HIS MAJESTY'S GOVERNMENT OF NEPAL

MINISTRY OF WATER RESOURCES

MASTER PLAN STUDY ON THE KOSI RIVER WATER RESOURCES DEVELOPMENT

FINAL REPORT

Volume 4

APPENDIX V
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MARCH 1985

JAPAN INTERNATIONAL COOPERATION AGENCY

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AGRICULTURE DEVELOPMENT

1. SOIL AND LAND USE

1.1 Soil

1.1.1 General

Various reconnaissance surveys have been carried out in the Study area and results of the findings are presented in the following reports:

- Report on the General Reconnaissance Soil Survey of the Eastern Terai Plain in Nepal, 1970, Nippon Koei Co., Ltd.
- Draft Land System Report, 1983, Land Resources Mapping Project
- A Reconnaissance Inventory of the Major Ecological Land Units and Their Watershed Condition in Nepal, 1980, Integrated Watershed Management, Torrent Control and Land Use Development Project, Department of Soil Conservation and Watershed Management, FAO, UNDP
- Soil Survey Reports, Soil Science Section, Department of Agricultural Education and Research, Ministry of Land Reform, Food and Agriculture
  - No. 6 Soil Survey of Japa District, 1966
  - No. 7 Soil Survey of Morang District, 1966
  - No. 8 Soil Survey of Sunsari District, 1966
  - No.11 Soil Survey of Siraha District, 1966
  - No.12 Soil Survey of Saptari District, 1966
- Soil Survey Reports, Forest Resources Survey Office, Department of Forestry.
  - Soil Survey of Janakpur Division, 1970
  - Soil Survey of Hanuman Nagar Forest Division, 1972
  - Soil Survey of Mechi Forest Division, 1974

The present soil study aims to identify major soil groups and their distribution and to justify the suitability of each soil group for irrigation farming on the basis of field investigation and review of previous study reports mentioned above.

1.1.2 General Description of Soil in the Study Area

(1) Soil in the Terai Area

The Terai Area is a part of the Gangetic alluvial plain, bounded by the Siwalik Hills on the northern edge and the Indian border on the south. The Terai Area has been depositing sediments since the Pliocene era. Rivers continue to deposit large sediment loads, and maximum sedimentation thickness is estimated at about 1,600m. Parent materials of soils are sedimentary and metamorphic rocks such as sandstones, silt stones, shales, mica schists, etc. Soil in the Terai Area has developed mostly on recent and sub-recent alluvial sediments, forming nearly level to gently undulating plain. The land is extensively cultivated, although a small portion is covered by tropical deciduous forest.

The Terai Area can be divided into 3 pedogenetic soil types; namely, active alluvial deposits, recent alluvial deposits and older alluvial deposits. And these soil types are generally classified as Entisols, Inceptisols and Mollisols, respectively. Active alluvial deposits are distributed in the lower ground adjacent to major rivers such as the Kamla, Bagmati and Sapt Kosi rivers. These soils consist of coarse sand to loamy sand, and fertility is relatively low due to limited pedogenetic development. Recent alluvial deposits are found in slightly higher areas where greater stability results in somewhat more mature soil development. It is considered that these soils are most suitable for agricultural production in the Terai Area. Older alluvial deposits are the most mature soils and are found in the forest and newly cultivated area adjacent to the Siwalik Hills.

The land of older alluvial deposits is used for rainfed agriculture and forestry. The same has great production potential due to its suitability for irrigated agriculture but attention must be given to erosion control. Out of the total area of about 740,000ha the most predominant soil distribution is Inceptisols (72% of the total area). Mollisols, older alluvial deposits, cover about 19% while the remaining area is covered by Entisols (9%).

(2) Soil in the Hill Area

The Hill area is defined as the area between altitudes of 300-3,000m and according to the report "A Reconnaissance Inventory of the Major Ecological Units and Their Watershed Condition in Nepal", the Hill Area can be divided into 2 areas --the Siwaliks and the Middle Mountains in view of topography and ecology (FIG. 5-1-1).

1) Siwaliks

The borders of the Siwaliks are defined on the south by the Terai Zone and on the north by the Main Boundary Fault which separates the Tertiary bedrocks of the Siwaliks from the Precambrian bedrock of the Middle Mountains.

The major geomorphic process here is rapid river erosion. Almost all the streams meander amongst the Siwalik mountains. Meandering and braiding streams in some of the lower, softer segments of the Siwaliks have sediment loads which exceed their carrying capacity. Lateral planation is an important erosion process in these areas. Chemical weathering coupled with river processes in clay and silt deposits has led to an intricate landscape of narrow gorges, blade-like ridges and broad, braided drainage ways.

Parent materials of soil consist of (interbedded) Tertiary sandstone, siltstone, shale and conglomerate. Ustorthent, Ustifluvent and Ustchrepts are found in the lower Inner Terai, while Dystrochrepts and Ustochrepts are found in other areas.

2) Middle Mountains

This zone is ecologically divided into 3 regions; namely, the Eastern Mahabarat Lekh, Sun Kosi and Arun-Tamur regions.

The Eastern Mahabarat Lekh Region consists basically of a single main ridge and secondary ridges extending from the Sapt Kosi. This region is drained by the Sun Kosi and Tamur on the north and various Terai-Siwalik streams on the south, including the Kankai, Trijuga and Kamla rivers. Parent materials consist of granites and gneisses in the central part and schists and sedimentary rock on the flanks. A group of Ochrepts and Orthents are found in this area.

The Sun Kosi Region is drained by the Sun Kosi River and the major tributaries of the same are the Tama, Khimti, Likhu, and Dudh Kosi. Elevation in this region ranges from 400m along the Sun Kosi to about 3,000m north of Jiri. Parent materials include a mixture of schists, gneisses, augen gneisses, migmatites and phyllites.

The Arun-Tamur Region consists of one basin with the Arun-Tamur rivers under an elevation of 3,000m. This area has a series of faulted nappes forming thrust zones. The Mahabarat Lekh syncline is on the southern border. Parent materials consist of schists and gneisses. Dystrochrepts, Eutrochrepts, Ustochrepts and Ustorthents are found in the Sun Kosi and Arun-Tamur Regions. No significant difference in weathering and pedogenesis is found in comparing these regions. Soil developments are weak because of severe erosion.

The soil of the river valleys are developed on a series of river terraces of Recent and Subrecent alluvial deposits and Subrecent Lacustrane sediments. The terrain is characterised by nearly level to gently undulating eroded and dissected land, flood plains and alluvial fans and cultivation associated with rice, maize, wheat and vegetable crops. The soils of the upland areas in the Middle Mountain zone are developed mostly on metamorphic, sedimentary and igneous rocks. The landscape is very steep to deep and the soils are usually eroded and stony.[1/]

(3) Mountain Soils

Mountain area over 3,000m is underlain by a core of nappes. Main rocks are gneisses with Tibetan sediments, mostly limestones and dolomite, and are distributed along the northern margin of the region. Haplumbrepts and Cryorthents are found in the lowland of the Mountain Area. In the high areas, however, where year-round snow and glacier occur, soils tend to be stony and skeletol.

1/ Nepal Atlas of Economic Development, 1980 HMG

1.1.3 Soil in the Terai Area

(1) General

Soil survey in the Terai Area has been conducted since the 1960s. A soil map of the Terai between the Sapt Kosi an Bagmati rivers was prepared by FAO/UNDP. Soil surveys were also carried out by HMG authorities throughout the Terai Area. Furthermore, a land capability and land system map was prepared under the Land Resources Mappin Project (LRMP). Information from the above is summari ed below.

The soils of the Terai Area are developed mostly on recent and subrecent alluvial sediments and transported by rivers and streams from the Siwalik Hills, Mahabharat and Great Himalayan Mountain ranges. General properties of these soils are of the hydromorphic soil type and sandy loam to clay loam soil in texture (TABLE 5-1-1). Therefore, these soils have relatively high permeability.

The field survey focussed on the following items:

- Confirmation of collected data and information
- Alternation of land utilities
- Identification of soil erosion in the Terai Area

Based on field survey results, most of the existing data and information are considered acceptable and can be used for the selection and delineation of irrigable area. It was confirmed that the LRMP report, in particular, has sufficient information and data for the study. However, considering the present situation of soil erosion, destruction of farmland by small rivers and devastation of forest, the confirmation of actual conditions should be reaffirmed in future.

(2) Delineation of the Reconnaissance Soil Survey Area in the Terai Area

The area for the reconnaissance soil survey is delineated by the Bagmati River to the west, by the Kankai River to the east, by the Indian border to the south, by the Siwalik Hills in the west part of the Sapt Kosi and by the Mahabarat Lekh in the eastern part of the same to the north. The area thus delineated has a gross land area of about 740,000ha ranging in elevation from 60-333m.

(3) Soil Types

As described in section 1.2.1, soil of the Terai Area is divided into 3 pedogenetic soil types. General conditions of each soil are shown in TABLE 5-1-1. Soils in the irrigation study area have been classified according to soil taxonomy (Soil Survey Staff, 1975). Soil taxonomy is not only recognized and understood internationally but also useable in the field where the soil surveyor may have had no experience with the soil landscape. Moreover, this taxonomy should become familiar to the Nepalese and will likely be adopted as a national system. The characteristics of the 3 major soil units in the irrigation study area are presented below.

1) Entisols

Entisols are very common because of the dynamic nature of Himalayan landscape whereby mountain slopes are continually being worn down and sediments are constantly being deposited, thus preventing the soil from developing pedogenetic horizons. They are particularly common on steep slopes, at high elevations and adjacent to major rivers throughout the country.

2) Inceptisols

Inceptisols are the single most common Soil Order in Nepal. Located on slightly more stable landscapes than Entisols, they show distinct weathering in the subsoil. The variety of Inceptisols found is due to differences in climate, slope, and parent material throughout the country.

3) Mollisols

Mollisols are fairly common, especially on the upper piedmont of the Terai Area under forest. They also occur on basic rock types at higher elevations throughout the High Mountain physiographic Region. Type of vegetation, local climate and parent material will determine the presence of Mollisols.

(4) Soil Classification and Conditions

According to LRMP, soil in the Terai Area is also divided into 3 land systems with 3 major soil groups. These 3 land systems are subdivided into 12 land units, each of which has significantly different characteristics that affect land use (TABLE 5-1-2). A soil (land system) map is attached to this report. The area of each district of the above classification is also shown in TABLE 5-1-3.

Soil conditions and land use for each unit are given below.

- 1a Present river channel
- 1b Cultivation impossible due to erosive floods; soil texture is excessively coarse and severe wind erosion of sandy areas occurs in dry season.
- 1c Increasing productivity of grazing land with pasture management; collection of elephant grass for thatch; with proper care, wildlife habitat. Groundwater is available for winter cultivation of high value cash crops with intensive management. Severe river flood virtually every year. Coarse textures limiting dry season cropping possibilities and soil is subject to wind blowing if cleared.
- 1d Severe monsoon flooding with heavy sediment deposit and scouring; any permanent structure could be badly damaged. Coarser upland soils tend to be droughty and subject to wind blowing. Occasional severe flooding precludes heavy capital investment for irrigation. Dike construction for flood protection will be expensive and may be ineffective. Catechu tree (Acacia catechu) plantations would thrive in areas not suitable for cultivation. Crops that can withstand flooding such as rice are appropriate in some 1d units which have slow moving flood waters. Pigeon pea is suitable in faster moving flood water providing flooding does not last for long periods.
- 2a High water table and surface ponding throughout the monsoon precludes all crops but rice; finer textures more difficult to till; winter cropping limited due to poor drainage and heavy soils.
  Introduction of long season, high yielding rice and followed by legumes. With irrigation, suitable for rice/rice/legume;

drainage for upland crops in monsoon is not feasible.

- 2b Upland crops will not grow on these sites between July and September due to ponding; areas adjacent to high relief are subject to gullying. Possibly the best land in the Terai Area for rice or sugar cane production. With increasing cropping intensities, increased use of fertilizers is mandatory. Well suited to irrigation.

- 2c Low areas subject to inundation; if levelled, very coarse subsoils now found beneath ridges may be exposed. Major rivers occasionally change course onto 2c land area.
Highly suited to irrigated agriculture, rice and wheat; groundwater readily available for irrigation; optimum utilization variable from place to place because of differences in drainage and texture.

- 2d Coarse textures and deep water tables result in droughty soils subject to wind erosion if bare; fallow in March through May.
With irrigation and fertilization, can be very productive for year-round production of vegetables, tobacco, fruit trees, etc.; high areas also suited to horticultural crops of high value; best location for north-south roads.

- 3a Serious sheet erosion where areas are overgrazed or bare cultivated without erosion control; newly cleared sites are highly fertile for a few years because of residual organic matter. However, organic matter oxidizes quickly and drastic yield declines occur in 3 or 4 years if fertilizer is not used. With good conservation and fertility management; a diverse range of crops could be grown with high returns. However, with present over utilization of forests adjacent to population centers, some areas are being degraded. Unless alternate timber, fodder and fuel sources are found for people on the Terai, these areas will be required for forest and timber area.

- 3b Generally coarse droughty soils cannot sustain crops through the dry season and have high irrigation demands. Upon clearing, with no protection, the soils are subject to serious surface erosion. Low cation holding capacity is especially limited in this area.
With fertilization, erosion control and irrigation, many of these soils could be

cultivated. Plantation trees would be especially suitable. However, given the present system of management with the already severe shortage of timber, fodder and fuel, these areas should be preserved for forest.

- 3c Areas of high relative relief are subject to gullying; sheet erosion is common with some cleared areas subject to wind erosion. High topographic position precludes gravity irrigation; in some areas portions are subject to wind blowing if in bare fallow in spring. Can support sustained agriculture with proper management. Lack of irrigation water is biggest single limitation to use. Maintenance of soil fertility requires considerable compost additions. At present forest maintenance requires better care of ground cover to prevent surface washing.
  Under present management, timber, fuel and fodder production is critical for adjacent cultivated areas.

- 3d Severe surface erosion precludes clearing for cultivation unless terracing is carried out. Without irrigation droughty soils give low yields.
  The upland ridges should be maintained as forest for erosion control. Natural species such as Aegle spp., Ziziphus spp. and Phyllanthus spp. have considerable value for their fruit.
  The low productivity of these ridge soils precludes their use in agriculture.

(5) Soil Profile Survey

Soil profile survey was carried out on the basis of a Soil (Land System) Map, LRMP, and 23 soil pits which were dug to a depth of about 1-1.5m FIG. 5-1-2

The aim of the soil profile survey was to:

a) identify general soil conditions in the Terai Area;
b) check previous data and information; and
c) pin-point Landsat images and classified soil moisture conditions.

Some typical soil profile surveys are shown TABLE 5-1-3.

(6) Main Features of Soils in the Irrigation Study Area

Concerning soil conditions for irrigation purposes, essential soil properties are important for soil fertility. Fifty-seven samples of known locations and 39 samples of unknown locations which were collected from previous survey reports were identified for judging essential soil properties from the entire irrigation study area. The p^H factor, organic matter cation exchange capacity and water quality are discussed hereinafter.

1) p^H factor

Soil p^H of each rating are shown in the following table. The standard sub-division was applied from the Soil Survey Manual, USDA 1962.

p^H RATING OF SAMPLES

p^H	Rating	Sample Number		Total
		Known Location	Unknown Location	
4.5 - 5.0	Very strongly acid	1	1	2
5.1 - 5.5	Strongly acid	5	9	14
5.6 - 6.0	Moderately acid	12	6	18
6.1 - 6.5	Slightly acid	7	5	12
6.6 - 6.9	Very slightly acid	13	7	20
7.0	Neutral	4	1	5
7.1 - 7.3	Very mildly alkaline	3	3	6
7.4 - 7.8	Mildly alkaline	7	4	11
7.9 - 8.4	Moderately alkaline	4	3	7
		56	39	95

On the basis of the above, the p^H value of the irrigation study area ranges from a low of 4.9 (H_2O) to a high of 8.3. Alkaline soils were found in the area between the Kamla and Bati Balon rivers. The p^H in this area is from very slightly acid to moderately alkaline. Soil of other areas reacted as acid.

2) Organic matter

Contents of organic matter of 96 samples are tabulated on the following page.

ORGANIC MATTER OF SAMPLES

Organic Matter (%)	Rating	Sample Number Known Location	Sample Number Unknown Location	Total
- 1.0	Very low	33	16	49
1.1 - 2.0	Low	18	21	39
2.1 - 4.0	Medium	5	3	8
4.1 - 6.0	High	0	0	0
6.0 -	Very high	0	0	0
		56	40	96

As the above indicates, contents of organic matter range from 0.16 - 3.18%. Presently, organic and chemical fertilizer is not commonly used, and farmers cultivate under the traditional agricultural system. The soil in the Terai Area has not been adequately developed under tropical and subtropical conditions. Accordingly, accumulation of organic matter has not increased while almost all nutritional elements for crops originate from irrigation water. Some forested areas have accumulated organic matter, but the same has decreased due to conversion to agricultural land.

3) Cation exchange capacity (CEC)

The Cation Exchange Capacity (CEC) is the capacity of a soil to absorb or hold cations and to exchange species of those ions in reversible chemical reactions. The CEC provides an indication of the nutrient holding capacity of a soil.

The CEC of 39 samples in the irrigation study area are tabulated on the following page.

CATION EXCHANGE CAPACITY OF SAMPLES

CEC (me/100g)	Rating	Sample Number Known Location	Sample Number Unknown Location	Total
- 6	Very low	8	9	17
6 - 12	Low	8	11	19
13 - 25	Medium	1	2	3
26 - 40	High	0	0	0
40 -	Very High	0	0	0
		17	22	39

The CEC in the above samples ranged from 1.40-15.4me/100g of soil. In general, the CEC value seems to be low. This condition is dependent on the soil texture, clay minerals and organic matter. The soils in the Terai Area are young with fewer characteristics of prolife development which results in low organic content.

4) Water quality

The quality of irrigation water directly affects soil management and crop growth. The main hazard is usually considered to be salinity. The water quality of rivers in the Terai Area and of the Sun Kosi are tabulated in TABLE 5-1-5.

Water flow in the Terai Area is very high quality (C1-S1: USBR rating). Moreover, precipitation in the irrigation Study area exceeds 1,000mm throughout the Terai Area which provides soil with significant flushing each year of any salts that may have accumulated during the irrigation season. Accordingly, potential hazard arising from poor water quality has not been considered.

1.1.4 Land Capability in the Terai Area

The Terai Area is very gentle and flat. The area has relatively uniform topographical and climatic conditions. Concerning pedogenetics, the distribution of soils is very complex due to erosion, sedimentation, meandering of streams and flooding. Land capability in the area was studied by both the USBR land classification approach and Landsat imagery analysis. A description of each method and the results of the same are presented hereunder.

(1) USBR Land Classification System

In the Land Capability Map prepared by LRMP, 2 legends in which 5 categories are used for classification as shown below.

- Land Capability Legend
  - Dominant classes
  - Subclasses (temperture regions)
  - Subdivision (moisture regions)
- Irrigation Classification Legend
  - Dominant classes
  - Subclasses

Upon review of the irrigation study area of the Terai, however, it was concluded that there are no significant differences among 4 of the 5 land categories, excluding the dominant classes of irrigation classification. Accordingly, the irrigation suitability classification for the study was used to identify arable land suitable for irrigated agriculture. The said classification is delineated below.

(2) Irrigation Suitability Classification: Dominant Classes

1	Diversified crops - arable (suitable)
2	Diversified crops - arable (moderately suitable)
1R	Wetland rice - arable (suitable)
2R	Wetland rice - arable (moderately suitable)
5	Nonarable - tentative
6	Nonarable

The results indicate that two classes each exist for diversified crops and wetland rice distinguished by favorable and less favorable physical characteristics. In addition, two nonarable land, classes were also identified.

The area of each classification is shown in TABLE 5-1-6. As the said table shows, about 74% of the total gross irrigable area (under the 450ft contour line) is suitable for cropping and 92% of same can be used for irrigated farming. Therefore, the Study area is judged to be suitable for agricultural development.

(3) Analysis of Landsat Imagery

1) Background of landsat imagery analysis

Recently, landsat imagery has been used for investigation of wide areas such as soil and land utilization, geological resources and environments, etc. Landsat imagery allows investigation of wide area from the same viewpoint, estimation of areas which cannot be surveyed on the ground, and preparation of an image assumed for a certain purpose by computer.

The irrigation study area in the Master Plan is difficult to survey because of the lack of motorable roads. Nevertheless, analysis of the soil conditions is very important for irrigation planning. For this reason the Team used landsat imagery analysis for the proposed Kamla Irrigation Scheme.

The purpose of this analysis was to determine the general conditions of soil for suitability of irrigation in the dry season, and in particular to estimate soil texture from reflection of sunshine. The Team applied analysis of landsat images in the Terai Area from the Bagmati River in the west to the Bati Bharon River in the east. The landsat image which is used for this study is Path No. 151, Row No. 41 and was filmed on 20 March 1977 by Landsat 4.

2) Results of analysis

Soil conditions are divided into six different sections. These conditions and Characteristics for each sections are shown below and TABLE 5-1-7.

Section I River channel and riverbeds; coarse and fine sand, flooding in rainy season and dry in dry season

Section II Fan and high areas and areas where rivers traverse; sandy soil and weak soil profile development, light brownish soil color, difficulty of cultivation in dry season because of silty texture

Section III	Flat alluvial plain; sandy to loamy soil, good soil profile development, relatively dark soil color
Section IV	Flat alluvial plain, silty loam to loamy soil, good soil profile development
Section V	Flat alluvial plain and lower area; loamy to clayey soil, good soil profile development, cultivation difficult in dry season under present conditions.
Section VI	Forest and areas covered by other vegetation; results were not analysed because of vegetation cover.

Based on this analysis, the areas to be covered by irrigation planning are Section III to Section V. Some limitations for irrigation planning are envisioned except where rivers traverse. Section VI, which cannot be analysed because of vegeration cover, is basically fertile due to the high organic matter content from forest and plant decomposition.

The analysis was carried out at the master plan study level and accordingly, information from analysis provides fundamental data. However, information such as soil texture and soil development level are very important components of detailed irrigation planning and should be further studied at the feasibility study level.

1.2 Land Use

1.2.1 Present Condition

(1) General

Information on land use in Nepal, including the Study area, is scarce at present except for some parts of Nepal, data for which were prepared by LRMP as reported in the Land Utilization Report for the Far and Middle Western Development Region 1982Large discrepancies occur in the sources of information. The National Planning Commission (NPC) estimated land use status and changes in Nepal from 1975-80 (TABLE 5-1-8). These estimates show a reduction in the forest area of more than 700,000ha which is equivalent to 5% of the total geographical area or 15% of the former forest area in the country. On the other hand, there has been an increase of more than 800,000ha or 34.34% of cultivated land within the said period.

TABLE 5-1-8 **LAND USE IN NEPAL**

Use	1975		1980		Change	
	km^2	%	km^2	%	km^2	%
1. Forests	48,230	34.19	40,997	29.06	-7,233	-15.00
2. Cultivable Land	23,260	16.49	31,268	22.17	8,008	34.43
3. Area Under Perpetual Snow	21,121	14.97	21,121	14.97	-	-
4. Pasture Land	17,857	12.66	17,857	12.66	-	-
5. Water Bodies	4,000	2.84	4,000	2.84	-	-
6. Settlements and Roads	300	0.21	300	0.21	-	-
7. Others	26,291	18.64	25,516	18.09	-775	-2.05
Total	141,059	100.00	141,059	100.00		

Source: National Planning Commission; The Sixth Plan, 1981

(2) Kosi Basin

Detailed land use status for the Kosi Basin is unobtainable.[1/] The Study Area includes Terai, Hill and Mountain area covering about 40,000km^2 of land from Mt. Everest to the Terai Area. Vegetation and land use patterns accordingly differ greatly respective to ecological zone. Distribution of land area in the Terai, Hill and Mountain Areas is 26.1%, 48.9% and 25.1%, respectively. The farmland ratio of the same is 67.0%, 28.2% and 4.4%, and accordingly, farmland distribution is 728.100ha (54.0%) in the Terai, 574.30ha (42.6%) in the Hills and 45,500ha (4.4%) in the Mountains (TABLE 5-1-9). Definite information on forest conditions in the Project Area does not exist. However, it has

1/ Information on land use including a land use map (1/50,000) on the Kosi Basin is to be completed by the end of 1984 by LRMP.

been estimated that about 300,000ha or less is covered by forest at present which assumes a 15% decrease from 350,000ha in 1975 (TABLE 5-1-10).

(3) Terai

Since 1958, efforts to eradicate malaria have made development of the Terai Zone including the Inner Terai possible in terms of agriculture and human resettlement. Land use problems in the Terai Area have been accentuated by concentration of development within the same over the past two decades. The trend of deforestation and changes in land utilization with new human resettlement activities began only in 1910, and rapid changes in the region's ecology and socio-economic situation have occured only in the last 20 years.

Land use analysis in the Terai Area was conducted based on available data and land utilization maps presented by LRMP. The maps, 1:50,000 in scale, covered about 85% of the irrigation study area in the Terai Area (TABLE 5-1-11). According to analysis, in the irrigation study area, about 695,000ha (76.5%) of land area is farmland, and 138,000ha (15.1%) is forest land (TABLE 5-1-12) while 76,000ha (8.4%) is classified under non-agricultural use such as rivers, roads, residential areas, etc. Out of the total farmland area, 587,000ha (84.4%) is actually used for farm operation due to lack of irrigation water, and other natural and socio-economic constraints.

The most dominant land use type is paddy field, accounting for about 514,000ha (87.6%), while the remaining area is used for cultivation of other cereals and commercial crops (TABLE 5-1-13).

1.2.2 Problems Related to Land Use

(1) Hills

The basic problem of land use is the excessive pressure of population on land resources. This has led to devastation of forest resources, subdivision of agricultural holdings below economically viable limits, as well as to accelerated soil erosion and declining soil fertility and productivity. There is now an apparent shortage of agricultural land. The pressure of population on agricultural land in the absence of other employment opportunities is clearly seen in the very high percentage of population engaged in agriculture.

This pressure has led to the denudation of forest cover on steep hill slopes through slash and burn cultivation and overcutting for fodder and fuel, etc., which cause soil erosion, landslides and loss of fertility. The extension of cultivation to steep slopes and marginal lands has been partly due to the small uneconomic agricultural holdings in the hills. This has contributed substantially to acceleration of soil erosion and depletion of soil fertility. The situation calls for urgent action for stabilization and conservation of land, followed by resource inputs to build up soil fertility.

The conditon of the hill area in future, under normal conditions, would be further worsened as more steep slopes and marginal lands in the hills will be brought under cultivation which will severely aggravate the soil erosion problem; holdings in the hills will be further fragmented, exceeding economic viability; denudation of forest cover on steep slopes will continue causing soil erosion, landslides and loss of fertility; and, widespread underemployment and land hunger in the hills will result in encroachment on more forest areas in the Terai Area.

The worsening situation urgently calls for deliberate planning for optimum land use. It is obvious that the major land uses in the hills are agriculture and forestry.

(2) Terai Area

Land use in the Terai Area is surrounded by many contraversies. The problem is usually posed in the form of a choice between protecting the present forest areas against further encroachment by agriculture on the one hand, versus agricultural development of the entire Terai Area on the other. The problems of Terai land use have been further accentuated by the fact that the development efforts of the past two decades have been highly concentrated in the Terai Area. Demands for land for forestry, agriculture, highways and urban centers have been increasing. Moreover, population in the last 10 years or so has increased enormously and as a result, the balance of the major land using agencies has been upset.

The basic land use problem in the Terai Area is thus connected with increased conflicting demands for land for different purposes. The focal issues concern the setting of boundaries between major land uses and the speed at which the land most suited for a particular use can be developed.

1.2.3. Necessity of Land Use Planning 1/

The question of proper land use planning has often been raised both by researchers and planners. The Sixth Five Year Plan envisages an integrated approach to problems pertaining to environment and land use. However, besides some government endeavours and a few cross-sectional studies examining the resource allocation pattern within an entire farm framework, no substantial effort has been made to develop an optimum land use plan for the whole country. Allocation of land resources for different purposes at the national and farm level results in direct competition between livestock and human population in conpsumption of farm resources, deterioration in environmental conditions, migration to the Terai Area, and declining yield.

The question of land use patterns revolves around the forest and crop-livestock issue. The interdependence between the crop and livestock sub-sector of the agricultural sector is so significant in the farming system that one component cannot be adequately examined without taking into account the other. Any bottleneck in one would affect the whole farming system, especially in the hills. Thus, a balance between these components in terms of land allocation is necessary to achieve the desired level of agricultural development.

1/ Study Proposal, Perspective Land Use Planning, 1983, Agricultural Projects Services Centre (APROSC)

Land vegetation patterns in the hills form a mosaic and the hill ecosystem is generally very fragile. Although stable land use catchment areas do exist, few studies have been carried out in this direction. Moreover, very little has been done by land use planners, on the basis of pointers provided by whatever available data, to improve the land use pattern. Consequently, the question arises as to what minimum ratio between agriculture and forest land should be maintained to achieve sustained growth in productivity without avoidable environmental degradation. This kind of knowledge becomes all the more important from the viewpoint of ecological deterioration, resulting from reckless grazing and collection of firewood and fodder, and negative affects of the same on crop productivity not only in the hills but also in the Terai Area.

There is absolutely no hope for substantially increasing the area of agricultural land in the hills. However, there is a need in the hills to ascertain optimum capacity for the agricultural land use intensity that could be sustained in every ecosystem without ecological deterioration. The absence of extensive areas of undeveloped land of agricultural potential in the Terai Area also warrants the need for this kind of assessment.

The Terai forests are increasingly being cleared for farmland migrants from the hills. Lack of adequate regulation to prevent this encroachment and inadequate land development and settlement efforts to keep pace with demand are responsible for the undesired depletion of forest resources from the Terai Area. The current problem confronting planners is one of a choice between preserving the current forest area from further encroachment by farming, or allowing agriculture to extend over all forest land in the Terai. From a practical standpoint, however, the choice is confined to a relatively small area which could be used either for forestry or for agriculture. In this case, forestry is the obvious choice on the poorer lands while agriculture may be viable over forestry on more fertile lands. For smooth agricultural development not only of the Terai Area but also of the hills, there is, therefore, a need to set boundaries between these two land classes and uses and the pace at which land suitable for agriculture can be developed in the Terai Area.

Crop yields have declined during the last 20 years, more specifically during the Fifth Plan period (1975-1980) when agricultural production declined by an average of 1.1%/year. This declining productivity can be attributed to several factors. In addition to environmental deterioration which is exerting a negative influence on crop productivity, inefficient allocation and management of land resources could be another significant factor. Taking into account the various factors explained above, it is believed that objective land use planning would contribute substantially to solving the various socioeconomic problems that Nepal faces today.

2. AGRICULTURE

The study for irrigation and agricultural planning was carried out in the Terai Area situated between the Bagmati and Kankai rivers with a gross area of 749,000ha. The irrigation schemes proposed in the Study aim to increase agricultural production and thereby improve the living standard of the farmers through the exploitation of water resources in the Kosi River. The present study on agriculture in this area was conducted in order to assess potential productivity and to measure the possible difference in agricultural production with and without project development.

This section presents the results of the agricultural development study covering the present situation of agriculture and future agricultural development programs in the Study area relevant to the irrigation schemes proposed in the Master Plan.

2.1 Agricultural Production in Nepal

2.1.1 Area Under Cultivation

For the purpose of agricultural statistics, Nepal is classified into three different agro-climatic zones according to elevation; namely, the Terai, Hill and Mountain Zones. A comparison of agricultural production in Nepal from 1970-83 was made and the changes in area under cultivation for 5 important food grains in each of the said zones was analysed (FIG. 5-2-1 to 5-2-5). The results of the study are summarized in TABLE 5-2-1.

2.1.2 Crop Production

Crop production, particularly of paddy, wheat and maize is greatly affected by several yield component factors such as drought, unexpected rainfall, pests and diseases. Fluctuations in production of each major crop in the different agro-climatic zones are illustrated in FIG. 5-2-6 through 5-2-10.

According to agricultural statistics, production of paddy in 1982/83 in the Terai Zone was quite low compared with other cropping seasons and was a direct result of drought. Wheat production in the Terai Area from 1970-72 was also notably low, because of untimely rainfall during the harvest season which resulted in a great reduction in quantity and quality of the crop. The results of crop production analysis from 1970-83 are summarized in TABLE 5-2-2.

About 77% of paddy production occurs in the Terai Zone as opposed to a low 2% of national production in the Mountain Zone. Annual paddy production in Nepal is normally about 2,279,000t while wheat production in recent years has reached about 729,000t. Although wheat production in the Terai and Hill Zones has shown marked increase over the last decade, in the Mountain Zone it has been decreasing.

Millet and maize are also important as supplementary food grains, particularly in the Hill and Mountain Zones. Production of these cereal grains in the different agro-climatic zones, however, has been decreasing rather than increasing. Production of barley which has a long history of importance in regional and daily life, has also been decreasing.

2.1.3 Crop Productivity

Crop productivity is a major component in analyzing and forecasting crop production. The results of a comparative study on the productivity of major food crops in the different agro-climatic zones and the Project area are shown in FIG. 5-2-11 to 5-2-15.

The annual yield/ha of paddy in both the Mountain and Hill Zones has tended to decrease. A similar trend is also occuring in the Terai Zone and the Study area. Comparison of paddy productivity in the 3 zones and the Study area revealed that yield/unit area is highest in the Hill Zone and lowest in the Terai Zone and Project area.

In contrast, the yield of wheat/ha is lowest in the Mountain Zone, compared with each of the other zones. Maize, millet and barley productivity is greater in the higher altitude zones than in the Terai Zone, illustrating the fluctuation in crop productivity which occurs according to agro-climatic zones.

2.2 Present Food Balance and Future Forecasting

2.2.1 Present Food Balance

According to analysis of the food balance in Nepal in a recent normal crop production year (1981/82), current production for the entire country exceeds about 20.8% of the total demand. This is due to high production in the Terai Zone which produces about 76.5% of the nation's harvest. As shown in TABLE 5-2-3 and FIG. 5-2-16 however, rice supply in the Hill and Mountain Zones has a deficit of about 18.4% and 15.3%, respectively.

The supply balance of wheat, which is also an important food grain, is some what different. About 63% of the national wheat product is produced in the Terai Zone and 33.8% in the Hill Zone. Both areas have a surplus in wheat production. Production of other food grains, such as maize and millet, and including buckwheat and barley, are deficit in all the agro-climatic zones. From the viewpoint of total food grain supply and demand, there is a surplus of about 11.6% at the national level. In the Terai Zone itself supply of food grains exceeds total demand by about 36.2%. Due to inadequacies of transportation networks and natural constraints, however, distribution of food grains in the Hill and Mountain Zones is inefficient.

2.2.2 Future Food Balance

Future food balance forecasting was analysed with the year 1981/82 as the base year. Actual food balance for the year 1981/82 obtained from the Department of Food and Agriculture Marketing Services, differs from the trend indicated by analysis results. The analysis was based on several assumptions stated below.

a) Annual population growth rate and projected population were based on information obtained by the Agricultural Project Services Centre (APROSC) which assumes average population growth including migration.

b) Increased annual growth of per capita cereal consumption per year was assumed at 1.6kg where per capita consumption is 150kg in the year 1981.

c) The base production level of cereals in edible form was estimated at 2,205,000t per year. This base was computed on the basis of cultivated area in 1981/82 and the average yield during the period from 1976/77 to 1981/82.

d) Gross production was converted to production processed and available for consumption by assuming an overall 15% loss and wastage including animal feed. A conversion rate of 60% was used for paddy, and 90% for other cereals. Seed requirement per hectare was assumed at 55kg for paddy, 45kg for maize, 100kg for wheat and 30kg for millet and barley.

According to the results of analysis, the trend of food balance indicates that the earlier food surplus became deficit in 1982. Future food supply appears to be decreasing with an estimated food grain deficit of 41.7% of the total demand by the end of this century. This trend continues, exceeding 50% in 2005 (TABLE 5-2-4). The above analysis results indicate a similar trend to those of ADB's analysis conducted in 1982 and of the Nepal Agriculture Sector Strategy Study report. These reports estimate that to supply minimum food and nutritional needs, cereal production should at least double from present levels by the year 2000.

2.3. Present Situation of Agriculture in the Study Area

2.3.1 Present Cropping Pattern and Crop Production

(1) Cropping Pattern

Major crops grown in the Study area include both traditional and improved varieties of paddy. With the recent introduction of Mexican varieties of wheat and successful plant breeding, cultivation of wheat has increased rapidly. Several kinds of oilseeds and pulses are also grown as illustrated in FIG. 5-2-17. Jute is grown in the eastern portion of the Study area while tobacco is mainly cultivated in the west. Mono cropping is prevalent, involving about 34.9% of farmland. The ratio of fallow land resulting from lack of irrigation water is calculated at about 15.6% as shown in TABLE 5-2-5.

Double cropping of paddy and oilseeds is prominent including relayed cropping. Paddy/paddy, jute/paddy, and maize/paddy cropping patterns are practiced in areas where irrigation water is available while maize/tobacco and paddy/wheat cropping patterns are practiced in both irrigated and rainfed areas. The total area of double cropping is larger than that of mono cropping, calculated at more than 41.2%.

The area where triple cropping occurs is small, involving only 8.3% of total farmland. This pattern includes paddy/paddy/mixed crops, paddy/paddy/winter cereals, jute/paddy/wheat and maize/paddy/wheat.

(2) Cropping Intensity

Cropping intensity was calculated based on data from the Land Resources Mapping Project (LRMP) and information obtained at the site. Cropping intensity in the case of single cropping was calculated at 100% while that for double cropping was converted to 200%. Cropping intensity for miscellaneous crops is assumed at 125% while, in consideration of crop rotation, the intensity for triple cropping is assumed at 250%. Total cropping intensity of the Terai Area in the 8 districts covered by the LRMP was calculated at 137.8% (TABLE 5-2-6).

(3) Crop Yield and Crop Production

As shown in TABLE 5-2-6, paddy production in the said area is estimated at about 1 million tons involving 62% of the total cropped area. Paddy productivity is low in the Study area at about 1.7t/ha in comparison with the Terai, Hill and Mountain Zones.

Wheat cultivation has been increasing. Cultivated area is still limited, however, due to low availability of irrigation water and lack of a proper sowing schedule to coordinate combined cultivation of long duration paddy varieties which are harvested during the months of November and December. Wheat productivity is low at 1.1t/ha while production reached about 0.1 million tons in the area.

Oilseed crops, particularly mustard, have local importance, but poor management results in yields as low as 0.65t/ha. Maize, millet and barley are supplementary food crops while jute, tobacco, potato and sugar cane are important cash crops in the area. Productivity of these crops is quite low, in comparison with the potential of the same. Pulse yield is estimated at only about 0.35t/ha, although pulses are extremely important in the local diet, supplying about 75% of the total protein requirement.

2.3.2 Animal Husbandry

Livestock are an indispensable part of the agricultural production system in Nepal, providing both food and other products as well as transportation. According to the report on the Nepal Agriculture Sector

Strategy Study, 1982, published by the Asian Development Bank, livestock products are a significant factor in the Nepalese economy contributing about 15% to the overall GDP and 25% to the agricultural GDP.

A major by-product of cattle and buffalo raising is dung used as compost in maintenance of soil fertility and as fuel. The current estimated annual value of cattle dung is about Rs. 150/head. In other words, about 0.83t of compost is produced annually per head of cattle, providing about 4.1kg of nitrogen, 2.0kg of phosphorus and 4.1kg of potassium.

The above study reported that based on the assumptions that 1g of protein is needed per kilogram of human body weight per day, and that the minimum satisfactory protein intake must be obtained from animal sources, present livestock production levels must be tripled by the year 2000 in order to meet food and nutritional needs. There are, however, many problems which must first be resolved and factors which must be improved to achieve the said target. Presently, lack of fodder resources is a major obstacle to the development of animal husbandry.

In the Terai region, deforestation, a result of migration from hill areas and other causes is a serious factor in reduction of fodder supplies. ADB has stated that the present level of nutrition is barely adequate for livestock to subsist on at the present low level of productivity. Fodder utilization is wasteful as 90% of available feed is utilized merely to keep livestock alive while only 10% is used for productive purposes.

The estimated livestock population in the Project districts is given in TABLE 5-2-7. There are about 1,038,600 cattle, 292,400 buffalo, 622,400 goats and 12,000 sheep in the area. Based on the assumption that cattle and buffalo are equivalent to 1 animal unit with 250kg of body weight and goat and sheep represent 0.2 animal units with 50kg of body weight, 1,457,948 animal units are estimated in the area. Livestock population in farmland areas is about 2 animal units per hectare (500kg). The estimated dry fodder requirement per animal unit is 9kg per day. Annual requirement of dry matter for all livestock in the Study area is 4,789,359t while crop residue from all farmland is estimated at about 924,037t. Hence, fodder supply from farmland is only 19.3% of the total fodder requirement.

2.3.3 Agricultural Institutions and Supporting Services

(1) Land Tenure System and Farm Size

Land holding status and farm size are the most important indicator of socioeconomic conditions and future possibility of collecting water service fees from beneficiaries under the Project. Available data is limited, however, to the most recent statistical survey, the National Sample Census of Agriculture 1971/72 conducted by the Central Bureau of Statistics, HMG, Nepal. As tabulated in TABLE 5-2-8, land holding patterns differ, the major pattern being the individual holding pattern, which accounts for about 97.9% of farmland in the Project's districts.

During the rainy season, when farmland utilization is maximum, out of the total number of farm households the landowners ratio is 65.8% with 64.8% of farms managed by landowners themselves. The average size of farms managed by landowners is 1.56ha in rainy season while only 0.447ha of farmland is operated during the dry season (TABLE 5-2-9). The tenant farmer ratio is 11.1%, and the land holding is 12.9% in the rainy season with an average size of about 1.81ha. In the area, there are about 21% of owner-cum-tenant farmers operating about 22.4% of farmland in the wet season. The average farm size operated by those owner-cum-tenant farmers is about 1.69ha in the rainy season. The overall average farm size per farm household including landless farmers in the Project's districts is about 1.584ha during the rainy season and 0.417ha in the dry season which can be converted with a land use intensity of 126.3%. The percentage of landless farmers was a low 2.1% of total farm households in 1971.

Land tenure status varies, having several different patterns with a different ratio of sharing as given on the following page.

- area rented for a fixed sum of cash: 13.5%
- area rented for a fixed amount of production: 4.6%
- area rented for a fixed sum of cash and production: 2.8%
- area rented on a mortgage basis: 0.3%
- area rented on a crop sharing basis: 75.8%
- area rented in exchange for services: 0.8%.

As shown in TABLE 5-2-10, of the majority of landholders, about 65.2% are small landholders owning up to 2.0ha. With increased population growth and migration from other areas, limited land resources will be re-distributed resulting in an estimated average farm size per household of about 0.8ha by the end of this century. For this reason, maximization of land utilization and increased crop productivity are the main targets of Project implementation.

(2) Agricultural Research

Agricultural research in the country is carried out at eight main agricultural stations at Tarahara, Parwanipur, Rampur, Nepalganj, Jumla, Surkhet, Jiri and Dhankuta. These stations serve as experimental sites for national level disciplinary programs and commodity development programs and as centers for technical support and training for extension activities. At the next level are agricultural farms which serve as experimental sites for national level research trials, production and supply of planting materials and provide technical support for the production programs. At several locations, livestock and fishery stations and farms are located together with the crop station and farm. However, integrated research is not conducted. Major agricultural stations and farms concerned in the Study area are tabulated in TABLE 5-2-11. There are several factors which presenly restrict the improvement of crop production as stated below:

1) Production and supply of improved seeds

In Nepal the amount of improved seeds supplied by the Agricultural Input Corporation is quite small. Research indicates that the same supplies only 5% and 1% of total demand for improved wheat and paddy seeds, respectively. The most popular paddy variety in the Project area has been observed as a photosensitive type of Masuri, which has a 165 day growth period, although the original Masuri variety is characteristically photo-insensitive with a crop duration of 135 days. The longer growth period of 165 days for the preferred Masuri variety however, severely restricts the cropping calendar as sowing is undertaken from the middle to the end of June and harvest from the end of November to the middle of December. This affects wheat sowing, making it impossible to sow the same at the most appropriate time. Development and supply of paddy varieties with shorter duration periods is thus of paramount importance in present crop research.

2) Breeding of high yield pulse and flowering synchronization

Current problems in pulse cultivation are low productivity, and non-synchronization of flowering and maturing periods. Realization of the cropping pattern, cropping intensity and crop production proposed under the present Project, combined with breeding experiments, will contribute to the solution of these problems and reduction of production cost.

3) Farmers' income generation plan

A farmers' income generation plan which involves the development and extension of medicinal plants, spice crops or perfume crops should be considered in order to support the increasing population and compensate those who will be resettled for the construction of reservoirs.

4) Fodder crop development

Maximum utilization of non-arable land to grow more fodder crops and trees is also an important area for research and development. In the low altitude areas, the ipil-ipil tree would be an ideal source of fuel and animal fodder and adaptability of the same should therefore be researched.

5) Crop research along the river

In the Study area about 5.6% of land is currently non-arable due to flooding and water logging along the river. Under the Project, some of these areas will be studied for draining and reclaiming and the need for guide banks will also be studied for the alignment of main canals which cross the rivers. These areas may then be used in cultivation of fruit trees and some kinds of vegetable crops, particularly of the gourd family. Trials within each area will be necessary however, before adoption.

(3) Agricultural Extension

A national agricultural extension service is provided under the Department of Agriculture (DA), Division of Agricultural Training and Extension, through offices at regional and district levels. At the regional level, there are Regional Directorates of Agriculture headed by Regional Agicultural Directors (RAD). Under RADs are agricultural production farms (excluding research farms), training centers and district agricultural offices. At the district level, there are district agricultural offices managed by Agricultural Development Officers (ADOs).

In the district agricutural offices, there are Agriculture Officers, Junior Technicians (JTs) and Junior Technical Assistants (JTAs). The number of JTs and JTAs varies from 4 to about 40 depending upon the size of the district, its agricultural potential and ongoing programs. Panchayat Level Agricultural Assistants (PLAAs) and Agricultural Assistants (AAs) are the field extension agents.

The number of agricultural extension personnel in the Terai Area (8 districts) is presented in TABLE 5-2-12.

(4) Agricultural Input Supply

The procurement, storage and distribution of basic inputs for agricultural production in the Study area is in the hands of the Agricultural Input Corporation (AIC). AIC is required to ensure that fair priced fertilizer, seeds, chemicals and implements are available to the farming community at strategic locations in the producing areas. The main distribution channel for the former is through the regional office and branch office of the Agricultural Development Bank of Nepal (ADBN), through the district cooperative union and the Panchayat Sajhas. Mainly fertilizers and improved seed varieties are handled in this way, whereas chemicals are also traded through private retail outlets. In a few cases private dealers are appointed to distribute seed inputs. Fertilizer sales are subsidized and cost the same at each district storage. Transport costs from there to the Sajha and farmers are borne by the former.

Agricultural inputs supplied by AIC in different parts of the country in 1979/80 are summarized below. In terms of value, fertilizers account for more than 90% of the total sales of AIC.

TABLE 5-2-13 **AGRICULTURAL INPUTS SUPPLIED BY AIC, 1979/80**

Inputs	Hills	Kathmandu Valley	Terai	Total
Chemical Fertilizers (mt)	9,593	16,503	24,191	50,287
Improved Seeds (mt)	809	a/	2,103	2,912
Insecticides & Pesticides (Rs '000)	440	a/	1,116	1,556
Agricultural Implements (Rs '000)	492	a/	1,306	1,798

a/ Included under Hill Area
Source: Agriculture Inputs Corporation, Nepal

(5) Agricultural Credit

The Agricultural Development Bank of Nepal (ADBN) is the main source of institutional credit in agriculture; two commercial banks play a minor role in this sector. ADBN extends short, medium and long-term loans to individual farmers, groups of farmers, cooperative societies and village committees. Overall lending has increased considerably over recent years, and now covers about 25% of total agricultural credit needs. ADBN's financial position is sound, and loan recovery has been satisfactory under the circumstances; overdues ran at about 24% of loans outstanding over the past years.

Repayment performance of cooperative societies, however, has been poor and a number of Government programs are underway to improve the functioning of these important groups. Loans are extended by ADBN for a wide variety of purposes, including irrigation, mechanization, warehousing and marketing. Interest rates vary with loan purpose between 11 and 15%; the interest rate for crop loans is 15%. ADBN is making efforts to reach more small farmers directly and recent externally assisted projects are designed to strengthen these efforts. Application procedures for institutional credit are lengthy, so many farmers tend to seek somewhat easier credit from private lenders, although at higher cost.

About two-thirds of the short-term production credit is disbursed by ADBN through the Sajha cooperatives. The Sajha itself disburses the loan to the farmers in kind. Thus, the functioning of this credit provision depends largely on the efficiency of the Sajhas. These, however, have limited commercial orientation, mainly due to the lack of properly qualified staff.

(6) Cooperatives and Sajhas

Sajhas and the cooperatives are grassroot organizations supplying credit and inputs to the farmers.

The establishement of cooperative societies as a means for providing agricultural inputs was first initiated in 1957. Most of the cooperatives were, however, found to be ineffective mainly because of poor management and administration. In order to improve the stagnant condition of the cooperative societies, HMG launched a compulsory cooperative system called the Sajha Programme. The Sajha covered 30 districts, including all Terai districts and 1,350 village panchayats.

The functions of the Sajha Cooperative Societies are credit service, marketing service, and farm and home requisites supply service. The Sajha Cooperative Society also acts as the sole dealer of the Agricultural Input Corporation (AIC), National Trading, Nepal Oil Corporation, Jute Development and Trading Corporation, and the Nepal Food Corporation, etc. at the village level.

The number of Sajha institutions in the Terai Area (8 districts) is listed in TABLE 5-2-14.

2.3.4 Present Farm Labor Conditions

(1) Human Resources

In the Project's 8 Terai districts, there are about 476,672 farm households with a total farm household population of 2,698,592. The average size of farm household is calculated at about 5.67 persons as shown in TABLE 5-2-15. The labor force according to age groups and sex has been assumed as given in TABLE 5-2-16. The potential labor force of the average farm family is estimated at 0.63 persons in the 10 to 14 year age group which is considered to have a 46% labor rate, and 3.00 persons in the 15 to 59 year age group considered to have a 90% labor force rate. Those over 60 years of age, considered to have only a 48% labor force rate, are estimated at 0.25 persons per household. The total labor force of one farm household therefore is calculated at 3.14 persons. Currently in the Project districts, the distribution of farm households per hectare of farmland is estimated at 0.58.

The number of potential working days in one year per farm laborer is estimated at 240 days in consideration of many factors such as farmer's festivals, holidays and non-workable days due to heavy rainfall or heat waves. In the Study area therefore approximately 421 man-days/year/ha have been estimated with the available labor force being distributed over a 12 month period and allowing for a 5% accident and illness rate. From the present cropping pattern and ratio of different crops throughout the year in one hectare of farmland, the total man-day requirement is calculated as shown in TABLE 5-2-17.

The balance of the labor force in the peak months of July and August, which is illustrated in FIG. 5-2-19 is 15% in July and 34.3% in August indicating a surplus potential labor force. In the meantime, during the slack seasons from January to June and September to November, about 70-90% of the potential farm labor force remains untapped.

(2) Draft Animals

In the Study area, bullocks and male buffalos are generally used as draft animals. The number of draft animals available per hectare of farmland is estimated at 0.57 for bullocks and 0.06 for male buffalos. During the survey period, figures concerning the availability of mechanized labor in the area and seasonal supply of draft animals from outside the area could not be obtained. Calculation of draft animals for land preparation, intertillage, hauling of farm products and input materials as well as threshing labor supply was therefore based only on available draft animals. Draft animals were counted by the head for calculation purposes although the general practice in Nepal is to calculate the same in pairs.

For calculation of the available draft animal force/ha, 240 working days per year were assumed per head with a 5% default ratio. The monthly draft animal labor potential is estimated at about 11.97 animal-man-days/ha. The results of the study are shown in TABLE 5-2-18 and FIG. 5-2-20. In the peak month of July when land preparation for paddy cultivation begins, a deficit in draft animals of about 70.4% is indicated. The demand for draft animals is thus concentrated in the said month after the onset of the south-west monsoon.

From the results of the above, it is clear that further survey and investigation will be necessary at the feasibility study stage regarding available mechanized labor and supply of hired draft animals from outside the Study area.

2.4 Agricultural Development Plan

2.4.1 Development Concept and Strategy

In the Sixth Plan initiated in 1980, HMG places greater emphasis on direct productive activities by giving high priority to agricultural development. The agricultural sector is expected to make major contributions to the achievement of Sixth Plan objectives, including an increase in production and export earnings, employment creation, social equity and environmental protection.

Taking into consideration the policy of HMG and the present situation in the Study area, basic strategy for the planning of agricultural development in the same has been formulated as follows:

a) Crop yield/ha and production of crops should be improved through the establishment of a new irrigation system and through introduction of improved farming practices.

b) Crop yield and production should be maximized by full utilization of water resources and optimum application of agricultural inputs.

c) Attention should be paid to the strengthening of agricultural support services, including extension service, credit service, and marketing service.

2.4.2 Development Plan

(1) Proposed Cropping Pattern and Anticipated Yield

1) Selection of crops

Selection of crops for the proposed cropping pattern was based on consideration of natural conditions and local economic need. Accordingly, paddy, wheat and maize were selected as basic crops. Potato and sugar cane are presently important cash crops with future potential while jute is an important industrial crop in the eastern part of the Sapt Kosi River and tobacco in the western part. Oilseeds are one of the important crops for local consumption as well as for commercial use.

2) Proposed cropping pattern

From the viewpoint of distribution of different crops, two cropping patterns are proposed, another for the western study area (FIG. 5-2-21) and one for the eastern (FIG. 5-2-22) both of which are divided by the Sapt Kosi River. The basic pattern is the same for both areas; however, the crops selected are different. Jute will be cultivated in the eastern area and tobacco in the western area.

Single cropping will be limited to sugar cane which is usually cultivated as a perennial crop for three consecutive years. Double cropping patterns will predominate, accounting for 82% of total farmland area as tabulated in TABLE 5-2-19 and 5-2-20, while triple cropping patterns are proposed for 17% of the land area in both eastern and western areas.

In addition to the above mentioned crops, pulses are a promising leguminous crop, high in protein, the use of which will increase soil fertility by providing synthetic nitrogen and organic materials to the soil. Cultivation of 25-27% summer and winter pulses for a 4 year cropping rotation is therefore proposed to recover soil fertility.

3) Cropping intensity

A substantial increase in cropping intensity from the existing 137.8 to 216% is projected under the Project as mentioned in TABLE 5-2-21 and 5-2-22. The major change in cropping intensity with Project implementation will be in cereal grains including paddy, wheat and maize which will increase from the existing 105 to 169% in the eastern area and to 172% in the western area.

(2) Anticipated Yield

Present crop yields in the Study area are low. This is caused by various factors, including lack of technology, inadequate irrigation water supply, poor soil fertility management, segregation of proper varietal characteristics, insufficient application of fertilizer due to economic limitations, and inadequate distribution system.

It is envisaged that Project implementation will result in stable irrigation water supply and improvement of the agricultural input distribution system. In addition, development of support institutions is also expected in such areas as research and breeding activities, agricultural extension, agricultural credit, organization of cooperatives, rural development, agricultural input supply, and marketing. These activities should be pursued prior to, or in conjunction with, construction of the Project's material structures. It is forecasted that demands for food grains will be doubled in the country by the year 2000, the Project's target year for agricultural development.

The anticipated yield of each crop has been projected as given in TABLE 5-2-21, 5-2-22 and 5-2-23. In consideration of yield potential and the envisaged success of the subjects discussed above, these target yields are believed to be reasonable and attainable.

(3) Future Farm Labor Conditions

1) Projection of farm household population

The future population growth rate in the districts in the Study area has been assumed by the Study Team of the Land Use Plan Section, Agricultural Project Services Center (APROSC), Kathmandu up to the year 2006 which is the final year of the expected Tenth Five Year Development Plan. This study forecasts the population growth rate not only in consideration of natural growth but also including migration trends.

For calculation of the future balance of farm labor engaged in agricultural activities, the annual population growth rate assumed by APROSC was adopted for the Study area. It is estimated that the future farm household number for the same will increase from a present estimated number of 403,640 to 759,981. The distribution of farm households/ha of farmland is accordingly estimated at 1.1 and the potential available farm labor force/ha at about 3.43 persons.

2) Projection of draft animal population

It is difficult to predict increases in the number of draft animals in the Study area with the available data as increase in animal population is affected by various factors, including fodder resources, veterinary services, improvement of livestock productivity and social constraints. The livestock population of Nepal, and particularly that of draft animals because of their role in agricultural production, does however, constitute a large potential asset. At the Master Plan study level, the annual growth rate of the draft animal population was tentatively assumed by adopting the annual growth rate of farm household population providing the number of draft animals owned by one farm household remains constant.

The draft animal density/ha of farmland based on the above assumption, was calculated at 1.2 head/ha.

3) Farm labor balance

Manpower

Under the Study, the proposed cropping intensity will increase from the present 137.8% to 216%. On the basis of the proposed cropping pattern and the projected farm household size, the balance of manual labor was calculated as shown in TABLE 5-2-24 and FIG. 5-2-23 for the proposed eastern Study area, and as in TABLE 5-2-25 and FIG. 5-2-24 for the proposed western Study area.

Upon completion of the Project, a deficit of about 14% in available farm labor will occur in the peak month of November both in the eastern and western areas. The greatest demand for labor in this peak month is in harvesting, threshing and transportation of improved rainy season paddy. Another area requiring a large labor input is wheat cultivation including land preparation, sowing, etc. These crops account for about 90% of the total labor requirement. Accordingly, more detailed studies on farm mechanization, manpower sources outside the Study area, etc., are required at the Feasibility Study level.

Draft animals

The animal labor balance differs more than that of manpower in the eastern and western Study areas due to cultivation of different crops and different intensities of the same. However, the peak months for both areas appear to be March, June to July and November as shown in TABLE 5-2-26 and FIG. 5-2-25 for the eastern Study area, and in TABLE 5-2-27 and FIG. 5-2-26 for the western Study area.

During the month of March, the highest demand for draft animals is in land preparation for summer paddy cultivation. In the secondary peak months of June and July, draft animals are mainly utilized in preparation of land for rainy season paddy cultivation. During the month of November, the labor requirement increases resulting in a deficit of close to 80%. Half of the demand for draft animals in November however, is for transportation of farm products.

The possibility of farm mechanization, increased draft animal population and introduction of different modes of transportation to reduce the said deficit ratio are important subjects for analysis at the Feasibility Study Stage.

2.4.3 New Land Development and Resettlement

(1) Past Resettlement Programs

The earliest resettlement effort in the Terai Zone began in the year 1910 with a limitless land ceiling to increase the land revenue. At that time, ecological conditions in the Terai Area were not suited to settlement due to dense forests, poisonous snakes, malaria and wild animals. In 1951, floods, landslides and erosion were caused by heavy rainfall. Adequate food supply became increasingly difficult due to simultaneous increases in population and decreases in agricultural productivity.

The government started the Rapti Valley Multipurpose Development Project in the Inner Terai at Chitwan district in 1956 to alleviate the food shortage. The Malaria Eradication Program was launched in 1958 under the tripartite agreement of USOM, WHO and the Nepal Government. The Nepal Resettlement Company (NRC) was formed in 1965 under the Nepal Company Act 2021 as an executive agency of the government's resettlement program.

At the beginning of the new land resettlement program, 2.68ha of land were distributed to each farm household. The distributed area was reduced to 2.0ha in 1974, and further reduced to 1.0ha in 1978. The International Development Association (IDA) financed NRC's resettlement project, providing 2.25ha farmland as a special project. An Agricultural Officer reported to the Team during the study that the ceiling on irrigated land area for distribution has been kept at 0.3ha since 1982. A summary of the NRC program's progress up to 1980 and of the Development Plan during the Sixth Plan period are given in TABLE 5-2-29 and 5-2-30.

(2) New Land Development Plan

Under the Sixth Plan, the Government has restricted clearing of forest land for agricultural and resettlement purposes and the Team is also following this policy in formulation of its land use plan. The Team must consider and formulate future strategy within limited conditions for the new land development plan, besides the farmers' income generation plan, to accomodate expected resettlers from proposed dam reservoir areas.

It is strongly recommended that study of a new land development plan to utilize currently unused lands for agricultural production be undertaken at the Feasibility Study Stage. Such lands are distributed along the rivers and cover about 6% of land area in the Terai Area.

2.4.4 Measures for Crop Production Increment

(1) General Trends

As stated in a previous section, the forecasted trend for national food balance represents a large deficit. Cultivated land increased by more than 800,000ha from 1975-80 while forest area was reduced by more than 700,000ha. National cultivated area for each major cereal crop has been stable or increasing, particularly in recent years. However, at the same time, major crop production, except that of wheat, fluctuated and declined since 1970. A similar trend occured for crop yield/ha. Wheat production was affected positively by irrigation water availability and negatively by untimely rainfall during maturing and harvesting. In 1970 and 1971 untimely rain during maturing and harvesting periods in the Terai Zone caused low crop production.

Kharif crops (rainfed crops) are quite sensitive to fluctuations in rainfall, as most of the same are dependent on natural precipitation. This characteristic is evident in the Terai Zone where Kharif yield fluctuations correspond to both flood and drought damage. In the year 1972/73 and 1982/83, paddy harvest in the Terai Zone fell noticeably short of the average due to reduction of cropped area and crop yield caused by serious drought. Again, in the year 1978/79, paddy production fell due to limitation of cropped area and yield from flood damage.

(2) Crop Production Component

Crop production fundamentally consists of two major components, i.e., cropped area and yield/unit area. The important factor restricting cropped area is water management, including both shortage and drainage of excess water. Crop yield component factors include water availability, farmers' technology inputs, farmers' incentive, etc. To achieve high crop yield, broad based inputs are required. However, a key factor in the same is water control. Moreover irrigation and drainage are also the basic means to increase production to target levels.

(3) Need for Irrigation

As most cultivation in Nepal is rainfed, crop production is unstable. Due to restriction of land reclamation, erosion of existing farmland, and unstable climate, nation-wide crop production has tended to decline while food demand is rapidly increasing. It is forecasted that food grain production will supply less than 50% of the nation's demand by 2005 even in consideration of natural growth increase in crop productivity. Increased crop production is therefore the most urgent need at this time.

To achieve this, the traditional crop production system should be diversified and modernized. Cropping intensities under rainfed conditions range from 100 to 120% with the success of both first and second crops dependent upon the pattern of monsoon rainfall. With assured supply of irrigation water and provision of drainage as necessary, double or even triple cropping may be possible, increasing cropping intensities to over 200%. At the same time, productivity of each crop will increase due to reduced risk of crop loss from drought. Farmers can thus safely enhance the level and quality of inputs and package practices.

Of the several irrigation development plans in the Study area, the Sun Kosi-Kamla Diversion Plan has the greatest economic riability with the largest irrigation benefit. Moreover, if this project is implemented, the project itself will produce about 746,000t of incremental grain products by 2005, thus supplementing 15.6% of the national food grain deficit. Analysis results show that implementation of this project as soon as possible is an urgent priority.

(4) Measurement for Incremental Production

Of the various alternative irrigation plans under the proposed Sun Kosi-Kamla Diversion Plan, the net command area of 175,100ha between the Bagmati and Kanro rivers has been selected as the optimum plan from an economic viewpoint. Other potentially irrigable areas have also been determined such as the Sun Kosi-Trijuga diversion plan which has a net command area of 17,100ha, and the Tamur-East Terai diversion plan which will serve the eastern area from the Sapt Kosi River with a net command area of 49,350ha.

Assuming that the target year of full agricultural development under the said projects is 2005, estimated cereal crop production is about 446,000t without project and 1,468,800t (TABLE 5-2-28) with project for the area within the above irrigation plans (about 241,550ha). With implementation of these three irrigation plans, about 1,023,000t of cereal products is expected to be made available incrementally by 2005. Food balance forecasting analysis results indicate that by 2005 a deficit equivalent to over 50% of the food requirement will occur if food is not imported.

The envisaged incremental product under these proposed plans may cover about 21.5% of the deficit.

3. IRRIGATION

3.1 Present Status

3.1.1 Terai Area for Irrigation Planning

The Terai Area for irrigation planning is located in the eastern Terai Zone. The area is bordered by the Bagmati River to the west, the Kankai River to the east, the Indian border to the south and the Siwalik Hills in the western part of the Sapt Kosi and the Mahabharat range in the eastern part of the same to the north.

There are numerous rivers and rivulets in the area traversing from north to south. The Sapt Kosi, the largest river in Nepal runs through the area, dividing it into two portions; namely the western area and eastern area. Rivers in the Study area can be classified into three types according to the origin of the river. The Sapt Kosi is the first type of river which has its source in snow and glaciers in the Himalayan Mountains. The second type consists of rivers which have their sources in the Mahabharat range; namely, the Kankai, Kamla and Bagmati rivers. A number of small streams and creeks originating from the Siwalik Hills are classified as the third type. The latter have not been taken into account in irrigation planning as their water value during the dry season is very limited.

Administratively, the area includes 8 districts; Jhapa, Morang, Sunsari, Saptari, Siraha, Dhanusha, Mahottari and Sarlahi. The population of these 8 districts was 3.3 million in 1981 while population of the irrigation study area is estimated to be about 2.8 million of which about 82% is considered to be engaged in the agricultural sector.

3.1.2 Topography and Climate

The districts of the irrigation Study area are located on the Terai, which is bordered on the north by the Siwalik Hills and Mahabharat range, and slopes gradually southwards to the Indian border with a gentle average incline of 1/400. The said plain, which is approximately 75-150m above sea level, is composed of a narrow strip of Himalayan piedmont about 30km in width. The Mahottari hilly area which extends through Mahottari, Sunsari and Morang districts, has scattered forests and sparsely wooded areas. The irrigation Study area, which extends 250km in an east-west direction is traversed by numerous rivers of varying size, including the Sapt Kosi which springs from Tibet, all of which flow south to join the Ganges River. Medium and small-scale flows tend to dry up during the dry season.

The climate in the irrigation Study area is typical sub-tropical monsoon type, with occasional rains starting in May and the southwest monsoon covering the area during June to October. A relatively dry period occurs from November to April under the influence of the northeast monsoon. Mean annual precipitation in the east section of the Sapt Kosi is 1,631mm and in the west 1,265mm, more than 90% of which occurs between May and October. Temperatures rise steadily from a minimum of 8.4°C in January to a maximum of 34.5°C in April. A summary of the climate of the Study area is presented below.

TABLE 5.3.1 **SUMMARY OF CLIMATIC DATA FOR IRRIGATION STUDY AREA**

	Mean Monthly Temperature (°C)		Mean Monthly Rainfall (mm)		Mean Monthly Evaporation (mm)	
	West	East	West	East	West	East
Jan	16.3	15.8	10.3	12.1	58.9	62.0
Feb	18.3	17.8	9.3	10.5	67.2	81.2
Mar	22.9	22.0	12.3	11.5	145.7	142.6
Apr	27.5	26.6	43.6	57.3	201.0	177.0
May	28.4	27.7	81.6	123.8	204.6	182.9
Jun	29.3	28.5	218.3	318.5	171.0	174.0
Jul	28.8	28.5	363.1	465.0	145.7	133.3
Aug	28.6	28.5	280.8	274.7	139.5	127.1
Sep	28.1	27.8	166.3	231.8	120.0	108.0
Oct	26.1	25.5	70.3	96.6	99.2	105.4
Nov	22.1	21.6	5.2	15.0	78.0	84.0
Dec	17.5	17.3	4.2	14.8	65.1	65.1
Total	-	-	1,265.3	1.631.3	1,495.9	1,442.6

3.1.3 Water Sources and Existing and On-going Irrigation Projects

(1) Water Sources

Agriculture in the Study area depends mainly on rainfed cultivation during the wet season in which the majority of annual precipitation is concentrated. Present irrigation systems provide supplemental water to rainfed farmland in the wet season.

In the Study area, there are 4 main rivers which originate either from the Mahabharat range or from the Himalayas; namely, the Bagmati, Kamala, Sapt Kosi and Kankai rivers. Main irrigation projects are located in the downstream reaches of these rivers. However, discharge of the same varies greatly depending on the season, and, with the exception of the Sapt Kosi, about 90% of annual discharge occurs in the wet season from June to December. The remaining 10% is distributed over the 6 month period from December to May.

Water sources for irrigation within the Study area consist of surface water from each river traversing the area including the 4 rivers mentioned above, and groundwater from the right bank of the Sapt Kosi.

(2) Present Condition of Irrigation Projects

Total net command area of existing projects in the Study area is 233,900ha. Of this, 205,400ha, or 87.8%, consists of direct intake irrigation schemes, and 12,200ha (5.2%) consists of project main canals and lift irrigation from each river. The remaining 16,300ha (7.0%) consists of a groundwater irrigation scheme deriving water supply from the Sapt Kosi right bank.

However, the area actually under irrigation is only about 78,100ha or 33.3% of the above 233,900ha of irrigation plans. Moreover, due to shortage of irrigation water supply in the dry season, planned crop intensity is less than 150%, with the exception of the Kankai Irrigation Project (TABLE 5.3.2).

There are seven main irrigation projects in the Study area; namely, Kankai, Sunsari-Morang, Kosi-West Canal, Rajbiraj Pump Canal, Trijuga/Chandra, Kamla and Bagmati irrigation projects. All the project areas are irrigated with surface water by constructing barrages or head works on the upper stream of the main rivers. There are also some small-scale projects which use ground water and surface water. These projects primarily supply supplemental irrigation water during rainy season. Water supply in the dry season is therefore only 10-30%.

Features of the seven major irrigation projects are described hereunder.

1) Bagmati Irrigation Project

The Bagmati Irrigation Project forms the westernmost boundary of the Study area. The command area of the same is located on both sides of the Bagmati River, amounting to 122,000ha. The said area is divided into the right and left bank areas with net command areas of 56,000ha and 66,000ha, respectively.

This project is composed of 2 phases; namely, intake by barrage of Bagmati River natural flow (Phase I) and contruction of a high dam about 2km upstream from the envisaged barrage site and extension of the left bank (Phase II). Although the command area for Phase I is 74,500 and that for Phase II is 47,500ha, the 66,000ha on the left bank are included in the present Master Plan Study area. Of this 66,000ha, the 18,500ha from the Bagmati to the Jhim River is in the Phase-I project area, while the remaining 47,500ha from the Jhim to the Marha River comprises the Phase-II project area.

2) Kamla Irrigation Project

The Kamla Irrigation Project is located on both banks of the Kamla River which flows southwards through the center of the Study area on the west side of the Sapt Kosi River.

Main canals extend on both banks from the head works. The main canal on the right side has a capacity of 12.5m^3/s and irrigates about 12,500ha of paddy in Dhanusha district. The left main canal has the same capacity and irrigates 12,500ha in the Siraha district, thus providing irrigation for a total of 25,000ha (net) of paddy. The main canal length of the right canal system is 5.5km while that of left canal system is about 31km.

The water source in the above area is the Kamla River, and irrigation water is supplied to both banks by means of an overflow weir type barrage equipped with sluice gates and located 1km upstream from the highway which runs in an east-west direction. The project provides supplemental irrigation during rainy season and crop intensity is 125%.

3) Kosi West Canal Irrigation Project and Rajbiraj Pump Canal Irrigation Project

The Kosi West Canal Project consists of diversion of irrigation water from the Bimnagar Barrage constructed near the border of India and Nepal on the Sapt Kosi River (including the Indian area). The command area of the same is approximately 11,300ha on the south side of the main Canal route through Nepal, and maximum design discharge of this canal is approximately $300m^3/s$.

The Rajibiraj Pump Canal Irrigation Project is designed to lift irrigation water from the Kosi West Canal with a pump head of about 16m to irrigate the 11,700ha command area between the Bhati Balon and Kanro rivers. This command area is located on the north side of the above mentioned Kosi West Canal Irrigation Project.

Pump stations are provided to lift water in two steps, 1.4km and 4.66km with a lift of about 9m and 7m, respectively. Main canal length is about 16.3km and maximum design discharge is $11.3m^3/d$.

4) Trijuga/Chandra Canal Irrigation Project

The Trijuga/Chandra Canal Irrigation Project is located on the right bank of the Sapt Kosi River and has a command area of 8,200ha. The said command area consists of an existing irrigated area of 6,750ha and an extension area of 1,450ha at the tail portion of the main canal presently under construction.

The water source for the project is the Trijuga River and irrigation water will be diverted from a weir type barrage constructed in the upper Trijuga River through a main canal about 24km long.

5) Sunsari-Morang Irrigation Project

The Sunsari-Morang Irrigation Project is located on the left bank of the Sapt Kosi River and covers a net command area of 66,000ha out of the gross command area of 107,400ha.

The water source for the same is the Sapt Kosi River and irrigation water is to be supplied via a main canal about 37.9km long from the existing Chatra intake facilities. Maximum discharge capacity of the main canal is $45.3m^3/s$. Construction of the project was begun in 1964 and is still on-going. Area under irrigation in 1980 amounted to 17,000ha.

At present, the project is complicated by sedimentation at the front of the Chatra intake and silt discharge in the canal. Improvement plans to counteract these problems are presently in progress.

6) Kankai Irrigation Project

This project is being implemented as the First Phase of the Kankai Multipurpose Project (33,000kw hydropower; 36,000ha irrigation area; and flood control). The main canal for the net command area of 5,000ha on the right bank of the Kankai River is completed while irrigation works for an additional 3,000ha are presently underway. The 8,000ha included in this project will, with construction of the envisioned dam upstream, be provided with year-round irrigation and accordingly, the same was omitted from the present Study area.

3.2 Planning and Design Criteria

3.2.1 Planning Criteria

(1) Irrigation Study Area

The Study area for irrigation planning extends from east to west for about 250km between the Bagmati and Kankai rivers in the Terai Area. The said area ranges in width from 15-45km from north to south sloping southwards to the Indian border with an incline of

1/200-1/400. Of the 749,000ha of land included within the said area, 620,000ha of existing farmland is considered as a potential irrigation area for the Study. A net command area of 234,000ha (37.7%) is presently covered by existing or on-going projects.

(2) Water Resources

Required irrigation water for the Study area will be supplied mainly from three sources, the Sun Kosi, Tamur and Sapt Kosi rivers. Intake from local rivers in the Terai Area, except the Kamla and Trijuga rivers, was not considered as these local flows tend to dry up during dry season.

(3) Irrigation System and Target

Based on the results of technical and economic analyses, gravity irrigation was selected as the most suitable method for irrigation planning. The upland areas within the command area where gravity irrigation is not possible will be considered for future lift irrigation schemes. Alignment, cross-section and slope of canals will likewise be determined according to technical and economic considerations.

The target for the proposed irrigation plan is facilitation of year-round irrigation, which will result in subsequent increase in agricultural production and alleviation of expected increases in food demand.

(4) Optimum Canal Alignment

Canal alignment has been planned to include as much command area as possible considering technical and economic conditions of the irrigation study area. Canal alignment has been investigated on the basis of a 1/50,000 scale topographical map with a 100ft contour line.

(5) Irrigation Project Area

As mentioned in section 3.5, the 3 areas where on-going or proposed year-round irrigation projects presently exist within the gravity irrigation system (namely, the Kosi West Canal, Sunsari-Morang and Kankai Irrigation Projects) have not been included in the proposed project area. Lift irrigation (Rajbiraj Pump Canal Project) and groundwater irrigation projects, on the other hand, will be considered for possible future integration into the irrigation system of the Study area upon termination of their respective project lives.

Inclusion of the same within the gravity irrigation system is expected to be less costly than rehabilitation and cost for operation and maintenance. The west part of the Study area included in the existing Bagmati Irrigation Project was originally planned as a year-round irrigation project in Phase II of the Bagmati Project in the initial stage. HMG has decided, however, that this area should be designated for supplementary irrigation due to water shortage for the comprehensive Bagmati River Water Resources Development Plan.

(6) Cost Estimates

Preliminary cost estimates have been prepared for all irrigation schemes based on the following conditions:

a) The exchange rate used in the estimation is US$ 1.00 = NRs. 15.60 (end 1983 level);

b) Civil works are to be carried out by international competitive bidding with the contractor supplying heavy construction machinery and equipment;

c) Project costs consist mainly of temporary work, civil work, O/M facilities, administration and engineering costs and physical contingency;

d) Taxes on construction materials, machinery and equipment to be imported from abroad are exempted from the cost estimate;

e) Unit cost rates of civil works have been derived from cost parameters obtained from recently executed or planned irrigation projects in Nepal;

f) Cost estimates are based on price levels at the end of 1983;

g) Administrative and engineering service cost is assumed to be 10% of direct cost including O/M facilities;

h) Annual operation and maintenance cost is estimated to be 3% of direct cost; and,

i) Physical contingency of 8% of total cost is included in the Project cost in view of the preliminary nature of the estimate.

3.2.2 Design Criteria

(1) Data

The following data were available for irrigation planning in the Study area.

1) Maps and photographs

Various maps and photographs were utilized for irrigation planning as set in below:

- Topographical map	scale	1:50,000
- Land utilization map	"	1:50,000
- Land capability map	"	1:50,000
- Aerial photographs	"	1:50,000
- Landsat image	"	1:200,000
- General district map	"	1:250,000

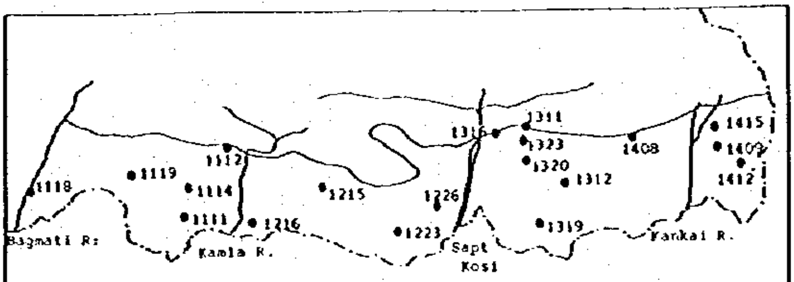
A composite map based on the general district map for each district was used for identification of an irrigation project. Items recorded on the same include major rivers, principal roads and location of district headquarters.

In addition, location of forest areas according to the 1972 Landsat Image and of existing irrigation projects based on previous reports were demarked. Moreover, present farm boundaries were mapped out as a land use distribution map based on the finding of the Study. In planning the irrigation scheme, studies were based on 1:50,000 scale maps.

2) Meteorological and hydrological data

Meteorology

Meteorological data were obtained from 20 meteorological stations as shown in FIG. 5-3-1. However, data from most of these stations were limited almost entirely to precipitation levels. Data necessary to calculate water requirement were obtainable only from Hardinath (Index No. 1114) and Tarahara (Index No. 1320) stations.



Index No.	Meteorological Station	Index No.	Meteorological Station
1111	Janakpur Airport	1311	Dharan Bazar
1112	Chisapani Bazar	1312	Harainaha
1114	Hardinath	1316	Charata
1118	Manusmara	1319	Biratnagar Airport
1119	Gaushala	1320	Tarahara
1212	Phatepur	1323	Dharan British Camp
1215	Lahan	1408	Damak
1216	Siraha	1409	Anarmani Birta
1223	Rajbiraj	1412	Chandra Gadhi
1226	Barmajhiya	1415	Sanischare

FIG. 5-3-1 **METEOROLOGICAL STATIONS IN THE TERAI**

Hydrology

Discharge data collected for irrigation planning in the area are as follows:

TABLE 5-3-3 **GAUGING STATIONS IN THE TERAI**

Gauging Station No. & Name of River	Catchment Area (km^2)	Annual Average ($m^3/s/100km^2$)	Period of Record
Terai			
500 (Bagmati)	585	0.69	1962-74
590 (Bagmati)	2,720	5.89	1965-68
Kamala (Kamla)	1,470	3.04	1956-70
770 (Kankai)	1,150	4.53	1964-69

(2) Calculation of Water Requirement

Irrigation water requirement has been determined on the basis of the proposed cropping pattern and the total anticipated water operation loss including that from canal seepage, etc. The basic factors determining irrigation water demand are consumptive use of water for crops and percolation.

1) Calculation method

The Pan Evaporation Method was used to determine the water requirement since figures for the highest and lowest humidity levels for the calculation by the Modified Penman Method were unavailable. Moreover, the Pan Evaporation Method is used in the Bagmati Irrigation Project.

The command area has been divided into 2 sections, west and east due to differences in climate and crop type, with the Sapt Kosi as the dividing line. Data from Hardinath and Tarahara Stations have been adopted for the west and east section, respectively.

2) Calculation of probable standard year

In determination of the design standard year, the 1/10 probable standard year was calculated on the basis of rainfall data from the Hardinath Meteorological Station (1969-80) for the Sapt Kosi West Zone, and data from the Tarahara Meteorological Station (1971-80) for the Sapt Kosi East Zone.

The probable standard year for each respective area is as follows (Table 5-3-4).

- Sapt Kosi West Zone: 1969
- Sapt Kosi East Zone: 1972

3) Consumptive use of water for crops

The following factors have been used to calculate the consumptive use of water for crops.

Meteorological data

Meteorological data at Hardinath and Tarahara stations including precipitation, temperature, humidity, wind velocity, sunshine hours, and evaporation were obtained, and are compiled in the Data Book.

Calculation of ETo

Reference crop evapotranspiration (ETo) in each month has been calculated by the Pan Evaporation Method. In calculation of ETo in the Sapt Kosi West Zone, the standard year (1969) was adopted for Epan data. Averages from a 10-year period (1971-80) were used to calculate other factors.

In calculation of ETo in the Sapt Kosi East Zone, the standard year (1972) was adopted for Epan data. Averages from a 10-year period (1971-80) were used in calculation of other factors.

Reference crop evapotranspiration (ETo) can be obtained as follows:

ETo = kp · Epan

Where,

Epan = Pan evaporation in mm/day and represents the mean daily value of the period considered

kp = Pan coefficient

Values for kp are given in the following Table.

TABLE 5-3-5 **PAN COEFFICIENT (Kp) FOR CLASS 'A' PAN FOR DIFFERENT GROUND COVER LEVELS OF MEAN RELATIVE HUMIDITY AND 24 HOUR WIND**

Class A pan	Case A: Pan placed in short green cropped area				Case B1/ Pan placed in dry fallow area			
RHmean %		low <40	medium 40-70	high >70		low <40	medium 40-70	high >70
Wind km/day	Windward side distance of green crop m				Windward side distance of dry fallow m			
Light <175	1	.55	.65	.75	1	.7	.8	.85
	10	.65	.75	.85	10	.6	.7	.8
	100	.7	.8	.85	100	.55	.65	.75
	1 000	.75	.85	.85	1 000	.5	.6	.7
Moderate 175-425	1	.5	.6	.65	1	.65	.75	.8
	10	.6	.7	.75	10	.55	.65	.7
	100	.65	.75	.8	100	.5	.6	.65
	1 000	.7	.8	.8	1 000	.45	.55	.6
Strong 425-700	1	.45	.5	.6	1	.6	.65	.7
	10	.55	.6	.65	10	.5	.55	.65
	100	.6	.65	.7	100	.45	.5	.6
	1 000	.65	.7	.75	1 000	.4	.45	.55
Very strong >700	1	.4	.45	.5	1	.5	.6	.65
	10	.45	.55	.6	10	.45	.5	.55
	100	.5	.6	.65	100	.4	.45	.5
	1 000	.55	.6	.65	1 000	.35	.4	.45

SOURCE: FAO IRRIGATION AND DRAINAGE PAPER NO.24

Crop evapotranspiration (ET crop: kc·ETo)

Crop coefficient (kc) value indicates the crop factor which varies according to the crop growing stage. At the time of the Study, no experimental results with regards to crop factor except paddy and wheat were available from the irrigation Study area. Therefore, kc value of each 10 day period in a month has been calculated according to "FAO IRRIGATION AND DRAINAGE PAPER NO. 24".

Percolation in paddy field

In the irrigation Study area, soil types vary from sandy to clayey soils. Data obtained at the Hardinath Pilot Farm was used to evaluate seasonal variation of percolation losses in the paddy field.

Effective rainfall

Based on the basic year, 1969 for the Kosi West Zone and 1972 for the Sapt Kosi East Zone, approximately 80% of the average daily rainfall between a minimum of 5.0mm and a maximum of 80.0mm was adopted as effective rainfall for paddy.

For other crops, the monthly effective rainfall calculated by the USDA and SES Method was used.

4) Field application and conveyance losses

Field application losses

In the case of paddy, a deep percolation loss of 3-6mm was taken as application loss. On the other hand, application loss for upland crops includes deep percolation and surface runoff assumed at 30%.

Conveyance losses

Conveyance losses have been assumed at 25% for paddy and 30% for upland crops.

5) **Calculation Procedure**

Calculation procedures adopted in this Study are as shown in the following equation.

Paddy: CWR = NS + LP + ET + PL
GWR = (CWR - ER) / IE

Upland Crops: CWR = LP + ET
GWR = (CWR - ER) / IE

where,

CWR : Crop Water Requirement

GWR : Gross Water Requirement
NS : Nursery
LP : Land Preparation
ET : Evapotranspiration
PL : Percolation
ER : Effective Rainfall
IE : Irrigation Efficiency

(3) Design of Project Facilities

1) Barrage

Site selection

In selection of the barrage site, the following items were examined:

a) efficient and economical construction work;
b) relationship with main canal alignment; and,
c) accessibility for operation and maintenance.

Basic design conditions

For the preliminary design of the barrage, the following conditions have been established.

Hydrological and hydraulic conditions

In the case of design discharge, the sum of peak water requirement for the irrigation area is taken as the design intake discharge. In the case of design flood discharge, the maximum recorded discharge from previous hydrological data is taken as the flood discharge.

Sediment control facilities

In due consideration of heavy sediment build-up in the river, the barrage is provided with a gate. To determine sediment load, reliable information on the volume and nature of river sediment is needed in the design.

Required facilities for barrage

Other than the intake structure, floodway, scouring sluice and desilting basin, the barrage will be provided with a raftway and fish ladder when judged to be required.

2) Irrigation canal system

Canal system

The irrigation canal system which is planned to distribute irrigation water diverted from the intake structure through the diversion canal, can be classified into the following:

- Main Canal
- Main Secondary Canal
- Branch Secondary Canal
- Tertiary Canal

Canal layout

In this Master Plan, the layout of canals has been made on a map on a scale of 1/50,000 with contour of 100ft. In canal planning, the following matters were taken into consideration:

a) canal alignment is designed to run with the gradient of 1/10,000 along the foothills so as to command as much area as possible;

b) embankment portions have been minimized as much as possible; and,

c) excavated fill has been balanced with fill required for embankment as far as possible.

Design canal discharge

The design discharge for irrigation canals was obtained by calculations based on peak required irrigation water.

Velocity

Calculation of maximum permissible velocity for lined and unlined canals is necessary to prevent scour, while calculation of minimum permissible velocity is required to prevent siltation, growth of aquatic plants and moss. Considering soil characteristics and conditions of aquatic vegetation, the maximum and minimum permissible velocities were determined as follows:

- Maximum velocity	lined (wet brick masonry lining)	1.2m/s (main canal)
	unlined	0.9m/s

- Minimum velocity	lined	0.7m/s (main canal)
	unlined	0.45m/s

Roughness coefficient

The n-value by the Manning Formula was adopted to determine the roughness coefficient of canals as given below:

Main Canal (brick lining)	0.017
Other Canals (unlined)	0.025

Freeboard

Freeboard is normally subject to canal size and location, velocity, water surface fluctuation caused by check gates and wind action, and availability of materials for embankment. Herein freeboard is determined as follows:

$Fb = 0.3 \times h$ where Fb: Freeboard

h: Water level for the respective canal discharge

Tunnel

Tunnels are often used in irrigation systems to introduce irrigation water to areas to be irrigated. In selection of tunnel sites, the following items have first been studied:

a) selection of the shortest distance possible in consideration of geological conditions; and,

b) avoidance of tunnel installation where openings would occur at the conjunction of underground and surface water.

3) Design of related structures

A number of canal structures of various types are required in connection with irrigation canals. The configurations of these structures have been selected in consideration of the functions of the same, canal layout, operational program and social conditions in the Study area.

Check structures

Check structures have been provided where canal water surface adjustment is needed upstream and water control is required downstream of the structure. When canal flow is at partial capacity checks will be designed to maintain the canal water surface elevation required for upstream water deliveries. Checks will also be designed with two or more slide gates combined with stoplogs. The size will be determined by ease of manual operation.

Turnouts

Turnouts have been provided to divert water from secondary canals and tertiary canals. Turnouts will be designed to consist of a conduit for road crossing, a weir combined with staff gauge as a measuring device and one or more slide gates combined with stoplogs. The size of slide gate has been minimized for easy manual operation. All turnouts will be designed to be full at any surface level regulated by the check structure.

Siphons

Siphons are provided where it is difficult to transport water by means of open canals. As there are many rivers in the projected command areas, siphons are provided where canals must cross the same.

Velocity is maximized as much as possible by decreasing the diameter of the siphon to minimize construction costs and siltation. The following standards will be used for siphon design velocity:

- Minimum velocity	1.5 times the velocity in the upstream canal
- Maximum velocity	2.5m/s - 3.0m/s for rectangular reinforced concrete conduits

Culverts

A culvert with a closed conduit conveys canal water under roads and rivers, etc. The design velocity of culverts will average 1.5m/s.

4) Design of drainage canals

Drainage canals will be provided in the upper side of the main canal considering that construction of river crossing structures will not be economical because of numerous rivers and rivulets in the area.

3.3 Possibilities for Irrigation Development

3.3.1 Basic Concept for Development

The project aims to increase agricultural production and thereby improve farmers' living standards in the project area through the development of water resources in the Kosi Basin as well as provision of prerequisite facilities for irrigation and drainage purposes. The project also facilitates the Government policy for realization of social welfare in the project area.

The major concepts for agricultural development in the project area can be summarized as follows:

(1) Unit yield and production of wet season rice should be stabilized and improved through the establishment of new irrigation systems and introduction of improved farming practices.

(2) Planted area in dry season should be increased by a year-round irrigation system thus maximizing total rice production.

(3) Attention should also be paid to the increasing irrigation area up to the possible maximum area in conformity with the government's policy for equalization as well as for maximum total benefits.

(4) Poor drainage conditions should be improved so as to assure high rice productivity under improved irrigation conditions.

(5) Present farm road conditions should be improved and the road network strengthened to stimulate and support agricultural activities.

(6) Agricultural institutions which support agricultural development should be strengthened, especially field level agricultural extension services.

3.3.2 Delineation of Irrigation Area

The irrigation area for the Study was delineated in due consideration of physical constraints and socioeconomic conditions. The rainfed area in the Terai Area is estimated at about 62% of total farmland, and the remaining area is either presently irrigated or planned for irrigation. The area of year-round gravity irrigation within the remaining area accounts for only 15% (excluding the Bagmati Irrigation Project and Rajbiraj Pump Canal Project) of total farmland while 23% of the area accounts for supplemental irrigation.

The proposed irrigation area has been delineated in order to irrigate the majority of the farmland (76.6%) except for the year-round gravity irrigation area and the area between the Ratuwa-Kankai rivers. The said area can be sub-divided into 6 component areas according to geographical location and accessiblity to the water supply sources. FIG. 5-3-2 gives the locations and designations of each component area. Detailed technical figures for each area are given below.

TABLE 5-3-6 **MAIN INDICATORS FOR EACH AREA**

Designation of Component Area	Gross Area (ha)	Irrigable Area (ha)
BM	88,700	66,500
MK	138,200	103,700
KB	99,000	74,300
BN	44,200	33,200
NS	33,200	24,900
SR*	71,500	53,600
Total	474,800	356,200

* This area includes 9,400ha (SR-3) along the left bank of the Sapt Kosi, which is a part of the Sunsari-Morang Irrigation Project, but not fully irrigated.

3.3.3 Considered Water Sources

In view of topographical and geographical conditions, possible water sources for irrigation in the delineated area include on the Sapt Kosi right bank either diversion from the Sun Kosi to the Kamla and Trijuga rivers or direct irrigation water intake from the Sapt Kosi River, and on the Sapt Kosi left bank, supply from the Sapt Kosi or the Tamur River.

The Agricultural Development Plan which utilizes the water resources of the Kosi River in the area of the Sun Kosi and Sun Kosi-Trijuga diversion schemes was studied in 1972 by the Food and

Agricultural Organization (FAO). Under the said schemes, water from the Sun Kosi is to be diverted for irrigation of the Terai Area at two points along the southern meandering portion via diversion tunnels which will connect the Sun Kosi with the Kamla and with the Trijuga tributaries, respectively, at the points of least distance between the same. Taking into account the above, diversion of irrigation water from the Sun Kosi River and the Sapt Kosi River was studied in irrigation planning for the Sapt Kosi West Zone. In the case of the Sapt Kosi East Plan, diversion of irrigation water from the Sun Kosi and Tamur rivers near the proposed Mulghat dam was studied.

3.3.4 Determination of Project Area

(1) Project Area Formulation

The irrigation Study area is divided into 3 separate irrigation schemes in consideration of possible alternative sources from the Kosi and other rivers traversing the area from north to south. Component areas BM, MK, KB and BN will be covered by diversion from the Kurule site on the Sun Kosi River to the Kamla River. River discharge of the Kurule site for this component area on the Sun Kosi River is abundant and, even during the driest month, April, discharge is approximately $130m^3/s$. Under the present plan, this abundant discharge will be diverted via a diversion tunnel about 16.6km long through the Mahabharat range from the Sun Kosi River to an upstream tributary of the Kamla River. Irrigation water will be supplied to the Terai Area on both banks of the Kamla River. Possible irrigation area comprises about 356,200ha between the Bagmati and Kanro rivers.

Component area NS will be covered by diversion from the Sun Kosi River to the Trijuga River or Sapt Kosi River. This component area covers a gross area of 33,200ha which lies between the Kanro and Sapt Kosi rivers and is divided into 2 areas, north and south (Component NS-1, NS-2) by the Trijuga River.

Component area SR will be covered by direct intake from the Sapt Kosi River or diversion from the Trijuga River to the Terai Area on left bank of the Sapt Kosi River. The same component area consists of 71,500ha of the Terai Area excluding the forest zone and the existing Sunsari-Morang Irrigation Project (I.P) between the Sapt Kosi and Ratuwa rivers. The above area can be further divided into 3 areas consisting of Component SR-1 between the Sansari-Morang Irrigation Project (I.P) and the forest zone spreading east to west along the northern Terai Area, Component SR-2 between the Sunsari-Morang I.P and the Ratuwa River, and Component SR-3 along the Sapt Kosi River.

The three irrigation schemes are delineated from west to east as follows:

- Sun Kosi Multipurpose Scheme
- Sapt Kosi West Irrigation Scheme
- Sapt Kosi East Irrigation Scheme

The command area of each scheme, was formulated to obtain maximum irrigation area.

(2) Alternative Plans

Alternative plans were developed for each of the above mentioned irrigation schemes by using the different Kamla river intake levels for the Sun Kosi Diversion Scheme and the different diversion plans for the Sapt Kosi West and Sapt Kosi East Irrigation Schemes.

Particularly in the case of the Sun Kosi Diversion Scheme, potential irrigation area is extensive and the area under irrigation will vary greatly according to the amount of diversion from the Sun Kosi River. In order to maximize irrigated area, construction of a dam on the Kamla River to store irrigation water can also be considered. These and other possibilities must be thoroughly studied in order to determine optimum irrigation scale.

For the Sun Kosi Multipurpose Scheme, three alternative cases were studied to determine the appropriate design irrigation area; namely, the area including both Phase I and II of the on-going Bagmati Irrigation Project, the area including only Phase II of the same, and the area including neither of the above. Various plans combining different intake systems and component command areas, as well as with and without diversion hydropower components, should be studied to determine the most economically feasible plan for each scheme. In the case of the Sapt Kosi West Irrigation Scheme two plan alternatives may be considered; the Sun Kosi-Trijuga Diversion Plan which could cover only component NS-1, and intake from the Sapt Kosi which could cover both NS-1 and NS-2 components.

Irrigation water for the former plan will be supplied to a tributary of the Trijuga River via a diversion tunnel approximately 5km long located on the Sun Kosi River, 32km upstream from the convergence of the 3 rivers of the Sapt Kosi. Irrigation water for the latter plan will be supplied by an intake dam which will be constructed at a site 4km downstream from the Sapt Kosi High Dam from which a diversion tunnel about 6.5km long will carry irrigation water supply to the component NS-2 area.

As for the Sapt Kosi East Irrigation Scheme, Component SR-1 of the same has an elevation range of 91-152m and the intake elevation for irrigation water must therefore be located above 152m. However, the level at the intake site on the Sapt Kosi River is approximately El100m. Therefore, gravity intake of irrigation water will require construction of an intake dam on the Sapt Kosi River. However, construction of a dam would result in substantial impediment of the Sapt Kosi High Dam Power Generation Project, greatly raising the tailrace water level of the same. Further study should therefore be undertaken in future.

An alternative plan to intake from the Sapt Kosi is intake from the Tamur River. In this case, construction of a 68m dam would be required at the Mulghat site on the Tamur River and diversion of water from the same via a tunnel about 18km long to the Khadam River which flows through the foothills of the Mahabaraht range. The main drawbacks of the above plan are the fact that the envisioned Mulghat Dam would be submerged upon completion of the future Sapt Kosi High Dam, and the poor geological conditions along the 18km tunnel route. These points require further study.

The outline of these irrigation schemes, alternative plans and irrigation component areas are as follows:

Sun Kosi Diversion Irrigation Scheme

- Chisapani Barrage Intake Plan

Area covered	Bagmati River - Kanro River (Case, SK-400-BK)
"	Jhim River - Kanro River (Case, SK-400-JK)
"	Marha River - Kanro River (Case, SK-400-MK)

- Kamla Dam Intake Plan

Area covered	Bagmati River - Kanro River (Case, SK-450-BK)
"	Jhim River - Kanro River (Case, SK-450-JK)
"	Marha River - Kanro River (Case, SK-450-MK)

Sapt Kosi West Irrigation Scheme

- Sun Kosi - Trijuga Diversion Plan

Area covered: Khanro River - Sapt Kosi River (Case, SW-ST Diversion) (without North area of the Trijuga River)

- Sapt Kosi Intake Plan

Area covered: Kanro River - Sapt Kosi River (Case, SE-Dam Intake) (with North area of the Trijuga River)

Sapt Kosi East Irrigation Scheme

- Sapt Kosi Intake Plan

Area covered: Sapt Kosi River - Ratuwa River (Case, SE-Dam Intake)

- Tamur River - East Terai Diversion Plan (Case, SE-TT Diversion)

Area covered: Sapt Kosi River - Ratuwa River

The formulated command areas based on the above are shown in FIG. 5-3-3 and tabulated in TABLE 5-3-7.

3.4 Irrigation Water Demand

3.4.1 General

Irrigation water demand for the overall plan is estimated for each proposed benefit area. The Study area has a length of 230km from east to west. Cropping patterns and climate vary slightly between the Sapt Kosi right and left bank areas and irrigation water demand was calculated seperately for the Sapt Kosi West Zone and East Zone.

3.4.2 Crop Water Requirement

(1) Required Factors for Calculation of Crop Water Requirement

Required factor (ETo, kc) for calculation of crop water requirement was calculated according to the design criteria (section 3.2.2). The results are shown in TABLE 5-3-8 for ETo, and TABLE 5-3-9 for crop coefficient value.

(2) Calculation of Crop Water Requirement

Water requirement for each crop calculated according to the Pan Evaporation Method is given in TABLE 5-3-10.

The calculation of water requirement was based on the proposed cropping patterns which aim to provide year-round irrigation for maximization of crop production. With provision of year-round irrigation, the double cropping pattern is possible for paddy crops including early summer paddy (Aus Type) cultivation. Productivity and cropping intensity of upland crops, such as wheat, maize, oilseeds and pulse crops will be improved through the provision of agricultural inputs and supply and optimum use of irrigation water.

As agreed in the minutes of 7 August, 1984, water requirement for the sandy area left bank along the Sapt Kosi River (9,400ha) was calculated based on a maximum of 3.5 l/sec/ha for paddy in rainy season and 1.0 l/sec/ha for upland crops in dry season. The results of water requirement calculation (l/s/ha) in the Sapt Kosi West Zone and East Zone areas show that maximum requirement occurs in October while the minimum is in June. In comparison, the maximum and minimum water volumes required for crops in the east area are lower than that for the west area. This is due to higher effective rainfall in the east area.

The results of water requirement calculations for standard cropping patterns in the Sapt Kosi West Zone, the Sapt Kosi East Zone and the sandy area along the Sapt Kosi River are shown in TABLE 5-3-11.