of well to moderately well drained soils developed in old Brahmaputra alluvium. These soils occupy summits of very gently undulating, relatively high ridge complexes. They occur in few areas in association with Nakla and Sherpur series. The topsoil colour ranges from pale olive to brown and texture ranges from sandy loam to loamy sand. The moist subsoil colour is pale brown to pale yellow: occasionally grayish brown or brown. The texture of the subsoil is loamy sand, rarely sand. General Soil Type of this series is Noncalcareous Alluvium. These soils are above normal flood levels. Droughtiness in the dry season and coarse texture are the limitations to cropping.

Sherpur Series

This series includes intermittently flooded, moderately well to imperfectly drained, medium textured soils developed in old Brahmaputra alluvium. These soils occupy summits to middle slopes of very gently undulating ridge complexes. They occur widely in Phulpur *thana*. Less than 1 percent of the project area is occupied by these soils. The moist colour of the topsoil ranges from light grey to olive brown. The subsoil texture is usually silt loam, rarely silty clay loam. General Soil Type of this series is Noncalcareous Brown Floodplain. Wetness in the monsoon season is a limitation to cropping. There is slight droughtiness in the dry season.

Silmandi Series

This series consists of intermittently and seasonally flooded, poorly to imperfectly drained, moderately fine textured soils developed in old and oldest Brahmaputra floodplain. These soils occupy about one-tenth (9.5 percent) of the project area. They occupy the middle to lower slopes of very gently undulating ridges and ridge complexes. The topsoil ranges from grey to olive-grey in colour, and loam to silty clay loam in texture. In the subsoil, the oxidation colour is dark yellowish brown to olive-brown, rarely brown or strong brown. The texture of the subsoil is silty clay loam. General Soil Type is Noncalcareous Grey Floodplain. The soils in this series have been grouped into highland phase and medium highland phase. The highland phase is intermittently and the medium highland phase is seasonally shallowly flooded for two to five months. They occupy 78 percent and 22 percent of the soils in the series, respectively. Wetness or annual flooding in the monsoon and droughtiness in the later part of the dry season are the limitations for cropping. Occasionally, a rapid rise of flood water causes damage to crops in some areas.

Sonatala Series

This series comprises intermittently and seasonally flooded, imperfectly to poorly drained, medium textured ridge soils developed in Brahmaputra alluvium. Generally, these soils occur on summits to upper slopes of very gently undulating ridges throughout the project area. In the western part, they occupy broad in filled channels. About 7 percent of the project area is occupied by these soils. The moist matrix colour of the topsoil is usually grey to light olive-grey, sometimes olive-grey or olive. The texture of the topsoil is silt loam. In the subsoil, the oxidation colour is generally dark yellowish brown to olive-brown, occasionally strong brown or dark brown. The subsoil texture is silt loam, rarely loam or very fine sandy loam. General Soil Type is Noncalcareous Grey Floodplain. Droughtiness late in the dry season and intermittently or seasonal shallow to moderately deep flooding provide limitations to cropping. Rapid rise of flood water causes damage to pre-monsoon crops.

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Susang Series
This series includes seasonally flooded, poorly drained soils developed in fine textured, relatively young piedmont alluvium. These soils occupy about 10 percent of the project area. They occupy the upper to lower slopes of ridges, depression margins and depressions. The colour of the topsoil is usually grey, occasionally olive-grey or dark grey. The topsoil texture is clay, rarely clay loam. The subsoil colour is yellowish brown, with strong brown and yellowish red mottles. The subsoil is clay in texture. General Soil Type is Acid Basin Clay. The soils include: medium highland phase (1 percent), medium lowland phase (40 percent), lowland phase (20 percent), irregular relief phase (13 percent), smooth relief phase (12 percent), and irrigated phase (14 percent). Seasonal flooding, droughtiness in the dry season, heavy consistence, rapid rise in flood water and wetness early in the dry season are the limitations to cropping. Irregular relief limits the irrigation in some areas.

Tarakanda Series
This series consists of intermittently and seasonally flooded, imperfectly to poorly drained, coarse textured soils developed in old Brahmaputra alluvium. These soils occur patchily in sub-recent sandy deposits in minor areas. The topsoil is generally grey to light olive-grey, occasionally dark grey. It is underlain by grey to olive grey, usually finely mottled yellowish brown to olive-brown. The topsoil is loose to very friable, fine sandy loam to fine sand. The sub-surface horizon is generally structureless, rarely very coarse prismatic. They occur on summits to lower slopes of very gently undulating ridges and ridge complexes. They are also found in depressions, shallow inter-ridge depressions and in filled channels. Noncalcareous Alluvium is the General Soil Type. Droughtiness in the dry season, wetness or seasonal flooding, and low fertility level are the limitations to cropping.

2.10 Land Capability

Six land capability associations are found in the project area (Figure 3). The classification is based on grouping of soils of an area to show their relative suitability for the sustained production of common crops adapted to the environment. The area occupied by each land capability class is provided in Table 2.6.

Land capability ranges from mainly good to very good with some moderate agricultural lands in more than half of the project area. Soils in this area have moderate to severe limitations for crop production in the pre-monsoon and monsoon season. The soils occur mainly in AEZ 9b. These soils are level to very gently undulating and most of them are easy to cultivate. They are shallowly to moderately deeply flooded and imperfectly to poorly drained. Improvement of drainage and dry season irrigation in these lands can produce two to three crops per year.

About one-fourth of the project area is occupied by moderate to good agricultural lands. Soils in these lands have moderate to severe limitations for crop production in the pre-monsoon and monsoon season and moderate limitations in the dry season. These lands occur mainly in AEZ 9b. They are shallowly to moderately deeply flooded lands and consist of poorly drained soils with heavy consistence. Flood protection, drainage improvement and irrigation facilities are required to increase agricultural production in these lands.

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Table 2.6: Land Capability Class

Class	Area (sqkm)	Percent of Project Area
Mainly good with very good agricultural land Poorly drained highland and seasonally shallowly flooded	39.7	26.5
Mainly good with some moderate and very good Seasonally shallowly and moderately deeply flooded	40.3	26.9
Mainly good with some moderate land Moderately well to poorly drained highland	6.6	4.4
Mainly moderate with some good land Basins with flood hazard	39.3	26.2
Mainly moderate with some poor land Basins with flood hazard (slow draining and irregular relief)	19.5	13.0
Mainly moderate land Predominantly moderate	4.6	3.1

Source: SRDI, 1968.

Exclusively moderate agricultural lands occur in a small area. Soils in these lands have severe limitations during monsoon and post-monsoon seasons, and moderate limitations in the dry season. These lands are found in AEZ 9b. They include seasonally moderately deep flooding soils accompanied by rapid rise in flood water level and wetness early in the dry season. Flood protection and irrigation facilities can increase productivity of these lands.

Moderate to poor agricultural lands occupy more than one-tenth of the project area. Soils in these land shave severe limitations for crop production almost throughout the year. The limitations are due to seasonal moderately deep to deeply flooding combined with slow drainage in the dry season, severe risk of crop damage or loss by rapid rise of flood water. They are found in AEZ 22b. Flood protection is the main requirement for increasing agricultural production in these lands.

2.11 Crop Suitability

The soil series identified in the project area have been rated according to the their suitability for different crop production (Table 2.7a & 2.7b). The crop suitability range from class 1 to class 4. Each class indicates the suitability of individual crop for a soil series. The description of the classes are as follows.

Class 1: Well suited
Physical and hydrological characteristics of these soils are favourable to grow at least one crop in a year. Fertility level is moderate to high. Crops grow well and produce moderate to high yield with traditional management. High crop yield levels can be achieved with improved crop management.

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Class 2: Moderately suited
Physical and hydrological characteristics of these soils are somewhat unfavourable to grow crop. Soil fertility level is moderate to low. Crops produce poor to moderate yield with traditional management. Occasionally, crops are subject to damage or failure by flooding. Drainage improvement and irrigation management is required to achieve high yield levels.

Class 3: Poorly suited
Physical and hydrological characteristics of these soils are unfavourable to grow crop. Soil fertility level is low and difficult to improve. Crops produce poor yield with traditional management. Crops are usually subject to damage or failure by flooding. Flood control and intensive management practices could produce moderate to high yield.

Class 4: Not suited
Physical and hydrological characteristics severely limit crop production. Crops produce very low yield with traditional management. Flood protection, intensive and special management could produce moderate to good yield.

According to the crop suitability rating in the project area, the *boro* is well suited in all the major soil series. The t. *aman* is well suited in Lokdeo, Kangsha and Sherpur series which cover less than one-third of the cultivated area. This crop requires drainage improvement in more than two-thirds of the cultivated area to produce high yield. Drainage improvement can also contribute to increase pulse, oilseeds, vegetables and other non-rice crops production in Ghatail, Susang and Balina which are the major soil series in the project area.

2a

Table 2.7: Crop Suitability Rating
a. Unirrigated Crops

Soil Series	Kharif Crops				Rabi Crops					Sugar-cane
	B. aus	T. aman	B. aman	Jute	Wheat Maize	Millet Sorghum	Pulse Oilseed	Vege-table	Gr. nut	
Balina	4	4	3	4	4	4	4	4	4	4
Barhatta	4	4	2	4	4	4	4	4	4	4
Chinakuri	4	4	3	4	4	4	4	4	4	4
Ghatail	3	4	2	3	4	3	3	4	4	3
Kangsha	2	1	*	2	3	2	2	2	2	3
Kendua	2	2	*	2	3	1	1	2	1	4
Lokdeo	1	1	*	1	3	1	1	2	1	3
Mohanganj	4	4	3	4	4	4	4	4	4	4
Nakla	2	3	*	2	3	2	2	2	1	2
Nandail	3	4	2	3	4	2	2	4	4	4
Phulpur	3	4	4	3	3	2	3	3	2	3
Sherpur	1	1	*	1	3	1	1	2	1	2
Silmandi	2	2	*	2	3	1	1	2	1	4
Sonatala	2	2	*	2	3	1	1	2	1	4
Susang	4	4	2	4	4	4	3	4	4	4
Tarakanda	2	2	*	2	3	2	2	2	2	4

*: Soils are more suitable for t. aman crops.
Source: SRDI.

Table 2.7: Crop Suitability Rating
b. Irrigated Crops

Soil Series	Irrigated Kharif Crops					Irrigate Rabi Crops						Irrigated
	B. aus	T. aus	T. aman	B. aman	Jute	Boro	Wheat Maize	Millet Sorghum	Pulse Oilseed	Vege-table	Gr.nut	Sugar-cane
Balina	4	4	4	3	4	1	4	4	4	4	4	4
Barhatta	4	4	4	2	4	1	4	4	4	4	4	4
Chinakuri	4	4	4	3	4	1	4	4	4	4	4	4
Ghatail	3	4	4	2	3	1	4	4	4	4	4	3
Kangsha	1	2	1	*	1	1	1	1	1	1	1	3
Kendua	2	3	2	*	2	2	1	1	1	1	1	4
Lokdeo	1	2	1	*	1	1	1	1	1	1	1	3
Mohanganj	4	4	4	3	4	1	4	4	4	4	4	4
Nakla	4	3	3	*	1	3	2	1	1	1	1	2
Nandail	3	4	4	2	3	1	4	2	2	4	4	4
Phulpur	2	4	4	4	2	4	3	2	2	2	2	3
Sherpur	1	3	2	*	1	3	1	1	1	1	1	1
Silmandi	2	3	2	*	2	1	1	1	1	1	1	4
Sonatala	2	3	2	*	2	2	1	1	1	1	1	4
Susang	4	4	4	2	4	1	4	3	4	4	4	4
Tarakanda	1	2	2	*	1	3	2	2	2	2	2	3

*: Soils are more suitable for t. aman crops.

Source: SRDI.

3. CROP PRODUCTION SYSTEM

3.1 Crop Season

Temperature in the project area is suitable for cultivation and growth of crops throughout the year. The main parameter determining the growth of crops is soil moisture supply. Rainfall and flooding are the natural sources of soil moisture; these are supplemented by irrigation.

Variation in agroclimatic parameters during the year has led to the division of the crop year into two distinct crop seasons: *Kharif* and *Rabi* (Table 3.1). The *Kharif* season starts at the end of March and continues until the end of October. The *Rabi* season starts in late October and ends in March.

Table 3.1: Area of Major Crops

Crop Season	Crop	Area (ha)
Kharif	*aus*	1534.8
	B. *aman*	83.5
	T. *aman*	10957.1
	Jute	21.2
	Other*	20.0
	Total	**12616.6**
Rabi	*boro*	10783.3
	Wheat	163.5
	Oilseeds	666.4
	Other*	193.9
	Total	**11807.1**

*: Vegetables, spices, sugar cane etc.
Source: Land use Survey; NERP, 1994/95.

During *Kharif* season crops occupy 51.7 percent of the total cropped area. This crop season is further divided into *Kharif* I (end of March to June) and *Kharif* II (July to October) depending on adaptability and culture of crops. Unreliable rainfall, high temperature and evaporation, drought at the planting time, and pre-monsoon flash floods are the characteristics of *Kharif* I. Major crops grown during the *Kharif* I is *aus* rice. The other crops grown in this season are photosensitive deepwater or b. *aman*, jute, summer vegetables and chili. The *boro* rice grown in the *rabi* season is also harvested in *Kharif* 1 season. The project area is subject to shallowly to moderately deep flooding, early floods and rapid rises of flood-levels in *Kharif I* following heavy rainfalls in the northern Meghalaya Hills. Early floods and the rapid rise of water are the major limiting factors to crop production during *Kharif* I. Early floods damage mature *boro*, and young plants of *aus*.

Kharif II is characterised by high humidity, heavy rainfall and monsoon floods. Crop production in this season is mainly limited by flooding and late drainage of flood water. The major crop grown in the *Kharif* II is t. *aman*. Deepwater *aman* also continues to grow through the season. Both are photosensitive crops which flower with the approach of short day length. During the *Kharif* II, flooding damages standing crops and transplantation is delayed resulting in reduction of crop production.

The *Rabi* season is characterised by low rainfall and humidity, high solar radiation and evapotranspiration rate, low temperature, and wide variation in day and night temperature. The crop environment during the season is very favourable for higher yields. However, crop production is mainly governed by the availability of residual soil moisture or irrigation water. Delay in sowing or planting due to late drainage of depressions, inadequate residual soil moisture and low-moisture holding capacity of soils are the limitations to crop production in the *Rabi* season. In this crop season, *boro* rice is extensively cultivated on vast areas. Local *boro* is cultivated in the relatively lower parts, and improved local *boro* or HYV *boro* is cultivated in the area where drainage is better. The other crops grown in this season are wheat, mustard/rape, vegetables, and spices. The *Rabi* season is well suited for diversification of crops.

3.2 Crops

Rice

The land-use survey confirmed that rice dominates crop farming, accounting for 95.6 percent of the total cropped area (Table 3.2). It is grown in a multitude of environments, representing five ecosystems. These are rain-fed upland (b. *aus*), rain-fed or partially irrigated (t. *aus*), deepwater (b. *aman*), rain-fed lowland (t. *aman*) and irrigated (*boro*).

T. *aman* is the major crop in terms of area under rice. The crop is grown in the monsoon season and covers 44.9 percent of the total cropped area. *Boro* or winter rice occupies 44.1 percent of the total cropped area, and *aus* or pre-monsoon rice occupies 6.3 percent. Deepwater *aman,* which is sown in the pre-monsoon season and harvested with t. *aman*, accounts for 0.3 percent of the total cropped area.

Table 3.2: Distribution of the Total Cropped Area

Crop	Total Cropped Area (ha)	Percent of Total Cropped Area
Rice	23359	95.6
Wheat	164	0.7
Jute	21	0.1
Oilseed	666	2.7
Other*	214	0.9
Total Cropped Area	24424	100.0

*Vegetables, spices, sugar cane, etc.
Source: Land survey; NERP, 1994/95

About 50.5 percent of the total rice area is under local varieties. The HYVs cover about 49.5 percent of the total rice area, and are mainly cultivated in the *boro* season. The HYVs account for 72.9 percent of the total area under *boro* rice, 32.3 percent of the total area under t. *aman* rice and 10.6 percent under *aus* rice.

Non-rice

Rape and mustard are the major non-rice crops. The crop accounts for 2.7 percent of the total cropped area. The other major non-rice crops, such as wheat, occupy 0.9 percent of the total cropped area, jute 0.1 percent, and vegetables and spices 0.9 percent. A small area is used for the production of other non-rice crops.

3.3 Crop Patterns

Crop patterns in the Basin differ from farm to farm. They are not determined only by physical factors (topography in relation to flooding, flooding characteristics, availability of moisture and irrigation water, length of the growing season, availability of inputs, etc.). The biological factors (growth duration of crops, varietal characteristics, etc.) and socioeconomic factors (financial resources, availability of credit, ratio of input and output of the produce etc.) are also important. Farmers adjust crop patterns continuously, with the changes mainly in physical and socioeconomic conditions. The present crop patterns are given in Tables 3.3. These data are based on information which was obtained from land use surveys (Figure 4). Major crop area by land type are given in Tables 3.4. It was determined by the flood depths on the cultivated land in the monsoon season.

Transplanted *aman* production in F2 and F3 lands is an important characteristic of the crop patterns practised in the project area. This rice is usually grown in F0, F1 and F2 lands. As shown in Table 3.4, t. *aman* crops occupy 94 percent of the F2 land and 79 percent of the F3 land. Early flooding, rapid rise of flood water, inundation with large volume of water, quick drainage of lands and recurrence of flood are the characteristics of these lands. With the drainage of flood water the F2 and F3 lands become almost flood free. This enables farmers to transplant *aman* crops in these lands. However, the yield is decreased when early flash floods delay transplantation and the crops are almost completely damaged when late floods submerge fields.

Aus or jute followed by early wheat or mustard are the main crops on high ridges (F0) with permeable soils. On impermeable soils in highland (F0) and medium highland (F1), *aus* or jute is grown in the pre-monsoon season and t. *aman* in the monsoon season. T. *aman* is followed partly by *Rabi* crops in some areas.

HYV *boro* followed by HYV t. *aman* is practised on the land where irrigation is available in the dry season. On medium lowland (F2) and lowland (F3) depressions mainly HYV *boro* is grown followed by local t. *aman*. Rape or mustard is cultivated immediately after the harvest of t. *aman*, followed by *boro* on mainly double cropped medium highlands (F1) and medium lowlands (F2). Present crop calendar is provided in Figure 5.

3.4 Intensity of Land Use

Of the net cultivated area, 10.4 percent is single cropped, 84.3 percent is double cropped, and 5.4 percent is triple cropped. A small area remains fallow each year. Cropping intensity or ratio of the total cropped area to the net cultivated area is 1.95. In single cropped areas local/improved *local boro* is the major crop followed by HYV *boro* and local t. *aman* (Figure 4). Local/HYV t. *aman*-HYV *boro*, local t. *aman*-local/improved local *boro*, local *aus*-local/HYV t. *aman*, and local *aus-Rabi* crops are the major crop patterns practised in double cropped areas. The local/HYV t. *aman*-rape/mustard-HYV *boro* and b. *aus* or jute-t. *aman-Rabi* are the main crop patterns in triple cropped areas.

Table 3.3: Present Crop Patterns by Land Type (ha)

Crop Pattern	F0	F1	F2	F3	Total
Mixed B. Aus and B. Aman	-	-	83.5	-	83.5
B. Aus-Rabi	42.1	48.4	81.8	94.5	266.8
B. Aus-HYV T. Aman	25.0	91.5	122.6	30.5	269.6
B.Aus-Local T. Aman	21.4	150.3	145.2	60.0	376.9
B. Aus-Local T. Aman-Rabi	4.7	44.8	5.7	1.5	56.7
B.Aus-HYV T. Aman-Rabi	80.6	21.5	12.6	-	114.7
Local T. Aus-Local T. Aman	148.6	-	-	-	148.6
Local T. Aus-Local T. Aman-Rabi	18.8	5.6	23.0	4.8	52.2
Local T. Aus-HYV T. Aman-Rabi	-	-	2.7	-	2.7
HYV T. Aus-Local T. Aman-Rabi	-	10.3	26.1	17.9	54.3
HYV T. Aus-HYV T. Aman-Rabi	9.7	17.3	48.9	32.9	108.8
Jute-Local T. Aman-Oilseed	2.1	7.9	-	-	10.0
Jute-Fallow	-	-	9.9	1.3	11.2
HYV Aman-Fallow	-	-	3.4	-	3.4
Local T. Aman-Fallow	1.3	20.4	12.4	43.2	77.3
Local T. Aman-Rabi	40.6	5.5	27.4	-	73.5
Loc T. Aman-Oilseed-Local/Improved Local Boro	0.7	3.9	13.3	2.9	20.8
Local T. Aman-Oilseed-HYV Boro	5.6	47.3	25.9	11.4	90.2
HYV T. Aman-Oilseed-HYV Boro	1.9	45.8	103.1	9.2	160.0
HYV T. Aman-Oilseed-Local/Improved Local Boro	-	-	2.2	-	2.2
HYV T. Aman-HYV Boro	359.7	352.3	1057.2	924.0	2693.2
HYV T. Aman-Loc/Improved Loc Boro	-	-	107.5	80.0	187.5
Local T. Aman-HYV Boro	8.0	262.5	1700.3	2701.8	4672.6
Local T. Aman-Loc/Improved Loc Boro	-	170.1	986.0	625.8	1781.9
HYV Boro-Fallow	-	6.7	1.9	231.7	240.3
Local/Improved Local Boro-Fallow	4.5	4.4	103.3	822.4	934.6
Vegetables	-	1.8	2.3	25.4	29.5
Sugarcane	-	-	-	-	0.4
Fallow	1.4	-	-	-	1.4
Total	**776.7**	**1318.7**	**4708.2**	**5721.2**	**12524.8**

Table 3.4: Distribution of Major Crops Area by Land Types (ha)

Crop	F0	F1	F2	F3	Total
B. *aus*	173.8	356.5	451.4	186.5	1168.2
Local T. *aus*	167.4	5.6	25.7	4.8	203.5
HYV T. *aus*	9.7	27.6	75	50.8	163.1
B. *aman*	-	-	83.5	-	83.5
Local T. *aman*	251.8	728.6	2965.3	3469.3	7415.0
HYV T. *aman*	476.9	528.4	1460.2	1076.6	3542.1
Local/Improved Loc *boro*	5.2	178.4	1212.3	1531.1	2927
HYV *boro*	375.2	714.6	2888.4	3878.1	7856.3
Wheat	50.8	55.4	53.5	3.8	163.5
Oilseeds	144.3	170.4	234.9	116.8	666.4
Jute	2.1	7.9	9.9	1.3	21.2
Vegetables and Spices	11.7	34.3	87.6	79.9	213.5
Sugarcane		0.4			0.4
Total Cropped Area	1668.9	2812.0	9561.0	10401.6	24423.7
Net Cultivated Area	777.0	1319.0	4708.0	5721.0	12525.0
Cropping Intensity	2.15	2.13	2.03	1.82	1.95

Source: Land use survey, NERP, 1994/95; and land elevation and 1:5 year flood levels analysis, NERP.

3.5 Crop Cultivation Practices

Farmers practice sole-stand cropping for the major crops, but the system of mixed cropping is preferred for vegetable cultivation. Agricultural production technology is almost exclusively based on manual labour, with the country plough, ladder, rake, hoe and sickle the most important and sometimes the only agricultural tools. The exceptions to this are the installation of tubewells (STW, DTW and HTW) for irrigation and employment of power sprayers to treat crops against diseases and insects. Although modern varieties exist for many crops, their use is not very widespread. Wheat is the only exception. The cultivation practices of major crops in the project area are described as follows.

Rice

In Bangladesh, rice is not merely a food - it is the lifeline of the Bangladeshi people. There are hundreds of different ways of cooking and using rice, and no part of the plant is wasted. Rice bran is used as livestock feed and husks as fuel wood. Farmers use rice straw as fodder, fertiliser and thatch for houses. Rice is a measure of wealth and a major commodity, traded for other daily necessities. Therefore, the major cropping patterns in each agroecological environment are rice-based and almost all segments of the net cultivated land in the project area are cropped with at least one rice crop in a year. The crop is grown either solely or in rotation with dryland crops. Following are the cultivation practices of rice in different seasons in the project area.

Aus: The *aus* rice includes photoperiod-insensitive varieties sown in the pre-monsoon season and harvested in the early monsoon season. The crop is grown on both flooded and non-flooded lands. It is mainly broadcast as a dryland crop but is also transplanted. The varieties grown in the project area include mainly local varieties. Land preparation for dryland cultivation of *aus* is accomplished through three to five ploughings, mostly by country plough, followed by laddering. Very little or no basal fertilisers are applied before the final ploughing except in HYV fields where moderate doses of fertilisers are applied. Seeds are broadcast and covered by soil for dryland cultivation. Under wetland cultivation, land is puddled by alternate applications of water and ploughing. Three- to four-week-old seedlings, raised on separate seedbeds, are transplanted on the puddled land. Fields are weeded two to three times, depending on weed infestation. Rice is harvested manually with a sickle. Plants are cut from 5-50 cm above the ground depending on the method of threshing to be used, distance to threshing floor and straw requirements. The harvested parts are tied in small bundles and carried to the threshing floor. The most popular method of threshing is trampling of harvested plants by cattle. Occasionally, paddle threshers are used. Sometimes rice is threshed manually by beating on bamboo frames or racks, wooden pieces, or floors. The rice is winnowed and sun-dried, mainly by women, before being put in the store.

Broadcast (Deepwater) Aman: The deepwater *aman* is sown broadcast in the pre-monsoon season. These include photoperiod-sensitive varieties harvested after the monsoon season. The varieties elongate with the gradual rise of water levels. Only traditional deepwater *aman* varieties are grown as there are no modern varieties. Deepwater *aman* seeds are inter-sown with *aus* under dryland conditions after ploughing in the pre-monsoon season. When the plants are about six to eight weeks old, they start to elongate with the gradual rise of flood level. The crop flowers with the coming of the shortened day length. After maturity, the plants are cut with panicles 60 to 70 cm from the top. Most of the straw or stubble is either left on the field or collected later. Rice is threshed mostly by trampling of harvested plants by cattle. Other post-harvest operations are similar to those used for *aus*.

Transplanted Aman: T. *aman* is sown in seedbeds and transplanted as seedlings in the monsoon season. The crop is transplanted either on single cropped land, on land where *aus* or jute has been harvested or on land to be followed by *boro*. This type also includes photoperiod-sensitive varieties harvested after the monsoon season. Both local varieties and HYVs are cultivated. The crop is transplanted with the recession of flood water. The land is puddled with three to four ploughings followed by laddering. Basal doses of fertilisers are applied before the final ploughing. Three- to more than ten-week-old seedlings are transplanted on the puddled land. Intercultural operations include weeding, top-dressing of fertilisers and pesticide application. Being photosensitive, the plants flower at the beginning of the shorter day length. After maturity, plants are cut between 5-15 cm above the ground. Post-harvest operations are similar to those used for *aus*.

Boro: The *boro* rice includes photoperiod-insensitive varieties. The crop is transplanted in the early dry season and harvested in the pre-monsoon season. *Boro* is mainly grown with irrigation and is followed by t. *aman*. The varieties cultivated include local varieties, local improved varieties and HYVs. Four- to six-week-old seedlings, raised on separate seed beds, are transplanted on puddled land. Basal doses of fertilisers are used very often on HYVs and improved local varieties, but seldom on local varieties. Weeding, top-dressing of nitrogen fertiliser and pesticide application continues until the plants flower. When the crops are mature, the plants are cut at the base if the field is dry; otherwise, they are cut 30-50 cm from the top. The harvested plants are carried to the threshing floor in bundles. Post-harvest operations are similar to those of *aus*.

Wheat

Wheat is grown in the *Rabi* season. Land is prepared at the beginning of the season with three to four ploughings followed by laddering. Basal doses of fertilisers are applied before the final ploughing. Seeds are broadcast and covered with soil by shallow ploughing and laddering. Depending on variety, the crop matures in 100 to 120 days. The plants are cut at the base and carried to the threshing floor in bundles. The grains are detached from the plants by beating against hard objects. Local varieties are not cultivated, more than a dozen HYVs are available.

Jute

Jute is grown in the *Kharif* season. Land is prepared by four to five ploughings followed by laddering to attain fine tilth. Seeds are broadcast under dry-land conditions. Seedlings are thinned and consumed as vegetables. Profuse growth of weeds requires two to three weedings. The plants are cut at the base when 40 to 50 percent of the plants have flowered, and are left on the field for a few days to allow the leaves to shed. The leaves add organic matter to the soil. The plants are tied in bundles and submerged under water for two to three weeks for rotting. Clear water with mild currents helps maintain the quality of fibre. The fibre is separated from the stalk, washed and sun-dried manually.

Oilseeds

Oilseed crops are grown on well-drained soil. Rape and mustard are the major oilseed crops grown in the project area. The crops are mostly grown in the early *Rabi* season. In t. *aman-boro* patterns under irrigated areas, the land remains fallow for 80-90 days after the harvest of the *aman*. During this period, rape or mustard is grown in many areas. This third crop gives additional benefits in that the fertilisers applied to these crops effect the next crop. The oilseeds crops are usually grown as sole stands. Seeds are broadcast and covered with pulverised soil. Basal doses of fertilisers are applied to the soil during the last ploughing. Plants are top-dressed with urea before flowering. Improved varieties are available. Crops are harvested either by pulling or cutting at the base of the plants.

Vegetables

Vegetables are grown on well drained land. The important vegetables grown in the project area are *brinjal* (egg plant), pumpkin, arum, *chal kumra, chichinga, danta, karala, jhinga, palang, patal* and *barbati*. Most of the vegetable area is cultivated around homesteads in the *Rabi* season. Both organic and inorganic fertilisers are applied during the preparation of the soil. Vegetables are grown in pits, in furrows and on raised beds. Seedlings are raised in separate seed beds or in polyethylene bags. *Jhinga*, gourds, cucumbers, beans and Indian spinach *(pui shak)* require supports to grow. Usually thin, upright bamboo sticks are used to support plants when they are 10 to 15 cm in height. Overhead trellises (*macha*) are provided at a height of 1-1.5 m. Arum is grown in medium high to medium low lands where rainwater is pounded. The land is well puddled before planting. Both local, improved local and modern varieties are used for vegetable cultivation.

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Spices
Spice crops are cultivated in flood-free areas with well-drained soil. Chili, garlic and coriander are the major spice crops grown in the project area. They are mainly grown during the *Rabi season*. Chili is also grown in the pre-monsoon season. Both manure and fertilisers are applied to the soil. Fertilisers are also top-dressed. Chili seedlings are raised in separate seed beds and transplanted in rows. Cloves of garlic are planted in furrows. Coriander seeds are broadcast. Spice crops are mostly local varieties.

Sugarcane
Sugar cane is an annual crop grown on high and medium high lands where rain or flood water does not stand for long periods. Land is ploughed three to four times and basal doses of fertilisers are applied. Sugar cane cuttings, or sets, are placed in furrows prepared with a country plough in November-December. They are covered with pulverised soil. As the crop grows, ridges are developed progressively along with top dressing of fertiliser at the side of the row. The plants are harvested a year after planting when sucrose content is highest.

Fruits
Fruits are grown as a supplement to the major field crops, usually in and around the homesteads. More than a dozen fruit crops, belonging to many families, are grown. Their growth habits and management differ widely. Fruits are very sensitive crops; raising them requires specialised techniques. Many varieties of good quality fruits are available in the project area.

3.6 Input Use

Irrigation
Irrigated crops cover almost half of the total cropped area. These crops mainly include local, improved local and HYV *boro* rice. Land use surveys suggest that the total rice area in the *boro* season is irrigated. In the *aus* season irrigation is used for early seedling raising, and for the t. *aus* during initial seedling establishment. Supplemental irrigation in the t. *aman* area has been reported in non-flood years. Among the non-rice crops, wheat, oilseeds, vegetables and spices are partially irrigated. About 75 percent of the wheat, 40 percent of the vegetables and spices, and 20 percent of the rape and mustard areas are irrigated.

Seeds
The average amount of seed used for broadcast rice cultivation is 90 kg/ha, and 25 kg/ha for transplanted rice cultivation. For wheat cultivation, the seed used is 130 kg/ha under irrigated and 105 kg/ha under non-irrigated conditions. The average seed requirement for jute, potato, pulse and rape or mustard is 7 kg/ha, 1,600 kg/ha, 35 kg/ha and 12 kg/ha, respectively. Usually, farmers save their seeds from the harvested crop. They sometimes exchange seeds among themselves. Seeds of HYVs or improved varieties are available at *thana* BADC seed distribution centres. The seeds are supplied by BADC Seed Processing Centres before the planting period. There are four to five seed processing centres in the country. The centres supply seeds to the BADC seed distribution centres at *thana*.

The *thana* centres distribute mainly rice and wheat seeds. Jute, mustard, potato and vegetable seeds are also available. The total amount of seeds distributed to the farmers is lower than the average requirement for the cultivation of most crops. Moreover, seeds do not arrive at the *thana* centres on time. The nearest seed processing centre is in Tangail district.

Fertilizer
Fertilizer uses in the project area for major crops are given in Table 3.5. As seen in the table, nitrogen is the most common and widely used nutrient, and urea is the major source of nitrogen. Phosphate is second only to nitrogen in frequency and total volume of use as a fertilizer. The most widely consumed phosphate fertilizer is TSP. Potash is the third most widely used nutrient, and MP is the only source of potash. The other fertilizers include ASP, SSP, DAP, zinc sulphate and gypsum.

Fertilizers are available in the local markets. The price of fertilizer increases in the *Rabi* season when it is used in larger quantities for *boro* rice, wheat, rape and mustard.

Fertiliser application is poorly balanced, with the actual-to-recommended ratio being low. Most of the farmers use no potash. Flooding, inadequate drainage facilities, poor communication, unavailability of fertilizers in time, use of local varieties and poor extension works result in the use of poorly balance use of fertilizer. The potential for balance fertilizer use could be considerably enhanced with drainage improvement, increased confidence of the farmers and shifts from local to modern varieties. The exploitation of potential however also depends upon a number of other price and non-price factors. These include i) access to infrastructure, ii) delivery systems, and iii) extension services including on-farm training to farmers.

Table 3.5: Fertilizer Uses (kg/ha)

Crop	Urea		TSP		MP	
	Actual	Recommended	Actual	Recomnd.	Actual	Recomnd.
Local T. Aman	50.7	70	-	55	-	40
HYV T. Aman	142.1	185	4.6	90-95	-	40-70
Local/Imv L Boro	72.1	90-105	17.3	50-60	8.7	25-35
HYV Boro	173.9	180-210	41.4	90-125	10.2	50-70
Wheat	76.2	180-220	8.6	140-180	34.6	40-50
Oilseed	24.6	140-180	58.1	90-175	15.3	60
Vegetable	84.6	100-150	50.8	200-300	16.9	50-150
Spice	14.8	100	24.7	200	9.9	100

Source: The actual rate of application was obtained from farm monitoring and land use survey.
The recommnded fertilizers application rate was obtained from DAE 1992 and BARC 1991.

Labour Use
Labour requirements for the various farm activities vary by the crops and the season. There is high demand of labour during the rice transplantation. Farmers suggests that HYV transplanted rice production requires substantially more labour inputs and this discourages cultivation of these varieties, especially in *boro* season. Farm monitoring study shows that average labour requirements per ha for HYV production in *boro*, *aman* and *aus* seasons are 153 man days, 133 man days and 128 man days, respectively. In production of local rice varieties the labour requirement per ha is 96 for b. *aus*, 75 for b. *aman*, 108 for local t. *aman* and 110 for local/improved *boro* production. Vegetable production requires more labours (232 man days/ha)

than other crops, Spices and jute also requires high labours, 172 man days/ha and 165 man days/ha respectively. Labour requirements are low in wheat (87 man days/ha) and oilseeds (91 man days/ha) production.

Draught Animal Use

Draught animals are not adequately available. Traditional land preparation in crop production involves ploughing, puddling and laddering which require substantial draught power. Timely tillage, as well as proper tillage depth are not achieved due to the shortage of draught power. Cattle are the main source of draught power. The present draught animal requirement is 60 to 68 bullock days/ha in transplanted HYV rice, 28-38 bullock days/ha for transplanted local rice, 71 bullock days/ha for vegetables and 34 to 49 bullock days for other non-rice production.

Farm Machinery Use

Tillers and shallow tubewell are the farm machineries used by the farmers.
In the project area few large farmers own tillers. Medium and small farmers use them renting from others. The tillers are used mainly for ploughing as they are low in efficiency for puddling and laddering compared with bullock drawn country-plough and ladder.

Pesticides

Mainly granular types are used in the project area. The other pesticides include conventional pest complex, acaricide, fungicide and rodenticide. Pesticides are mainly applied on HYV rice. They are rarely used in local rice varieties.

It was estimated from the farm monitoring that about 14% percent of the total cropped land in the project area is treated with pesticides. The application rate is significantly below than the recommended rate. The highest application rate on average is 0.9 kg/ha compared with the recommended dose of 16.8 kg/ha in HYV boro cultivation. The application rate varied from 0.1 kg/ha to 0.6 kg/ha for other crops.

3.7 Agriculture Extension Service

Agricultural extension activities in the project are carried out by the Department of Agricultural Extension (DAE) through Purbadhala and Phulpur Thana Agriculture Officers (TAO) with the supervision of Deputy Director of Netrokona and Mymensingh Districts respectively. Each TAO is supported by a Subject Matter Officer, an Additional Thana Agriculture Officer (ATAO), an Assistant Agricultural Extension Officer (AAEO), a Junior Agricultural Extension Officer (JAEO), and Block Supervisors (BS).

Diffusion and adoption of the modern technology in the project area are the responsibility of the extension personnel. Extension activities are mainly organised through regular visits by the BS to sub-blocks. At each sub-block there are contact farmers through which messages concerning improved practices are passed on to the farming community. In addition, the BS attends training and conference sessions where farmers' problems are discussed. He also maintains demonstration plots in farmers' field. The extension activities are supported by Agricultural Support Services Programme that aims to concentrate activities in key areas including minor irrigation operations and on-farm water management.

Poor communication is the main problem in contacting farmers and conducting demonstrations. *Thana* agriculture offices do not receive enough funds for extension activities. Funds and materials do not arrive promptly. Therefore, contact farmers do not receive the materials in time. The *thana* agriculture office is understaffed.

3.8 Marketing

The marketing system in the project area is largely traditional and in the hands of small traders. Products which are marketed are channelled from the grower through primary markets and secondary markets to the terminal markets of Netrokona, Mymensingh and Dhaka.

Nearly 61% of farmers sell their crops mainly to meet their immediate needs including daily necessities of life, repayment of loans and purchase of agricultural inputs. They sell crops in the primary markets which generally sit twice a week. About 90% of rice (both husked and unhusked) marketed in primary markets are sold directly by the farmers, the remaining being undertaken by traders.

As given in section 3.9, the area produces about 68,500 tons of unhusked rice. About 43% of this production are supposed to be consumed locally (based on 454 gm of husked rice per capita per day for a population of 119,000 by 1995). The farmers also preserve seeds from the harvest.

Rice sale of rice is at its peak during harvesting period. During this period rice price becomes low by 20 to 25% from the average price of the year. Again more grains pour in the primary markets at the onset of monsoon to avoid grain loss by floods and the price is also reduced by 10 to 12%.

There is no community storage facilities in the area. Farmers store the grains in household based mini storage bins. Although small farmers, share croppers and deficit growers have no surplus but they sell a large part of their harvest immediately after threshing not because of storage problems but to pay loans and to meet other needs.

Marketing Margins

Price differentials between primary markets and the farmgate are generally 3 to 4%. Margins between primary and secondary markets are typically of a similar level. The price spread between farmgate and retail prices varies according to location, season and other factors, farmgate prices of rice are generally being between 80 to 85% of retail prices. The rice market in the area is seasonably competitive and efficient, the profit margins are not excessive.

3.9 Crop Production

Rice

Annual rice production (all rice yield and production in this study relate to unhusked rice) in the project area is about 68,307 tons (Table 3.6). The average rice yield level is 2.9 tons/ha. The yield decreases when the crop is damaged by floodings. Almost two-thirds of the total rice production is irrigated *boro*. T. *aman* accounts for one-third of the total rice production, although the crop occupies major areas. This low production of t. *aman* rice in the project area is associated with widespread use of local varieties, delays in plantation due to the late drainage of flood water and the damage caused by recurrent floods. About 0.2 percent of rice production is b. *aman* and more than 4 percent is *aus*. Of the total rice production, local varieties account for one-third, and HYVs for two-thirds. The average HYV rice yield is nearly 4.0 ton/ha compared with 1.9 ton/ha for local varieties.

Table 3.6: Present Crop Production

Crop	Flood Damage Free Area			Flood Damage Area			Total	
	Area (ha)	Yield (t/ha)	Prdn (t)	Area (ha)	Yield (t/ha)	Prdn (t)	Area (ha)	Prodn (t)
Local B Aus	1097.2	1.80	1975.0	71.0	0.87	61.8	1168.2	2036.8
Local T Aus	185.5	2.10	389.6	18.0	1.60	28.8	203.5	418.4
HYV T Aus	150.1	3.90	585.4	13.0	3.10	40.3	163.1	625.7
Local B Aman	33.4	1.60	53.4	50.1	1.28	64.1	83.5	117.5
Local T Aman	1607.3	2.20	3536.1	5807.7	1.60	9292.3	7415.0	12828.4
HYV T Aman	331.6	3.40	1127.4	3210.5	2.60	8397.3	3542.1	9474.7
Loc/Imprvd Loc Boro	2889.0	2.40	6933.6	38.0	1.81	68.7	2927.0	7002.3
HYV Boro	7296.3	4.60	33563.0	560.0	4.00	2240.2	7856.3	35803.6
Wheat	163.5	2.03	331.9				163.5	331.9
Oilseeds	666.4	1.00	666.4				666.4	666.4
Jute	21.2	1.50	31.8				21.2	31.8
Vegetables	170.8	10.70	1827.6				170.8	1827.6
Spice	42.7	3.50	149.5				42.7	149.5
Sugarcane	0.4	22.00	8.8				0.4	8.8

Non-rice

About 330 tons of wheat are produced annually, with an average yield of 2.03 ton/ha. The crop accounts for 0.5 percent of the annual foodgrain production. Annual production of oilseeds is 666 tons, with an average yield of 1.0 ton/ha. About 32 tons of jute are produced in the project area, and the average yield of jute is 1.5 ton/ha. Annual production of vegetables is 1830 tons and spice is 150 tons. The average yields for vegetables and spices are 10.7 ton/ha and 3.5 ton/ha, respectively.

3.10 Crop Damage

Flooding

Flooding is the major cause of crop damage in the project area. The loss of rice production due to flood damage is more severe than that of other crops. The loss of rice is higher in the monsoon season since a greater area is under cultivation of t. *aman* crops then. Early floods damage mature *aus* and *boro*, young t. *aman* plants, jute, vegetables, and rice seedlings on the seed bed. Damage to the crops and amount of yield decreases depending on the length of submergence and the growth stage of the crop. Slow and late drainage of flood water delays the plantation of crops, and the late plantation brings down the crop yield levels. The yields of t. *aman* rice decrease substantially when the crops are extensively damaged at the reproductive stage by late-monsoon floods. Thus, low rice yields and unstable food production due to flooding are common in the project area.

Pests
The following pests infest rice fields. Significant damage, however, has not been reported by the farmers.

aus:	Stemborer, rice bug, hispa and thrips.
t.*aman*:	Stemborer, case worm, rice bug, hispa and rat.
boro:	Stemborer, thrips and hispa.
b. *aman*:	Rat.

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4. TRENDS IN CROP PRODUCTION SYSTEM

4.1 Land Use

Net cultivated land

According to the *Census of Agriculture* in 1983-84, the net cultivated area was 11,160 ha or 74.4 percent of the project area. About 2.4 percent of the net cultivated area was fallow. The NERP land use survey in 1994-95 shows that the net cultivated area increased by 12.2 percent over the past decade, and now stands at 83.5 percent of the project area. Fallow land now accounts for less than 0.1 percent of the net cultivated area.

Intensity of Land Use

With the increase in the net cultivated area, decreases in fallow land and more intensive cropping, the total cropped area has increased by 38.5 percent during the past decade (Table 4.1). The cropping intensity has increased from 1.58 to 1.95 during the same period. Increase in the irrigated *boro* rice area in the winter season has led to the expansion of the double-cropped area. The triple-cropped area has increased mainly due to production of more oilseed crops between t. *aman* and *boro* rice.

Table 4.1: Changes in Crop Area (ha)

Crop	1983/84[a]	1994/95[b]
B. *aus*	3805.0	1168.2
Local T. *aus*	202.4	203.5
HYV *aus*	245.6	163.1
B. *aman*	695.6	83.5
Local T. *aman*	5545.7	7415.0
HYV *aman*	1154.5	3542.1
Loc\Improved Loc *boro*	979.2	2927.0
HYV *boro*	2405.2	7856.3
Wheat	109.1	163.5
Oilseeds	311.8	666.4
Jute	1254.1	21.2
Other	928.9	213.9
Total Cropped Area	17637.2	24423.7
Net Cultivated Area	11161.5	12525.0
Cropping Intensity	1.58	1.95

Source: [a] Agriculture Census; 1983/84.
[b] Land use survey; NERP, 1994/95.

It appears that high population, increasing land pressure and a primary dependence on unpredictable crop harvests have compelled farmers to bring more area under cultivation and intensify crop production. These systems of farming are hazardous because of uncertainty and the ever-present risk of flooding. This could be avoided by not establishing crops when there is considerable likelihood of flooding. Economic circumstances, however, are such that farmers have no option but to take risks to produce food for their consumption.

4.2 Cropped Area

Rice

Rice is the most important crop produced in the project area. There have been significant changes in area under rice over the last ten years. According to the *Census of Agriculture*, rice

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covered 15,000 ha in 1983-84. The NERP land-use survey shows that the rice-cropped area increased by 52.6 percent to 23,350 ha in 1994-95. The increase has mainly resulted from the expansion of area under HYVs. HYVs now share more than 49.5 percent of the total rice-cropped area. The share has doubled from 25.3 percent in 1983-84. The HYVs rice area has increased by more than threefold in the *boro* and t. *aman* seasons. In the *aus* season, however, the area has declined by almost half. The land use survey suggests that HYVs *aus* area have been converted into HYVs *boro* areas.

The major factors to the increase in HYVs rice area are the expansion of irrigation facilities in the winter season and the availability of short growth duration HYVs in the t. *aman* season. The short-growth-duration t. *aman* HYVs are somewhat suitable for lands where drainage of flood waters is early in the monsoon season. Under this condition, the short-growth-duration t. *aman* HYVs yield 30 to 37 percent low compared to HYVs of normal growth duration.

In 1994/95, the total area under local varieties was the same as in 1983-84. However, the area under *aus* declined by 76 percent and that under b. *aman* by 87 percent. Most of the *aus* and b. *aman* lands have been converted to HYV *boro* lands with the availability of irrigation in the dry season. The area under local varieties has increased by more than threefold, mainly in the dry season, and has increased by more than one-fifth in the monsoon season. The availability of improved varieties has helped farmers increase the area under local rice in the *boro* season. The improved varieties are well adapted for conditions where irrigation supply is poor, and inadequate for HYVs. Local t. *aman* area has increased mainly due to the increase in cultivated land area.

Non-rice
Between 1983/84 and 1994/95 the area under non-rice crops has declined by 60 percent. A fall in jute prices has led to a significant reduction in jute area. The area under vegetables, spices and other non-rice crops has declined significantly. Non-rice crops that have seen an increase are oilseeds and wheat. The area under these two crops has almost doubled.

4.3 Crop Production

The present crop production data obtained from the land use survey were compared with 1983/84 full count Agriculture Census data which was collected at the *mauza*(comprising several villages) level. No crop production data was collected to that level after 1983-84 census.

Rice
Rice production has changed during the past decade, increasing from 31,300 tons in 1983/84 to 46,480 tons in 1993/94. Average yield levels have declined from 2.1 t/ha to 2.0 t/ha.

The increase in rice production was mainly due to the expansion of area under high-yielding, lodging resistant and fertiliser-responsive modern varieties (HYVs) in the *boro* season. Other factors include the expansion of irrigation facilities and the increased application of chemical fertilisers. The irrigated *boro* now shares 63 percent of the total rice production compared to 44 percent in the early 1980s. In the t. *aman* season, rice has increased its share of total production from 32 to 33 percent. The share has declined from 21 to 5 percent in the *aus* season and 3.8 to 0.2 percent in the b. *aman* season.

The production of local varieties declined from 54 percent of the total rice production in the early 1980s to 33 percent of the total production in 1994. The share of HYVs to the total rice production has increased from 46 to 67 percent. Increases in HYV rice production have mainly occurred in the *boro* season. More than 78 percent of the HYV rice is now produced in this season.

Non-rice

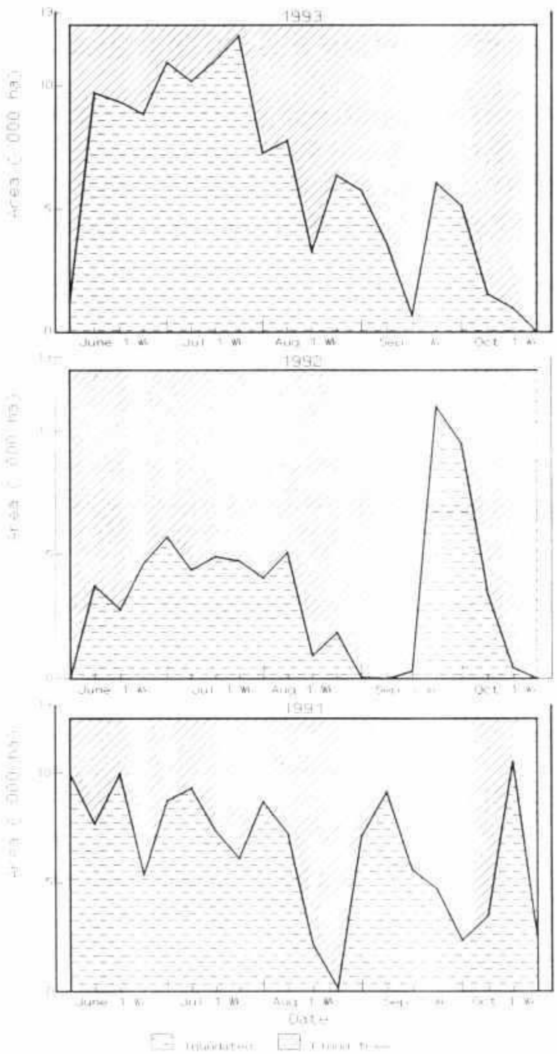
The production of wheat has doubled during the past decade. There has been abrupt fall in the jute production. Increase in the production of mustard/rape is noticeable. Vegetables and spices are increasing in production. Production of winter vegetables and spices has increased significantly.

4.4 Crop Damage

Recent flood patterns show that the crop production system in the project area is coming under increasing pressure. It appears that effective t. *aman* season is getting shorter and the amount of land available for rice cropping in the monsoon season is decreasing.

Three consecutive floods of 1991, 1992 and 1993 caused substantial damage to t. *aman* rice and other standing crops. In 1991, about 80 percent of the net cultivated land was inundated by floods in the early monsoon season. In the late monsoon, recurrent floods inundated more than 84 percent of the net cultivated land. In 1992, the inundated area increased to 88 percent by late September and 76 percent continued to be

Graph 4.1: Cultivated Area Inundated by Floods in the Monsoon Season



Source: Annual Flood Depth Map, NERP

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inundated until early October. In 1993, about 78 percent of the net cultivated area was inundated in the early monsoon. The area increased to 96 percent in mid-monsoon, and 43 percent of the net cultivated area continued to be inundated till October.

The 1995 flood severely damaged crops as well, submerging all cultivated land in the project area. Recurrence of flood and heavy rainfall extensively damaged t. *aman* crops at the early growth stages. Mature *aus*, jute, vegetables and spices were also inundated. Consequently, standing crops were substantially damaged.

5. LIMITATIONS TO CROP PRODUCTION

Limitations to agricultural production in the project area are associated with physical, biological and socioeconomic constraints. The major constraints are described below.

5.1 Flooding

More than two-thirds of the project area is flooded over one metre in the monsoon. The floods are a combination of flood inflows from the Kangsha River, seasonal rainfall and slow drainage in low-lying area. Floods occur more than once in a year, mostly between June and September. The volume of these floods is large enough to completely inundate standing crops. Flood levels rise very quickly, sometimes more than one metre in a day. Drainage is slow and always delayed on low-lying lands. According to the depth of inundation and period of flooding and drainage, cultivated land in the project area can be categorised into four land types (Figure 6). These are:

- shallowly to moderately deeply flooded, poorly to imperfectly drained land,
- intermittently to shallowly flooded, moderately well to poorly drained land,
- shallowly to deeply flooded, poorly and slowly drained land with irregular relief, and
- shallowly to moderately deeply flooded, part with intermittently flooded land.

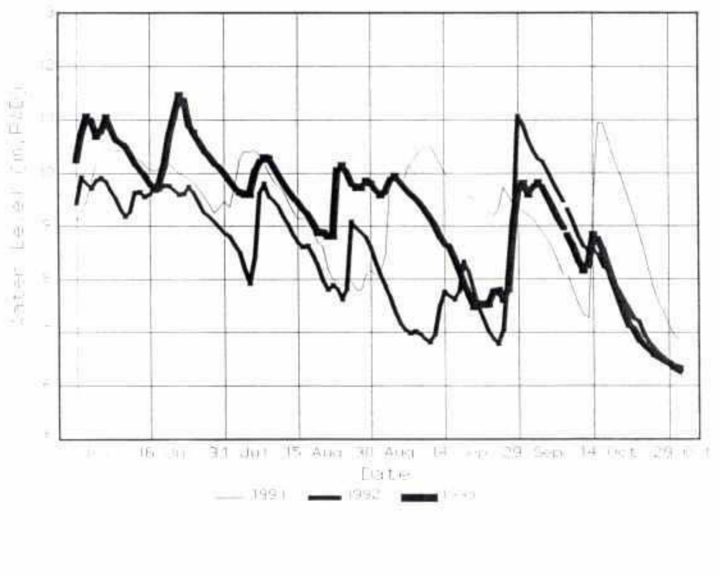
On the basis of these flooding characteristics the major limitations identified in the project area are the damage or loss of crops, slow and late drainage of flood water, delay in the plantation of crops, shortage of rice seedlings, and incomplete crop plantation. These are described below.

Flood Damage

Crop production losses due to flooding are frequent. Rice is the main crop damaged by floods. The flood water level and duration are variable but rice plants are usually completely submerged. Graph 5.1 shows the depth and duration of flooding in the project area.

Early floods and rapid rise of flood level submerge mature *aus* rice, jute, vegetables and spices and cause damage of the crops. The standing t. *aman* rice, which is the major crop in the project area, is also damaged. Early floods destroy young plants of t. *aman* after a few days of inundation. The damage takes place when the crops are at the vegetative growth or tillering stage. In some areas, mature *boro* rice is inundated when the crop is at the harvest stage. The inundation follows heavy

Graph 5.1: Depth and Period of Flooding



rainfall in the area and occurs in depressions without sufficient drainage outlets. This occurs mainly on shallowly to moderately deeply flooded, poorly to imperfectly drained land.

Crops are damaged extensively when flood occurs in the late monsoon season. Late floods inundate t. *aman* rice crops when they are at the final vegetative growth stage or early reproductive stage. The yields decrease due to this inundation. This yield-decreasing effect could be attributed to impaired tillering and decreased area of photosynthetic leaf surface.

Slow and Late Drainage of Flood Water

Water levels in the lower-lying areas rise with the onset of monsoon rains, restricting the cultivation of crops in the monsoon season. Cultivated land remains flooded for longer periods and transplantation of rice is delayed. Usually the land is not drained until early *Rabi* (winter) season. The sowing of the *Rabi* crops can be delayed, but the soil moisture drys out in mid-season. This restricts the cultivation of non-rice crops to intermediate lands.

Late-transplantation

Aman transplantation period in the project area extends from early to late monsoon. Land-use survey shows that transplantation usually begins in late June and continues until late September. Flooding depth on the land where the crop is transplanted usually vary from 0 to 30 cm (within fields *bundhs*), but taller seedlings are transplanted in land eventually flooded to more than 30 cm. *Aman* is re-transplanted when destroyed by early floods, but yields for these late-planted crops decrease significantly. The yield-decreasing effects of late-plantation could be attributed mainly to low tillering of plants. Transplantation of rice is extremely delayed on low-lying lands due to the late drainage of flood water. Cultivation of HYV rice is difficult due to this constraint. Table 5.1 shows the inundated area and flood-free land available on different dates for the transplantation of *aman* rice through the monsoon season.

Table 5.1: Availability of Flood-Free Land for Rice Transplantation in the Monsoon Season

Date	Inundated Land (ha)	Flood-Free Land (ha)	Percent of Total *Aman* Rice Area Available for Transplantation
Late June	9618	2863	26.1
Early July	9580	2901	26.5
Middle July	9384	3097	28.3
Late July	9060	3421	31.2
Early August	7965	4516	41.2
Middle August	5829	6652	60.7
Late August	5170	7311	66.7
Late monsoon	-	12525	100.0

Source: 1:2 year flood depths analysis; NERP, 1995.

Seedling Scarcity

Demands for *aman* rice seedlings increase for re-transplantation following the recession of flood water. Farmers make every effort to manage seedlings. However, their efforts are often thwarted by acute shortages and high prices. Seedlings are sold at a high price in flood-free areas. Transplantation costs increase by three to five times and the raising of fresh seedlings is not possible as the transplantation period ends before the new seedlings are ready. These factors restrict re-transplantation of land and leave considerable areas uncultivated.

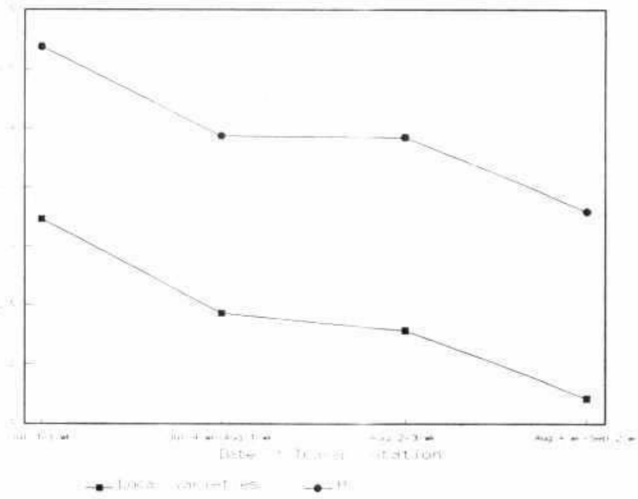
Incomplete Plantation

Poorly drained, low-lying lands remain flooded for three to four months at depths greater than one metre. In low-lying lands transplantation of rice is extremely delayed or uncompleted, and farmers are compelled to keep land fallow when late floods occur. Late floods also keep land flooded longer into the dry season, and slow drainage prevents cultivation of *boro* (winter) rice in very poorly drained soils.

5.2 Low Rice Yield for Late-transplantation

Yields decrease in relation to late planting dates (Graph 5.2). The yield-decreasing effects can be attributed to use of old seedlings and late-planting.

Graph 5.2: Relation between Yield and Date of Transplantation in Transplanted *Aman* Season (Source: crop cut experiment, NERP, 1993)



Seedlings for t. *aman* rice are raised in upland nurseries. The seedlings are transplanted with the recession of flood water. Since the final recession time is unpredictable and varies from year to year, rice seedlings are kept ready from the beginning of the transplanting period. Moreover, taller seedlings are preferred for transplantation in flooded lowlands. In severe flooding years seedlings are collected from other areas for re-transplantation, usually a good distance from the project area. Thus, use of aged, old and unhealthy seedlings is common. These seedlings recover slowly after transplanting, require increased growing time and give poor yields.

Transplanted *aman* rice is a short-day plant. It initiates panicle or flower primordia in response to short photoperiod or day-length. When planted late it matures at its usual time despite shortened vegetative growth period. The plant cannot produce adequate tillers because of limited vegetative growth. Tillers are branches that develop from the leaf axils of the main stem or from other tillers during the vegetative stage. In rice cultivation, the number of panicles per unit area is largely dependant on tillering performance. Panicle numbers affect the grain yield of rice.

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Graph 5.2 shows the result of delayed planting. September transplanting, two months later than usual, shows the lowest yield for all varieties. In the project area, farmers prefer not to transplant aman rice after August. Long growth duration by early plantation does not increase the yield because excessive vegetative growth will cause lodging.

5.3 Poor Performance of Irrigation System

In the project area, irrigated agriculture is as popular as in other parts of the country. Farmers who can afford to buy tube-wells, sell water to small farmers and share croppers in the dry season. Field studies suggest that irrigation water supply is not timely, assured, regular or sufficient.

5.4 Monoculture

Rice is well-suited to the present agro-hydraulic conditions in the project area. Many areas where non-rice crops were grown in the winter season have been converted to *boro* rice lands. This increase in monoculture has some negative social impacts. Employment opportunities are limited to rice production in specific seasons, and imbalances in food production affects food security at the household level.

5.5 Inadequate Agricultural Research

Farmers in the project area require appropriate technologies for use in various aspects of the agricultural production system. Lack of suitable technology for farm, water and land management systems limits agricultural development. Important aspects include:

- high yielding t. *aman* rice varieties for late transplantation,
- profitable cropping patterns with the increase of non-rice crop area,
- opportunities for agricultural diversification,
- successful control of insects and diseases,
- optimum fertiliser application,
- efficient water management,
- maintenance of land productivity, and
- efficient pre- and post-harvest operations.

Simple machines and tools, which are easy to use and affordable, need to be developed using locally available materials. This illustrates the importance of comprehensive studies in the project area. Bangladesh Agricultural Research Institute (BARI) and Rice Research Institute (BRRI) have several sub-stations and farming system research sites in the country. However, the project area does not contain any such station.

5.6 Inadequate Extension Service

The extension services provided by Department of Agricultural Extension (DAE) through *thana* agricultural offices are limited. The services tend to concentrate primarily in the use of modern variety of rice crop, paying little attention to other areas. This results in poor motivation and knowledge of farmers on crop selection, input use, crop production practices, efficient irrigation and water managements, and maintenance of land productivity. There is no strong integration among the agencies providing support services. This considerably limits support services, leading to difficulties in obtaining extension services, seed, fertilisers, credit and other inputs.

5.7 Land Ownership and Tenancy

Big landowners have little interest in improving farming practices because of the investment required. Many of them appoint tenants or share croppers. The tenants or share croppers are not interested in using new production technologies because the cost of labour, fertilisers and other inputs would be borne by the tenant while the increased output would be shared with the landowner.

5.8 Access to Inputs and Credit

Farmers are willing to use improved production practices and modern agricultural inputs. They need reliable and timely access to inputs including seed, fertilisers and credits. However, problems persist in the supply of inputs. Distribution of improved and HYV seed is lower than the average requirements. Fertilisers are not wisely used and poorly balanced; this appears to be associated with availability. Prices of fertilisers rise with the increase in demand.

There are several credit institutions that finance loans to farmers, the most important being the Agricultural Bank and the commercial banks. Bureaucratic formalities complicate the loan application and farmers cannot get the loan at the right time or in adequate quantities. Two or three months are required to get a loan from a bank, and few farmers can submit all the documents the banks require. The eligibility criteria are not suitable to illiterate farmers and ultimately, few have access to institutional credit. Most borrow from money lenders, at exorbitant interest rates.

5.9 Harvesting, Post-harvest Activities and Marketing

Flooding and heavy rainfall reduce yields during the harvest of crops in the pre- and early monsoon seasons. Heavy rain also hampers the processing of rice. Temporary threshing ground on relatively high land and courtyards are used for post-harvest activities (threshing, winnowing and drying). The threshing and drying of rice are made difficult by heavy rainfall and persistence cloudiness, particularly during the *boro* harvesting period. Lack of knowledge about simple storage and preservation techniques results in the loss of seed stock.

Crop marketing patterns within the project area, like in other areas of Bangladesh, are largely traditional. Producers are compelled to dispose of part or, sometimes, all of their crops immediately upon harvest. Farmers are unable to store their crops because of a need for cash, lack of proper storage facilities (these typically consist of granaries located inside the household's main house), crop loan obligations and high transport cost. Often farmers are obliged to replace what was sold by buying rice later at a much higher price.

6. OPPORTUNITIES FOR IMPROVEMENT

A comprehensive program for flood control, drainage improvement, irrigation, land utilisation and other important parameters is required to increase agriculture production in the project area. The program should be developed since agriculture is responsible for ensuring food supplies, securing farmers' income, conserving natural environments, and changing the relationship between agriculture and non-agriculture sectors through diversification of farm management. Integration of crops, fishery, livestock and forestry into the farming system must be considered to optimize resources. Emphasis should be given to infrastructure improvement, development of farming systems, effective agricultural extension services, credit systems, and streamlined marketing facilities. There should be a separate body who would be responsible for land, water and farm management. Within this context, the possible ways to increase agricultural production in the project area are described below.

6.1 Flood Control and Drainage Improvement

Flood protection and drainage improvements are required to increase agricultural production in the seasonally flooded and poorly drained lands. Rice is well suited to conditions found in most of the project area. A high potential for increasing t. *aman* rice production in the monsoon season exists in the project area. Adequate flood protection is needed to increase t. *aman* production. Improvement in drainage is required to reduce yield losses, increase farmers' confidence and produce more crops. These factors would also contribute to bringing a larger area under cultivation.

Higher output in the monsoon season may relieve pressure for growing rice in the dry season. This may lead farmers to shift from rice-only production to high-value non-rice crops that require small investments, low management and a reduced share of irrigation water. Flood protection, drainage improvement and the increased confidence of the farmers would help in investment, adaption of the modern technologies and diversification of agriculture.

6.2 Development of Suitable Crop Varieties

Quick-maturing varieties with high yield potential are needed in the project area. Transplanted *aman* rice varieties with high-yield potential need to be developed for late transplantation. Suitable varieties of *Rabi* crop are needed for introduction before transplantation of HYV *boro* rice.

6.3 Establishment of Seedling Nursery

An agency could consider the establishment of seedling nurseries in appropriate places in the project area. This would ensure a timely supply of healthy rice seedlings, especially in severe flooding years.

6.4 Improved Irrigation Management Systems

Efficient irrigation systems and water management are required to provide more profitable opportunities in farming. Existing irrigation facilities must be utilised more efficiently. For this, it is essential to improve the water-use efficiency, water distribution, irrigation performance and

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management. Farmers can make dramatic gains in agricultural production with improved irrigation management systems.

6.5 Agricultural Diversification

Diversification of agricultural production is required to increase agricultural output, encourage economic activities and promote change in food and nutrition in the project area. Promising possibilities for agricultural diversification include high-value non-rice crop production, intensive livestock and poultry production, improved rice-fish culture, introduction of small-scale mixed farming, improvement of agro-forestry and extension of information on efficient management of inputs and post-harvest activities.

6.6 More Agricultural Research

There is considerable scope for research to help farmers in developing appropriate technologies. This requires increased focus on site-specific conditions, long-term research and cropping systems used by farmers. Physical, technical and institutional constraints in the project area need to be extensively studied. Farmers' knowledge about agricultural production, irrigation management, post-harvest technology, seed production and storage should be evaluated. Comprehensive studies need to be carried out to include all the components into the farming system. The studies must select profitable farm enterprises, and provide useful and reliable technical guidance on the selected enterprise, appropriate advice for group farming, and information and guidance for marketing of farm products. This would help in the organisation of effective extension activities and training for farmers.

6.7 Adequate Extension Service

Irrigation, flood control and drainage, introduction of modern varieties and use of recommended doses of fertilizer form a complementary package to realize yield potential. In the project area, 67% of the farmers are subsistent and illiterate. Hardly they are aware of development of any new high yield variety and its management. Moreover, their adoptability is very slow as they do not like to take any risk because they cannot afford to lose at least what they have now. So, to realize high yield potential, they need advice and guidance about efficient irrigation and water management, selection of crop varieties and cropping patterns, and use of recommended dozes of fertilizers. This can be achieved by strong and effective agricultural extension service.

High yield potential can be realized and crop production can be increased through the improvement of extension services. These require:

- placement of efficient motivated extension workers;
- better interaction between extension workers and farmers;
- guidance on the efficient use of agricultural inputs (fertilizers, pesticides and irrigation water) for increased agricultural production;
- effective water management system;

- creation of local farmers' groups which would assist in quick transfer of information and knowledge to the whole farmers community; and,

- arrangement credits, seeds, fertlisers and pesticides.

6.8 Socioeconomic Study

Socioeconomic constraints in the project area should be extensively studied. Studies are required to evaluate the greater involvement of large land owners in the production system. The studies could provide information of efficient farming and good use of agriculture resources. Studies are required for the establishment of the economically viable farm and to foster the role of farming groups. To promote stable and effective use of land, increase the agricultural production, diversify the agriculture and supply the high quality of food production it is essential to prevent the large farmers from using their lands selfishly. Policies need to be developed to improve farm structure. There must be a limitation to holding lands in the project area. Policies supporting small farmers and share croppers should be suggested.

6.9 Easy Access to Inputs and Credit

Liberalisation of the irrigation and fertiliser distribution system during the 1980s in the country has resulted in the growth of irrigated agriculture and a substantial improvement in fertiliser availability at the farm level. However, further improvement is required to make important inputs more accessible. A credit system is required for small and marginal farmers, including share croppers, who represent a large part of the project population. Crop production loans should be issued for seasonal agricultural operations while medium-term loans should be available for capital investment. This system will help farmers to repay crop production loans. Crop production loans should include fertilisers, seeds and cash for labour costs. Agricultural diversification loan schemes should be considered to enable credit institutes to provide farmers with loans for livestock, poultry, horticulture and fish farming.

6.10 Marketing

The promotion of cooperative and group marketing and the supply of marketing information can help to provide alternate marketing channels to farmers and improve the efficiency of the marketing system.

7. IMPACT OF FLOOD CONTROL AND DRAINAGE IMPROVEMENT ON CROP PRODUCTION

7.1 Flood Control and Drainage Interventions

As described in the preceding chapters, the main constraint to crop production in the project area is the floodings from the Kangsha River. The floods inundate cultivated land, submerge crop fields and damage rice extensively in the monsoon season. Rice and non-rice crops are also damaged in the pre-monsoon season by drainage congestion caused by rainfall runoff. To protect the crops from damage by flood and drainage congestion, the following flood control and drainage (FCD) interventions are proposed in the project area:

- construction of full flood embankment along Kangsha River right bank from Jaria to Meda,
- re-sectioning of Caritas road along Netrokona to use it as an embankment,
- utilization of the existing regulators at the outfall of Kalihar River and Balia Channel,
- provision of drainage outlets south of Naterkona village and at the outfall of Mohespatti *khal*, and
- re-excavation of Dhalai River.

7.2 Impact of FCD Interventions

Land Use Pattern
Land use patterns will change in future with the FCD interventions and also without the interventions due mainly to the construction of embankment and expansion of homestead area, increase in ponds, development of infrastructures, more homestead plantation and cropping in low-lying *beels* (Table 7.1). Implementation of the proposed FCD project will require 51 ha of land for the construction of embankment to control flooding from the Kangsha River (see Annex A for details). Of this, 25 ha will be taken from the present cultivated land and the remaining 26 ha from the agro-forestry and homestead plantation area.

With the increase in flood free area in future with project, people will invest more on pond fish culture. This will expand pond area. A NERP fisheries survey conducted in the neighbouring BWDB Kangsha Project area suggests that the pond area will increase by 50 percent from the present area of 120 ha. The new ponds will occupy highlands in the present cultivated area. More public infrastructures and growth centres will be developed after the implementation of the FCD project. These will further reduce the cultivated area. The net cultivated area will decrease by 2 percent in future with project compared to that at present.

The land use patterns in future without FCD interventions will change due to demand of more homestead area for housing the increased population. Demand for land for social and economic infrastructure will also increase. These will result in the decrease of the present cultivated area by 1 percent. The *Beel* area would shrink due to expansion of cropping even in areas prone to flooding resulting from population pressure.

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Table 7.1: Land Use Patterns - Present, Future With (FW) Project and Future Without (FWO) Project (ha)

Land Use	Present	FW	FWO
Net cultivated land	12525	12292	12377
Homesteads	470	546	546
Ponds	120	180	135
Agro-forestry, homestead plantation	810	831	857
Infrastructure	485	515	500
Embankment	-	51	-
Channel	415	415	415
Beel	175	170	170
Total	**15000**	**15000**	**15000**

Cultivated Area

Implementation of the FCD project will reduce flood water level in the monsoon season. The flood routing analysis shows that the maximum polder water level for 5-year rainfall conditions will decrease by 86 cm from 10.80 m, PWD to 9.94 m, PWD (see Annex A for details). This reduction in the water depth will result in the increase of flood free land (Table 7.2).

Land types in future with project and without project conditions were determined by adjusting the flood depths on the cultivated land according to the water level in the project area with the proposed FCD interventions and without the interventions, respectively. The flood depths in future with project conditions were determined on the basis of maximum polder water level of 9.94 m, PWD. In future without project conditions, the flood depths were determined on the basis of 1:5 year maximum water levels of the Kangsha River.

Table 7.2: Land Type in Future With (FW) Project and Future Without (FWO) Project on the Basis of Monsoon Flooding Depth

Land Type	Flood Depth (m)	Net Cultivated Area (ha)		
		Present	FW	FWO
F0	0.0 - 0.30	777	8517	650
F1	0.30-0.90	1319	1582	1300
F2	0.90-1.80	4708	1339	4705
F3	>1.80	5721	854	5722
Total		12525	12292	12377

More than two-thirds of the net cultivated land would be flood free (F0) in future with project conditions compared to 5 percent in future without project and 6 percent at present. Similarly, cultivated area in medium highlands (F1) will increase by about 20 percent in future with project compared to that in future without project and at present. On the other hand, there will be a significant decrease in the cultivated area in medium lowlands (F2) and lowlands (F3). The risk of flood and drainage problem would be decreased in these lowlands in future with project.

Cropping Patterns and Crop Production
The FCD interventions will increase crop production in the monsoon season and diversify cropping in the dry season. The increase in crop production will result mainly from the decrease in crop production losses by floodings, changes in cropped area, increase in cropping intensity, switching to HYVs in the monsoon season and more non-rice cultivation in the dry season. Future crop patterns and crop production with project are provided in Tables 7.3 and 7.4 respectively. These were determined by adjusting the present crop patterns and crop yield levels according to the flood depths on the cultivated land in future with project.

With the project it is expected that flood protection and drainage improvement would mainly permit timely transplantation of rice, enable HYV to replace low-yielding traditional varieties and secure t. *aman* crops in the monsoon season. It will open an opportunity for farmers to bring more area under t. *aman* rice. Timely transplantation and harvest of the *aman* rice would contribute to increase HYV rice area in the monsoon season. Projected crop calendar in future with project is provided in Figure 7.

By making cultivation timely and secure, farmers will be encouraged to use more intensive cultivation practices with the improved crop management, investment, adaption of the modern technologies and diversification of crops. Higher output in this season may encourage farmers to intensify non-rice crops production in the dry season. This may lead farmers to shift from rice-only production to high value non-rice crops which require small investments, low management and reduced share of irrigation water. The rape and mustard, which are grown as a relay crop between transplanted *aman* and HYV boro, could be grown more widely. These will increase cropping intensity to 2.02 from 1.95 at present and 1.94 in future without project as described in the following section.

Improvement in drainage will save *boro* and *aus* from damage in the pre-monsoon season. Timely cultivation will increase yield levels of t. *aman* rice. There will be a significant increase in total rice production with the increase of t. *aman* crop production. Total rice production per year would increase by more than 15 percent compared to that in future without project. Annual non-rice production will increase by 67 percent.

The agriculture in the project area has a special characteristics; most of the farms are small and mainly produce rice. The cropping systems here need to be directed for the increased non-rice crop production, fodder, fuel and other commodities. Water control through the FCD interventions will have an important role to ensure maximum agricultural land use, timely plantation of crops, improve cropping system, diversify crop production, and higher output per unit area in order to raise the level of well-being of farmers, the rural landless who depend on them for employment, and of the customers who rely on them for food. It is expected that the improvement of the cropping systems will be accompanied by the adoption of modern agricultural technology and more intensive use of labour. This will increase employment, generate higher incomes, and ultimately bring an overall improvement in the quality of life of the people.

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Table 7.3: Projected Crop Patterns - Future With Project (ha)

Crop Pattern	FO	F1	F2	F3	Total
B. Aus-Rabi	187.9	11.1	11.2	-	210.2
B. Aus-HYV T. Aman	161.3	13.6	-	-	174.9
B. aus-Local T. Aman	247.1	10.5	28.3	21.6	307.5
B. aus-Local T. Aman-Rabi	115.6	15.7	1.8	-	133.1
B. Aus-HYV T. Aman-Rabi	301.6	-	-	-	301.6
Local T. Aus-Local T. Aman	81.6	-	-	-	81.6
Local T. Aus-local T. Aman-Rabi	41.7	1.8	-	-	43.5
Local T. Aus-HYV T.Aman-Rabi	7.6	-	-	-	7.6
HYV T Aus-Local T. Aman-Rabi	44.1	33.5	1.0	-	78.6
HYV T Aus-HYV T. Aman-Rabi	108.0	7.0	1.2	-	116.2
Jute-local T. Aman-Oilseed	1.8	18.4	-	-	20.2
Jute-local T. Aman	-	-	1.3	-	1.3
HYV Aman-Fallow	3.3	-	-	-	3.3
Local T. Aman-Fallow	20.4	-	9.7	-	30.1
Local T. Aman-Rabi	68.4	0.7	30.1	-	99.2
Local T.aman-Oilseed-Local/Improved Local Boro	17.7	31.5	-	-	49.2
Local T.aman-Oilseed-HYV Boro	30.5	28.0	-	-	58.5
HYV T. Aman-Oilseeds-HYV Boro	164.7	-	-	-	164.7
HYV T. Aman-Oilseeds-Local/Improved Local Boro	73.0	-	-	-	73.0
HYV T. Aman-HYV Boro	3825.1	778.8	251.9	99.9	4955.7
HYV T. Aman-Local/Improved Local Boro	329.9	139.6	43.4	8.9	521.8
Local T. Aman-HYV Boro	1361.9	273.8	501.9	251.6	2389.2
Local T. Aman-Local/Improved Local Boro	1304.3	164.0	188.6	97.6	1754.5
HYV Boro-Fallow	6.7	24.6	42.4	79.5	153.2
Local/Improved Local Boro-Fallow	5.4	21.3	210.7	294.9	532.3
Vegetables	5.0	8.4	15.6	-	29.0
Sugarcane	0.4	-	-	-	0.4
Fallow	1.4	-	-	-	1.4
Total	8516.4	1582.3	1339.3	854.0	12292.0

Table 7.4: Crop Production - Future With Project

Crop	Flood Damage Free Area			Flood Damage Area			Total	
	Area (ha)	Yield (t/ha)	Prodn (t)	Area (ha)	Yield (t/ha)	Prodn (t)	Area (ha)	Prodn (t)
B. Aus	1127.3	1.80	2029.1				1127.3	2029.1
Local T. Aus	132.7	2.10	278.7				132.7	278.1
HYV T. Aus	194.8	3.90	759.7				194.8	759.7
Local T. Aman	3913.0	2.20	8608.6	1132.2	1.60	1811.3	5045.2	10920.1
HYV T. Aman	5913.5	3.40	20105.1	405.3	2.60	1053.8	6318.8	21159.7
Local/Imprvd Loc Boro	2930.8	2.40	7033.9				2930.8	7033.9
HYV Boro	7721.3	4.60	35518.7				7721.3	35518.0
Wheat	206.9	2.24	463.5				206.9	463.5
Oilseeds	843.8	1.10	928.2				843.8	928.2
Jute	21.5	1.50	32.3				21.5	32.3
Vegetables	267.1	12.2	3258.6				267.1	3258.6
Spice	66.8	4.98	332.7				66.8	332.7
Sugarcane	0.4	22.0	8.8				0.4	8.8

7.3 Impact in Future Without FCD Interventions

Analysis of the recent flood frequency and BBS annual crop production data shows that crop losses would increase in the monsoon season with the increase in recurrence of flood, inundated area and period of inundation in future without any interventions. These would mainly aggravate losses of local t. *aman* and decrease the present area under this crop in lowlands (F3) by 4 percent. Projected crop calendar in future without project is provided in Figure 8. The short growth duration HYV t. *aman* varieties could replace 5 percent of the present local t. *aman* varieties in medium highlands and medium lowlands where drainage occurs relatively early. The improved local varieties would increase by more than 5 percent replacing HYVs in the *boro* season. The reduction of t. *aman* area will result in the decrease of the present rice area by 1 percent and the cropping intensity from 1.95 to 1.94. The future crop patterns and crop production without intervention are provided in Table 7.5 and Table 7.6, respectively. These were determined by adjusting the present crop patterns and yield levels according to the flood depths on the cultivated land in future without project.

Among the non-rice crops, wheat area could increase in future without project by one-third in the highlands where irrigation supply is not adequate for the production of *boro* rice. Increased price and development of road communication facilities would contribute to the expansion of vegetables area by 3 percent replacing oilseed crops in the medium highlands. The total rice production in the project area will decrease by 1.5 percent in future without project compared to the present situation. The wheat and vegetable productions may slightly increase.

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Table 7.5: Projected Crop Patterns - Future Without Project (ha)

Crop Pattern	FO	F1	F2	F3	Total
Mixed B. Aus and B. Aman	-	-	83.5	-	83.5
B. Aus-Rabi	35.1	48.4	81.8	94.0	259.3
B. aus-Local T. Aman	17.9	147.6	145.2	60.0	370.7
B. Aus-Local T. Aman-Rabi	4.0	44.8	5.7	1.5	56.0
B. Aus-HYV T. Aman	21.0	89.8	122.6	30.2	263.6
B. Aus-HYV T. Aman-Rabi	67.3	21.5	12.6	-	101.4
Local T. Aus-Local T. Aman	83.8	-	-	-	83.8
Local T. Aus-Local T. Aman-Rabi	15.8	5.6	23.0	4.8	49.2
Local T. Aus-HYV T.Aman-Rabi	-	-	2.7	-	2.7
HYV T Aus-Local T. Aman-Rabi	40.5	10.3	26.1	17.9	94.8
HYV T Aus-HYV T. Aman-Rabi	8.1	17.3	48.9	32.9	107.2
Jute-Fallow	-	-	9.9	1.3	11.2
Jute-Local T. Aman-Oilseed	1.7	8.1	-	-	9.8
HYV Aman-Fallow	-	-	3.4	-	3.4
Local T. Aman-Fallow	1.1	20.4	12.4	43.2	77.1
Local T. Aman-Rabi	34.0	5.3	27.4	-	66.7
Local T.aman-Oilseed-Local/Improved Local Boro	0.6	33.9	13.3	2.9	50.7
Local T.aman-Oilseed-HYV Boro	4.7	17.3	25.9	11.4	59.3
HYV T. Aman-Oilseed-HYV Boro	1.5	45.8	103.0	9.2	159.5
HYV T. Aman-Oilseed-Local/Improved Local Boro	-	-	2.2	-	2.2
HYV T. Aman-HYV Boro	300.9	415.3	1356.0	923.0	2995.2
HYV T. Aman-Local/Improved Local Boro	-	-	107.5	80.0	187.5
Local T. Aman-HYV Boro	6.7	90.0	1372.0	2699.6	4168.3
Local T. Aman-Local/Improved Local Boro	-	265.4	1012.1	477.5	1755.0
HYV Boro-Fallow	-	6.7	1.9	236.7	245.3
Local/Improved Local Boro-Fallow	3.8	4.4	103.2	970.7	1082.1
Vegetables	-	1.8	2.3	25.4	29.5
Sugarcane	-	0.4	-	-	0.4
Fallow	1.4	-	-	-	1.4
Total	650.0	1300.0	4705.0	5722.0	12377.0

Table 7.6: Crop Production - Future Without Project

Crop	Flood Damage Free Area			Flood Damage Area			Total	
	Area (ha)	Yield (t/ha)	Prodn (t)	Area (ha)	Yield (t/ha)	Prodn (t)	Area (ha)	Prodn (t)
B. Aus	1063.5	1.80	1914.3	71.0	0.87	61.8	1134.5	1976.1
Local T. Aus	117.7	2.10	247.2	18.0	1.60	28.8	135.7	276.0
HYV T. Aus	189.0	3.90	737.1	13.0	3.10	40.3	202.0	777.4
B. Aman	33.4	1.60	53.1	50.1	1.28	64.1	83.5	117.5
Local T. Aman	1033.7	2.20	2274.1	5808.0	1.60	9292.8	6841.7	11566.9
HYV T. Aman	612.2	3.40	2081.5	3210.5	2.60	8347.1	3822.7	10428.8
Loc/Imprvd L Boro	3039.5	2.40	7294.8	38.0	1.81	68.8	3077.5	7363.63
HYV Boro	7067.6	4.60	32511.0	560.0	4.00	2240.0	7627.6	34751.00
Wheat	195.7	2.24	438.37				195.7	438.37
Oilseeds	633.3	1.10	696.60				633.3	696.60
Jute	21.0	1.50	31.50				21.0	31.50
Vegetables	176.2	12.2	2149.64				176.2	2149.64
Spice	44.1	4.98	219.62				44.1	219.62
Sugarcane	0.4	22.0	8.80				0.4	8.80

7.4 Impacts

The agricultural sector will realize the largest impact from the project, mostly from increases in aman crop production during the Kharif II monsoon season. In the monsoon season, benefits will be achieved in the FW project situation due to: i) gains from earlier (i.e., more timely) planting of late (LT) and HYV Aman; ii) intensification of production by switching from broadcast and local transplanted LT aman to HYV aman rice varieties; and, iii) higher long term overall average yields due to reduced flood losses. In the rabi season, improved drainage may protect the irrigated boro crop from damage and facilitate crop intensification through more extensive cultivation of boro rice and rabi season crops. In addition, young aus seedlings will be protected from pre-monsoon rainfall run-off and waterlogging.

During the Kharif II season, crop production will increase by approximately 43 percent. The impact on rice production in the aus and rabi seasons is comparatively very low; production is expected to increase by about 1 percent in each season. However, the project will have considerable impact on the production of non-rice rabi crops which are expected to increase by nearly 47 percent. This increased crop diversification is also considered a benefit of the project.

y2

The project is expected to increase rice crop production from 67,260 MT (FWO) to 77,200 MT FW or 9,942 MT (14.8 percent) and non-rice crop production from 3,544 MT to 5,022 MT or 1,478 MT (41.7 percent) per year. The cropping intensity increases by 4 percent from 1.94 to 2.02. It is also expected that the project will have a considerable impact on the adoption of HYV rice. The ratio of the area under local rice varieties to HYV rice is expected to change from a 60: 40 ratio to a 40: 60 ratio in the FW project scenario.

Additionally, the project will have a considerable impact on agricultural employment in the region. Due to increases in cropping intensity, the demand for labour per hectare of land should increase from an average of 126 to about 137 person days (or 8.7 percent) per annum. Total agricultural employment in the project area is expected to increase from 3.03 million person days to 3.41 million person days per year.

All of these calculations ignore the probability that some flooding is still going to occur, albeit rarely, because of both external (river-flooding) and internal (rainfall) events. To account for this likelihood, all of the preceding projections regarding production and employment should be deflated by about eleven percent (see Section D.5.9).

Additional details regarding the anticipated on-farm impacts are provided in Section D.11 following.

7.5 Adjustments to Increased Agricultural Benefits

There are two required downward adjustments to the basic estimate of net increment of crop production calculated previously. These are:

- The project is designed to give protection against (externally-generated) monsoon floods for a 1:20 year return period. Thus, it is probable that during the 30-year project period the entire crop might still be completely destroyed about 1.5 times. This is mathematically equivalent to a loss of about 5 percent of the incremental net benefit/annum.

- The drainage system has only been designed for a 1:5 year rainfall. This "internal event", therefore, will still generate additional flooding 20 percent of the time irrespective of the flood control measures here being considered. It is expected that this will effectively destroy about 30 percent of the crop affected in this manner. This is mathematically equivalent to about 6 percent of the incremental net benefit/annum.

Table 7.7: Simulated Annual Net Incremental Agricultural Benefit
Base Case - Final Estimate

	Annual Net Incremental Benefit			
	Rice (ton)	Non-Rice (ton)	Net Economic (mtk)	Employment (mpd)
Non-Probabilistic Estimate	9,942	1,478	43.49	0.38
Less Damage from Residual External Flood Probability (5%)	-497	-74	-2.18	-0.02
Less Damage from Residual Internal Flood Probability (6%)	-597	-89	-2.61	-0.02
Base Case - Annual Incremental Benefit	8848	1,315	38.70	0.34

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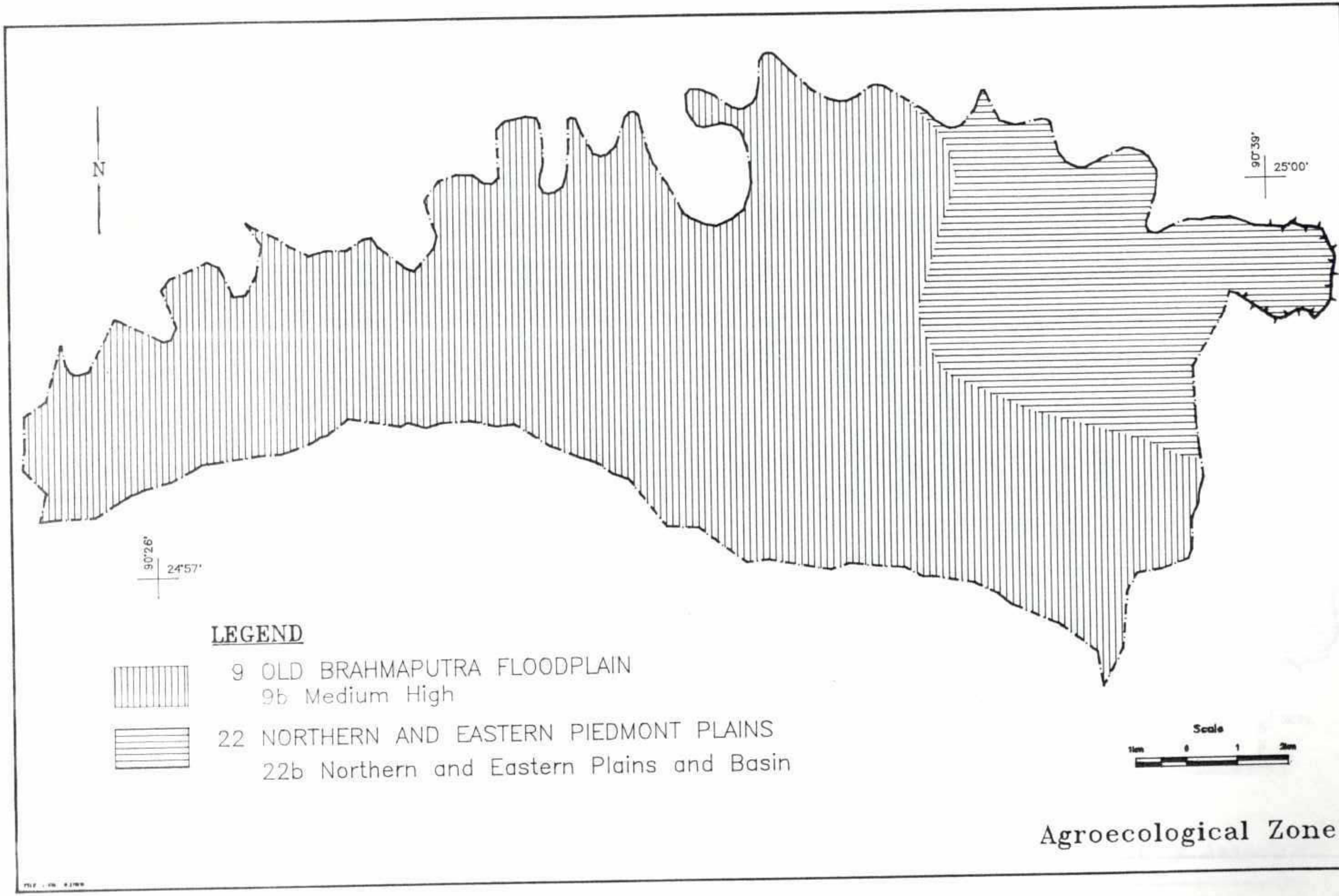
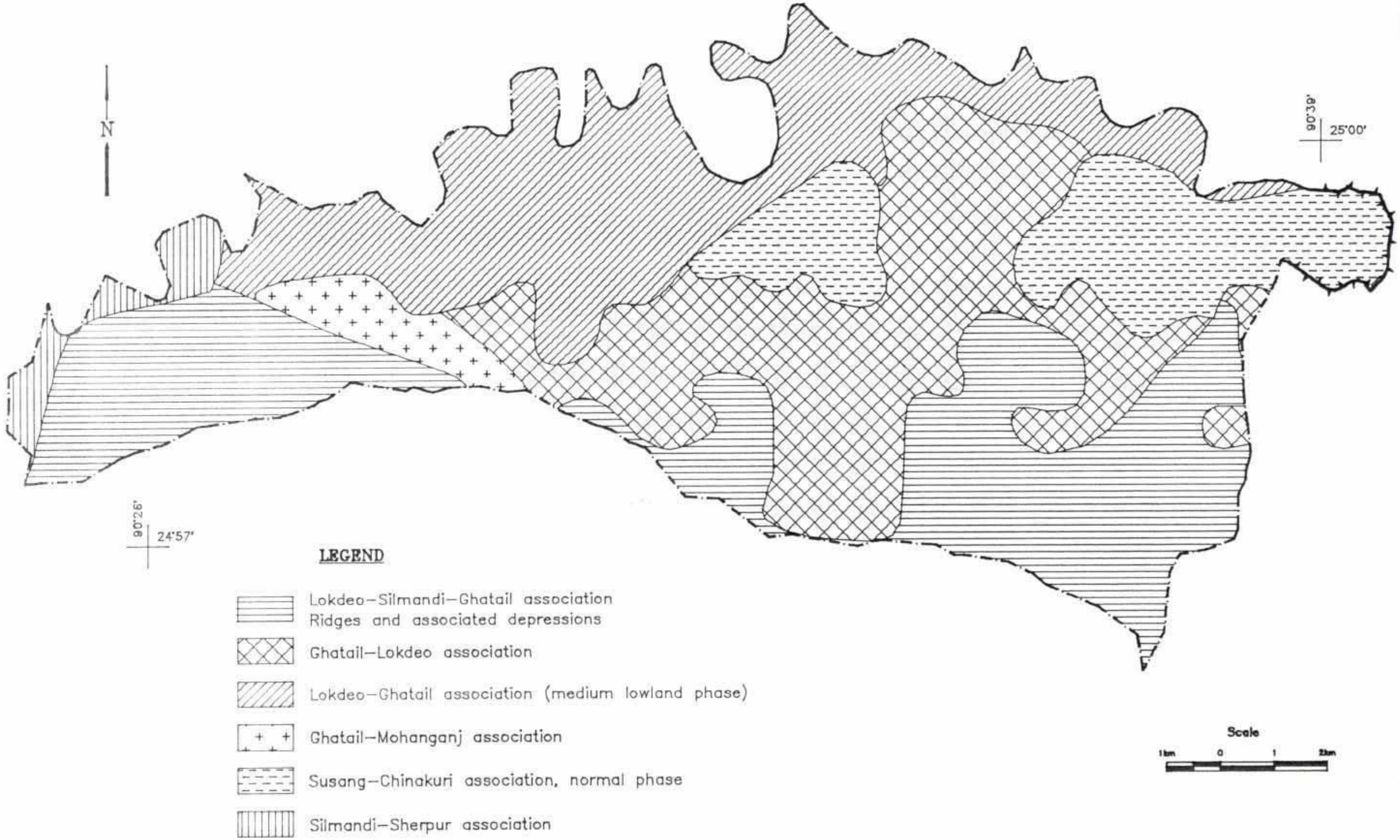
FIGURES

Figure 1



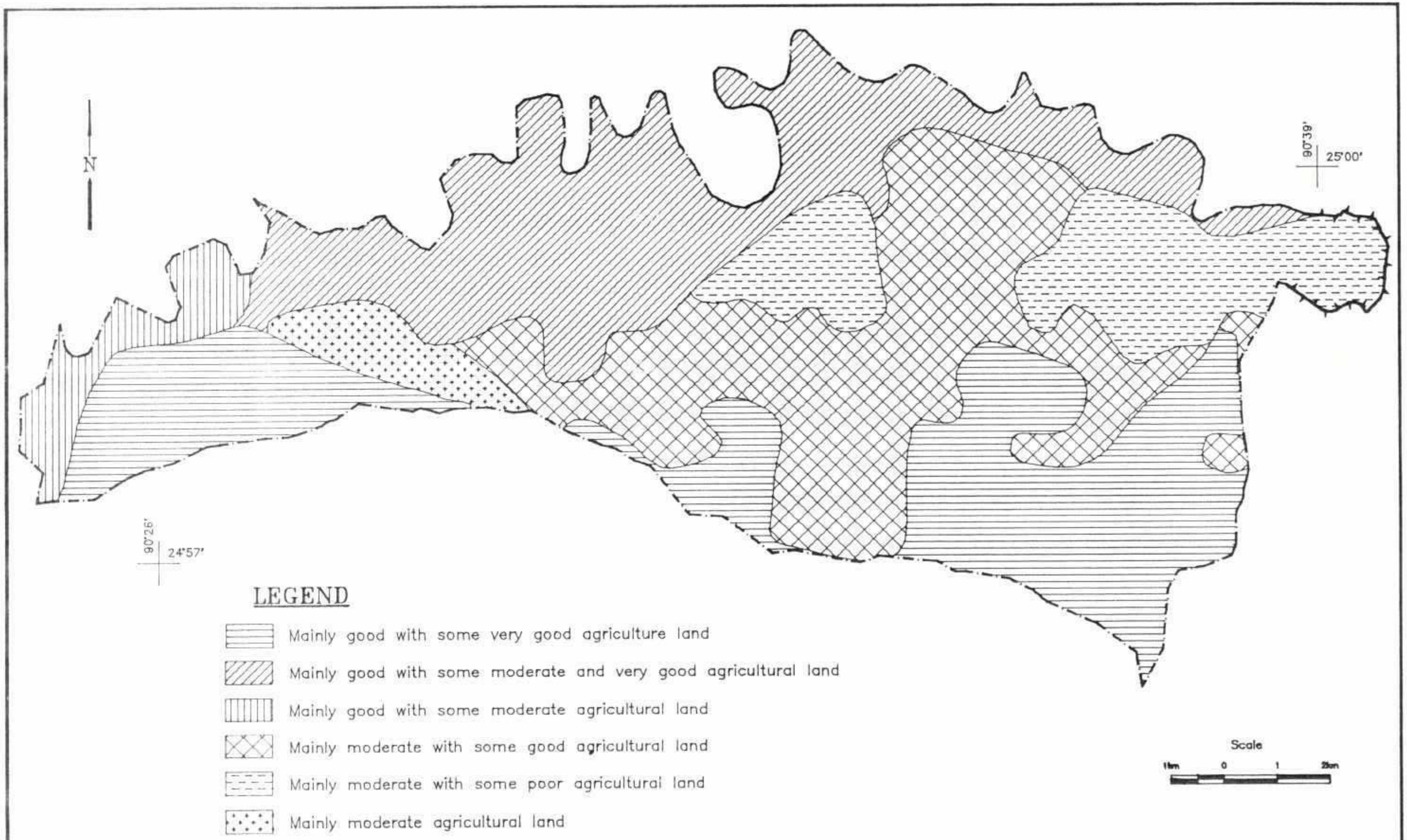
Agroecological Zone



Soil Association

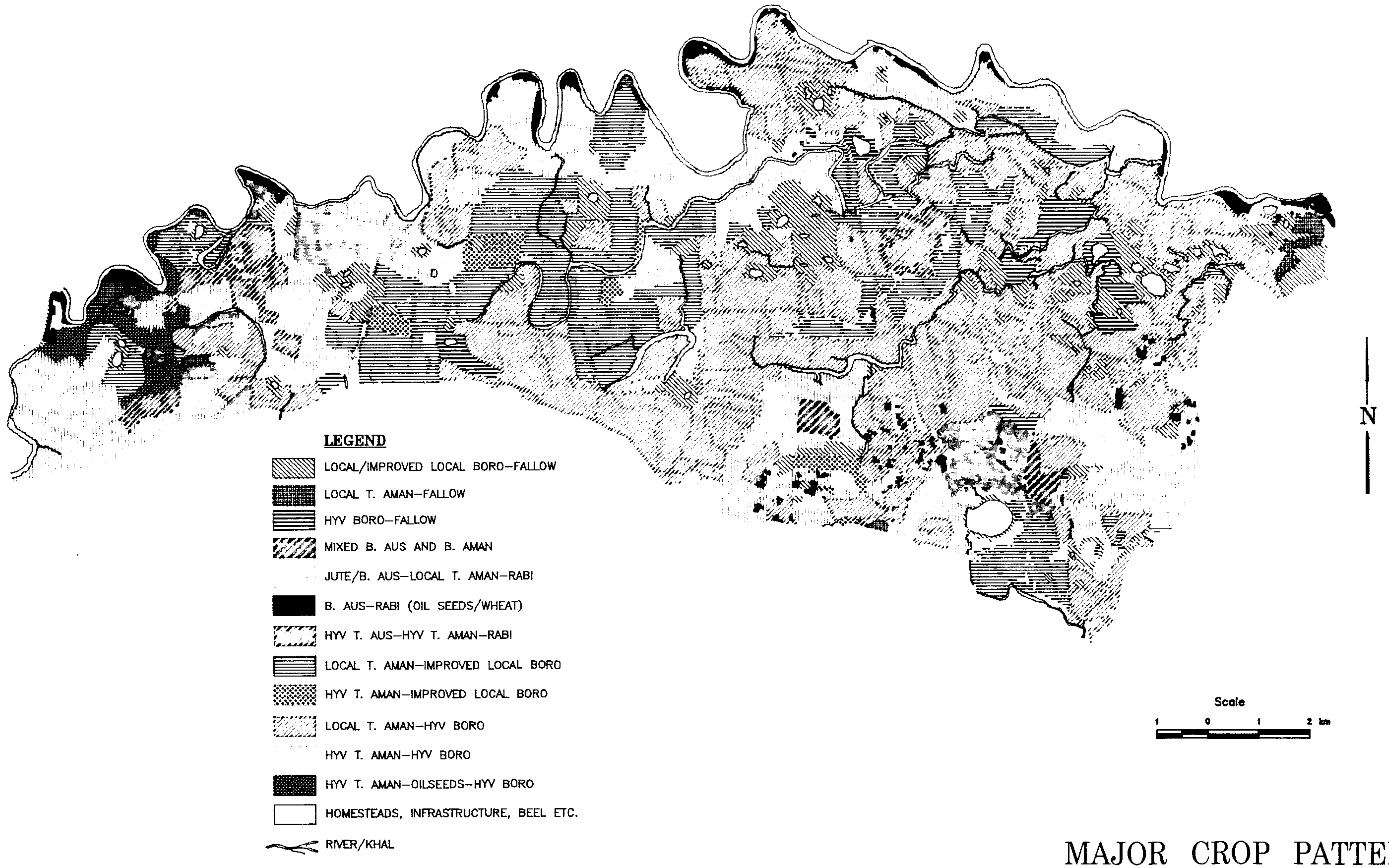
Figure 2

Figure 3



Land Capability Association

Figure 4



MAJOR CROP PATTERNS

Dampara Water Management Project

FILE: PRESENT.DWG

Crop Pattern	Area (ha)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
B. Aus-Rabi	42.1												
B. Aus-HYV T. Aman	25.0												
B. Aus-Local T. Aman	21.4												
B. Aus-Local T. Aman-Rabi	4.7												
B. Aus-HYV T. Aman-Rabi	80.6												
Local T. Aus-Local T. Aman	148.6												
Local T. Aus-Local T. Aman-Rabi	18.8												
HYV T. Aus-HYV T. Aman-Rabi	9.7												
Local T. Aman-Fallow	1.3												
Local T. Aman-Rabi	40.6												
Jute-Local T. Aman-Rabi	2.1												
Local T. Aman-Oilseeds-Local/Imprvd Loc Boro	0.7												
Local T. Aman-Oilseeds-HYV Boro	5.6												
HYV T. Aman-Oilseeds-HYV Boro	1.9												
HYV T. Aman-HYV Boro	359.7												
Local T. Aman-HYV Boro	8.0												
Local/Imprvd Loc Boro-Fallow	4.5												

Present Crop Calendar
FO Land

Dampara Water Management Project

FILE: NERP-420.DWG

Figure 5b

Crop Pattern	Area (ha)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
B. Aus-Rabi	48.4												
B. Aus-HYV T. Aman	91.5												
B. Aus-Local T. Aman	150.3												
B. Aus-Local T. Aman-Rabi	44.8												
B. Aus-HYV T. Aman-Rabi	21.5												
Local T. Aus-Local T. Aman-Rabi	5.6												
HYV T. Aus-Local T. Aman-Rabi	10.3												
HYV T. Aus-HYV T. Aman-Rabi	17.3												
Local T. Aman-Fallow	20.4												
Local T. Aman-Rabi	5.5												
Jute-Local T. Aman-Rabi	7.9												
Local T. Aman-Oilseeds-Local/Imprvd Loc Boro	3.9												
Local T. Aman-Oilseeds-HYV Boro	47.3												
HYV T. Aman-Oliseeds-HYV Boro	45.8												
HYV T. Aman-HYV Boro	352.3												
Local T. Aman-HYV Boro	262.5												
Local T. Aman-Local/Imprvd Loc Boro	170.1												
HYV Boro-Fallow	6.7												
Local/Imprvd Loc Boro-Fallow	4.4												
Vegetables	1.8												
Sugarcane	0.4												

Present Crop Calendar
F1 Land

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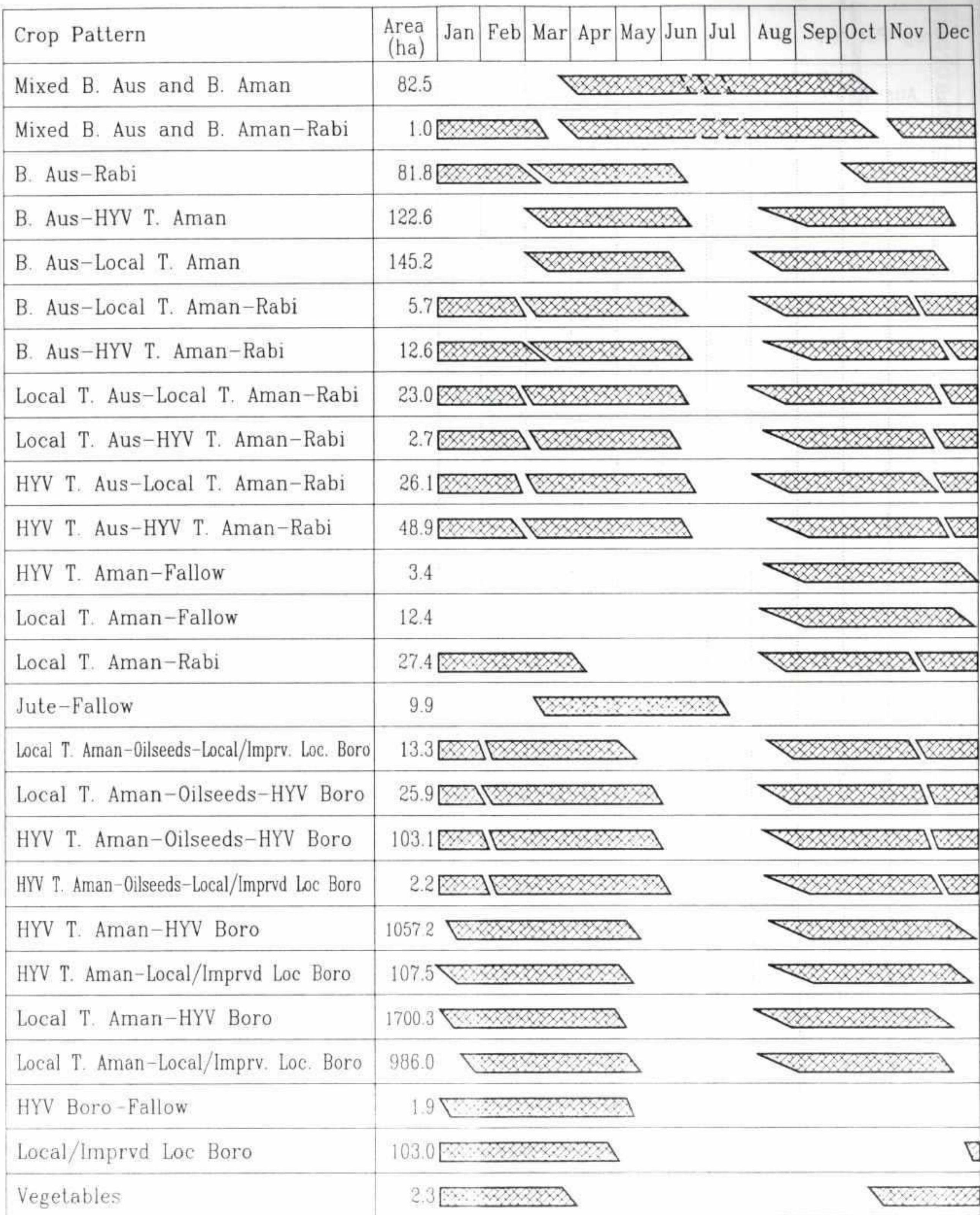
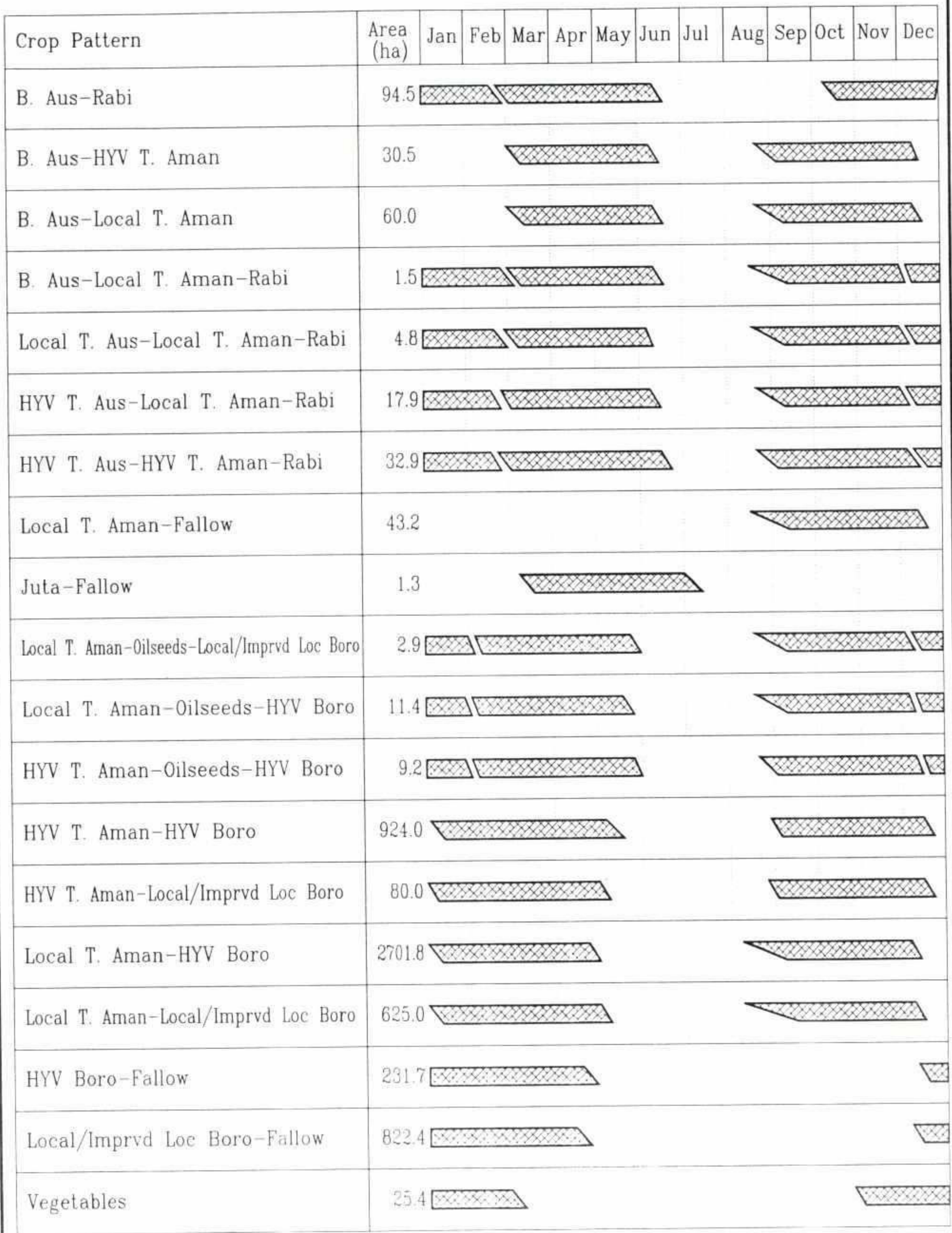
Figure 5c



Present Crop Calendar
F2 Land

Dampara Water Management Project

FILE: NERP-422.DWG



Present Crop Calendar
F3 Land

Dampara Water Management Project

FILE: NERP-423.DWG

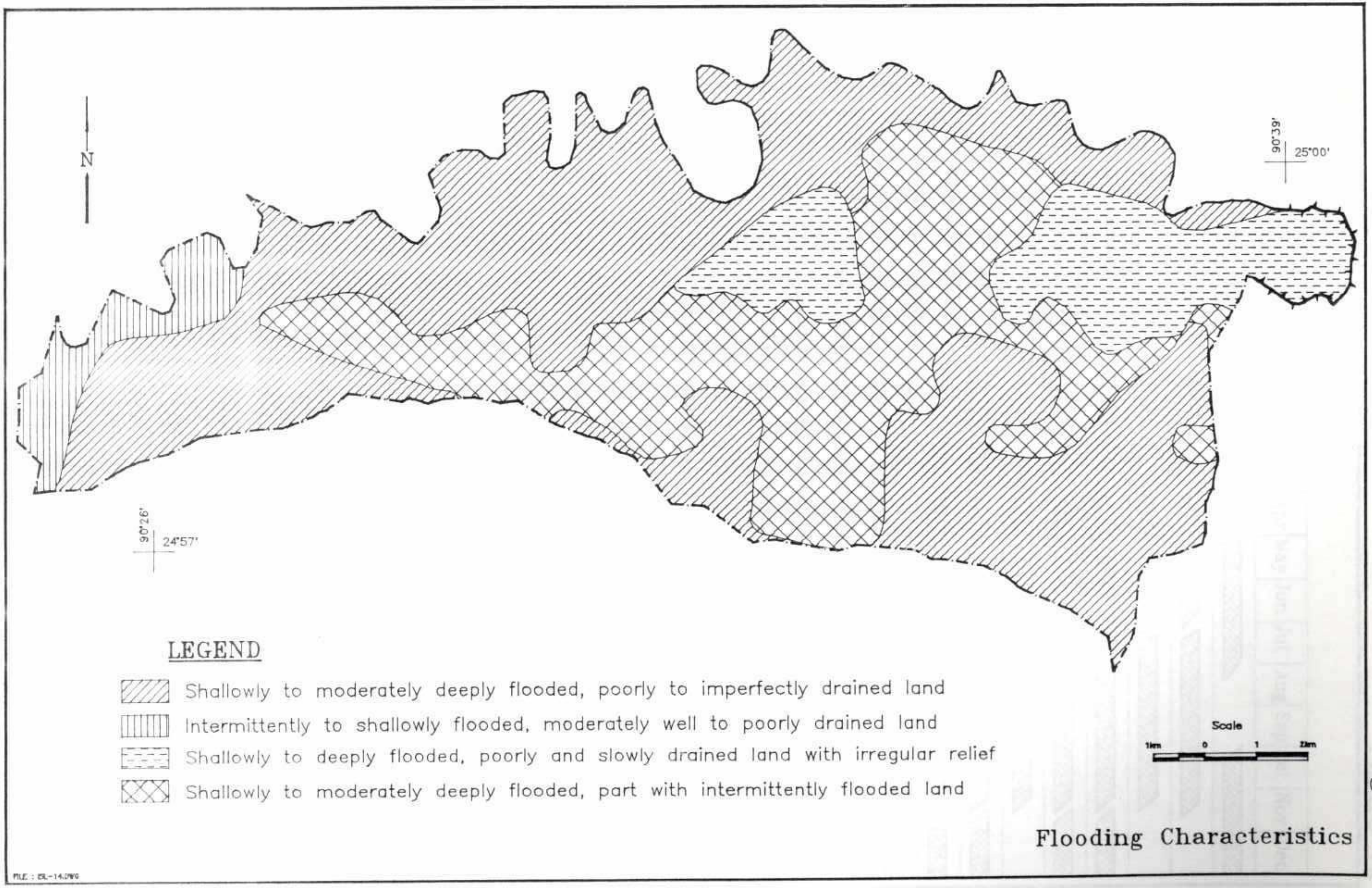


Figure 6

Flooding Characteristics

Figure 7a

Crop Pattern	Area (ha)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
B. Aus-Rabi	187.9												
B. Aus-HYV T. Aman	161.3												
B. Aus-Local T. Aman	247.1												
B. Aus-Local T. Aman-Rabi	115.6												
B. Aus-HYV T. Aman-Rabi	301.6												
Local T. Aus-Local T. Aman	81.6												
Local T. Aus-Local T. Aman-Rabi	41.7												
Local T. Aus-HYV T. Aman-Rabi	7.6												
HYV T. Aus-Local T. Aman-Rabi	44.1												
HYV T. Aus-HYV T. Aman-Rabi	108.0												
Local T. Aman-Fallow	20.4												
Local T. Aman-Rabi	68.4												
Jute-Local T. Aman-Oilseeds	1.8												
HYV T. Aman-Fallow	3.3												
Local T. Aman-Oilseeds-Local/Imprvd Loc Boro	17.7												
Local T. Aman-Oilseeds-HYV Boro	30.5												
HYV T. Aman-Oilseeds-HYV Boro	164.7												
HYV T. Aman-Oilseeds-Local/Imprvd Loc Boro	73.0												
HYV T. Aman-HYV Boro	3825.1												
HYV T. Aman-Local/Imprvd Loc Boro	329.9												
Local T. Aman-HYV Boro	1361.9												
Local T. Aman-Local/Imprvd Loc Boro	1304.3												
HYV Boro-Fallow	6.7												
Local/Imprvd Loc Boro-Fallow	5.4												
Vegetables	5.0												
Sugarcane	0.4												

Projected Crop Calendar in Future With Project
F0 Land

Dampara Water Management Project

FILE: NERP-441.DWG

Crop Pattern	Area (ha)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
B. Aus-Rabi	11.1												
B. Aus-HYV T. Aman	13.6												
B. Aus-Local T. Aman	10.5												
B. Aus-Local T. Aman-Rabi	15.7												
Local T. Aus-Local T. Aman-Rabi	1.8												
HYV T. Aus-Local T. Aman-Rabi	33.5												
HYV T. Aus-HYV T. Aman-Rabi	7.0												
Local T. Aman-Rabi	0.7												
Jute-Local T. Aman-Oilseeds	18.4												
Local T. Aman-Oilseeds-HYV Boro	28.0												
Local T. Aman-Oilseeds-Local/Imprvd Loc Boro	31.5												
HYV T. Aman-HYV Boro	778.8												
HYV T. Aman-Local/Imprvd Loc Boro	139.6												
Local T. Aman-HYV Boro	273.8												
Local T. Aman-Local/Imprvd Loc Boro	164.0												
HYV Boro-Fallow	24.6												
Local/Imprvd Loc Boro-Fallow	21.3												
Vegetables	8.4												

Projected Crop Calendar in Future With Project
F1 Land

Dampara Water Management Project

FILE: NERP-442.DWG

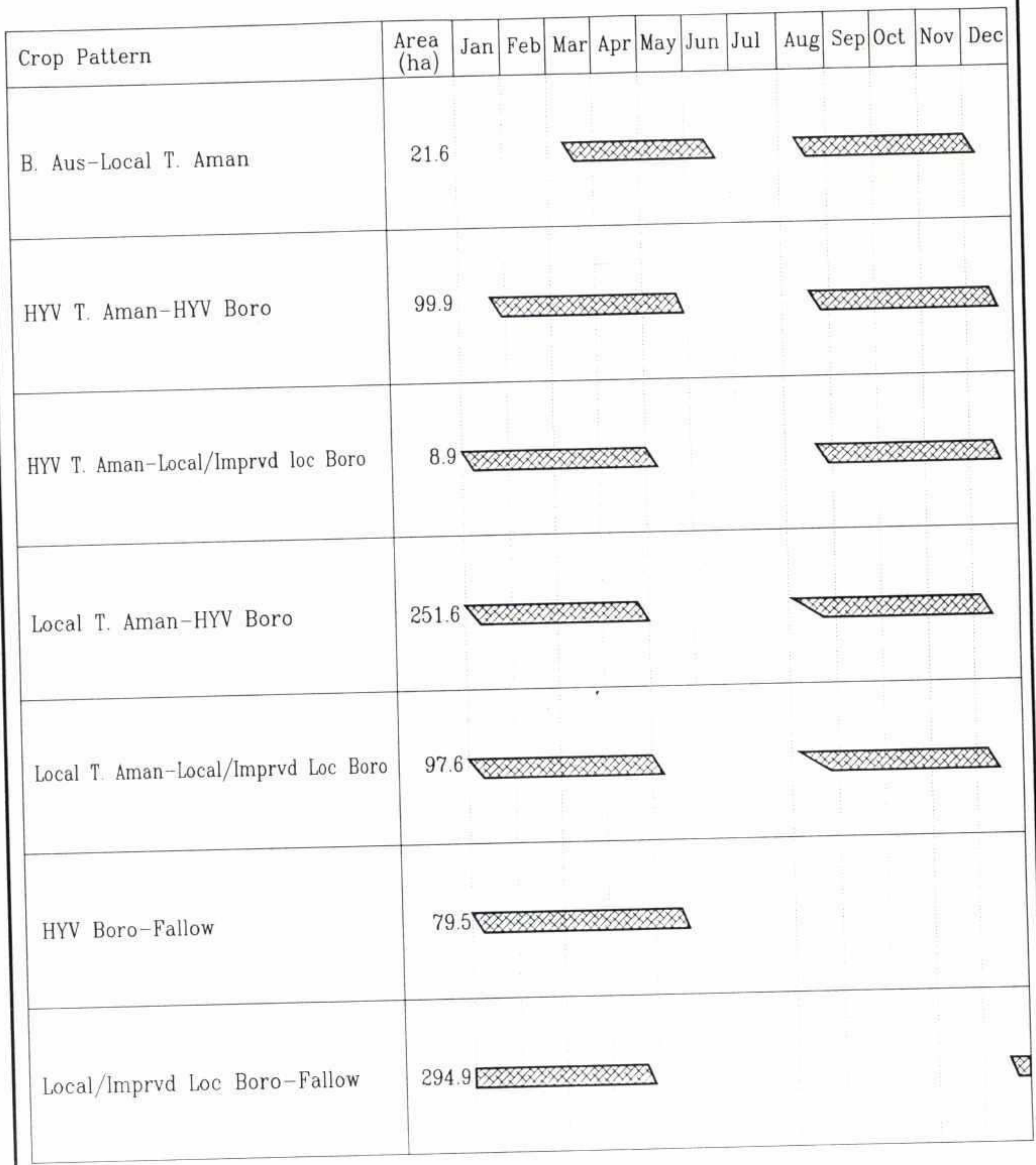
Figure 7c

Projected Crop Calendar in Future With Project
F2 Land

Dampara Water Management Project

FILE: NERP-443.DWG

Figure 7d



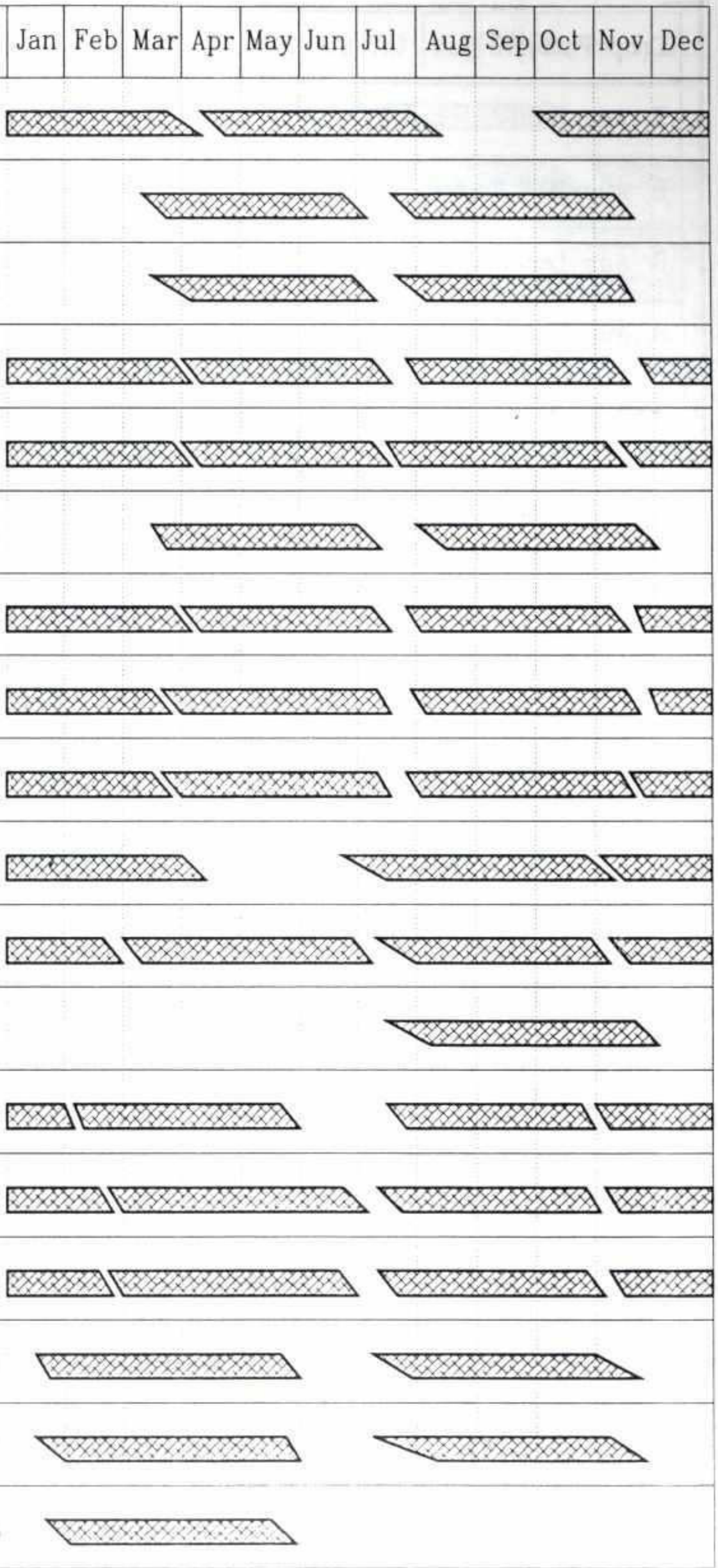
Projected Crop Calendar in Future With Project
F3 Land

Dampara Water Management Project

FILE: NERP-444.DWG

Figure 8a

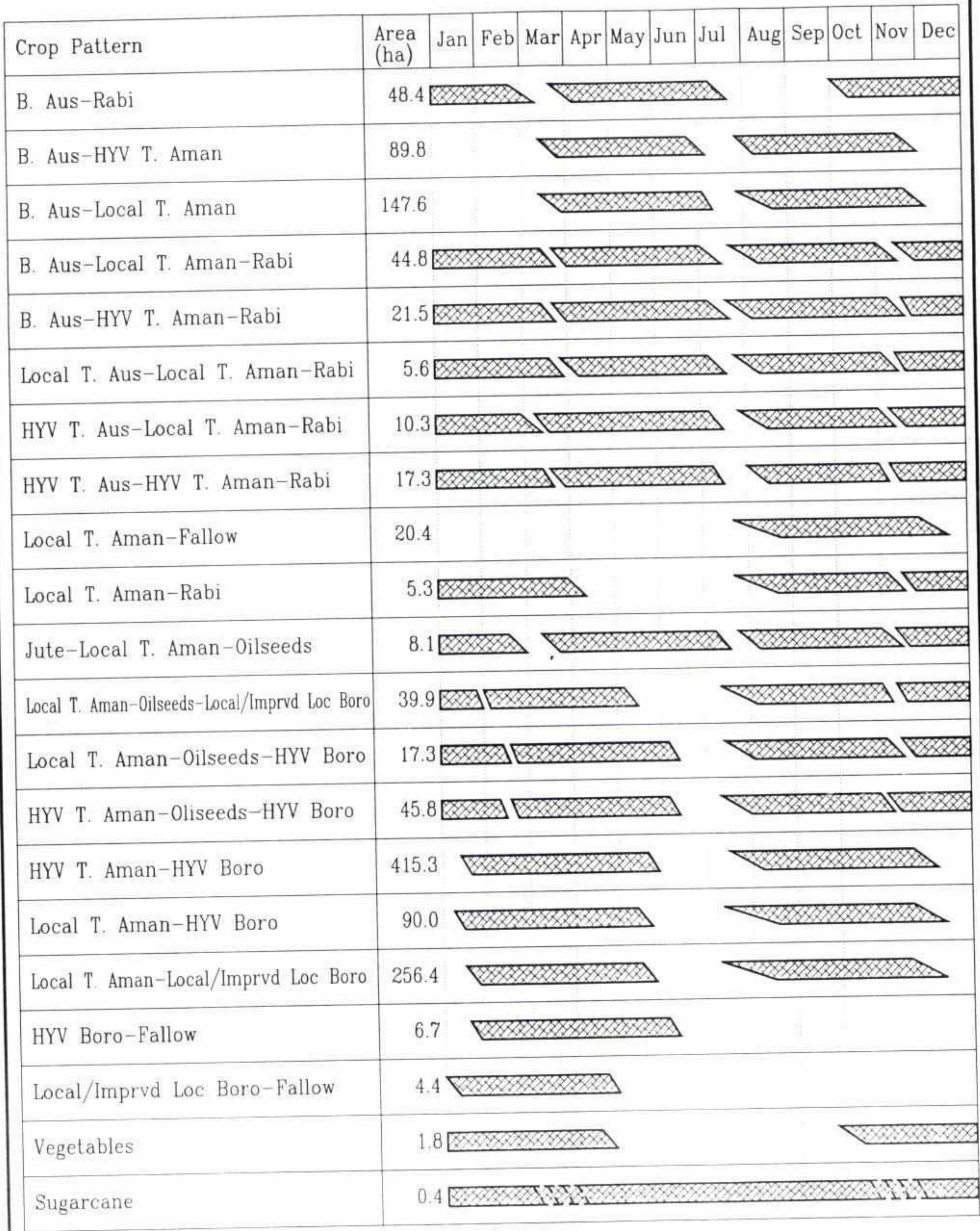
Crop Pattern	Area (ha)
B. Aus-Rabi	35.1
B. Aus-HYV T. Aman	21.0
B. Aus-Local T. Aman	17.9
B. Aus-Local T. Aman-Rabi	4.0
B. Aus-HYV T. Aman-Rabi	67.3
Local T. Aus-Local T. Aman	83.8
Local T. Aus-Local T. Aman-Rabi	15.8
HYV T. Aus-Local T. Aman-Rabi	40.5
HYV T. Aus-HYV T. Aman-Rabi	8.1
Local T. Aman-Rabi	34.0
Jute-Local T. Aman-Oilseeds	1.7
Local T. Aman-Fallow	1.1
Local T. Aman-Oilseeds-Local/Imprvd Loc Boro	0.6
Local T. Aman-Oilseeds-HYV Boro	4.7
HYV T. Aman-Oilseeds-HYV Boro	1.5
HYV T. Aman-HYV Boro	300.9
Local T. Aman-HYV Boro	6.7
Local/Imprvd Loc Boro-Fallow	3.8



Projected Crop Calendar in Future Without Project
F0 Land

Dampara Water Management Project

FILE: NERP-436.DWG



Projected Crop Calendar in Future Without Project
F1 Land

Dampara Water Management Project

FILE: NERP-437.DWG

Crop Pattern	Area (ha)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mixed B. Aus and B. Aman	82.5												
Mixed B. Aus and B. Aman-Rabi	1.0												
B. Aus-Rabi	81.8												
B. Aus-HYV T. Aman	122.6												
B. Aus-Local T. Aman	145.2												
B. Aus-Local T. Aman-Rabi	5.7												
B. Aus-HYV T. Aman-Rabi	12.6												
Local T. Aus-Local T. Aman-Rabi	23.0												
Local T. Aus-HYV T. Aman-Rabi	2.7												
HYV T. Aus-Local T. Aman-Rabi	26.1												
HYV T. Aus-HYV T. Aman-Rabi	48.9												
HYV Aman-Fallow	3.4												
Local T. Aman-Fallow	12.4												
Local T. Aman-Rabi	27.4												
Juta-Fallow	9.9												
Local T. Aman-Oilseeds-Local/Imprvd Loc Boro	13.3												
Local T. Aman-Oilseeds-HYV Boro	25.9												
HYV T. Aman-Oilseeds-HYV Boro	103.0												
HYV T. Aman-Oilseeds-Local/Imprvd Loc Boro	2.2												
HYV T. Aman-HYV Boro	1356.0												
HYV T. Aman-Local/Imprvd Loc Boro	107.5												
Local T. Aman-HYV Boro	1372.0												
Local T. Aman-Local/Imprvd Loc Boro	1012.1												
HYV Boro-Fallow	1.9												
Local/Imprvd Loc Boro-Fallow	103.2												
Vegetables	2.3												

Projected Crop Calendar in Future Without Project
F2 Land

Dampara Water Management Project

Crop Pattern	Area (ha)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
B. Aus-Rabi	94.0												
B. Aus-HYV T. Aman	30.2												
B. Aus-Local T. Aman	60.0												
B. Aus-Local T. Aman-Rabi	1.5												
Local T. Aus-Local T. Aman-Rabi	4.8												
HYV T. Aus-Local T. Aman-Rabi	17.9												
HYV T. Aus-HYV T. Aman-Rabi	32.9												
Local T. Aman-Fallow	43.2												
Juta-Fallow	1.3												
Local T. Aman-Oilseeds-Local/Imprvd Loc Boro	2.9												
Local T. Aman-Oilseeds-HYV Boro	11.4												
HYV T. Aman-Oilseeds-HYV Boro	9.2												
HYV T. Aman-HYV Boro	923.0												
HYV T. Aman-Local/Imprvd Loc Boro	80.0												
Local T. Aman-HYV Boro	2699.6												
Local T. Aman-Local/Imprvd Loc Boro	477.5												
HYV Boro-Fallow	236.7												
Local/Imprvd Loc Boro-Fallow	970.7												
Vegetables	25.4												

Projected Crop Calendar in Future Without Project
F3 Land

Dampara Water Management Project

FILE: NERP-439.DWG