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# Monitoring and Analysis of Hydro-Environmental Condition in the North Western Part of Bangladesh and Development of a Satellite Based Aridity Assessment Algorithm

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University of Rajshahi

# MONITORING AND ANALYSIS OF HYDRO-ENVIRONMENTAL CONDITION IN THE NORTH WESTERN PART OF BANGLADESH AND DEVELOPMENT OF A SATELLITE BASED ARIDITY ASSESSMENT ALGORITHM

Ph.D. THESIS

SUBMITTED
BY
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A thesis submitted to the Department of Applied Physics & Electronic Engineering, Faculty of Sciences of University of Rajshahi for the fulfillment of Doctor of Philosophy (Ph.D.).


**SUBMITTED**

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**June 2008**

## Declaration

I am Md. Sajidur Rahman submitting my research work incorporated in this thesis entitled *"Monitoring and Analysis of Hydro-Environmental Condition in the North Western Part of Bangladesh and Development of a Satellite Based Aridity Assessment Algorithm"* to the University of Rajshahi for the fulfillment of Doctor of Philosophy (Ph.D.) from the Department of Applied Physics and Electronic Engineering. I thereby declare that this submission is my own work and that, to best of my knowledge and belief, it contains no material previously published or written by another person nor material which to a substantial extent has been accepted for the award of any other degree, except where due acknowledgement has been made in the text.


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BANGLADESH SPACE RESEARCH AND
REMOTE SENSING ORGANIZATION
(SPARRSO)

## *CERTIFICATE*

This is to certify that Md. Sajidur Rahman, has carried out a research work entitled *"Monitoring and Analysis of Hydro-Environmental Condition in the North Western Part of Bangladesh and Development of a Satellite Based Aridity Assessment Algorithm"* for the fulfillment of Doctor of Philosophy (Ph.D.) from the Department of Applied Physics and Electronic Engineering, University of Rajshahi. The research work deals with the satellite based hydro-environmental monitoring and analysis in the north western part of Bangladesh. This work has been carried out at Bangladesh Space Research and Remote Sensing Organization (SPARRSO), Agargaon, Sher-e-Bangla Nagar, Dhaka, Bangladesh.

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## Abstract

In the present work the functioning of a coupling of multi type data like remote sensing data, geophysical data, climatic data and other ancillary information, has been studied to address the driving forces related with the geo-environment of Barind Tract and adjacent flood alluvial plane land, and to monitor such processes. Time series remote sensing data have been analyzed over a period of about 27 years (1973 to 1998) to characterize the aridity of Barind tract area and flood alluvial plane land, situated in the northwestern part of Bangladesh. Two adjacent but characteristically different land areas, (i) semi-arid Barind Tract and (ii) Ganges alluvial flood plane land has been selected for the present study where different hydro-environmental conditions prevail over the year. The study reveals that the radiometric responses of Landsat TM are characteristically different for the two study sites having different environmental conditions. Spatio-temporal analysis from Landsat TM derived spectral response curve shows appropriate seasonal trend and an overall trend towards increased vegetation over the Barind tract area that is consistent with field observation over the study interval. Impacts of climatic variables particularly that of rainfall and temperature on the hydro-environment of the area have been studied. Both rainfall and temperature seems to play a dynamic role in fixing up the hydro-environmental setup of the area. Barind Tract area never flooded, here rainfall is the only source of all hydrological activities. Coupling of satellite-derived land cover information with landform and hydro-climatic data reveals that in surface cover dynamics and its seasonal transformation of surface categories over time and space, are a function of landform characteristics and the prevailing hydro-climatic condition of the area. The sensitivity of surface cover change to the rainfall amount is higher in Barind tract area in comparison with the flood plain areas. The semi-arid Barind Tract area remains either mostly bare (about 90 percent) or highly vegetated (vegetation cover greater than 75 percent) depending on the season, which is in contrast to the flood plain areas that are found to be moderately vegetated throughout different seasons, though both sites receive an almost similar amount of seasonal and annual natural facilities.

Variation in soil moisture and vegetation condition due to seasonally varying precipitation, introduce sequential variability in the surface absorption level, thereby provoking seasonal rhythmic variation in the surface albedo and surface temperature over the area. Values of surface albedo and surface temperature are found to be significantly higher in the Barind tract area in comparison to that for flood plain areas and it seems albedo is a land type dependent seasonal indicator of an area. Normalization value ($a_{SD}/a_{Mean}$) of standard deviation of albedo ($a_{SD}$) by mean value of albedo ($a_{Mean}$) indicates the degrees of surface cover variation. Lower values of $a_{SD}/a_{Mean}$ means lower surface cover variation i.e., surface is homogeneous. And lower degrees of surface cover variation produces minimum variation in surface temperature due to the spatial variation.

Analysis on rainfall data over a period of about 50 years shows that the rainfall is substantially higher over these areas in comparison to other semi-arid region in the world. From the analysis of rainfall it is seen that in recent years there is a change in rainfall pattern, and rainfall patterns are seen having dual peaks on both sides of August. Analysis of temperature data shows characteristically different two trends: (i) gradual increase of temperature extremity is observed from 1964 to 1988 and (ii) gradual decrease of temperature extremity is observed from 1989 to 1998. In recent years the cause of this change in temperature extremity change may be due to the increase of vegetation activities and this is till under study.

Information on the ground water table reveals that thin and poor ground water reservoir weathered by nearly impermeable thick clay layer with poor specific yield characterizes the lithology of Barind Tract. The depth of the ground water table in semi-arid Barind tract area is relatively higher in comparison to that of the flood plain areas. Due to over exploitation probably for irrigation purposes ground water level over Barind Tract area is gradually declining. It is found that ground water level in Barind Tract area has noticeable dependency on annual rainfall amount and recharge maximum in rainy season.

The crest/ridge of up-warped Barind Tract having downward slope on both side follows a line through broadly dissected terrace and closely dissected terrace. Slope of elevated surface and developed drainage system control the hydro-environmental activities through partitioning the surface water. In this area elevated topography having different slope angle, underlying thick clay layer (8m to 24m) and high rate precipitation are playing major role in controlling the drainage pattern as well as drainage density. Sloppy surface with smart passage of runoff, underlying clay loam with low infiltration rate and high rate precipitation instigate expeditious and heavy runoff, and slows down the infiltration rate. Analyzing the Surface Roughness Length (SRL) it is found that SRL controls the speed of surface flow through making physical obstacle. SRL varies with the variation of seasonal cropping activities. Higher SRL shows during rainy season due to the rain feed aman crop. Higher SRL make delay surface flow and allow surface more time for infiltration.

Integration of remote sensing, climatic and other ancillary data along with geophysical constituents has been employed to study the dynamic characteristics of land use and cropping patterns in response to various hydro-environmental and socio-economic driving forces. Climatic variables, local geology and land physiography together with human intervention collectively determine the nature of utility of land of an area. From the land use pattern of 1968 and 1990 it is seen that there are changes in land type and land use patterns. The causes of land type changes are river course change and erosion, and happenings of land type change observed only in flood alluvial plain areas. Due to the land type change there is a change in cropping pattern but a significant change of cropping pattern have been observed due to the emergence of dry season irrigated crop (high yield) principally exploiting ground water. In flood plain areas there are also a trace of increased Mango orchard activities.

Spatially Averaged Wetness Index of the Earth's Surface (SAWINES) model has been developed using satellite image specially Landsat TM image. The model has been applied on different upazilas and has demonstrated a good sensitivity to Earth's surface moisture content and is capable to represent the overall wetness condition of an area. The result also justified the sufferings of Barind Tract from severe soil moisture deficiency during dry season.

So elevated sloppy surface covered by thick clay layer having poor infiltration capacity, poor ground water reservoir may be responsible for dryness of Barind Tract and scarcity of ground water, specially in dry season. Particularly, the depth of flooding in relation to land elevation during the wet season in flood plain areas and soil moisture deficit during dry season in Barind Tract area seemed to be the two major determinative variables governing land use of the area. Climatic variables, particularly precipitation, appear to be the main driving force that brings out the dynamic changes in the geo-environmental condition in both study sites. The study also reveals that coupling of satellite based information with the landform and local geophysical constitutes an effective way of understanding and real-time monitoring of land surface processes over local to regional scale particularly well-suited for arid/semi-arid lands.

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## List of Abbreviations

| | |
|---|---|
| ADEOS | – Advanced Earth Observing Satellite |
| AVHRR | – Advanced Very High Resolution Radiometer |
| AVNIR | – Advanced Visible and Near-Infrared Radiometer |
| BBS | – Bangladesh Bureau of Statistics |
| BMDP | – Barind Multipurpose Development Project |
| DEM | – Digital Elevation Model |
| DN | – Digital Numbers |
| EMR | – Electro Magnetic Radiation |
| ESRI | – Economic and Social Research Institute |
| ForTran | – Formula Translation |
| GCP | – Ground Control Points |
| GIS | – Geographical Information System |
| HRV | – High Resolution Visible |
| $I^2S$ | – International Imaging System |
| IR | – Infrared |
| IRS | – Indian Remote Sensing Satellite |
| LCC | – Lambart Conformal Conic |
| LISS | – Linear Imaging Self Scanning System |
| LUCC | – Land use and land cover change |
| MSS | – Multi Spectral Scanner (MSS) |
| NDVI | – Normalized Difference Vegetation Index |
| NIR | – Near Infra-Red |
| NOAA | – National Oceanic and Atmospheric Administration |
| OCTS | – Ocean Color and Temperature Scanner |
| RVI | – Ratio Vegetation Index |
| SARSAT | – Search And Rescue System Satellite |
| SAWINES | – Spatially Averaged Wetness Index of the Earth's Surface |
| SD | – Standard Deviation |
| SMAC | – Simplified Method for the Atmospheric Correction |
| SMI | – Soil Moisture Index |
| SP1 | – First Split |
| SP2 | – Second Split |
| SPOT | – System Pour Observation de la Terre |
| SRL | – Surface Roughness Length |
| SVA | – Soil-Vegetation-Atmosphere |
| TM | – Thematic Mapper |
| Ts | – Surface temperature |
| VAX/VMS | – Operating system of DEC VAX |

## List Of Publications

Published/Presented:

- Sajidur Rahman, Hafizur Rahman and Mumnunul Keramat, 2007: Study on the Seasonal Changes of Land Cover and Their Impacts on Surface Albedo in the North-Western Part of Bangladesh using Remote Sensing. Published in *International Journal of Remote Sensing*, London. Volume 28, No. 5, Pages 1001-1022.
- Sajidur Rahman and Hafizur Rahman, 2007: Remote Sensing and Geophysical Investigation on the Impediment of Crop Intensification in Seasonal Semi-Arid Zone in the Northwestern of Bangladesh. Paper presented and published in e-proceedings of "*International Workshop on Earth Observation Small Satellites for Remote Sensing Applications*" held at Kuala Lumpur in Malaysia from 20-23 November 2007.
- Sajidur Rahman, Hafizur Rahman and Mumnunul Keramat, 1999: Soil Moisture Dependency of Atmospheric Scattering effects on the Remote Sensing Monitoring of Bare Soil. *Journal of Remote Sensing and Environment*, Dhaka. Vol.3.
- Sajidur Rahman, Hafizur Rahman and Mumnunul Keramat, 2003: Monitoring Hydro-Environmental Condition and Its Evolution in the North-Western Part of Bangladesh using Combined Remote Sensing, GIS and Geophysical Data. Paper presented (abstract published) in an *International Conference on the Role of Natural Resources and Environment in Sustainable Development in South and Southeast Asia (NESDA)* held at Dhaka in Bangladesh from 7-20 January 2003.
- Hafizur Rahman, Sajidur Rahman, Sajjad Rahman and Majedul Ahmed, 2004: Satellite Image Based Information Retrieval on the Geoenvironment in the Northwestern Part of Bangladesh: Effects of Image Resolution. Paper presented and published in proceedings of "*7th International Conference on Computer and Information Technology (ICCIT 2004)*" held in BRAC University, Dhaka, Bangladesh from 26-28 December 2004, ISBN: 984-32-1836-1.
- Mirza A.F.M. Rashidul Hasan, M. Keramat, Hafizur Rahman and M. Sajidur Rahman, 2008: Computer Based Groundwater Resource Evaluation in Nawabganj Thana, Bangladesh. Journal of Remote Sensing and Environment, SPARRSO, Dhaka, Bangladesh. Published in *Journal of Remote Sensing and Environment*, Dhaka. Volume 4, Pages 71-76.

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# *Chapter One*
## *Introduction*

# 1. Introduction

## 1.1 Basic Consideration

Land surface processes have become a great concern in the context of global change and increased natural hazards the world over (Goel and Norman 1990). Through the geo-biospheric processes it controls the environmental, hydrological and climatic condition of an area.

Surface topography and local geology along with the climatic condition over the area fixes-up the land use and land cover pattern (Rahman and Rahman 2007; Rahman et al. 2007). But land use and land cover pattern may change due to mitigate more various demands for increased population, land type change and climatic change.

The ever expanding human population exerts increasingly high pressure on the available land and its natural resources (Rahman and Rahman 2007). Very often these lands and the natural resources therein are exploited for various urban, agricultural and industrial purposes in such a manner that causes significant damage and degradation to the whole ecosystem. Moreover, during the last few decades, extensive efforts have been made in agriculture sector for multiplying the crop production to meet up the increased food demand over the world. A significant progress has already been achieved through intensification of agricultural activities round the year using chemical fertilizer, pesticides, improved crop varieties, and irrigation (through surface and ground water etc.).

All the foregoing issues have specific impacts or consequences on the hydrological and environmental condition of an area and often associate certain problems to the whole ecosystem that put the sustainability of the whole operation in question. Some of these damages are irreversible in nature and are very much harmful to both environment and ecology. In many cases, such local scale problems often provoke global scale consequences depending on the gravity of the situation.

Eventually, remedy and mitigation of such problems require a good understanding and monitoring of the involved processes. This ensures efficient handling of the whole system in a sustainable manner. Remote sensing is the best tool for monitoring environmental activities due to it can sense remotely any place, any time, in all weather condition and repeatedly. And an integration of remote sensing, geophysical and climatic data through GIS is the complete solution of environmental studies.

## 1.2 Semi-Arid Region and Related Issues

From the conclusion of different authors and researchers it is clear that acute shortage of moisture is the only problem of arid and semi arid zone. Causes behind the shortage of water may be many, suppose elevation, low rainfall, high diurnal temp, low vegetation, poor surface and subsurface storage etc. Last four causes (low rainfall, high diurnal temp, low vegetation, poor surface and subsurface storage) are climatic dependent variables. Climatic condition of an area influences the causes of aridity. In some cases it repeals the involvement in the list of causes of aridity.

Arid and semi-arid regions cover a large portion of the total land area in the world where water deficiency is a common event that usually occurs. Generally, such lands exhibit high surface albedo, low precipitation, low soil moisture, relatively high temperature gradient between day and night with relatively low vegetation density (Rahman et al. 2007). Vegetation and agricultural productions are very much limited due to acute water deficiency over these regions. The availability and distribution of water over an area is a principal governing factor for agriculture production and in maintaining ecological balance. The lack of up to date baseline information concerning the aquatic conditions over a region throughout the year is a fundamental problem associated with proper planning and sustainable development of agriculture in Bangladesh. Proper management of hydrological resources can drastically improve the agricultural potentiality over these regions. However, for such an efficient management, knowledge of the nature and extent of the aridity over the region is a prerequisite that can ensure the optimum use of available water resources in a efficient way.

## 1.3 Objectives of the Study

Barind Tract covers a significant area in the north-western part of Bangladesh. The potential uses of this area can contribute effectively to the overall development of the country through an effective and appropriate land budgeting scheme. Though discrete efforts have been made in the past couple of decades to increase the land utilization through irrigation during dry season. Utilization of large-scale deep tube-well in accordance with other irrigation means exploit ground water in an unplanned way. Such an utilization of ground water provokes certain adverse effects both on environment and ecology. Eventually, the present study is aimed at for furnishing the following objectives:

(i) To assess the applicability of combined Remote Sensing (RS), GIS and geophysical data for monitoring the hydro-environmental condition and characterizing both flood plain & semiarid areas situated in the north western part of Bangladesh.

(ii) To study the dynamic behaviour of land cover in relation to physiography and seasonally varying meteorological condition and to have an understanding about the temporal and geographical dynamics of land use and land cover changes.

(iii) To perform a RS-GIS based analysis on the causes of aridity and to understand the driving forces that change the land use and land cover.

(iv) To develop an integrated spatial database in a GIS platform containing information on land use, land cover as well as their spatial and seasonal dynamics, ground water condition, soil properties, lithology, climate, surface temperature etc.

(v) To develop a GIS based model that will integrate all the information and will provide a better understanding about the land surface processes over the area.

(vi) To develop a remote sensing based spectral model "Spatially Averaged Wetness Index of the Earth Surface (SAWINES)" useable in a GIS environment for the automatic evaluation of aridity of a given geographic area using satellite data and application of SAWINES in conjunction with satellite data for evaluating aridity of a given region.

Our approach is to study the hydro-environmental condition of semi-arid zone Barind Tract situated in the north-western part of Bangladesh, using remote sensing data supplemented by meteorological and geophysical data through the integration of GIS technology.

# Chapter Two
## *Land Surface Processes and Their Biophysical Contexts (Review of Literatures)*

## 2.1 Concept of Radiative Transfer

Sun is the only natural source of radiative energy, which helps to migrate and change status of masses. Solar radiation propagates through space and finally strikes the earth's surface. Mass and energy intercept at earth surface and at atmosphere. Interfacing part of earth's surface comprises with the different composition of soil, vegetation and water. And atmosphere is the integration of various gaseous molecules, aerosol and dust particles.

Depending on the type of surface as well as atmosphere various complex processes like absorption, scattering and reflection changes the direction and amount of incoming energy. This is a continuous bi-directional activity of changes and conversion of mass and energy that processed at the intercepting part (Dickinson 1983). Geometry of interactive objects such as surface roughness, soil texture, structure, color & moisture content, vegetation density, leaf orientation, underlying surface properties of vegetation, turbidity of water, absence & presence of ozone layer and other gases, thickness of ozone layer and cloud density influence largely interaction activities. The main cause of reduction of energy in the visible and near-visible region is scattering (aerosols and molecules) and in infrared region is absorption due to water vapor, ozone and different gasses. Induced energy developed by incident EMR (electromagnetic radiation) in the interactive objects works as a secondary source of radiation (Reeves 1975). Incoming energy interact with the surface and depending on the dynamics of surface composition portion of it again transmitted through the atmosphere as a reflected energy and add signatures of the atmosphere and finally received by the satellite sensor. Remote sensing makes uses of this energy for retrieval of the surface related information and atmospheric information. Like many other agents' illumination, viewing angle and receiving angle (Rahman and Dedieu 1994, Tanre et al. 1983), wavelength and amplitude are also responsible for perturbation or degradation of remote sensing information.

### 2.1.1 Solar Radiation

Emitted energy from the sun in the form of Electromagnetic Radiation (EMR) propagates through space directly with the speed of $3\times10^8$m/s. Max Planck theory defines the propagation of EMR and showed that radiation energy E is directly proportional to the frequency f and inversely proportional to the wave length $\lambda$ of radiation.

So,

$$E = Pf$$

$$= P/\lambda \quad (2.1)$$

Here P is the Planck's constant ($P = 6.626 \times 10^{-34}$ joule/Sec)

Plot diagram of solar irradiance shown in figure 2.1 as a function of wave length $\lambda$ ($\mu$m). From the Planck's radiation law (described below) it can say effective temperature of the sun is wavelength dependent.

$$S_\lambda = 2\pi P v^2/\lambda^5[\exp(vP/\lambda BT) - 1] \quad (2.2)$$

$S_\lambda$ - Spectral radiant existence in W/($m^2$-$\mu$m)

v - Velocity of light

B - Boltzmann's constant = $1.38054 \times 10^{-23}$ $WsK^{-1}$

T - Temperature in degrees Kelvin

$\lambda$ - Wavelength in meter (m)

## 2.2 Soil-Vegetation-Atmosphere (SVA) System

The earth's biosphere and atmosphere forms a closely coupled dynamic system where interaction between the Soil-Vegetation-Atmosphere (SVA) system takes place through t h e exchange of mass and energy. One of the parameter of SVA system is vegetation, which is actively involved with the complete intricate chain of energy change and conversion. To assess local and global climate accurately and to manage earth's biotic activity it needs to estimate biophysical parameter of SVA system (Goel and Norman 1990). Growth of vegetation and vegetation area, both vary due to the seasonally varying climatic variables in associated with other factors soil type, and biotic interfaces (Saxena et al. 1992). Vegetation uses mass and energy in their photosynthesis activities. Water distributes through the process of precipitation over the soil surface, where a portion of the precipitated water infiltrate into the soil and the excess water causes run-off. Moreover, water in the soil and vegetation evapotranspirate to the atmosphere in the form of latent heat (energy). Due to Absence, presence and any volumetric change of water and vegetation in an area SVA system suffers

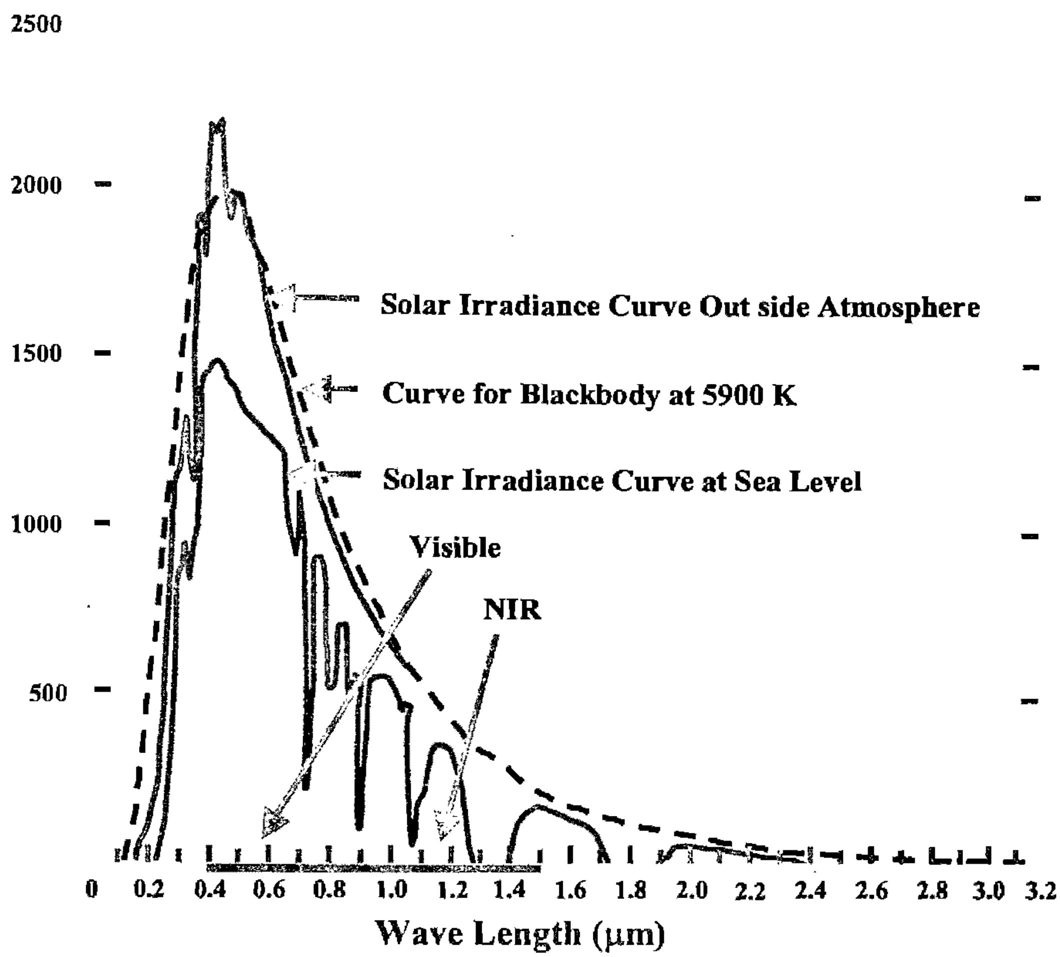



Figure 2.1: A plot diagram of solar radiative energy derived with the help of Planck's law.

a drastic change. Presence of water on leaf surface reduce the temperature which is also reduces back radiation and as a result increase net radiation (Linacre 1972). Due to irrigation, precipitation and dew leaf wetness increase and due to evaporation leaf wetness decrease (Goel and Norman 1990). With the increase of soil moisture in soil thermal conductivity and heat capacity increase (Kalma 1971) that directly influence heat flow and temperature change (Goel and Norman 1990). Numerous biochemical-processing rates controlled by plant temperature (Dickinson 1983). Extreme high and low temperature hampers crop yields and timber yields (Dickinson 1983). Thereby, the exchange of mass and energy takes place at the SVA interface. The change in any one component of SVA system will affect the other components of the system. Rainfall, net radiation, albedo, surface temperature, potential evapotranspiration, available surface water over the region, soil moisture, ground water condition etc. are the most important components actively related with water balance condition as well as SVA system. Seasonal variation with climatic change control SVA system which intern controls radiative interaction mechanism (Dickinson, 1983).

### 2.2.1 Earth's Radiation Budget

Solar energy comes at earth surface through atmosphere and depending on wavelength different portions of incoming energy uses by earth surface in different ways. Transmitted energy changes in different degrees and migrates into another formation due to absorption, scattering and reflection. Radiation budget is an important factor for earth's energy budget and plays pivotal role in hydro-environmental activities. Difference between the total incoming radiation and the total outgoing radiation is the earth's radiation budget (Reeves 1975). Radiation budget is often called net radiation and denoted by $Q_n$ as expressed below:

$$Q_n = Q_S + Q_D + Q_L - [S(Q_S + Q_D) + Q_O] \quad (2.3)$$

$$Q_n = (1-\alpha)Q_S + Q_{nL} \quad (2.4)$$

Here

$Q_D$= diffuse short wavelength radiation

$Q_L$= incoming long wavelength radiation

$Q_O$= outgoing long wavelength radiation

S = surface reflectance

$\alpha$ = albedo and

$Q_S$= incoming short wavelength radiation and may be write as

$$Q_s = \varepsilon_s \sigma T^4 \quad (2.5)$$

Here,

$\varepsilon_S$ = emissivity of the radiating surface and

$\sigma$ = Stefan-Boltzman's constant = $5.7\times10^{-8}$ $Wm^{-2}{}^{\circ}K^{-4}$ and

T = absolute temperature of the radiating over surface °K

Sum of the converted formations of energy relevant to geo-biospheric process is the net radiation and shown below mathematically:

$$Q_n = H_S + H_A + H_{LE} + H_P + H_M \tag{2.6}$$

Here,

$H_S$= soil heat flux

$H_A$= heat flux into the air

$H_{LE}$= Latent heat flux ($H_L$ for vaporization or condensation and $H_E$ for evaporation)

$H_P$= radiation for photosynthesis

$H_M$= radiation for miscellaneous conversion.

### 2.2.1 Earth's Water Budget

Water is the fundamental and prime component for sustaining life and is directly related with agricultural, meteorological and hydrological condition of an area. The availability and distribution of water over an area is a principal governing factor for agriculture production and ecological sustainability.

Water moves through the process of precipitation, charging (infiltration), discharging, evapotranspiration and maintain a hydrologic cycle. Minimum and saturation level of water demand for a certain geographic area are important and to study it and define it is water budget. To study the water budget of an area we have to consider the water sharing and contributing components. Precipitation is the main source of surface water. Immediately after precipitation precipitated water involves in the next process of water distribution like infiltration, runoff etc. Rate of change of water of a place can be defined with the following equation-

$$\frac{\nabla W}{\nabla t} = P - I - E - R \tag{2.7}$$

$\Delta W/\Delta T$= Rate of variation of soil moisture

P = Rate of precipitation

I = Rate of infiltration in the deeper soil

E = Rate of evapotranspiration

R = Runoff

# Chapter Three
## Remote Sensing and GIS in Monitoring Earth's Surface

## 3.1 Roles of Remote Sensing

Remote sensing is a technique, which is involved with observing and collecting temporal and spatial data of targeted area by a device (such as balloon, aircraft and satellite) apart from the target i.e., not visiting the spot. Now a days remote sensing is very popular due to it's wide range of coverage and multidisciplinary task i.e. multi spectral and multi temporal data collection capability. In addition it can sense remotely any place, any time repeatedly in all weather condition.

Widely used forms of the electromagnetic spectrum (figure 3.1) are cosmic rays, gamma rays, x-rays, ultraviolet, visible, infrared (IR), radar and television & radio waves. Infrared region uses wavelengths from 0.7μm to 300μm. Optical region (0.3μm to 15μm) of IR spectrum can be divided into different sub spectrums like visible (0.4μm to 0.7μm), near infrared (0.7 to 1.3μm), middle infrared (1.3 to 3.0μm), far infrared (3.0 to 14μm), ultraviolet (0.3 to 0.4μm), reflective (0.3μm to 3.0μm), emissive (3.0 to 14.0μm) and photographic (0.3 μm to 0.9μm). This optical portion uses by satellite remote sensing to detect and sense earth's surface features and atmospheric parameters.

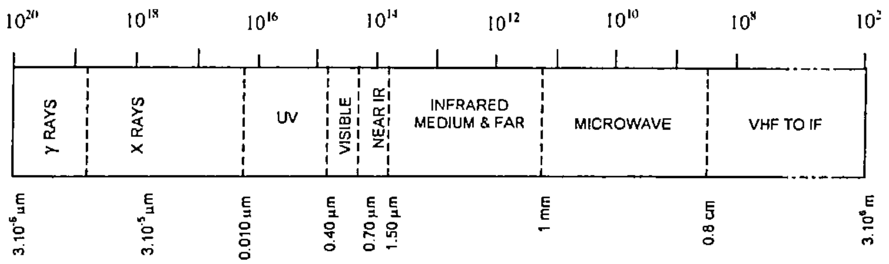



Figure 3.1: The Electromagnetic spectrum with wavelength (adapted from Parker and wolf 1965, Estes and Senger 1974).

Remote sensing techniques are used to accumulate huge data for a large area. With the partial support of field data sampling this technique allows (i) water resources inventory and management for agricultural and industrial purposes (ii) differentiate major crop types and its area measurement and crop yield estimation (iii) mapping thermal signature of soil and water (iv) mapping land use (v) mapping major soil classification, characteristics and conservation (vi) monitoring plant diseases (vii) disaster monitoring and prediction and (viii) global and regional weather monitoring (National Research Council 1970, Schanda 1976). Scientists of agriculture, geography, geology, hydrology, oceanography and meteorology are using remote sensing data. Different kinds of tools are used in remote sensing system to collect data such as radar, lidar, aircraft and satellites. Different satellites are developed and launched to study and fulfill different requirements such as earth observing satellite, communication satellite, meteorological satellite, ocean monitoring satellite and marine observation satellite etc. Different satellite has different area of coverage, which introduced in table 3.1.

Table 3.1: Different satellite and it's area of coverage.

| Satellites | Area of Coverage | Description |
|---|---|---|
| LANDSAT | Worldwide | Earth observing satellite |
| TIROS-N | Worldwide | Environmental satellite |
| NOAA-6 etc | Worldwide | Earth observing satellite |
| GOES-E, GOES-W | USA and adjacent | Geostationary weather satellite |
| METEOSAT | Half of Earth (nearly) | Weather satellite |
| LANDSAT | Global | Earth observing satellite |
| OrbView-3 | Global | High resolution earth imaging satellite |
| TiungSAT-1 | Earth orbital (Global) | Earth observing and meteorological satellite |

(Cracknell 1981, Othman and Arshad 2001)

### 3.1.1 Concept of Atmospheric Window

During the both way travel of electromagnetic energy i.e., from source to earth and earth to receiver it suffers and changes depending on the type and gravity of traveling and interfacing media and also on wave lengths of energy. The main cause of reduction of energy is scattering and absorption in the visible and near-visible range of spectrum. The absorption and attenuation of energy is not equal at every portion of optical range. Optimum attenuation suffers due to atmosphere at larger wave lengths longer than 18mm (American Society of Photogrammetry 1963, Estes and Senger 1974). A portion of the optical range where energy transmission is high and attenuation is very little is called atmospheric window and ranges approximately 0.3 to 2.5, 3.0 to 4.0, 4.2 to 5.0 and 7.0 to 15.0 μm (Swain and Davis 1978, Lillesand and Kiefer 1979).

### 3.1.2 Components of a remote sensing system

For the complete remote sensing system basic components are source of energy, target, sensor/ receiver and media. On the basis of energy source, remote sensing system can be divided into two groups active and passive.

**Active remote sensing:** Active remote sensing has it's own artificial energy source. It sends radiation to the target and receives reflected radiation from the target. Radar and Lidar are examples of active remote sensing system.

**Passive remote sensing:** In this case remote sensing system has no it's own energy source. It just receives radiated or reflected energy comes from objects. Satellite remote sensing is the passive remote sensing system and using solar energy as an energy source.

### 3.1.3 Satellite sensors

Sensor is a device that receives energy and converts into suitable digital format for the next use in different purposes. Actually satellite receiver is an array of sensor. Different types of satellite use different kinds of sensor according to their aspects of target. In table 3.2 has shown most widely used sensors, respective satellites and their spatial resolutions:

Table 3.2: Major sensor types, respective satellites and spatial resolutions.

| Sl. No. | Sensor | Satellite | Resolution |
|---|---|---|---|
| 01 | Multi Spectral Scanner (MSS) | Landsat | 79m |
| 02 | Thematic Mapper (TM) | Landsat | 30m |
| 03 | High Resolution Visible Imaging System (HRV) | SPOT | 10m Panchromatic<br>20m Multispectral |
| 04 | Linear Imaging Self Scanning System LISS-I | IRS-1A | 72.5m |
| 05 | Linear Imaging Self Scanning System LISS-II | IRS-1B | 36.25m |
| 06 | Advanced Very High Resolution Radiometer (AVHRR) | NOAA | 1.1Km at Nadir |

Satellite sensor can never sense whole spectrum at a time. It divides the large spectrum into many small suitable fractions and those are spectral bands. Table 3.3 containing the description of spectral bands of LANDSAT TM 4 & 5 satellite.

Table 3.3: Spectral dimension of different bands of Landsat TM satellite.

| Band | Band Name | Wave Length (μm) | Spectral Sensitivity |
|---|---|---|---|
| 1 | Blue/Green | 0.45-0.52 | Good for water penetration, strong vegetation absorption |
| 2 | Green | 0.52-0.60 | Strong vegetation reflection |
| 3 | Red | 0.63-0.69 | Very strong vegetation absorption |
| 4 | NIR | 0.76-0.90 | High land/water contrast very strong vegetation reflectance |
| 5 | IR | 1.55-1.75 | Very moisture sensitive |
| 6 | Thermal IR | 10.4-12.5 | Very sensitive to soil moisture and vegetation |
| 7 | Middle IR | 2.08-2.35 | Good geologic discrimination |

(Bamber 2008)

## 3.2 Roles of GIS

Geographical Information System (GIS) is a latest development of functional and procedural technology, which introduced computer and digital technology into geography (GIS Standards and Standardization 1998). A complete system organized by hardware, software and earth's surface related digital information is GIS. Digital formation of stored data helps for easy and quick manipulation of huge volume data. Using powerful tools of GIS it is possible to process, analyze, co-relate and update multi layer thematic data. In GIS, information of different layers maintains separately instead of combines all the different kinds of information in a single layer. It is also possible to combine or overlay number of layers such as hydrology, land use, topology and remote sensing data according to the project aspect. In GIS geo-reference system works as a tunnel to communicate between different thematic layers.

Initial feeding sources of GIS data are remote sensing data, geophysical data, aerial photograph, maps and different kinds of survey data. Formation of stored data may be in vector form or in raster form and combined of these two forms is also possible. GIS is a powerful database management system where it is possible to interface database system of other packages. Statistical analysis, risk assessment, environmental hazard study, erosion assessment, change and shift detection and assessment of conservative use of surface and subsurface resources are easily and accurately possible in GIS environment.

### 3.2.1 Spatial Data Management

The term spatial is related to or referred to target object is in space. Any interactive data related with surface, subsurface and space attached by locational identifier is known as spatial data (Reeves 1975). Spatial data comprises with graphical and aspatial data. The synonyms of these two types are entities and attributes respectively. Vector and raster forms are the two distinct structures of spatial data placed in GIS database and stores in a physical storage device in logical format to access easily for any kinds of manipulation. Vector data managed by an array of coordinates and raster data managed by an array of cells characterized by a row and a column number. In spatial data management system data coupling of different structure supports with all kind of facilities. Customarily spatial data displayed in map form (Reeves 1975).

### 3.2.2 Facilities of Spatial Data Analysis

GIS based spatial database is a rich resource of information. Different research team can look through different window to spatial database and can find different ideas. In GIS system with the spatial data statistical analysis, surface trend and terrain analysis, spectral analysis can be done. Integration, conversion, calculation, polygon overlay such type of functions support spatial data management system. The result of demand and expectation to control over social, economic, and environmental process is the spatial information system (Reeves 1975).

# Chapter Four
## Description of Study Area

## 4.1 Location

The study area shown in figure 4.1 is geographically located in the north–western part of Bangladesh and comprises with the completely different two types of landforms, named Barind Tract and flood alluvial plain. It covers eight small administrative units (Upazila) of three districts Nawgaon, Chapai Nawabgoanj and Rajshahi. The longitude and latitude of the study area are 88°01′ E to 88°40′ E and 24°22′ N to 25°01′ N respectively. It is bordered in the north, south and west by India, in north-east corner by Porsha upazila of Nawgaon district and eastern side by Mohadebpur and Manda upazila of Nawgaon district and Mohanpur, Paba and Boalia upazila of Rajshahi district.

## 4.2 Physiography

Figure 4.2 shows physiograhy of the study area. Bangladesh has been divided into three major physiographic units such as hills (12-percent of total land), terrace (8 percent) and vast flood plain (80 percent) which are again divided into twenty physiographic units (Choudhury and Ali 1998, Morgan and McIntyre 1958). The present study area consists of a variety of land characteristics including highland, lowland, sandy areas, rivers etc. Such a wide spectrum of land categories gives rise to varying vegetation activities over the areas in the spatio-temporal domain.

Landscape of Barind Tract is elevated hummocky land with low soil moisture and poor surface cover. And sufficient soil moisture as well as surface cover seasonal and permanent vegetation characterizes the flood alluvial plane land. Figure 4.2 shows in detail the physiographic condition of study area. Landscape of Barind Tract comprises with the broadly dissected terrace, closely dissected terrace and level, intermittently terrace. Major portion of Barind Tract are under broadly and closely dissected terrace. And northeast and part of eastern side are under level, intermittently terrace. Low land adjacent to the northern side of Barind Tract is under the old flood plain basin. The flood alluvial plane consists with the active and very young meander flood plain, mixed Ganges and Mahananda flood plain, young meander flood plain, oldest meander flood plain and level, covered terrace. Maximum of north and north-western part including central part and south-western and southern part of flood alluvial plane land are under mixed Ganges and Mahananda flood plain and active and very young meander flood plain respectively. The minimum and maximum elevation above

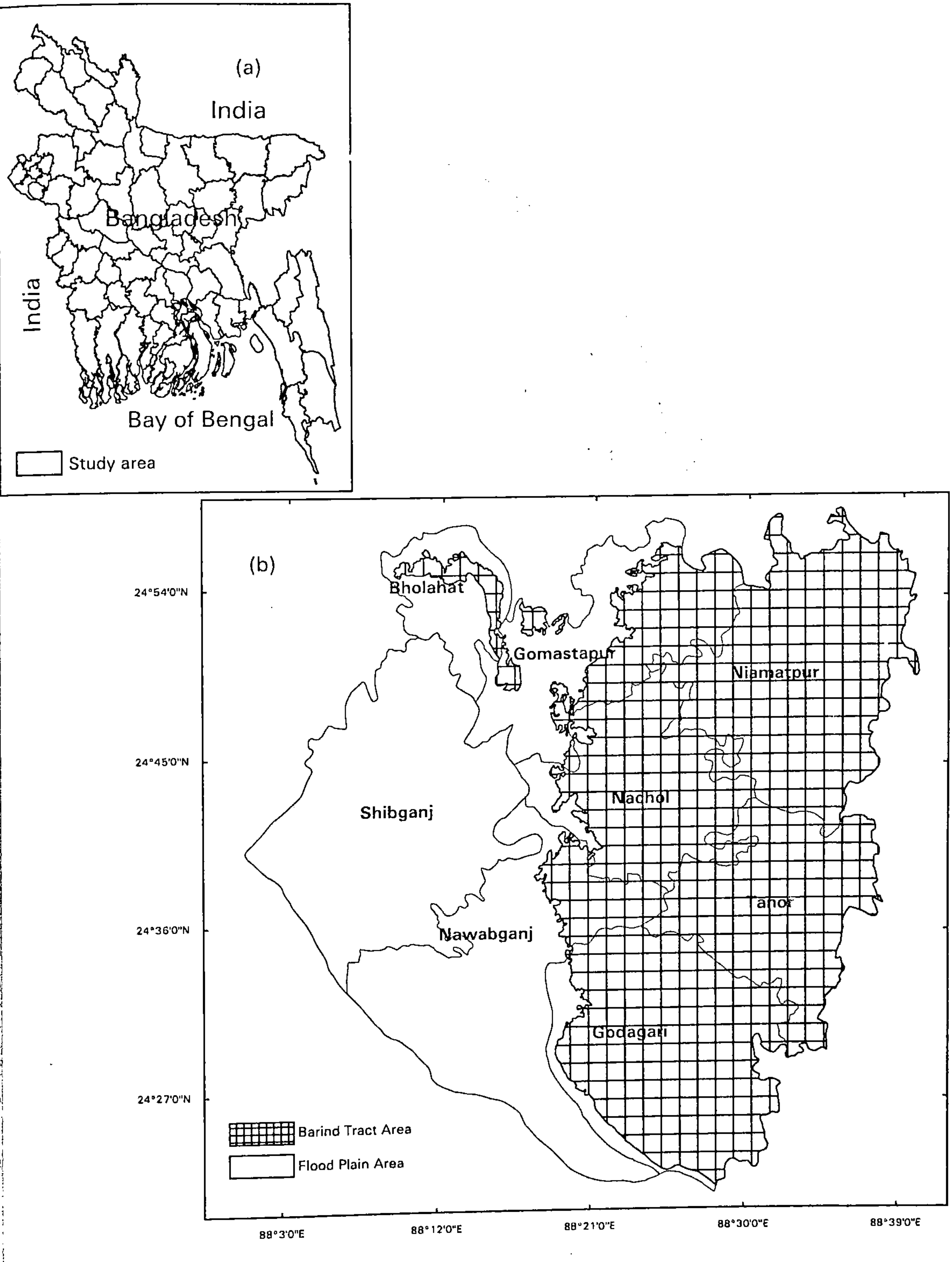



Figure 4.1: Location map of the study area.

mean sea level is 21 meter in northern side of the study area and 40 meter in the north-eastern side high Barind area respectively (Haque 1997).

### 4.3 Geography

Characteristically different two zones eastern side dry zone and western side normal moist zone of the study area are separated by Mahananda river. The south and eastern part of the flood plain area are weathering due to erosion of two rivers Ganges (Padma) and Mahananda. The Ganges river travels from south-west to south-east and Mahananda river travels from extreme north to extreme south. These two rivers are playing major role on the ecological and socio-economic conditions of study area. Except these two rivers numbers of narrow braided canals and tributaries are seen all over the area.

#### 4.3.1 Climate

The study area has tropical monsoon climate like whole area of the country. Depending on the climatic behaviors there is three distinct seasons observes in this region with unequal duration. But Bangladesh pronounces a country of six seasons with equal duration i.e., each season continues up to two months. At Barind Tract and adjacent areas it is observed that rainy season extent from May to October, winter from November to February and summer extent from March to April. Duration of rainy season is almost half of the year.

Rainy season is humid and more than 80% annual rainfall occurs during this season. Longer rainy season dominates the soil moisture and vegetation activities over this area. In winter weather is cool and dry, and recorded minimum temperature is less than 10°C. Summer is dry and recorded maximum temperature often exceeds 45°C. Relative humidity varies from 60% in winter to more than 85% in rainy season. Natural hazards like high temperature, no rainfall, fall of ground water level and crisis of surface water occur if weather like summer extents. Except summer, winds are generally light. But in summer thunder storm and sand or dust storm are very common.

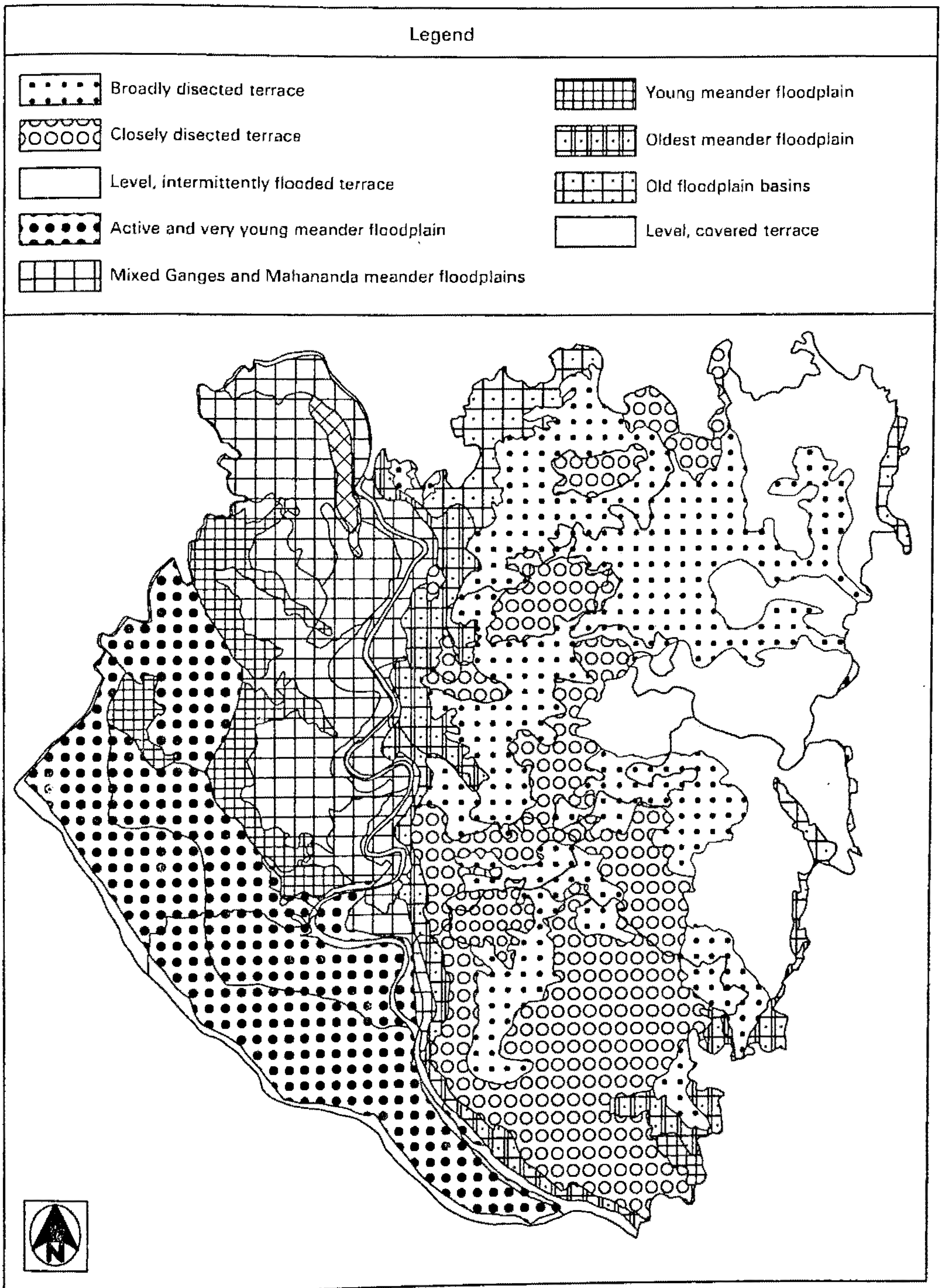



Figure 4.2: Physiographic units of the study area (BBS 1987).

### 4.3.2 Drainage

Drainage system of Barind Tract comprises with the canals, tributaries, distributaries and foot slopes of hill shapes. Drainage pattern of Barind Tract is distributory in nature and carries surface water to adjacent basins. Elevated sloppy surface of semi-arid Barind Tract are responsible for prompt surface runoff. In some cases foot slopes of hill shape makes bowl shape low land water logging area. Surface water drains into the Mahananda and Ganges river from west, and into the Atrai, Little Jamuna and Shib river from east. In other hand in flood plane areas including Ganges and Mahananda rivers there are some other narrow branch rivers, canals and channels. And there are also numbers of large surface water bodies (bils). Most of the rivers and tributaries are linked with the Bay-of-Bengal.

In dry season canals, tributaries at Barind Tract become dry but surface water bodies like ponds, slope adjacent low lands and low lying swampy lands hold water. Some of the low lying swampy lands in flood alluvial plain area are locally known as bils, which are quite big and perennial (SPARRSO 1989) along with Ganges, Mahananda and some other branch rivers hold water in dry season also.

### 4.3.3 Vegetation

In Barind Tract major vegetation activities are seasonal, especially in rainy season maximum of cultivated area goes under cropping. In Dry season lands are generally overwhelmed by a thin coverage of Tamarisk and reedy grass. There are no forests in Barind Tract. Homestead and road side forests including some scattered vegetation are the main vegetation activities in this area. The common species of vegetation are Babul (*Acacia arabia*) and Mango orchard (*Mangifera indica*). The coverings of highly elevated lands comprises with bamboo, grass, imperata arumdinacea, andopogon ociculutus, banyan, pipal and semul. Vallisnenia and other plants grows huge in old river beds, ponds and marsh and stream with sluggish current. Palms and Khejur (date palm) trees are seen all over the study areas but in southern area it grows widely. In flood plain area Mango gardens are very common and a large portion of total lands are occupied by Mango garden.

### 4.3.4 Population

According to the population census of 1991 the population of the study area is 1720492. Like other parts of the country the population of the study area is also increasing. The population of the study area was 775328 according to the census of 1961. Population of different upazila of study area according to the population census from 1961 to 1991 is shown in the table 4.1.

Table 4.1: Population status according to the different population census.

| Upazila | 1961 | 1974 | 1981 | 1991 |
|---|---|---|---|---|
| Gomastapur | 81456 | 127138 | 153767 | 191972 |
| Niamatpur | 87430 | 128859 | 150297 | 193197 |
| Nachol | 36186 | 60780 | 74888 | 97119 |
| Tanor | 58863 | 91571 | 113230 | 138015 |
| Nawabganj | 189916 | 271945 | 315696 | 389524 |
| Godagari | 88934 | 143869 | 172240 | 217811 |
| Bholahat | 29143 | 47094 | 55338 | 70507 |
| Shibganj | 203400 | 287845 | 333510 | 422347 |

## 4.4 Geology

### 4.4.1 Regional Geological Setting

Bangladesh belongs to the western part of Bengal Basin. Part of the Basin is geo-synclinal sedimentation area and still in course of settlement. *The Bengal Basin is bounded to the west by the Rajmahal Hills, to the north by the Shilong Plateau of Assam, and to the east by the Tripura Hills.*

### 4.4.2 Structural and Tectonics

The Barind Tract is developed over Modhupur clay and is one of the major sedimentary basin in the world and comprises a part of Bengal Basin. Two distinct tectonic units of Bengal Basin are the western stable shelf in which Barind Tract is situated and the eastern mobile foredeep flank (Guha 1978). Tectonic classification map of Bengal Basin has shown in figure 4.3.

In Barind Tract there are number of major subsurface faults and cracked which is not visible at surface. This zone is tectonically active and in different places there are evidences of recent tectonic activities (Morgan and McIntyre 1958, Khandoker 1987, Khandoker 1989).

Barind Tract is surrounded by a number of subsurface faults. Maldah-Kishangang Fault is in the west, Padma Fault is in the south, Dhubri-Jamuna Fault is in the east and Karatoya Fault is in the north.

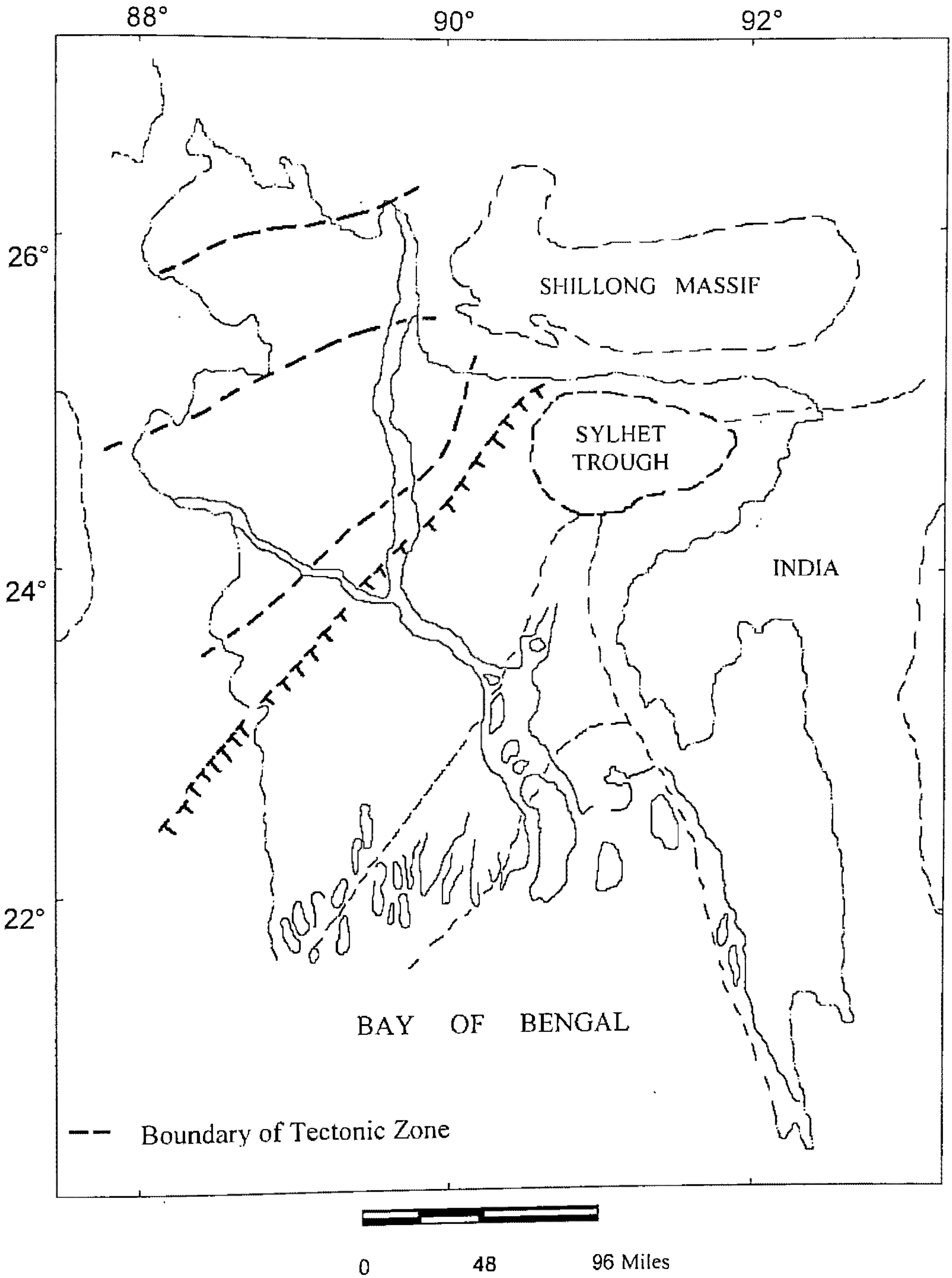



Figure 4.3: The Tectonic Map of Bangladesh (Guha 1978).

# *Chapter Five*
## *Materials and Methods*

## 5.1 Description of Data

In this research work effort has been made to study the hydro-environmental condition of north-western part of Bangladesh. For this study multi-dimensional data has been used as stated below:

i. Remote Sensing data

ii. Geophysical data

A. Lithology B. Ground water and C. Charging and discharging information of ground water reservoir.

iii. Climatic data

A. Rainfall B. Temperature C. Humidity and D. Radiation

iv. Soil information

A. Soil type B. Soil physical properties and C. Soil moisture

v. DEM and others ancillary data

A. Elevation
B. Physiography
C. Topo Map
D. Crop information and
E. Statistical data.

To enrich the research work multi-dated and multi-dimensional remote sensing data were selected like new generation Landsat TM, SPOT HRV and NOAA AVHRR images (Table 5.1). Effort was made to select cloud free images but there have few patches of clouds in some images. In this study major and maximum support have been furnished with the Landsat TM images. Time series of Landsat TM images have been selected to study the seasonal behavior of surface parameters and selected data set covers three main seasons summer (dry), rainy (wet) and winter.

Table 5.1: Details of different remote sensing images those have been used in this study.

| Sl. No. | Name of Image/Satellite | Number of Bands | Path & Row | Acquisition Date |
|---|---|---|---|---|
| 01 | Landsat TM | 7 | 138/043 | Nov 08 1988 |
| 02 | Landsat TM | 7 | 138/043 | Mar 08 1992 |
| 03 | Landsat TM | 3 | 138/043 | Feb 18 1997 |
| 04 | Landsat TM | 7 | 138/043 | Feb 05 1998 |
| 05 | Landsat TM | 7 | 138/043 | May 12 1998 |
| 06 | Landsat TM | 7 | 139/043 | Oct 14 1988 |

| | | | | |
|---|---|---|---|---|
| 07 | Landsat TM | 7 | 139/043 | Apr 11 1990 |
| 08 | Landsat TM | 7 | 139/043 | Oct 20 1990 |
| 09 | Landsat TM | 7 | 139/043 | Jan 03 1995 |
| 10 | Landsat 7 | Panchromatic | 138/043 | Oct 17 2001 |
| 11 | MSS | 4 | | Feb 22 1973 |
| 12 | SPOT HRV Col. | 3 | | Oct 25 1990 |
| 13 | SPOT HRV Mono | Panchromatic | | Dec 21 1988 |
| 14 | NOAA AVHRR | 5 | | October 20, 2001, February 16, 2002 and April 10, 2002 |

## 5.2 Software Used

**A. For analysis and interpretation different data were processed with the following software**

i. Erdas Imagine 8.3, 8.4 & 8.5

ii. Erdas Imagine 8.5 for Virtual GIS

iii. Arc Info 3.5.2 & 4.0

iv. Surfer

v. $\alpha$ Plotting

vi. MS-Excel and MS-Word.

**B. For analysis and interpretation some images were processed by**

i. $I^2S$ (International Imaging System) on VAX/VMS

ii. ForTran Programming on VAX/VMS

## 5.3 Methodology

### 5.3.1 Digital Image Processing

Remote sensing data as received from earth observing satellites are represented as picture format in most of the cases (Mulder 1986). For interpretation and analysis remote sensing data needs some processing. Digital image processing is the complementary part of remote sensing and GIS. Digital image processing perform different types of correction, contrast enhancement, classification and specialized mathematical manipulation.

Before conduct any process to retrieve information, remote sensing image need some corrections like geometric correction, atmospheric correction etc. to remove extraneous effects. To convert the location information of remote sensing data into the proper geographic address, remote sensing data needs geometric correction. To get at surface information it needs to remove extraneous effects due to atmospheric parameters like gasses, molecules, aerosol and ozone and this procedure is called atmospheric correction.

### 5.3.1.1 Geometric Correction and Geo-referencing

Geometric correction corrects and rectify distortion or shifting, skew or rotation and scale difference and introduced with the assigned map projection system. Here image gets new geo-location from ground control points (GCPs) or from hard copy of image (map) or from another image of same area which was previously corrected. Aforementioned second system is known as image-to-image registration system and the correction system with the help of hardcopy of image (map) or GCP is called image-to-image or image-to-GCPs registration system. Reference image may or may not define with the map projection system. If the reference image is not previously geo-referenced then the distorted image needs assigning map projection system which is concerned for map coordinates.

In this study here used image-to-image registration system and as a reference Landsat TM images were used which were geo-referenced to the Lambert Conformal Conic (LCC) map projection system.

### 5.3.1.2Atmospheric Correction

Satellite sensor receives digital signal which returns from surface with some extraneous effects due to atmospheric parameters during the both way traveling of EMR through atmosphere.

Incoming signal reaches at surface and after interact with objects it returns through atmosphere. During the travel through atmosphere there adds some extraneous effects. Satellite sensor receives these contaminated signal returns from surface through atmosphere. According to the Bernstein (1983), extraneous effects due to atmosphere are not errors, are the part of signal received by satellite sensors. But to analysis matching and changes of surface it is often necessary to remove the atmospheric effects (ERDAS Field Guide 1999). Using some mathematical model extraneous effects due to atmosphere can be separated.

After proper registration Digital Numbers (DN) of each band (Band1 to 5 and 7) of Landsat TM images have been converted into the at-satellite radiance ($mWcm^{-2}sr^{-1}\mu m^{-1}$) and reflectance (Hill and Sturm 1991, Tassan 1992). Then to get the apparent at surface radiance and reflectance images have been corrected for atmospheric effects, particularly for gaseous absorption and scattering due to molecules and aerosols, using a model 'Simplified Method for the Atmospheric Correction' (SMAC) developed by Rahman and Dedieu (1994).

### 5.3.1.3 Digital Classification

Classification is the process of assigning pixels or group of pixels of a raster having common characteristics according to the interpretation criteria. Major surface classes are soil, vegetation and water. Classification may be a group within the major surface type like moist zone, arid zone, semi-arid zone, low land, high land, crops, forests, turbid water, clear water and saline water etc. To define a training sample for classification spectral signature is very important which represents a class (ERDAS Field Guide 1999). On the basis of filed experience selective range of DN values/reflectance of different bands (spectral signature) have been chosen for particular group or class or depending on colors and textures, areas that look alike of displayed image on the computer monitor (ERDAS Field Guide 1999). Depending on the numerical values of image pixels, mathematical idea can be implemented to define a class to classify a digital image. Following developed classifiers may be used to classify a digital image:

A. Minimum distance to means classifier
B. Parallelepiped classifier
C. Gaussian maximum likelihood classifier
D. Preprocessing transformations

Depending on training sample there are two classification methods (i) Supervised classification and (ii) Unsupervised classification and in this study both methods have been conducted for different types of analysis and interpretation.

#### 5.3.1.4 Calculation of Physical Parameters

After remove all unexpected extraneous effects, images were conducted to calculate different physical parameters like albedo, at surface reflectance, surface temperature, NDVI, and RVI etc.

##### 5.3.1.4.1 Albedo ($\alpha$)

Using the at surface reflectance albedo ($\alpha$) value has been calculated by the following equation:

$$\alpha = \frac{1}{w}(\rho_1 + \rho_2 + \rho_3 + \rho_4 + \rho_5 + \rho_7) \qquad 5.1$$

Where ρ1, ρ2, ρ3, ρ4, ρ5 and ρ7 are the at surface reflectance for bands 1,2,3,4,5 and 7 respectively of Landsat TM images and

W is the weighting factor, depends on the total number of bands using.

##### 5.3.1.4.2 Surface Temperature ($T_S$)

Conversion of thermal infrared data of Landsat TM image to apparent temperature was carried out using the model developed by Markham and Barker (1986). To calculate surface temperature (Ts) maximum radiance $L_{max}$=1.56 and minimum spectral radiance $L_{min}$=0.1238 are used at quantitized radiances $Q_{calmax}$=255 and $Q_{cal}$=0 respectively (Markham and Barker 1987, Smith and Choudhury 1991).

##### 5.3.1.4.3 NDVI and RVI

Following equations has been used to calculate the Normalized Difference Vegetation Index (NDVI) and Ratio Vegetation Index (RVI) from geometrically corrected Landsat TM images.

The Normalized Difference Vegetation Index (NDVI) is defined by the following equation-

$$NDVI = \frac{\rho 4 - \rho 3}{\rho 4 + \rho 3} \qquad 5.2$$

The Ratio Vegetation Index (RVI) is defined by the following equation-

$$RVI = \frac{\rho 4}{\rho 3} \quad 5.2$$

Where, ρ3 and ρ4 are the reflectance in band 3 (situating in the visible) and band 4 (situating in the near-infrared) of Landsat TM image.

### 5.3.2 Data Capture and Processing

To accumulate information in GIS system is a difficult thing and consumes much time. There are various methods, such as digitization, scanning to capture and enter data into a GIS system, where it is stored in a digital format. Data can be captured from hard copy of map, PET film map, remote sensing raster data, and GPS etc.

#### 5.3.2.1 On Screen Digitization

Digitizing is the process of data conversion from hard copy or raster form to digital vector form i.e., this procedure develop a vector layer for the expected regions or features. There are different ways to develop a vector layer, such as i. Tablet digitizing, ii. On Screen digitizing and iii. Converting raster layer to vector layer (ERDAS Field Guide 1999). Here it is used 'On Screen' digitizing to develop a vector layer with the support of Erdas Imagine vector module. Vector tools, developed based on the ESRI data model to generate a vector layer, and mouse has been used for digitization. Different type of vector features such as point, line and polygon are generated for various purposes. Single precession data type was selected during creating a new vector layer. In vector data, attribute data carries additional information about the objects represented in the system. And hence during the collecting and entering spatial data, attribute data has been entered into GIS data.

#### 5.3.2.2 Vector Layer Processing

During digitization, for individual feature there were developed individual layer, and saved in the computer with the individual identity. In vector form, preserve only vertices of vector data. not every x, y points that makes up the element. After developing vector data into a GIS, it needs further editing, to remove errors, and further processing. For vector data it must be made 'topologically correct' for some advanced level of analysis and to overlay on other spatial data. To construct the topology that makes a relationship with different features or with other spatial data within the geographic area or boundary Arc/Info provides two commands Build and Clean. For construct topology the procedure Build and in some cases both the procedures Build and Clean have been conducted. Other processes like 'Buffer', 'Create Labels' etc. have also been conducted for special purposes and analysis.

# Chapter Six

## Study on the Digital Image Based Spectral Behaviour of Semi-Arid Land Surface for the Characterization and Identification of Object Classes

Land use and land cover change is a hot issue throughout the world. To study the land use and land cover change, surface related database is very much essential. To develop a surface related database with the help of remote sensing technology spectral response dynamics of surface features are important.

In order to separate or classify the spectral signature of different surface features the atmospheric situation, amount of radiation and spectral response of the sensor should be considered (Gomarasca and Lechi 1989). Geo-location and seasonal variation strongly influence the spectral properties (Gomarasca and Lechi 1989). Spectral response of surface and surface cover changes with the change of seasonal climatic behavior. A response to the band of an object is the spectral signature of a particular object and that varies from feature to feature and band to band. Quality of major surface features soil, vegetation and water may vary due to the variation of inherent properties of the components. Optical properties of soil characterizes by the particle size, aggregation, surface roughness, superficial factors, soil moisture etc. (Rahman 1997, Norton et al. 1979), leaf area, vegetation height, vegetation cover density, leaf orientation angle etc. characterizes the vegetation optical properties (Rahman 1997) and water is characterized by the turbidity, salinity etc. All these major surface types are spectrally separable, and all these have its own optical properties i.e., spectral response patterns (Lillesand and Kiefer 1979). Any type of surface feature can be identified with the help of sensitivity of that feature to the visible, near-infrared and middle-infrared region of spectrum (Ormsby 1992).

Photosynthetically active parts of vegetation are highly absorbent to the visible range of spectral band (0.4-0.72 μm) and moderately reflective to the near infrared region (0.72-4.0 μm). Soil shows higher reflectance with the increase of wavelengths (bands). Soil and vegetation are more sensitive to middle-infrared and near-infrared region respectively, in all the season. Response of water decreases with the increase of wavelengths (bands) i.e., response at band3 is higher than the response at band4, which is higher than the response at band5.

Received satellite data needs some processing to extract expected surface related information. But it is difficult job to identify specific surface features. For better result field survey or ground truth data is necessary along with the remote sensing data. Here we used spectral response data (extracted from Landsat TM images) for surface and surface cover identification.

In this part it is tried to identify and characterize different surface features and surface cover with the help of remote sensing images and also tried to study the potentiality of remote sensing data to study the earth surface and related environmental processes in semi-arid and flood plain lands.

To infer and understand the surface properties, it's change of geo-biospheric activities with seasonally varying meteorological condition in associated with other forces two steps has been initiated, point data analysis and profile data analysis. In point data the properties of a particular pixel area for a particular season and it's corresponding changes with the seasonal climatic change have been studied. And same studies like point data, have been conducted for a profile intersecting large area. For both point data and profile data collection two Landsat TM images were used, one dated 11 April 1990, was used for dry season and another dated 20 October 1990, was used for wet/rainy season.

### 6.1 Point data

During point data collection, it was paid special attention, so that it covers maximum surface features like different types of soil, vegetation and water, and its variation due to seasonal climatic change. Point data have been collected using 'Spectral Tool' provided by ERDAS Imagine. Collected spectral response of different surface features has shown in figure (6.1a, c, e, g and i) for dry season and in figure (6.1b, d, f, h and j) for rainy season. To study the seasonal changes data of summer season has been taken as a reference and the corresponding changes in rainy season have been studied.

Response of soil, having different quality due to the geographical variation, physiographic variation and moisture level variation, have been composed in figure 6.1a. From figure 6.1a it is seen that, spectral responses of soil at band5 and at band3 are higher than the response at band4. Dry soil shows higher response at all bands in all the season in comparison with moist soil. The response of dry soil at band5 and at band4 within the range of 45 to 56 and for moist soil response at band7 is below 30.

Spectral response of crops, having different quality has shown in figure 6.1c for dry season. High value with sharp peak at band4 observed for dense and healthy crops. From figure 6.1c and point data, it is found that, the differences of band4 and band5 of Landsat TM images indicates the crop health condition. For healthy crops it has found that the difference of |band4 and band5| is high, and this is independent on seasonal variations.

Response of permanent vegetation in summer has shown in figure 6.1e. For permanent vegetation, pattern of spectral response is just like a crop except having lower amplitude at band4. But response at band5 is higher than crop. In summer, for old leaf chlorophyll activities are low, and in this time less quantity of leaf contents of plants make more structural gaps. These structural gaps act as a tunnel for dry soil background, which contribute to the response at band5.

Sparse vegetation is basically the less dense as well as poor health vegetation area and most of the cases these are unexpected vegetation like grass or green algae or the early stage of crops. The underlying surface may be soil or water which contributes much more than the vegetation cover. Generally underlying soils are found dry, in summer and moist/wet in rainy season. Responses of sparse vegetation for summer have been composed in figure 6.1g. In this case it is seen that the reflectance at band4 is higher than the response at band3 but nearly equal to the response at band5. At sparse vegetated area with soil background, the response at band 5 is little bit higher than the response at band 4 in most of the cases.

Response of water having different turbidity has shown in figure 6.1i. For water, value of spectral response generally decreases with the increase of bands. But due to the sediment concentration, this order may change. For turbid water, high peaks are seen over sediment sensitive band band3. For clear water reflectance at band5 and band7 is very low and response at band7 is less than the response at band5.

Maximum of bare soil and sparse vegetated areas in summer converted into healthy and dense cropping areas in rainy season. In some areas there develops crops and some areas converted into water bodies in rainy season where there were crops in summer. In bare soil areas changes moisture level, but did not convert into any other classes due to seasonal climatic change. Soil in this season found with a higher degrees of moisture content.

In permanent vegetation areas, there are no changes of cover types due to seasonal variation. But in rainy season plants are found with higher quantities of newly grown healthy and wet leafs and hence permanent vegetation area shows sharp response at band4 (figure 6.1f). A response curve in the permanent vegetation group (figure e & f) marked by a *, which shows highest value in both the season and that may be the response of a different variety of plant.

Due to seasonal changes there are no changes in water bodies. Maximum water bodies of summer season remains same in rainy season but there is a change in level of turbidity and areas. In Barind Tract and adjacent, water bodies are seen with more turbidity in dry season than in rainy season. In some areas there grows green algae and hence to shows higher response at band4 than at band5.

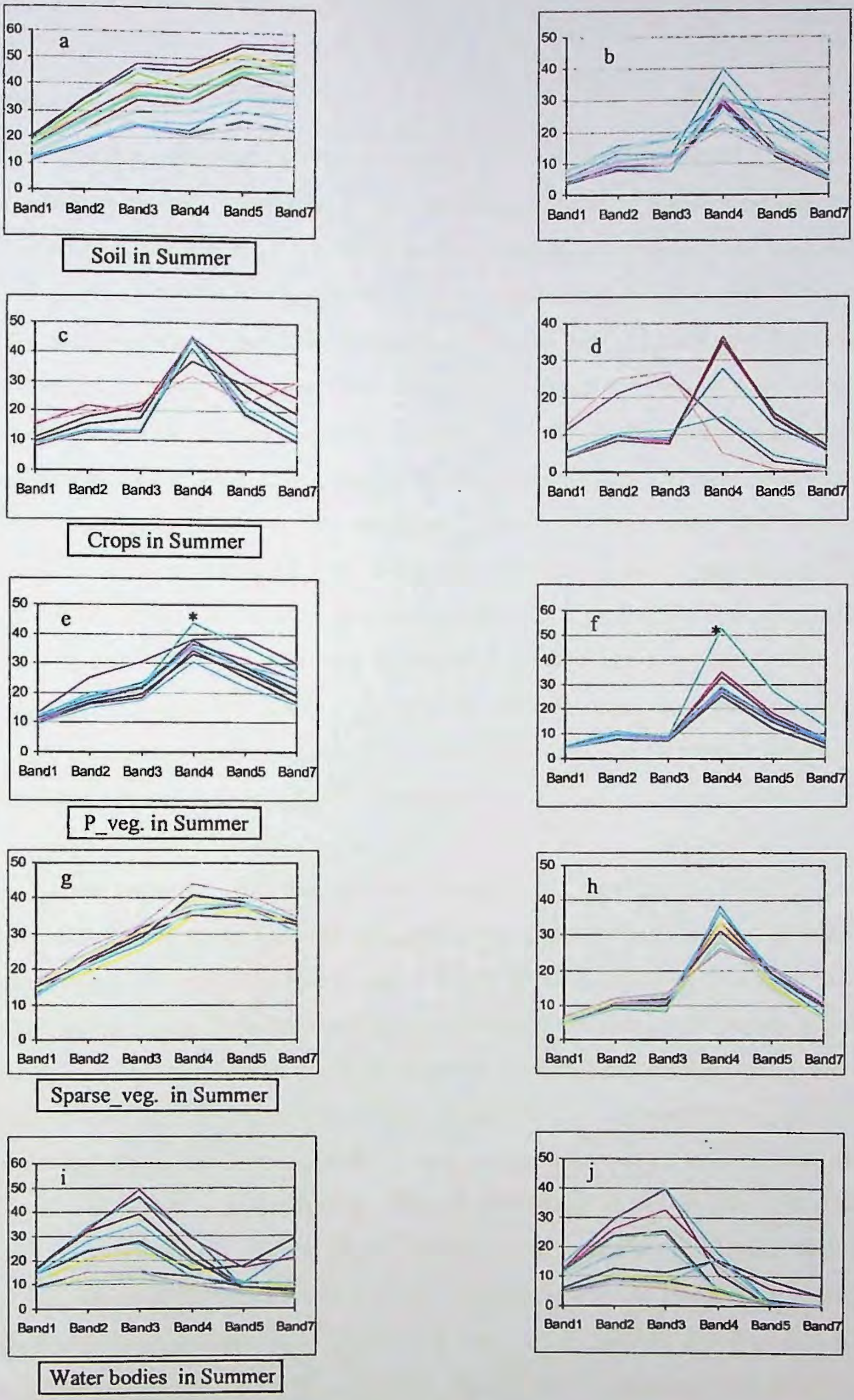



Figure 6.1a,b,c,d,e,f,g,h,i,j: Pixel wise spectral response of individual feature type of different surface features for summer and the corresponding changes of same pixel area in rainy season due to seasonal climatic changes.

## 6.2 Profile data

Profile data has been taken for better understanding the landscape as well as to understand the surface cover type and it's sensitivity to the seasonal changes. It is possible to demonstrate surface properties with the help of spectral response at band4 and at band5 and for this reason profile data graph have been composed with the spectral responses at two bands (band4 and band5). For soil, response at band5 is greater than the response at band4, and for vegetation and water response at band4 is higher than the response at band5. Two profiles were drawn over the same place and from same direction covering the flood plain and Barind Tract areas for two seasons summer and rainy. During profile area selection it was paid maximum attention so that profile intersects with maximum types of surface cover. The responses at band4 and at band5 were extracted from the profile intersecting points and shown in figure 6.2a and 6.2b for summer and rainy season respectively. In figure 6.2b it is demonstrated the dynamics of surface cover variation due to seasonal climatic variation with respect to the surface condition in summer. These two profiles are composed with the integration of different type of surface features like bare dry soil, moist soil, sandy areas, cropping areas, permanent vegetation and different kinds of water bodies.

Profile data were collected with the help of 'Spatial Tool' provided by ERDAS Imagine. Profile started from the south bank of Ganges river and then it crosses through the river adjacent sandy area, flood alluvial plain, low land (bil), Mahananda river, then again low land and ended at Barind Tract. These two profile passes through the maximum surface features of both flood plain and Barind Tract areas. In summer, Barind Tract suffers due to acute soil moisture and shows high reflectance as well as surface albedo. In summer, vegetation areas are seen with underlying dry bare soil and the trace of vegetation is also poor. Values at band 5 and at band 4 is higher in dry season for all types of surface covers, due to the turbulently domination of background. Surface and surface cover types in Barind Tract are homogeneous, which demonstrated in the profile response curve. In flood plain areas, soils are mainly loamy type and having sufficient soil moisture in summer. Surface and surface cover are heterogeneous in flood plain areas. From the profile spectral response curve of summer it is seen that on both banks of Ganges river there are huge deposition of sand. In alluvial flood plain, adjacent to the sandy area there is a trace of seasonal vegetation. In flood alluvial plain there is a bil with scattered vegetation activities and followed by permanent vegetation on both sides. On both sides of Mahananda river there are flood alluvial low lands with vegetation and water. River course of Mahananda is comparatively static then the Ganges river and due to poor fluvial process there are less deposition of sediments on both sides of Mahananda river and there are no trace of sediment deposition in profile response curve. Ganges river course is dynamic with time and on both sides a large portion is under the active fluvial process (figure 6.2a and 6.2b). At the starting point of profile dry sand shows highest reflectance and at northern side moderately moist sand shows moderate response. And in summer there seen low depth water channels on both sides of Ganges river. Major portion of active fluvial process zone inundates during flooding in rainy season. Main stream and channels charges in rainy season and gets wider shape and it is possible to trace out from the satellite data.

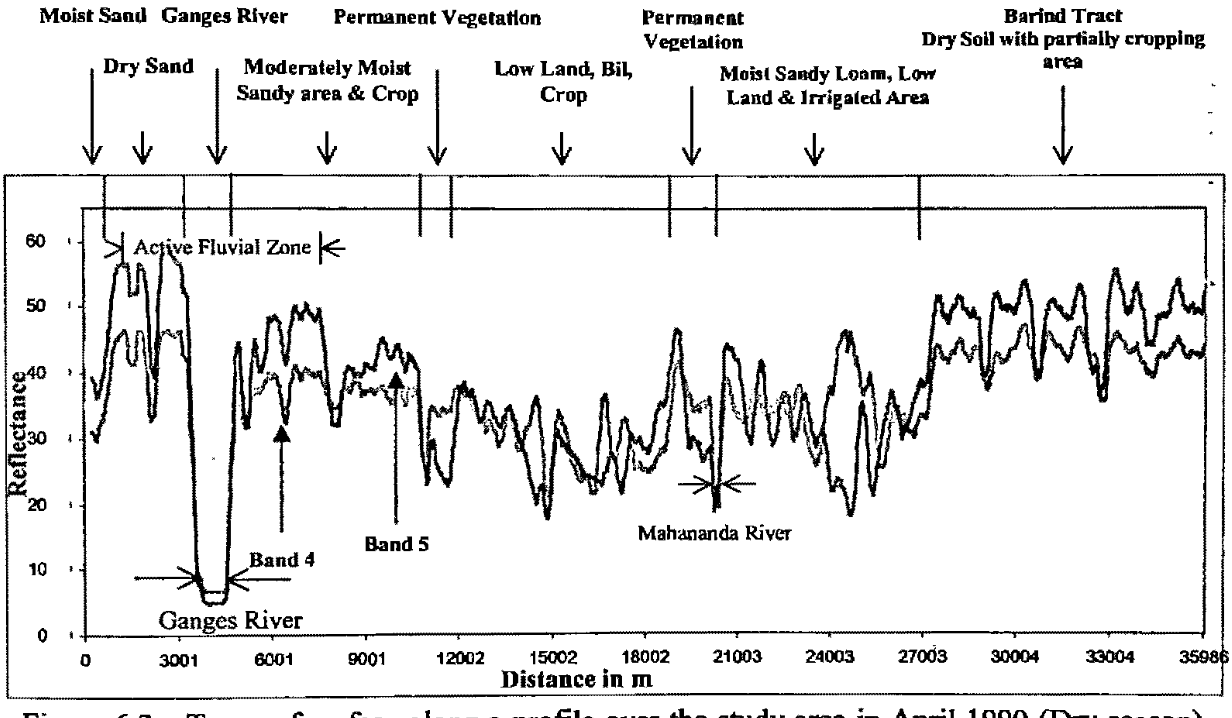


Figure 6.2a: Types of surface along a profile over the study area in April 1990 (Dry season) identified by Landsat TM satellite data.

Figure (6.2a) shows the surface response of profile intersecting areas in summer. From this figure it is seen that Ganges river side (at profile starting point) dry sand shows highest reflectance at band5 and the value is around 60. At the northern side of Ganges river the response of moderately moist sand at band5 is within the range of 40 to 50. At Ganges river bed the response of water (river water) at band4 and band5 are around 5 and the response at band4 is little bit higher than the response at band5. Except dry sandy area highest response shows Barind Tract area and values of reflectance ranges from 35 to 56.

In between the north bank of Ganges river and Barind Tract there is a flood alluvial plain land and there are traces of low land vegetation activities. Crops at low lands and bil area show response within the range of 18 to 38 for both band4 and band5. Response of permanent vegetation is around 35 at band4.

Rivers and channels over this area like whole country charges in rainy season. In figure 6.2b in comparison with figure 6.2a, it is seen that the width of full charged Ganges river is about three times wider in rainy season. Turbidity of Ganges water is also high in this time due to erosion and shows higher values at band4 and lower value at band5 then the response in dry season. At permanent vegetated area photosynthetically active portions are more sensitive in rainy season due to greenness healthy and watery leafs. Over Barind Tract areas a prominent change has observed, which indicate the change of vegetation activities due to seasonal behavior change. In this area response at band4 is higher then the response at band 5.

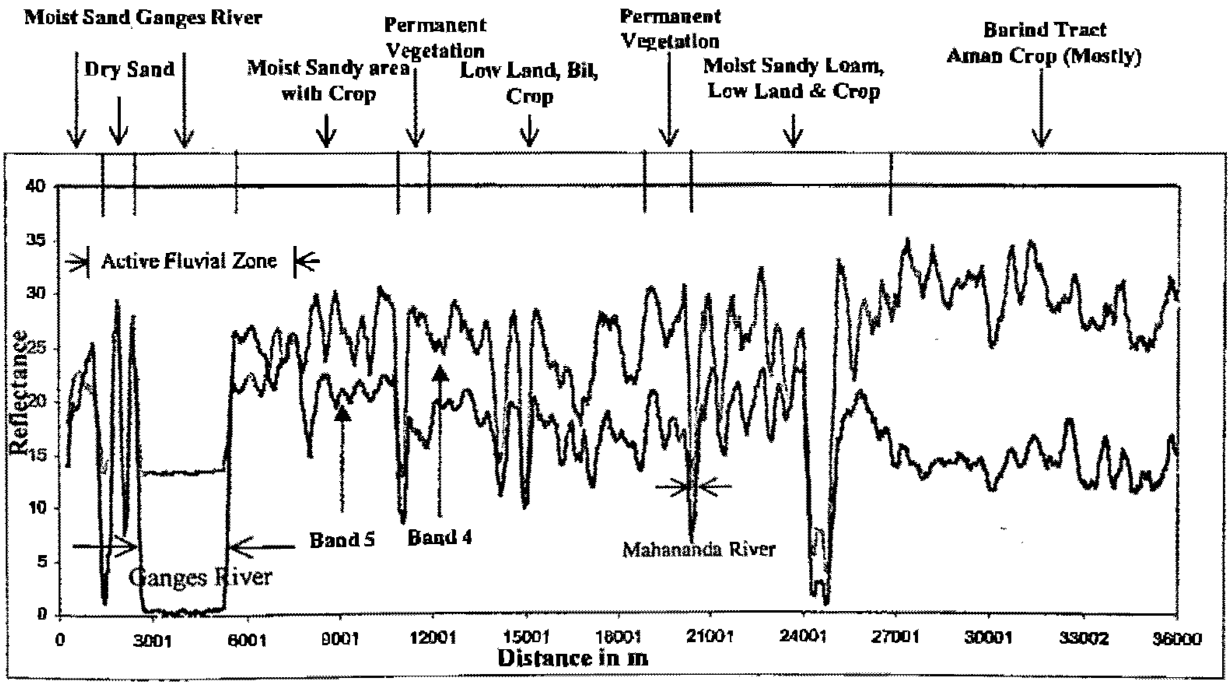



Figure 6.2b: Change of surface types due to seasonal as well as climatic change with respect to the surface types in summer detected by Landsat TM satellite data.

## Chapter Six Conclusion:

In this chapter it has been studied the potentiality of remote sensing data for environmental study. From the analysis it is found that the dynamics of geographic phenomenon can easily be identified using satellite images. Even dynamics of geo-biospheric activities due to seasonal climatic variation can be identified. For information extraction from Landsat TM images, here it were used point data and profile data extraction systems. For landscape study here it was used profile data and for a small area (like a pixel area) it was used point data.

Except river side dry sand, dry soil shows highest response in any seasonal meteorological condition. Dry soil of Barind Tract also shows higher response than the dry soil of flood plain areas. Changes of vegetation activities, both in flood plane and Barind Tract areas are identified in profile data. Crops, sparse vegetation and permanent vegetation shows higher response in summer than the response in rainy season at all bands due to the turbulently domination of background. The overall response at band 4 in rainy season is around 30 which is lower than the reflectance value of same band in summer. Crop health can be monitored with the remote sensing data. Higher values of |Band4~Band5| indicates the good health vegetation and it is independent on meteorological as well as geographical variation.

There is a large water body adjacent to the Barind Tract and that is clearly identified in the rainy season profile. But in the profile response curve of summer, the trace of this low land/water body is not so prominent. The water of low land/bil area is comparatively clear than river water of Ganges and Mahananda. And the response at band 4 over bil area is also lower than the responses over river water. Hence it can say degrees of turbidity variation can be monitored with the aid of remote sensing data.

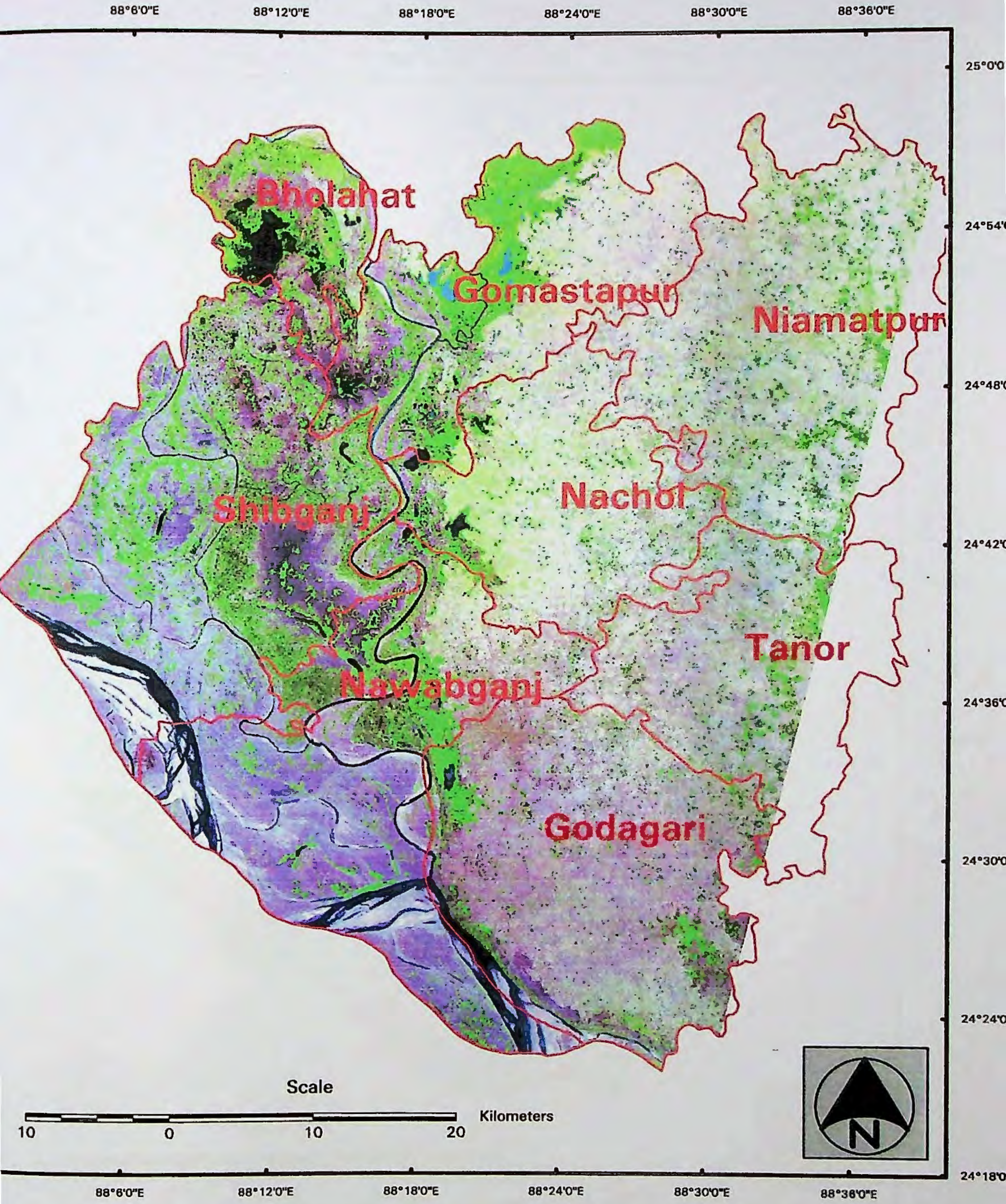
# Chapter Seven
## Feature Based Analysis of the Thermo-Environmental Variability Using Multitemporal Landsat TM Data

Surface temperature is one of the indicator of biophysical change of land-surface and land-surface cover (Lambin and Strahler 1994). Thermal behavior of surface is influenced by the variation of soil moisture, vegetation activities and elevation, and also by the climatic variables which varies due to seasonal variation. Incoming energy is independent on land surface processes but in net radiation surface and surface cover has clear involvement (Linacre 1972). Satellite based vegetation indices is the powerful tool to study the land-cover and it's changes due to spatial, physiographic and seasonal variation. Ratio Vegetation Index (RVI) and surface temperature jointly shows the mechanism and contribution of vegetation on thermal stabilization.

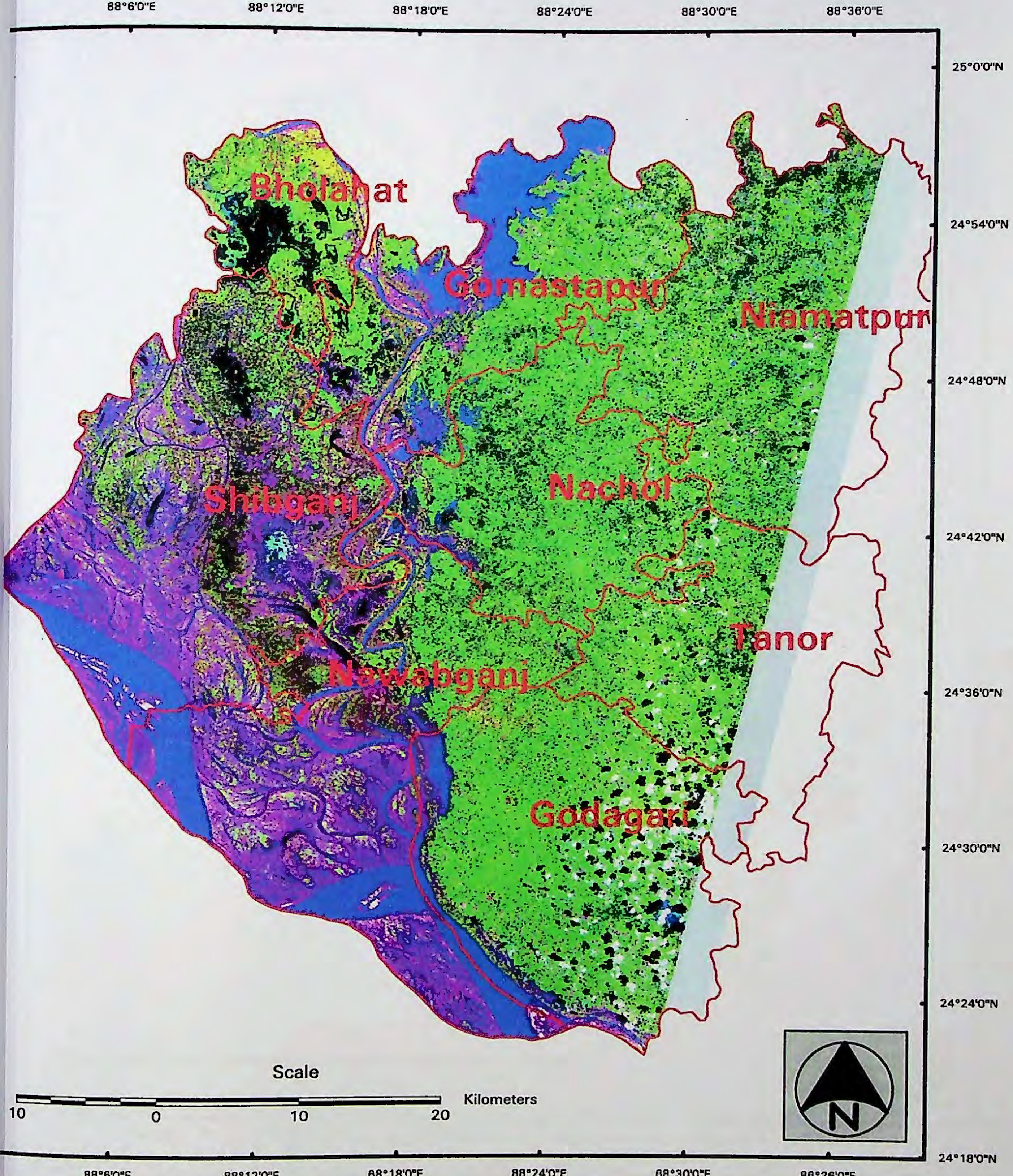
## 7.1 Dynamics of Seasonal Changes of Surface Types

As Bangladesh is an agriculture-based country, a variety of crops is cultivated throughout the country in different proportions. Here, it should be mentioned that rice is the major crop of Bangladesh and it is cultivated over more than 70 percent of cultivated areas (BBS 1998). Different varieties of rice are grown in Bangladesh. Aman (physiological race of *Oryzoe Sativa*) rice is grown during July-December, while Boro rice is grown during December-May. Aman is a rain fed crop whereas Boro is not a rain fed crop and the water requirement of the Boro crop during the dry season is met through irrigation. In face of high population density (about 774 person per square kilometer) and its rapid expansion, cropping intensity in Bangladesh increased from 151 percent to 179 percent between 1972 and 1995 with an increase of rice production from 9.9 million tons to 18.34 million tons (Tyson 2002) as an initiative to meet up the increasing food demand of the country.

Figures 7.1a, 7.1b and 7.1c represent the spectral colour composites of Landsat TM images of April 11, 1990; October 20, 1990 and February 09, 1991 corresponding to summer (dry) season, rainy (wet) season and winter season respectively covering the study area. Each of the colour composite images is composed of bands 2, 4 and 3 of Landsat TM in red, green and blue plains respectively. From these figures, it is evident the dynamic changes in vegetation cover in areas under the present study.




gure 7.1a: Spectral colour composite of Landsat TM (April 11 1990) of Barind Tract and flood pl
eas, in the north-western part of Bangladesh. The composite is composed of Bands 5,4 and 3
ed, green and blue).




gure 7.1b: Spectral colour composite of Landsat TM (October 20, 1990) of Barind Tract and
od plain areas, in the north-western part of Bangladesh. The composite is composed
Bands 5, 4 and 3 (red, green and blue).

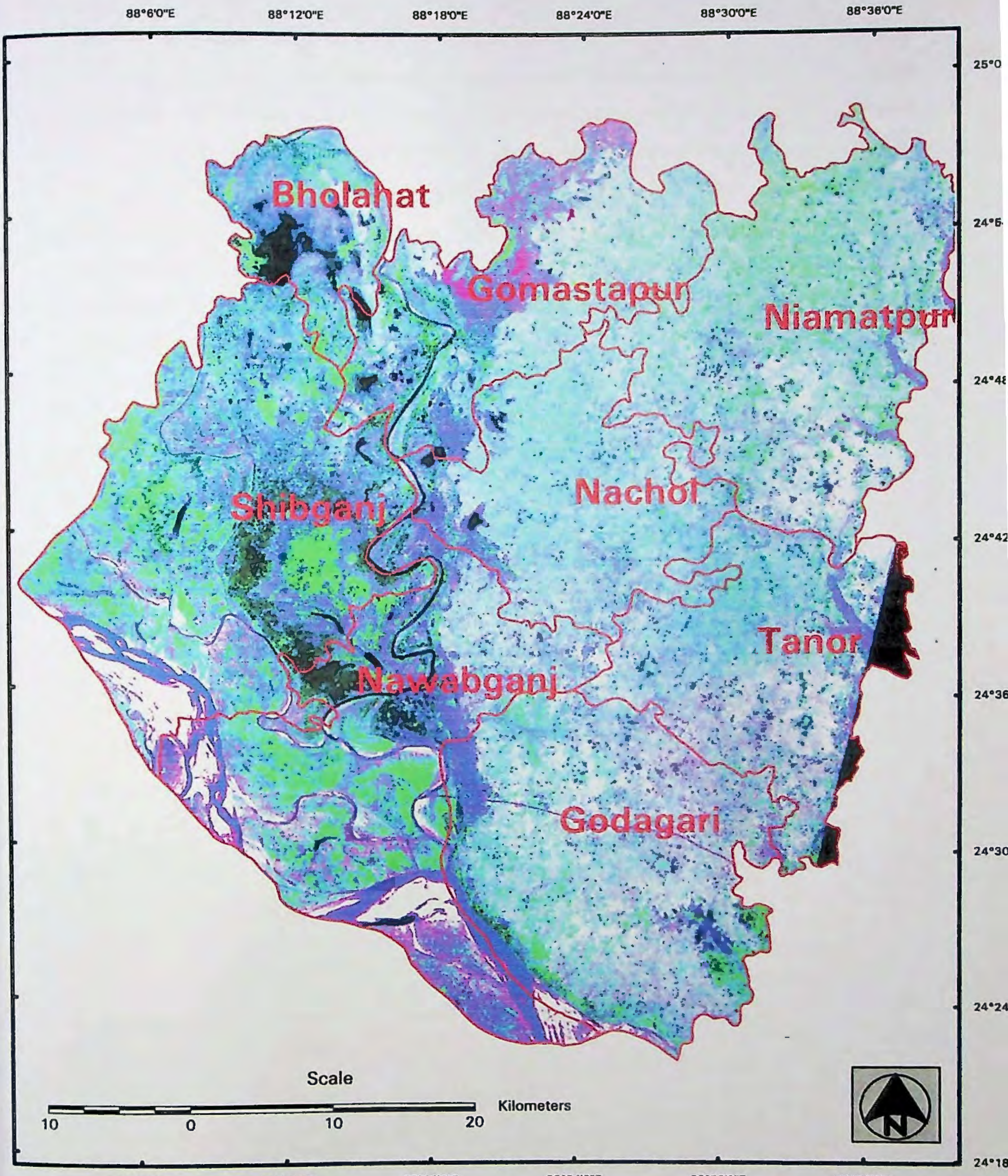



Figure 7.1c: Spectral colour composite of Landsat TM (February 09, 1991) of Barind Tract and flood plain areas, in the north-western part of Bangladesh. The composite is composed of Bands 5, 4 and 3 (red, green and blue).

Table 7.1 provides upazila-wise distribution of different surface features in summer, rainy and winter seasons over the study area as obtained through digital classification of Landsat TM images of different dates mentioned earlier. Comparison of physiography of the area (figure 4.2) with satellite image shows that the density and type of surface cover as well as its condition are not evenly distributed over the study area. The geomorphological influence is quite evident in the zoning of vegetation with factors including slope, drainage and soil type and its composition. These findings are quite in agreement with the results obtained by Jacobberger and Hooper (1991) or Jacobberger-Jellison (1994) on semiarid area of Ngamiland district in north-western Botswana.

Table 7.1: Upazila-wise area distribution of different surface features in summer, in rainy and in winter season as derived from multi-temporal Landsat TM images.

| Name of Upazila | Seasons | Area (hectare) corresponds to | | | | |
|---|---|---|---|---|---|---|
| | | Bare soil | Water | Vegetation | | |
| | | | | Mango orchard | Crop | Other vegetation |
| Nachol | Summer | 24,862 | 359 | 490 | 1,713 | 1,079 |
| | Rainy | 5,398 | 731 | | 20,913 | |
| | Winter | 25,442 | 1,024 | | 623 | |
| Niamatpur* | Summer | 35,248 | 125 | -- | 2,960 | 1,579 |
| | Rainy | 5,532 | 75 | | 25,215 | |
| | Winter | 39,093 | 442 | | 3,037 | |
| Tanor* | Summer | 17,663 | 20 | -- | 2,086 | 633 |
| | Rainy | 3,360 | 62 | | 11,577 | |
| | Winter | 25,410 | 437 | | 1,100 | |
| Godagari* | Summer | 37,414 | 881 | 972 | 3,808 | 909 |
| | Rainy | 13,990 | 2,077 | " | 22,152 | |
| | Winter | 36,639 | 2,758 | " | 3,342 | |
| Nawabganj | Summer | 33,319 | 3,026 | 4,255 | 5,589 | 359 |
| | Rainy | 27,282 | 8,644 | " | 6,082 | |
| | Winter | 27,626 | 7,397 | " | 7,115 | |
| Bholahat | Summer | 4,658 | 1,190 | 2,433 | 4,363 | -- |
| | Rainy | 3,138 | 1,322 | " | 5,645 | |
| | Winter | 5,090 | 2,613 | " | 2,434 | |
| Shibganj | Summer | 29,998 | 1,705 | 14,635 | 7,403 | -- |
| | Rainy | 31,417 | 4,681 | " | 2,642 | |
| | Winter | 23,883 | 3,763 | " | 10,530 | |
| Gomastapur | Summer | 18,542 | 1,066 | 2,606 | 9,624 | 62 |
| | Rainy | 9,403 | 6,492 | " | 13,314 | |
| | Winter | 23,934 | 3,107 | " | 2,166 | |

* Upazila area is not fully covered by the satellite images in a given date. Missing areas for Niamatpur, Tanor and Godagari upazilas are respectively about 4,132, 8,925 and 29 hectares in summer, 187, 2,263 and 0 hectares in winter and 11,501, 12,933 and 4,007 in rainy season. Missing areas are about 4.5, 0.8 and 10 percent respectively in summer, winter and wet season.

### 7.1.1 Barind Tract Area

Referring to image of April 11 1990 (figure 7.1a) representing the summer (dry) period situation, two characteristically different tones are observed in the flood plain areas and Barind Tract areas. The variation in landscape corresponding to different landform units is clearly visible in this optical image. An overall relatively brighter response is observed all over the Barind Tract area in comparison to flood plain areas. Whitish and pink traces over the Barind area are mostly denude lands having different moisture contents. Soil in general suffers from moisture deficit during dry period in the Barind area as is observed in general over the semiarid region (Verstraete and Pinty 1991). Variation in soil moisture content results in varying spectral properties and tonal variation in the image due to different levels of water absorption. Bright white tone in nearby river areas of active and very young meander floodplains (figure 4.2), mainly represents comparatively dry sandy lands (e.g., location S in image 7.1a). Yellowish and light greenish traces represent the soil with sparse vegetation or grass.

The ecosystems of the Barind Tract and the adjacent areas are not stable. Wide scale denudation of land and expansion of rice monoculture has contributed to soil erosion (Haque 1997). Evidences of land degradation have been reported over the area in which low soil fertility is recognized to be at the root of the land degradation (Reazuddin et al. 2002). Land degradation due to aridity and loss of crops due to droughts have caused considerable economic losses and human suffering in Bangladesh. The Barind Integrated Area Development Project (BIADP) (later renamed as Barind Multipurpose Development Authority (BMDA)) started in 1985 was implemented to mitigate the processes of land degradation of the Barind region.

The upazilas of Niamatpur, Tanor, Shibganj, Godagari and Nachol upazila are mostly semi-arid areas having very small amount of vegetation cover and relatively high spectral response.

In the northern central part of the study area, i.e., in the Gomastapur upazila, the eastern part of the upazila includes the Barind formation under broadly dissected and closed dissected terrace areas. The areas are relatively dry as observed in bright color and are generally devoid of vegetation. While the western part under old flood plain basins and oldest meander floodplain shows relatively lower spectral response. The highly dry zone seems to be situated in Nachol (very bright spectral response). Contrarily, in Godagari upazila, under closely dissected terrace and a small portion under broadly dissected terrace surface seems to contain relatively higher moisture. In the Bholahat upazila, the existence of a relatively narrow bright zone corresponding to Barind formation comprising of level, covered terrace (figure 4.2) is noticed that extends up to Gomastapur upazila.

According to table 7.1, about 90 percent of the Barind area under the present study is found to be under bare soil or fallow land category in summer. Whereas, only about 9.6 percent of the area is found to be as vegetated under different vegetation classes including homestead vegetation. Here, it should be pointed out that the proportion of water area in relation to total land area of Barind Tract is significantly small (less than 1 percent of the total land areas). Moreover, there is a lack of rainfall during summer (figure 7.2) and soil contains relatively low moisture as mentioned earlier. Such a limitation largely restricts the potential uses of the area for crop cultivation through surface water irrigation particularly during the period of water deficit, i.e., in summer and winter. However, cultivation over certain areas in the Barind Tract through ground water irrigation is developing in the recent years and thereby exploitation of ground water is also increasing (BBS 1987; BBS 1997). In general, the only means of irrigation in this area is deep tube-well.

Referring to image of October 20 1990 (figure 7.1b) representing the wet period condition, deep green and light green traces all over the Barind Tract are the Aman rice areas. About 76 percent of the land area in Barind Tract under the present study is covered by vegetation of which 72 percent belongs to Aman rice area. Here, it should be mentioned that due to sufficient rainfall during this season (figure 7.2), Aman rice is generally cultivated in most of the areas and very few exposed soil areas are generally visible during this period. The present situation in the Barind area is completely in contrast to the observed situation in summer when the area remains mostly dry and fallow. Landform characteristics and hydro-climate mainly determine the agriculture and other vegetation activities over the area. In the image of October, the presence of several small white clusters followed by darker shadows particularly in the Godagari upazila are due to the presence of scattered clouds over the area at the time of satellite data acquisition.

Spectral characteristics of water bodies over different parts of the study area show significant variability over time and space. Comparison between different dates shows relatively darker appearance of water bodies in summer due to relatively lower spectral response in all the three bands 2, 3 and 4 of Landsat TM. In summer, water bodies generally do not contain any significant amount of sediments. While, in rainy season, water bodies contain significant amount of sediments. Since band 3 of TM is most sensitive to sediment concentration in comparison to other bands of TM (Rahman et al. 1996), a dominance of blue colour is noticed over the water areas when band 3 is loaded in blue plain of the display system. Increase in sediment content in water bodies results in an increase in bluish tone in colour composite images comprising of bands 2, 3 and 4 (R,G,B) of Landsat TM. Another point is to be noted that the rivers appear to be much wider in the rainy season in comparison to summer and winter seasons.

Field investigation based on remote sensing data indicates that some scattered clusters of very light green, yellowish color traces in Barind Tract are thin coverages of Tamarisk and reedy grass Babul (*Acacia arabia*) and Mango (*Mangifera indica*) which are not well-distinguishable from each other in these colour composite images comprising of bands 2, 4 and 3 of Landsat TM. This is due to relatively small cluster size of the class elements and TM spatial resolution of 30 m. In some areas, presence of very few mango orchards and other trees is noticed but is not very common. The coverings of highly elevated lands over this area comprise of bamboo, grass, imperata arumdinacea, andopogon ociculutus, banyan, pipal and semul. Palms and date palm (Khejur) trees are seen all over the study areas but in the southern side, it is grown widely.

In the winter season, in Barind Tract area, the presence of rabi crops are almost insignificant except a few traces particularly in the Godagari upazila as is evident from figure 7.1c. Only about 8 percent of the total land area of Barind Tract under the present study is found to be as vegetated area. While, about 91 percent of the total land area is found to be as fallow or bare land. This is due to unavailability of water, lack of rainfall and deficit of moisture content in the soil layer over the area during winter as explained earlier.

From the analysis of the images of different seasons (figures 7.1a, 7.1b and 7.1c), it is evident that Barind tract is basically a single cropping area where about 90 percent of land is found to be as bare or fallow during winter and summer (table 7.1). While, about 76 percent of the total land area is found to be as vegetated during rainy season of which about 72 percent area is covered by Aman rice. Small portion in Barind Tract corresponds to double or triple crop.

### 7.1.2 Flood Plain Area

The alluvial flood plain areas of the rivers Old Ganges, New Ganges and Mahanada are generally characterized by gentle topography. In general, low, level to very gently undulating ridges and broad, almost level, basins between them constitute the landscape of the area. Slight differences in elevation between ridges and adjoining basins are noticed over the area. Plain lands (location 1 in figure 7.1a), swampy (low/bil) lands (location 2) and eroded sandy lands (location 3) etc. are the generally seen surface features of the area. Referring to figure 7.1a of April 11, 1990 representing the summer (dry) period, presence of Boro rice (green colour area) is noticed over the swampy lands in a significant portion of low land areas.

Seasonal flooding is one of the important characteristics of hydrology of the flood plain area in relation to agriculture and vegetation cover. Depth of flooding as determined by the topographical position determines the vegetation development over certain flood plain areas under the present study. The basin soils are subjected to varying degree of flooding during wet season, consequently relatively low-lying areas of the flood plain often remain wet or under water even in the early part of the dry season, as they receive seepage and run-off from adjoining high land. Thereby, these areas support rice crop cultivation during dry season when cultivation is often constrained by the lack of required rainfall and soil moisture particularly in the Barind area. The presence of Boro rice area is very much visible in the north-western part (green traces) particularly in north-western part of Gomastapur upazila comprising of old floodplain basins, northern part of Bholahat comprising of mixed Ganges and Mahananda flood plains, sides of Mohananda river in the Nawabganj upazila. Here it should be mentioned that Boro rice is generally grown in summer when no significant rainfall occurs over the area. Water supply is maintained to the Boro crop area through irrigation in most of the places. According to table 7.1, a total of about 22.3 percent of the flood plain area under the present study is under Boro cultivation. During wet season, about 6 percent of the area of the flood plain is found to be under water. In contrast, Barind Tract is generally positioned at above flood level and becomes droughty in the dry season.

In figure 7.1a, green and light green traces in northern part of Barind Tract, in some low lands and drainage areas, in areas adjacent to settlement as small clusters distributed all over the Barind area and in the lower part of Godagari upazila adjacent to Padma river are the Boro rice areas. It is seen that Boro rice areas are also situated around lake surface bed and drainage bed areas.

Figure 7.1b shows the distribution of vegetation and other surface features during wet (rainy) season as observed in Landsat TM of October 20, 1990. In rainy season Aman rice is grown besides swampy lands as indicated in figure 7.1b in green colour. In general, swampy lands are flooded annually and as such cultivation of Aman rice is very much limited over this area. Thus major portion of the area is found to be as bare land (violet colour in figure 7.1b). A total of about 9.8 percent of the flood plain area under the present study is found to be covered by Aman crop (table 7.1). While, about 63 percent of the land remain as bare or fallow. In arable areas of plain lands, Boro rice is grown in summer and Aman rice is grown in rainy season.

From figure 7.1c representing the winter period, it is evident that rabi crops are mostly concentrated in the flood plain areas particularly over relatively large areas of Shibganj (about 10,530 ha) and Nawabganj upazilas (7,115 ha) situated in the flood plain areas and over a few places in the Bholahat and Gomastapur upazilas (about 2,434 and 2,166 ha respectively). In the active and very young Ganges meander flood plain (figure 4.2), the parent materials are predominantly sandy and silty and calcareous throughout (Reconnaissance Soil Survey 1968). This type of soil is not suitable for rice cultivation. Consequently, only rabi crops like wheat, pulses, mustard and some winter vegetation are generally grown over these areas during winter season as indicated in figure 7.1c (e.g., locations R1, R2 and R3). It is found that about 20 percent of the flood plain area under the present study is covered by rabi crops (table 7.1).

Dark green traces in the low land areas (young meander flood plain of the river Mahananda, figure 4.2) of Shibganj upazila (location M1 in figure 7.1a), upper western part of low land of Bholahat upazila, in both sides of Mahananda river, lower part of Godagari upazila besides

Padma river and in the pocket of 'U' shape of Mahananda river in Nawabganj upazila (location M2 in figure 7.1b) are the Mango Orchads. In this area Mango Orchard is very common, about 20 percent of total plain land areas are occupied by Mango Orchard with a small portion of other local fruits (figures 7.1a, 7.1b and 7.1c). Here it should be mentioned that the commercial production of mangoes is mainly concentrated in Nawabganj and Shibganj upazilas.

In the Gomastapur upazila, the northwestern part that was covered by Boro rice in summer (green colour in figure 7.1a), presence of water in October (blue colour in figure 7.1b) is very much visible in the digital image. Few scattered green spots in some river channels in the image of April 11, 1990 (figure 7.1a) are Boro rice, where the presence of water is noticed in the image of October 20, 1990 (figure 7.1b). Field investigation shows that an all-season crop sugarcane is grown randomly as small individual clusters over different parts of this plain land, however, these clusters are not well-distinguishable in the image.

Analysis of figures 7.1a, 7.1b and 7.1c corresponding to flood plain area shows that a significant portion of area correspond to double crop and small portion to single and triple crop. Major crops in summer are Boro rice, in winter Rabi crops and in rainy season Aman rice. In plain land deep tube-well, shallow tube-well, tube-well and normal wells are used for irrigation. In dry season canals, tributaries become dry but surface water bodies like ponds, bowl shape low land and low lying swampy lands hold water.

Seasonal land cover conversion is very much dynamic in the study site particularly over the semi-arid Barind Tract area. As a general observation, the flood plain areas are moderately vegetated throughout different seasons which is in contrast to Barind Tract area that remains either mostly bare (about 90 percent) or highly vegetated (vegetation cover greater than 75 percent) depending on the season. Availability of water appears to be the main governing force that controls almost entire vegetation activity over this area. Such a behaviour is in consistent with the remarks made by Winkworth (1970) that in arid and semi-arid zone soil water regime dominates the vegetation and crop growth pattern. In the flood plain areas, presence of a significant portion of permanent vegetation (trees) ensures all season vegetation cover over significant part of this area. On the contrary, in Barind Tract, no significant presence of permanent vegetation (trees) is noticed. In the semi-arid Barind Tract area the cover change is maximum and the vegetation cover ranges from a value of 8 percent to a value of 76 percent during the seasonal transition from summer to rainy season. Whereas, in the flood plain areas cover change is moderate and the vegetation cover varies from a value of 36 to a value of 44 percent, i.e., an increase of only about 6 percent is noticed.

The agricultural functionality of an area is greatly influenced by a number of factors particularly whether the area is flooded deeply or for long period, whether its soils retain moisture during the period of drought, how high above and far from sources of surface or under ground water the fields may be in the dry season (Johnson 1982). Depth of flooding in relation to land elevation during wet season, and soil moisture content during dry season are seemed to be the two major determinative variables that governing the land use of the study area. Flood plain areas are mainly used as single and double cropped land with some areas triple cropped. Whereas, Barind Tract area is mainly used as a single crop land and the crop is transplanted Aman.

## 7.2 Study of Thermo-Environmental Characteristics

### 7.2.1 Seasonal Meteorological Variability

Incident solar radiation, rainfall and temperature are the major meteorological parameters influencing the earth's energy budget. Figure 7.2 shows the ten years (1986 to 1995) variation of mean monthly rainfall pattern of Nachol upazila, central part of the study area and the variation of mean monthly temperature pattern of Rajshahi zone. From this figure it is evident that from November to April there occurs no significant rainfall. However, apart from April, rainfall gradually increases up to the next consecutive months and reaches to its peak value around June/July and then rainfall starts decreasing. While, temperature time chart exhibits that, maximum temperature observed at April with gradual low values on both sides.

Figure 7.3 shows the variation of monthly mean net radiation pattern recorded at Bogra station for the period of 1991 to 2000. From this figure it is evident that net radiation changes with time and a significant variation is observed. From figure 7.3 it is seen that net radiation starts increasing from January and shows it's maximum value in April. Apart from April net radiation decreases and minimum value observed in December. The lowest and highest values of the recorded net radiation are about 200 and 350 cal/sq. cm/day respectively, i.e., minimum value is about 75 percent lower than the maximum value with respect to lowest value.

### 7.2.2 Land Cover Dynamics and Thermal Environment

Surface temperature has derived using thermal data having spatial resolution of 120m of Landsat TM images dated April11, 1990 and October 20, 1990 for dry season and rainy season respectively. Spatial distribution of surface temperature derived from satellite thermal data has shown in figure 7.4a and 7.4b for dry season and rainy season respectively. There is no relation between the satellite derived surface temperature and recorded temperature at meteorological station but there is a simulation with the historical meteorological data. Satellite data is the average of instantaneous response of a pixel area and varies from pixel to pixel. And meteorological data is the average value of a large area and records only maximum and minimum value. Local area variation within this zone can never be considered.

From figure 7.4a for dry season, it is seen that semi-arid zone Barind Tract and flood alluvial plane land exhibits the temperature of almost same range. But most of the area of Barind Tract are under the medium to highest temperature range while the over all response of plane land are under the medium to lowest temperature range. Low land and low land cropping areas at Bholahat upazila, low land cropping areas of northern part of Gomastapur upazila, low land cropping areas of eastern side of Mahananda river, scattered cropping areas, small water bodies in Barind Tract and water of Ganges and other river shows the lowest temperature. In this season crops are mainly irrigation types. Dense cropping areas, low land cropping areas, underlying water at sparse vegetation, irrigated areas and water itself having the properties of high specific heat, may be the cause of lowest temperature demonstration. Permanent vegetation of Nawabganj, Shibganj and Bholahat upazila shows moderate temperature. North-east corner, eastern side and central part cropping areas and homestead vegetation of Barind Tract also shows moderate temperature.

With the increase of soil moisture, thermal conductivity and heat capacity of soil generally increases (Kalma 1971) which directly influence the heat flow and temperature change of soil (Goel and Norman 1990). Eventually, in dry season, comparatively high moist area in the southern portion of the Barind Tract area and some portions of flood plain area exhibits relatively high surface temperature.

In table 7.2 provided the values of thermal properties of different earth surface features. Soil generally has lower specific heat than vegetation. As a result, soil temperature increases more than vegetation temperature under a given external thermal agitation.

Table 7.2: Thermal properties of selected earth surface materials (Reeves 1975).

| Surface features | K | ρ | C | κ | P |
|---|---|---|---|---|---|
| Clay soil (moist) | 0.0050 | 2.8 | 0.20 | 0.009 | 0.0530 |
| Sandy gravel | 0.0060 | 2.1 | 0.20 | 0.014 | 0.0500 |
| Sandy soil | 0.0014 | 1.800 | 0.24 | 0.003 | 0.0240 |
| Water | 0.001429 | 0.998 | 0.999 | 0.0014 | 0.0378 |

**Here, K is the thermal conductivity in W $m^{-1}$°K, ρ is the density of the substance in gm $cm^{-2}$, C is the specific heat in cal $gm^{-1}$ ° $K^{-1}$, κ is the thermal diffusivity in $cm^2$ $sec^{-1}$ and P is the thermal inertia in cal $cm^{-2}$ $s^{-1}/2$.**

Maximum surface temperature in the semi-arid zone Barind Tract in dry season is 41°C and minimum is 26°C. Denude soil surface temperature is found to be relatively higher and ranging from 29°C to 39°C. Within this range, surface temperature varies place to place and this variation is in agreement with the soil moisture variation. Top corner of Niamatpur (maximum), middle of Nachol and few scattered areas shows temperature ranges from 29°C to 32°C. Maximum of Godagari, major portion of Tanor and few scattered parts of Gomastapur shows the temperature variation from 35°C to 39°C. Maximum area of Nachol, Niamatpur and major portion of Gomastapur shows temperature from 33°C to 35°C.

In the alluvial flood plain minimum and maximum observed temperatures are 26°C and 40°C respectively. For bare soil with normal moisture content, surface temperature ranges from 33°C to 37°C.

Surface temperature over permanent vegetation having faded color matured leaf varies from 28°C to 32°C. Over seasonal cropping in both areas lower surface temperature are noticed and it varies from 26°C to 31°C. In both the areas, in both seasons cropping patterns are almost same. In summer here grows boro rice and in rainy season grows aman and both the cropping areas are seen with underlying water. Water bodies of both Barind Tract and flood plain area shows lowest temperature and ranges from 25°C to 28°C.

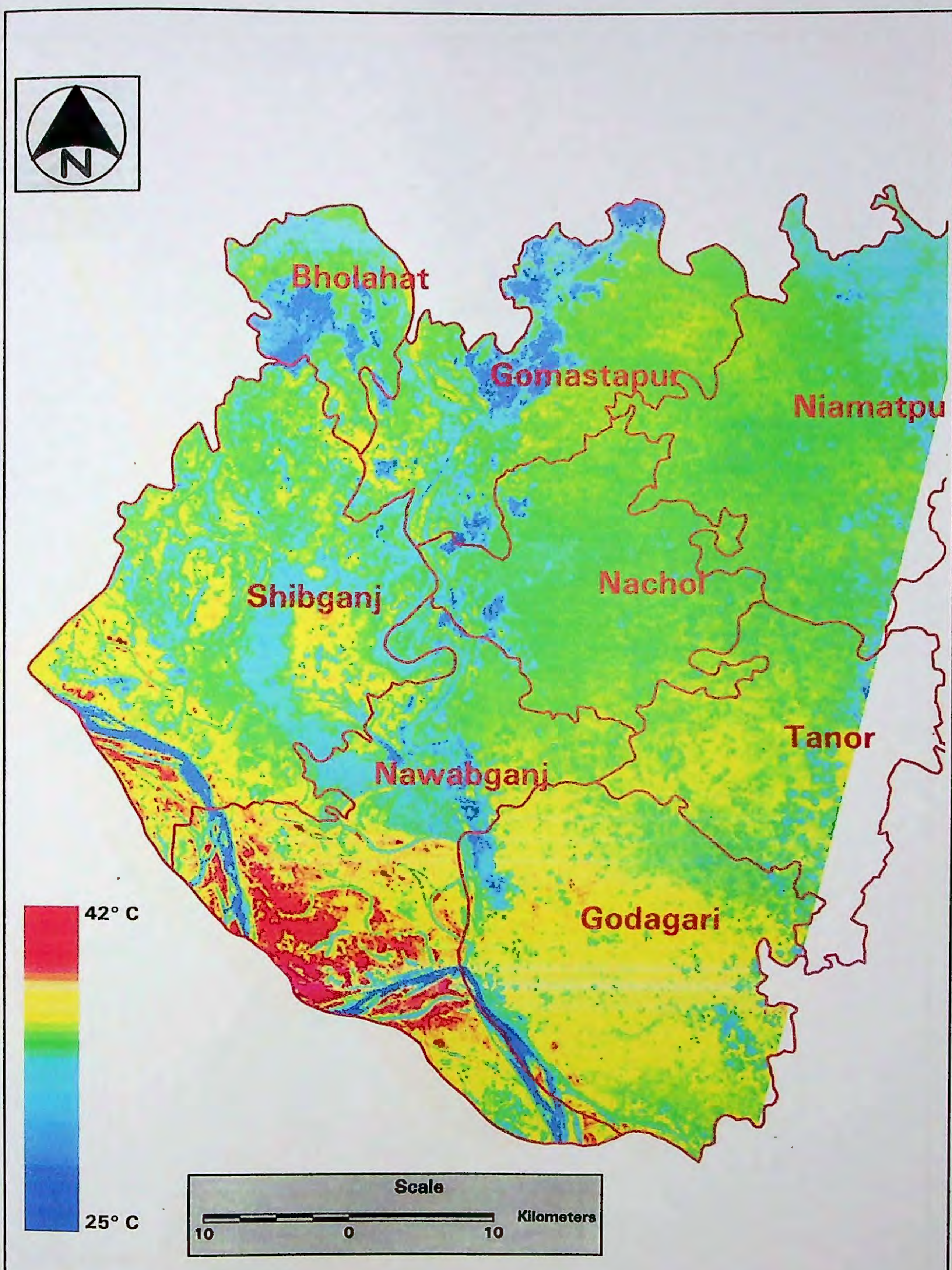



**Figure 7.4a: Surface temperature distribution pattern over the Barind area as derived from Landsat TM image on April 11 1990.**

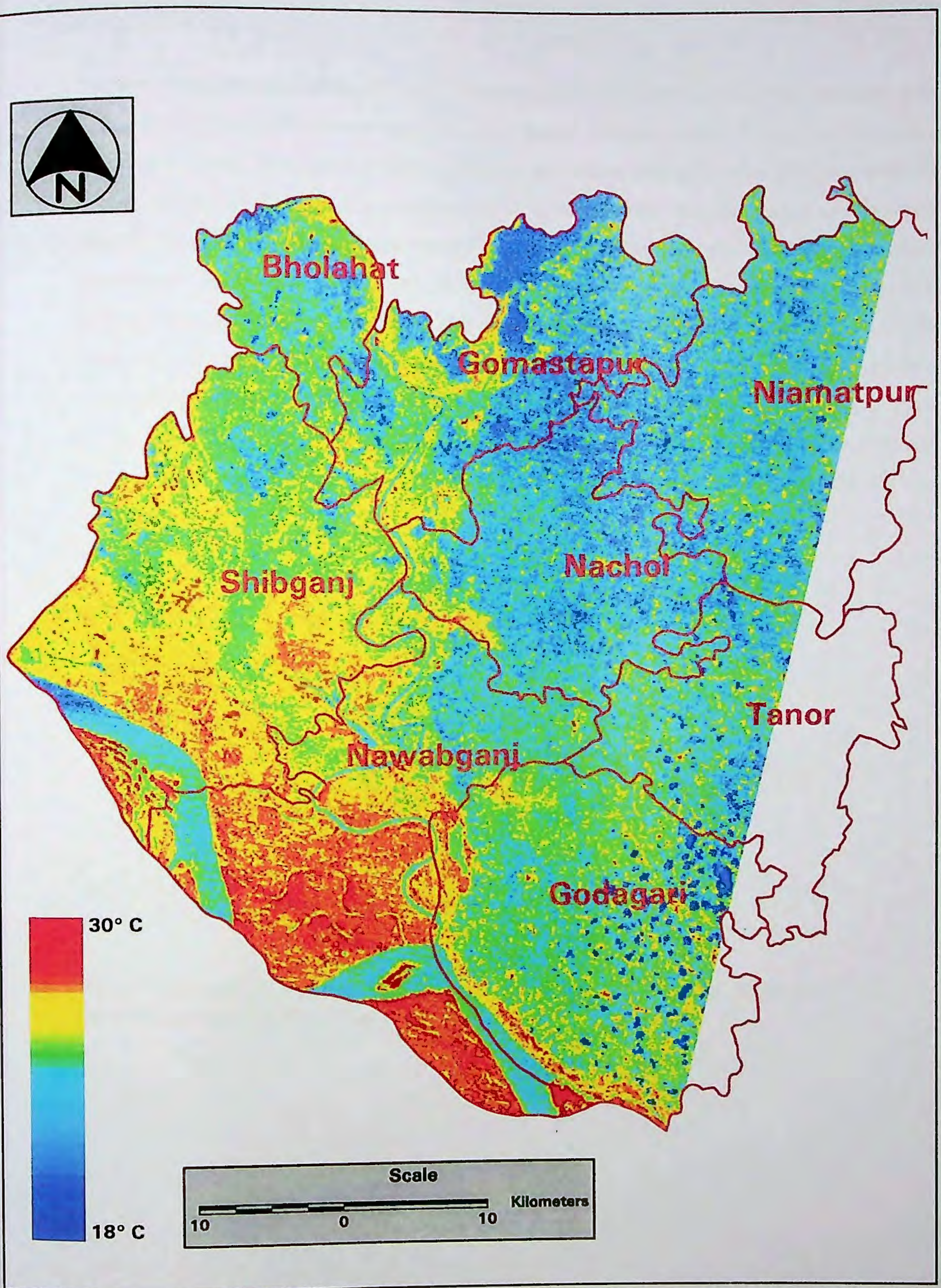



Figure 7.4b: Surface temperature distribution pattern over the Barind area as derived from Landsat TM image on October 20 1990.

Surface cover dynamics of Barind Tract is most sensitive to seasonal variation. Surface cover changes maximum with the seasonal climatic change. In rainy season here grows huge rain feed Aman crops. Maximum rainfall occurs in this season and soil areas are found with its saturation level of moisture. Crop and moist soil both has lower specific heat. And hence this area shows relatively lower surface temperature in rainy season. But the sensitivity of surface from profile intersecting points for both summer and rainy season. Surface temperature and RVI has been plotted against the same X,Y plane and shown in figure 7.5a and figure 7.5b for summer and rainy season respectively. From these figures it is evident that surface temperature is low and RVI is relatively high in flood plain areas. And for Barind Tract surface temperature is high and RVI is low.In the context of seasonal variation, surface exhibits high temperature and low RVI in summer and low temperature and high RVI in rainy season.

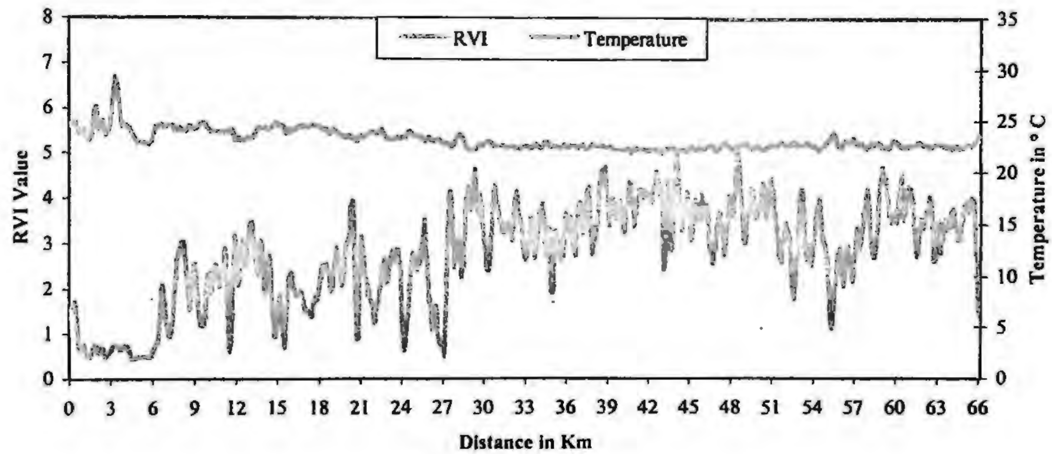



Figure 7.5a: Spatial Variation of Surface Temperature and Satellite Based RVI Value as derived from Landsat TM image dated April 11, 1990.

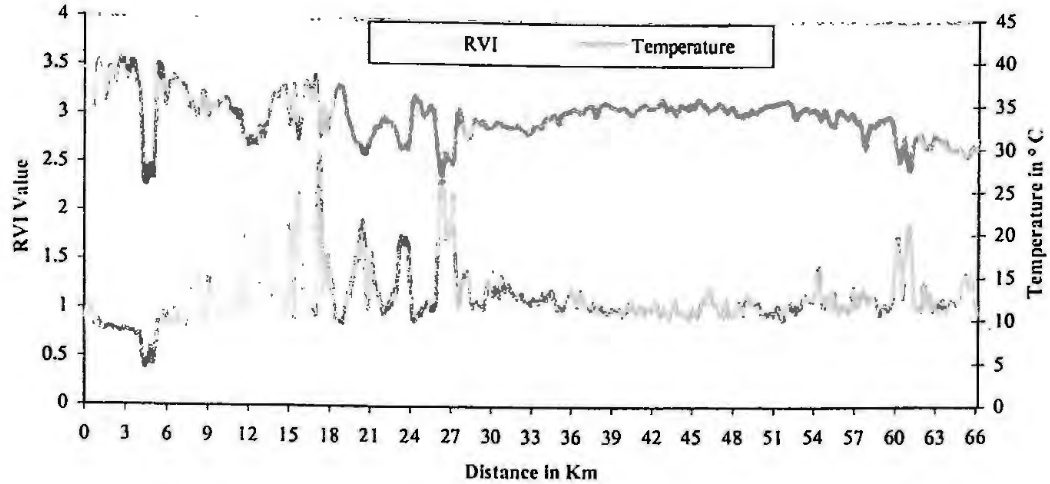



Figure 7.5b: Spatial Variation of Surface Temperature and Satellite Based RVI Value as derived from Landsat TM image dated October 20, 1990.

Figure 7.6, demonstrates the properties of Ratio Vegetation Index (RVI) as a function of satellite derived surface temperature. RVI of different earth's surface features and their corresponding surface temperature has been extracted from Landsat TM image of April11, 1990 for both Barind Tract and flood plain areas which also shown in table 7.2. From figure 7.6 it is evident that with the increase of RVI values surface temperature decreases and vice-versa, and this relation is independent on seasonal variation. Decreases of RVI make surface temperature (Ts) dependent of underlying surface. Zero (0) RVI means 100% soil and surface temperature is the soil surface temperature.

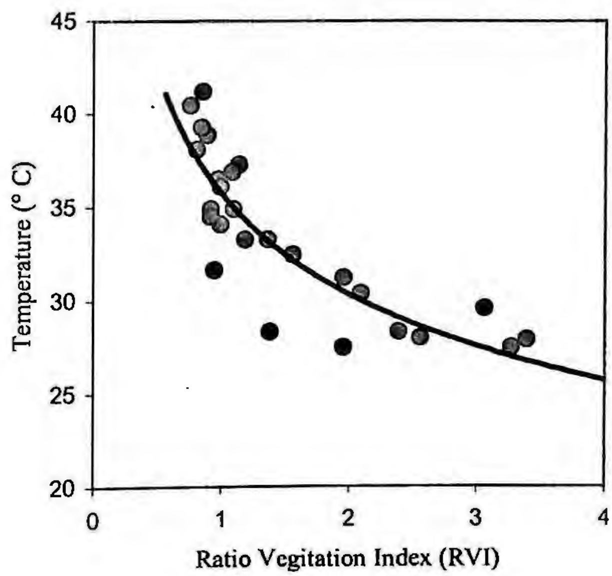



Figure 7.6: Dependency of satellite based surface temperature on the satellite based vegetation index.

RVI values as shown in figure 7.6, varies within the range of 0.7 to 3.3, while the corresponding variation of surface temperature are found between 26°C to 40°C. But with the increase of RVI, surface temperature gradually becomes less sensitive to the changes of RVI and after a certain value of RVI, surface temperature becomes almost leveled-off or insensitive to RVI.

In this case it is seen that vegetation is a major factor governing the surface temperature. For bare soil solar radiation reaches directly to the surface and fixes up the surface temperature accordingly. However, for a thin coverage of vegetation, the incident solar radiation is intercepted by the top vegetation layer and part of this intercepted energy is then transmitted to background. As the vegetation density increases, decreases the transmitted energy to background. In such a manner, increased vegetation tends to keep the surface temperature in reduced value. Thus the vegetation layer acts as a thermal shield between the atmosphere and the soil layer and thereby stabilize the surface temperature under varying incident thermal agitation.

Table 7.3: Values of reflectance, temperature and corresponding RVI of different earth's surface features as derived from Landsat TM data of April 1990.

| Feature type | Landsat TM Reflectance | | | | | | Temperature | RVI |
|---|---|---|---|---|---|---|---|---|
| | Band 1 | Band 2 | Band 3 | Band 4 | Band 5 | Band 7 | | |
| Dry Soil | 18.17 | 29.76 | 45.97 | 44.76 | 51.68 | 54.19 | 36.52 | 0.97 |
| Moist Soil | 12.94 | 20.07 | 26.79 | 23.79 | 31.67 | 27.40 | 38.90 | 0.89 |
| Moist Soil | 13.69 | 22.78 | 30.76 | 35.06 | 43.64 | 37.35 | 37.31 | 1.14 |
| Dry Soil | 22.01 | 35.69 | 54.93 | 50.55 | 59.70 | 54.19 | 34.91 | 0.92 |
| Semi Dry Soil | 15.94 | 26.55 | 36.02 | 39.43 | 49.30 | 43.30 | 34.91 | 1.09 |
| Dry Soil | 22.34 | 36.64 | 46.83 | 44.28 | 55.55 | 54.19 | 31.64 | 0.95 |
| Semi Moist Soil | 16.19 | 27.09 | 38.19 | 37.98 | 47.81 | 43.80 | 36.12 | 0.99 |
| Moist Soil | 13.19 | 21.16 | 29.88 | 29.68 | 35.57 | 32.38 | 34.10 | 0.99 |
| Dry Soil | 19.90 | 32.42 | 47.26 | 43.31 | 53.17 | 55.67 | 34.51 | 0.92 |
| Dry Soil | 13.94 | 30.83 | 39.93 | 43.31 | 49.60 | 52.21 | 36.92 | 1.08 |
| Heavy Moist Soil | 11.43 | 17.34 | 22.35 | 18.86 | 24.16 | 23.41 | 39.29 | 0.84 |
| Dry Sand | 30.28 | 45.98 | 61.67 | 46.70 | 57.03 | 63.56 | 40.46 | 0.76 |
| Moist Sand | 16.93 | 29.23 | 40.36 | 32.62 | 42.45 | 46.77 | 38.11 | 0.81 |
| Dry Sand | 20.63 | 36.64 | 45.54 | 38.95 | 53.76 | 63.07 | 41.23 | 0.86 |
| Vegetation | 9.40 | 15.14 | 17.43 | 36.52 | 23.56 | 13.91 | 30.39 | 2.10 |
| Den. Veg | 8.89 | 14.59 | 14.73 | 50.07 | 21.45 | 11.40 | 27.86 | 3.40 |
| Sp. Veg | 14.69 | 23.32 | 30.76 | 36.52 | 37.36 | 32.38 | 33.28 | 1.19 |
| Den. Veg | 10.16 | 20.61 | 21.01 | 53.91 | 27.77 | 16.91 | 27.96 | 2.57 |
| Sp. Veg at Water side | 11.43 | 17.89 | 21.46 | 29.68 | 16.32 | 10.90 | 28.28 | 1.38 |
| Per. Veg | 8.38 | 13.49 | 13.83 | 33.10 | 20.54 | 12.40 | 28.28 | 2.39 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Per. Veg | 9.65 | 16.24 | 17.88 | 35.06 | 22.35 | 14.91 | 31.22 | 1.96 |
| Den. Veg | 8.89 | 14.59 | 14.28 | 43.80 | 24.16 | 14.91 | 29.55 | 3.07 |
| Den. Veg at Sandy area | 13.19 | 15.69 | 20.57 | 32.13 | 23.56 | 21.91 | 32.46 | 1.56 |
| Per. Veg at sandy area | 9.16 | 14.59 | 15.63 | 30.66 | 18.73 | 9.40 | 27.43 | 1.96 |
| Veg at water side | 7.62 | 12.39 | 12.48 | 40.89 | 19.03 | 10.90 | 27.43 | 3.28 |
| Sp. Veg | 12.94 | 20.61 | 26.79 | 36.52 | 39.46 | 27.40 | 33.28 | 1.36 |
| Water | 17.68 | 31.89 | 42.96 | 20.34 | 9.97 | 17.41 | 30.39 | 0.47 |
| Water | 10.16 | 16.79 | 20.12 | 12.41 | 9.66 | 13.41 | 32.05 | 0.62 |
| Cl. Water | 11.68 | 20.61 | 24.13 | 13.41 | 12.39 | 9.90 | 31.22 | 0.56 |
| Cl. Water | 10.67 | 19.52 | 21.01 | 9.92 | 5.70 | 4.38 | 26.14 | 0.47 |
| Water | 11.43 | 16.79 | 16.53 | 8.93 | 8.75 | 8.39 | 27.00 | 0.54 |
| Water | 8.13 | 12.39 | 14.73 | 12.91 | 6.02 | 3.37 | 26.57 | 0.88 |
| River Water of Ganges | 12.18 | 19.52 | 20.12 | 6.43 | 5.42 | 2.87 | 25.28 | 0.32 |
| River Water of Mahananda | 14.44 | 22.78 | 27.67 | 12.41 | 7.54 | 6.89 | 27.86 | 0.45 |

## Chapter Seven Conclusion:

In this chapter, thermo-environmental variability of the study area has been studied using remote sensing and climatic data. Thermal information derived from thermal band of Landsat TM images exhibits the significant variability of thermo-environment both in spatial and temporal domains.

The Barind Tract area shows a relatively homogeneous pattern of surface temperature both in dry and wet season, which has clear conformity with surface and surface cover. With the seasonal climatic change, level of soil moisture content and surface cover changes maximum in Barind Tract area. Here develops huge vegetation specially rain feed aman crop in rainy season. Surface temperature of Barind Tract is most sensitive to the seasonal climatic variation as well as surface cover change. Except river side dry sandy area Barind Tract shows highest temperature in dry season. Barind Tract found with low soil moisture, as well as low vegetation cover in dry season. Change of soil moisture initiates surface cover change and both of this combinedlly control surface temperature.

Flood plain area found with satisfied soil moisture in dry season and shows moderate surface temperature. Soil moisture content and surface cover of flood plain shows moderate response to the seasonal climatic change. Thermal sensitivity of flood plain to the seasonal climatic condition and vegetation activity change is also moderate.

Temperature over copping areas varies due to seasonal climatic variation but there is no variation due to geographical variation. In vegetated areas, temperature also varies due to the variation of vegetation health and density. In cropping areas there maintain sufficient soil moisture in dry season through irrigation system. And in rainy season level of soil moisture and depth of water varies on the amount of rainfall and level of flooding. In permanent vegetation areas there also varies surface temperature due to the seasonal climatic variation. Plants growth, number of leaf content and water content within the leaf, increases with the increase of soil moisture and rainfall in rainy season. RVI indicates the status of health and density for any kinds of vegetation and indicates the status of surface temperature. RVI is inversely related with the surface temperature and after a certain value of RVI surface temperature becomes insensitive to the RVI increase and this is the mechanism of thermal shielding.

# *Chapter Eight*

## *Study on the Spatio-Temporal Dynamics of Land Use and Land Cover Changes and Their Impacts on Surface Radiation Budget through Surface Albedo*

Earth's surface albedo controlling the mass and energy exchange at the surface-atmosphere interface (Rahman 1998) plays a dynamic role in the world's climatic and environmental processes. A number of studies have been conducted to investigate the importance of surface albedo to biospheric and atmospheric processes (Sellers 1985, Dickinson 1983, Charney et al. 1977). Through an experiment Charney (1977) showed that an increase in surface albedo can significantly reduce the precipitation and thereby, significantly affects the environmental and ecological condition of an area.

Earth surface is a combination of different geologic formations e.g., low lands, high lands, rivers, river plains etc. having spatially varying types and density of vegetation cover. The local geology and climate primarily determine the biophysical activities over an area. Evapotranspiration (Monteny 1972) and other physical activities related to earth's radiative transfer processes largely depend on vegetation types as well as on their temporal and spatial variability. Earth's surface cover undergoes continuous changes in response to seasonally varying meteorological condition and human interference due to various agricultural and urban activities. Seasonal changes generally include variation in temperature, rainfall, windiness and duration of sunshine and in turn chlorophyll activation time. Modification and degradation of earth surface and global environment are associated with both long-term and short-term processes.

Behavior of climate system is influenced by the condition, composition and physical changes of earth's surface (Kellogg and Schware 1982). The earth's geo-sphere and biosphere together form a closely coupled dynamic system (Verstraete and Pinty 1991). In such a soil-vegetation-atmosphere (SVA) system the processes of mass and energy exchange take place. The change of any one component affects the other components. The possible relationship between surface albedo and temperature has been discussed in different issues (Jackson and Idso 1975, Norton et al. 1979).

Climatic variability and human impacts in arid lands biotic responses exhibit inherently complex behaviour. The changes in earth's radiative budget due to changes in ecological and environmental conditions of a given area affect the whole ecosystem. How vegetation changes affect the climate or how climate changes affect the terrestrial vegetation is quite complex and is still to be investigated with realistic surface condition. The threatening consequences of these undesirable changes harmonize the needs for their monitoring and mitigation.

The dynamic behaviour of vegetation leading to varying spectral properties significantly influences the earth's radiative budget through different biophysical activities. Thereby, the terrestrial vegetation plays an important role in world's climate system (Keeling et al. 1982). Particularly, the transfer of energy, water, carbon and momentum are controlled by the vegetation through its effects on albedo, stomatal resistance, photosynthesis, and respiration and surface roughness. Numerous trace gases and chemical compound are being released by the vegetation in the atmosphere. The optical and structural properties of vegetation together with the properties of underlying soil surface determine the spectral behaviour of the vegetation canopy system (Pinty et al. 1993). Spectral properties of soil depend on soil type and texture, color, water content and surface roughness (Bunnik 1978, Choudhury 1987).

Satellite based observations of arid and semiarid land processes have opened a new era of research aiming towards proper and potential utilization of such technology. The development of different sensors having coarse to high spatial resolution on board the satellites offers reliable and timely information on the earth's surface condition from local to regional scale. Various efforts have been made to relate spatial variation of such space based spectral measurements to individual surface processes or parameters (Dickinson et al. 1990, Rahman et al. 1993a and Rahman et al. 1993b). Such an approach enables one to infer relevant information on the earth's surface condition.

The purpose of the present work is to study the dynamic changes of seasonal land cover in the north-western part of Bangladesh through spatiotemporal analysis of Landsat TM data integrated with landform, local geology information and climatic data. The impacts of such changes in surface cover on the radiative transfer at the earth's surface particularly on surface albedo have been studies.

Table 8.1: Upazila-wise distribution of land areas belonging to flood plain and Barind Tract.

| Name of Upazila | Total area in hectare | Area in hectare under | |
|---|---|---|---|
| | | Barind Tract | Flood plain |
| Niamatpur | 44341 | 44341 (100%) | 0 (0%) |
| Gomastapur | 31876 | 15304 (48%) | 16572 (52%) |
| Bholahat | 12572 | 2535 (20.16%) | 10037 (79.84%) |
| Shibganj | 52815 | 0 (0%) | 52815 (100%) |
| Nawabganj | 46752 | 7283 (15.58%) | 39469 (84.42%) |
| Nachol | 28659 | 25584 (89.27%) | 3075 (10.73%) |
| Tanor | 29840 | 29840 (100%) | 0 (0%) |
| Godagari | 44622 | 40251 (90.20%) | 4371 (9.80%) |

Table 8.1 provides upazila-wise areas belonging to flood plain and Barind Tract covering the present study area. Here it should be mentioned that, upazila is the smallest administrative unit in Bangladesh. The Barind formation includes most of the Nachol, Niamatpur and Tanor, major parts of Godagari, large portion of Gomastapur and part of Nawabganj and Bholahat upazilas. While, total Shibganj and rest of the areas of other upazilas belongs to floodplain category.

The study area has tropical monsoon climate like whole area of the country. Three main seasons are generally observed over this region. Summer (dry) season extends from March to April, rainy (wet) season extends from May to October and winter season extends from November to February and maximum rainfall is recorded in rainy season.

## 8.1 Results and Discussions

The present analysis involves study on the dynamic changes of vegetation cover in relation to landform characteristics and seasonally varying meteorological and hydrological conditions of the study area and their impacts on the radiative transfer processes at the soil-vegetation-atmosphere interface through surface albedo. For the purpose, time series data of Landsat TM data have been used. Analysis has been performed considering major surface classes like soil, agricultural crops, permanent vegetation and water.

Both the hydrological and agricultural conditions in Bangladesh are mainly controlled by the rainfall activities in and around the country. Figures 8.1a shows the monthly variation of mean rainfall averaged over the ten years period from 1986 to 1995 in the Nachol upazila belonging to Barind Tract area and Nawabganj upazila belonging to flood plain area respectively. Figure 8.1b shows the monthly variation of mean temperature averaged over the ten years period from 1986 to 1995 in and around the study area. Rainfall and temperature show almost similar behaviour in terms of pattern and amplitude over the two characteristically different land areas. From the figures, it is evident that, during the period November to April no significant rainfall usually occurs in both the upazilas. However, apart from April, rainfall gradually increases during the next consecutive months and reaches to a peak value around June/July and then rainfall decreases. While, temperature gradually increases from January and reaches to its maximum value around March/April, and then gradually decreases.

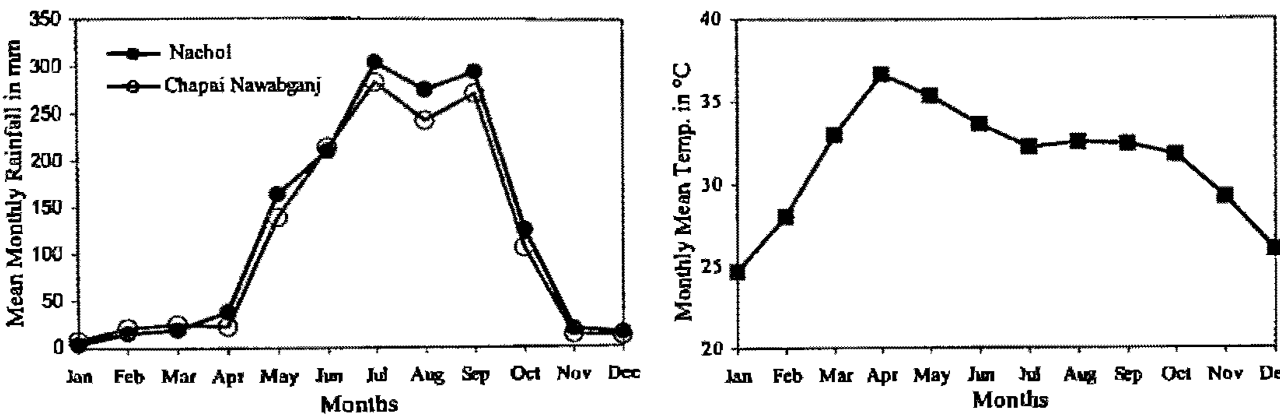



Figure 8.1: (a) Variation of mean monthly rainfall patterns averaged over the last ten years period from 1986 to 1995 in the Nachol upazila (Barind Tract area) and Nawabganj upazila (flood plain area). (b) Variation of mean monthly temperature patterns averaged over the last ten years period from 1986 to 1995 in and around the study area.

Table 8.2 provides a comparison of certain hydrological parameters corresponding to Barind Tract and flood plain areas. From the table it is evident that the amount of annual rainfall does not vary significantly between the two areas. However, the annual rainfall value is much higher than that is generally observed over the semiarid lands (>500 mm per year). The depth of ground water table is higher in case of Barind Tract area in comparison to that in flood plain areas. The soil permeability of Barind Tract area is relatively poor, whereas, in flood plain area soil permeability is good. As a result, water propagation into the upper surface layer from the ground water level through vertical percolation is relatively lower over the Barind area in comparison to flood plain area.

Table 8.2: Comparison of certain hydrological parameters corresponding to Barind Tract and flood plain areas (Bangladesh Meteorological Department (BMD), Bangladesh Water Development Board (WDB), Haque 1997).

| Parameter | Barind Tract Area | Flood Plain Area |
|---|---|---|
| Annual Rainfall | 1431*cm | 1440*cm |
| Permeability of soil | Poor | Good |
| Depth of Ground Water Table | 16 m (Nachol in 1994) | 7 m (Bholahat in 1994) |
| Terrain characteristics | Sloppy | Plain land |
| Elevation above sea level | 20m-40m | 22m-28m |

*23 Years mean annual rainfall

Furthermore, the sloppy nature and relatively higher elevation in comparison to flood plain area result in a quicker surface runoff of the intercepted rainfall water over the Barind Tract area. Thereby, charging of ground water reservoirs through infiltration is largely restricted over the Barind Tract area. A detail study on this topic has been reported in a separate chapter (chapter-10). Such a situation ultimately results in a lack of soil moisture in the Barind Tract area particularly during dry season. On the contrary, flood plain area is relatively flat and has lower depth of ground water table and the area retains relatively good amount of soil moisture throughout the year.

### 8.1.1 Seasonal Variation of Surface Albedo

The condition of the Earth's land surface largely affects the surface atmosphere fluxes of water, energy, and momentum (Shukla and Mintz 1982, Shuttleworth 1991). Particularly, the properties and distribution of vegetation and its underlying soil play very important roles (Ross and Marshak 1989, Huete 1988, Rahman 2001) in such processes. The absorption of solar energy at the Earth's surface is the primary driving force behind all climatic processes (Dickinson 1983) and its amount in the optical region is mainly controlled through surface albedo. In the overall processes, soil moisture significantly influences the nature of the fluxes, by controlling the amount of net radiation absorbed by the surface (Eltahir 1998) as well as the partitioning of available energy between latent and sensible heating (Entekhabi and Rodriquez-Iturbe 1994, Jacobberger and Hooper 1991).

The study area represents significant dynamisms in the functionality of the ecosystem. Land cover conversion followed by seasonal and meteorological variability influences the radiative transfer processes hence the surface albedo. Albedo a ratio of the outgoing vs. incoming solar radiation is significantly influenced by the prevailing hydro-environmental condition, local geology and meteorological condition, and physiography.

Each of the individual constituents of the ecosystem plays their respective roles in the energy partitioning processes at the surface. Soil, vegetation and water are the three basic ingredients of the ecosystem. Intrinsic properties of soil, vegetation and water particularly, soil moisture content, density, coverage and status of vegetation collectively determine the physical environment. Consequently, properties of soil, water and vegetation ultimately play a deterministic role in the complex processes of mass (in the form of precipitation) and energy (in the form of latent heat) exchange between the surface and the atmosphere. For a dense vegetation cover, soil background effect is largely masked out by the vegetation layer. Whereas, for a sparse canopy the soil background properties is very much important in determining the surface response. So it is crucial to study the response characteristics of each components of the whole ecosystem.

In the sandy areas particularly near the riverside, albedo value is relatively high throughout the year as sand usually has high reflectivity and low moisture content. Albedo value as high as 40 to 45 is observed in summer. In general, water-holding capacity of sand is relatively poor. So after a given rainfall event, top sand layer rapidly transmits the intercepted water into the deeper level and thereby, results in quicker dry off the top layer. The albedo value corresponding to winter season is found to be about 29-36 percent lower than that in summer.

Table 8.3: Seasonal albedo values of selected surface features over the Barind Tract and flood plain areas as derived from Landsat TM images of three different dates.

| Position under observation | | | Albedo | | |
|---|---|---|---|---|---|
| Feature type | Land type of the area | Geographical coordinate | Summer season | Rainy season | Winter season |
| Water | Low land in flood plain area (Shibganj) | 88° 14' 59.46"<br>24° 44' 58.95" | 11.0 | 3.7 | 7.0 |
| | Pond, Barind (Godagari) | 88° 22' 38.57"<br>24° 31' 38.54" | 13.0 | 6.1 | 8.0 |
| | Padma River (Godagari) | 88° 18' 42.28"<br>24° 28' 44.99" | 13 | 12.1 | 9.0 |
| Soil | Barind Tract (Tanor) | 88° 28' 39.12"<br>24° 36' 17.27" | 29.0 | 17.9 | 17.0 |
| | Flood plain (Gomastapur) | 88° 17' 05.25"<br>24° 49' 48.51" | 30.0 | 18.9 | 19.0 (rabi) |
| | Flood plain (Shibganj) | 88° 15' 30.63"<br>24° 45' 01.23" | 35.0 | 24.1 | 17.0 |
| Sand | Flood plain Padma River (Nawabganj) | 88° 17' 44.70"<br>24° 27' 29.15" | 48.0 | 11.5 (water) | 34 |
| | | 88° 16' 57.46"<br>24° 28' 00.80" | 45.0 | 44.2 | 29.0 |
| Aman rice | Barind Tract (Godagari) | 88° 23' 22.62"<br>24° 31' 35.75" | 38 (soil) | 10.9 | 22.0 (soil) |
| | Flood plain (Gomastapur) | 88° 13' 44.57"<br>24° 46' 19.61" | 19.0 (Boro) | 11.7 | AM |
| Boro rice | Flood plain (Gomastapur) | 88° 19' 23.72"<br>24° 50' 30.53" | 17.0 | 15.5 (clay) | 18.0 (soil) |
| | Barind Tract (Niamatpur) | 88° 33' 14.75"<br>24° 54' 26.53" | 18.0 | 13.9 (Aman) | 23.0 (soil) |
| Mango Orchard | Flood plain (Shibganj) | 88° 10' 05.68"<br>24° 40' 42.95" | 18.0 | 11.9 | AM |
| | | 88° 14' 59.12"<br>24° 41' 07.12" | 19.0 | 10.0 | 13.0 |

N.B.: AM means that the area is not covered by the digital image on a particular date. The term within bracket indicates the category (e.g., soil, water, rice area etc.) in a particular season that deviates from the mentioned category for which surface albedo value has been extracted.

Absence of vegetation over the area during dry period often initiates soil erosion particularly during windy period. During dray season albedo value as high as 29-35 percent is found over the soil area (table 8.3). Moreover, due to absence of vegetation exposed soil area comes to a direct contact with the atmosphere that causes greater opportunity for the soil moisture to an accelerated and exhaustive evaporation and thereby, the surface becomes dry.

Over the green vegetated area, the absorption due to chlorophyll activity in the photosynthetic region results in relatively lower value of surface albedo (Tucker and Sellers 1986). Seasonal changes of surface cover as well as the variation in the condition of soil layer have profound effect on such radiative transfer process (Sellers 1985). The agricultural crops having relatively shorter lifetime undergoes to systematic phenological changes. Consequently, albedo over such surface varies in accordance with the crop life cycle (Bunnik 1978, Asrar et al. 1984). After, harvesting, the paddy field becomes dry and almost bare that significantly increases the surface albedo value at the end of the crop life cycle.

Albedo is usually higher in the Barind Tract area than that in the flood plain areas, by several percent. The major underlying factors are: (1) there is more bare soil in the Barind Tract; and (2) the bare soil is more reflective in the Barind Tract area. In both the areas, albedo is relatively higher in dry season than that in the winter and rainy seasons. In the dry season lack of soil moisture due to the absence of significant rainfall over the area increases the surface albedo significantly. On the other hand, occurrence of significant rainfall during wet period keeps the moisture content of the soil layer to a satisfactory level for a certain period of time even after the rainfall event. Emergence of vegetation over the area is noticed after getting sufficient rainfall. The combined effect of high soil moisture and emergence of vegetation during wet season significantly reduces the surface albedo that is in contrast to the dry season condition. Such a contrast in wet and dry season albedo is quite in agreement with the observation over the Sahelian region (Norton et al. 1979).

Seasonal variation of surface albedo over Barind area shows a general trend of high value in summer, relatively lower value in rainy season, whereas, a moderate value in winter. With reference to point A in table 9.4 corresponding to Godagari upazila in Barind Tract area, surface albedo is significantly high in summer about 38 when the area is mostly bare under water deficit condition. However, in rainy season, Aman rice is largely cultivated and point A now represents Aman crop area. The surface albedo now reduces to a value of about 11 that is significantly lower in comparison to that in rainy season. Such a value of albedo is quite consistent with reported value of Wilson and Henderson-Sellers (1985) for rice crop. In winter, Aman crop is harvested and the value of surface albedo reaches to a value of about 22 which is higher than that in summer but significantly lower than that in rainy season. At this time, crop residual (hay) remains and soil retains relatively higher moisture content than in summer. Thus surface results in a moderate value of surface albedo in winter.

Albedo over water surface shows significant temporal and spatial variabilities. Albedo over pond and river area and water in low land areas show relatively higher value in summer, lowest in rainy season and a moderate value in winter. Suspended sediments in water principally determine the dynamics of surface albedo over water that largely depends on the characteristics of reservoir source and the origin of water. Erosion activities along the riverside are closely related to the variation of sediments. In rainy season, the amount of rainfall is high and this effectively reduces the sediment concentration in water and that results in smaller value of albedo. Moreover, the river erosion is relatively lower during rainy season as the water over flows. In early winter sediment content is higher due to erosion is maximum. Contrarily, in summer, river water level goes down, and the rate of water flow (speed) is relatively low. Such a condition results in lesser erosion of the riverbanks.

Semi-arid Barind Tract area and flood plain area observe almost similar tropical climatic condition. However, differences in landform and variation in local geology over the two areas mainly introduce the variation in soil moisture level that ultimately governs the vegetation growth over the area and the observed variability in surface albedo values. As such the variation in surface albedo value appears to be dependent on the landform types.

Climatic variables particularly the rainfall seems to be the main driving force that brings out the dynamic changes in the surface cover over this area that in turns changes the surface albedo. A comparison of seasonal rainfall amount (figure 8.1a) and Landsat TM derived vegetation area shows that maximum vegetation covers occurs during the season of occurrence of maximum rainfall. The yearly variation in vegetation cover seems to follow the seasonal variation in precipitation amount. The occurrence of rainfall during July to October results in a reduction of albedo values in most of the places over the study area.

Albedo values are relatively lower in low land area especially in swampy lands. Its value increases from bottom of low lands to plain lands with changing moisture level. Moisture content has a profound effect on the spectral properties of soil that generally has the trend of lowering the surface albedo (Dickinson 1983). The underlying reason is partly due to absorption by water and partly from a reduction of scattering caused by the water film filling gaps between soil particles and thus effectively reducing the number of scattering interfaces (Reeves 1975, Norton et al. 1979). When a soil is desiccated there usually is crust formation at the surface. The moisture present below this crust hardly affects its spectral response (Bunnik 1978). Low-density vegetation cover exhibits the combined effects of the responses from the vegetation and its background layer (Huete 1988). Sparse vegetation shows higher albedo values in arid areas due to relatively bright response of the background soil. In alluvial flood plain land sparse vegetation shows lower values of surface albedo in low lands and higher values in plain lands and sandy lands.

Albedo value does not differ significantly over the Aman crop area situated in the Barind Tract and flood plain areas. This is because Aman is a rain fed crop and in general during Aman season (July to November), rainfall in Bangladesh is frequent and satisfactory that restricts any significant variation of soil moisture level over the two cited areas. Moreover, surface albedo corresponding to Aman rice area in monsoon and Boro rice area in summer differs largely and Aman rice area exhibits about 30 to 35 percent lower values of surface albedo than that of Boro rice area in summer. During Boro season, rainfall is almost insignificant and Boro crop is supplied with water through irrigation. However, irrigation is not maintained throughout the entire crop life cycle but instead irrigation is provided two or three times instantaneously with selective time intervals. This results in relatively high value of albedo over Boro area.

In the annual fallow land areas (location B1, B2 and B3 in figure 7.1a), the surface albedo undergoes to systematic changes following the seasonal variation of meteorological condition. Particularly, variation in precipitation and evaporation introduces the variability in moisture level of the soil layer that in turns changes the surface albedo value. Albedo values of denude soil in Barind Tract area in dry period are about 34 to 55 percent higher with respect to that in flood plain areas. It is seen that during rainy season in both the areas a significant portion of the previously (in summer) exposed soils are covered with sparse vegetation and soil in general contains relatively high moisture.

Mango plantation covers a significant portion of the land of flood plain area. It is a major source of income of people over this area. Analysis shows a systematic variation in surface albedo over such area. Albedo value is comparatively higher in summer, lower in rainy season and moderate in winter that is quite in agreement with the seasonal changes in the mango plantation. In rainy season, absorption is relatively high due to increased chlorophyll activity in photosynthetic region as number of leave and their greenness augment, soil contains relatively high moisture and leaf surface is generally wet. Wetting the leaf increases the net radiation and reduces back radiation (Linacre 1972) as well as albedo (Norton et al. 1979). Vegetation also in growing season lowers the albedo (Federer 1968, Bunnik 1978).

Table 8.4: Surface albedo statistics along different profiles over the study area.

| Location | Profile No. | Albedo (dry season) | | | Albedo (wet season) | | | Albedo (winter season) | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | $a_{MEAN}$ | $a_{SD}$ | $a_{SD}/a_{MEAN}$ | $a_{MEAN}$ | $a_{SD}$ | $a_{SD}/a_{MEAN}$ | $a_{mean}$ | $a_{SD}$ | $a_{SD}/a_{MEAN}$ |
| Barind Tract | 1 | 34.85 | 4.02 | 0.115 | 24.92 | 3.91 | 0.157 | 21.29 | 2.6 | 0.12 |
| | 2 | 34.59 | 3.45 | 0.099 | 24.02 | 4.51 | 0.188 | 21.09 | 2.69 | 0.13 |
| | 3 | 33.90 | 4.91 | 0.145 | 23.50 | 7.79 | 0.331 | 21.46 | 3.03 | 0.14 |
| | 4 | 34.31 | 5.68 | 0.166 | 19.27 | 6.87 | 0.357 | 21.27 | 3.05 | 0.14 |
| | 5 | 31.74 | 3.65 | 0.116 | 23.80 | 4.89 | 0.205 | 19.98 | 2.63 | 0.13 |
| Flood plain | 6 | 24.92 | 3.91 | 0.157 | 13.32 | 2.31 | 0.173 | -- | -- | -- |
| | 7 | 24.02 | 4.51 | 0.188 | 13.64 | 2.75 | 0.202 | -- | -- | -- |
| | 8 | 23.5 | 7.79 | 0.331 | 12.19 | 4.33 | 0.355 | -- | -- | -- |
| | 9 | 19.27 | 6.87 | 0.357 | 13.36 | 2.95 | 0.221 | -- | -- | -- |
| | 10 | 23.8 | 4.89 | 0.205 | 13.35 | 2.83 | 0.212 | -- | -- | -- |

In order to study the spectral behaviour of the surface, spatial profiles were drawn along different straight lines with equal spatial intervals over both the semi-arid and flood plain areas from north to south and east to west on the digital images. During drawing profiles, efforts have been made in order to include maximum surface features (surface type variation) under the profile. Mean value and standard deviation (SD) of albedo along each profile were derived individually and the values are given in table 8.4. The image corresponding to flood plain area in winter season contains only three bands. So, albedo calculation was not possible for the flood plain area in winter.

Comparison of albedo profiles shows distinct differences in observed albedo values corresponding to semiarid Barind Tract and flood plain areas. It is observed that albedo values are relatively higher in semiarid zone than that in the flood plain areas. Mean value is near about 35 to 40 percent higher in the semi-arid zone with respect to mean value of flood alluvial plain over most of the spectral profiles.

In table 8.4, standard deviation of albedo along a given profile ($a_{SD}$) over the image, normalised by the mean value of albedo ($a_{MEAN}$) along the same direction i.e., $a_{SD}/a_{MEAN}$ indicates the spatial heterogeneity of the surface in terms of surface classes on a particular date. In general, higher is the value of $a_{SD}/a_{MEAN}$ means, higher is the spatial heterogeneity. In the ideal case, for a completely homogeneous surface, $a_{SD}/a_{MEAN}$ approaches to zero. In general, Barind Tract area is relatively homogeneous both in summer and winter. Consequently, the value of $a_{SD}/a_{MEAN}$ is relatively lower in both the seasons. However, in wet season, about 76 percent area of the Barind Tract is covered by Aman rice. The remaining area of Barind Tract is mostly bare and homestead area. Such a situation gives rise to a relatively moderate value of $a_{SD}/a_{MEAN}$ in the wet season. On the contrary, in the flood plain area, surface features significantly vary over space and season. Such a variability in surface features gives rise to relatively higher value of $a_{SD}/a_{MEAN}$ both in summer and winter. From the table, it is also seen that albedo values corresponding to summer and winter seasons are higher than that corresponding to rainy season. Barind Tract area mostly represents the bare soil both in summer and winter and Aman crop in rainy season.

## Chapter Eight Conclusion:

The dynamic interaction between the earth's biosphere and atmosphere takes place at the soil-vegetation-atmosphere (SVA) interface through the process of mass and energy exchange. In such a process, surface albedo plays an important role particularly in partitioning the energy incident on it. In this chapter, seasonal changes of surface albedo and it's relationship with the vegetation cover and surface condition have been studied over two adjacent but sharply contrasted and physiographically different land areas, using Landsat TM time series data. Surface albedo over the area shows a distinct seasonal trend that is in consistent with the vegetation dynamics. Seasonal variation of rainfall seems to play a dual role on the dynamic changes in surface albedo. Firstly, precipitation increases the soil moisture that in turn reduces the surface albedo due to increased absorption of solar radiation by the increased soil moisture content. Secondly, seasonal changes in rainfall amount gives rise to the variation in vegetation cover and thereby, introduce a variation in the surface albedo. In addition, local geology and landform characteristics of an area also influence the surface albedo values by controlling the surface cover variability.

# *Chapter Nine*
## *Analysis of Hydro-Climatic Condition and Its Recent Trends in the Study Area using Remote Sensing, GIS and Meteorological Data*

## 9.1 Behaviour of Climatic Variables

The climate of an area is the average of weather i.e., the composite of every day weather and atmospheric elements for certain period of time (Trewartha and Horn 1980). The climatic variables that define the climatic condition are solar energy, temperature, rainfall and humidity. Climatic elements are closely related with each other and the variation of one element is the indication of change of other elements (Donn 1975). For man and his well-being earth's climate and its change is an important factor. In developing countries impact of climatic changes on life is severe. Geographical (Kellogg and Schware 1982), changes as well as changes of climatic variables influence the behaviors of the climatic system. Insufficient data of required place and for required time is one of the major problem in climatological study.

The climate of Barind Tract and adjacent floodplain area is tropical monsoon type like whole area of the country. There are three distinct seasons observed in this region, rainy season extent from May to October, winter season extent from November to February and summer season extent from March to April.

### 9.1.1 Rainfall

Rainfall is not equally distributed throughout the year in Bangladesh as well as in the study area. Mean monthly and annual rainfall patterns of different upazilas of study area are shown in figure 9.1 & 9.2. Monthly mean rainfall has been calculated for different periods. First part (SP1) is from 1963 to 1988 for Nachol, from 1962 to 1988 for Tanor, from 1970 to 1988 for Niamatpur, from 1963 to 1988 for Godagari, from 1962 to 1988 for Bholahat, from 1962 to 1988 for Nawabganj and from 1962 to 1988 for Shibganj upazila. Except Tanor all other places has data missing of one or couple of years. Second graph (SP2) is from 1989 to 1995 for all upazilas. Total period of rainfall year (1963~1995) has been splited into two parts, just to support the trend of maximum and minimum temperature gradients. From the mean monthly rainfall pattern it is seen that precipitation are minimum for the periods of January

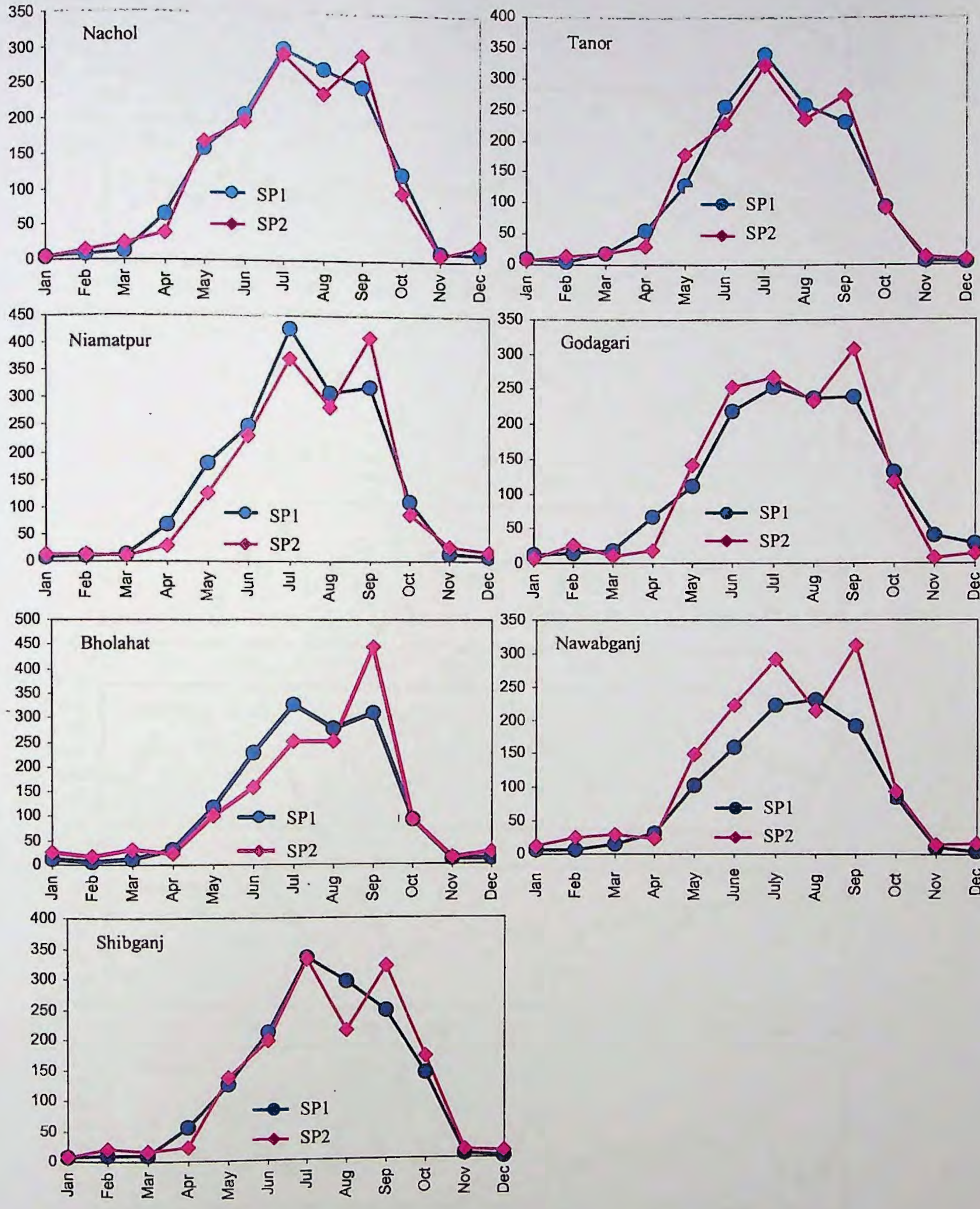



Figure 9.1: Monthly mean rainfall pattern of different upazilas for two periods one is up to 1988 and another is from 1989 to 1995.

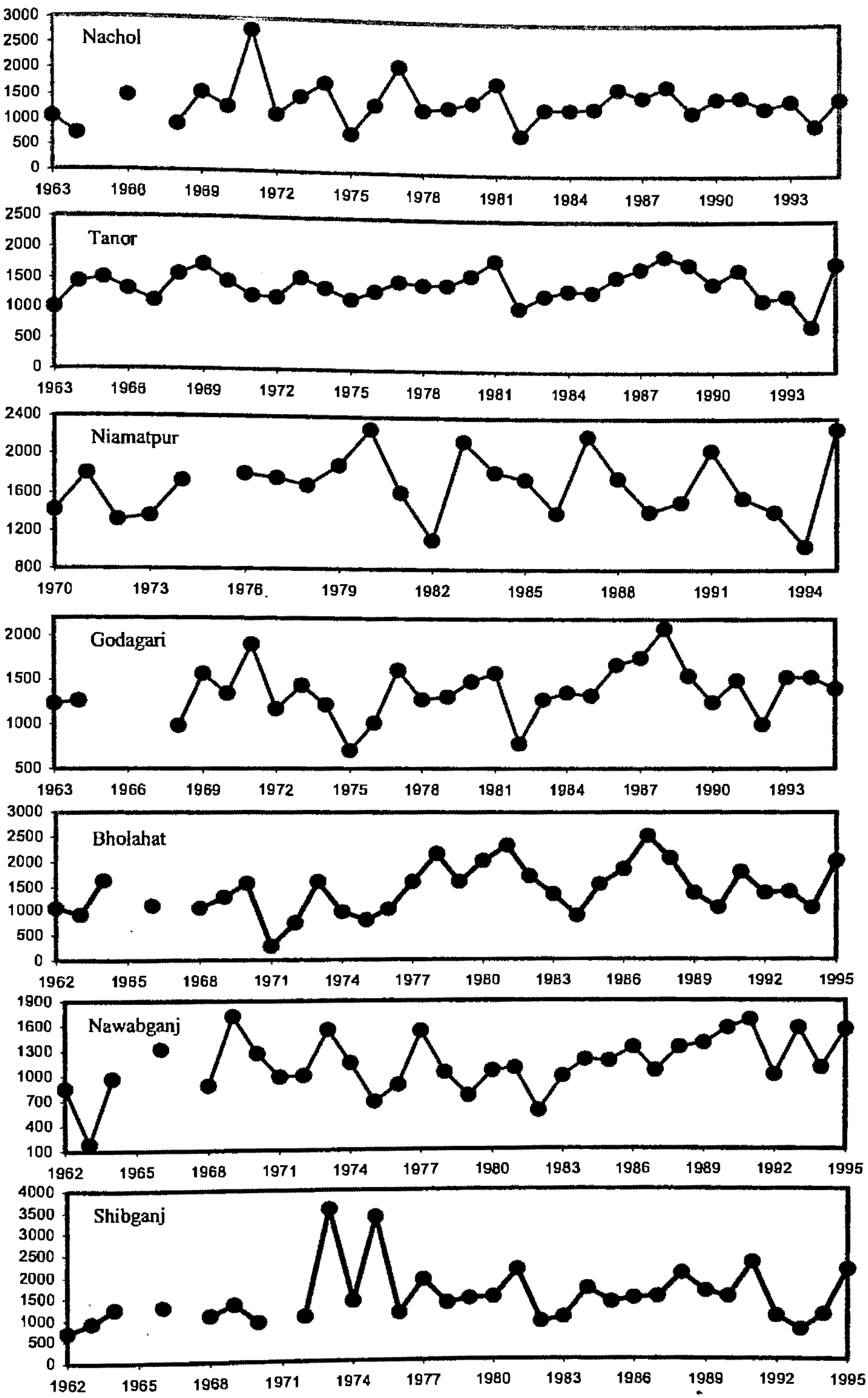



Figure 9.2: Variation of mean annual rainfall pattern of different upazilas of study area.

to March and November to December and maximum from the month of July to September. April to June and October are the transition periods of minimum to maximum and maximum to minimum rainfall respectively.

In the mean monthly time series dynamics of rainfall pattern, it is seen that there are differences in mean monthly rainfall pattern. The pattern SP1 has a single peak, which indicates the maximum rainfall month is July and varies from place to place. Maximum rainfall month is July for Nachol, Niamatpur, Godagari and Bholahat, June for Tanor and Shibganj, and August for Nawabganj. SP2 is the rainfall pattern having dual peak on both sides of August and same for all upazilas except Bholahat. Except in peak rainfall month, difference of rainfall amount between SP1 and SP2 is small for Nachol, Niamatpur, Tanor, Godagari and Shibganj upazila. But the difference of rainfall amount is large between two patterns SP1 and SP2 for Bholahat and Nawabganj upazila. In Bholahat upazila rainfall amount are lower in June, July and August and higher in September and unchanged in remaining months in SP1 in comparison with SP2. In Nawabganj upazila rainfall amount are higher in May, June, July and September, and unchanged in remaining months in SP2 in comparison with SP1.

In comparison with SP1 it can say maximum rainfall month has been shifted to September in SP2 for all upazilas except Tanor and Shibganj upazila. In Tanor and Shibganj maximum rainfall month remains unchanged and the maximum rainfall month is July. In the rainfall patterns of Nawabganj upazila, the maximum rainfall month is August for SP1 pattern and September for SP2 pattern. The average (7 upazilas) rainfall in September for the pattern SP2 is 83.4mm which is higher then the pattern SP1 for all upazilas. In peak rainfall months (July, August and September) the change of rainfall amount is prominent and the statistics of rainfall amount of maximum rainfall months shown in table 9.1 in percent for both SP1 and SP2 patterns. And from this table it is seen that the change of happening of maximum rainfall in August and September is remarkable. In recent years i.e., in pattern SP2 decreased amount of rainfall has observed in August and increased amount of rainfall has observed in September.

In Barind Tract areas the change of rainfall amount for the months of January to June and October to December are less prominent. But for the flood plain areas the changes are distinguishable for the same sequence. The over all trend of annual rainfall is increasing.

Except some scattered values for some upazilas, there is a continuous increasing trend. In the period from 1960 to 1995, minimum annual rainfall 182.37 mm is observed in 1963 at Nawabganj upazila and maximum annual rainfall 3562.6 mm is observed in 1973 at Shibganj upazila. Both maximum and minimum rainfall happening places are flood plain area.

Table 9.1: Statistics of rainfall amount (in mm) of peak rainfall months July, August and September of different upazilas of study area.

| Upazila | July | | August | | September | |
|---|---|---|---|---|---|---|
| | SP1 | SP2 | SP1 | SP2 | SP1 | SP2 |
| Tanor | 55 | 60 | 25 | 0 | 20 | 40 |
| Shibganj | 55 | 50 | 40 | 0 | 5 | 50 |
| Niamatpur | 56 | 43 | 25 | 14 | 19 | 43 |
| Nachol | 43 | 20 | 38 | 20 | 19 | 60 |
| Godagari | 31 | 33 | 31 | 17 | 38 | 50 |
| Nawabganj | 36 | 50 | 50 | 0 | 14 | 50 |
| Bholahat | 40 | 17 | 25 | 33 | 35 | 50 |

### 9.1.2 Temperature

Air temperature received at a fixed point in meteorological station. Daily maximum and minimum temperature data are recorded here, which represents the response of a large area. Unfortunately there is no localized (upazila wise) temperature data available like rainfall. Here used temperature data recorded at Rajshahi meteorological station. The recorded data exhibits that the area under this station is a high temperature zone. Monthly maximum and minimum temperature are the mean of daily maximum and minimum temperature. Mean monthly maximum and minimum temperature patterns of two time series S1 (1964-1988) with data missing of 1970 and S2 (1989-1998) are shown in figure 9.3a and 9.3b respectively. Mean monthly maximum and minimum temperature patterns exhibit that March to July is the period of highest temperature, December to February is the period of lowest temperature and rest of the time is the period of moderate temperature. In series S1, maximum temperature observed in May, June and October in comparison with other months. Actually in this series there is no sharp peak. In pattern S1, from March to October temperature ranges from 30°C to 33°C. In pattern S2, there is a sharp peak and peak temperature months are April and May and corresponding temperature are 37°C and 35°C respectively. In comparison with pattern S1, pattern S2 shows higher temperature for the months of February to September and shows lower temperature for October. In comparison with pattern S1 & S2, it is seen that, in recent years maximum temperature in April shows 4.8% higher. In minimum temperature pattern there is no remarkable changes. But S2 pattern shows slightly lower values for the period of September to February.

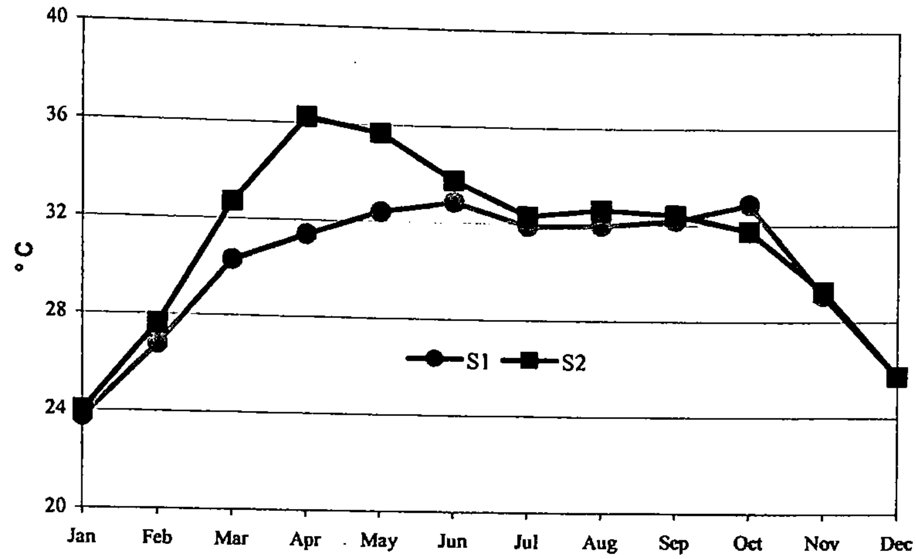



Figure 9.3a: Monthly mean maximum temperature pattern of two different periods one from 1964 to 1988 and another from 1989 to 1998.

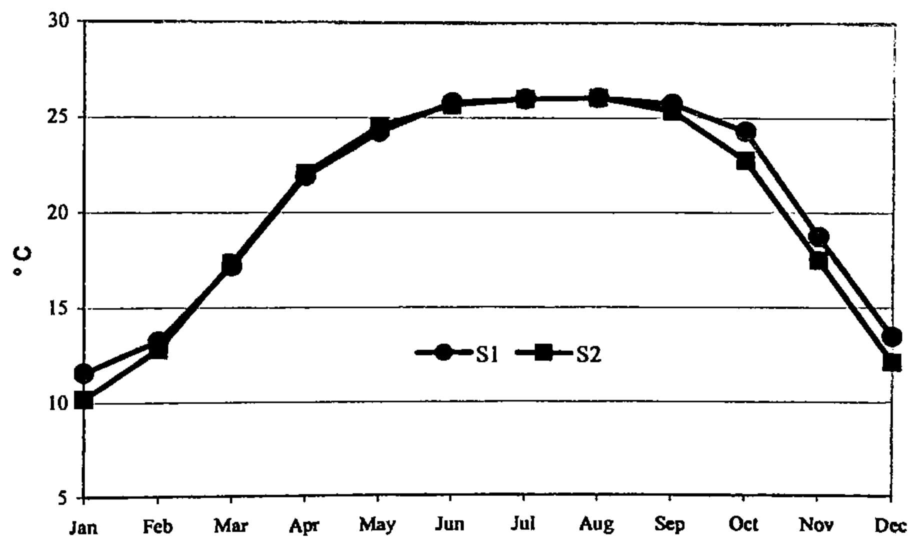



Figure 9.3b: Monthly mean minimum temperature pattern of two different periods one from 1964 to 1988 and another from 1989 to 1998.

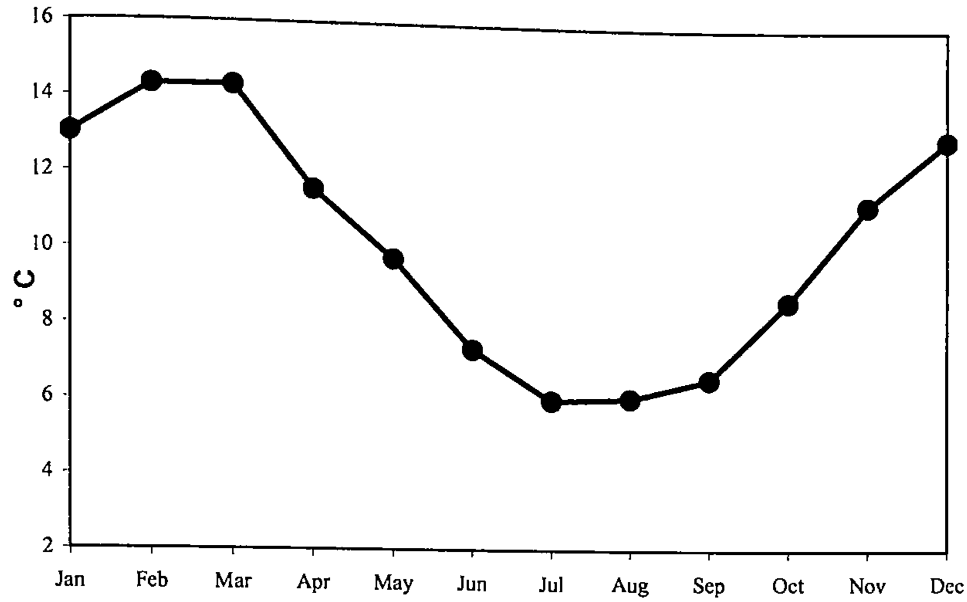



Figure 9.4a: Mean monthly maximum and minimum temperature gradient pattern of study area.

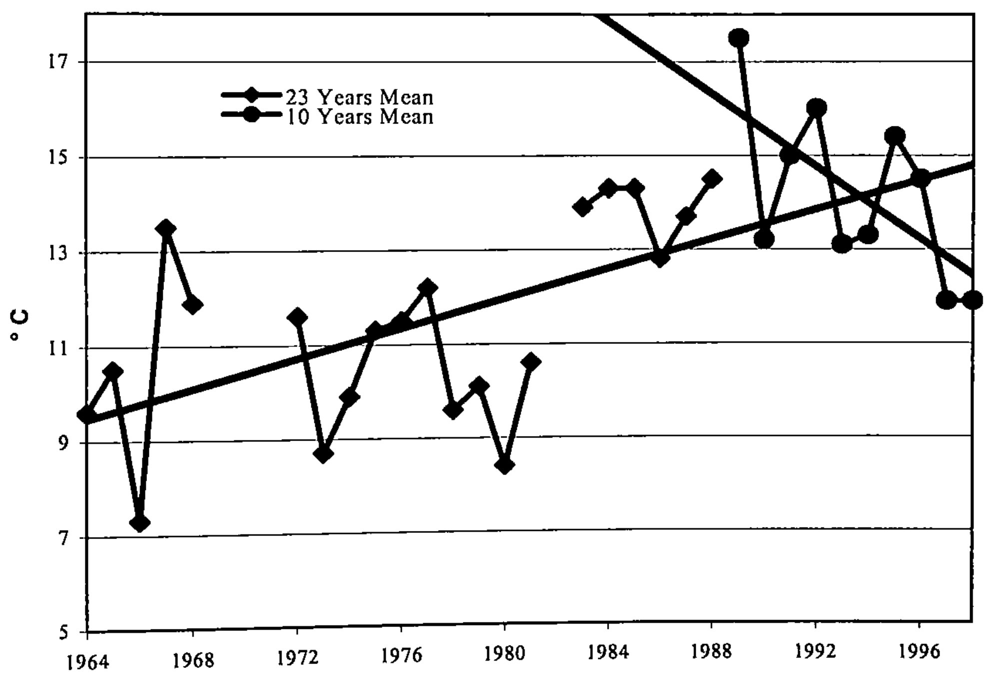



Figure 9.4b: Trend of changing monthly maximum and minimum temperature difference pattern for two different periods one from 1964 to 1988 and another from 1989 to 1998 of study area.

Figure 9.4a exhibits the difference of monthly mean of maximum and minimum temperature. From this figure it is seen that temperature difference is maximum in February and March and minimum from June to October. In February, March and April surface founds with poor surface cover in accordance with relatively low soil moisture and humidity. Minimum temperature difference period (June to October) is the rainy season, and this is the period of maximum rainfall, maximum soil moisture, maximum humidity and maximum vegetation cover. Vegetation areas are also found with underlying water or moist soil.

Difference of maximum and minimum temperature has been calculated for the month of April for two periods S1 and S2 and has shown in figure 9.4b. First part is for the series S1 and second part for the series S2. From figure 9.4b, it is seen that there is increasing trend in temperature gradient from 1964 to 1989 and decreasing trend in recent years. The highest temperature gradient 17.5°C is showing in 1989 and 11.9°C is showing for last two years 1997 and 1998.

In figure 9.4b it is seen that there is an indication of change in the nature of temperature difference trend between two periods. In recent years in study area, increasing vegetation activities both permanent and seasonal. And the cause of temperature gradient change may the change of vegetation activities which is till under study. The rainfall pattern has been splited according to the time period of two temperature trend time period just to show the rainfall activities during the two different time periods.

### 9.2.3 Humidity

Humidity is the amount of water in air. Water holding capacity of air is directly related with temperature i.e., water holding capacity of warm air is higher than cold air (Donn 1975). The mean monthly humidity pattern has shown in figure 9.5, which exhibits low moisture in air in February to April and ranges from 60% to 65%, and for rest of the period humidity is high and ranges from 75% to 85% (around).

In this region rainy season is comparatively longer and precipitation rate (per month rainfall) is high. Longer rainy season dominates the ground water, surface water and agricultural pattern over this region. Monthly humidity pattern (figure 9.5) is also directly related with the monthly rainfall pattern and inversely related with the temperature gradient pattern (figure 9.6). Maximum, almost 80% annual rainfall observed in June to September, then observed humidity is around 85% and temperature difference is minimum. With the help of temperature difference curve it can say that in this period thermal inertia is high.

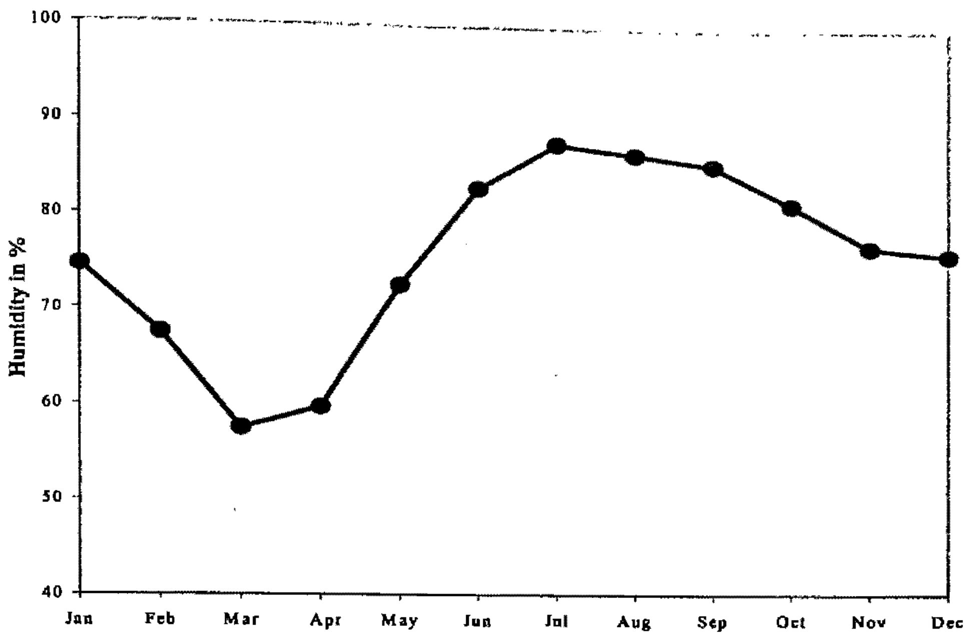



Figure 9.5: Mean monthly humidity pattern of study area.

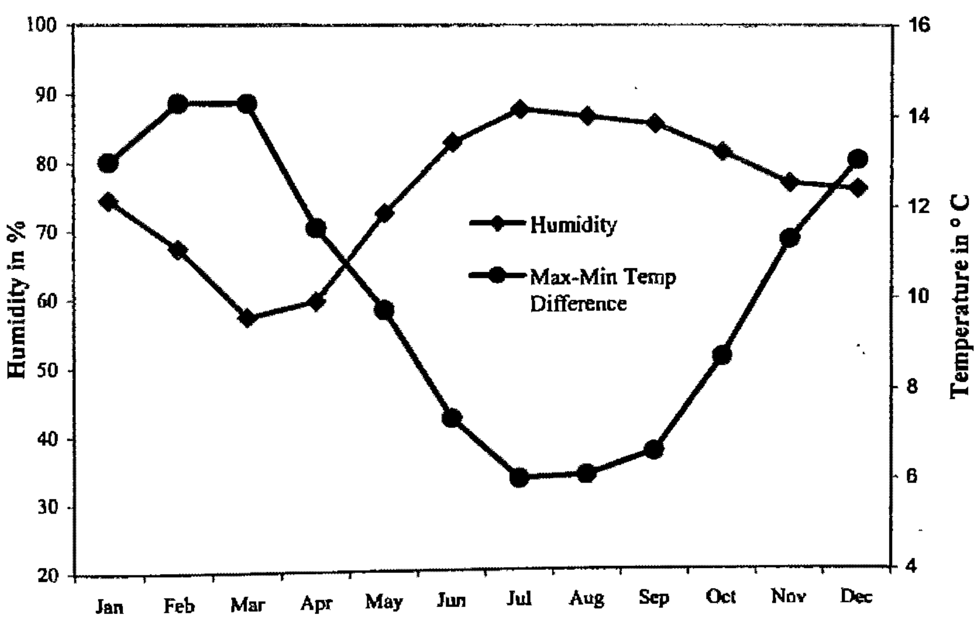



Figure 9.6: Dependency of mean monthly humidity on the variation of mean monthly temperature gradient (difference of maximum and minimum temperature).

Humidity of an area is the combined result of temperature, surface water, soil moisture and precipitation. Soil moisture and surface water of an area are the controlling factor for humidity as well as air temperature and plant growth (Ravelo and Decker 1979). With the help of monthly rainfall, humidity and temperature pattern it is found that the highest temperature is observe in March and April with low humidity as well as low soil moisture.

## 9.2 Seasonal Fluctuation of Surface Water

Rainfall water and flood water at different surface reservoirs are the surface water and all these surface storage renew annually. In contradictory physiographic zones Barind Tract and flood alluvial plane land, sources of surface water are different. Barind Tract, especially ridges never flooded. In this area precipitation is the only source of surface and subsurface water as well as drainage water also. But flood plain areas flooded annually and depth of flooding depends on physiographic variation. Both the region receives maximum rainfall in rainy season and minimum rainfall in dry season. Area of surface water bodies has been delineated from Landsat TM images of April 1990 for dry season, and October 1990 for rainy season, to study the seasonal dynamics of surface water. Surface water bodies of two different season summer and rainy, has shown in figure 9.7. Total area of surface water bodies excluding ponds and rivers are 2539 ha in dry season and 31043 ha in rainy season.

In both the areas use of surface water for homestead purposes has considered constant, though the use in Barind Tract is comparatively higher. The pond areas are taken unchanged with respect to seasonal change. Huge amount of sub-surface water is extracts for irrigation and homestead purposes. Most of the water doesn't add to the usual surface reservoir due to the protective use. And Irrigation areas are not treated as surface water bodies.

In Barind Tract areas foot slopes of hill and hummocky land makes a bowl shape low land water logging area. In this area there are no large surface water bodies like bil. Huge numbers of ponds has observed in Barind Tract area, which uses generally for homestead purposes. Soil of this sloppy high land Barind Tract is basically silt clay type. High rate precipitation prompts surface runoff. Drainage networks of this semiarid Barind Tract area redistribute surface water into the adjacent low lands and rivers in flood alluvial plane.

In flood alluvial plane, precipitated water and annual flooding water are the sources of surface water. In flood alluvial plane land there are number of low lands/bils that hold precipitated and flood water. Maximum rainfall observed during the flooding period, hence the contribution of precipitation is minimum in floodplain areas to the surface water.

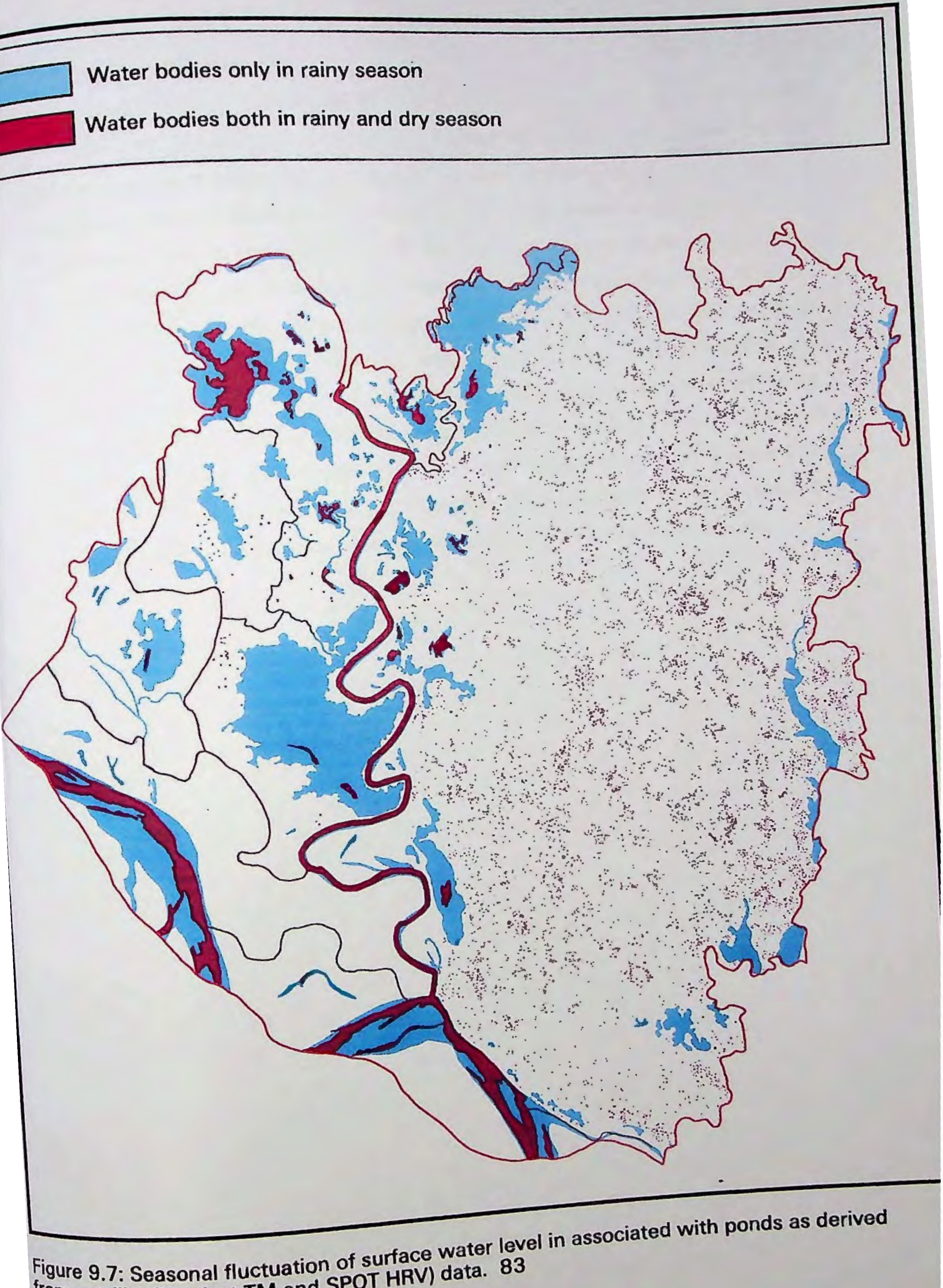



Figure 9.7: Seasonal fluctuation of surface water level in associated with ponds as derived from satellite (Landsat TM and SPOT HRV) data.

## Chapter Nine Conclusion:

Both Barind Tract and flood alluvial plain land enjoy same natural facilities like rainfall, temperature etc. But there is exceptionality in flooding. Flood plain areas flooded annually and renew surface water bodies. And Barind Tract area never flooded; here precipitation is the only source of all hydrological activities like surface water, subsurface water and drainage water. In this area, in dry season observed maximum temperature, minimum rainfall and minimum humidity, and in rainy season observed moderate temperature with maximum rainfall and humidity. Minimum temperature observed in winter season with minimum rainfall and moderate humidity. In recent years there is a change in rainfall pattern, and rainfall patterns are seen having dual peaks on both sides of August. Temperature difference curve (figure 9.4b) is showing characteristically two different trends: (i) gradual increase of temperature extremity is observed from 1964 to 1988 and (ii) gradual decrease of temperature extremity has observed from 1989 to 1998. The cause of this temperature extremity change in recent years may be due to the increase of vegetation activities and this is till under study.

# Chapter Ten

## Study of Drainage Characteristics and Hydrological Surface Properties in Relation to Surface Runoff through the Coupling of Digital Elevation Model (DEM) and Remote Sensing Data

Drainage network of an area is a system of fluid flow integrated with surface and sub-surface flow. Surface and sub-surface run-off is directly concern with the precipitation or surface snow melting. If precipitation rate is more than infiltration capacity, or if there is no surface storage or water detention system, or if surface storage overflow, then drainage excess water. The local geology and surface geometry define the total drainage network. Biophysical activities and surface water drainage very much influence air temperature (Luxmoore et al. 1981) and surface reflectance. Surface and subsurface drainage are influenced by SVA (Soil-Vegetation-Atmosphere) system, precipitation intensity and duration, infiltration capacity (Morisawa 1968) and surface storage. Intense rainfalls intensify surface runoff and redistribute precipitation water over the surface (Winkworth 1970). Soil properties like soil texture, structure, vegetation cover, biologic structures, initial soil moisture and surface condition define the infiltration capacity of particular soil (Morisawa 1968) which also influences surface runoff. Generally surface, underlain by clay layer has a high drainage density (Morisawa 1968). In a sloppy hilly area depending on slope nature sometimes sub-surface run-off added water to the surface drainage. Slope angle and orientation control the runoff rate and define the drainage direction.

## 10.1 Preparation and analysis of Drainage pattern map

Drainage network of Barind Tract and adjacent flood plain area has been constructed from multi dated LANDSAT TM and SPOT HRV images. And a digital elevation model (DEM) has been generated with the elevation data of 1km resolution. The most significance of interpretations are, how the elevated surface dominates the drainage system, how the developed drainage redistributes the surface water and intensifies the dryness of Barind Tract.

The combination of Medium NIR, NIR and red spectral bands of Landsat TM image of January 25, 1995 (figure 10.1), and green, red and NIR bands of SPOT image of October 25, 1990 were displayed to compile drainage patterns and drainage basins. January is the transition period of rainy season to dry season. Generally surface of Barind Tract are found bare and dry in summer while in rainy season most of the surface area are found covered with dense vegetation (mainly Aman crop) with underlying water or with heavy moist soil (like muddy) background. December is the harvesting period of Aman crop and January is the post harvesting period of Aman crop. Hence in January surface are found with medium soil moisture and poor surface cover. Exposed surface viewed from satellite express the surface condition for varying soil moisture level. In image some lines and traces of pink, light pink, purple, blackish and light greenish color are seen. These tonal differences are developed due to the variation of moisture level. Drainage areas are distinct with high moisture level in comparison with surrounding areas. Contrasts of drainage area are not equally sharp in all places and due to this multi dated and multi type images were selected to extract drainage network. It was not possible to grading drainage patterns at image level due to absorption of surrounding soil and data collection system of sensor within the spatial resolution area. Drainage and adjacent area shows same tonal response at image level. Faint and dense brush shape patterns are seen at dry part of Gomastapur and Nawabganj, maximum of Nachol and upper southern part of Godagari areas. These type of branches are the initial order of drainage network. There are some prominent blackish bending shapes are seen which are tributaries, distributaries. These are the last order of drainage network, which flows through valleys and caries surface water to concern basins.

In dry season most of the branches of different grading of drainage system becomes dry. Dynamic process of water flow repeats annually, and varies with the variation of seasonal time duration as well as seasonal climatic phenomena.

Hierarchical line reveals the drainage network of terrace landscape Barind Tract and has shown in figure 10.2. Drainage network of Barind Tract comprises tributaries, distributaries, numerous canals and channels, which passes through the valleys and adjoining low lands of hills and hammocks. Formation of drainage branching, nature and length of individual branch and their nodding with the next feeding line are different in different areas and depends on the surface topology and climatic regimes (Small 1978). Classification of drainage network considering the pattern of drainage branching is called drainage pattern. Some patterns of the drainage are seen is like a denude tree and this type of drainage pattern is called dendritic type. In maximum areas it is found that most of the drainage patterns are dendritic type. Another pattern found at Niamatpur (* star mark area) is a Trellis type. Close look on a small area of drainage network shown in figure 10.3 and the drainage pattern is radial drainage pattern type. If it is consider the whole area then it can say drainage pattern of Barind Tract area is a complex type. In figure 10.3 there shown a separation line which is ultimately the

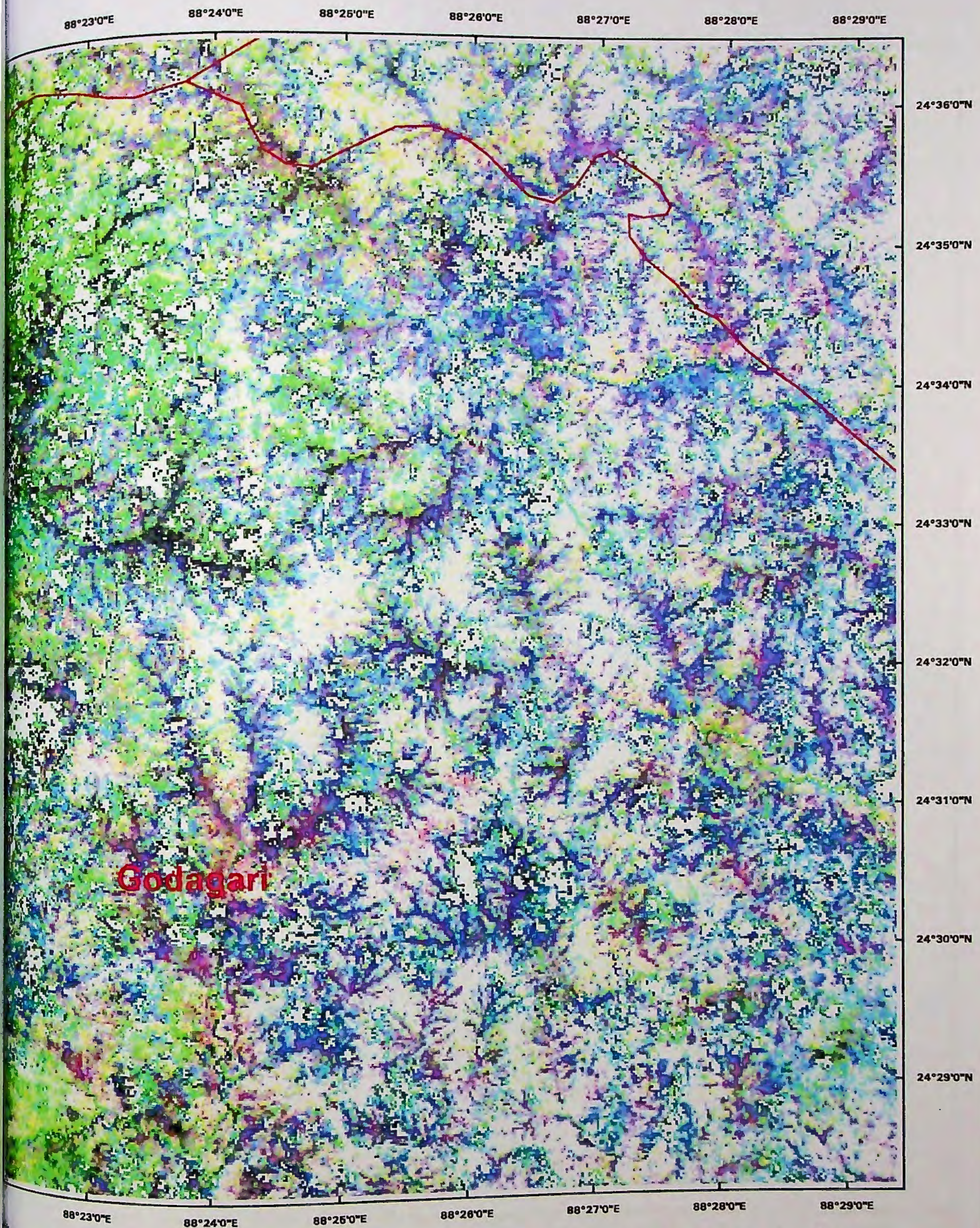



Figure10.1: Readily visible drainage pattern of part of Godagari upazila observed by Landsat TM satellite.

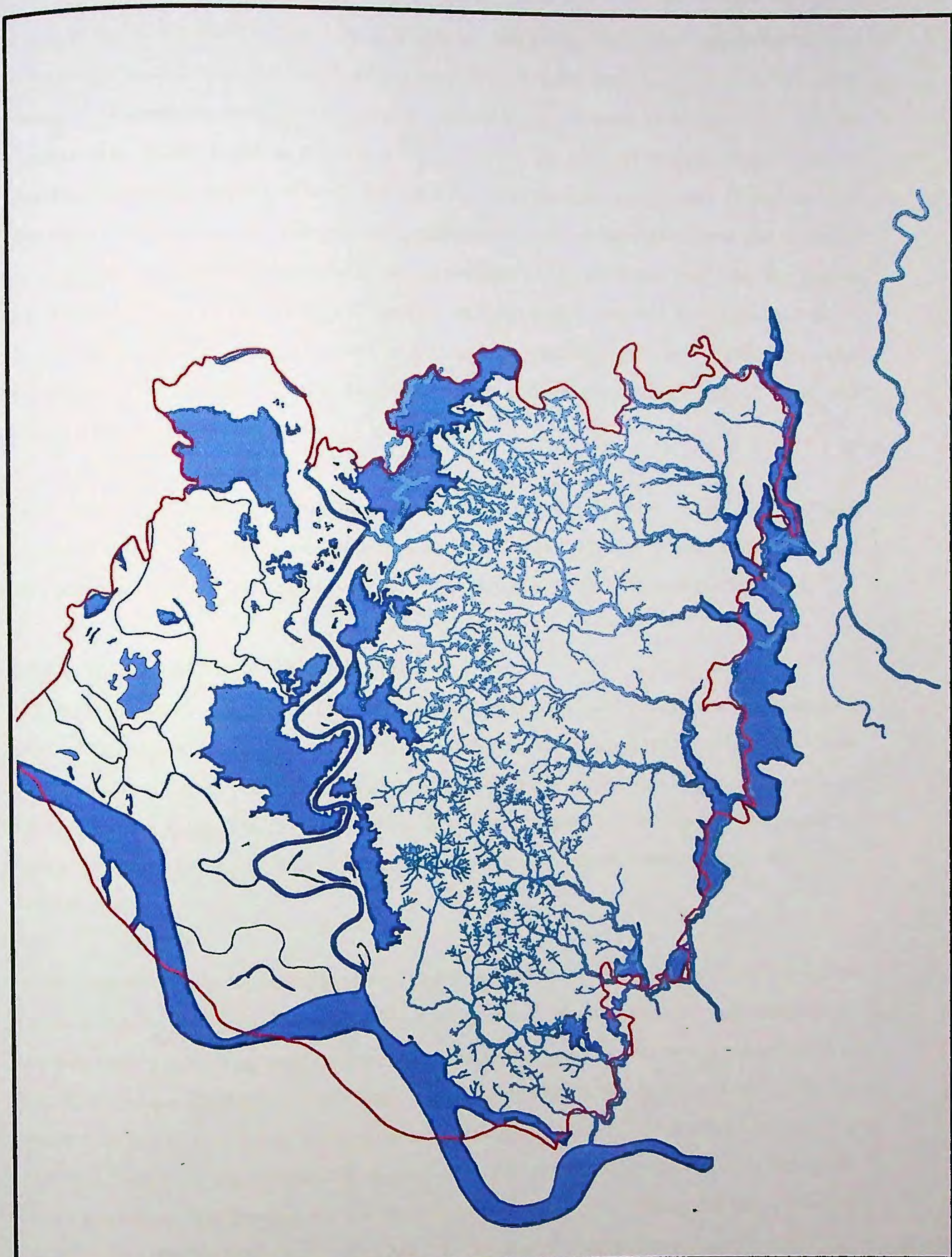


Figure 10.2: Surface water distribution network as derived from combined LANDSAT TM and SPOT HRV data.

crests of elevated surface terrain. Crests are the starting point and surface basins are the end of drainage system. And the length of drainage system from crest to basin is the traveling distance. Drainage network of eastern side travels more distance in comparison with the western side. Slope angle is steeper in western side. In view of morphometric analysis developed drainage network of study area is a fourth order drainage pattern. Designation of drainage order is settled depending on the drainage dimension which developed due to runoff hydrography and distance of travels. Drainage network of Barind Tract is a complete system i.e., all the branches of the drainage system are in some way connected with surface basin at flood alluvial plane. Drainage system in this area is unidirectional and distributory, and direction of flow is towards basin. Drainage system collects precipitated surface water and carries it to the adjacent basins.

In accordance with rainfall flood plain area flooded anually in rainy season. So drainage system of flood plain area carries both rain water and flood water. Drainage network of this area consists with very few numbers of rivers and canals, and water flow is bi-directional.

### 10.1.1 Analysis of Slope Characteristics

If a line is imagined in figure 10.2 through the starting point of initial surface water collecting point of drainage network then that finds the crest or ridge of up-warped surface with both sides downward slope. The drainage system is distributed on both sides of the ridge and also separated by the ridge. The ridge is like a series of overlapping hill shapes i.e., undulating in nature. Uplifted surface in Barind Tract area distributes surface water through developed drainage system.

Image, concern for the slope angle shown in figure 10.4, has been prepared with the digital elevation data of very poor resolution (1km ×1km). A 3×3 window uses around each pixel to calculate slope angle along with the prevailing direction it faces. In this process slope angle is concern for slope direction. In 360 degree angular dynamics, 0 degree and blue color is assigned for north, 90 degrees and cyan color is assigned for east, 180 degrees and magenta color is assigned for south, and 270 degrees and red color is assigned for west direction. Values more than 360 degrees are not for any direction i.e., 361 degree for plane surface (ERDAS Field Guide 1999). Figure 10.4 has demonstrated the slope angle variation and their

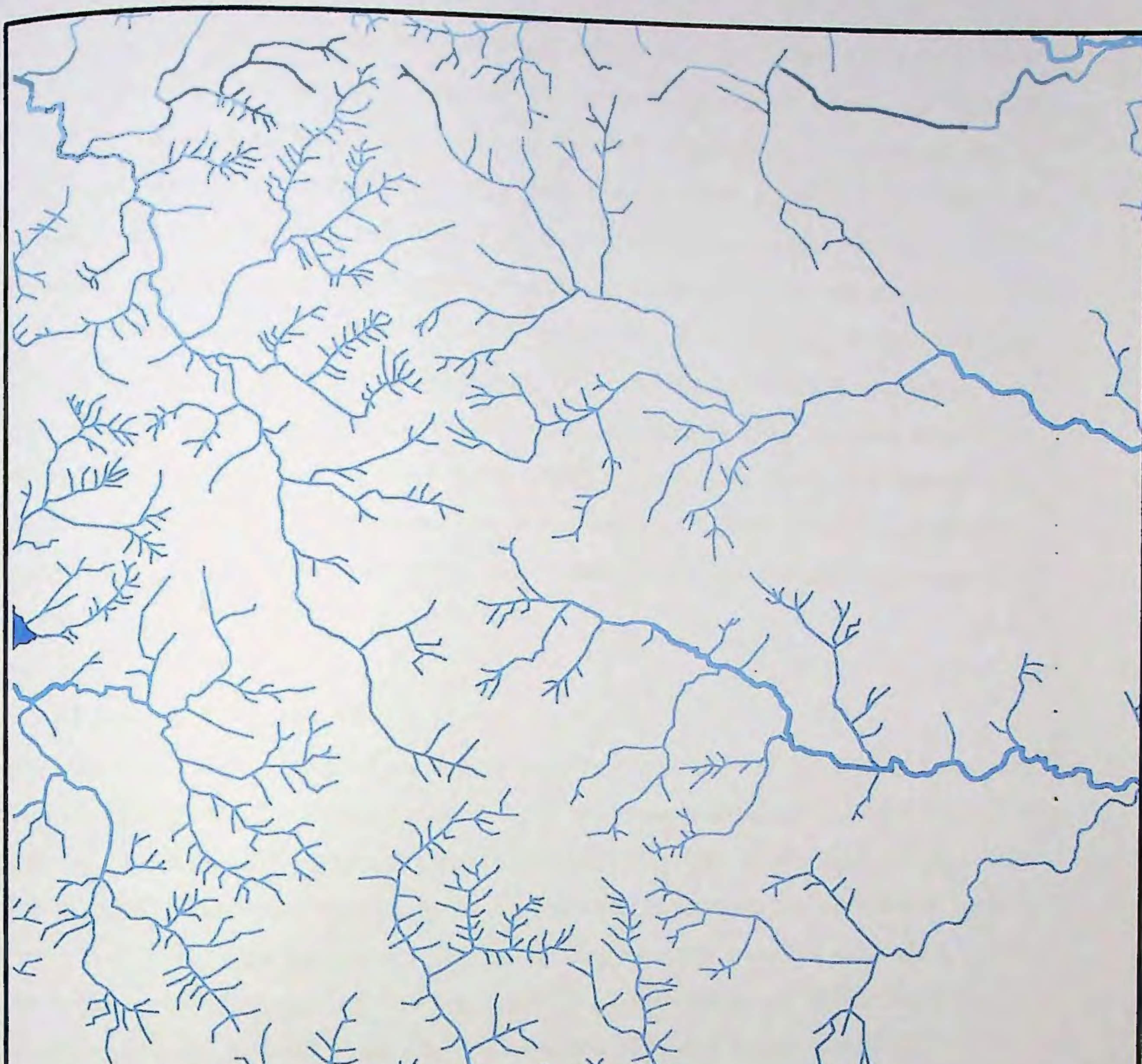


Figure10.3: Enlarged view of the part of drainage pattern map.

orientation, which is the ultimate result of tilting surface topology. Slopes are comparatively steep at north and west side, and comparatively gentle to the east, east-south and southern side. Slopes of north and north-eastern sides are the result of aggregation of rectilinear slopes. In the combination of slopes higher angle followed by lower angle and steepness falls gradually to the downward and then it follows slightly tilted areas. From figure 10.4 comparatively higher steep slopes are seen at middle of Godagari, south-east of Tanor, south-east of Niamatpur, north-western of Nachol and north-east of Gomastapur. Highest steep slope forms with the small part of Nawabganj, Tanor and Nachol, and that defined drainage flow towards south-west direction i.e., towards Mahananda river adjacent low lands. Elevation and slope angles influence the drainage branching. In drainage network, dense branching observed at north, west and west-southern areas. Slopes are also comparatively steep in these areas. In east, east-southern side gentle sloppy areas drainage branching is less dense.

### 10.1.2 Aspect Characteristics

In figure 10.5, it is demonstrated the aspect characteristics of Barind Tract area. In this figure it is seen that Barind Tract areas are divided into two sharply contrasted regions. These two regions are concerned for separation and distribution of surface water. Dark and gray side, which covers Niamatpur, Tanor, part of Nachol and Gomastapur are distributing surface water to the Atrai, little Jamuna and Shib basins. Surface water of bright part, which covers Gomastapur, part of Nachol and Nawabganj upazila are distributing to the adjacent low lands locally called bils and old flood plain basin. These bils and basins are linked with the Mahananda basin, which in turn also connected with the Ganges basin. Maximum area of Godagari upazila belongs to both bright and dark & gray region and distributing surface water to the Atrai basin. Atrai basin is also connected with the Ganges basin.

### 10.1.3 Altitude Characteristics

Landscape of semi arid Barind Tract is characterized with the hummocky terrain (figure 10.6). This hummocky terrain representing a series of fault blocks. Terrain surface formed an north-south align up-warped elevated hill shape having two peaks of 42 and 38 meter heights above mean sea level, with downward slope to the east and west sides. There is an extension of elevated shape towards northeast at Niamatpur and Godagari upazilas. These elevated profile followed by some little tilted formations. Crests of elongated hummocky terrain are

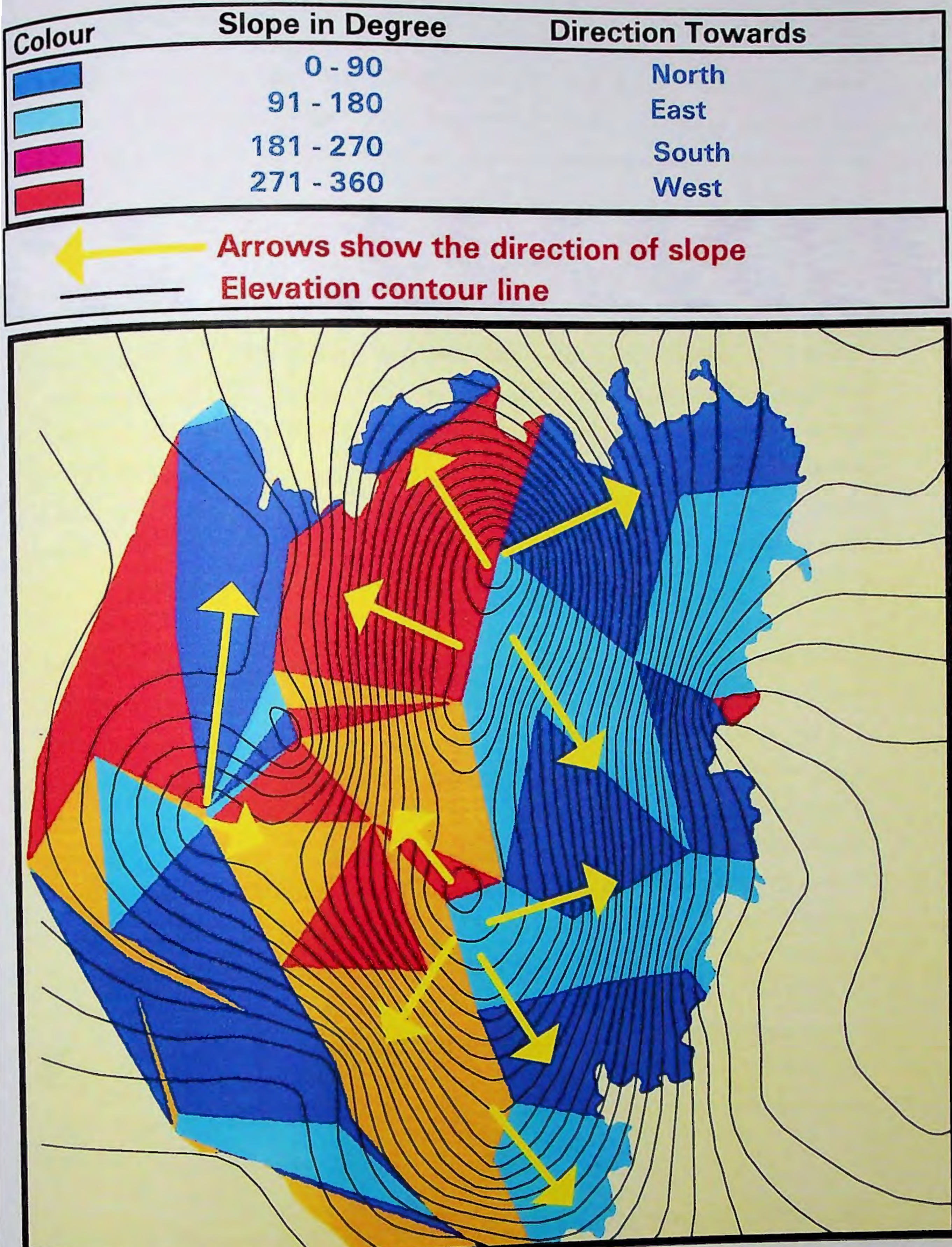



Figure 10.4: Slope aspect of study area as derived from the combination of elevation data and Landsat TM image.

not so steep as seen in image. It is multiplied 250 times in Z direction only, and X and Y direction it is unchanged. Narrow stream less valleys with slope variations dissected hilly areas. Central part is the maximum sloppy area. The maximum and minimum elevation above mean sea level is 40 meter in north-eastern high Barind area and 21 meter in east side of study area respectively (Haque 1997).

## 10.2 Surface Roughness Length

The aerodynamic roughness length ($Z_o$) calculated using NOAA AVHRR data. Surface roughness length (SRL) over this area varies mainly due to the seasonally varying biospheric activities. Spatial variation of SRL depends on vegetation morphology. SRL calculated here to study the mechanical interaction of surface runoff with geometrical properties of surface vegetation of elevated Barind Tract. Vegetation and it's density controls the speed of surface runoff i.e., surface with higher vegetation slows down the water transport velocity and water gets enough time to infiltrate to deeper surface.

SRL for rainy season, winter season and dry season has been calculated using NOAA AVHRR images of October 20 2001, February 16 2002 and April 10 2002 respectively, and shown in figure 10.7. SRL shows highest value in October and lowest value in April. In October maximum of Barind Tract shows value ranges from 0.0295m to 0.0356m but whole Barind area covers within the rage of 0.0195m to 0.0356m. And in this time flood alluvial plane area shows lower value and ranges from 0.0065m to 0.01276m. In Barind Tract in rainy season grows huge aman rice and this is the cause to show higher SRL. In February most of the areas of both Barind Tract and flood plain shows moderate values (0.004m to 0.018m) but maximum area covers within the range of 0.004m to 0.0114. And some scattered areas in western side of Shibganj and central part of Barind Tract shows value of SRL is 0.018m. In April both the area shows lowest value and ranges from 0.004m to 0.010m, and some areas at northern side of Bholahat and northern side of old flood plain basin shows comparatively higher values which ranges from 0.020m to 0.036m. Here grows huge boro rice in this season and hence shows higher SRL.

In this zone maximum rainfall observed in rainy season while maximum surface found covered by vegetation. And for this reason rainfall does not come to direct contact of soil surface and this is why erosion is less in this area.

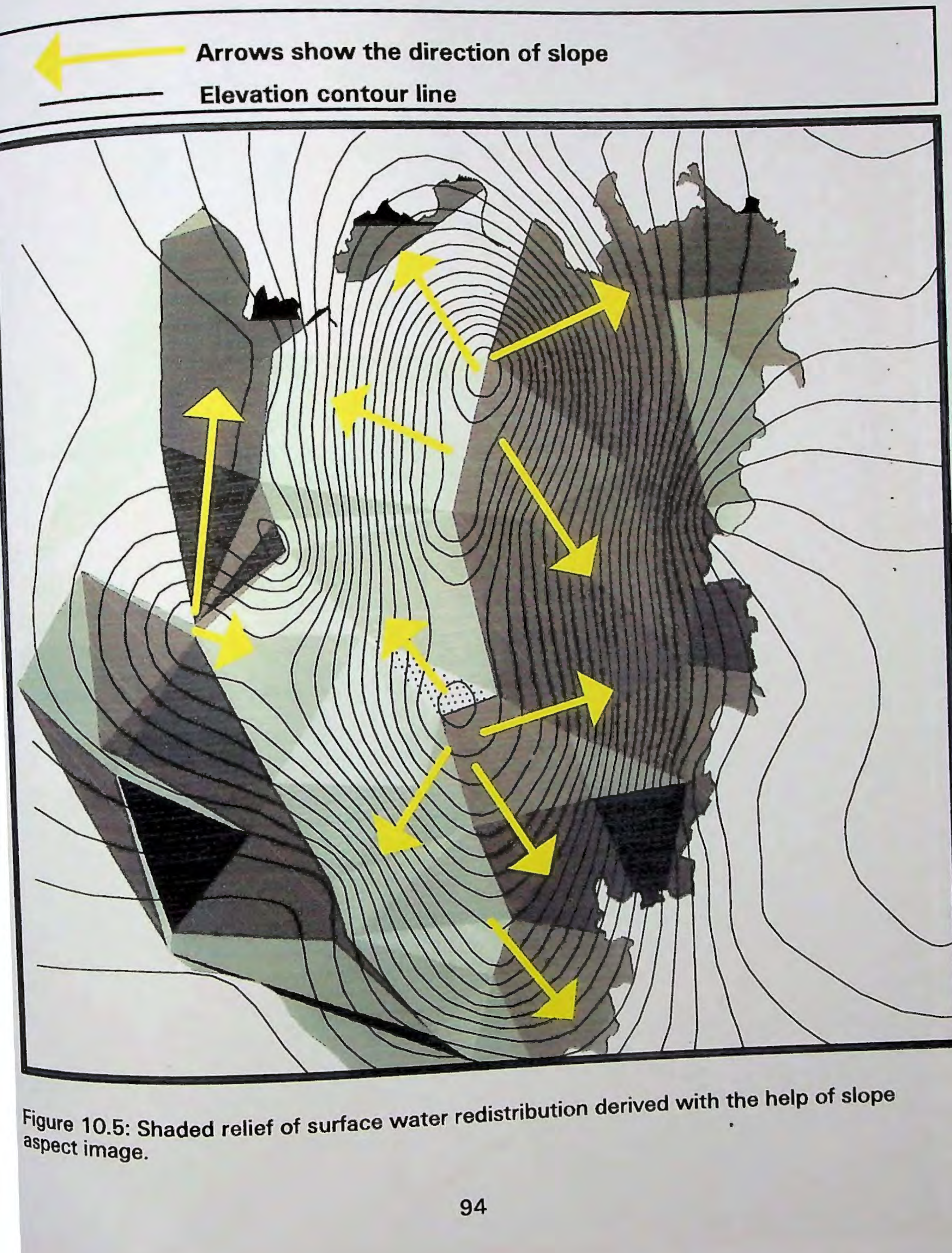



Figure 10.5: Shaded relief of surface water redistribution derived with the help of slope aspect image.

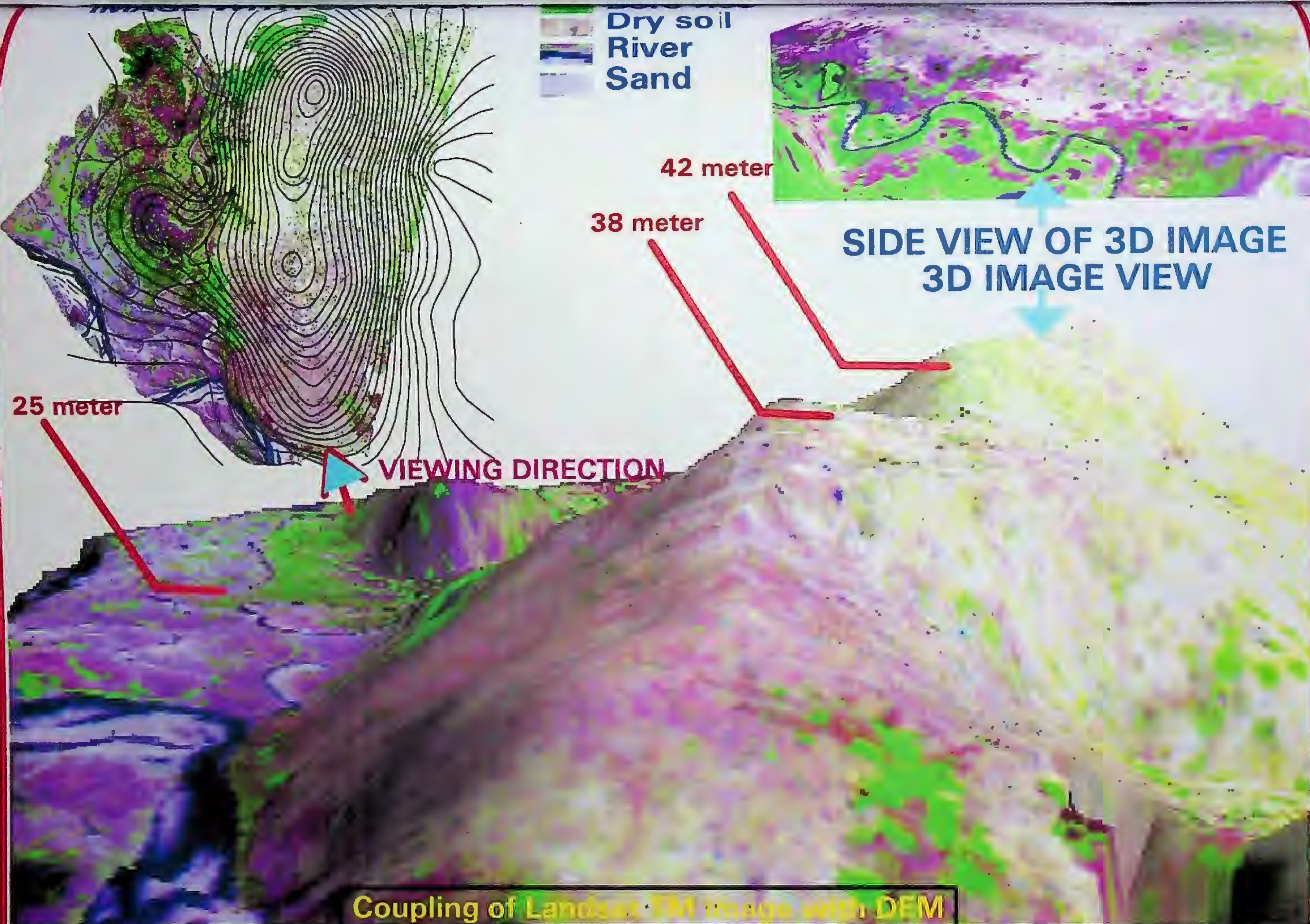



Figure 10.6: 3D view of surface topography of study area (Multiplied only in Z direction) along with 1km resolution DEM contour map.

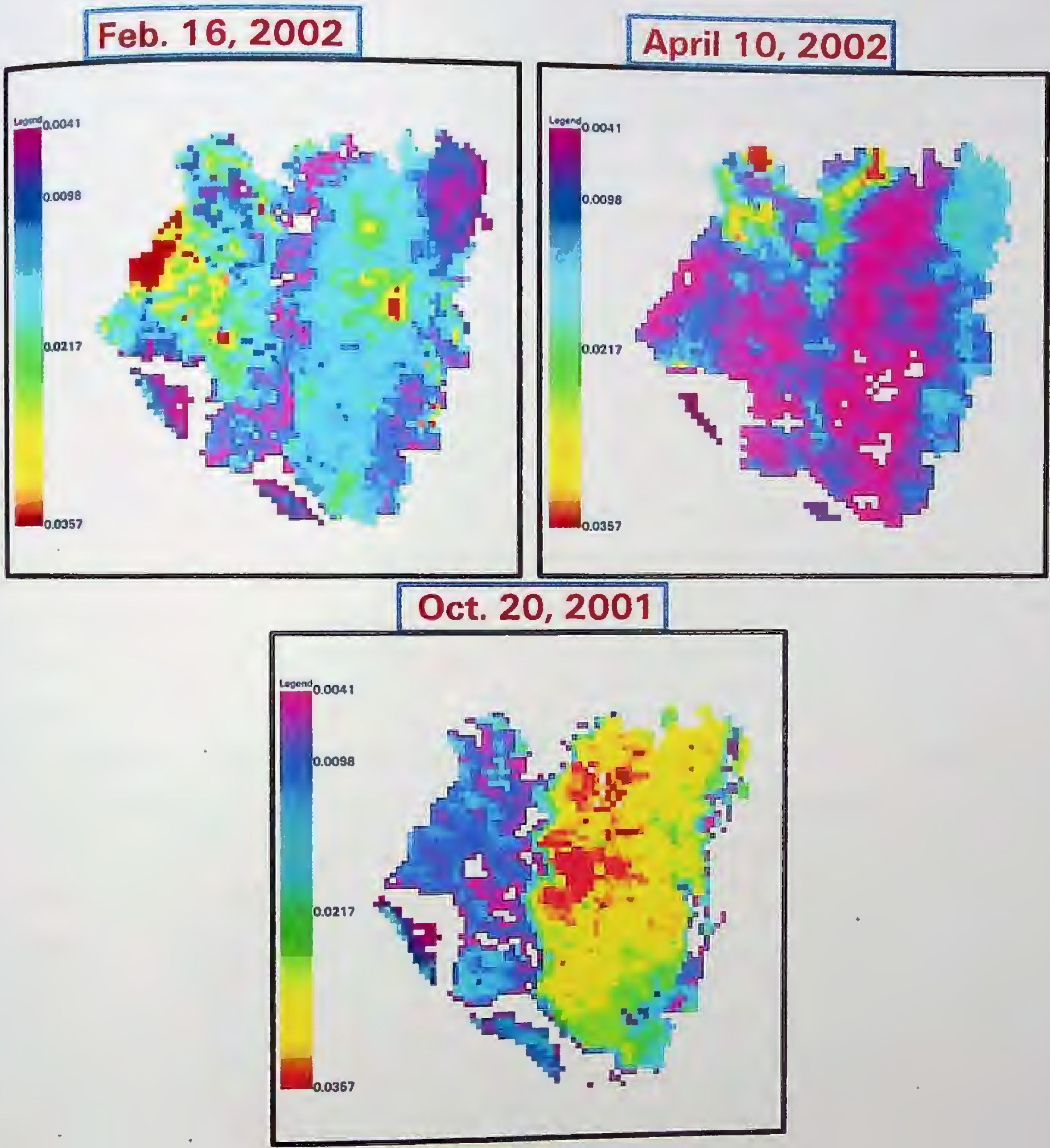



Figure 10.7: Surface roughness length as derived from NOAA AVHRR.

## Chapter Ten Conclusion:

Barind Tract is the hierarchy of mixed type of drainage network. Drainage system has been delineated using multi type satellite images. And also derived and analyzed aspect, altitude and terrain characteristics using satellite images. Drainage pattern and drainage density of an area influences by underlying surface, elevation, rainfall and soil type (King 1984). But all over the Barind Tract area landform and land use patterns are same with the climatic variables of same intensity. Only slope angle varies with the spatial variation and playing major role in controlling the drainage density and pattern. In associated with these, underlying thick clay layer has involvement in the domination of drainage branching as well as drainage density. Underlying clay loam with less infiltration rate, high precipitation rate and surface slope helps expeditious and heavy drainage. Dense branching of drainage network is also seen in steep sloppy areas. Barind Tract is the north-south aligned up-wrapped elevated hill shape formation having two peaks of 42m and 38m above mean sea level. To demonstrate the elevation and 'formation shape' of Barind Tract it is amplified 250 times in Z direction only. 360° angular dynamics representing the slope angle variation and orientation of a tilting surface. Aspect characteristics demonstrated concerned two regions for separation and distribution of surface water. The sloppy nature also negatively influences the infiltration rate. Due to slope surface water moves downward first and interactive surface doesn't get sufficient time for infiltration.

In Barind Tract surface roughness length (SRL) shows highest value in rainy season and this varies due to the seasonal surface cover variation. Here grows huge Aman crops in rainy season and this is the cause of showing highest SRL. SRL has domination on surface fluid flow. It slows down the surface runoff and allows surface much time for infiltration, and also protect surface from heavy soil erosion.

# *Chapter Eleven*

## *Analysis of Lithological Characteristics of Soil Pertinent to Infiltration and Investigation on the Variability of Ground Water Level under Varying Hydro-Meteorological Compulsion*

Among three major surface types (soil, vegetation and water) water is the main driving force next to the solar energy and has different formations like solid, liquid and vapor. Absence and presence of water on a surface plays a pivot role. Soil moisture, vegetation quality and quantity, local and regional climatic variables have clear dependency on water availability. Depending on reservoir or storage and it's physical condition it has many names like surface water, ground water, cloud, glacier like so many names.

For agricultural and domestic purposes groundwater plays a major role. Main source of ground water is surface water as well as precipitation. At the initial stage total precipitation at surface is surface water. Within a few moments of being surface water it faces different processes like infiltration (absorption), runoff etc. and distribute among many reservoirs. Part of infiltrated water goes to the subsurface storage and latter on that water uses for different surface purposes.

## 11.1 Analysis of Lithological Properties

Compositional arrangement and thickness of sub-surface layers having different hydro-geological properties is the lithology. The occurrence of water extraction and availability define the ground water storage quality, which depends upon lithological condition of the reservoir (Dunne and Leopold 1978). Charging and discharging condition, soil porosity, permeability, specific yield and transmissivity should be considered to study the storage amount of water.

### 11.1.1 Soil permeability

Water transmission capacity of soil or rock through it is permeability (Small 1978, Dunne and Leopold 1978). Water can't use total pore space (voids) for transmission, it is controlled mainly by the size of openings (Dunne and Leopold 1978). High porosity doesn't mean high permeable area, but in some cases permeability enhanced by porosity (Small 1978).

### 11.1.2 Specific yield

For unit change of hydraulic head the corresponding volumetric change of water storage is specific storage or storativity or specific yield (Dunne and Leopold 1978, Freeze and Cherry 1979). The volume of porosity defines the amount of water for a reservoir or storage. But total stored water can never be extracted for the surface use. Storativity of storage defines the amount of useable water. For unconfined aquifer productivity is called specific yield (Freeze and Cherry 1979). Specific yield is generally expressed as a percentage of the total volume of aquifer or pore space.

For unconfined aquifer storage coefficient $S_C$ is equal to the specific yield $S_Y$ but for confined aquifer it does not (Khaleque 1994). From the aquifer lithology it is clear that the storage of study area is unconfined in nature and for this $S_C = S_Y$. Specific yield $S_Y$ of the study area has been calculated with the help of standard value defined by the hydrologic laboratory of the U.S. Geological Survey (USGS) for unconfined storage parameters (Khaleque 1994). Weighted sum of individual layers and specific yield in percent is the specific yield. Height of individual aquifer has fixed up by the bore-logs information which has provided by the Barind Multipurpose Development Authority (BMDA). The storage capacity was obtained by normalizing the total value by 100. So the storage capacity of a place is the specific yield in percent.

Dynamics of storage capacity of study area has shown in figure 11.1, which exhibits the storage condition as well as the quality of the sub surface water table condition. From figure 11.1, it is seen that the storage capacity in most of the areas of Barind Tract ranges from 1 to 8. Storage capacity in flood plain areas is rich and ranges form 9 to 19.

The layer properties of the aquifer or water bearing formations define the storage quality. According to the borehole information, it is found that subsurface formation has four layers, top clayey, fine sand, composite sand and black plastic clay layer and compositional dynamics of subsurface formation has shown in figure 11.2. From the figure 11.2 it is seen that composite sandy layer with varying thickness is overlying a thick clayey/silt clayey layer and a very thin fine sand layer. The permeability and specific yield of the top clayey layer is poor. The physical properties of aquifer i.e. the thickness of the fine sand and composite sand is the quantifier of aquifer. Due to the poor thickness and fine grain size of fine sand layer, the domination of this layer on total aquifer quality is negligible. Only the composite sandy layer with mixed grain size is favorable for ground water reservoir and also for ground water exploration. The thickness of the composite sand layer is directly influencing the ground water storage quality which is comparatively thin in Barind Tract area.

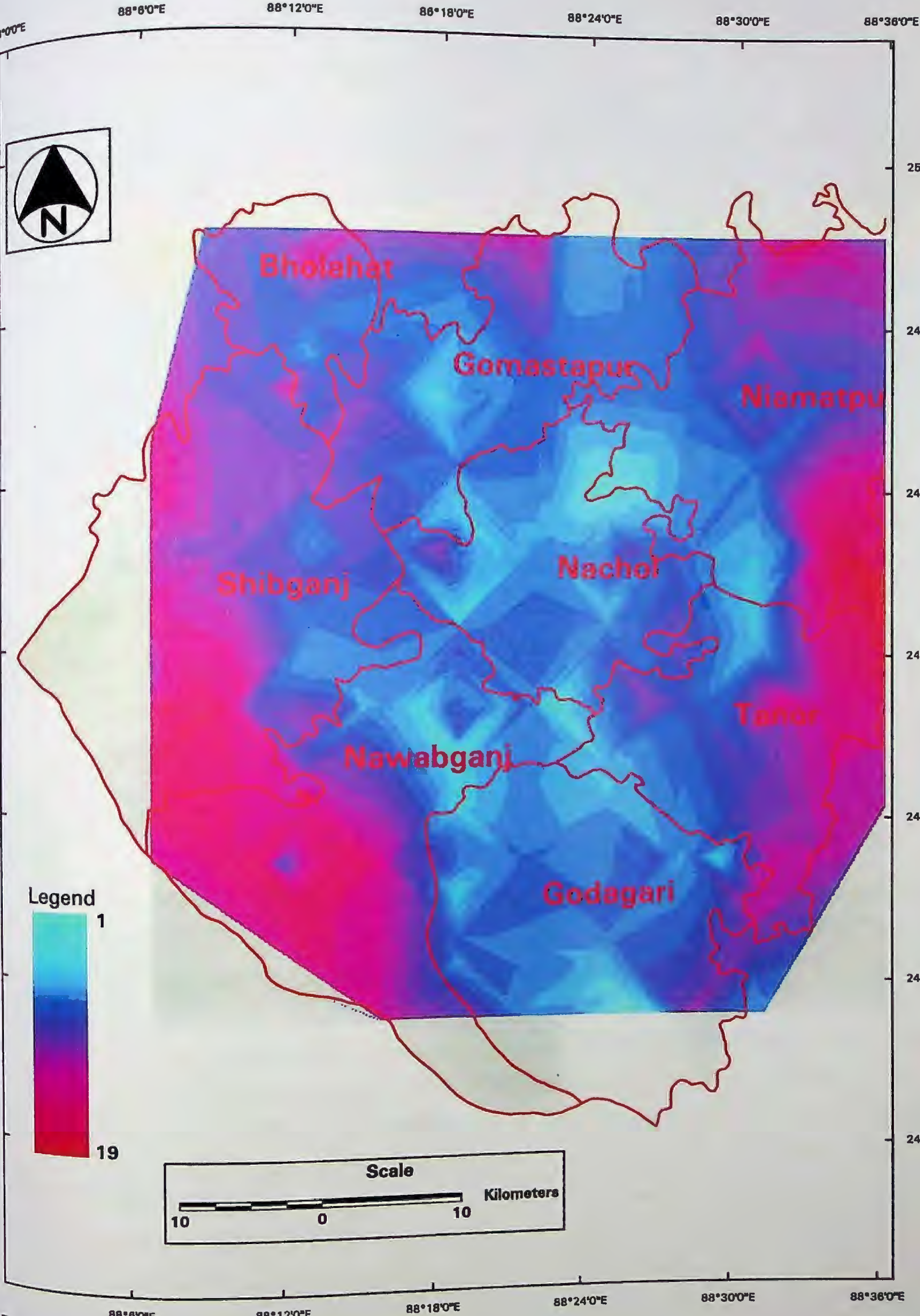



Figure 11.1: Storage capacity map of study area.

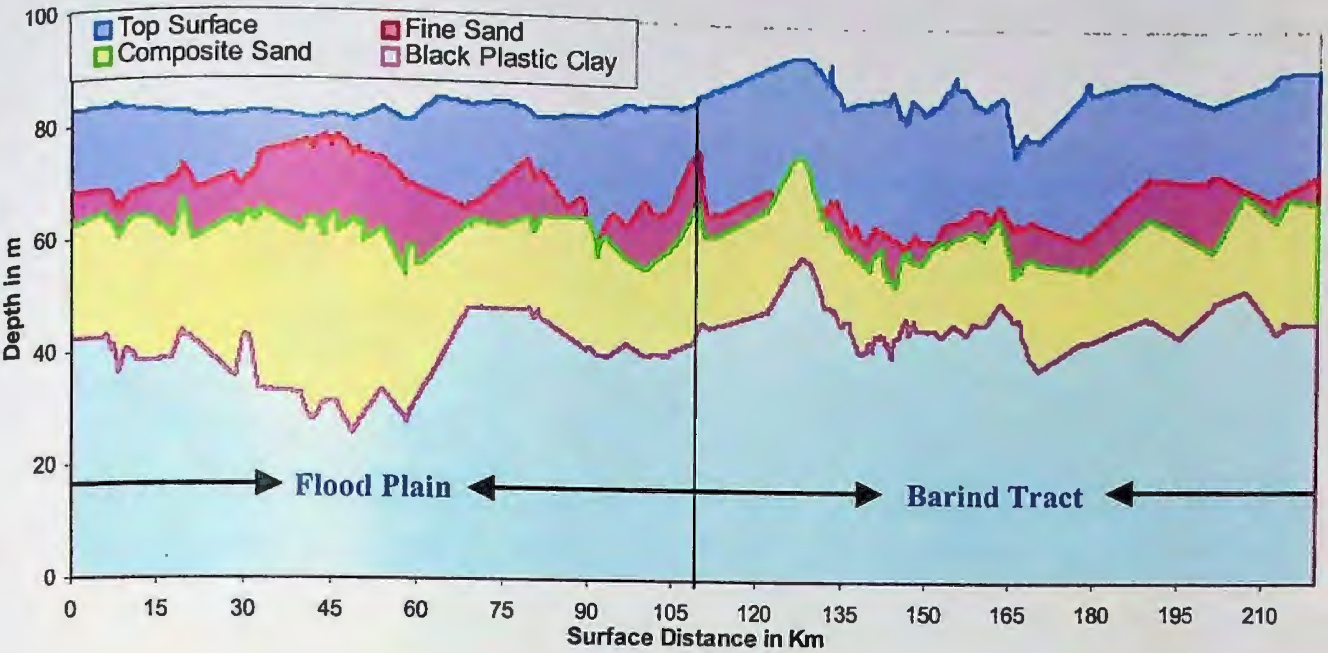



Figure 11.2: Compositional arrangement with varying thickness of sub-surface formation for both

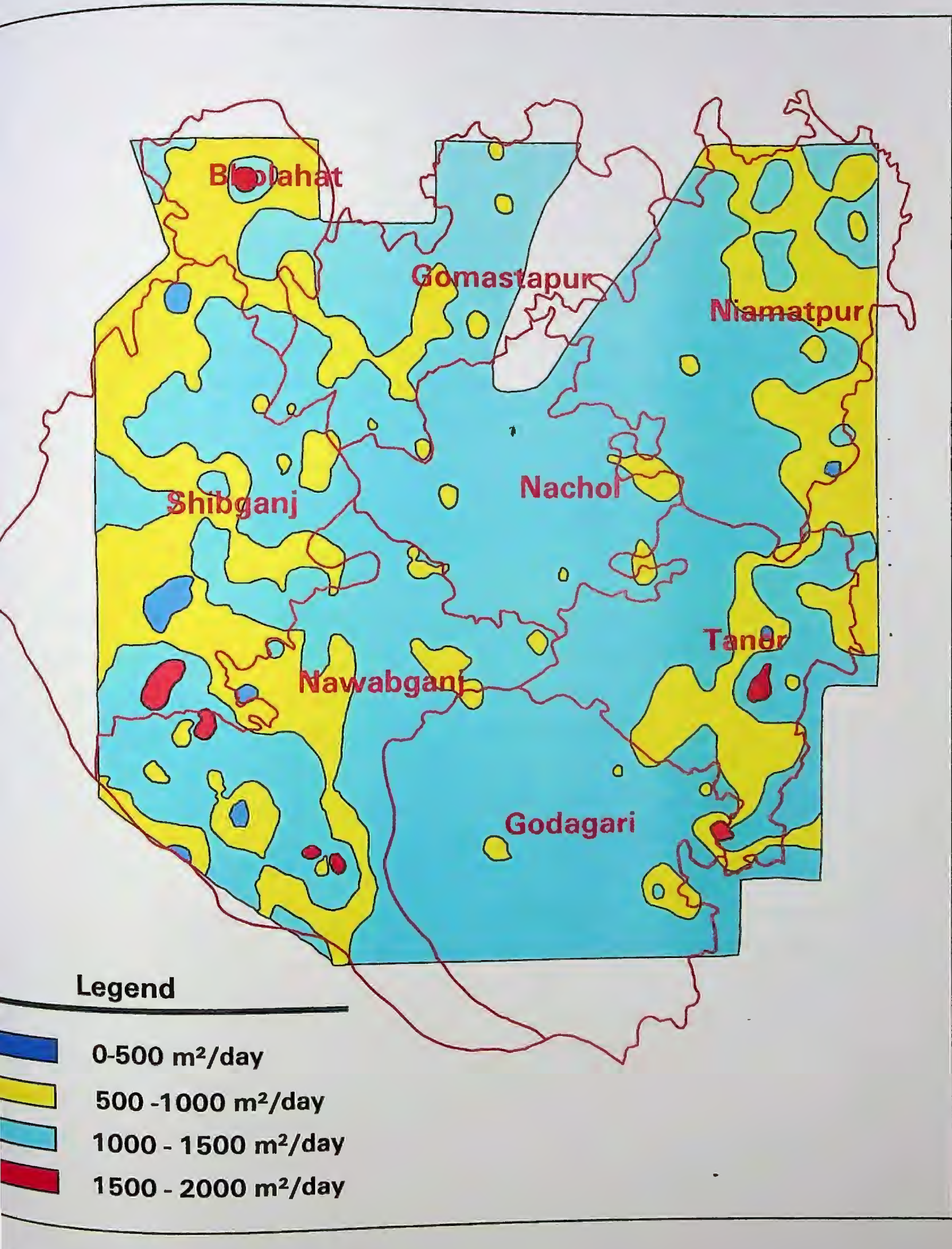
### 11.1.3 Transmissivity

To study the aquifer quality, transmissivity is a basic component. For an aquifer, the transmissivity T, the thickness D and coefficient of permeability P follows the following relation (equation 11.1).

$$T=DP \qquad (11.1)$$

The unit of T is $L^2/T$ when the unit of K is L/T, if K is gal/day/ft$^2$ then the unit of T will be gal/day/ft. For a good aquifer transmissivity T is greater than 1296m$^2$/day or 13824ft$^2$/day or 100000gal/day/ft (Freeze and Cherry 1979).

Using this standard formula transmissivity has been calculated. The thickness of individual layers of different formation and their corresponding permeability collected form the bore-hole data. Calculated transmissivity of individual layer are then added and that is the transmissivity of the storage. Transmissivity of the study area varies from 0-2000 m2/day and shown in figure 11.3. Most of the part of study area i.e., maximum of Barind Tract and major portion of flood alluvial plain lands are under the range of 1000 to1500 m2/day. This range of transmissivity supports the suitability criteria for ground water exploration. Very small




...re 11.3: Transmissivity map of the study area.

scattered areas in both flood alluvial plain and Barind Tract areas are under the maximum and minimum range of transmissivity i.e., from 1500 to 2000 m2/day and from 0 to 500 m2/day respectively.

## 11.2 Variation of Depth of Ground Water Table

Ground water is a limited renewable natural resource. It's conservative use needs planning. Water exploitation by any means is discharging and water storing by any means is recharging or charging. Over exploitation, more than charging is hazardous for a reservoir and water quality, and also for echo system. Figure 11.4 exhibits the seasonal and annual variation of ground water level, and the variation has been calculated with respect to the top surface. In figure 11.4, dry season and wet season are the discharging and charging period respectively. In dry season, in these areas ground water uses mainly for irrigation purposes along with the regular use of household purposes throughout the year. Maximum (above 80%) rainfall observes in rainy season and ground water reservoir charges through infiltration. With the spatial variation there is a variation in water level, but the variation is not homogeneous and it doesn't follow any sequence or order. In Barind Tract and its adjacent area ground water level are in maximum depth. At Nachol, the center part of Barind Tract, depths of ground water level from surface are highest for both seasons. Ground water levels are in suitable depth at Shibganj and Bholahat, which is situated in flood plain area. In figure 11.4, second periodic curve is not only expressing the water level in wet season, it is also expressing the charging condition of the respective areas. Water level and charging condition at Shibganj are better. Among Barind Tract areas charging condition at Niamatpur is better.

Charging condition in 1991 is remarkable for the whole study area. In some areas it reaches at surface. The probable cause of this is rainfall. The recorded rainfall amount of this year is also higher then any other consecutive years on both sides of 1991.

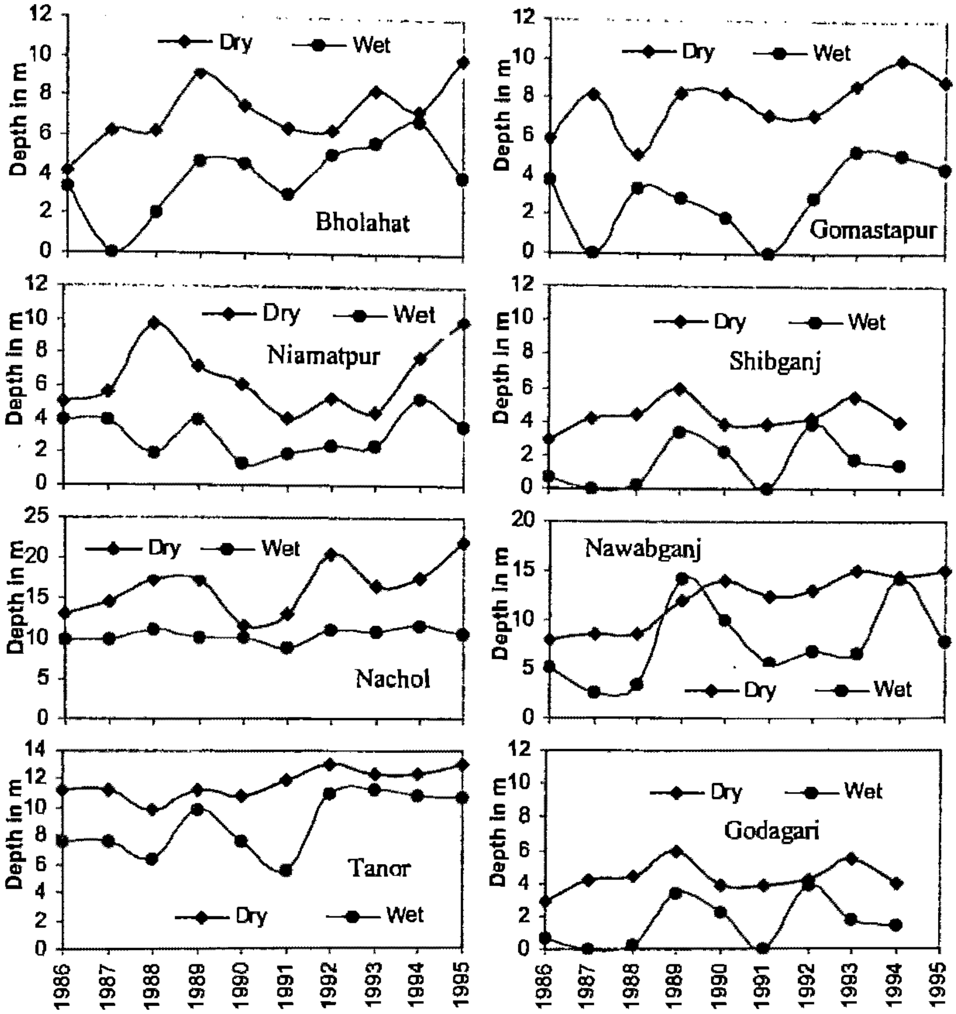



Figure 11.4: Dynamics of ground water depths with respect to seasonal climatic variation as well as annual variation.

The hydrographs (Figure 11.4) of a time series data from 1986 to 1995, exhibits a declination trend of ground water level i.e., the discharging is more than charging. The ground water exploitation is gradually increasing with the increasing irrigation area. If the trend of increasing irrigation activities continues the water level will be beyond economic exploitation level and severe water shortage will damage whole ecosystem.

## 11.3 Dependency of Depth of Ground Water Level on Rainfall Amount

In both Barind tract and flood plain areas, water level falls during dry season and increases during wet season, which is in conformity with rainfall amount. Ground water reservoirs renew annually from surface water, which is the ultimate result of flood, precipitation and irrigation return.

Figure11.5 exhibits the ground water level fluctuation with the variation of rainfall amount, for both dry and rainy season. From this figure it is evident that, in rainy season ground water level varies with the variation of rainfall amount in both areas. But the response of ground water table to rainfall amount is not identical all over the study area. In dry season ground water level of dry area Barind Tract has clear dependency on rainfall amount. In Nachol the sensitivity of ground water dependency on rainfall amount is maximum. But for flood alluvial plane land rainfall amount has minimum influence on ground water level.

Both the regions are characterizes with the high rate precipitation, and receives maximum rainfall in rainy season and in dry season receives minimum rainfall. Barind Tract, especially ridges never flooded. So surface and subsurface receives only precipitation water. In these areas there are no large surface water bodies like bil to hold rain water, but in some areas foot slopes of hill and hummocky land makes a bowl shape low land water logging area. Elevated surface topography along with high rate of precipitation, make prompts surface runoff. The soil permeability of Barind Tract area is relatively poor. As a result, water propagation into the upper surface through vertical percolation is relatively lower, over the Barind area. Thereby, charging of ground water reservoirs through infiltration is largely restricted over Barind Tract area, though a large portion of subsurface water charges instantly during rainfall.

This scenario is same for dry season in Barind Tract area. In this season ground water level of Barind Tract area (Niamatpur, Nachol, Tanor and Godagari) has clear dependency on rainfall amount. In this season minimum rainfall and minimum irrigation return are the sources of ground water charging.

In flood plain areas, along with rainfall flood water are the sources of surface water in rainy season. But in dry season, along with minimum precipitation, irrigation return and water in


● Positions of Ground Water Level Measuring Station



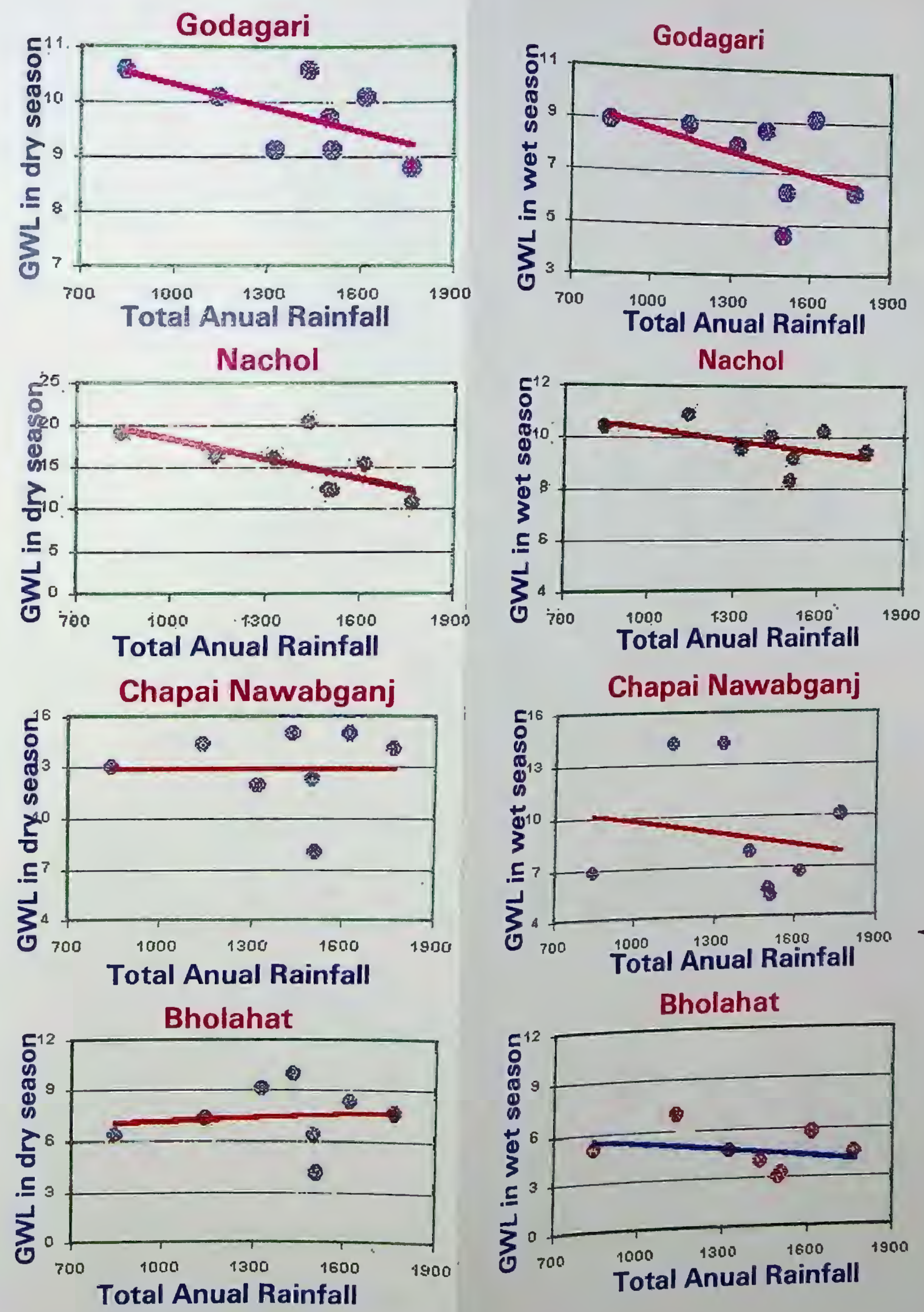



Figure 11.5: Sensitivity of ground water table to the rainfall amount in both dry season and wet season.

low land areas, are the sources of surface water. In this area there are number of low lands/bils, that hold precipitated and flood water and helps for long tenn charging in both the season. In flood alluvial plane land and it's adjacent (Bholahat, Gomastapur, Shibganj and Nawabganj) rainfall amount have minimum influence on ground water in dry season. But in rainy season ground water has clear dependency on rainfall amount. The soil penneability of flood plain area are good. A large portion of plane land in this areas are occupied by deep rooted permanent vegetation Mango Orchards, which may also influence the charging rates by bi-folding mechanism one is loosing the compactness of soil and another is making delay the water transmission time. In rainy season precipitated and flood water stays for a long time at surface due to flatness, and surface gets enough time for infiltration. And in dry season this zones also gets maximum support from overlying large perennial water bodies and the contribution of rainfall amount to surface water is also minimum. Gomastapur is under Barind Tract area but there is a large surface water body and ground water gets maximum support from this source and hence the dependency of ground water on rainfall amount is also minimum.

## Chapter Eleven Conclusion:

Quality of subsurface water bearing zone depends on the thickness of fine sand and composite sand. Thick layer of fine sand and composite sand enriched the sub surface water bearing zone of flood plain area. And hence the storage capacity is high. Ground water level (from surface) has dependency on rainfall amount in rainy season but shows minimum dependency in dry season. Ground water reservoir in this area charges from precipitation and flood water in rainy season and in dry season it charges from water in low land areas. High rate charging, overlying flat surface having good permeability and good transmissivity has made a good aquifer in flood plane areas. And a reservoir having all these quality is suitable for water extraction for irrigation and other purposes.

In Barind Tract area the groundwater storage condition is different; here ground water storage is comparatively thin and followed by overlying a thick clay layer (8m to 24m) of low permeability. Elevated sloppy surface with thick clay layer of poor permeability restricts the infiltration rate in Barind Tract area. Due to the poor thickness of water bearing formation (fine sand and composite sand layer), the storage capacity is also poor. But another quantifier transmissivity which defines the economically exploitable amount of ground water is suitable for Barind Tract area. This information makes conflict with the charging condition of ground water reservoir in Barind Tract area. From a time series data it is seen that there is a declination trend in ground water level. And if it is continue or increase then total ecosystem has to face a severe problem due to water deficiency. Along with above problem the subsurface storage of Barind Tract charges only from precipitation water and maximum water collects in rainy season. In both season the ground water storage has clear dependency on rainfall amount. So arrange of artificial water logging area may allow enough time to charge the subsurface storage for this area and water of logging areas may be used in dry season irrigation purposes, which may give release the pressure on subsurface water use.

# Chapter Twelve
## Study on the Driving Forces of Land use and Land Cover Changes and Analysis of Their Environmental and Socioeconomic Consequences

Environment for the people and due to the people are main objectives of environmental studies. It is difficult to manage everything to make environment suitable for man due to ever increasing population and their demand for better leaving. The ever expanding human population exerts increasingly high pressure on the available land and its natural resources. Very often these lands and the natural resources therein are exploited for various urban, agricultural and industrial purposes in such a manner that causes significant damage and degradation to the whole ecosystem. Some of these damages are irreversible in nature and are very much harmful to both environment and ecology. In many cases, such local scale problems often provoke global scale consequences depending on the gravity of the situation.

World Meteorological Organization (WMO) has one of the major target to study the environmental change in terms of social activities (Kellogg and Schware 1982). The sustainability of socio-economic development closely linked with the land-use and land-cover which changes natural resources such as SVA system, climate and biodiversity (Yuan et al. 2002, Mather and Sdasyuk 1991). To study and understand the land-use and land-cover dynamics is one of the prime research objective of global environmental research (Yuan et al. 2002, Turner et al. 1993, Turner et al. 1994, Lambin et al. 1999, Lambin et al. 2001). Climatic or environmental changes like drought, flood and desertification severely affect the people of developing countries. Keeping all other terms unchanged increasing population is the threat for population itself. Because with the increasing population per capita land is decreasing and food demand is increasing. So to provide sufficient food for the increased people/population is a factor. During the last few decades, extensive efforts have been made in agriculture sector for multiplying the crop production to meet up the increased food demand over the world. A significant progress has already been achieved through intensification of agricultural activities round the year using chemical fertilizer, pesticides, improved crop varieties, and irrigation (through using surface and ground water).

All the foregoing issues have specific impacts or consequences on hydrological and environmental condition of an area and often associate certain problems to the whole ecosystem that put the sustainability of whole operation in question. In imbalance carbon cycle, man has a major contribution which initiates global warming and the severe consequences due to the global warming have to face all living organism including human being also. Main forces that are driving hydro-environmental processes are natural and socioeconomic.

## 12.1 Socioeconomic Factors (Driving Forces)

### 12.1.1 Population

According to the population census of 1991 the total population of the study area is 1720492. Like other areas of the country, the population of the study area is also increasing. The population of the study area was 775328 according to the census of 1961. Population changes from 1961 to 1991 of different upa-zila have shown in figure 13.1. Population increased in 1991 with respect to the population in 1961 is 136% in Gomastapur, 121% in Niamatpur, 168% in Nachol, 134% in Tanor, 105% in Nawabganj, 145% in Godagari, 142% in Bholahat and 108% in Shibganj upa-zila.

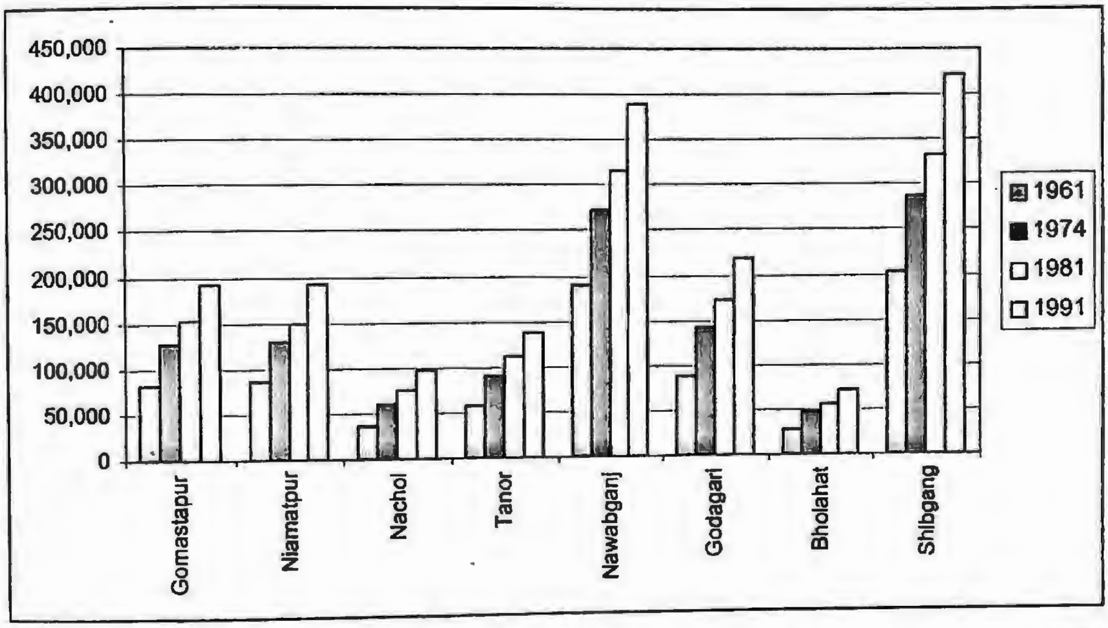



Figure 12.1: Population change dynamics of individual upazila of study area according to the different population census conducted by Bangladesh Bureau of Statistics.

### 12.1.2 Decrease in Per Capita Land Ownership

With increasing population, capturing more lands to residential area is also increasing, and farm land and forest area decreasing as well as per capita land is also decreasing. Decreased per capita lands are using to serve multiple purposes i.e., to support increasing food demand and increasing residential demand etc. The amount of per capita land and it's redistribution to the increased population has been calculated according to the different population census and has demonstrated in figure 12.2.

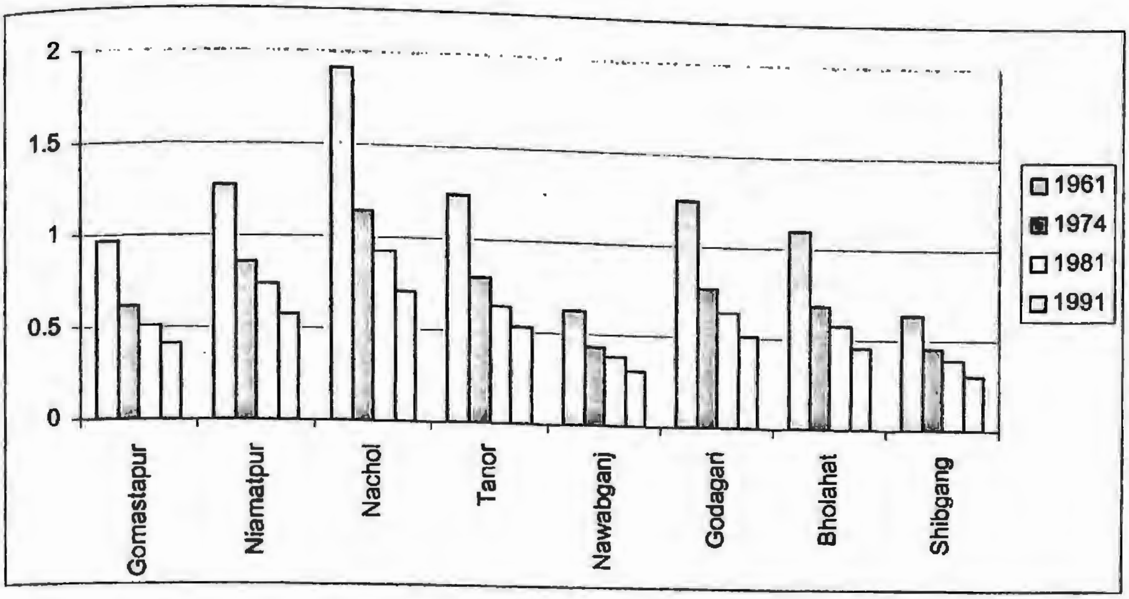



Figure 12.2: Per capita land and it's redistribution of different upazila of study area with respect to population census of different years.

## 12.2 Geophysical Factors (Driving Forces)

### 12.2.1 Land Physiography

The physiography of two zones of the study area is different and contradictory. One zone is semi-arid Barind Tract area and another zone is flood alluvial plane land. Broadly dissected terrace, closely dissected terrace and level, intermittently terrace comprises the Barind Tract. Physiography of the floodplain area are characterized by flood alluvial plain lands of different rivers like Old Ganges, New Ganges and Mahananda and active and very young meander flood plain, mixed Ganges and Mahananda flood plain, young meander flood plain, oldest meander flood plain and level, covered terrace physiographic units consists the flood alluvial plane. Swampy (low/bils) lands and eroded sandy lands are the landscapes of floodplain area.

Barind Tract is elevated and elongated north-south followed by a ridge having two peaks 38m and 42m above mean sea level. Barind Tract area is in general 2m to 5m elevated with respect to flood plain areas. Landscape of Barind Tract is the composition of hummocky lands with low soil moisture and poor surface cover. This is basically a water deficit area. In this area there are no large surface water bodies. But the presence of some small standing water bodies like ponds and bowl shape low lands formed by foot slopes of hill shapes are noticed. The existence of drainage network of minor tributaries and distributaries along with numerous canals are evident in addition with main streams. Most of these become dry in the dry season. Narrow, tightly entrenched and usually streamless valleys characterizes the drainage system in the Barind Tract area. *(Details about slope and drainage has described in Chpter-10).* Water is generally drained into the river, cannel and local water reservoirs adjacent to the Barind Tract area. In the east, most of the drainage water passes through the river Atrai, the Little Jamuna and the Shib while, in the west drainage water passes through the river Mahananda and the Ganges. All these rivers are subjected to continuous changes in terms of migration and formation of flood plain land.

## 12.2.2 Change of Cropping Intensity

### 12.2.2.1 Land Use Pattern 1968

For land-use, land-cover and land type change study, land use map of 1968 has been used as a reference map. This map was prepared by 'Reconnaissance Soil Survey' (1968). They classified the used land depending mainly on cropping intensity and then on land type.

Landform and land-use pattern of Broadly dissected, closely dissected and level, intermittently flooded terrace Barind Tract area were same with the climatic variable of same intensity and this is why whole Barind Tract area was treated as a single unit of cropping area of same intensity. And this area was predominantly a single cropping area. Rainy season was the main cropping season in this area and crops are mainly rain fed type. Transplanted aman, broadcast aman and aus were the major crops cultivated in this area. Lands were seen fallow remaining period of the year.

River alluvial flood plains were classified into multiple cropping units. Classified land use patterns were described with the reference of physiographic units. Except Mahananda river adjacent area, mixed Ganges and Mahananda meander flood plains were mainly single cropping with some double cropping lands. Mahanada river adjacent mixed Ganges and Mahananda meander flood plain and young meander flood plains of Shibganj and Nawabganj were mainly Mango Orchads area with some double cropping lands. Young meander flood plains of Bholahat upazila area was mainly a double cropping land with some perennial crop (sugarcane) lands.

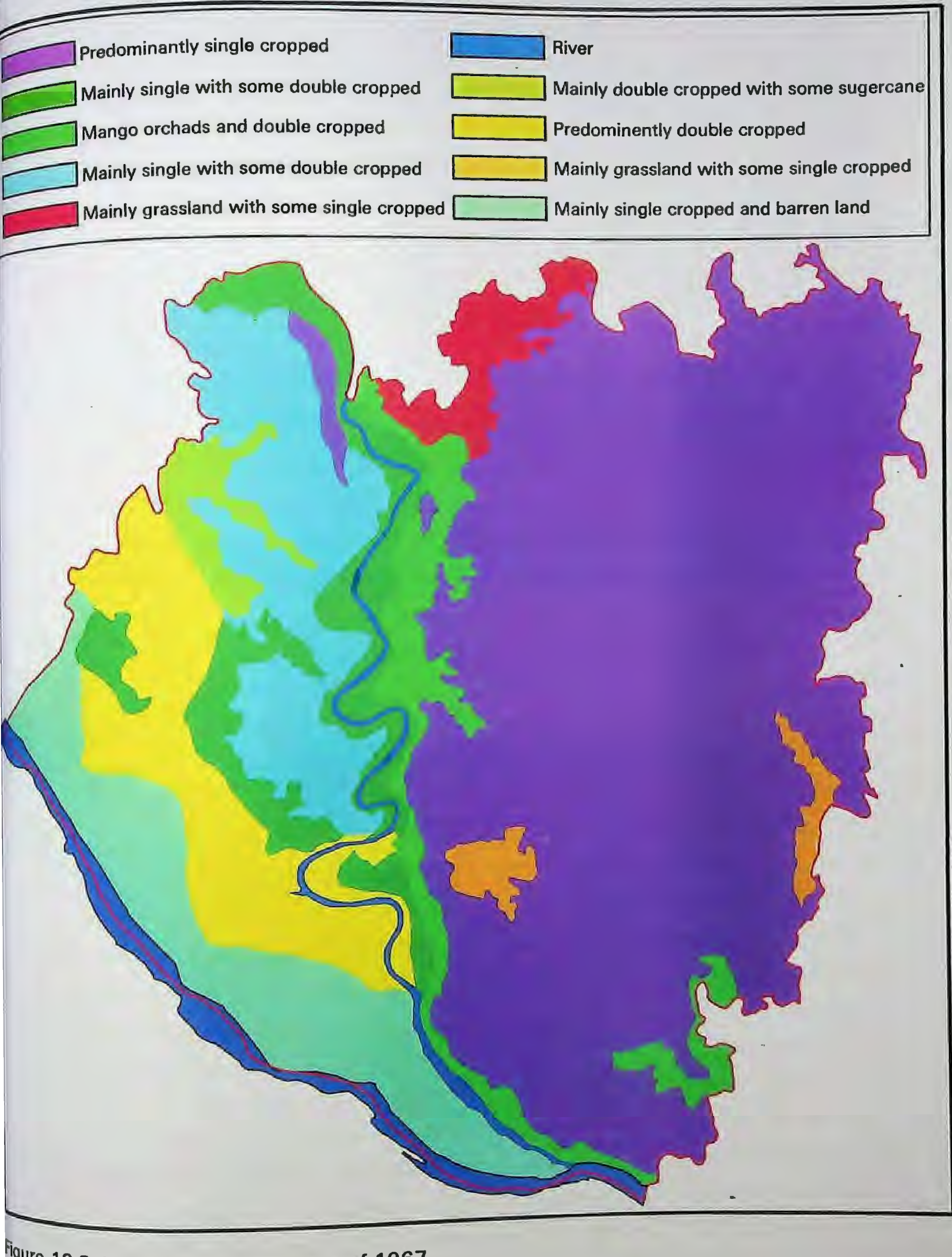



Figure 12.3: Land use dynamics map of 1967.

Active and very young meander flood plain area was divided into two cropping areas. Ganges river adjacent areas were mainly single cropping and barren lands. And another portion was suitable for predominantly double cropping.

Oldest meander flood plain (right side of Mahananda river) area was mainly single cropping with some double cropping lands. Northern side of old flood plain basins were mainly grassland with some single cropping lands.

#### 12.2.2.2 Land use pattern 1990

Land use map of 1990 has been prepared by using multi dated Landsat TM images. Images dated April 11, October 20 and February 05, were selected for summer, rainy and winter season respectively. Images are classified individually depending on the land cover dynamics to get the seasonal land use pattern. And then integrating all seasonal land-use maps it is prepared the annual land-use map. In the land use pattern map of 1990, Barind Tract area is also treated as a single cropping unit. And found mainly single with some double cropping land.

The semi arid zone Barind Tract is a water deficit area and characterized by poor vegetation cover and low soil moisture content during dry season, and higher vegetation cover and high soil moisture content during wet period. In arid and semi-arid zone soil water regime the vegetation and crop growth pattern (Winkworth 1970). As such, the area remains mostly fallow during the dry period and treated as a single cropping area except small portions correspond to double or triple cropping. Boro rice is generally grown in summer when no significant rainfall occurs over the area. Water supply is maintained to the Boro cropping area through irrigation. Cultivation of Boro rice, over certain areas in the Barind Tract through ground water irrigation is developing in the recent years. In this area the only means of irrigation is deep tube-well. Boro rice is grown over the swampy lands in a significant portion of comparatively low land areas. Here, it should be pointed out that soil moisture over the flood plain area remains almost to a satisfactory level throughout the year and thereby, which supports crop cultivation in different places during dry season when cultivation is often constrained due to lack of required rainfall particularly in the Barind area. The major crop in Barind Tract area is Aman and grows in rainy season. Barind adjacent northern side low land

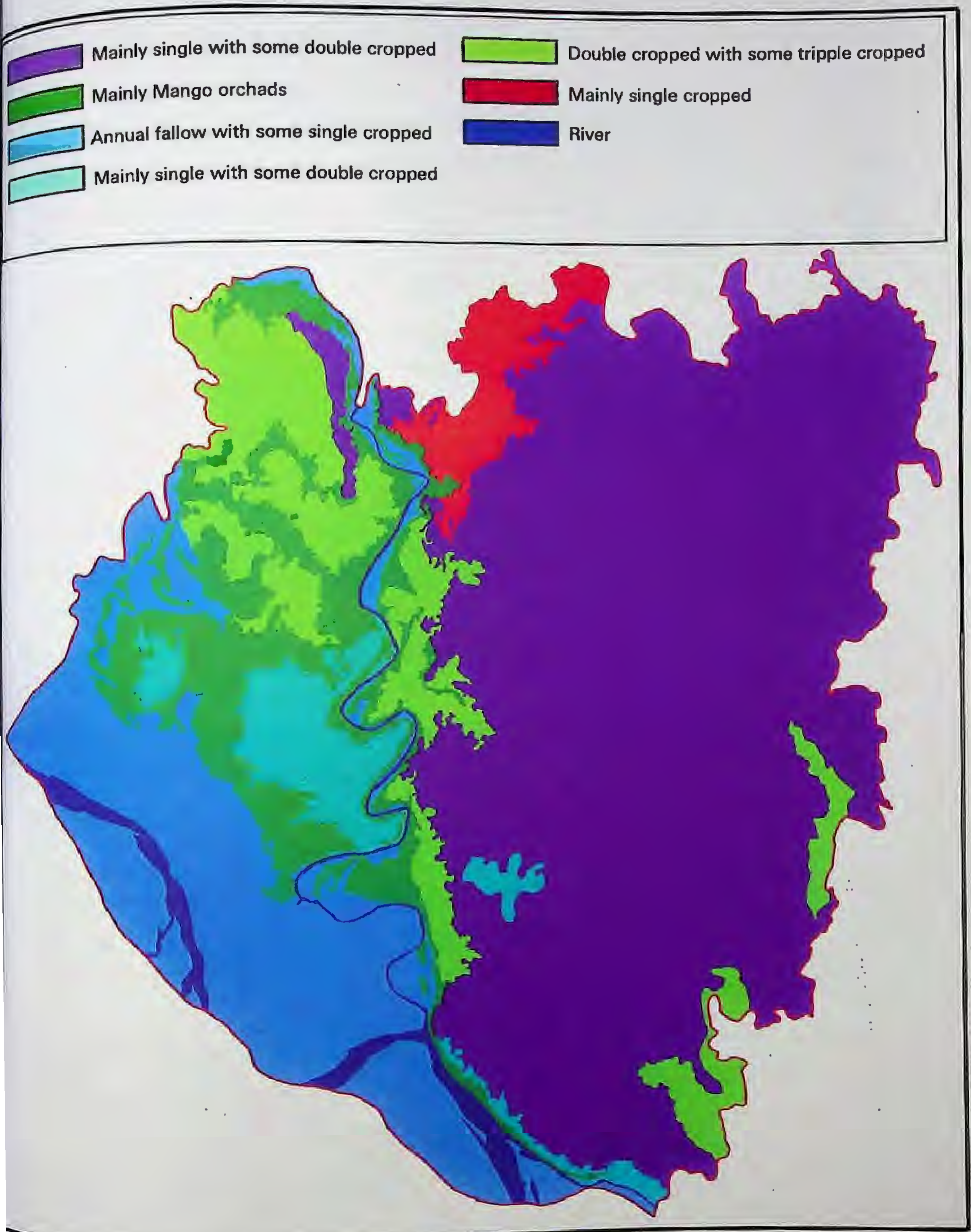



Figure 12.4: Land use dynamics map of 1990 prepared by using multi dated Landsat TM data.

(Old floodplain basins) is mainly a single cropping area. Here cultivates Boro rice during dry season and founds fallow rest of the year.

Major portion of flood plain areas are corresponding to double crop and small portion to single and triple crop land. Major crop in summer is Boro rice, in winter is Rabi crops and in rainy season is Aman rice. In some areas perennial crops, mainly sugarcane is also seen. In plain land deep tube-well, shallow tube-well, tube-well and dug wells are used for irrigation. During rainy season maximum portions of flood plain areas are found as a moderately to deeply flooded zone. Cultivation of Aman rice are very much limited over this area due to frequent flooding and thus major portion of the area are found to be as seasonal fallow in rainy season.

Upper and lower side of mixed Ganges and Mahananda mender flood plain of Bholahat upazila, both sides of Mahananda river, lower part of Godagari upazila besides Ganges (Padma) river and the 'U' shape pocket of Mahananda river in Nawabganj upazila in Oldest meander and Ganges and Mahananda meander flood plain are Mango Orchards area. In these areas Mango Orchard is very common. Mango Orchard occupies about 14 percent of total flood plain areas along with a small portion of other local fruits. Presence of a significant portion of permanent vegetation (trees) ensures all season vegetation cover over this area. On the contrary, in Barind Tract, no significant presence of permanent vegetation (trees) is noticed.

Oldest meander floodplain, mixed Ganges and Mahananda meander floodplains of Bholahat and Gomastapur are mainly double with some triple cropping lands. Some areas of Shibganj and low land of Nawabganj are mainly single with minor double cropping lands.

In the active and very young Ganges meander flood plain, New Ganges and Mahananda flood plain the parent materials of soil are predominantly sandy and silty and calcareous. This type of soil is not suitable for rice cultivation. Only Rabi crops are grown over these areas during winter season.

### 12.2.2.3 Land Use and Land type Change and Probable Driving Forces

Land use (land cover) and land type change study in context of socio-economic condition have profound implications. During last few decades land type, land use pattern and cropping intensity has changed tremendously due to river course change, increased food demand and introduced dry season cropping (practice of rice cultivation through irrigation system) etc.

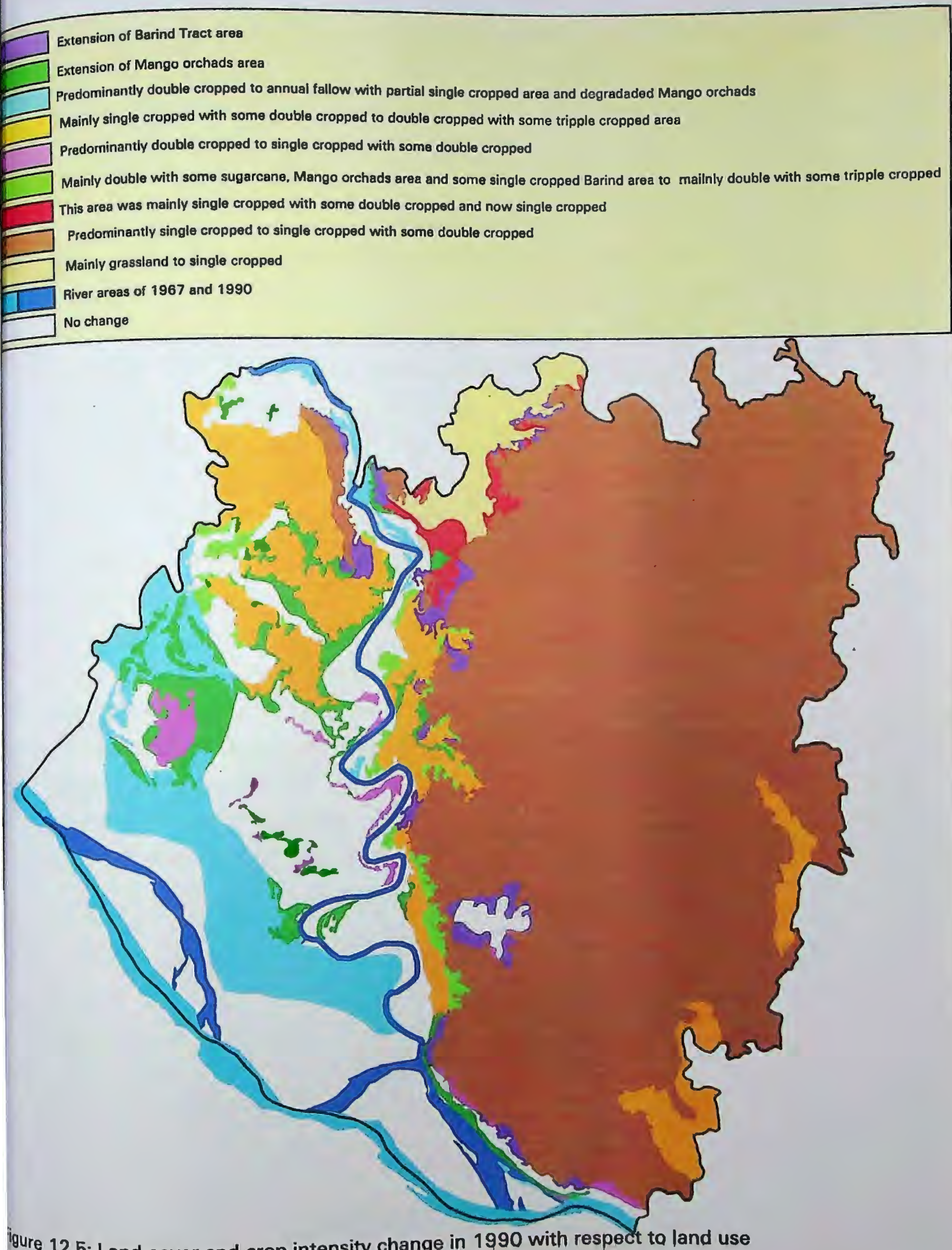
There is a partial change in land use pattern in Barind Tract. Here cultivating boro rice in some scattered areas in dry season using ground water. Irrigation is practicing in drainage bed, valleys and adjoining low lands of hammocks. In figure it is not shown separately, because whole Barind Tract has treated as a single cropping unit.

In figure 12.5, yellow and green color areas are remarkable crop intensified area. These areas were mainly single with partial double cropping land, but now predominantly double with partial triple cropping land. Some areas are also converted into sugarcane (perennial crop) and Mango Orchard areas. The cause of crop intensification over this area is to introduce high yield boro rice in dry season. And due to add this dry season crop, previously single and double cropping lands are now double and triple cropping lands respectively.

Northern side old floodplain basin grassland, now converted into farmland. This low land is predominantly a single cropping land and cultivating boro rice in dry season.

Deep green color indicates the extension of Mango Orchard area. Some double and single cropping areas are converted into Mango Orchard areas.

There is a major change in Ganges river course. In figure 13.5 it is demonstrated the river coarse in 1968 and in 1990 by two different colors. But in the river course of Mahananda there is no significant change i.e., the river course is almost stable. Ganges river course has shifted towards agricultural land at south-west of floodplain area and at south-west of Barind Tract area. With the Ganges river course change active fluvial zone also shifted and at or near active fluvial zone arable farmland has converted into sand and sandy land. This type of land is not suitable for copping. These areas are now found as annually fallow or grassland with minimum limited cropping activities once in a year and that is Rabi crops, which cultivates in winter season. Very few areas marked by violet color are crop dis-intensified areas. In




igure 12.5: Land cover and crop intensity change in 1990 with respect to land use
nd crop intensity map of 1967.

The cause of crop pattern change is due to land type change at Mahananda river side areas. Due to erosion land type has changed in these areas. At south-west of Barind Tract due to river course change there is no change of soil type at Barind Tract side. Probably due to elevation water can't carry sediment toward Barind Tract.

Analyzing the cropping pattern of 1968 and 1990 it is seen that cropping intensity of flood plain area is higher than the Barind Tract area. From the land use pattern of 1990, it is seen that crops are intensified in these areas like whole area of the country, due to Boro rice cultivation in dry season. Cropping activities are intensified through the repeated use of land, and using chemical fertilizer, pesticides, improved crop varieties and irrigation. And more lands are taking under crop cultivation every year.

### 12.2.3 Increase of irrigation

The study area is dominantly semi-arid region covering a significant area in Bangladesh. Water deficiency particularly during dry season is a major problem for agricultural activities over this area.

To support increased food demand from gradually decreasing arable farm land some improved techniques are already been adopted and there is a remarkable achievement. Crops are intensified through the multiplying use of land throughout the year and using chemical fertilizer, pesticides, improved crop varieties, and irrigation (through surface and ground water etc.). Moreover more lands are being taken under Boro rice activities every year converting other cropping lands, some forest lands and fallow lands also. And increase of

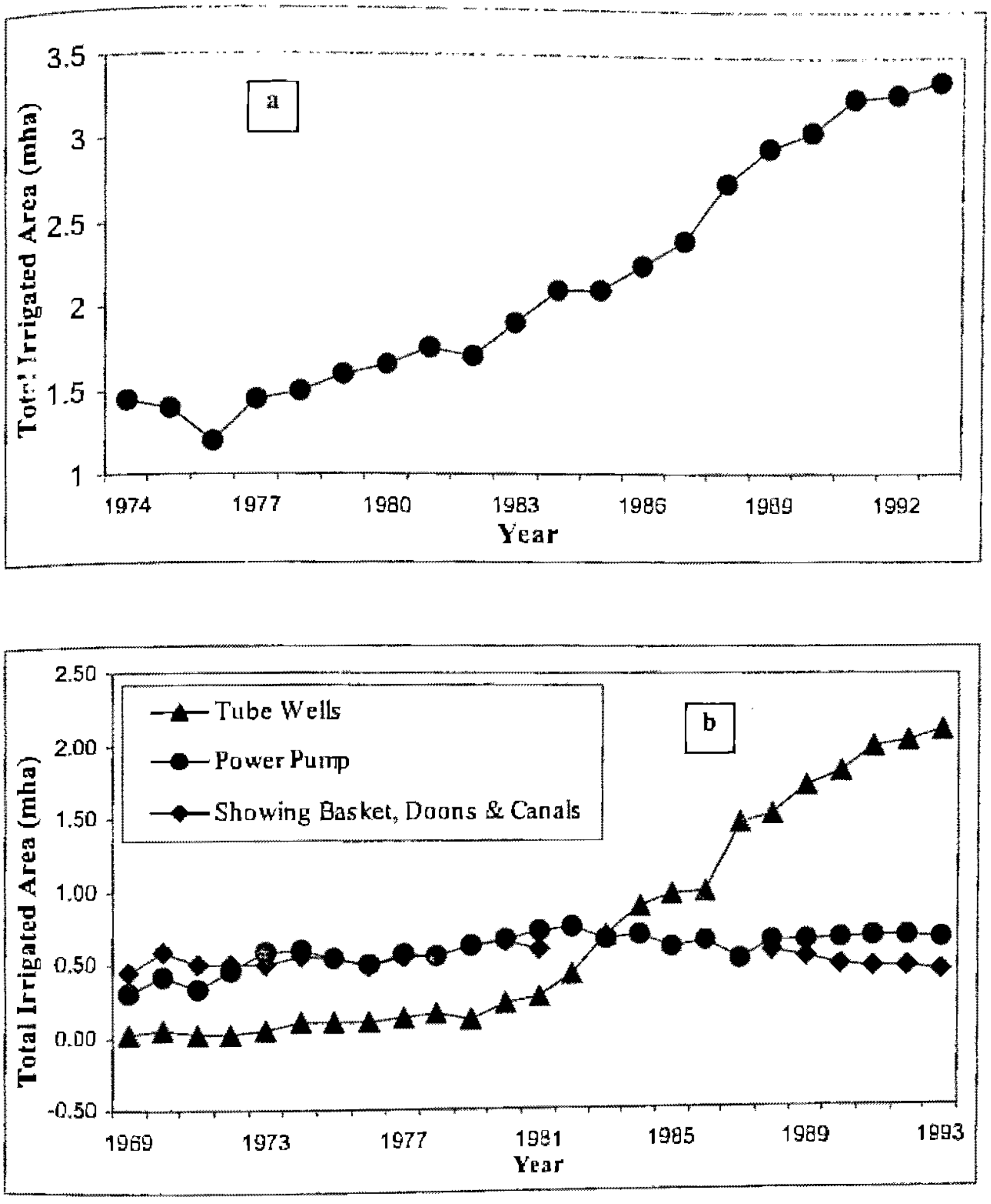



Figure 12.6: Change of irrigation (a) area and (b) means with the annual variation of irrigation areas.

land use for Boro rice through irrigation demonstrated in figure 13.6 (increase of irrigation area). In this figure it is also demonstrated the ways of irrigation. And from this figure it is seen that with the increase of irrigation area, dependency on ground water for irrigation is also increasing.

## Chapter Twelve Conclusion:

In this chapter it has studied the land use and land cover change and found that there are changes in land type and land use. Both socio-economic and natural causes are responsible for these type of changes. The cause of land type change is natural. Most of cases land type changes due to river course change and erosion. But the cause of land use pattern change is socio-economic. Introduce of Boro rice cultivation through irrigation system has been identified in recent years cropping patterns. In this areas there introduced Boro rice in dry season which are cultivating through irrigation system. In flood plain areas there is a trace of increased Mango orchard areas.

In this area, a same piece of land is using repeatedly round the year. As a result chemical fertilizer and pesticide are also using repeatedly. Throughout the year, especially in dry season, practice of rice cultivation is increasing tremendously. Such a mono type cropping practice is not suitable for land and ecosystem, and enhance the chance of land degradation. After some extent due to mono type cropping practice, production rate may be deteriorated.

# *Chapter Thirteen*

## *Development of Remote Sensing Spectral Index SAWINES (Spatially Averaged Wetness Index of the Earth Surface) for Environmental Monitoring and Aridity Assessment and Its Application in the Study Sites*

## 13.1 Introduction

Arid and semi-arid regions constitute a significant portion of the total Earth's land areas where water deficiency is a common event that eventually constraints the production of crop and vegetation. Generally, such land surfaces exhibit high surface albedo, low soil moisture, relatively high temperature gradient between day and night with relatively low vegetation density as well as low bio-diversity of vegetation species. The spatial and temporal variability of aridity caused principally due to low rainfall, high surface runoff and low infiltration rates and that affects the overall land use development over a region.

The continuously increasing human population over many parts of the world exerts a pressure on food production that ultimately leads to the quest for increased agricultural lands. Such a demand necessarily involves the proper utilization of both arable and waste lands to profitable agricultural lands. Particularly, the high potentiality of arid and semi-arid areas should be fully exploited, that covers a large portion of the Earth's land surface.

Water is a basic component for sustaining life and has immense importance on the agricultural, meteorological and hydrological processes over an area. The availability and distribution of water over a given geographical region is a principal governing factor for agriculture production and in maintaining ecological balance. Particularly, in case of arid and semi-arid regions such problem is very much pronounced. The lack of up to date baseline information concerning the aquatic conditions over a region throughout the year is a fundamental problem associated with proper planning and sustainable development of agriculture. Proper management of water resources can drastically improve the agricultural potentiality over these regions. However, for such an efficient management, knowledge on nature and extent of aridity, and their seasonal variation is a prerequisite that can ensure the optimum use of available water resources in a efficient way.

Eventually an efficient technique is required to monitor the aridity over a region on a regular basis. Satellite remote sensing having the potentiality of observing the Earth's surface with an adequate spatial, temporal and spectral resolution, offers a dynamic scope to monitor the aridity over a region. The high spatial resolution satellite sensor like the Landsat TM, AVNIR etc. offers information at a scale of about few meters whereas relatively coarse resolution satellite sensor like NOAA AVHRR or ADEOS OCTS provides measurements at scales of about a few hundreds to a kilometer range. However, the principal scientific question that must be addressed in this context is how to assess the aridity over a given region using remote sensing technique. In general a low level of moisture availability with high surface albedo and low vegetation content characterizes the arid or semi-arid region. The remote sensing technique has the potentiality to monitor such components individually. But the problem that remains are how to integrate or combine them to provide idea about the aridity.

One of the major part of our study is to develop a simple technique to monitor the aridity of a given region using satellite remote sensing. This task necessarily involves (i) the identification and selection of criteria that ultimately determine the aridity; (ii) development of techniques to obtain each of these criteria using remote sensing (iii) development of a technique to combine all these criteria and finally (iv) evaluation of aridity of a given land areas.

## 13.2 Theoretical Consideration

Water and vegetation are the two basic components that mainly determine the aridity of a given region. Development of vegetation in a region is directly related to the availability of water. The amount of available water in the form of surface water, soil moisture and ground water plays a vital role in the determination of dryness of a region. Different physical processes are involved in determining the water balance condition over an area. The Earth's atmosphere form a closely coupled dynamic system where interaction between soil, vegetation and atmosphere (SVA) system takes place through the exchange of mass and energy. Water is distributed through the process of precipitation to the soil, where a portion of the water is infiltrated into the deep soil and a portion is evapotranspirated through vegetation to the atmosphere in the form of latent heat (energy). Thereby, the exchange of mass and energy takes place at the SVA interface.

The radiative transfer between the atmosphere and the Earth's biosphere is a process that essentially involves the transfer of solar energy as latent heat and mass as precipitation. Such energy exchanges are significantly influenced by the properties of the Earth's surface cover, soil properties, atmospheric condition etc. The destruction of vegetation cover often associates increase of soil erosion, increased surface runoff. In consequence, phenomenon like drought or other disaster becomes more frequent.

### 13.2.1 Potentiality of Satellite Remote Sensing

Remote sensing technique is used to observe and collect temporal and spatial data of targeted area. In remote sensing technique optical portion of electromagnetic spectrum is used to detect and sense earth's surface features and atmospheric components. Response and sensitivity of earth surface features and atmospheric components are not equal to all portion of optical spectrum. For Landsat TM visible and near-infrared region of the solar spectrum are sensitive to vegetation cover and its content. Measurements performed in the middle or thermal infrared region is sensitive to moisture content. The spectral characteristics of the three primary classes of the Earth's surface have been analyzed. Soil generally offers high surface reflectance in band 5 than that in band 4. With the variation of moisture content, spectral responses from such surface vary significantly. Specifically, relatively dry soil reflects more than that a relatively humid soil does.

## 13.3. Approach

### 13.3.1 Automatic Separation of Primary Classes

This step consists of separating the three basic components of earth surface such as soil, vegetation and water within the image area using satellite image. For separation major surface classes (soil, vegetation and water) here it is used band3, band4 and band5 data of Landsat TM images. In the calculation of NDVI model, it is seen that subtraction from NIR-VIS, gives positive values for vegetation and negative values for soil and water (Liping et.al. 1994). Vegetation area has been separated from soil and water area by subtracting band 4 from band 3, that resulted in a positive value for vegetation and negative value for soil and water. The next step involves the separation of soil from water areas. This is done by using threshold technique on positive values of band 5. Thereby, soil, vegetation and water areas have been separated automatically and the respective area occupied by each surface class has been calculated.

### 13.3.2 Vegetation Assessment

The contribution from the vegetation distributed over the study area has been estimated using the following equation

$$NDVI_A = \frac{1}{N_1}\sum_{i=1}^{N1} NDVI_i \qquad (1)$$

Here, $N_1$ is the total number of pixel belonging to vegetation class and $NDVI_A$ is the normalized difference vegetation index averaged over the total pixels belonging to vegetation class. The Normalized Difference Vegetation Index (NDVI) has been calculated using equation (5.2).

For natural vegetated surface, NDVI value varies between 0 and 1 depending mainly on the vegetation density. For high vegetation density, NDVI value is high and for low vegetation density, NDVI value is low.

### 13.3.3 Soil Moisture

The soil moisture effect has been estimated by using the following equation

$$SMI_A = \frac{1}{N_2}\sum_{i=1}^{N2}\left[1 - \frac{Band5 - Band7}{Band5 + Band7}\right]_i \qquad (2)$$

Here, $N_2$ is the number of pixels belonging to soil class. For a given surface, high moisture content results in high value of SMI and low moisture level results in small value of SMI. In general, SMI value varies between 0 and 1.

### 13.3.4 Water

The water area has been estimated from the classified image.

### 13.4. Determination of Aridity

Earth surface is a composition of three basic components (soil, vegetation and water), and degrees of composition of components may vary due to the spatial variation. In order to assess the aridity, the individual contribution of each component is considered. Then individual result of three components has been integrated according to the defined mathematical model and that define the level of ultimate aridity of a given region.

Considering the spectral properties of three primary components of the earth's surface, developed a function namely Spatially Averaged Wetness Index of the Earth's Surface

(SAWINES). According to this function, the aridity of a given region assessed by using the following equation-

$$SAWINES = \sigma_1 NDVI_T + \sigma_2 SMI_A + \sigma_3 \quad (3)$$

Where, $\sigma_1$, $\sigma_2$ and $\sigma_3$ are relative proportion of soil, vegetation and water respectively within the study area. The 1st term takes into the effect of vegetation over a given region, the 2nd term expresses the contribution from soil portion and particularly due to varying soil moisture and 3rd term for water bodies.

For a given surface, in the extreme condition, the whole surface covered by water, then $\sigma 1$ and $\sigma 2$ becomes zero and $\sigma 3$ become 1. In this condition SAWINES attains its maximum value 1. For a surface having 100 percent vegetation cover, the level of aridity will be determined only by the value of NDVI. Finally, for surface having solely bare soil, Soil Moisture Index (SMI) will determine the value of SAWINES. In any case values of SAWINES varies between 0 and 1. Generally, higher value of SAWINES indicates higher level of moisture content in soil and conversely, lower value indicates lower level of moisture content in soil which ultimately indicate the dryness of a region.

### 13.5. Results and Discussions

Status of Arid and semiarid land processes observation through satellite have opened a new era of research aiming towards proper and potential utilization of such technology. Various contextual methods have been developed to relate spatial variation of space based spectral measurements to individual surface processes or parameters (Dickinson et al. 1990, Rahman et al. 1993a, Rahman et al. 1993b) and such an approach enables one to detect and categorize subtle forms of information on the earth's surface condition. Spatially Averaged Wetness Index of the Earth's Surface (SAWINES) have developed considering the spectral properties of major three classes on earth's surface to assess the moisture level condition of an area. The aridity assessment algorithm SAWINES has been applied on our study area to study the moisture level dynamics due to spatial and temporal variation. The study area having two differing geo-biophysical zones (i) Barind Tract with homogeneously distributed spatial structure of the landscape, a predominantly semiarid land suffering from moisture deficit in dry season and (ii) the adjacent flood plane area with relatively heterogeneously distributed spatial structure of the landscape, a relatively moist land. Geo-biophysical processes and physiographical dynamics over the area regimes the level of aridity.

This mathematical model SAWINES studies degrees of landscape behavior. For this study five Landsat TM images of different years and periods varying on climatic variation have been selected. In figure (7.3a & 7.3b) there shown two Landsat TM images of study area for two different season. From this optical information it is seen that there are spatio-temporal variations over these areas. Level of aridity of individual upazila of the study area has been calculated using the developed aridity assessment algorithm, SAWINES and the result has shown in table 13.1. From this table it is seen that there is a spatio-temporal variation in dryness dynamics in two different geo-biophysical zones Barind Tract and flood plain area. Highest index values are seen in rainy season and lowest in dry season (summer season), and in Barind Tract areas index values are higher in rainy season and lower in dry season than flood plain area and moderate in winter season which is conformity with the developed index idea as well as moisture level variation. The result is also consistent with the variation of seasonal surface moisture dynamics. Surface found with low moisture content in dry season, high moisture content in rainy season and moderate moisture content in winter season. Winter season is the transition period of rainfall and as well as content of soil moisture level. For two extreme conditions values of SAWINES varies between 0 and 1, SAWINES attains its maximum value 1 for 100% water bodies and SAWINES attains its minimum value 0 for 100% dry bare soil.

Though Both Barind Tract and flood plain area are found saturated with moisture in rainy season but there is a variation in spatial surface cover dynamics due to the physiographic variation. And hence there is a variation in SWAINES values. Barind Tract demonstrates higher values of SAWINES then flood plain areas in rainy season.

In dry season overall values of SAWINES are lower then rainy season. And between two areas flood plain area shows higher values then Barind Tract areas. Here, it should be pointed out that soil moisture over the flood plain area remains almost to a satisfactory level throughout the year and thereby, supports crop cultivation in different places during dry season when cultivation is often constrained due to lack of required rainfall particularly in the Barind area.

Echo system dynamics of Barind Tract is dependent on annual rainfall amount and other natural calamities. With the seasonal climatic change, the change in SAWINES dynamics is maximum in Barind Tract area. In summer this semi-arid area shows minimum index value and in rainy season shows maximum index value. And the change in SAWINES values for flood plain area is moderate. With varying seasonal dynamics Barind Tract has a remarkable change in spatial structure dynamics.

In rainy season and in winter season variations in index value among different upazilas are insignificant. But in summer remarkable variations have been observed in index values between Barind Tract and flood plain areas. In summer dry surface, in rainy season vegetation activities and water bodies, and in winter mainly moist soil and partly water bodies, dominate the values of SAWINES index respectively. In rainy season there is no significant variation in soil moisture level between two areas but there is variation in surface cover. An increase of about 68 percent (from 8 percent to 76 percent) vegetation activities is noticed in the Barind Tract areas in the wet season with respect to dry season. Whereas, in flood plain areas, only about 8 percent (from 36 percent to 44 percent) increase of vegetation activities is observed. With the change of higher percentage of surface cover the change of SAWINES values is also higher in Barind Tract area and in flood plain area change of surface cover is lower as well as change of SAWINES values is also lower. SAWINES value found higher in rainy season through the whole study area. In Barind Tract area, due to the seasonal activities change SAWINES value increases about 98 to 168 percent in rainy season with respect to the dry season SAWINES values. As a whole, SAWINES value seems to be the indicator of surface type as well as moisture content of an area. Climatic variable particularly the precipitation and flooding in flood plain area appears to be the main driving force of moisture content that brings out the dynamic changes of surface cover as well as SAWINES values over the area. Crop Moisture Index (CMI) and the Palmer Drought Severity Index (PSDI) was highly correlated with the regional soil moisture derived from remote sensing data (Liping et al. 1994).

Table 13.1: Results of 'Spatially Averaged Wetness Index (SAWINES)' tested on different small units (upazilas) of study area for different periods of climatic variation.

| Upazilas | Summer 11.04.90 | Rainy 20.10.90 | Winter 30.01.90 | Winter 05.02.98 |
|---|---|---|---|---|
| Bholahat | 0.42 | 0.73 | - | - |
| Shibganj | 0.43 | 0.57 | - | - |
| Nawabganj | 0.46 | 0.65 | - | - |
| Niamatpur | 0.29 | 0.79 | 0.46 | 0.55 |
| Gomastapur | 0.39 | 0.78 | 0.57 | - |
| Nachol | 0.31 | 0.81 | 0.48 | 0.56 |
| Tanor | 0.33 | 0.81 | 0.48 | 0.56 |
| Godagari | 0.38 | 0.78 | 0.48 | 0.61 |

-Area missing in images

In summer, out of five upazilas of Barind Tract two upazila (Gomastapur and Godagari) shows comparatively high index value. Areas of water body percentage of these two upazilas are comparatively higher than other Barind Tract areas. The western side i.e., the major portion of Gomastapur are characterizes by mixed Ganges and Mahananda meander floodplain and Old floodplain basin, and the eastern side of Gomastapur are characterizes by Barind formation like broadly dissected and closed dissected terrace. And Godagari is adjacent to the Ganges river, and there are some water bodies at northern and southern side. Acute dry area Nachol, Niamatpur and Tanor show lower index value.

In summer 1990, Niamatpur shows lowest index value and Nachol shows second lowest value. This means that Niamatpur is the most dry area and then Nachol. At Niamatpur percentage of soil area is highest and percentage of vegetation area and water area are lowest. Flood plain area Nawabganj shows highest index value i.e., this is the maximum moist area. Here percentages of soil area and vegetation area are moderate but percentage of water area is highest. And due to this highest proportionality of water bodies this area shows highest index value. And this statistics proves the potentiality of developed Spatially Averaged Wetness Index (SAWINES) to monitor the earth's surface aridity.

In rainy season Barind Tract shows higher SAWINES index value then flood plain area. Here grows huge aman in this season and aman crops are mainly rain feed. So there are minimum spatial variations in cropping areas over Barid Tract areas in rainy season. And degrees of moisture content over this area in rainy season are almost same. In rainy season two flood plain area Shibganj and Nawabganj shows lower index value but index value at Nawabganj is comparatively higher. Percentage of soil and water area of Nawabganj is almost double than percentage of soil and water area of Shibganj but percentage of vegetation area is higher in Shibganj. On the basis of soil area index value would be lower in Nwabganj, but index value is higher. This finding shows the domination of moisture level on aridity.

Index value of two upazilas of Barind Tract Nachol and Tanor are same in all the cases except in summer 1990. In summer 1990 there is a minor difference between two index values of Nachol and Tanor, and there are no particular causes to demonstration the same SAWINES value. The SAWINES values are fixes up by different proportions of area percentage and properties of soil, vegetation and water. An effective agricultural drought index will have a high degree of spatial variability for a combination of soil water status and land use (Jupp et al. 1998). Effects of spatial variation due to the seasonal climatic variation are seen in SAWINES index values.

### 13.5.1 SAWINES in Respect of Albedo

For dry surface Barind Tract, albedo shows higher value and dryness index shows lower value i.e., dryness index and albedo are inversely related, i.e., for higher value of surface albedo means dry surface and for higher value of dryness index means moist surface. In semi-arid areas, where plant life is almost totally dependent on seasonal rainfall the albedo rainfall relationship most pronounced (Norton et al. 1979), the higher albedo generally associated with low precipitation and vice-versa. The mean zonal albedo has been extracted using GIS analysis to compare with the zonal dryness index value. In April 11, 1990 among different upazilas of Barind Tract Niamatpur shows lowest index value and highest albedo and Godagari shows highest index value and lowest albedo. But Nachol and Tanor shows different index value for the same albedo. Index value at Nachol is lower than the index value at Tanor i.e., Nachol is more dry than Tanor. Area proportion of soil at Nachol is higher than Tanor and this is the cause of lower value of dryness index at Nachol. In addition this, soil proportion in Niamatpur is highest and lowest in Godagari. And from this statistics it can say in dry season and in dry areas, index value is dominating by dry soil areas.

In dry season (April 11, 1990) among flood plain areas, Bholahat shows lowest index as well as lowest albedo and Nawabganj shows just reverse i.e., highest index and highest albedo. Area proportion of water in Nawabganj is higher than Bholahat. Proportion of soil area in Nawabganj is also higher.

With the seasonal change surface cover changes but change of surface cover are not identical in all areas. Surface cover of Barind Tract is most sensitive to climatic behavior change. Here grows huge aman in rainy season and in this time cropping areas are found with underlying water or heavy moist soil (like muddy). In rainy season whole area shows lower albedo and higher SAWINES value. In comparison with flood plain, Barind Tract shows higher dryness index value in rainy season. Among Barind Tract areas Niamatpur, Gomastapur and Godagari show lowest dryness index value and highest albedo and Nachol shows highest dryness index and lowest albedo. But Nachol and Tanor shows same index value and different albedo and albedo is little bit higher in Tanor (at Tanor 12.62 and at Nachol 12.16). At Nachol in comparison with Tanor percentage of soil and water area are higher but percentage of vegetation area is lower. Lower proportion of soil area and higher proportion of vegetation area of Tanor are the causes of higher dryness index value at Tanor.

Among flood plain areas in rainy season Nawabganj shows different nature in index values with respect to spatial distribution of individual major class. This area shows moderate dryness index and highest albedo. Here, vegetation area lowest, and water and soil area highest. Highest proportion of water area is the cause to show high dryness index value at Nawabganj. Albedo in Nawabganj is highest in rainy season and that is 14.2.

## Chapter Thirteen Conclusion:

In this chapter, a model "Spatially Averaged Wetness Index of the Earth Surface (SAWINES)" has been introduced to study and monitor the moisture level variation as well the level of dryness of any geographic area using remote sensing data. In this new model, it is considered the involvement of all major surface types according to their occupied proportional areas. Proportionality of three major surface classes (soil, vegetation and water) dominate the surface condition, such as, major portion of soil in any given area increases the surface dryness, major portion of water area increases the surface moisture level and increase of vegetation area indicates the moderate surface condition. Weighting factor for soil is 0.01 and for vegetation is 2 has given to make the model most sensitive to moisture level. The SAWINES is a automatic aridity assessment model and the fixation of range from 0 to 1 made the model most sensitive to the minimum variation of moisture level. Here it means, lower values of SAWINES indicate the higher level of aridity of a region and vice versa.

This newly developed model "Spatially Averaged Wetness Index of the Earth's Surface (SAWINES)" has been applied individually on eight small administrative units (8 upazilas) of study area for multi dated images, which demonstrates a good sensitivity to earth's surface moisture content variation due to various geographical as well as seasonal climatic variation. From the result it is seen that for any geographic area due to seasonal climatic variation SAWINES model shows different values. Lower value shows for dry season and higher value shows for rainy season. In this area rainy season is highly enriched with heavy rainfall which helps to maintain maximum moisture level. In dry season, areas under Barind Tract show lower SWAINES index values then the areas under flood alluvial plane land. Variation in results due to the seasonal and geographical variation has established the potentiality of SAWINES model to represent the overall dryness condition of any geographical region.

# Chapter Fourteen
## Conclusions

# Conclusions

Land surface processes have become a great concern in the context of global change and increased natural hazards the world over. The ever expanding human population exerts increasingly high pressure on the available land and its natural resources. Very often these lands and the natural resources therein are exploited for various urban, agricultural and industrial purposes in such a manner that causes significant damage and degradation to the whole ecosystem. Moreover, during the last few decades, extensive efforts have been made in agriculture sector for multiplying the crop production to meet up the increased food demand over the world. And a significant progress has already been achieved through intensification of agricultural activities round the year using chemical fertilizer, pesticides, improved crop varieties, and irrigation (through using surface and ground water etc.). All the foregoing issues have specific impacts or consequences on the hydrological and environmental condition of an area and often associate certain problems to the whole ecosystem that put the sustainability of the whole operation in question. Eventually, remedy and mitigation of such problems require a good understanding of the involved processes. This ensures efficient handling of the whole system in a sustainable manner.

This research work mainly addresses the issues related to the application of remote sensing and GIS for major environmental aspects of hydro-environmental activities with special reference to Barind Tract and it's adjacent flood alluvial plane land, Northwestern part of Bangladesh. This research work contributed significantly towards understanding the hydro-environmental processes of the area and the on-going degradation therein. And to serve those purposes here introduced a multidisciplinary approach.

Here used remote sensing data due to it's properties like spatially continuous, repeated observation, large area coverage, easy access to any part of the globe and possibility of observation under all weather condition. And for preservation, analysis and archival of large volume, wide spectrum spatial data here used Geographic Information System (GIS). The present work is the successive integration of Geophysical information, remote sensing and GIS technology for hydro-environmental study.

Here an effort has been made to study the potentiality of remote sensing data for the present research work. Surface related information, it's variation due to temporal and spatial variation has been retrieved from remote sensing data. For proper and accurate interpretation of such data it needs proper understanding of spectral behaviour of different earth's surface features and its variation due to spatial, temporal, spectral, and directional variability. Information of maximum individual surface features has extracted through point data collection system. And the corresponding changes of the same pixel area (as selected for dry season) due to the seasonally varying meteorological condition has also been studied. For understanding the landscape and its seasonal dynamics due to seasonal variation, different surface profiles were drawn and information has extracted from the intersecting areas. Landsat TM derived spectral response shows characteristically different behaviour pattern for the flood plain and semi-arid areas and thereby, indicates the potentiality of the remote sensing data. The sensitivity of vegetation activities response to precipitation amount is significantly higher in the Barind Tract area in comparison to flood plain areas. Barind Tract area is found to be either bare or mostly vegetated depending on seasonal climatic condition. Except river side sandy areas, soil at Barind Tract shows higher response in dry season. In dry season response over crops, sparse vegetation and permanent vegetation areas is higher then the response in rainy season due to the turbulently domination of background. With the aid of spectral response remote sensing data can be used for crop health monitoring. For any meteorological condition and geographical areas in healthy cropping areas the result of |Band4-Band5| shows higher values.

Changes of river coarse, channels, and presence and absence of seasonal water bodies can also be identified with the remote sensing data. In rainy season main stream and channels gets wider due to charging from flood and rain water. For water body higher value at band4 indicates the higher sediment concentration and this idea can be used for sediment monitoring. It is also possible to identify the level of sediment concentration. Remote sensing data has been use to calculate and analysis thermal behavious, albedo, land use and land cover changes, NDVI, RVI, SRL, drainage pattern, cropping pattern and SWAINESS index.

Using thermal data of Landsat TM image, surface temperature of study area are has been calculated for different seasons. Surface temperature of Barind Tract is most sensitive which has clear conformity with the surface cover change due to the seasonal climatic variation. In dry season except river side dry sand, bare soil of Barind Tract area shows highest surface temperature. In both dry and rainy season the spatial variation of surface temperature is minimum over Barind Tract areas, which is due to the homogeneous distribution of surface cover. And the variation over flood plain area is maximum due to the heterogeneous distribution of surface cover. In rainy season both the areas shows almost same temperature and that is with in the range of narrow width (22° C to 24° C).

Temperature over cropping areas there is no variation due to the geographical variation for a particular season. Though cropping intensities are different but crop varieties and cropping systems are same in both the areas for both the season. Over permanent vegetation areas there is a variation of surface temperature due to the seasonal climatic variation. In dry season permanent vegetated area shows higher temperature. In rainy season due to the sufficient soil moisture and rainfall plants growth, numbers of new leaf and increased water content within the leaf lowers the surface temperature. The diagram in figure 7.6 demonstrates the mechanism of thermal shielding of vegetation cover. With the increase of ratio vegetation index (RVI) the surface temperature decreases and after some extent surface temperature shows constant value for the increase of RVI value.

Surface albedo is the indication of process of mass and energy exchange at SVA (Soil-Vegetation-Atmosphere) interface. There is a distinct variation in surface albedo due to the physiographic variation. In summer Barind Tract area shows high surface albedo. Degrees of moisture level play a dominating role in controlling the surface albedo. Over the area soil moisture varies due to the rainfall and flood water. Soil moisture plays multiple role which control the dynamic activities of surface albedo. Absorption of solar radiation increases due to the increase of soil moisture which in turn reduces the surface albedo. And vegetation cover changes due to the moisture level variation which also introduces the variation in the surface albedo. In addition local geology and landform has a clear domination over land cover variation which also introduces the variation in surface albedo.

The normalized value ($a_{SD}/a_{MEAN}$) of standard deviation ($a_{SD}$) and mean value ($a_{MEAN}$) of surface albedo along a profile is the indication of surface cover variation. Generally, higher value of $a_{SD}/a_{MEAN}$ means higher spatial heterogeneity. For the ideal case i.e., for a cent percent homogeneous surface $a_{SD}/a_{MEAN}$ approaches to zero. Barind Tract area is relatively homogeneous in both summer and winter, and the value of $a_{SD}/a_{MEAN}$ is relatively lower in both the season. Most of the Barind Tract area is found bare or vegetated due to the seasonal variation. In flood plain areas the spatial and temporal variation of surface cover rises up the $a_{SD}/a_{MEAN}$ value in both the season.

In contrasted geo-environment of Barind Tract and flood plain areas there is a variation in the mechanism of driving forces of hydro-environment. The level of flooding in the flood plain areas in wet season and soil moisture level in Barind Tract area in the dry season appear to be the two important driving forces that governing hydro-environmental and land use pattern over the area. Both Barind Tract and flood alluvial plain land enjoy the same facilities provided by nature like rainfall, sunlight etc. except flooding. Flood alluvial plain land flooded annually and renews surface water bodies. Where as Barind Tract never flooded, here rainfall is the only source of surface, subsurface and even drainage water. In this region maximum temperature, minimum rainfall and minimum humidity observed in dry season i.e., in summer and moderate temperature, maximum rainfall and maximum humidity observed in rainy season. And minimum temperature with minimum rainfall and moderate humidity characterizes the winter season. In comparison with the rainfall pattern of two different periods one is 1962 or 1963 to 1988 and another is 1989 to 1995, it is seen that in recent years there is a change in rainfall pattern and the change is common for both the Barind Tract and flood alluvial plain land. Rainfall patterns of recent years have dual peaks on both side of August. There is also a change in temperature gradient of recent years. Gradual increase of temperature extremity is observed from 1964 to 1988. But in recent years from 1989 to 1998 gradual decrease in temperature extremity is observed. And this change of temperature gradient may be due to the increase of vegetation activities and this is till under study.

Drainage network is a system of fluid flow integrated with the surface and sub-surface flow, which is directly engaged with the mechanism of hydro-environmental activities as well as mass and energy distribution of an area. In Barind Tract area surface and sub-surface run-off is directly concern with the rainfall amount. In this region maximum rainfall above 80% observes in rainy season from June to September i.e. within the four months. Hence the rate of precipitation is high in this region. Underlying surface, elevation, rainfall and soil type influences the drainage pattern and density (King 1984). But all over the Barind Tract landform and land use patterns are same with the climatic variable of same intensity. So it seems slope angle in associated with the underlying thick clay layer (8m to 24m), elevated topography and high rate precipitation is playing major role in controlling the drainage pattern as well as drainage density. Smart passage of runoff, underlying clay loam with low infiltration rate (0 to 4mm/hr.), high rate precipitation and sloppy surface helps for expeditious and heavy runoff, and slows down the infiltration rate.

Another mechanism of mass and energy interaction is surface roughness length (SRL). SRL varies in this region due to the variation of the seasonal vegetation activities. In Barind Tract SRL varies due to the variation of surface cover change which varies due to the seasonal climatic variation. During the heavy rainfall months here grows huge rain fed aman crops and shows highest SRL value and higher SRL helps surface to enhance the infiltration time. Highest SRL slows down the surface runoff and allows surface much time for infiltration, and protects underlying surface from heavy soil erosion.

In recent couple of decades there introduced dry season cropping through irrigation. In irrigation system using mainly ground water in associated with the partial support of surface water. So baseline information about groundwater is necessary for planning sustainable agricultural development and ecological balance. In comparison with flood plain areas the ground water storage of Barind Tract is comparatively thin and followed by a thick clay layer of low permeability over it. In associated with the poor storage capacity the charging rate is also poor due to the sloppy surface with thick clay layer of low permeability. Another quantifier of storage quality is transmissivity, which defines the economically viable exploitable amount of ground water. The transmissivity condition is suitable in Barind Tract area which conflicts with all other quantifier of ground water storage. Due to the uneven exploitation probably for irrigation purposes, the ground water level is gradually declining at Barind Tract region. Thick storage capacity with thin flat surface having good permeability along with good transmissivity enriched the aquifer of flood alluvial plane land. And ground water storage at flood plain area is suitable for ground water extraction.

In both Barind tract and flood plain areas, water level declines during dry season and increase during wet period, which is in conformity with rainfall characteristics. Response of ground water table to rainfall amount is not identical all over the study area. In both the season ground water level over Barind Tract has clear dependency on rainfall amount. In this region rainfall is the only source of surface as well as subsurface water. But in flood plain areas ground water level has dependency on rainfall amount in rainy season and minimum dependency in dry season. In rainy season ground water reservoir charges from precipitation and flood water. In flood plain areas there seen some larger surface water bodies and low lands. In dry season ground water reservoir gets maximum supports from these surface water bodies and hence shows minimum dependency on rainfall amount.

In socio-econonical aspect, study the land use and land cover change is important for an area. In both the region total population is increasing and per capita land is decreasing. So for the support of increased food demand and due to the technological development there introduced dry season cropping through irrigation system. From the land use pattern of two different periods 1968 and 1990 it is seen that there are changes in land type and land use patterns. Land type changes are observed only in flood alluvial plain areas and that is due to the river course change and erosion. In study area, land use pattern has changed due to the land type change and introducing dry season cropping. About cropping pattern of Barind Tract and flood alluvial plane land and 1968 & 1990 In flood plain areas there is also a trace of increased Mango orchard areas.

Over the whole study area the cropping pattern is such that here same piece of land is using repeatedly round the year. As a result chemical fertilizer and pesticides are also using repeatedly. In associated with the repeated use, here using land for the same type of crop specially rice and it's use is increasing tremendously. Such a practice may be the cause of land degradation and production rate deterioration. And also may be the cause of degradation to the whole ecosystem.

The development of a remote sensing based spectral model "Spatially Averaged Wetness Index of the Earth Surface (SAWINES)" is useable in a GIS environment for the automatic evaluation of aridity of a given geographic area using Landsat TM satellite image. This type of model is suitable for monitoring the level of aridity of an area. In this model it is considered the contribution of all major surfaces types (soil, vegetation and water) on the basis of their occupied area proportion. The fixation of range from 0 to 1, made this quantitative model SAWINES most sensitive to the minor change of moisture level. Generally, lower values of SAWINES indicate higher level aridity of an area and vice versa.

The newly developed dryness index model has applied on small individual units (Upazila) of study area for different seasons. From the result it is seen that for any area, the value in dry season is lower then the value in rainy season. And for geographical variation in dry season it is seen that areas (upzilas) under Barind Tract shows lower value then the areas under flood alluvial plane land. Due to the seasonal and geographical variation both the results have good conformity with the basic concepts of the model SAWINES. From the result it is found that, the index is sensitive to the moisture content and is capable to monitor the wetness of a region. From the analysis of index result it is found that the domination of soil area increases the dryness, the domination of water area increases the moisture level and the domination of vegetation areas indicates moderate surface condition.

In this research work remote sensing, GIS, geophysical, climatic and other ancillary data have been effectively integrated to analyze and monitor the hydro-environmental condition over the flood plain and semi-arid Barind Tract areas. The study reveals that such an integration of multiple technology provides an effective means to find out driving forces of a geographic area related with the hydro-environment and monitoring such processes.

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