# Technical Report

## Integrated Mission for Creation of Scientific and Comprehensive Soil & Land Resources Information System for Effective Implementation of Comprehensive Agriculture Management Program (CAMP)

### Cluster-2, Mawthadraishan & Mawkyrwat Blocks,

### West Khasi Hills & South West Khasi Hills Districts

November, 2019

*Prepared for*

**Directorate of Agriculture**

Government of Meghalaya
Cleve Colony,
SHILLONG – 793003

*Prepared by*

**REMOTE SENSING INSTRUMENTS**

*(An ISO 9001:2015 Company)*

Plot#7,Type-I, Industrial Estate, Kukatpally,
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# EXECUTIVE SUMMARY

Successful agriculture depends on technology in various stages of land and water resources management, that maximize the input use efficiency for getting higher yields and also to protect the scarce and precious land resource base. In order to achieve this and also for sustainable development in all sectors of agriculture in the state, this project has been initiated by Directorate of Agriculture, Govt. of Meghalaya at 1:10,000 scale using Remote Sensing and GIS technology.

Meghalaya state is divided broadly into 3 regions such as Jaintia Hills, Khasi Hills and Garo Hills. So, three clusters have been selected for the present study to represent each region. Each cluster occupies an area of 25,000 Ha, totaling to an area of 75,000 Ha. Among these three clusters, Cluster-2 under discussion is located in Mawthadraishan and Mawkyrwat blocks of West Khasi Hills and South West Khasi Hills Districts

For the present study, latest multispectral Deimos-2 foreign satellite data with very high resolution of 75cm, Cartosat-1 and Resouresat-2 data have been procured. Differential Global Positioning System (DGPS) control network has been established and Ground Control Points (GCPs) have been collected. With the help of the co-ordinates of the GCP's, all the satellite data procured have been geo-referenced and 10k grid has been generated.

Digital Elevation Model (DEM) has been generated using the geo-referenced Cartosat-1 data. Later on contours of 5m interval have been generated from DEM using photogrammetric techniques. Base Map has been prepared by using Remote Sensing and GIS techniques with administrative boundaries, contours, transport network, settlements, drainage system which is useful for local reference purpose.

Different thematic maps, namely land use/land cover, hydro geomorphology and soil have been prepared by visual interpretation of Deimos-2 satellite data and ground truth. Slope map has been prepared by using contours. Availability of limited land for agriculture and irrigation is noticed as it is a hilly terrain with moderate to steep slopes and covered with moderately dense to dense forest. So, paddy is mostly cultivated in valleys. Potato is grown on raised beds. Maize and Squash are observed in the uplands with gentle slopes. Occurrence of underutilized lands like grazing lands, scrub forest and fallow lands are also noticed.

Soil profile points have been dug and soil samples have been collected at different depths for analysis. The soil samples have been analyzed for different soil parameters like pH, EC, Organic Carbon, CEC, base saturation and for available major and micro nutrients such as Nitrogen, Phosporus, Potassium, Sulphur, Boron, Copper, Zinc, Iron, Manganese and Molybdenum. Mechanical analysis of the soil samples has also been carried out. The results indicate that the soils are moderately acidic to strongly and very strongly acidic. From the analysis of surface soil samples, it has been observed that the major deficiencies are in nitrogen, molybdenum, boron, sulphur and phosphorus. However, iron, copper, zinc, potassium and manganese are sufficient in most of the surface soil samples.

Derivative maps like land degradation, land capability, land irrigability and crop suitability have been prepared based on the soil map and analysis data. Soil erosion and soil acidity are the major land degradation problems in this area. Crop suitability analysis has been carried for prominent crops grown in this area namely, rainfed bunded rice, maize, sweet potato, banana, citrus, turmeric, ginger, potato, millets, tobacco, pine apple, soybean, areca nut and black pepper based on the topography, soil and environmental factors. The study area has been classified into highly/moderately/marginally suitable and currently/permanently not suitable classes for these crops.

Action plan for land resources development has been suggested by considering problems and potentials of soils, slope, existing land use, soil erosion, nutrient deficiencies, and soil acidity problems. The action plan suggested include various land and water resource development programmes like soil and water conservation measures, liming to increase the pH and to decrease the soil acidity for improving nutrient availability and application of deficient nutrients. The deficient nutrients can be applied in the form of organic manures in combination with inorganic fertilizers due to various reasons for having sustainable crop production.

Web based user friendly Soil and Land Resources Information System has been developed in GIS for usage of the data prepared in this study. The data can be retrieved by the farmers with reference to the grid information available in their soil health cards.

# CONTENTS

# CHAPTER - 1

## BACKGROUND

Successful agriculture depends on technology in various stages of land and water resources management, that maximize the input use efficiency, not only to meet the goal of stabilized & higher yields but also to protect the scarce & precious land resource base, so that inter-generational equity is attained. In order to achieve this and sustainable development in all sectors of agriculture in the state, it is necessary to analyze & evaluate production constraints. These constraints and indicators of current lower yields and also the suitable technologies needed to maximize production are to be addressed specifically. The scientific agriculture management in the state is possible by holistic approach and program planned on very reliable data-bases.

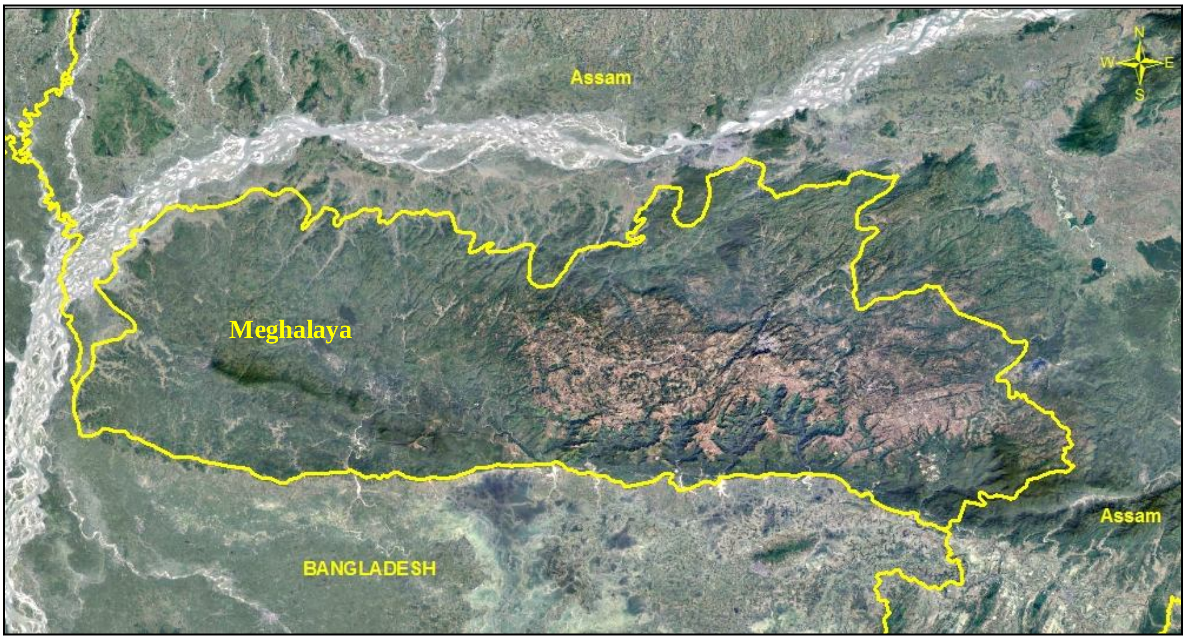



**Figure - 1: Meghalaya State**

In addition to these, some of the goals of Department of Agriculture, Govt. of Meghalaya are

- Attaining Food Security and Sustainable Growth by increasing production of food grains and improving productivity.

- Augment Farmer's Income through growing of suitable horticultural crops.
- Promote Commercial Agriculture through low volume high value crops.

In the above scenario, agricultural reforms have become the need of the hour to achieve the goals through utilization of new technologies like Agricultural Planning and Information Bank (APIB). APIB initiated in 1998, is one of the programmes suggested by planners, nurtured by technologies and implemented by farmers. It is multipronged approach to develop different databases, which contain information on both spatial and non-spatial parameters. The linkages between non-spatial and spatial databases will be facilitated through Geographical Information System (GIS). The Decision support system (DSS) which will emerge by the project will provide a framework for integrating database management systems, analytical models and graphics in order to improve the decision making process at farmers level.

In view of the above, Govt. of Meghalaya**,** desired to formulate the mega-scientific initiative to address the un-sustainability in all aspects of Agriculture and to develop very reliable data sets, which will be made available to all farmers in the state for their informed decision making.

# CHAPTER - 2

# INTRODUCTION

The growing population needs food, clothing, shelter, fuel and fodder for their livestock. In Meghalaya around 80% of the people live in rural areas but they neither have adequate land holdings nor alternate service opportunities to posses the above. In the absence of adequate employment opportunities, the rural people are unable to generate enough income to sustain their livelihood. Apart from lower income, rural people are also suffering from shortage of clean drinking water, poor health care and illiteracy, which adversely affect the quality of life.

In the absence of employment opportunities in industrial and service sectors, the rural income is generated from agriculture and the rural people who spend most of their earnings on food. Agriculture is the major source of livelihood but most of the farmers, particularly in the absence of assured source of water and external inputs, have not been successful in cultivating their land profitably. They have been treating agriculture as a family tradition, following age old practices and have adopted new changes only after observing the success of their neighbours. As the chances of crop failures on these lands are very high due to floods and drought, the farmers generally do not invest in external inputs like improved seeds, fertilisers and plant protection measures and end up with poor crop yields, even during normal years.

Meghalaya Plateau is one of the very few areas in the world having extremely high rainfall, which is the main source for agricultural production. However, due to deforestation and in the absence of adequate soil and water conservation measures, most of the rainwater runs off causing severe soil erosion and flooding the rivers. Due to high rainfall associated with high organic matter in the soils, they are becoming highly acidic which is not a favourable condition for many of the agricultural crops resulting in low yields. Therefore, proper characterization of these soils is important for their improvement and increasing crop production.

Forests have been providing many direct and indirect benefits to rural communities. In Meghalaya, only about 8% land is under the Forest Department and the remaining areas under forests are the community and private forests. These forest areas are subjected to the primitive agricultural practices of Jhum cultivation. As a result, the rural people, who are dependent on forest products for livelihood are being threatened. The ill effects of deforestation are evident in the form of shortage of fodder, fuel, timber, non-wood forest products and medicinal herbs. The indirect losses in the form of soil erosion, deepening of ground water table and reduction in green cover are far more serious. Deforestation has been directly suppressing agricultural production due to soil erosion which is yet to be realised by a major section of the rural society.

In spite of land scarcity, about 15 to 20% of the total area is either idle or under-utilised in Meghalaya. Such wastelands, unable to retain the rainwater, are promoting soil erosion, and flooding of rivers. Proper management of these wastelands by studying their inherent problems and potentials will improve their productivity, facilitate the percolation of rainwater and improve agricultural production.

Poor productivity of the land and livestock, and inefficient use of forests are the causes of seasonal employment in villages. Small farmers have work for only 3-4 months and grow only one crop in a year, which is not adequate to sustain their livelihood. Most of the grazing lands present in the area can be used for live stock production profitably with proper management.

In view of this, a project entitled **"Integrated Mission for Creation of Scientific and Comprehensive Soil & Land Resources Information System for Effective Implementation of Comprehensive Agriculture Management Program (CAMP)"** at 1:10,000 scale using Remote Sensing and GIS technology has been initiated by Directorate of Agriculture, Govt. of Meghalaya.

# CHAPTER-3

# STUDY AREA

Meghalaya state is divided broadly into 3 regions such as Jaintia Hills, Khasi Hills and Garo Hills. So, three clusters have been selected for the present study, to represent each region. Each cluster occupies an area of 25,000 Ha, totaling to an area of 75,000 Ha. Cluster-1 is located in West Jaintia Hills District, Cluster-2 is located in West Khasi Hills and South West Khasi Hills Districts and Cluster-3 is located in West Garo Hills District.

Among these three clusters, Cluster-2 is located in Mawthadraishan and Mawkyrwat blocks of West Khasi Hills and South West Khasi Hills Districts as shown in the Figure-2.

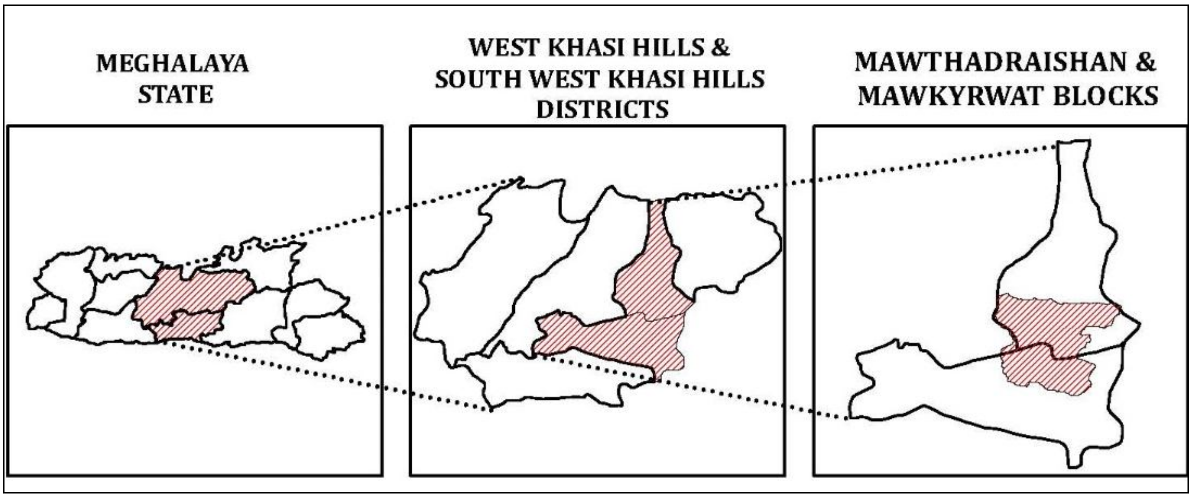



**Figure-2: Location Map of Cluster-2**

# CHAPTER-4

## SCOPE OF WORK

The scope of work for the present study is procurement of high resolution foreign satellite data namely Deimos-2, procurement of IRS satellite data namely Cartosat-1 Stereo data and Resourcesat-2 LISS-IV MX data. Establishing the DGPS control network and rectification of procured satellite data using Ground Control Points (GCPs). Preparation of base map, agriculture and other land use / land cover (ALULC) map, slope map, hydro-geomorphology map, soil map, land degradation map, land capability map, land irrigability map, action plan map for land and water resources development and crop suitability map on 1:10,000 scale, generation of hard copies for all these maps and creation and installation of web based user friendly "Soil and Land and Resources Information System".

# CHAPTER-5

# METHODOLOGY / TECHNOLOGY USED

## 5.1. Introduction:

Conventional ground-based surveys are time consuming, and expensive. Using of geospatial technologies is a proven approach for survey and preparing the digital database on time and cost effective mode. Hence, Integrated Mission for Creation of Scientific and Comprehensive Soil & Land Resources Information System for Effective Implementation of Comprehensive Agriculture Management Program (CAMP) has been carried out by using advanced state-of-the-art geospatial technologies involving Remote Sensing, GIS, Photogrammetry and GPS technologies etc.

## 5.2. Geospatial Technology:

Geospatial technology is also known as Geomatics. It is the discipline of gathering, storing, processing, and delivering geographic information, or spatially referenced information. In other words it consists of products, services and tools involved in the collection, integration and management of geographic data. GIS and Remote Sensing are major parts of the geospatial technology. Geospatial technology includes the tools and techniques, namely Remote Sensing, Cartography, Geographic Information Systems (GIS), Global Navigation Satellite Systems (GPS, GLONASS, Galileo, Compass), Land Surveying, Photogrammetry and Geography and related forms of earth mapping.

## 5.3. Remote Sensing (RS):

Remote Sensing is the Science and Art of obtaining information about an object, area, or phenomenon through the analysis of data acquired by a device that is not being in contact with the object, area, or phenomenon under the investigation. But simply we can say that "Collection of information about an object without actually being in contact with

**Figure-3: Remote Sensing Satellite**

it" as Remote Sensing. Remote Sensing is one of the techniques of geomatics. In Remote Sensing, object information will be obtained from Satellite Images and Remote sensing satellites will provide them. These Satellite images provide a synoptic view of a large part of earth surface in near real time. They depict accurate picture of earth surface and there is no need to work in the field as in the conventional method.

In the present study of Integrated Mission for Creation of Scientific and Comprehensive Soil & Land Resources Information System for Effective Implementation of Comprehensive Agriculture Management Program (CAMP), high resolution satellite data has been used.

**Image Interpretation:** Image interpretation is defined as the act of examining images for identifying objects and judging their significance. It will be carried out by either visual interpretation techniques or digital interpretation techniques. In this project the mapping has been carried out by visual interpretation.

**Visual Interpretation:** In the visual interpretation, interpreters study remotely sensed data by the elements of Image Interpretation and attempt through logical processes in detecting, recognizing and identifying, analysing, classifying, measuring and evaluating the significances of physical and cultural objects, their patterns and special relationship.

The elements of image interpretation are as follows

a) **Color:** Color is an important factor in classification of broad themes like blue for water, red for vegetation, white for snow, clouds and sand, black for deep water etc.

**b)** **Tone**: Tone within a color will give further differentiation among features like dark red for thick vegetation/dense forest, bright red for agriculture, dark blue for deep water, light blue for shallow water etc.

c) **Texture**: Different textures will give finer class like smooth light red for agriculture, coarse red for scrub, smooth white for clouds, course white for exposed sand etc.

d) **Shape**: With shape, one can differentiate man made tanks with natural tanks Agricultural lands with scrub forest, parks and grounds with wastelands, roads with rivers.

e) **Size:** Size will also differentiate specific features like villages with towns/cities, and ponds with reservoirs.

f) **Pattern**: Pattern will give information about features as in the case of clouds, waves in sea etc.

g) **Association**: Shades of clouds can be distinguished from dark tones with the help of its association with clouds, like wise streams can be identified with its association of valleys and tanks etc.

h) **Shadow:** They are cast due to Sun's illumination angle, size and shape of the object or sensor-viewing angle. The shape and profile of shadows help in identifying different surface objects like clouds, hill slopes etc. They also help in arriving at tree heights or building heights on aerial photos.

i) **Location:** The geographical site and location of the object often provide clue for identifying objects and understanding their genesis.

The advantages of visual interpretation are:

a) As it is done with human knowledge, differentiation of physical themes like roads, rivers, tones, clouds, and shades is better delineated.

b) Generalization is possible for quantification, which will give polygons of minimum mapping quality.

Visual interpretation will be usually carried out on hard copy by using light table. Now a day it is being done on-screen. In this project the mapping of base details and different thematic layers has been carried out by onscreen visual interpretation in Arc GIS environment by using the satellite images.

**Ground Truth/Field Work:** Ground truth in remote sensing based study is the ground investigation that is carried out to give the sensing investigator or operational user a realistic portrait of the target and also necessary in research and operational applications. The ground observations can be obtained from regularly collected or already available data sometimes, but often a ground investigation data collection program must be specifically designed for the particular activity. Because the ground investigations are very costly, it is essential to determine which info is required to meet the needs of a particular activity.

The ground truth has been carried out by the subject specific thematic specialists to collect information in the field regarding all doubtful areas noted down in the pre-field interpretation and also to conform the pre-field interpretation. Necessary corrections and additions have been noted in the field dairies. Representative photographs for each class in different themes were taken and their precise location recorded through handheld GPS receivers. Then all the thematic maps have been finalized by incorporating modifications noted in the field for each specific theme.

### 5.4. Geographic Information System (GIS):

GIS is a computer based information system designed with a set of tools for collecting, storing, retrieving at will, transforming and displaying data from real world for a particular set of purposes. In GIS, information is derived from the interpretation of satellite data, which are symbolic representations of geographic features. A corresponding database of thematic and statistical attributes are linked to the map features and can be sorted and classified, then queried to reveal important details, not readily seen on the maps. GIS can be used to capture, store, manipulate, analyze, manage, and present all types of geographic information in a spatial or "map-like" configuration in a computer. GIS applications are tools that allow users to create interactive queries (user-created searches), analyze spatial information, edit data in maps, and display the results of all these operations. When linked to a printer or plotter, the GIS can generate top quality maps for reports, field operations or office use. GIS can update maps and map attributes directly onto the computerized map.

In the present study of Integrated Mission for Creation of Scientific and Comprehensive Soil & Land Resources Information System for Effective Implementation of Comprehensive Agriculture Management Program (CAMP), digital database creation and map generation have been carried by using GIS Techniques.

### 5.5. Global Positioning System (GPS):

It is a space-based satellite navigation system that provides location and time information in all weather conditions, anywhere on or near the Earth where there is an unobstructed line of sight to four or more GPS satellites. It is maintained by the United States government and is freely accessible to anyone with a GPS receiver.

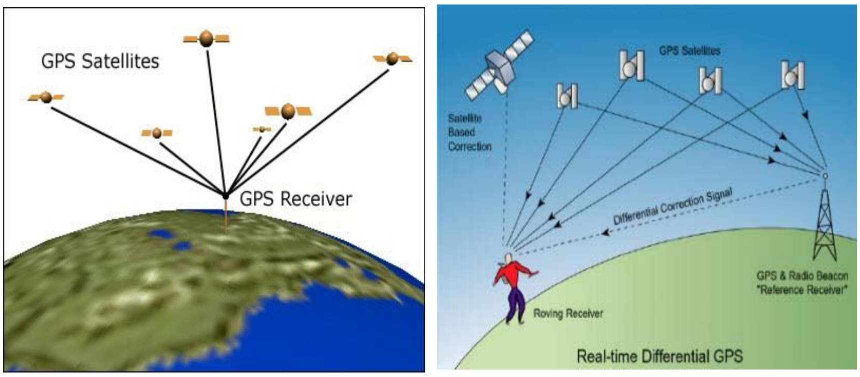



**Figure-4: GPS Satellite Receiving Process**

In the present study of Integrated Mission for Creation of Scientific and Comprehensive Soil & Land Resources Information System for Effective Implementation of Comprehensive Agriculture Management Program (CAMP), GPS has been used to collect the co-ordinates of the soil collection points and ground truth points during field work.

### 5.6. Differential Global Positioning System (DGPS):

GPS is a satellite-based technology where as DGPS (Differential GPS) means working with minimum a pair of GPS instruments.

In the present study of Integrated Mission for Creation of Scientific and Comprehensive Soil & Land Resources Information System for Effective Implementation of Comprehensive Agriculture Management Program (CAMP), DGPS survey has been carried out to collect the co-ordinates of the GCP's for geo-referencing of satellite data.

### 5.7. Photogrammetry:

Photogrammetry is the science of making measurements from photographs, especially for recovering the exact positions of surface points. Moreover, it may be used to recover the motion pathways of designated reference points located on any moving object, on its components and in the immediately adjacent environment. Photogrammetry may employ high-speed imaging and remote sensing in order to detect, measure and record complex 2-D and 3-D motion fields. Photogrammetry feeds the measurements from remote sensing and the results of imagery analysis into computational in an attempt to successively estimate, with increasing accuracy, the actual, 3-D relative motions within the researched field.

The output of photogrammetry is typically a map, drawing or a 3D model of some real-world object or scene like contours, ortho-images, DEM etc. Various Leica tools like LPS, Terra scan and Terra modeler will be used in this process.

In the present study of Integrated Mission for Creation of Scientific and Comprehensive Soil & Land Resources Information System for Effective Implementation of Comprehensive Agriculture Management Program (CAMP), DEM and contours have been generated by using Photogrammetry techniques.

# CHAPTER -6

# PROCUREMENT / COLLECTON OF INPUT DATA

## 6.1. Introduction:

India has launched different Remote sensing satellites with spatial resolution ranging from 360m to 0.8m and also with panchromatic and multispectral imaging capability, catering to the needs of the country in managing its natural resources. These satellite data products can be used for a diverse range of applications such as crop acreage and production estimation of major crops, drought monitoring and assessment based on vegetation condition, flood risk zone mapping and flood damage assessment, hydro-geo-morphological maps for locating underground water resources, irrigation command area status monitoring, snowmelt run-off estimation, soil resources mapping, land degradation studies, land use and land cover mapping, urban planning, biodiversity characterization, forest survey and mapping, wetland mapping, environmental impact analysis, mineral prospecting, coastal studies, integrated surveys for developing sustainable action plans and so on.

## 6.2. Selection of Satellite Data:

For the present study, very high resolution satellite data is required. So, Deimos-2 satellite data of 75 cm spatial resolution has been considered. In addition to it among the Indian satellites, Cartosat-1 stereo data with 2.5m spatial resolution under panchromatic imagery and Resourcesat-2 LISS-IV data with 5.8m spatial resolution under multispectral imagery has been considered.

## 6.3. Deimos-2 (Foreign Satellite) Data:

High resolution satellite data is required for mapping of different thematic layers on 1:10,000 scale. Indian satellites will provide high resolution multispectral imagery upto 5.8m resolution only. So, Deimos-2 foreign satellite data has been considered for the present study.

Deimos-2 is a very-high resolution (75-cm) multispectral optical satellite, fully owned and operated by Deimos Imaging. The Deimos-2 end-to-end system has been designed to provide a cost-effective yet highly responsive service to customers worldwide.

Deimos-2 has been launched on June 19, 2014 with 10 years life time. It operates from a Sun-synchronous orbit at a mean altitude of 620 km, with a local time of ascending node (LTAN) of 10h30, which allows an average revisit time of two days worldwide (one day at mid-latitudes). It provides 75-cm pan sharpened images with a 12km swath.Deimos-2 has 5 spectral bands viz., PAN of 560-900nm, Blue of 466-525nm, Green of 532-599nm, Red 640-697nm and NIR of 770-892nm.

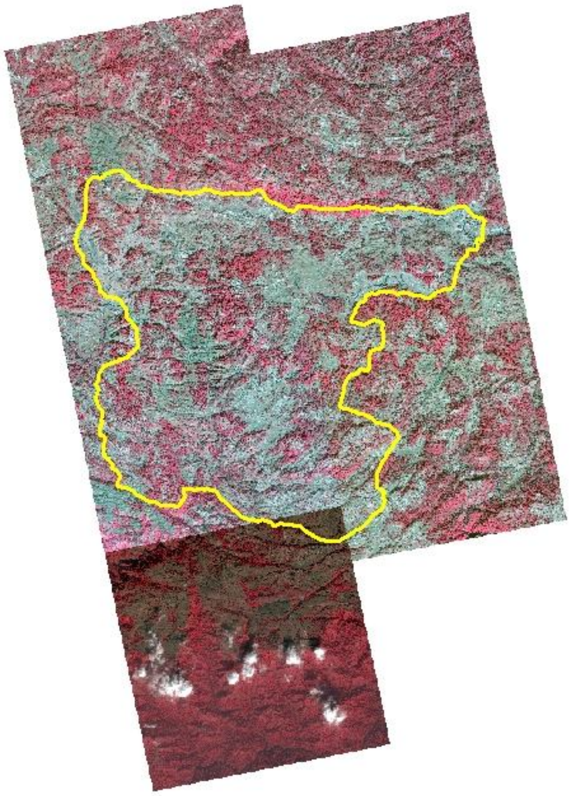


**Figure-5: Deimos-2 Satellite Data Procured**

For the procurement of data, cloud free multi-spectral Deimos-2 data is not available from the past 23 years. So, the data has been acquired freshly with minimum cloud cover, after flying of the satellite for several times above this cluster. The details of the Deimos-2 data procured is shown in the Figure-5 and given in the Table-1.

**Table-1: Details of Deimos-2 Satellite Data Procured**

| Sl. No. | Product Type | Product ID | Date of Pass |
|---|---|---|---|
| 1 | DE2_PSH_L1C | DE2_24533_2310 | 29-Dec-2018 |
| 2 | DE2_PSH_L1C | DE2_24533_BC67 | 29-Dec-2018 |
| 3 | DE2_PSH_L1C | DE2_24533_F961 | 29-Dec-2018 |
| 4 | DE2_PSH_L1C | DE2_24444_0D87 | 23-Dec-2018 |
| 5 | DE2_PSH_L1C | DE2_24444_F701 | 23-Dec-2018 |

## 6.4. Cartosat-1 Stereo Data:

The Cartosat-1 satellite has a number of advantages, as it provides high resolution near-instantaneous stereo data with a spatial resolution of 2.5m and 10 bit quantization. The Cartosat-1 carries two panchromatic cameras, which generate stereoscopic image of the area along the track. The Cartosat-1 satellite has two panchromatic cameras with 2.5m spatial resolution, to acquire two images simultaneously, one forward looking (FORE) at +26 degrees and one aft of the satellite at -5 degrees for near instantaneous stereo data. The time difference between the acquisitions of the same scene by the two cameras is about 52 seconds. The path and row details of the Cartosat-1 stereo data procured is shown in the Figure-6 and given in the Table-2.

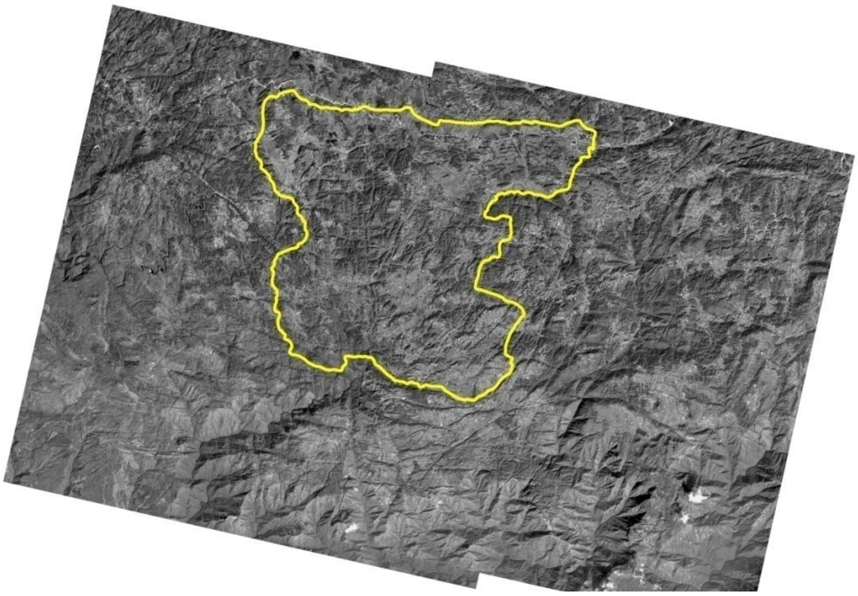


**Figure-6: Cartosat-1 Stereo Data Procured**

**Table-2: Scene Details of Cartosat-1 Stereo Data Procured**

| Sl. No. | Path | Row | Date of Pass |
|---|---|---|---|
| 1 | 602 | 280 | 10-Nov-2017 |
| 2 | 603 | 280 | 27-Jan-2018 |

## 6.5. Resourcesat-2 Data:

The Resourcesat-2 will provide both multispectral and panchromatic imagery of the earth surface. The payload system of Resourcesat-2 comprises of three optical remote sensing cameras, viz., Linear Imaging Self Scanning Sensor (LISS-IV), Linear Imaging Self

Scanning Sensor (LISS-III) and Advanced Wide Field Sensor (AWiFS). LISS-IV is a high resolution (5.8m) multi spectral camera operating in three spectral bands. This camera can be operated in two modes: Mono and Multi-spectral. In the Multi-spectral mode (Mx), data will be collected in three spectral bands (B2, B3 and B 4) and a swath of 23.5m is covered and in mono mode a swath of 70km is covered with any one spectral band. LISS-III provides 23.5m resolution in four bands with 140km swath and AWiFS camera provides with a spatial resolution of 56m in four bands with 740km swath.

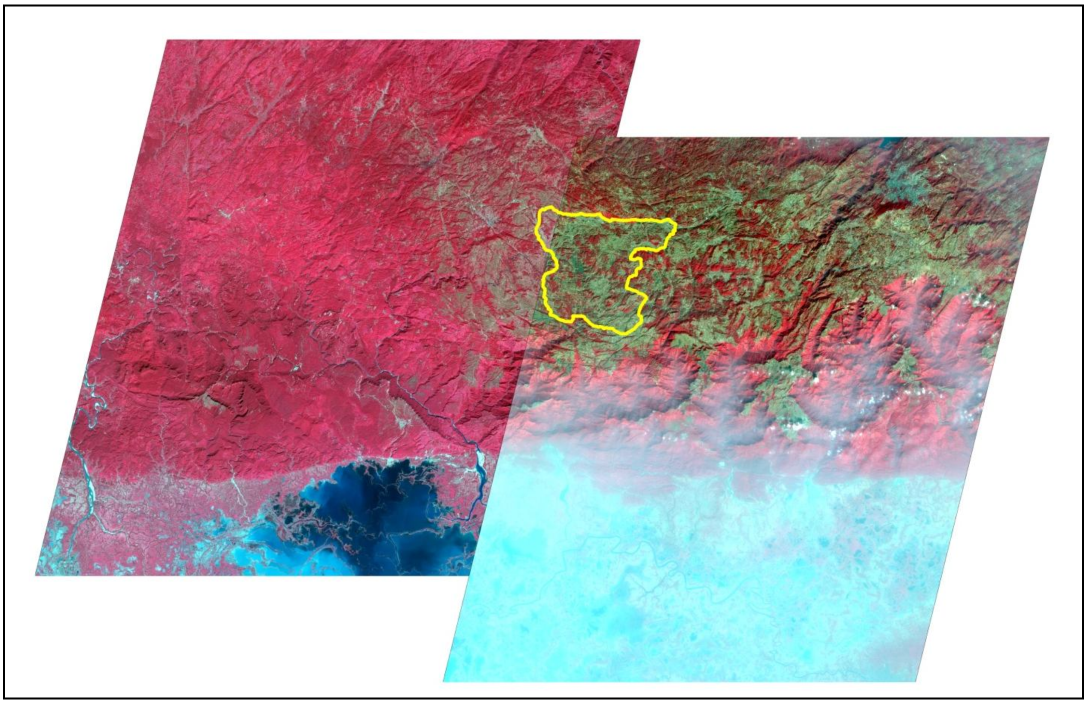


**Figure-7: Resourcesat-2, LISS-IV MX Data Procured**

For the present study, Resourcesat-2 LISS-IV MX data has been considered for the mapping of different thematic maps. The path and row details of the LISS-IV MX data procured is shown in the Figure-7 and given in the Table-3.

**Table-3: Scene Details of Resourcesat-2, LISS-IV MX Data Procured**

| Path | Row | Sub Scene | Date of Pass |
|---|---|---|---|
| 110 | 54 | A | 03-Nov-2017 |
| 110 | 54 | B | 14-Jan-2018 |

### 6.6. Procurement of Satellite Data:

Satellite move around earth from pole to pole. The area covered in one round is called path. Adjacent scenes from different paths are called Rows. The Path & Rows of the CARTOSAT-1 and Resourcesat-2 LISS-IV MX scenes covering this cluster has been browsed and selected from the website of National Remote Sensing Centre (NRSC). In the selection process, care has been taken in respect of cloud free data and date of pass as recent as possible.

NRSC is one of the centers of Indian Space Research Organisation and it is responsible for acquisition, processing, supply of aerial and satellite remote sensing data. The selected scenes of CARTOSAT-1 and Resourcesat-2 have been purchased from NRSC. Deimos-2 data has been purchased from Deimos Imaging through NRSC.

### 6.7. Survey of India (SOI) Toposheets:

Cluster-2 is falling in 4 toposheets namely 78O/6, 78O/7, 83O/10 and 78O/11 of 1:50,000 scale. All these Toposheets, have been collected from the Govt. Department in Geo Tiff format (in soft copy). These toposheets have been used in the preparation of Base maps.

### 6.8. Geological and Mineral Map of Meghalaya:

Geological and Mineral Map of Meghalaya has been collected from the Govt. Department in Geo Tiff format (in soft copy) and the same is shown in the Figure-8 and Figure-9. This data has been used in the preparation of Hydro-geomorphology maps.

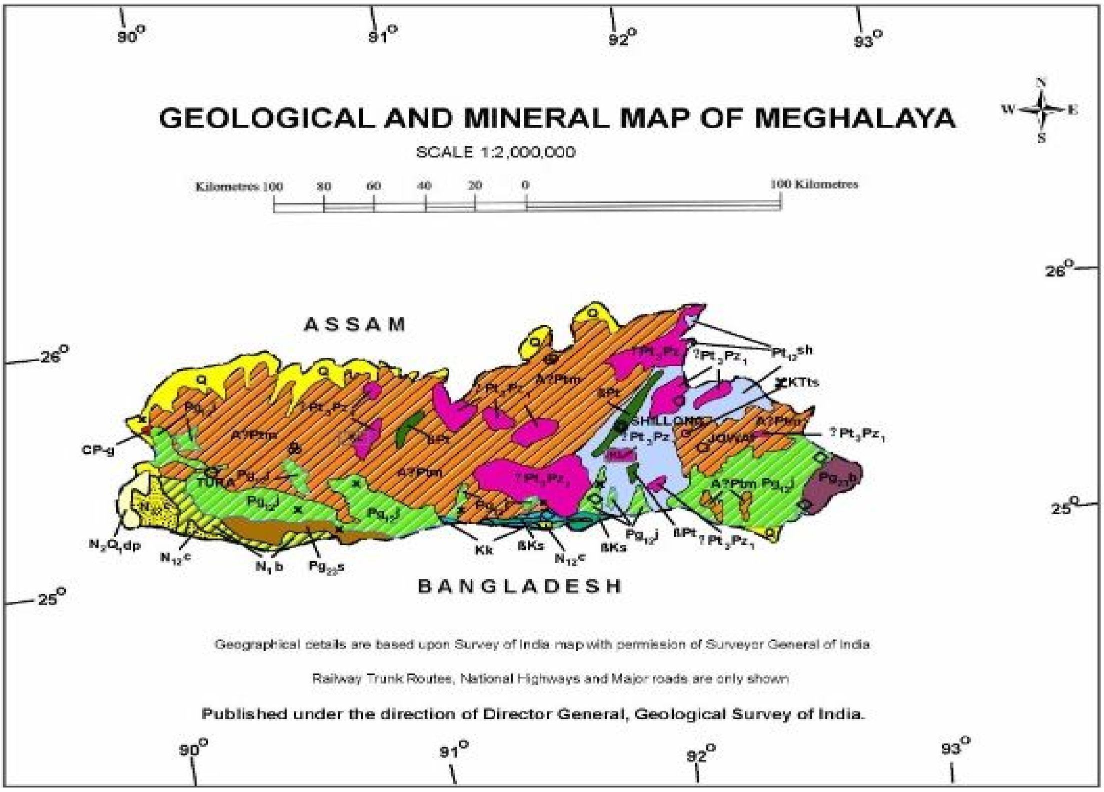



**Figure-8: Geological and Mineral Map of Meghalaya**

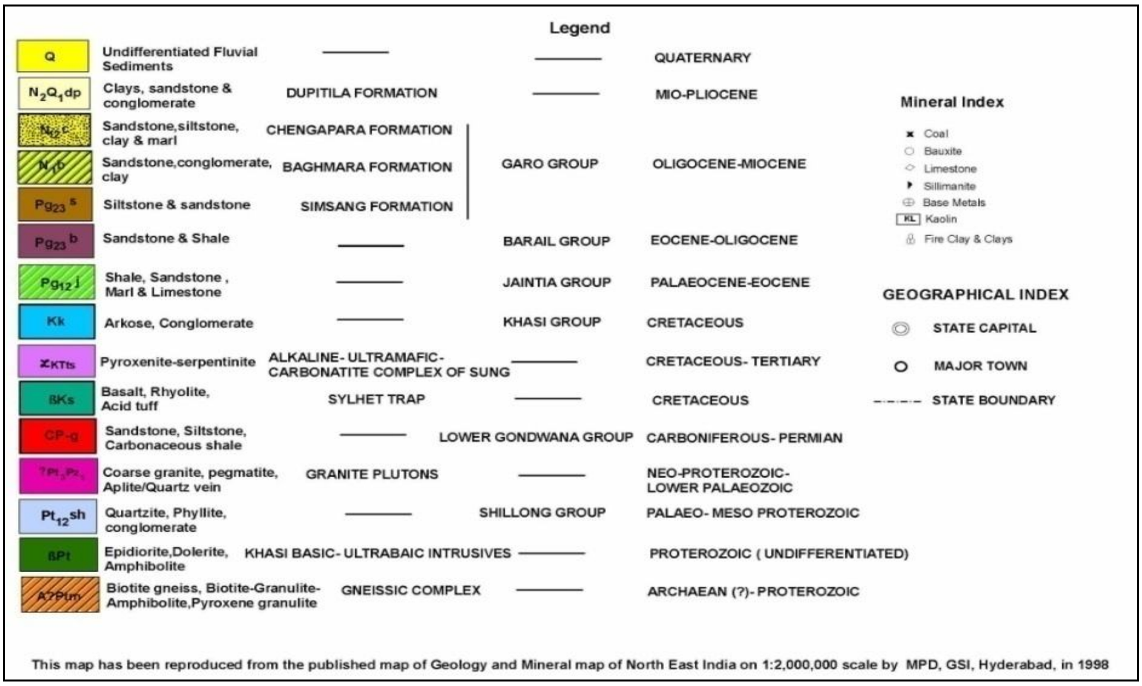



**Figure-9: Legend of Geological and Mineral Map of Meghalaya**

# CHAPTER -7

# ESTABLISHMENT OF DGPS CONTROL NETWORK

## 7.1. Introduction:

Precise ground control points (GCPs) are required for geo-referencing of the satellite data. GCPs will be collected using DGPS. GPS (Global Positioning System) is a satellite-based technology where as DGPS (Differential GPS) means working with minimum a pair of GPS instruments. In DGPS survey, one point is treated as base station and one instrument will be kept on this point for observing the satellites throughout the working period on continuous basis, while other instruments will be taken from one point to other points for measurement. DGPS instruments of the models Leica 1235 and Trimble R4 have been used for the present work. The system accuracies of the instruments used are given in the Table-4.

**Table-4: Details of DGPS Instruments Used**

| Model of DGPS Instrument used | Mode | Horizontal Accuracy | Vertical Accuracy |
|---|---|---|---|
| Leica 1235 | Static Mode | 5mm+0.5 ppm | 10mm+0.5 ppm |
| Trimble R4 | Static Mode | 3mm+0.5 ppm | 5mm+0.5 ppm |

## 7.2. Establishment of Main Reference/Base Point (MRP):

For the DGPS survey, establishment of Main Reference Point (MRP) is pre-required. So, Main Base Point has been established in Nongstoin, with 72 hours continuous observation by using dual frequency DGPS receivers. Later on it has been connected to the International Geodetic System (IGS) point to get the best available coordinates and the same are given in the Table-5.

Main Reference Point and all other points have been established with Horizontal Datum of WGS-84 (i.e., the latest version of the World Geodetic System standard for use in cartography) and Vertical Datum of MSL, i.e., the Mean Sea Level.

## 7.3. Establishment of Secondary/Site Base Point (SBP):

As the GCPs selected are far away from the Main Base Point, Site Base Points have been established. Site Base Points are established by keeping the duel frequency instruments at Main Base point and Site Base Points at a time. Post processing of the collected DGPS data of Site Base Points has been carried to derive geodetic coordinates and the same are given in the Table-5.

**Table-5: Details of Base Points Established by DGPS**

| Sl. No. | Point Type | Point ID | Latitude | Longitude |
|---|---|---|---|---|
| 1 | MRP | W 1 | 25° 31' 7.956" N | 91° 16' 0.822" E |
| 2 | SBP | W 2 | 25° 31' 57.788" N | 91° 22' 22.971" E |
| 3 | SBP | W 3 | 25° 29' 57.986" N | 91° 28' 48.251" E |
| 4 | SBP | W4 | 25° 31' 4.856" N | 91° 25' 22.692" E |
| 5 | SBP | W 5 | 25° 25' 14.504" N | 91° 22' 15.588" E |
| 6 | SBP | W 6 | 25° 24' 17.900" N | 91° 26' 1.580" E |

## 7.4. Selection of GCP'S:

In the present study, geo-referencing of satellite data has to be carried out with the help of GCP's (Ground Control Points). For this purpose 23 points have been selected covering entire Cluster-2. Locations of these GCP's are selected such that they must be identifiable both on the image and on the ground. The image of selected locations has been printed in larger scale and carried to the field for identifying the location on the ground.

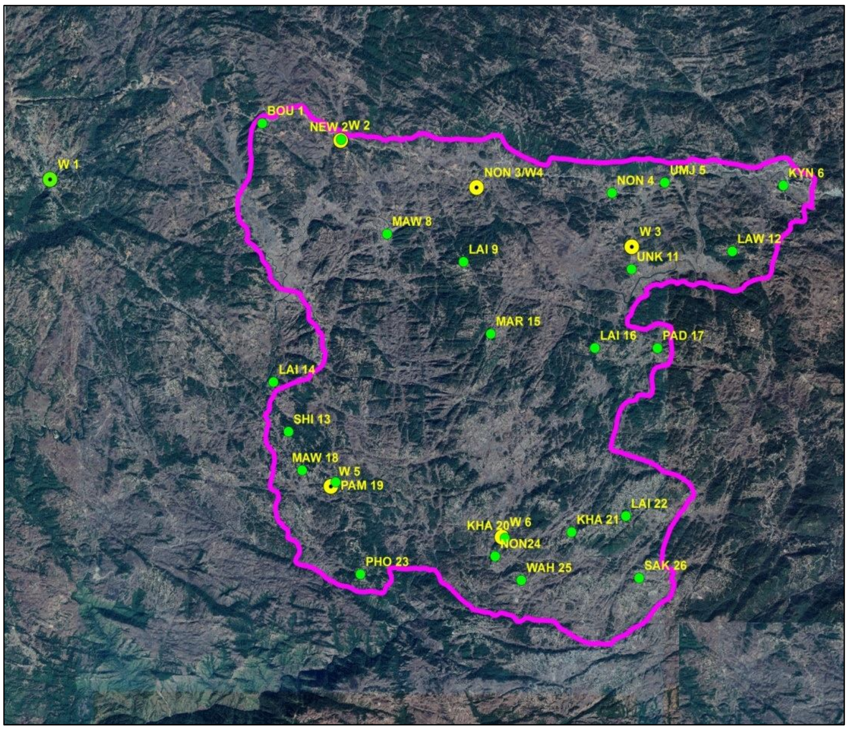



**Figure-10: Location Map of GCP's collected**

## 7.5. Collection of GCP'S by DGPS:

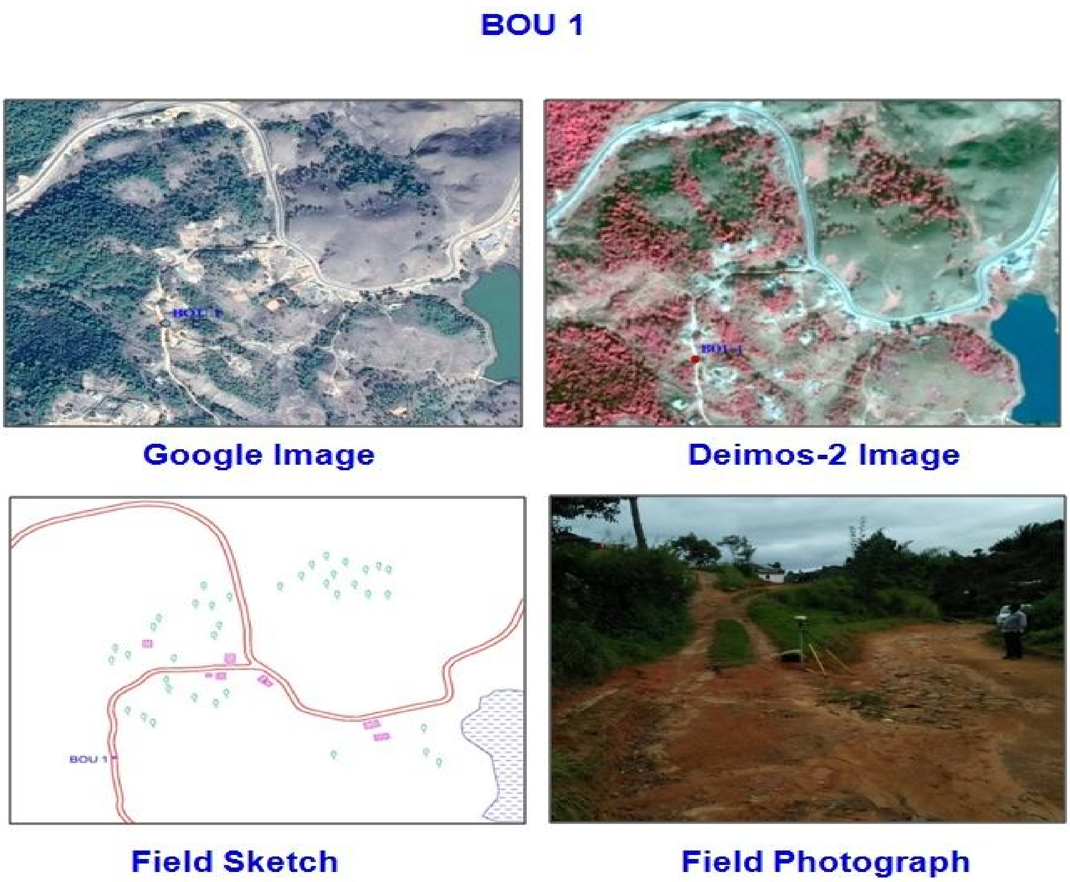
The location of each selected GCP point has been identified and approached with the help of the large scale maps of GCP locations. Then the co-ordinates of each selected GCP has been collected by keeping the duel frequency instruments at base points (Main base and site base) and single frequency instrument at GCP location as rover. Post processing of the collected DGPS data of GCP's has been carried to derive geodetic coordinates and the same are shown in the Figure-10 and given in the Table-6.

**Table-6: Details of GCP'S Collected by DGPS**

| Sl. No. | Type | Point ID | Latitude | Longitude |
|---|---|---|---|---|
| 1 | GCP | BOU 1 | 25° 32' 16.344" N | 91° 20' 39.211" E |
| 2 | GCP | NEW 2 | 25° 31' 58.634" N | 91° 22' 23.482" E |
| 3 | GCP | UNK 11 | 25° 29' 31.698" N | 91° 28' 48.201" E |
| 4 | GCP | PAD 17 | 25° 28' 0.071" N | 91° 29' 23.350" E |
| 5 | GCP | KYN 6 | 25° 31' 11.290" N | 91° 32' 6.816" E |
| 6 | GCP | UMJ 5 | 25° 31' 13.016" N | 91° 29' 30.642" E |
| 7 | GCP | LAI 16 | 25° 27' 59.514" N | 91° 28' 0.978" E |
| 8 | GCP | LAW 12 | 25° 29' 53.971" N | 91° 31' 0.508" E |
| 9 | GCP | NON 4 | 25° 31' 0.257" N | 91° 28' 21.151" E |
| 10 | GCP | MAR 15 | 25° 28' 14.511" N | 91° 25' 43.656" E |
| 11 | GCP | MAW 8 | 25° 30' 9.437" N | 91° 23' 25.478" E |
| 12 | GCP | LAI 9 | 25° 29' 37.969" N | 91° 25' 6.758" E |
| 13 | GCP | PAM 19 | 25° 25' 19.535" N | 91° 22' 21.609" E |
| 14 | GCP | MAW 18 | 25° 25' 32.751" N | 91° 21' 37.360" E |
| 15 | GCP | PHO 23 | 25° 23' 32.577" N | 91° 22' 55.687" E |
| 16 | GCP | LAI 14 | 25° 27' 15.203" N | 91° 20' 58.288" E |
| 17 | GCP | SHI 13 | 25° 26' 17.604" N | 91° 21' 18.776" E |
| 18 | GCP | NON24 | 25° 23' 55.428" N | 91° 25' 52.653" E |
| 19 | GCP | WAH 25 | 25° 23' 27.764" N | 91° 26' 27.578" E |
| 20 | GCP | SAK 26 | 25° 23' 32.114" N | 91° 29' 2.650" E |
| 21 | GCP | LAI 22 | 25° 24' 44.130" N | 91° 28' 44.287" E |
| 22 | GCP | KHA 21 | 25° 24' 24.586" N | 91° 27' 33.005" E |
| 23 | GCP | KHA 20 | 25° 24' 16.737" N | 91° 26' 5.313" E |

## 7.6. GCP Library:

The GCP library for each GCP collected has been prepared with satellite image of that point, field sketch, field photograph, latitude, longitude, description of the location etc. GCP library for two GCPs are shown in the Figure-11 and Figure-12.




| POINT No. | LATITUDE | LONGITUDE | EASTING | NORTHING | MSL Height |
|---|---|---|---|---|---|
| BOU 1 | 25°32'16.34" | 91°20'39.21" | 333636.33 | 2825544.37 | 1569.53 |

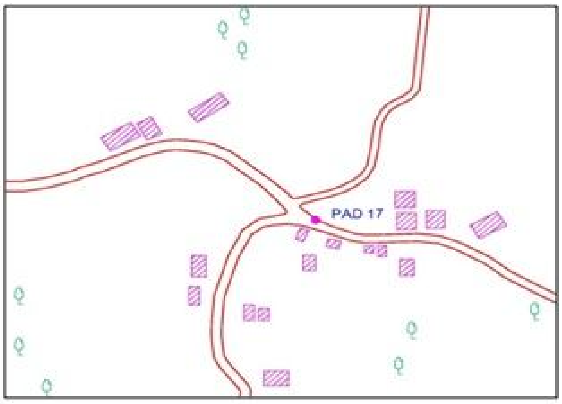
| | |
|---|---|
| DESCRIPTION | The point is marked on East of road edge, it is about 30m SW from NH106, it is about 500m West from Pamphyrnai Lake. |

**Figure-11: GCP Library**

## PAD 17

Google Image


Deimos-2 Image




Field Sketch

Field Photograph

| POINT No. | LATITUDE | LONGITUDE | EASTING | NORTHING | MSL Height |
|---|---|---|---|---|---|
| PAD 17 | 25°28'0.07" | 91°29'23.35" | 348177.63 | 2817485.37 | 1660.00 |

| | |
|---|---|
| DESCRIPTION | The point is marked at a tri junction on Longten-Pariyong-Lawbyrtun road, it is about 140m NW from Dommawleih Presbyterian Church. |

**Figure-12: GCP Library**

# CHAPTER-8

# RECTIFICATION / GEO-REFERENCING OF SATELLITE DATA

## 8.1. Introduction:

Correlating the image to the real world co-ordinates with a specific projection and specified units is called geo-referencing. The feature on the image doesn't have any reference to real world co-ordinates. Unless until, images are geo-referenced, they cannot be arranged sequentially or overlaid one upon another for any further analysis. We have to correlate the image to user specified referencing system, with projection.

The purchased satellite data is in digital media and simply geo-referenced with the help of latitude and longitude for 4 corner pixels and 1 central pixel only. This geo-referenced data is not being accurate for large scale mapping applications. So, refined geo-referencing of satellite image has been carried out by using relevant software in UTM WGS84 co-ordinate system with the help of GCP's (Ground Control Points) collected by DGPS survey.

## 8.2. Geo-referencing of Satellite Data:

With the help of the co-ordinates of the GCP's collected, all the Cartosat-1 scenes have been geo-referenced by using Erdas Imagine 9.1 software. Then Resourcesat-2 (LISS IV MAX) scene and Deimos-2 data have also been geo-referenced, by using the geo-referenced Cartosat-1 scenes. The collected toposheets also geo-referenced using the GCPs collected.

## 8.3. Image Processing of Satellite Data:

Remote Sensing Satellites orbit the earth from pole to pole and continuously scan the earth's surface, convert the reflection from it into digital numbers. This information will be sent to earth's receiving station (Shadnagar–India). This information (Data) is stored in Hi-density magnetic tapes and is sent to NDC (NRSC Data Centre). Inherently the data received from satellite, which is called raw data, consists of many errors. Removing the errors and preparing the data for use in applications is called image processing.

Image processing of all the purchased satellite data has been carried out by using relevant software. In this process, correction for Distortions, Degradations and Noise, removing of radiometric errors, contrast enhancement etc., has been carried out.

## 8.4. Mosaicking:

The joining of the adjacent images is called mosaicking. As this cluster is covering in more than one scene, they have been mosaicked. Toposheets are covering in 4 sheets, Cartosat-1 stereo data is covering in 2 scenes and Deimos-2 data is covering in 6 scenes. While mosaicking the scenes, care has been taken such that the features should be continuous in edge matching of side-by-side scenes, as they come from different paths and time. The mosaic of Toposheets, Cartosat-1 and Deimos-2 data are shown in the Figure-13, 14 and 15 respectively.

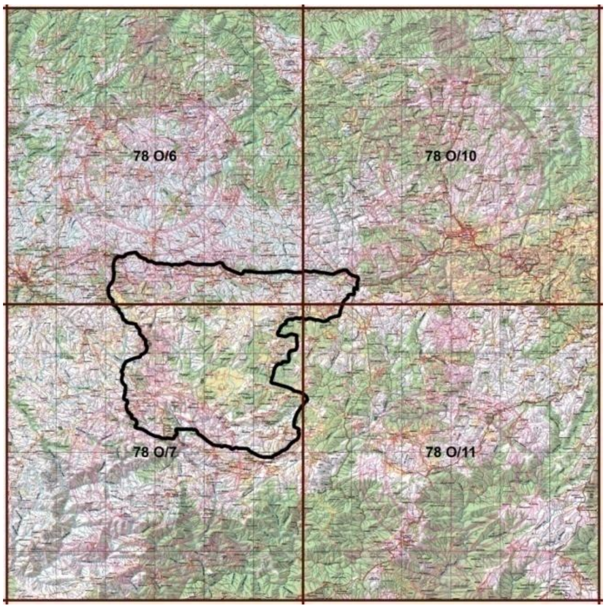



**Figure-13: Topo-sheet Mosaic**

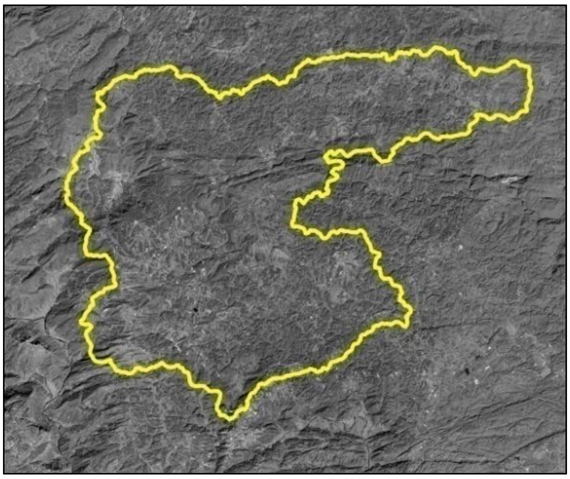


**Figure-15: Mosaic of Rectified Scenes (2 No’s) of Cartosat-1 Stereo Data**

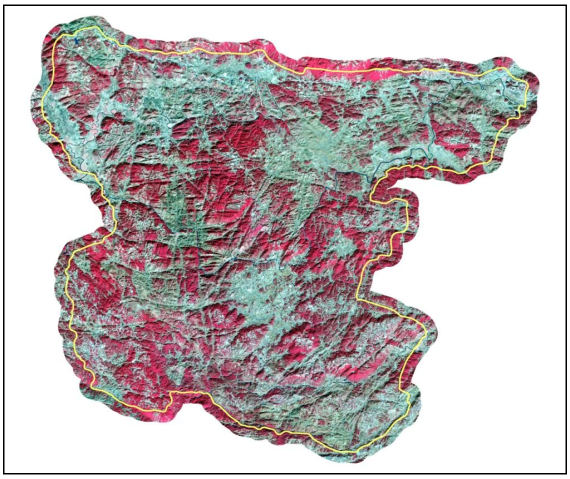


**Figure-14: Mosaic of Rectified Scenes (6 No’s) of Deimos-2 Image**

## 8.5. Generation of 1;10,000 Scale Grid:

As per the scope of work 1:10,000 scale grid has been generated covering entire Cluster-2, by using GIS techniques in WGS84, as shown in the following figure. A total of 18 grids have been generated and each grid has been attributed as per the Survey of India naming convention as shown in the Figure-16.

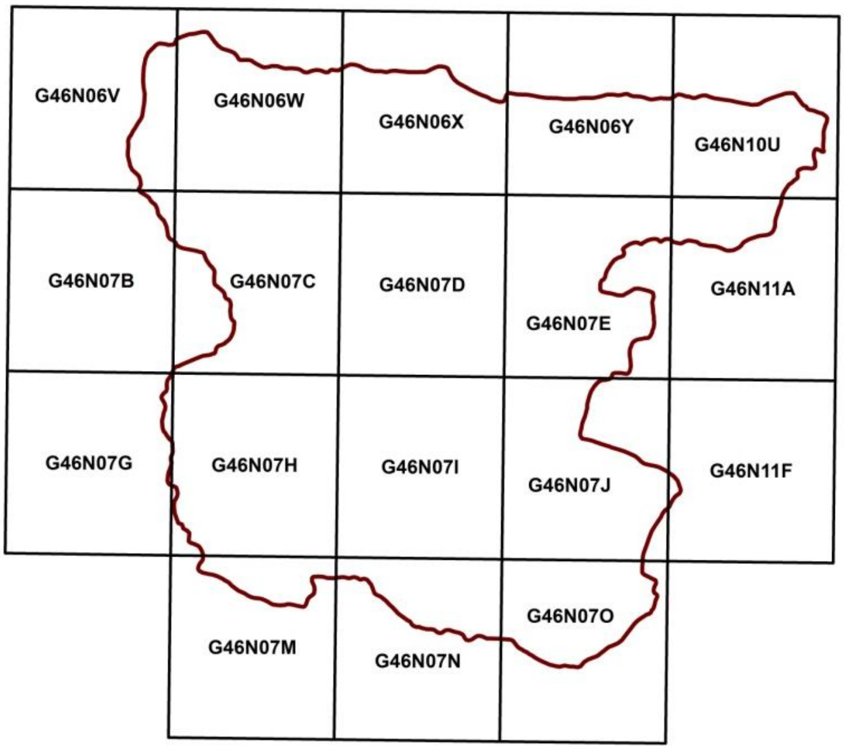



**Figure-16: 10K Grid Generated**

# CHAPTER-9

# PREPARATION OF BASE MAP

## 9.1. Methodology:

Base Map has been prepared by using Remote Sensing and GIS techniques with the following features.

- GCPs collected by DGPS Survey
- Topographical information with 5m interval contours and spot heights.
- Administrative setup up with State boundaries, District boundaries, Block boundaries, GS Circle boundaries and locations of head quarters of Block and GS Circles.
- Transport network with national highways, major roads, minor roads and cart track
- Settlements as Built-up
- Drainage system with rivers, reservoirs/ponds and streams. Rivers, reservoirs/ponds are further classified into perennial and dry.

This base map has been used as background reference information, onto which other thematic information is placed. Base map is used for location reference and often includes a geodetic control network as part of its structure.

## 9.2. Topographical Information:

In the base map, topographical information is represented by contours and spot heights. For the generation of topographical information, Digital Elevation Model (DEM) is required. So, DEM has been generated by using Cartosat-1 stereo data and GCP's with the help of photogrammetric techniques and it is shown in the Figure-17.

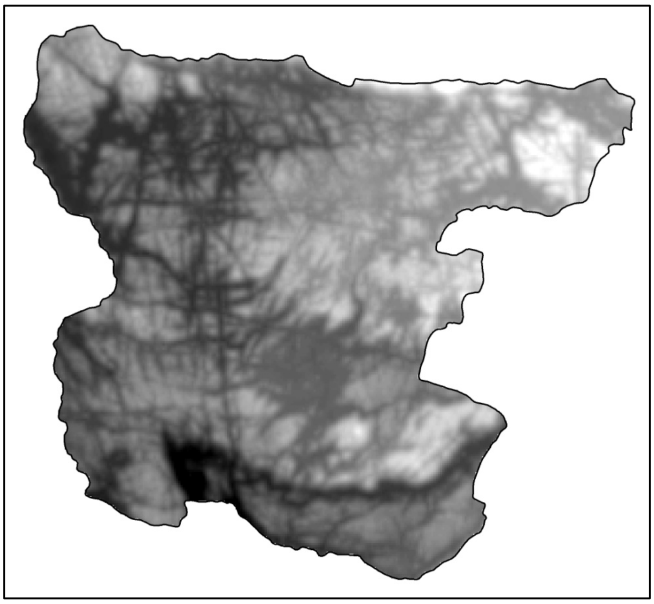


**Figure-17: DEM Generated**

Later on contours of 5m interval

and spot heights have been generated from DEM with the help of photogrammetric techniques and the same are shown in the Figures-18 & 19.

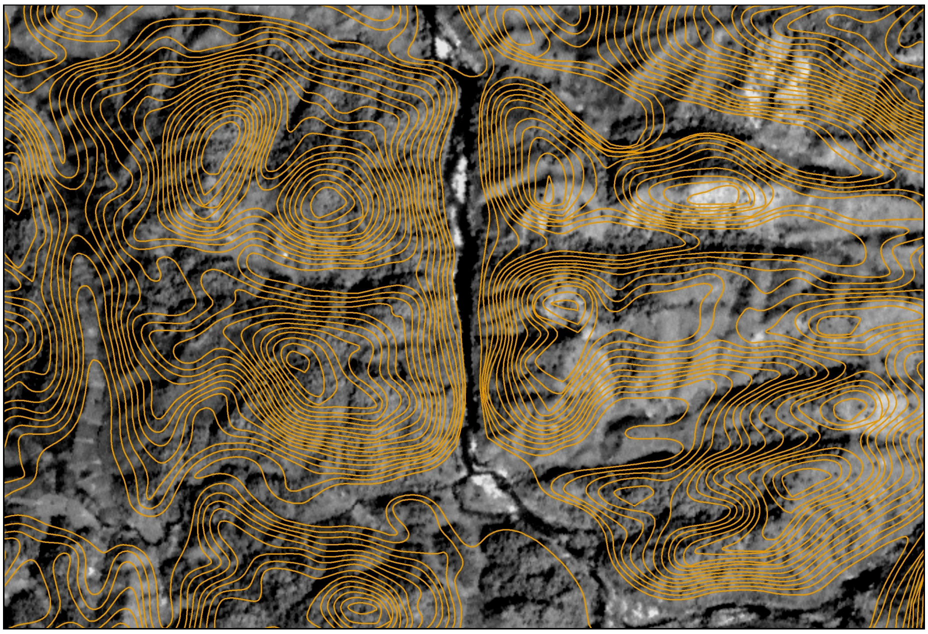


**Figure-18: Part of Contours Generated from DEM**

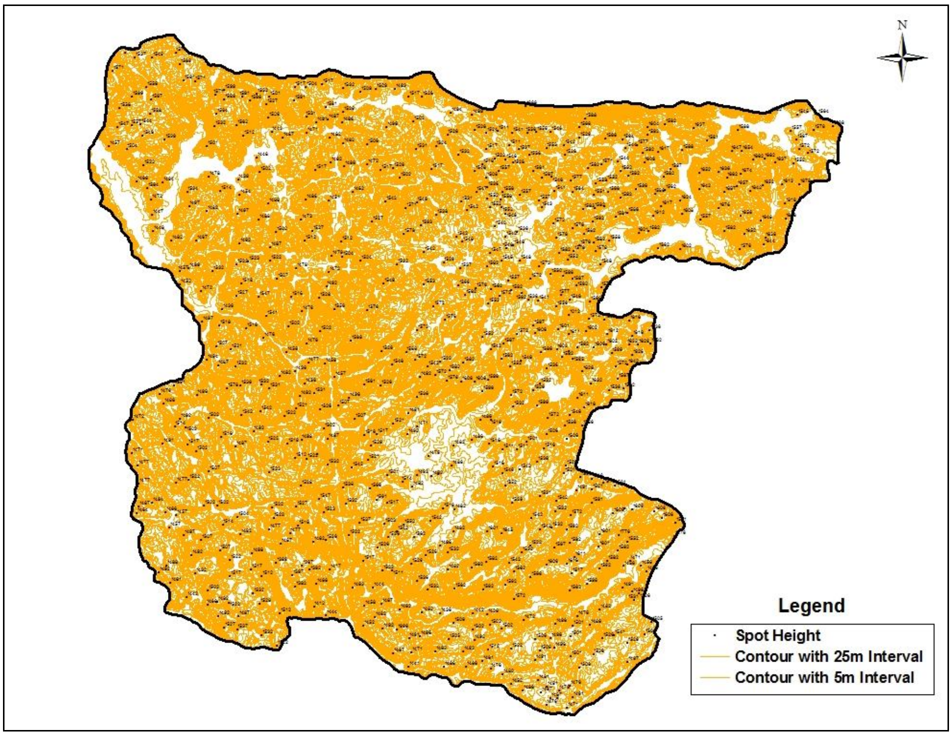



**Figure-19: Contours Generated from DEM**

## 9.3. Administrative Set-up:

Administrative setup is shown up to GS Circle level. The details of existing administrative set-up have been generated from the data collected from the respective department. All the State boundaries, Distrcit boundaries, Block boundaries and GS Circle boundaries have been shown in different symbols and each administrative unit is annotated with their names as shown in the Figure-20.

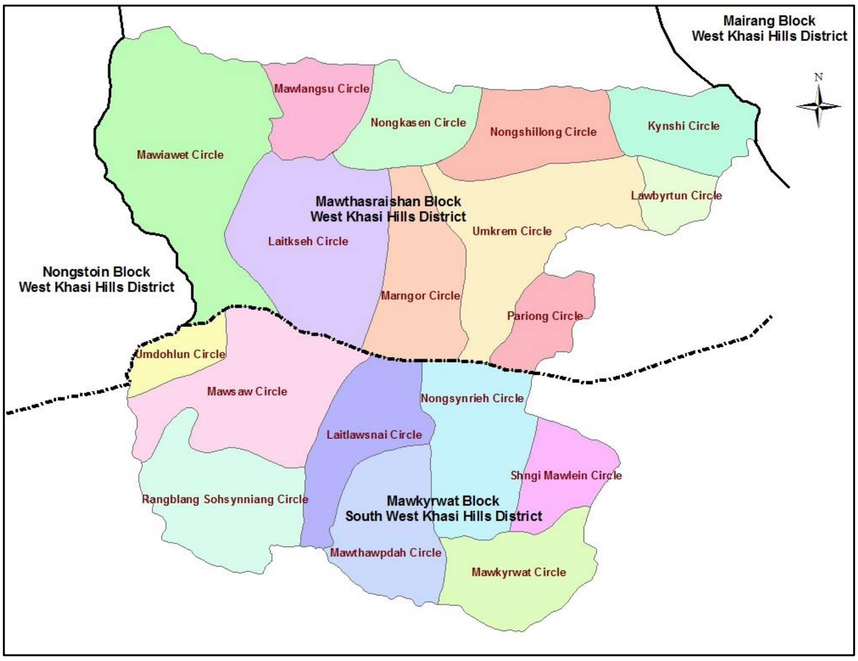



**Figure-20: Administrative set-up Map**

## 9.4. Transport Network:

The entire existing transport network has been mapped based on the high resolution satellite data (Deimos-2) as shown in the Figure-21 and they have been categorized

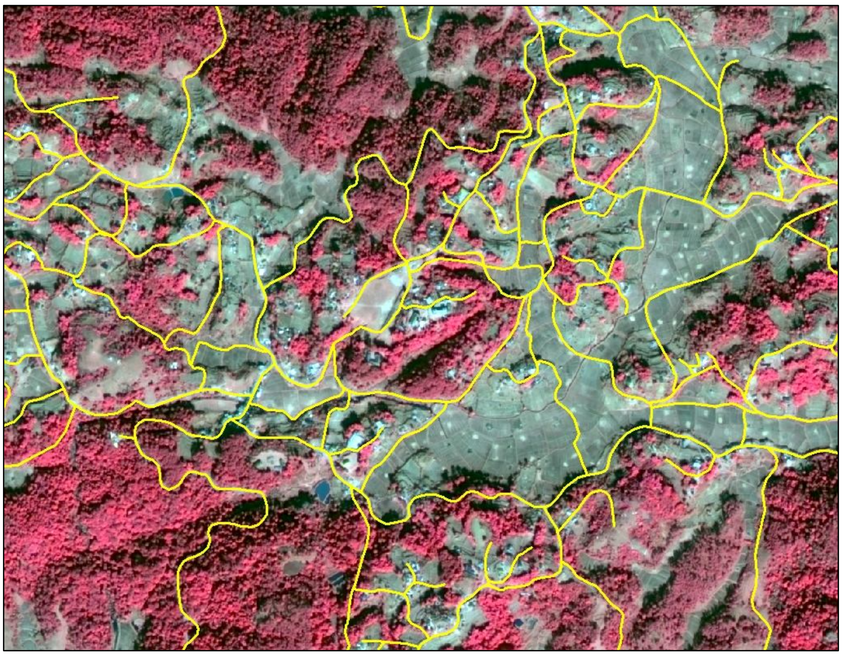


**Figure-21: Transport Network Layer Interpreted on Deimos-2 Image**

as National Highway (NH), major roads, minor roads and cart tracks as shown in the Figure-22.

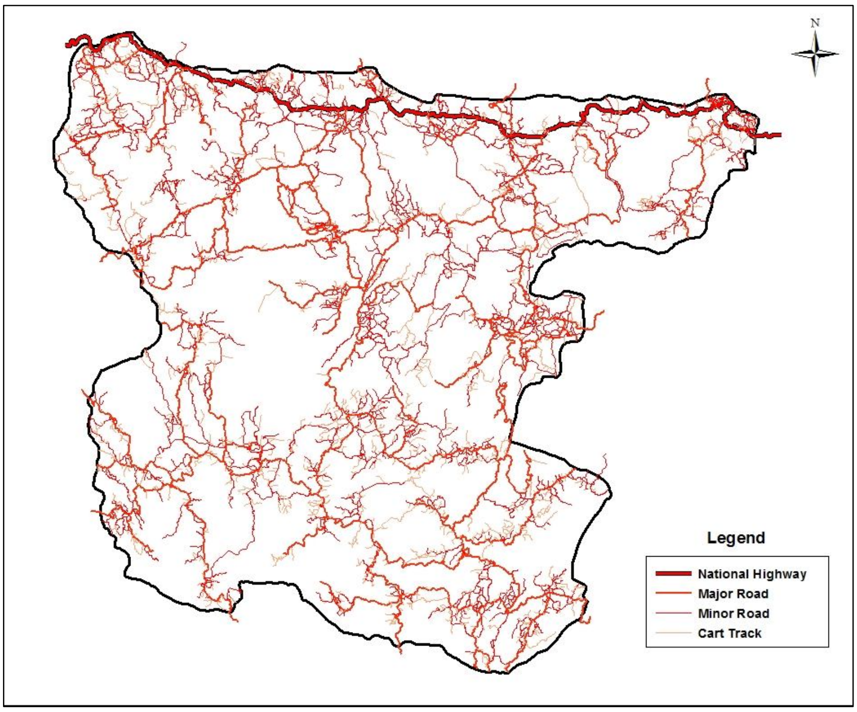



**Figure-22: Transport Network Layer Prepared from Deimos-2 Image**

### 9.5. Drainage System:

Entire drainage system including rivers, ponds, streams etc. have been mapped based on the high resolution satellite data (Deimos-2) and with reference to the contours as shown in the Figure-23 and they have been attributed with names available on the toposheets and information collected in the field. Water bodies are further classified as perennial and dry. Drainage map prepared for Cluster-2 is shown in the Figure-24.

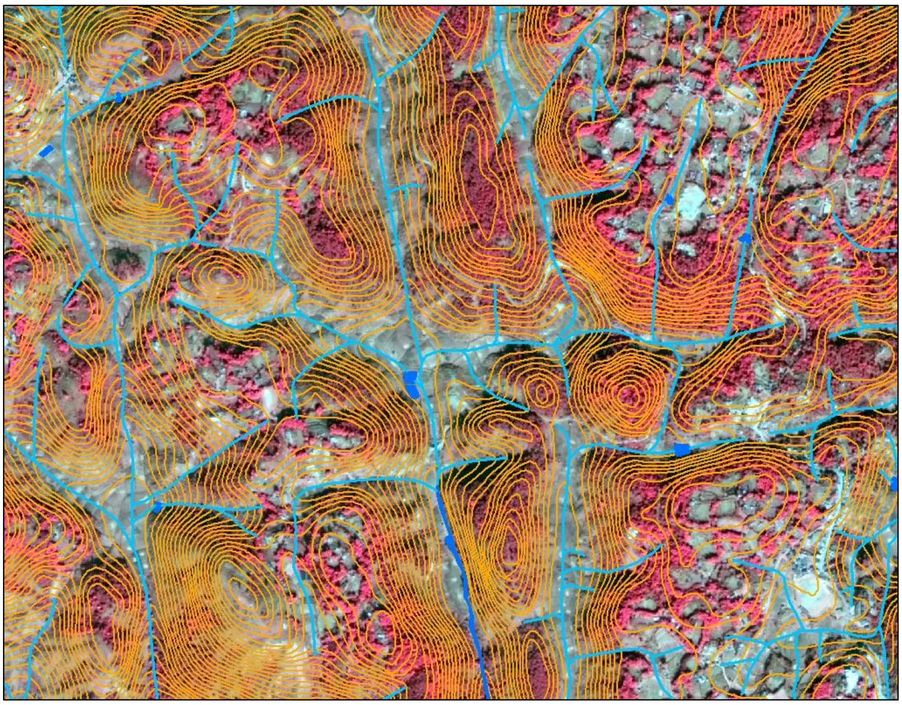


**Figure-23: Streams Interpreted on Deimos-2 Image**

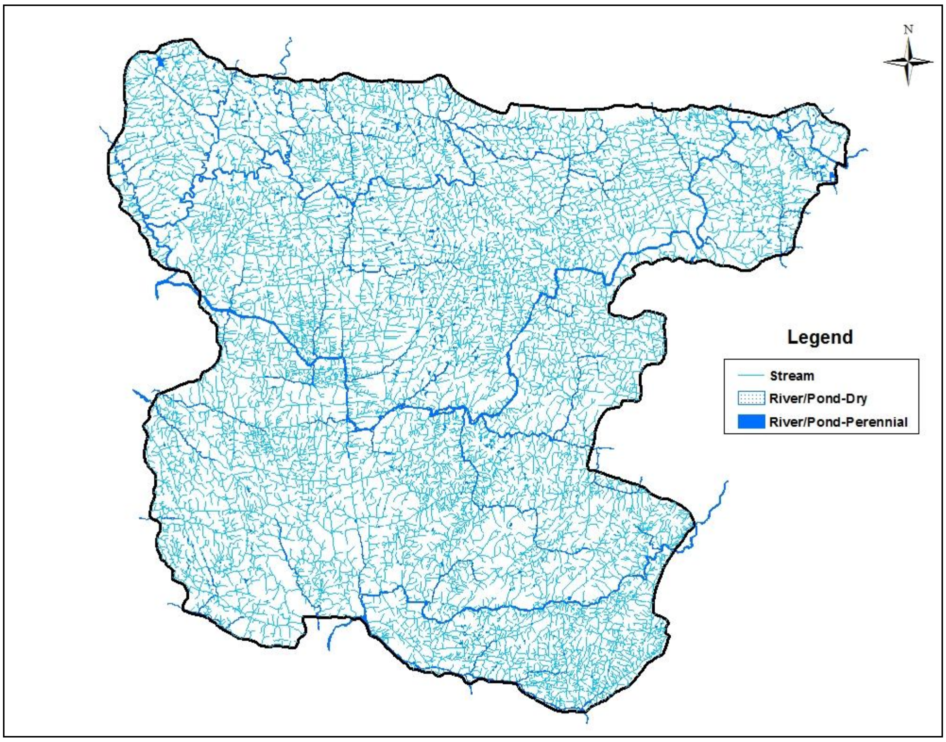



**Figure-24: Drainage Network Layer Prepared from Deimos-2 Image**

## 9.6. Settlements:

All the settlements present have been mapped based on the high resolution satellite data as shown in the following Figure-25.

**Figure-25: Settlements Interpreted on Deimos-2 Image**

## 9.7. Legend:

Legend for base map has been prepared with different colours and symbols for topographic details, administrative boundaries, transport network and drainage network as shown in the Figure-26, to identify each unit easily in the map.

## 9.8. Map Composition:

Base map has been composed in GIS environment, by incorporating topographic details, administrative boundaries, transport network and drainage network along with proper legend, scale bar, north arrow, source and relevant basic information. The base map prepared for is a grid shown in the Figure-27 and for Cluster-2 is shown in the Figure-28.

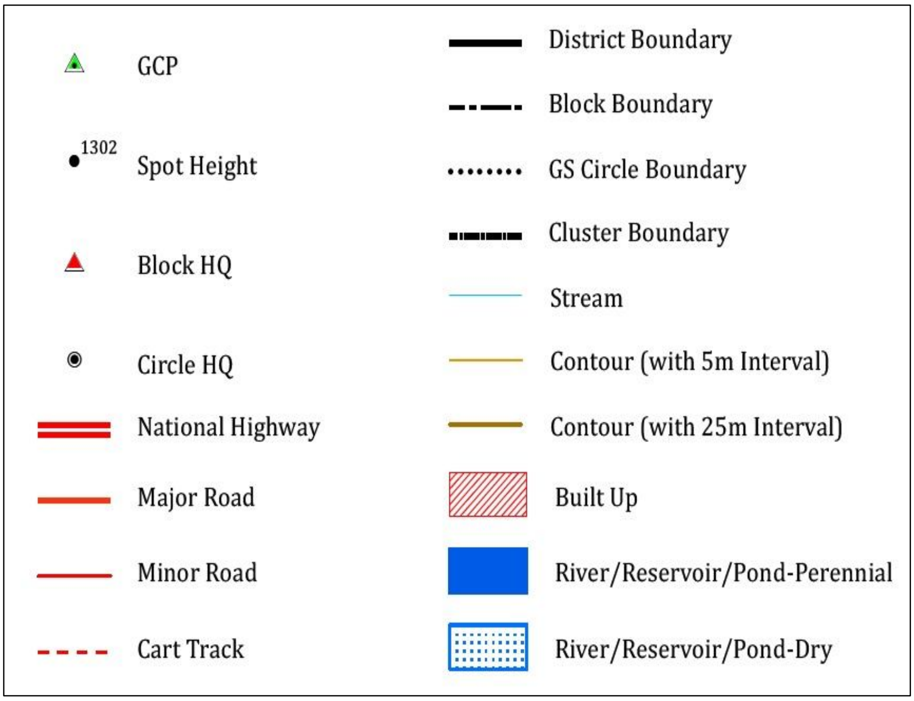



**Figure-26: Legend of Base Map**

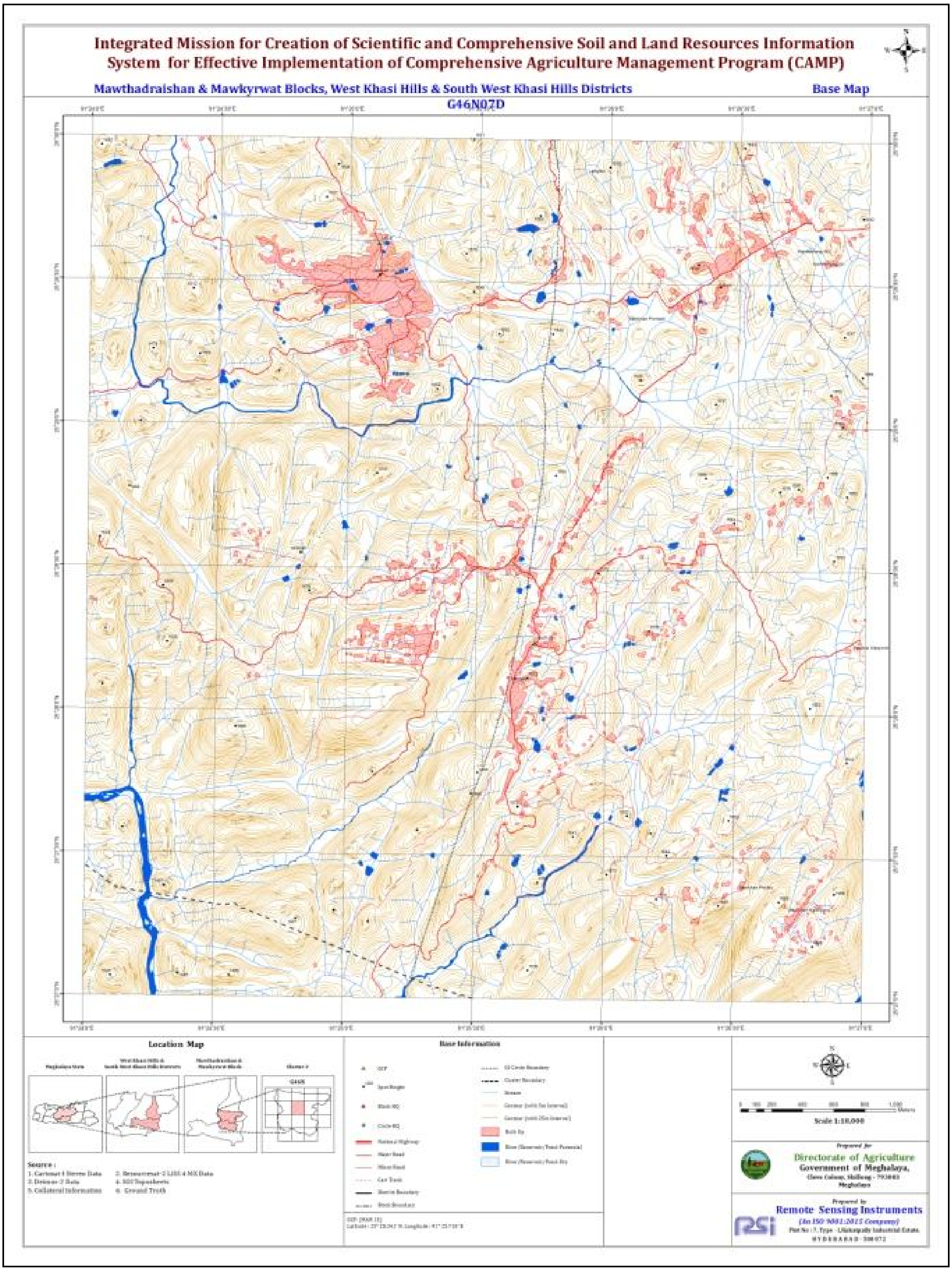



**Figure-27: Base Map of a Grid**

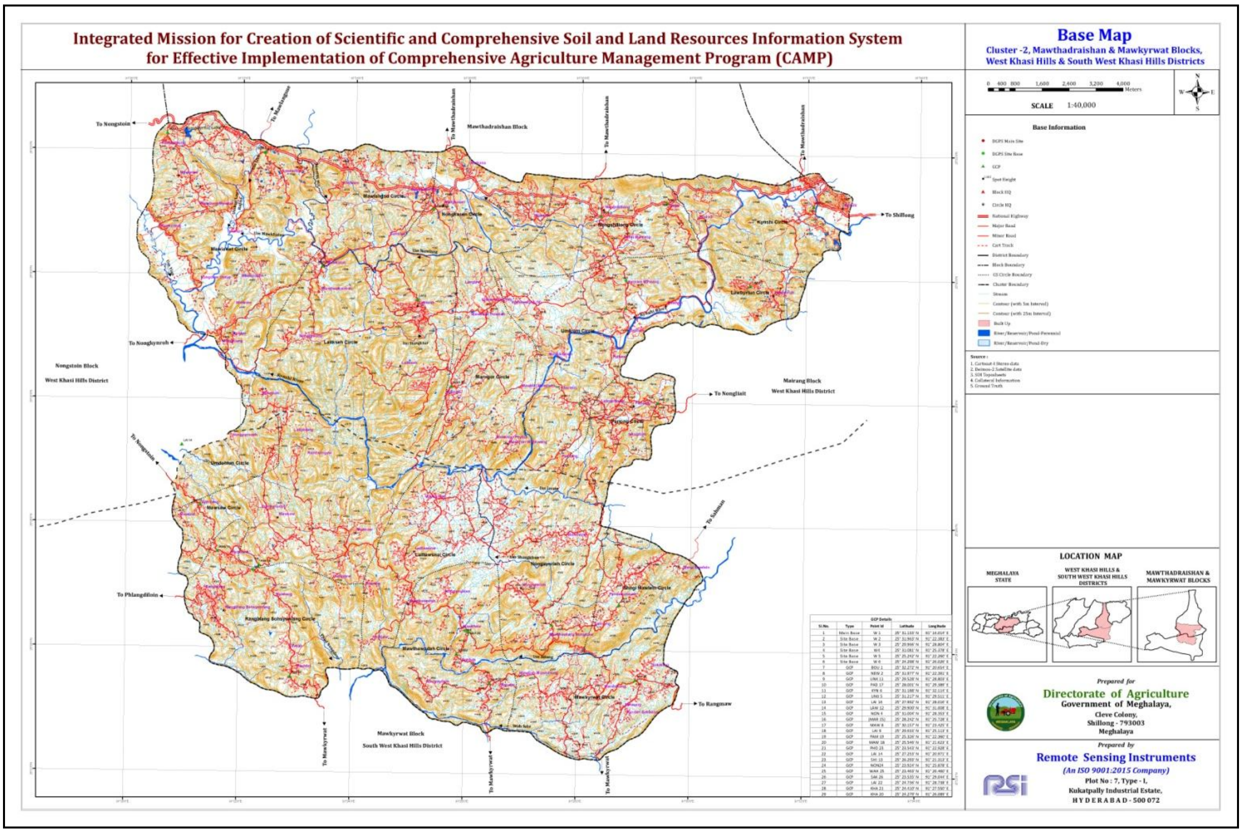



**Figure-28: Base Map of Cluster-2**

# CHAPTER-10

# PREPARATION OF AGRICULTURE AND OTHER LAND USE / LAND COVER MAP

## 10.1. Introduction:

Land use indicates the usage of land, i.e., manmade usage of the earth's surface like built-up lands, agriculture, etc., and land cover is the natural coverage like forests, water bodies, snow etc. Information on land use / land cover of the State is vital for planning a number of developmental activities like agriculture, horticulture, industries, and infrastructure and also for planning conservation measures to check damage likely to be caused by soil erosion, landslides and floods.

## 10.2. Methodology:

Mapping of different agriculture and other land use/land cover units has been carried out by on-screen visual interpretation of multi spectral satellite imagery with ground truth as per the classification system using Remote Sensing and GIS techniques in Arc GIS environment as shown in the Figure-29.

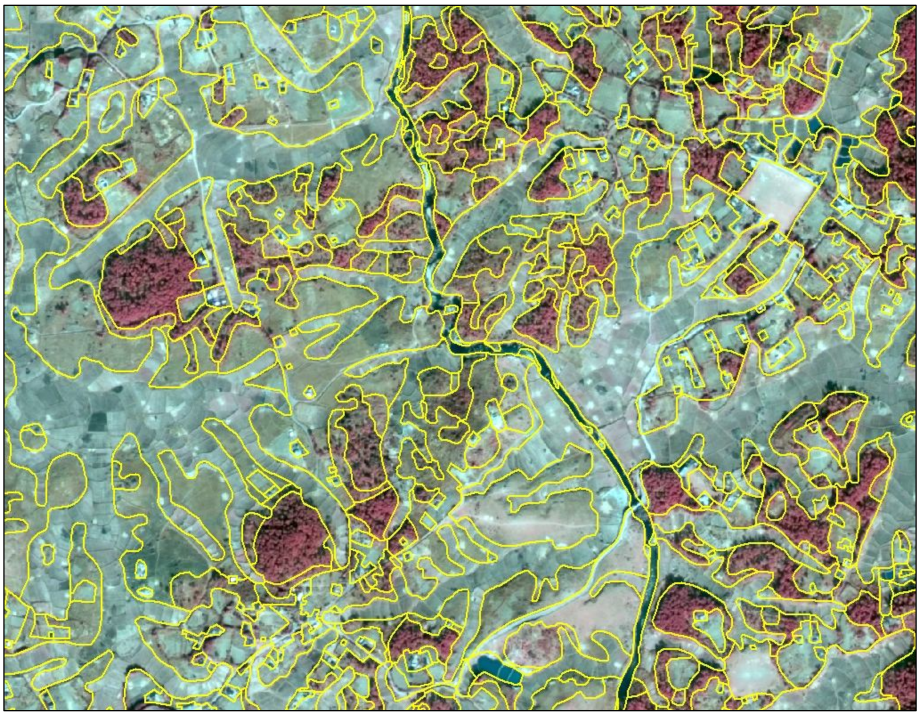
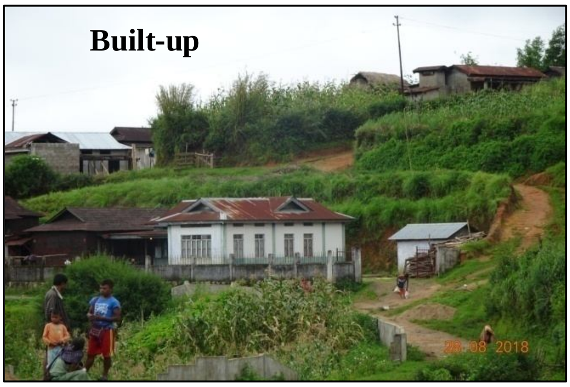


**Figure-29: Agriculture and Other Land Use Land Cover Layer Interpreted on Deimos-2 Image**

## 10.3. Classification System:

Agriculture and other land use/land cover units have been classified into built-up, agricultural land, waste lands, forest and water bodies depending on the local conditions.

**Built-up:** It is an area of human habitation developed due to non-agricultural use and that has a cover of buildings, industrial, transport and communication, utilities in association with water, vegetation, vacant lands and mining. Built-up land has been further classified as built-up, play ground, road cutting and mine/quarry.





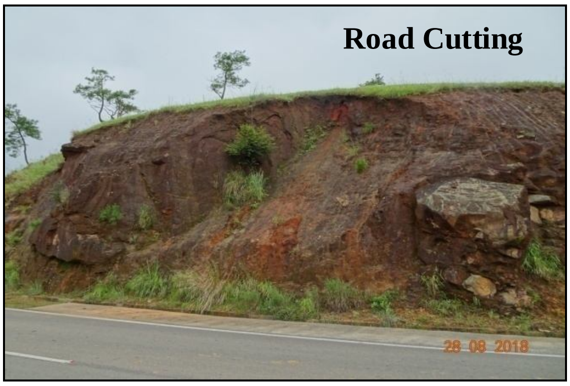



**Figure-30: Field Photographs of Built-up Categories**

**Agricultural Land:** These are the lands primarily used for farming and for production of food, fiber, and other commercial and horticultural crops.

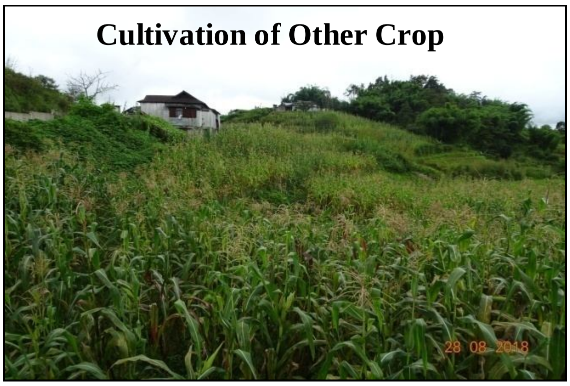




**Figure-31: Field Photographs of Agricultural Land Categories**

It includes land under crops (irrigated and un-irrigated, fallow, plantations etc.). They are further classified as paddy cultivation, cultivation of other crop, plantation, fallow land and aquaculture.


**Figure-32: Field Photograph of Agricultural Land Category**

**Forest:** These are the areas bearing an association predominantly of trees and other vegetation types (within the notified forest boundaries) capable of producing timber and other forest produce. They are further classified as scrub forest, open forest and moderately dense to dense forest.



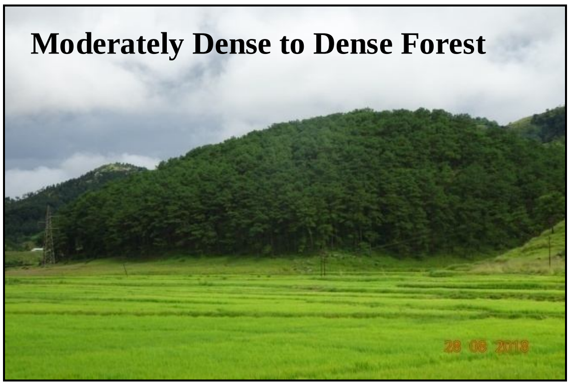



**Figure-33: Field Photograph of Forest Categories**

**Waste Land:** These are the degraded lands which can be brought under vegetative cover with reasonable effort and which are underutilized. Land, which is deteriorating for lack of appropriate water and soil management or on account of natural causes. They are further classified as grazing land and scrub land.


**Figure-34: Field Photograph Waste Lands**

**Water Bodies** This category comprises areas with surface water, either impounded in the form of ponds, lakes and reservoirs or flowing as streams, rivers etc. Based on the availability of water, water bodies are further classified as perennial and dry.

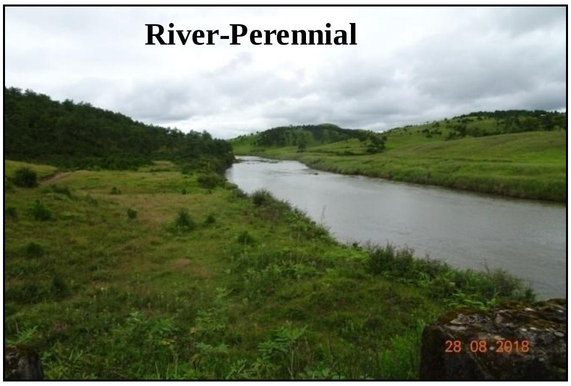




**Figure-35: Field Photograph of Water Bodies**

## 10.4. Legend:

Legend for Agriculture and Other Land Use Land Cover map has been prepared with different colours and labeled with numeric number for all the agriculture and other land use /land cover categories as shown in the Figure-36, to identify each unit easily

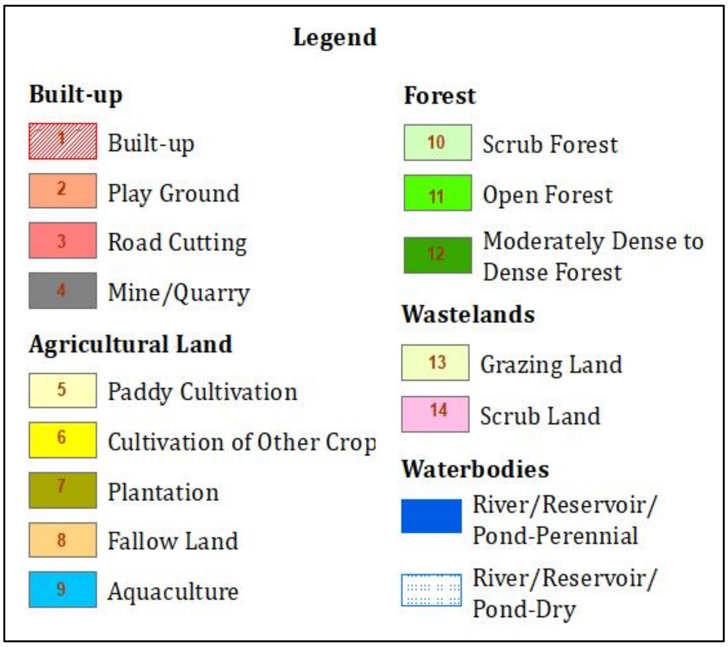



**Figure-36: Legend of Agriculture and Other Land Use /Land Cover Map**

## 10.5. Distribution of Agriculture and Other Land Use Land Cover Class:

From the Agriculture and Other Land Use Land Cover map prepared, it has been observed that most of the area (i.e., 28.1%) is covered by moderately dense to dense forest; scrub forest covers 10.1% and open forest covers 9%. Other than forest area, grazing land covers 17% and paddy cultivation covers 15.8%. Agriculture and Other Land Use Land Cover class wise area occupied is shown in the Figure-37 and given in the Table-7.

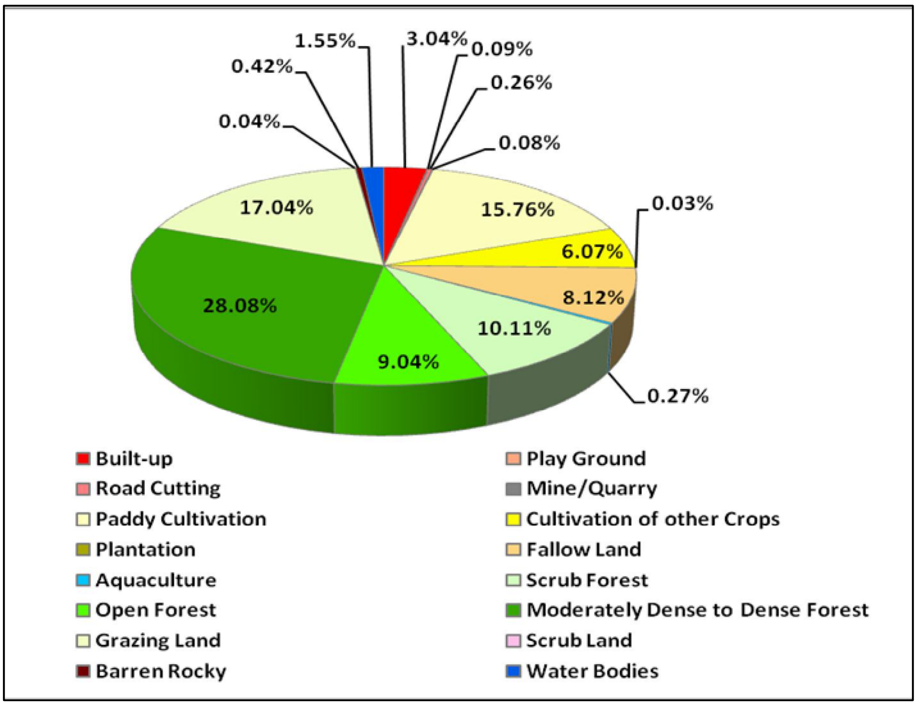



**Figure-37: Distribution of Agriculture and Other Land Use Land Cover Units Mapped**

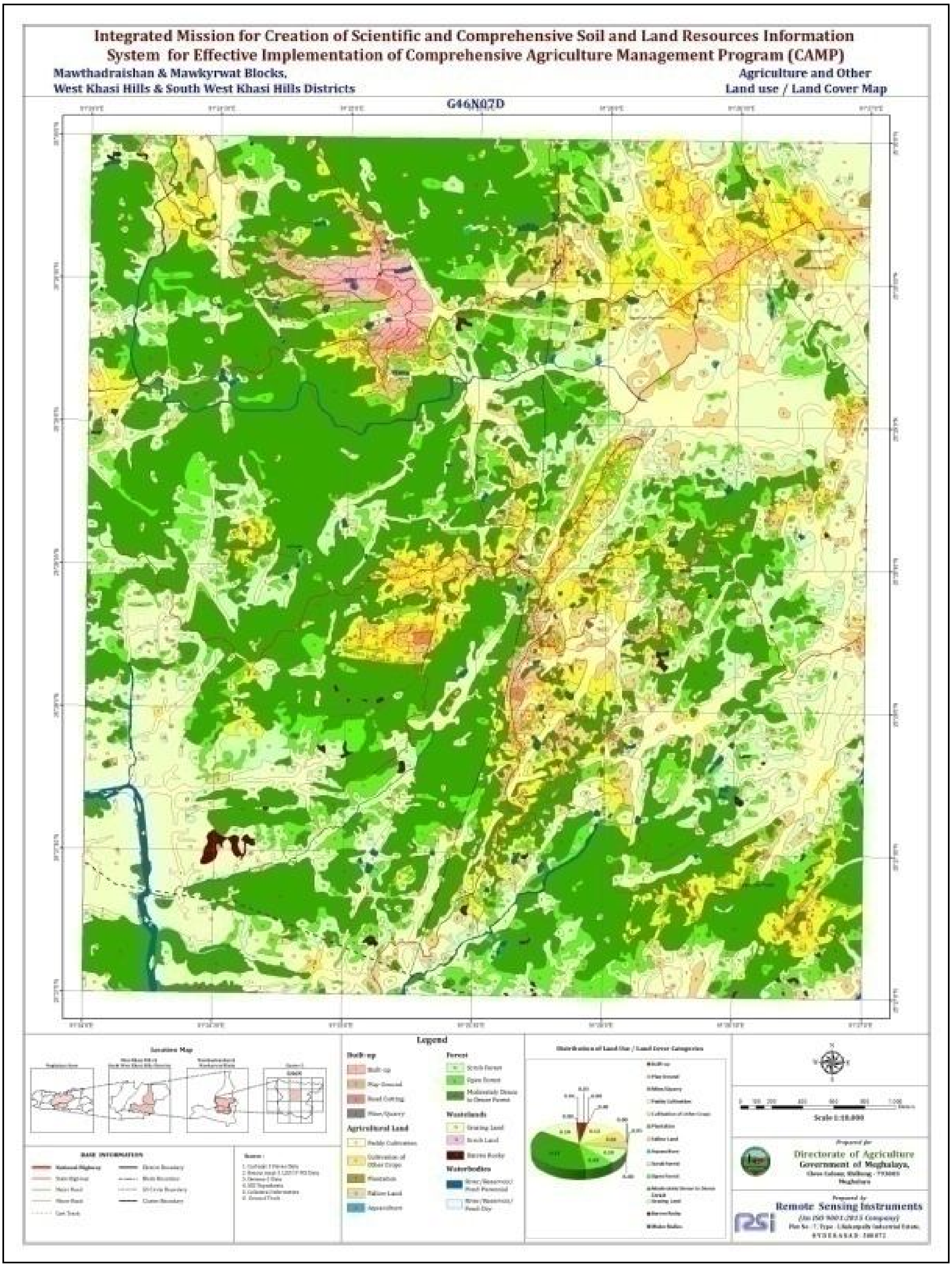
**Table-7: Details of Agriculture and Other Land Use Land Cover Mapped**

| Sl. No. | Agriculture and Other Land Use Land Cover Class | Area (in hectares) | Percentage to Cluster-2 Area |
|---|---|---|---|
| 1 | Built-up | 766.62 | 3.04 |
| 2 | Play Ground | 22.22 | 0.09 |
| 3 | Road Cutting | 66.05 | 0.26 |
| 4 | Mine/Quarry | 19.81 | 0.08 |
| 5 | Paddy Cultivation | 3,973.92 | 15.76 |
| 6 | Cultivation of other Crops | 1,531.44 | 6.07 |
| 7 | Plantation | 8.77 | 0.03 |

| Sl. No. | Agriculture and Other Land Use Land Cover Class | Area (in hectares) | Percentage to Cluster-2 Area |
|---|---|---|---|
| 8 | Fallow Land | 2,046.36 | 8.12 |
| 9 | Aquaculture | 67.90 | 0.27 |
| 10 | Scrub Forest | 2,549.18 | 10.11 |
| 11 | Open Forest | 2,279.46 | 9.04 |
| 12 | Moderately Dense to Dense Forest | 7,079.93 | 28.08 |
| 13 | Grazing Land | 4,297.64 | 17.04 |
| 14 | Scrub Land | 9.39 | 0.04 |
| 15 | Barren Rocky | 105.24 | 0.42 |
| 16 | Water Bodies | 391.92 | 1.55 |
| | **Total Area** | **25,215.83** | **100.00** |

## 10.6. Map Composition:

Agriculture and Other Land Use Land Cover map has been composed in GIS environment along with proper legend, scale bar, north arrow, source and base information. Each unit of the map has been labeled with numeric number to identify easily. Agriculture and Other Land Use Land Cover map prepared for a grid is shown in the Figure-38 and for Cluster-2 is shown in the Figure-39.




**Figure–38: Agriculture and Other Land Use Land Cover Map of a Grid**

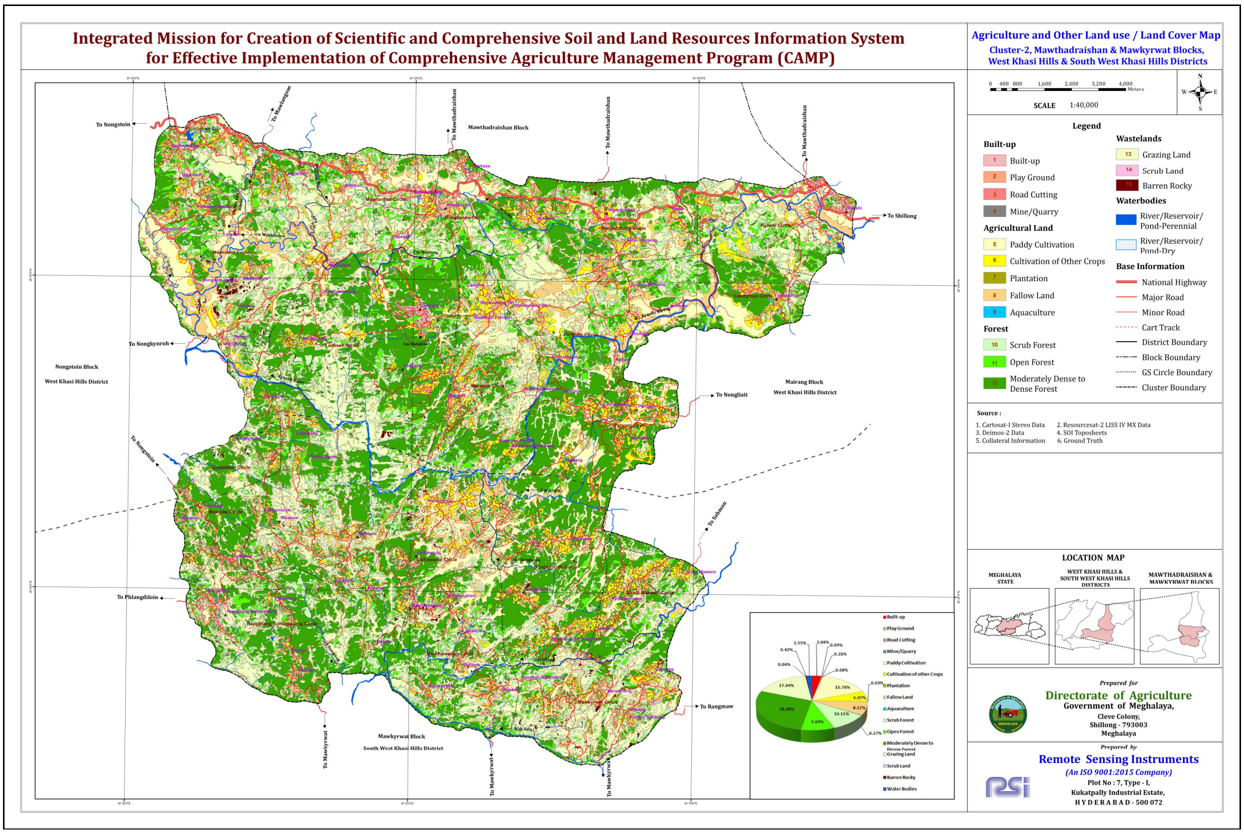



Figure-39: Agriculture and Other Land Use Land Cover Map of Cluster-2

# CHAPTER-11

# PREPARATION OF SLOPE MAP

## 11.1. Introduction:

Slope is an indicator of relief energy because it helps in the formation of erosional as well as depositional features. It is also an important indicator to understand the amount of precipitation that goes as runoff, land capability and land irrigability of the area and also to understand the vulnerability to natural hazards like landslides and floods.

Information on slope is particularly relevant to the north-eastern hill states, including Meghalaya, as it is an important parameter in planning developmental activities, soil conservation measures and in disaster mitigation studies.

## 11.2. Methodology:

Slope is a measurement of gradient of steepness between two places or points on land surface. It is measured as ratio of vertical interval and horizontal distance of a given surface. The slope is expressed in percentages or degrees.

Mapping of different slope categories has been carried out in Arc GIS environment by using contours of 5m interval and DEM generated from CARTOSAT-1 Stereo Data. Slope percentages have been derived from the following formula.

$$\text{Slope Percentage} = \frac{\text{Contour interval in meters}}{\text{Distance between the contours in meters x Scale factor}} \times 100$$

## 11.3. Classification System:

Based on the slope percentage, slope categories have been classified into 8 categories, depending on the local conditions, namely level to nearly level, very gently sloping, gently sloping, gently to moderately sloping, moderately sloping, moderately steeply sloping, steeply sloping and very steeply sloping based on slope percentage as given in the Table-8.

## 11.4. Legend:

Legend for slope map has been prepared with different colours and labeled with numeric number for all the slope categories as shown in the Table-8, to identify each unit easily. Slope percentage and description have been mentioned in the legend for each unit.

**Table – 8: Legend of Slope Map with Classification System**

| Map Symbol | Slope % | Description |
|---|---|---|
| 1 | 0-1 | Level to Nearly Level |
| 2 | 1-3 | Very Gently Sloping |
| 3 | 3-5 | Gently Sloping |
| 4 | 5-10 | Gently to Moderately Sloping |
| 5 | 10-15 | Moderately Sloping |
| 6 | 15-35 | Moderately Steeply Sloping |
| 7 | 35-70 | Steeply Sloping |
| 8 | > 70 | Very Steeply Sloping |

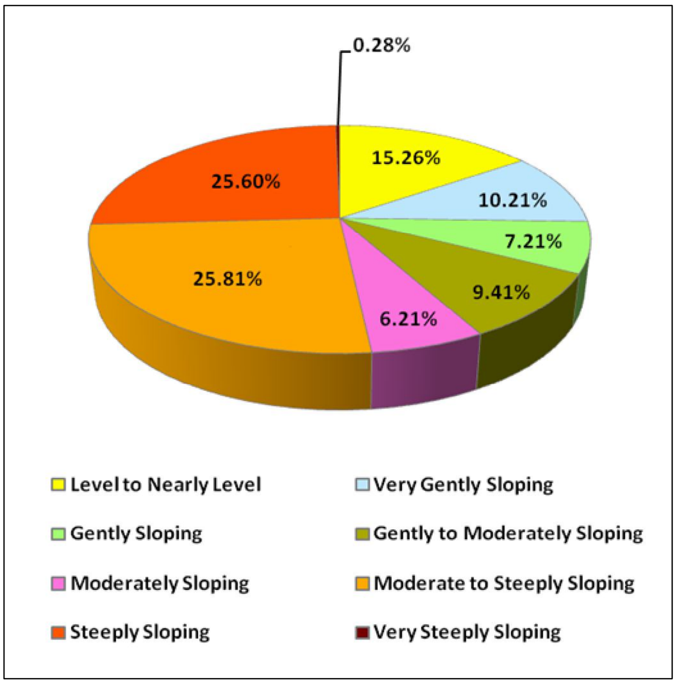
## 11.5. Distribution of Slope Categories:

From the slope map prepared, it has been observed that, moderately steeply sloping (15-35% slope) ground is occupied by 25.8% and steeply sloping (35-70% slope) ground is occupied by 25.6%, whereas 25.4% of the area is occupied by having < 3% slope. Slope category wise area occupied is given in the Table-9 and shown in the Figure-40.

**Table–9: Details of Slope Categories Mapped**

| Slope Category | Slope % | Description | Area (in hectares) | Percentage to Cluster-2 Area |
|---|---|---|---|---|
| 1 | 0 -1 | Level to Nearly Level | 3,846.97 | 15.26 |
| 2 | 1-3 | Very Gently Sloping | 2,575.49 | 10.21 |
| 3 | 3-5 | Gently Sloping | 1,819.04 | 7.21 |
| 4 | 5-10 | Gently to Moderately Sloping | 2,373.66 | 9.41 |
| 5 | 10-15 | Moderately Sloping | 1,565.18 | 6.21 |
| 6 | 15-35 | Moderately Steeply Sloping | 6,507.91 | 25.81 |
| 7 | 35-70 | Steeply Sloping | 6,456.06 | 25.60 |
| 8 | >70 | Very Steeply Sloping | 71.51 | 0.28 |
| | | **Total Area** | **25,215.83** | **100.00** |

**Figure–40: Distribution of Slope Categories Mapped**




## 11.6. Map Composition:

Slope map has been composed in GIS environment along with proper legend, scale bar, north arrow, source and base information. Each slope unit has been labeled with numeric number to identify easily in the map. Slope map prepared for Cluster-2 is shown in the Figure-41 and for a grid is shown in the Figure-42.

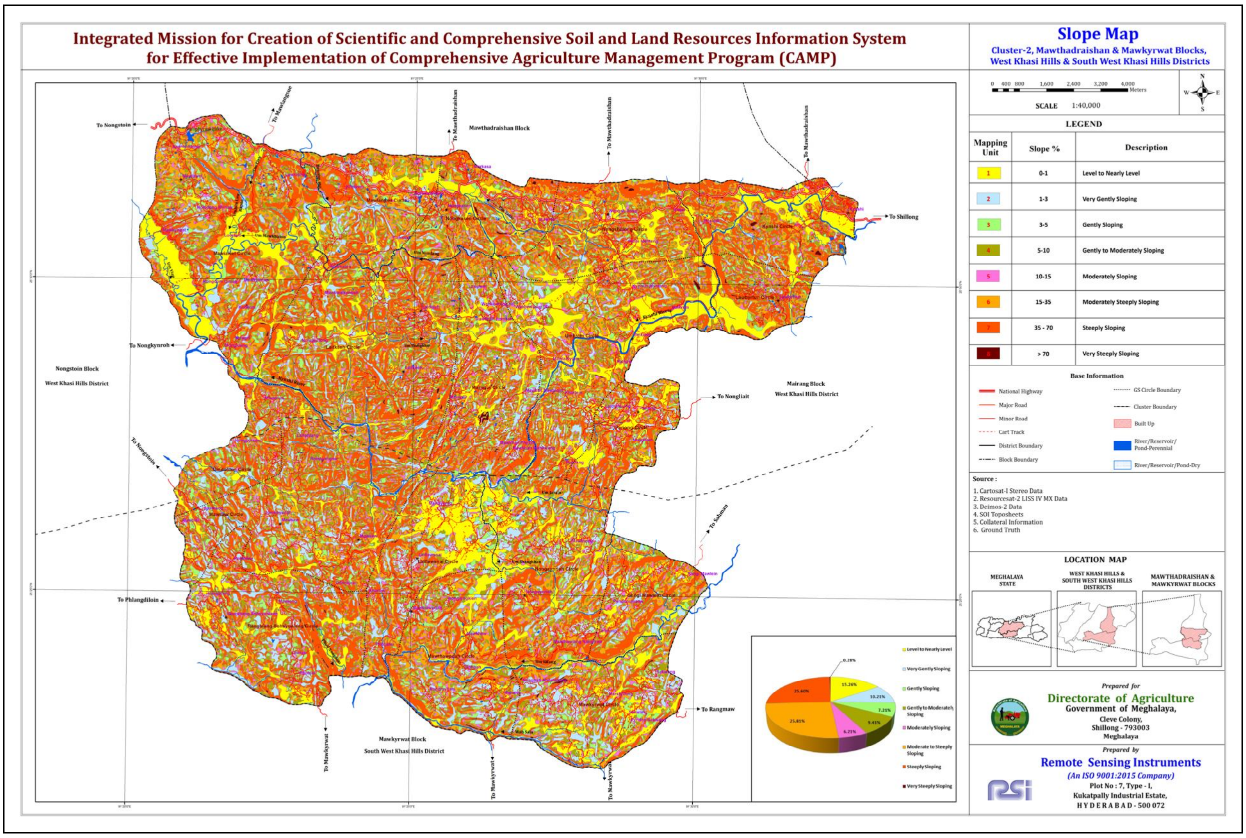
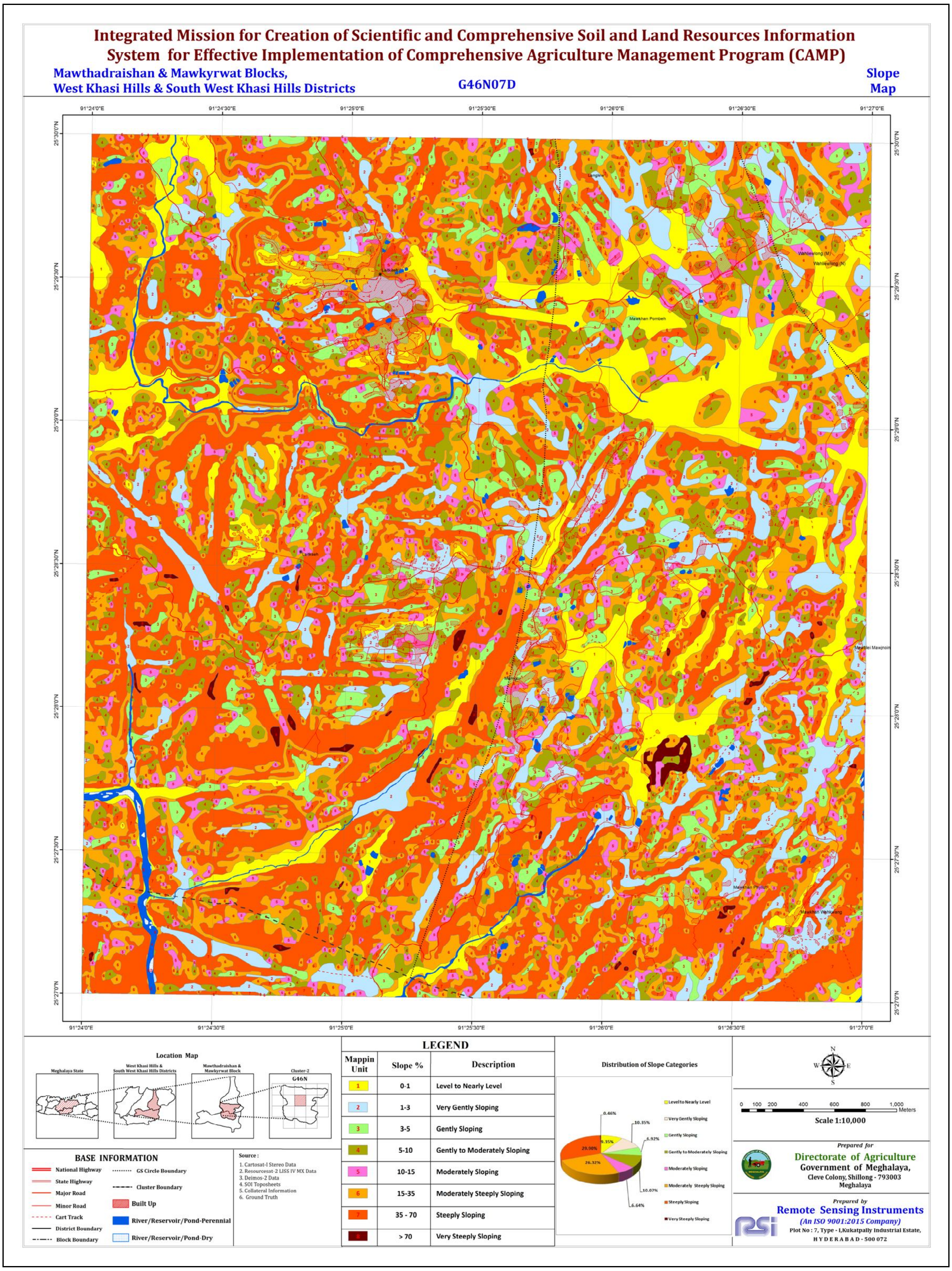



**Figure-41: Slope Map of Cluster-2**




**Figure–42: Slope Map of a Grid**

# CHAPTER -12

# PREPARATION OF HYDRO-GEOMORPHOLOGY MAP

## 12.1. Introduction:

Hydro-geomorphology is the combination of rock type/, landforms/ geomorphology, structure and recharge conditions. In the hydro-geomorphological unit the parameters namely rock type/lithology, landform/geomorphology, structure and recharge conditions are unique and the ground water prospects are expected to be unique.

Groundwater is considered as the preferred source of water for meeting domestic, industrail and agricultural requirements. However, the occurrence of groundwater is not uniform and is subject to wide spatio-temporal variations depending on the under lying rock formations, their structural fabric and geometry, surface expression etc. The role of geomorphology is decisive to correctly evaluate ground water resources. Hard-rock hydrogeological systems commonly exhibit complex geological and morphological features.

## 12.2. Methodology:

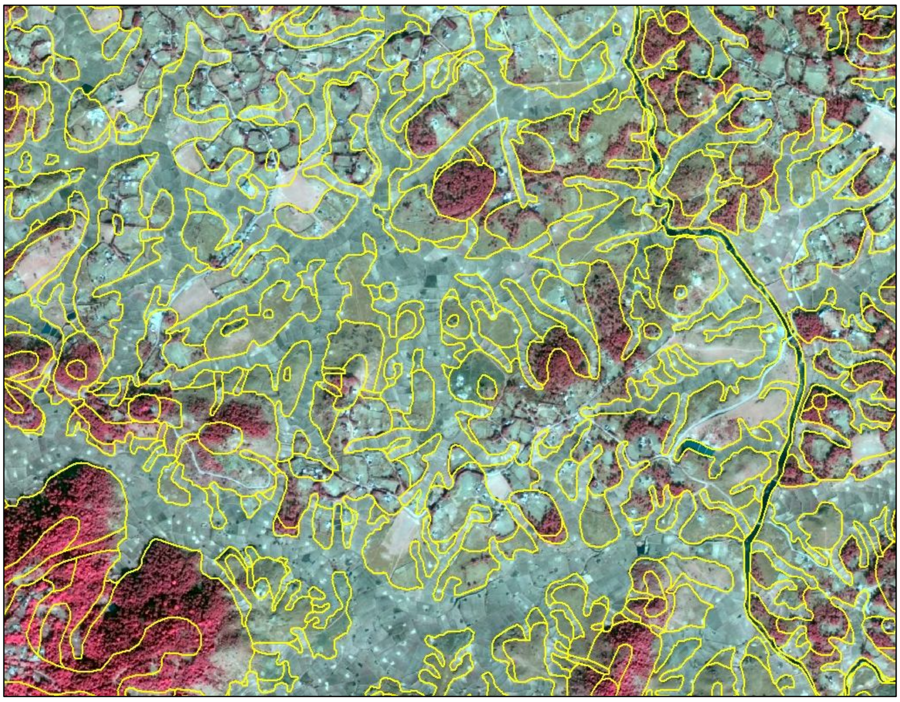
Hydro-geomorphology map has been prepared by the combination of lithology, geomorphology and lineament layers which have been prepared by visual interpretation of satellite data.

## 12.3. Preparation of Geomorphology Map:

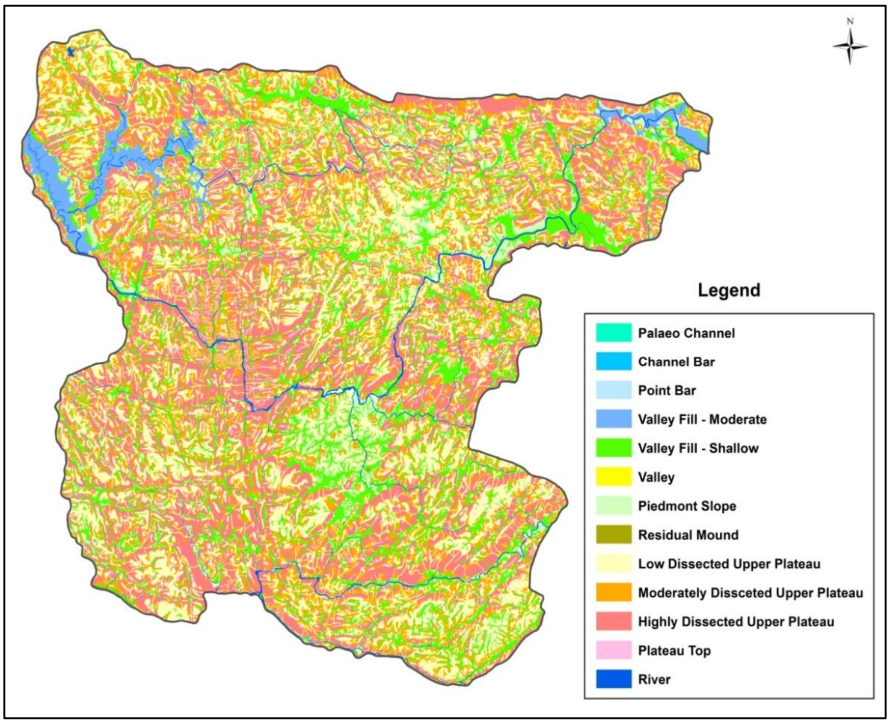
Geomorphology is an important theme, which brings out the spatial and temporal distribution of the landforms. Geomorphology, along with information on soil, water and vegetation has become one of the essential inputs in planning for various developmental activities.

All the land forms/ geomorphic units occuring in this cluster have been mapped by visual interpretation of satellite data with reference to SOI toposheets as shown in the Figure-43. Some of the units are further classified based on weathering, dissection and slope based on the local conditiopns. Each geomorphic unit has been assigned with two digit numeric code.

The geomorphic units delineated along with their codes are Channel Bar (01), Point Bar (02), Palaeo Channel (03), Valley Fill-Moderate (04), Valley Fill-Shallow (05), Valley (06), Piedmont Slope (067), Residual Mound (08), Less Dissected Upper Plateau (09), Moderately Dissected Upper Plateau (10), Plateau Top (11) and Highly Dissected Upper Plateau (12).



**Figure–43: Part of Geomorphology layer interpreted on Deimos-2 Image**




**Figure–44: Geomorphology layer Prepared from Deimos-2 Image**

## 12.4. Ground Truth:

The ground truth has been carried out by the subject specific thematic specialists to collect information in the field regarding all doubtful areas noted down in the pre-field interpretation and also to confirm the pre-field interpretation. Necessary corrections and additions have been noted in the field dairies. Representative photographs for each geomorphic unit were taken and their precise location recorded through handheld GPS receivers. Some of the photographs of different geomorphic units captured in the field are shown in the Figures-45. Then the geomorphology map has been finalized by incorporating modifications noted in the field and the same is shown in the Figure-44.

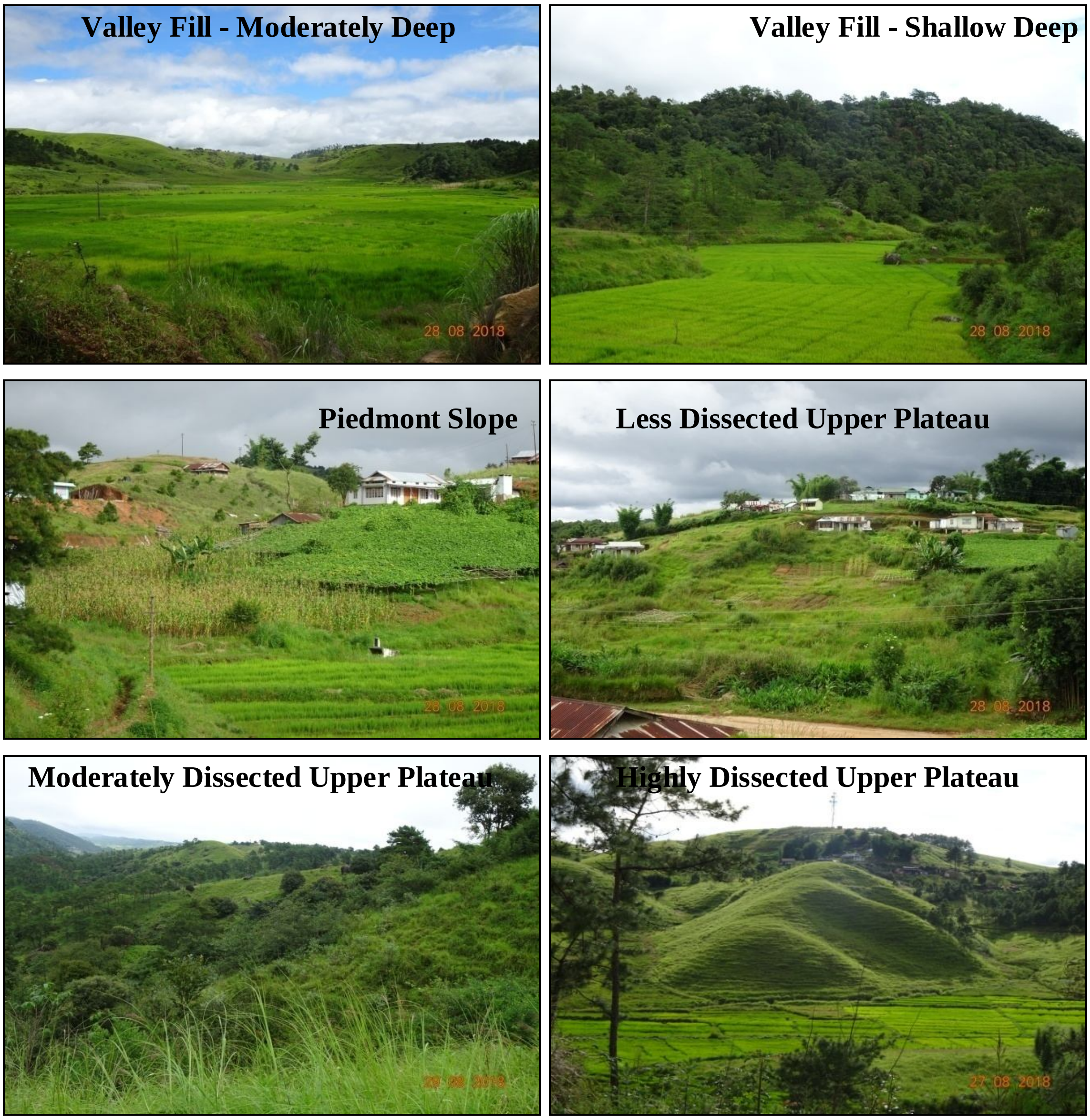



**Figure-45: Field Photographs of Geomorphic units**

## 12.5. Distribution of Geomorphic Units:

From the geo-morphology map prepared, it has been observed that most of the area (i.e., 26.7%) is highly dissected upper plateau, 19.8% of the area is less dissected upper plateau, 18.3% of the area is moderately dissected upper plateau and 17.3% area is of valley fill. Geomorphic unit wise area covered is given in the Table-10 and shown in the Figure-46.

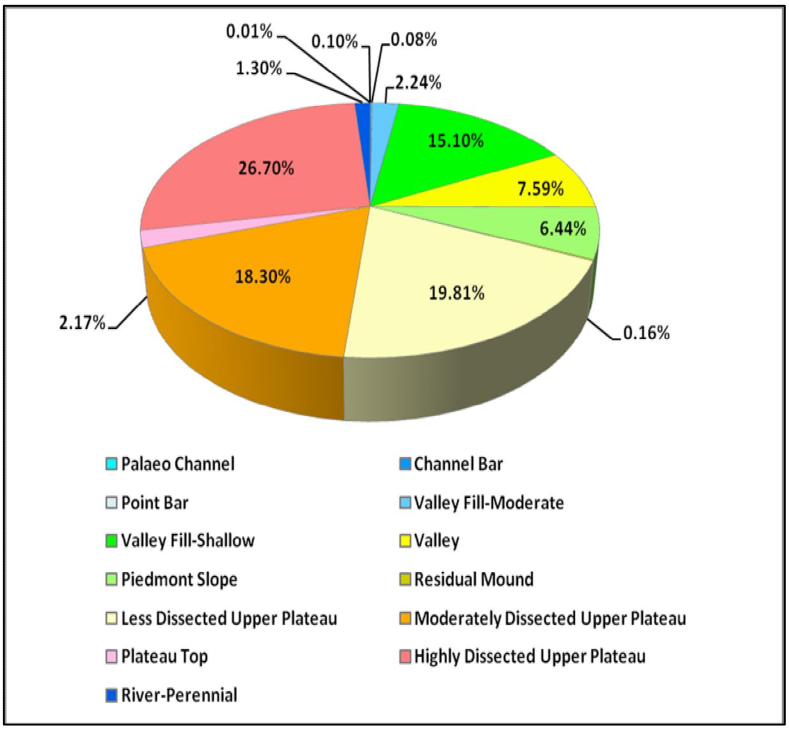



**Figure-46: Distribution of Geomorphic Units Mapped**

**Table-10: Details of Geomorphic Units Mapped**

| Unit Code | Geomorphic Unit | Area (in hectares) | Percentage to Cluster-2 Area |
|---|---|---|---|
| 01 | Channel Bar | 25.00 | 0.10 |
| 02 | Point Bar | 18.97 | 0.08 |
| 03 | Palaeo Channel | 1.70 | 0.01 |
| 04 | Valley Fill-Moderate | 564.98 | 2.24 |
| 05 | Valley Fill-Shallow | 3,806.66 | 15.10 |
| 06 | Valley | 1,913.35 | 7.59 |
| 07 | Piedmont Slope | 1,624.29 | 6.44 |
| 08 | Residual Mound | 39.82 | 0.16 |
| 09 | Less Dissected Upper Plateau | 4,996.43 | 19.81 |
| 10 | Moderately Dissected Upper Plateau | 4,614.80 | 18.30 |

| Unit Code | Geomorphic Unit | Area (in hectares) | Percentage to Cluster-2 Area |
|---|---|---|---|
| 11 | Plateau Top | 547.54 | 2.17 |
| 12 | Highly Dissected Upper Plateau | 6,733.80 | 26.70 |
| 13 | River-Perennial | 328.49 | 1.30 |
| | **Total Area** | **25,215.83** | **100.00** |

## 12.6. Preparation of Lithology Map:

All the rock formations occuring have been mapped under lithology layer by visual interpretation of satellite data based on the geological data of Geological Survey of India (GSI). For this, Geological and Mineral Map of Meghalaya collected from the Govt. Department has been used. In this lithology map, three units have been mapped and details of the same are given in the Table-11 and shown in the Figure-47. Each litho unit has been assigned with single digit numeric code.

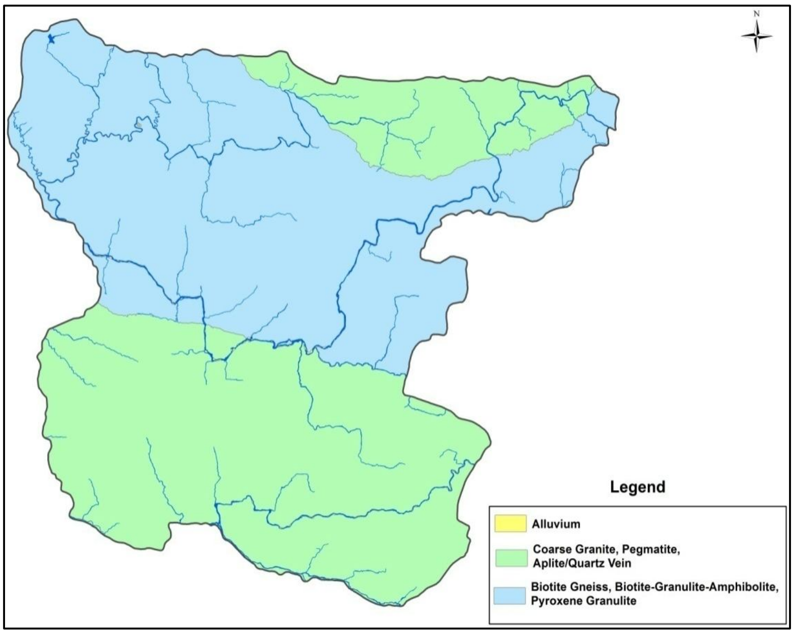



**Figure-47: Lithology Layer Prepared**

**Table-11: Lithological Units Mapped**

| Litho Unit | Lithology | Stratigraphy | Age |
|---|---|---|---|
| 1 | Alluvium | ---- | Holocene |
| 2 | Coarse Granite, Pegmatite, Aptite/Quartz Vein | Granite Plutons | Neo Proterozoic to Lower Palaeozoic |
| 3 | Biotite Gneiss, Biotite-Granulite-Amphibolite-Pyroxene Granulite | Gneissic Complex | Archaean-Proterozoic |

## 12.7. Preparation of Lineaments Map:

All the linear features except anthropogenic/cultural features like roads, railway lines, high tension lines etc., have been mapped as lineaments by visual interpretation of satellite data based on their linear nature, presence of moisture, alignment of vegetation, alignment of ponds, straight stream segments etc. These lineaments have been classified as major and minor based on their length. The lineaments map prepared for Cluster-2 is shown in the Figure-48.

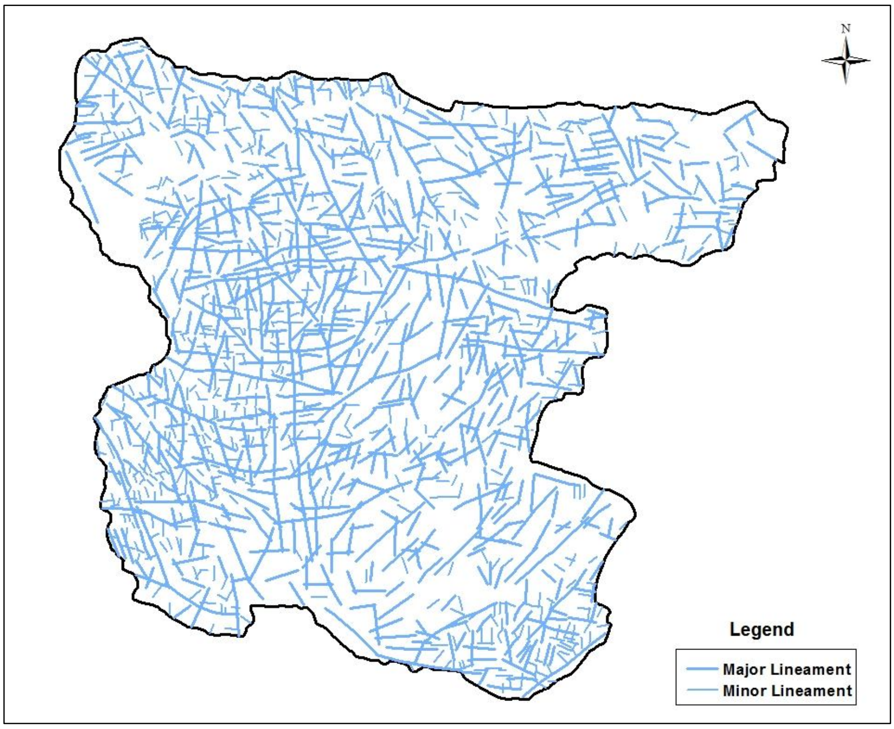



**Figure-48: Lineaments Layer Prepared from Deimos-2 Image**

## 12.8. Classification of Ground Water Prospects:

Ground water prospects have been classified into eight qualitative classes of ground water prospects viz, very good, good to very good, good, moderate to good, moderate, poor to moderate, poor and nil to poor. Different colours have been assigned to all the ground water prospects class shown in the Figure-49 to identify easily.

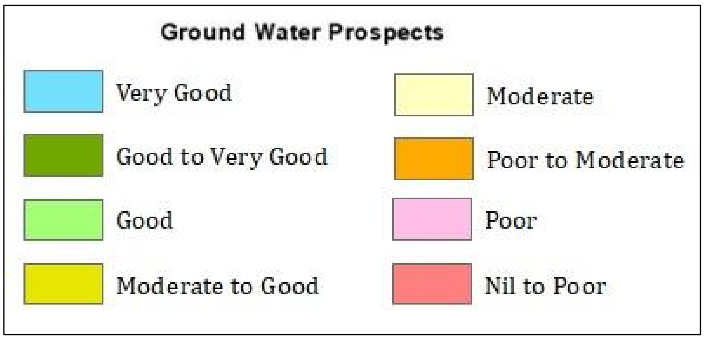



**Figure-49: Classes of Ground Water Prospects**

## 12.9. Preparation of Hydro-geomorphology Map:

Hydro-geomorphology layer has been prepared based on the integration of lithology and geomorphology layer in GIS environment. By integration of these layers lith-geom unit has been derived. Each lith-geom unit has been assigned with three digit numeric code as shown in the Figure-66. First letter indicate the lithology, second and third letters indicate the geomorphic unit. Ground water prospects has been assigned for each lith-geom unit by considering the hydrological conditions of that particular unit.

## 12.10. Legend:

Legend for hydro-geomorphology map has been prepared by assigning ground water prospects colours to each lith-geom unit and labeled with numeric code for all the lith-geom units as shown in the Figure-50a&b, to identify each unit easily. Lithology, stratigraphy, geological age, geomorphic unit and ground water prospects assigned for each lith-geom unit have been mentioned in the legend.

| Mapping Unit | Lithology | Statigraphy | Age | Geomorphic Unit | Ground Water Prospects |
|---|---|---|---|---|---|
| 101 | Alluvium (1) | ... | Holocene | Channel Bar (01) | Very Good |
| 102 | | | | Point Bar (02) | Very Good |
| 103 | | | | Palaeo Channel (03) | Very Good |
| 204 | Coarse Granite, Pegmatite, Aplite/Quartz Vein (2) | Granite Plutons | Neo Proterozoic to Lower Palaeozoic | Valley Fill - Moderate (04) | Good to Very Good |
| 205 | | | | Valley Fill - Shallow (05) | Good |
| 206 | | | | Valley (06) | Moderate to Good |
| 207 | | | | Piedmont Slope (07) | Moderate to Good |
| 208 | | | | Residual Mound (08) | Moderate |
| 209 | | | | Less Dissected Upper Plateau (09) | Moderate |
| 210 | | | | Moderately Dissected Upper Plateau (10) | Poor |
| 211 | | | | Plateau Top (11) | Poor to Moderate |
| 212 | | | | Highly Dissected Upper Plateau (12) | Nil to Poor |

**Figure–50a: Legend of Hydro-geomorphology Map**

| Mapping Unit | Lithology | Statigraphy | Age | Geomorphic Unit | Ground Water Prospects |
|---|---|---|---|---|---|
| 304 | Biotite Gneiss, Biotite-Granulite-Amphibolite, Pyroxene Granulite (3) | Gneissic Comlex | Archean - Proterozoic | Valley Fill - Moderate (04) | Good to Very Good |
| 305 | | | | Valley Fill - Shallow (05) | Good |
| 306 | | | | Valley (06) | Moderate to Good |
| 307 | | | | Piedmont Slope (07) | Moderate to Good |
| 308 | | | | Residual Mound (08) | Moderate |
| 309 | | | | Less Dissected Upper Plateau (09) | Moderate |
| 310 | | | | Moderately Dissected Upper Plateau (10) | Poor |
| 311 | | | | Plateau Top (11) | Poor to Moderate |
| 312 | | | | Highly Dissected Upper Plateau (12) | Nil to Poor |

**Figure–50b: Legend of Hydro-geomorphology Map**

## 12.11. Distribution of Ground Water Prospects:

From the hydro-geomorphology map prepared, it has been observed that, most of the area (i.e., 26.7%) is having nil to poor ground water prospects, 20% of the area is having moderate ground water prospects, 18% of the area is having poor ground water prospects, 15% of the area is having good ground water prospects, and 14% of the area is having moderate to good ground water prospects. Ground water prospects wise area covered is given in the Table-12 and shown in the Figure-51.

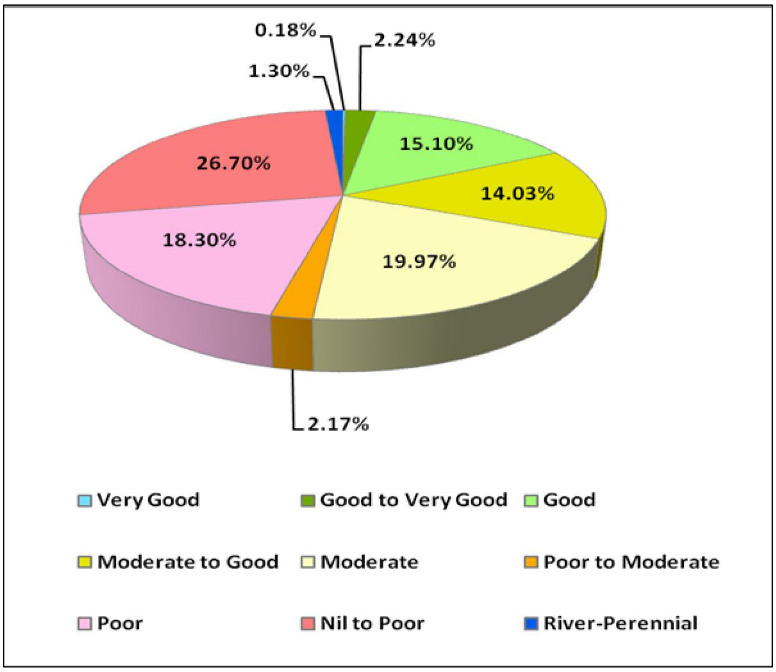



**Figure-51: Distribution of Ground Water Prospects**

**Table-12: Details of Ground Water Prospects**

| Sl. No. | Ground Water Prospects | Area (in hectares) | Percentage to Cluster-2 Area |
|---|---|---|---|
| 1 | Very Good | 45.68 | 0.18 |
| 2 | Good to Very Good | 564.98 | 2.24 |
| 3 | Good | 3,806.66 | 15.10 |
| 4 | Moderate to Good | 3,537.64 | 14.03 |
| 5 | Moderate | 5,036.25 | 19.97 |
| 6 | Poor to Moderate | 547.54 | 2.17 |
| 7 | Poor | 4,614.80 | 18.30 |
| 8 | Nil to Poor | 6,733.80 | 26.70 |
| 9 | River-Perennial | 328.49 | 1.30 |
| | **Total Area** | **25,215.83** | **100.00** |

### 12.12. Map Composition:

Hydro-geomorphology map has been composed in GIS environment along with proper legend, lineaments, scale bar, north arrow, source and base information. Each lith-geom unit has been labeled with numeric number to identify easily in the map. Hydro-geomorphology map prepared for a grid is shown in the Figure-52 and for Cluster-2 is shown in the Figure-53.

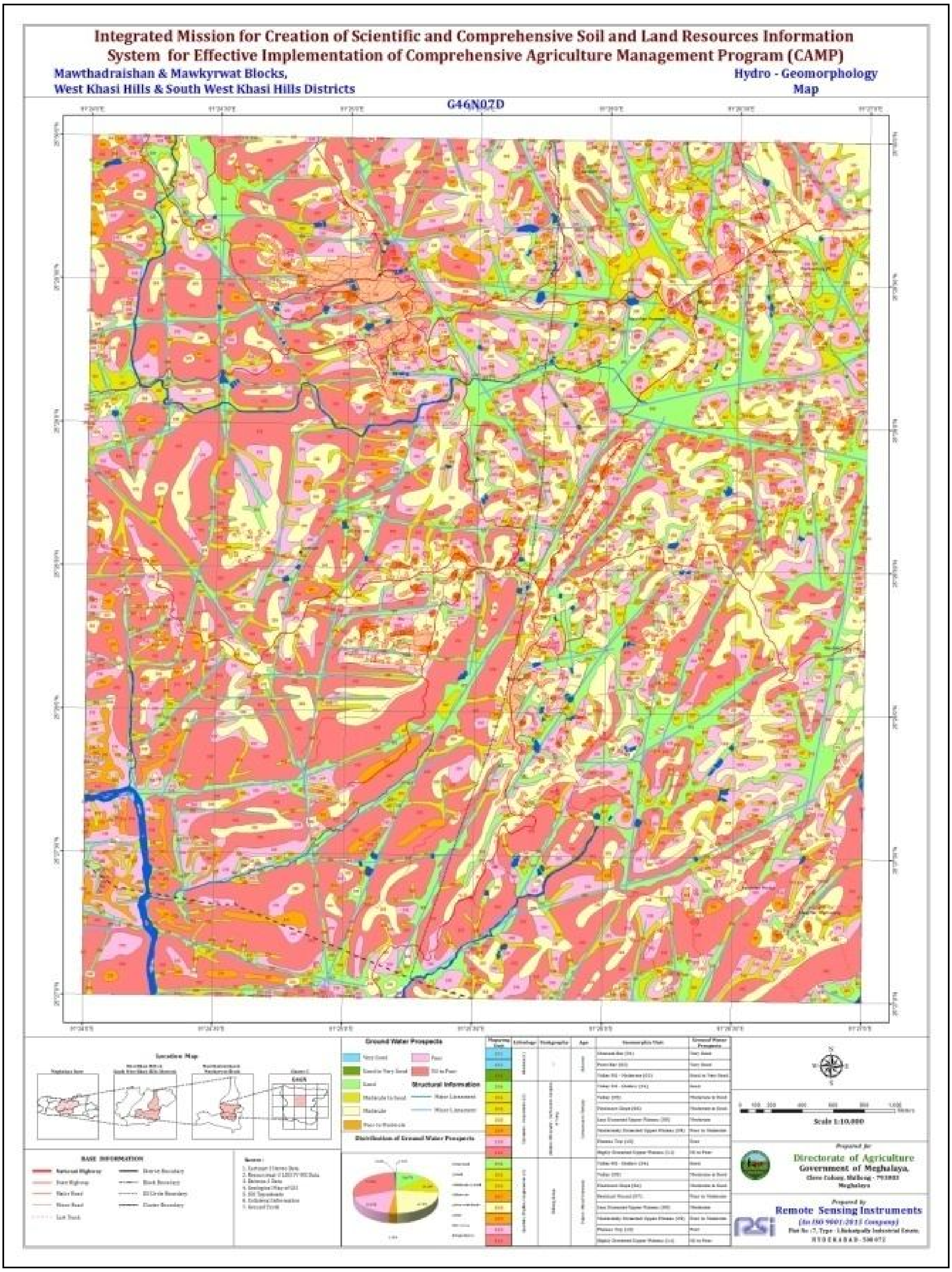



**Figure-52: Hydro-geomorphology Map of a Grid**

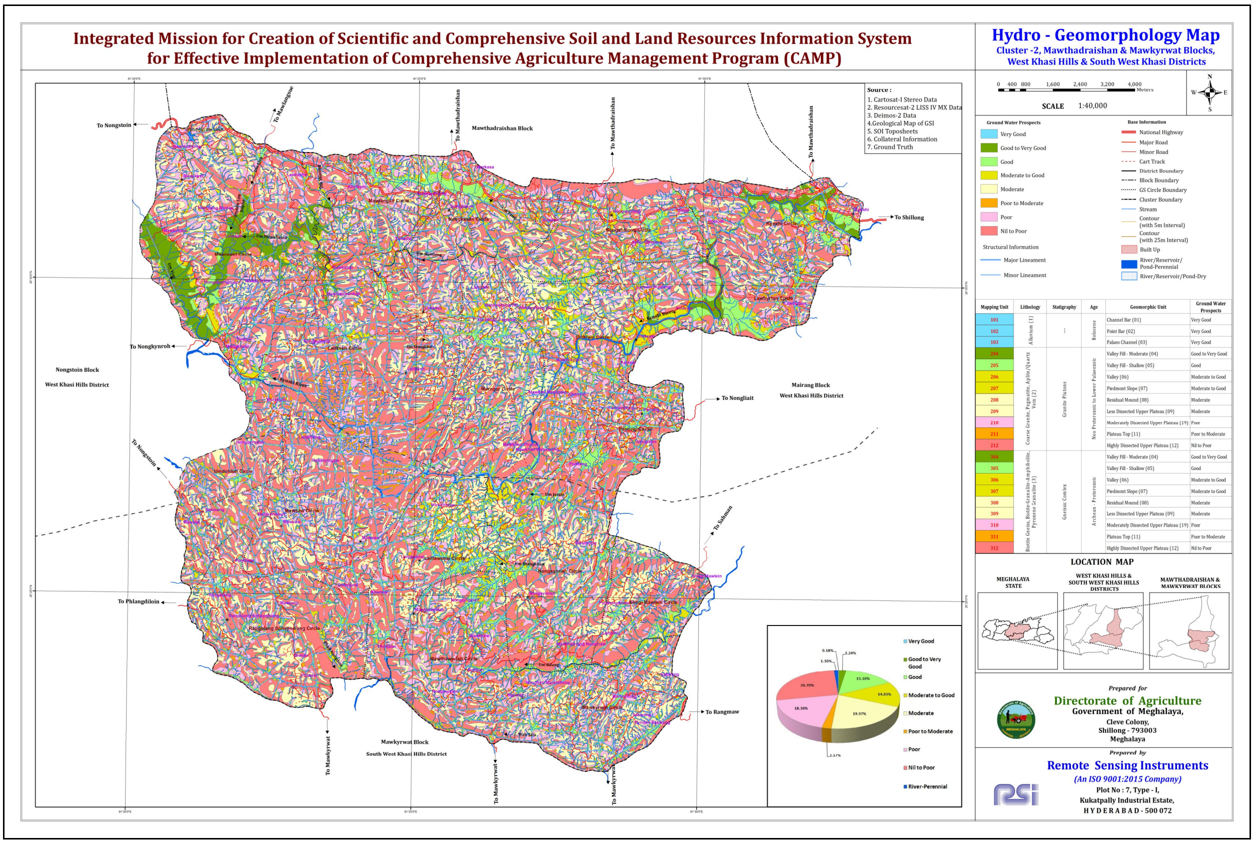



**Figure-53: Hydro-geomorphology Map of Cluster-2**

# CHAPTER-13

# PREPARATION OF SOIL MAP

## 13.1. Introduction:

Soil is a non-renewable natural resource and plays an important role in all the human related developmental activities. It is a major component of land system and important ingredient of primary production system. It is, therefore, necessary to have scientific information about the nature and types of soils of an area for planning for sustainable agriculture production.

The potentials and limitations of a soil for its use under varied farming systems like agriculture, horticulture, silviculture and pasture development as well as its responses to irrigation and agricultural chemicals are controlled by its inherent qualities. The qualities of a soil are derived from a set of its morphological, physical, chemical and physico-chemical characteristics. These characteristics are expressed in a taxonomic class as shown on soil map with location references. The soil map thus helps to know the qualities and characteristics of soils of the area to understand their problems, potentials and management needs for their optimal use, within the limitations of scale-specific abstraction level.

The soil map of the project area is aimed at fulfilling the following specific objectives.

- To characterize the soils for their morphological, physical and chemical properties
- To understand the land degradation problems in each soil type
- To classify the soils as per soil taxonomy
- To classify the lands as per the land capability classification
- To classify the lands as per the irrigability potential (Irrigability Classification)
- To evaluate the soils for their suitability for different crops
- To prepare the action plan for land resource development

The basic purpose of soil survey is to obtain clear understanding of the soils for their optimal utilization consistent with their qualities and potentials. It enables organizing and providing information on characteristics of the different soil class and evaluates their behaviour under different management systems. The data obtained from soil survey is translated for several varied uses.

## 13.2. Methodology:

Traditionally soil mapping will be carried out by field traversing procedures which are tedious, slow, subjective and limited to accessible areas only. Application of Remote Sensing helps to overcome these shortcomings of traditional system. Remote sensing methodology has been followed using Deimos-2 data for soil mapping. Deimos-2 satellite data was visually interepreted on screen for different soil mapping units as shown in the Figure-54, considering overall lithology, slope and land use land cover.

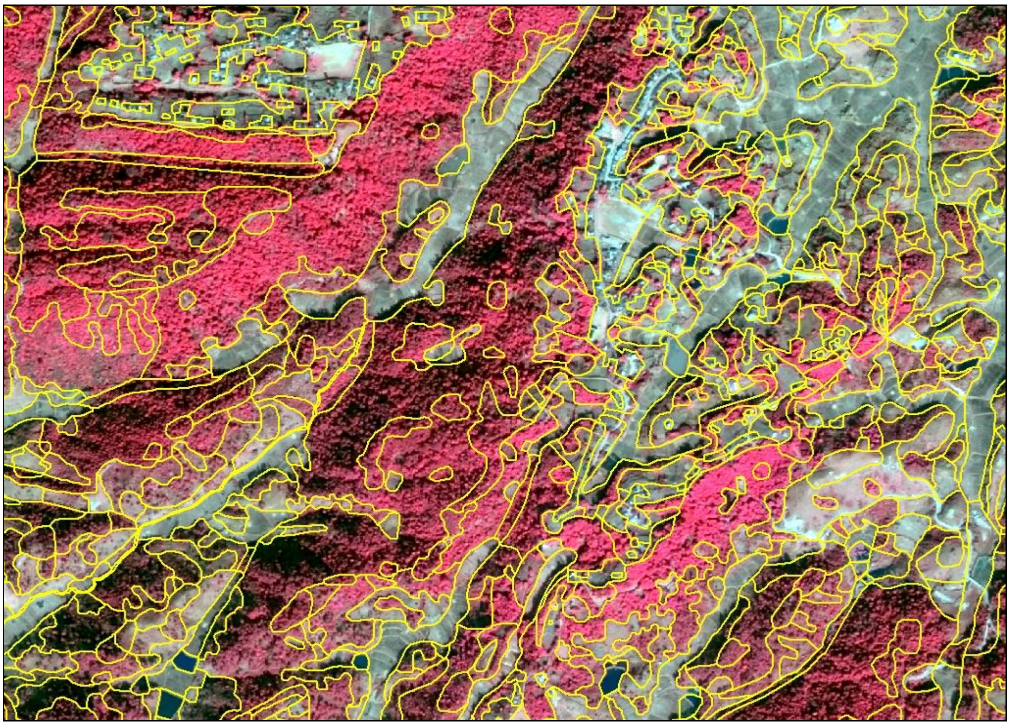


**Figure-54: Part of Soil units Mapped on Deimos-2 Image**

## 13.3. Soil Profile Studies:

Soil profile points have been selected to represent each mapping unit for ground truth collection. Field work was carried out by digging soil profiles as shown in the Figure-56, at the identified soil profile points. 94 soil profile pits have been dug upto a depth of 1 to 1.5m or upto the encounter of weathered parent material. 406 soil samples have been collected from these soil profile pits at different depths for analysis.


**Figure-55: Soil Profile Studies in the Field**

Soil profiles of the pits have been studied and noted the physical and morphological characteristics of the soil. Morphological characteristics for few soil samples collected from three soil profile pits are given in the Table-13.

**Table-13: Morphological Characteristics of Soil Samples Collected**

| Profile No. | Horizon Designa-tion | Depth (Cm) | Matrix Colours | | Texture | Coarse Fragments | | Structure | | | Consistence | | | Clay Cutans | | Roots | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | % | Type | | | | | | | | | | |
| | | | d m r | Munsell | (≤2mm) | | gr st | gr | size | type | d | m | w | p b c | tn tk mt | Vfw fw c m a | vfn fn md co |
| **Fine Loamy Typic Dystrudepts** | | | | | | | | | | | | | | | | | |
| SWK-018 | Ap | 0-10 | m | 7.5YR3/3 | SCL | 10 | gr | wk | Fn | sbk | - | fr, fi | s, p | - | - | c, m | fn, vfn |
| | A3 | 10-38 | m | 7.5YR4/3 | SCL | 5 | gr | mo | Md | sbk | - | fr, fi | s, p | - | - | c, m | fn, vfn |
| | Bw1 | 38-60 | m | 7.5YR3/4 | SCL | 5 | gr | mo | Md | sbk | - | fr, fi | s, p | - | - | c, m | fn, vfn |
| | Bw2 | 60-100 | m | 7.5YR5/6 | SCL | - | - | mo | Md | sbk | - | fi | vs, p | - | - | c, fw | fn, vfn |
| | Bw3 | 100-119 | m | 7.5RY4/4 | SCL | - | - | mo | Md | sbk | - | fi | vs, p | - | - | fw | fn, vfn |
| | C | 119-150+wpm | m | 7.5YR5/3 | SCL | 60 | gr | mo | Md | sbk | - | fi | ss, p | - | - | fw | fn, vfn |
| **Fine Loamy Typic Haplohumults** | | | | | | | | | | | | | | | | | |
| WK-066 | Ap | 0-20 | m | 5YR 3/3 | SCL | <10 | gr | wk | Fn | gr, sbk | - | vfr | s, p | - | - | m | vfn |
| | A3 | 20-45 | m | 5YR 3/4 | SCL | <5 | gr | mo | Md | sbk | - | fr | s, vp | - | - | fw | vfn |
| | Bt1 | 45-67 | m | 5YR 3/4 | CL | <5 | gr | mo | md, co | sbk | - | fr | vs, vp | p | tn | fw | vfn |
| | Bt2 | 67-87 | m | 7.5YR 4/4 | CL | <5 | gr | mo | Md | sbk | - | fr | vs, vp | p | tn | vfw | vfn |
| | Bt3 | 87-106 | m | 7.5YR 3/4 | CL | <5 | gr | mo | Md | sbk | - | fr | vs, vp | b | tk | - | - |
| **Fine Loamy Ultic Hapludalfs** | | | | | | | | | | | | | | | | | |
| WK-103 | Ap | 0-12 | m | 10YR3/4 | CL | 5 | gr | wk | fn | sbk | s | fr, fi | s,p | - | - | c, m | fn, vfn |
| | A3 | 12-39 | m | 10YR5/4 | L | 8 | gr | mo | md | sbk | - | fr, fi | s, p | - | - | c, fw | fn, vfn |
| | Bw1 | 39-62 | m | 10YR4/4 | L | - | - | mo | md | sbk | - | vfi, | vs, vp | - | - | fw | fn, |

| **Profile No.** | **Horizon Designa-tion** | **Depth (Cm)** | **Matrix Colours** | | **Texture** | **Coarse Fragments** | | **Structure** | | | **Consistence** | | | **Clay Cutans** | | **Roots** | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | **%** | **Type** | | | | | | | | | | |
| | | | **d m r** | **Munsell** | **(≤2mm)** | | **gr st** | **gr** | **size** | **type** | **d** | **m** | **w** | **p b c** | **tn tk mt** | **Vfw fw c m a** | **vfn fn md co** |
| | | | | | | | | | | | | exfi | | | | | vfn |
| | Bt1 | 62-78 | m | 10YR4/4 | CL | - | - | mo | md | sbk | - | vfi, exfi | vs, vp | p | tn | vfw | vfn |
| | Bt2 | 78-110 | m | 7.5YR4/6 | CL | 5 | gr | mo | md | sbk | - | vfi, exfi | vs, vp | b | tk | - | - |

During the field work the relationship between image elements and tentatively identified soil types was established that are delineated during preliminary interpretation. The sample points were readjusted depending upon the variability in the field and sufficient points were collected for finalization of maps.

During soil profile studies, correlation and classification has been carried out in the field prior to field validation of soil maps to ascertain reliability of mapped soil class and their boundaries with ground reality.

## 13.4. Analysis of Soil Samples:

The collected soil samples have been brought to Hyderabad for analysis at Soil Analysis Laboratory of RSI. The soil samples have been dried indoor as shown in the Figure-56, to remove the moister content.


**Figure-56: Drying of Soil Samples Collected**

Th dried soil samples have been powdered and analyzed for different soil parameters like pH, EC, Organic Carbon, CEC etc. using the analystical procedures as given in the Table-14. Soil Analysis was also carried for available major and micro nutrients such as Nitrogen, Phosporus, Potassium, Sulphur, Boron, Copper, Zinc, Iron, Manganese and Molybdenum using standard analytical procedures as given in the Table-14.


**Figure-57: Soil Scientists at Soil Analysis Laboratory of RSI**

**Table-14: Analytical Methods Adopted for Different Soil Parameters**

| Sl. No. | Parameters | Method | Reference |
|---|---|---|---|
| 1 | pH (1:2.5) Extract | pH Meter | ISRIC, FAO, 2008 |
| 2 | E.C (1:2.5) Extract | Conductivity Meter | ISRIC, FAO, 2008 |
| 3 | Organic Carbon | Wet Digestion Potassium Dichromate Method | Walkley & Black, 1934 |
| 4 | Exchangeable Cations/Exchangeable Bases (Ca, Mg, Na, K) | Extraction with 1N Neutral Ammonium Acetate and Estimation of Ca & Mg by EDTA Titration Method | Mervin and Peech, 1951 |
| 5 | Cation Exchange Capacity (meq/100 gm) | After the extraction of Exchangeable bases with Ammonium Acetate the Sample is treated with Sodium Acetate | ISRIC, FAO, 2008 |
| 6 | Available Phosporus ($P_2O_5$) | Bray and Kurtz P I method for acid soils | Bray and Kurtz, 1945 |
| 7 | Available Potassium ($K_2O$) | 1 N Neutral Ammonium Acetate | Jackson, 1958 |
| 8 | Available Boron | Hot Water Soluble Method | Berger and Troug, 1949 |
| 9 | Available Nitrogen | Alkaline Permanganate Method Using Kelplus Automatic Distillation Unit | Subbaiah and Asija, 1956 |
| 10 | Available Sulphur | 0.15% $CaCl_2$ Extraction by | Williams & |

| Sl. No. | Parameters | Method | Reference |
|---|---|---|---|
| | | Turbidity Method | Steinbergs, 1959 |
| 11 | Available Zn, Cu, Fe & Mn | DTPA Extraction | Lindsay & Norvell, 1978 |
| 12 | Available Mo | ABDTPA Extraction and with ICPU-AES | Soltanpour, 1991 |
| 13 | Soil Texture | Hydrometer Method | Bouyoucos, 1962 |

Analysis of soil samples have been carried for different soil parameters like pH, EC, Organic Carbon, CEC, available major and micro nutrients at Soil Analysis Laboratory of RSI as shown in the Figure-58. Mechanical analysis of the soil samples has been carried to know the percentage of sand, silt and clay present. The physical and chemical characteristics of some of the soil samples analyzed from three representative soil profile pits are given in the Table-15.

**Figure-58: Analysis of Soil Samples at Soil Analysis Laboratory of RSI**

**Table-15: Physical & Chemical Characteristics of Soil Samples Collected**

| Profile No. | Horizon Designation | Depth (Cm) | pH (1:2.5) | EC (dsm-1) | OC % | Na+ (Meq /100g) | K+ (Meq/ 100g) | Ca++ (Meq/ 100g) | Mg++ (Meq/ 100g) | CEC | BS % | Sand % | Silt % | Clay % | Texture (≤2 mm) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Fine Loamy Typic Dystrudepts** | | | | | | | | | | | | | | | |
| **SWK-018** | Ap | 0-10 | 4.69 | 0.019 | 1.74 | 0.17 | 0.28 | 5 | 2 | 25.8 | 28.88 | 62 | 17.4 | 20.6 | SCL |
| | A3 | 10-38 | 4.65 | 0.011 | 1.63 | 0.16 | 0.22 | 4 | 2 | 24.5 | 26.04 | 52.3 | 16.2 | 31.5 | SCL |
| | Bw1 | 38-60 | 5.13 | 0.007 | 1.48 | 0.13 | 0.09 | 5 | 3 | 29.5 | 27.90 | 53.2 | 17.3 | 29.5 | SCL |
| | Bw2 | 60-100 | 4.96 | 0.008 | 1.24 | 0.14 | 0.15 | 4 | 3 | 27.8 | 26.22 | 54.1 | 16.4 | 29.5 | SCL |
| | Bw3 | 100-119 | 4.88 | 0.008 | 0.87 | 0.13 | 0.07 | 5 | 3 | 28.7 | 28.61 | 60 | 17.4 | 22.6 | SCL |

| Profile No. | Horizon Designation | Depth (Cm) | pH (1:2.5) | EC (dsm-1) | OC % | Na+ (Meq /100g) | K+ (Meq/ 100g) | Ca++ (Meq/ 100g) | Mg++ (Meq/ 100g) | CEC | BS % | Sand % | Silt % | Clay % | Texture (≤2 mm) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | C | 119-150+wpm | 4.64 | 0.003 | 0.61 | 0.12 | 0.06 | 4 | 2 | 26.7 | 23.15 | 58.2 | 15.3 | 26.5 | SCL |
| **Fine Loamy Typic Haplohumults** | | | | | | | | | | | | | | | |
| WK-066 | Ap | 0-20 | 5.03 | 0.034 | 2.65 | 0.18 | 0.37 | 6 | 3 | 33.9 | 28.20 | 49.4 | 23.2 | 27.4 | SCL |
| | A3 | 20-45 | 4.98 | 0.032 | 1.48 | 0.18 | 0.16 | 4 | 3 | 31.9 | 23.10 | 59.4 | 17.2 | 23.4 | SCL |
| | Bt1 | 45-67 | 4.76 | 0.029 | 1.35 | 0.16 | 0.15 | 4 | 3 | 30.5 | 23.97 | 32.4 | 31.2 | 36.4 | CL |
| | Bt2 | 67-87 | 4.68 | 0.025 | 0.91 | 0.15 | 0.14 | 3 | 2 | 24.2 | 21.86 | 33.4 | 31.3 | 35.3 | CL |
| | Bt3 | 87-106 | 4.42 | 0.022 | 0.88 | 0.18 | 0.15 | 4 | 2 | 31.6 | 20.30 | 38.6 | 26 | 35.4 | CL |
| **Fine Loamy Ultic Hapludalfs** | | | | | | | | | | | | | | | |
| WK-103 | Ap | 0-12 | 4.56 | 0.021 | 2.41 | 0.32 | 0.25 | 4 | 4 | 14.4 | 59.50 | 38.6 | 36.2 | 25.2 | CL |
| | A3 | 12-39 | 4.55 | 0.014 | 2.22 | 0.31 | 0.24 | 4 | 4 | 16.4 | 52.13 | 38.2 | 37.3 | 24.5 | L |
| | Bw1 | 39-62 | 4.42 | 0.011 | 1.68 | 0.32 | 0.16 | 4 | 2 | 14.6 | 44.40 | 40.6 | 38.6 | 20.8 | L |
| | Bt1 | 62-78 | 4.46 | 0.011 | 1.17 | 0.33 | 0.16 | 4 | 3 | 15.4 | 48.64 | 36.2 | 28.4 | 35.4 | CL |
| | Bt2 | 78-110 | 4.62 | 0.011 | 0.88 | 0.28 | 0.14 | 5 | 4 | 18.3 | 51.50 | 38.6 | 28.6 | 32.8 | CL |


**Figure-59: Analysis of Soil Samples**

The results of physical and chemical properties of soil samples analyzed indicate that the textures are mostly sandy clay loams (SCL) and clay loams (CL) with occasional occurrence of sandy loams (SL) and clays (C). The pH is less than 6 with a minimum value of 4.2 indicating the soils vary from moderately acidic to strongly and very strongly acidic. EC content is very low and not significant as the soils are acidic. Organic carbon content of most of the soils is high especially in the surface and gradually decreases with depth. Exchangeable bases and base saturation are low as the soils are acidic. CEC is moderate. Major and Micro nutrients of the soil samples analyzed from three representative soil profile pits are given in the Table-16 and nutrient status of soil samples are given in the Table-17. Note: CL= Critical Level, L = Low, M = Moderate and H = High.

**Table-16: Available Major & Micro Nutrients of Soil Samples Collected**

| Profile No. | Horizon Designation | Depth (Cm) | N | | $P_2O_5$ | | $K_2O$ | | Sulphur | | Boron | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Availability in Kg/ha | Status | Availability in Kg/ha | Status | Availability in Kg/ha | Status | Availability in CL (10 ppm) | Status | Availability in CL (0.52 ppm) | Status |
| **Fine Loamy Typic Dystrudepts** | | | | | | | | | | | | |
| SWK-018 | Ap | 0-10 | 213 | L | 32.4 | M | 252 | M | 22.7 | Sufficient | 0.972 | Sufficient |
| | A3 | 10-38 | 176 | L | 31.2 | M | 103 | L | 15.8 | Sufficient | 0.612 | Sufficient |
| | Bw1 | 38-60 | 213 | L | 25.8 | M | 87 | L | 15.2 | Sufficient | 0.432 | Deficient |
| | Bw2 | 60-100 | 163 | L | 25.9 | M | 79 | L | 11.9 | Sufficient | 0.422 | Deficient |
| | Bw3 | 100-119 | 138 | L | 22.4 | L | 57 | L | 9.2 | Deficient | 0.351 | Deficient |
| | C | 119-150+w.p.m | 50 | L | 21.6 | L | 60 | L | 9.9 | Deficient | 0.342 | Deficient |
| **Fine Loamy Typic Haplohumults** | | | | | | | | | | | | |
| WK-066 | Ap | 0-20 | 388 | M | 69.3 | H | 291 | M | 15.4 | Sufficient | 0.837 | Sufficient |
| | A3 | 20-45 | 386 | M | 28.2 | M | 165 | M | 11.9 | Sufficient | 0.243 | Deficient |
| | Bt1 | 45-67 | 376 | M | 29.5 | M | 161 | M | 58.9 | Sufficient | 0.729 | Sufficient |
| | Bt2 | 67-87 | 326 | M | 19.5 | L | 123 | L | 54.8 | Sufficient | 0.648 | Sufficient |
| | Bt3 | 87-106 | 276 | L | 17.4 | L | 155 | M | 10.4 | Sufficient | 0.589 | Sufficient |
| **Fine Loamy Ultic Hapludalfs** | | | | | | | | | | | | |
| WK-103 | Ap | 0-12 | 225 | L | 60.5 | H | 198 | M | 9.3 | Deficient | 0.459 | Deficient |
| | A3 | 12-39 | 175 | L | 59.8 | H | 181 | M | 8.9 | Deficient | 0.442 | Deficient |
| | Bw1 | 39-62 | 162 | L | 39.5 | M | 173 | M | 8.7 | Deficient | 0.416 | Deficient |
| | Bt1 | 62-78 | 160 | L | 36.4 | M | 133 | L | 8.1 | Deficient | 0.403 | Deficient |
| | Bt2 | 78-110 | 160 | L | 27.4 | M | 112 | L | 6.9 | Deficient | 0.562 | Sufficient |

| Profile No. | Horizon Designation | Depth (Cm) | Cu | | Mn | | Fe | | Zn | | Mo | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Availability in CL (0.2 ppm) | Status | Availability in CL (3 ppm) | Status | Availability in CL (4 ppm) | Status | Availability in CL (0.6 ppm) | Status | Availability in CL (0.2 ppm) | Status |
| **Fine Loamy Typic Dystrudepts** | | | | | | | | | | | | |
| SWK-018 | Ap | 0-10 | 0.89 | Sufficient | 43.72 | Sufficient | 156.07 | Sufficient | 2.43 | Sufficient | 0.122 | Deficient |
| | A3 | 10-38 | 0.78 | Sufficient | 8.45 | Sufficient | 98.12 | Sufficient | 1.16 | Sufficient | 0.085 | Deficient |
| | Bw1 | 38-60 | 0.58 | Sufficient | 4.16 | Sufficient | 54.55 | Sufficient | 0.75 | Sufficient | 0.312 | Sufficient |
| | Bw2 | 60-100 | 0.56 | Sufficient | 3.98 | Sufficient | 53.12 | Sufficient | 0.68 | Sufficient | 0.232 | Sufficient |
| | Bw3 | 100-119 | 0.42 | Sufficient | 2.87 | Deficient | 125.02 | Sufficient | 0.41 | Deficient | 0.206 | Sufficient |
| | C | 119-150+wpm | 0.19 | Deficient | 2.67 | Deficient | 45.14 | Sufficient | 0.39 | Deficient | 0.085 | Deficient |
| **Fine Loamy Typic Haplohumults** | | | | | | | | | | | | |
| WK-066 | Ap | 0-20 | 0.76 | Sufficient | 5.98 | Sufficient | 56.68 | Sufficient | 2.87 | Sufficient | 0.488 | Sufficient |
| | A3 | 20-45 | 0.66 | Sufficient | 3.17 | Sufficient | 40.21 | Sufficient | 1.11 | Sufficient | 0.314 | Sufficient |
| | Bt1 | 45-67 | 0.62 | Sufficient | 2.98 | Deficient | 38.62 | Sufficient | 1.18 | Sufficient | 0.218 | Sufficient |
| | Bt2 | 67-87 | 0.98 | Sufficient | 2.25 | Deficient | 34.91 | Sufficient | 0.98 | Sufficient | 0.206 | Sufficient |
| | Bt3 | 87-106 | 0.98 | Sufficient | 3.39 | Sufficient | 27.64 | Sufficient | 0.92 | Sufficient | 0.218 | Sufficient |
| **Fine Loamy Ultic Hapludalfs** | | | | | | | | | | | | |
| WK-103 | Ap | 0-12 | 0.96 | Sufficient | 5.64 | Sufficient | 89.33 | Sufficient | 2.45 | Sufficient | 0.198 | Deficient |
| | A3 | 12-39 | o.87 | Sufficient | 3.24 | Sufficient | 76.23 | Sufficient | 0.98 | Sufficient | 0.112 | Deficient |
| | Bw1 | 39-62 | 0.77 | Sufficient | 2.67 | Deficient | 68.24 | Sufficient | 0.31 | Deficient | 0.098 | Deficient |
| | Bt1 | 62-78 | 0.59 | Sufficient | 2.53 | Deficient | 67.43 | Sufficient | 0.29 | Deficient | 0.092 | Deficient |
| | Bt2 | 78-110 | 0.44 | Sufficient | 2.34 | Deficient | 60.12 | Sufficient | 0.28 | Deficient | 0.206 | Sufficient |

**Table-17: Nutrient Status of Surface Soil Samples Collected**

| Nutrients | N | P2o5 | K2o | Cu | Mn | Fe | Zn | S | B | Mo |
|---|---|---|---|---|---|---|---|---|---|---|
| Sufficiency % | 51.52 | 81.31 | 83.34 | 100 | 80.30 | 100 | 87.88 | 74.65 | 74.65 | 56.34 |
| Deficiency % | 48.48 | 19.69 | 16.66 | 0 | 19.70 | 0 | 12.12 | 25.35 | 25.35 | 43.66 |

From the analysis of surface soil samples, it has been observed major deficiency in some nutrients namely, nitrogen in 48.5% of surface soil samples, molybdenum in 43.7% samples, sulphur in 25.4% samples, boron in 25.4% samples and phosphorus in 19.7% samples. However, iron and copper are sufficient in 100% samples, zinc in 87.9% samples, potassium in 83.3% samples and manganese in 80.3% samples.

## 13.5. Soil Classification:

Soils of this cluster have been classified initially at family level within the frame work of Soil Taxonomy (Soil survey staff- 2006). The soils of the world are classified into 13 orders in soil taxonomy. Out of 13 orders, 3 soil orders i.e. Inceptisols, Alfisols and Ultisols have been identified, based on presence or absence of different epipedons, subsurface diagnostic horizons, etc. They are further divided into different suborders, great groups, sub groups based on annual moisture conditions of the profile, organic matter content of the soils, base saturation, etc.

Each sub group has been further classified into different families based on texture of the soil, temperature class and mineralogy of the soils. The family level classification is very important from the plant growth point of view. In this area, the temperature class is thermic indicating that the temperature varies from 15 to $22^0$ C in summer. The mineralogy class is mixed indicating that no single mineral content is more than 40% in the soils. However, the textural class will be varying in different soils. An example of a taxonomic soil class is given below.

Soil class namely **Fine loamy, Thermic mixed, Typic Dystrudepts** indicates that it belongs to Inceptisol order; Udepts-suborder; Dystrudepts-great group and Typic dystrudepts-sub group. The family level textural classification is 'Fine loamy'; Temperature class is 'Thermic' and mineralogy class is 'Mixed'.

Each family level soil class is further classified into different soil series based on thickness and arrangement of different subsurface diagnostic horizon. Each series is further divided into different types and phases based on the variations in surface soil conditions such as slope, texture, gravelliness, soil depth, soil erosion, soil acidity/Soil alkalinity, etc.Soil code has been given for each mapping unit at phase level.

### 13.6. Soil Coding of different Mapping Units:

Soil code is represented by 9 digit alpha numeric code. First three letters suffixed by a numeral indicate name of the soil series. Fifth letter is represented by alphabet denoting the slope of the mapping unit, sixth letter is represented by numeral denoting the soil depth category of the mapping unit, seventh letter is represented by numeral denoting the soil reaction category of the mapping unit and eigth letter is represented by alphabet suffixed by a numeral denoting the soil erosion category of the mapping unit. For example in the soil code MRS4B53e2 MRS4 indicates Marshillong4 series; B indicates Gently sloping; 5 indicates moderately deep soil, 3 indicates moderately acidic and e2 indicates moderate erosion as shown in the Figure-60.

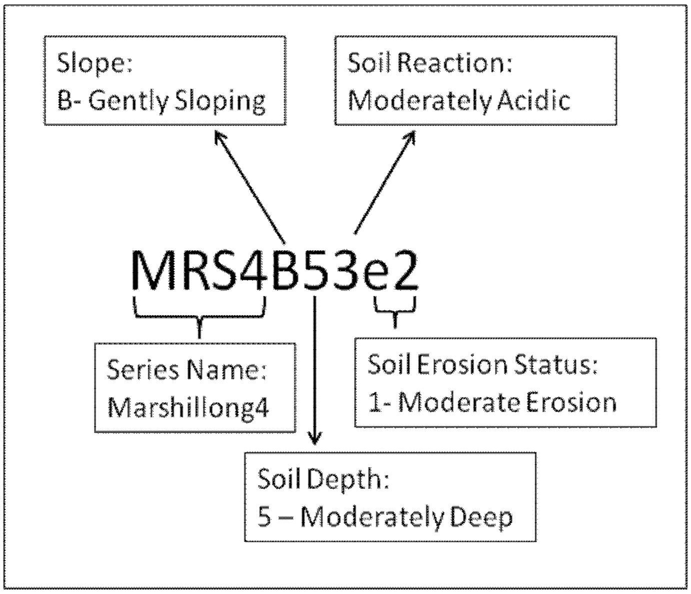



**Figure-60: Soil Code Generated**

### 13.7. Finalization of Soil Map:

Prefield interpreted soil map has been updated in light of ground truth and the results of soil sample analysis. Later on a detailed soil legend has been prepared at phase level.

By considering variations within the soils of the area, and in view of scale of soil mapping (1: 10,000), the soils have been sub divided into soil types and phases. In total 66 soil mapping units have been delineated under different landscapes, namely Alluvial Landscape, Gneissic Complex Landscape and Granitic Plutans Landscape.

## 13.8. Legend:

Legend for soil map has been prepared for all the 66 soil mapping units with different colours and labeled with numeric number for each unit to identify easily in the map as given in the Table-18. Soil code, description of soils and taxonomic class has been mentioned for each mapping unit in the soil legend. The phase level soil class is indicated by soil code. The name of the series, details of the various soil parameters such as slope, soil depth, soil reaction and soil erosion have been mentioned under description of soils.

**Table-18: Legend of Soil Map**

| Mapping Unit | Soil Code | Description of the Soils | Taxonomic Class |
|---|---|---|---|
| **Alluvial Landscape** | | | |
| 1 | WHJ8B44e1 | Wahsiej8, Gently Sloping, Sandy Clay Loam, Moderately Shallow, Strongly Acidic, Nil to Slight Erosion | Fine loamy Pachic Humudepts |
| 2 | WHJ2B44e2 | Wahsiej2, Gently Sloping, Sandy Loam, Moderately Shallow, Strongly Acidic, Moderate Erosion | Loamy Skeletal Fluventic Humic Dystrudepts |
| 3 | MRS4B53e2 | Marshillong4, Gently Sloping, Sandy Clay Loam, Moderately Deep, Moderately Acidic, Moderate Erosion | Coarse loamy Fluventic Humudepts |
| 4 | JSR3B43e1 | Jasiar3, Gently Sloping, Sandy Loam, Moderately Shallow, Moderately Acidic, Nil to Slight Erosion | Coarse loamy Pachic Humudepts |
| 5 | MRS6B34e3 | Marshillong6, Gently Sloping, Sandy Clay Loam, Shallow, Strongly Acidic, Severe Erosion | Loamy Skeletal Typic Dystrudepts |
| 6 | WHJ6A44e1 | Wahsiej6, Nearly Level to Gently Sloping, Sandy Clay Loam, Moderately Shallow, Strongly Acidic, Nil to Slight Erosion | Fine loamy Typic Humudepts |
| 7 | UKM1A65e2 | Umkrem1, Nearly Level to Gently Sloping, Sandy Clay Loam, Deep, Very Strongly | Fine loamy Typic |

| Mapping Unit | Soil Code | Description of the Soils | Taxonomic Class |
|---|---|---|---|
| | | Acidic, Moderate Erosion | Dystrudepts |
| 8 | JSR2A53e2 | Jasiar2, Nearly Level to Gently Sloping, Sandy Clay Loam, Moderately Deep, Moderately Acidic, Moderate Erosion | Coarse loamy Typic Dystrudepts |
| 9 | MTWA54e1 | Mawthawing, Nearly Level to Gently Sloping, Sandy Clay Loam, Moderately Deep, Strongly Acidic, Nil to Slight Erosion | Loamy Skeletal Humic Dystrudepts |
| 10 | NGS3A64e3 | Nongshillong3, Nearly Level to Gently Sloping, Clay Loam, Deep, Strongly Acidic, Severe Erosion | Fine loamy Humic Dystrudepts |
| **Gneissic Complex Landscape** | | | |
| 11 | NGK3A65e2 | Nongkasen3, Nearly Level to Gently Sloping, Sandy Clay Loam, Deep, Very Strongly Acidic, Moderate Erosion | Fine loamy Typic Rhodudalfs |
| 12 | PRG3A55e1 | Pariong3, Nearly Level to Gently Sloping, Clay Loam, Moderately Deep, Very Strongly Acidic, Nil to Slight Erosion | Fine Humic Hapludults |
| 13 | LTG3A64e2 | Laitnamlang3, Nearly Level to Gently Sloping, Sandy Loam, Deep, Strongly Acidic, Moderate Erosion | Coarse loamy Humic Dystrudepts |
| 14 | LTG1A64e2 | Laitnamlang1, Nearly Level to Gently Sloping, Clay Loam, Deep, Strongly Acidic, Moderate Erosion | Fine loamy Cumulic Humudepts |
| 15 | NGK4A64e2 | Nongkasen4, Nearly Level to Gently Sloping, Sandy Clay Loam, Deep, Strongly Acidic, Moderate Erosion | Fine loamy Humic Dystrudepts |
| 16 | NGK2A64e3 | Nongkasen2, Nearly Level to Gently Sloping, Clay Loam, Deep, Strongly Acidic, Severe Erosion | Fine Ultic Hapludalfs |
| 17 | SHPB65e2 | Shohphria, Gently Sloping, Sandy Clay Loam, Deep, Very Strongly Acidic, Moderate Erosion | Fine loamy Typic Dystrudepts |
| 18 | PTW6B64e1 | Pathew6, Gently Sloping, Sandy Clay Loam, Deep, Strongly Acidic, Nil to Slight Erosion | Fine loamy Humic Dystrudepts |

| Mapping Unit | Soil Code | Description of the Soils | Taxonomic Class |
|---|---|---|---|
| 19 | KSKG2B54e2 | Ksehkohlong2, Gently Sloping, Sandy Loam, Moderately Deep, Strongly Acidic, Moderate Erosion | Fine loamy Humic Dystrudepts |
| 20 | LRPB64e1 | Lawrapha, Gently Sloping, Sandy Clay Loam, Deep, Strongly Acidic, Nil to Slight Erosion | Fine loamy Cumulic Humudepts |
| 21 | NGD1B64e2 | Nongdom1, Gently Sloping, Sandy Clay Loam, Deep, Strongly Acidic, Moderate Erosion | Fine loamy Humic Dystrudepts |
| 22 | NGK1B53e3 | Nongkasen1, Gently Sloping, Sandy Clay Loam, Moderately Deep, Moderately Acidic, Severe Erosion | Loamy Skeletal Typic Dystrudepts |
| 23 | LTG2C34e2 | Laitnamlang2, Moderately Sloping, Sandy Clay Loam, Shallow, Strongly Acidic, Moderate Erosion | Fine loamy Typic Dystrudepts |
| 24 | NGD3C64e1 | Nongdom3, Moderately Sloping, Clay Loam, Deep, Strongly Acidic, Nil to Slight Erosion | Fine loamy Typic Dystrudepts |
| 25 | PRG7C44e2 | Pariong7, Moderately Sloping, Sandy Clay Loam, Moderately Shallow, Strongly Acidic, Moderate Erosion | Fine loamy Typic Humudepts |
| 26 | PRG2C63e1 | Pariong2, Moderately Sloping, Sandy Clay Loam, Deep, Moderately Acidic, Nil to Slight Erosion | Fine loamy Typic Haplohumults |
| 27 | UKM3C54e2 | Umkrem3, Moderately Sloping, Clay Loam, Moderately Deep, Strongly Acidic, Moderate Erosion | Fine loamy Cumulic Humudepts |
| 28 | PTW1C64e3 | Pathew1, Moderately Sloping, Sandy Loam, Deep, Strongly Acidic, Severe Erosion | Fine loamy Typic Hapludults |
| 29 | KSKG1D64e2 | Ksehkohlong1, Moderate to Steeply Sloping, Sandy Clay Loam, Deep, Strongly Acidic, Moderate Erosion | Fine Ultic Hapludalfs |
| 30 | NGD2D64e1 | Nongdom2, Moderate to Steeply Sloping, Clay Loam, Deep, Strongly Acidic, Nil to Slight Erosion | Fine loamy Humic Dystrudepts |
| 31 | PTW4D64e2 | Pathew4, Moderate to Steeply Sloping, Loam, | Fine loamy |

| Mapping Unit | Soil Code | Description of the Soils | Taxonomic Class |
|---|---|---|---|
| | | Deep, Strongly Acidic, Moderate Erosion | Typic Haplohumults |
| 32 | PRG1D63e2 | Pariong1, Moderate to Steeply Sloping, Clay Loam, Deep, Moderately Acidic, Moderate Erosion | Fine loamy Humic Dystrudepts |
| 33 | UKM4D64e2 | Umkrem4, Moderate to Steeply Sloping, Clay Loam, Deep, Strongly Acidic, Moderate Erosion | Fine loamy Humic Dystrudepts |
| 34 | PTW3D64e3 | Pathew3, Moderate to Steeply Sloping, Sandy Clay Loam, Deep, Strongly Acidic, Severe Erosion | Fine loamy Typic Dystrudepts |
| 35 | PTW2B63e1 | Pathew2, Gently Sloping, Sandy Clay Loam, Deep, Moderately Acidic, Nil to Slight Erosion | Fine loamy Typic Haplohumults |
| 36 | UKM2B64e2 | Umkrem2, Gently Sloping, Sandy Clay Loam, Deep, Strongly Acidic, Moderate Erosion | Fine loamy Typic Haplohumults |
| 37 | NGL1B44e2 | Nongklung1, Gently Sloping, Sandy Loam, Moderately Shallow, Strongly Acidic, Moderate Erosion | Fine loamy Fluvaquentic Dystrudepts |
| 38 | PTW5B64e3 | Pathew5, Gently Sloping, Sandy Loam, Deep, Strongly Acidic, Severe Erosion | Fine loamy Typic Haplohumults |
| 39 | NGL2B44e1 | Nongklung2, Gently Sloping, Sandy Loam, Moderately Shallow, Strongly Acidic, Nil to Slight Erosion | Fine loamy Typic Haplohumults |
| **Granitic Plutans Landscape** | | | |
| 40 | NGS2A34e2 | Nongshillong2, Nearly Level to Gently Sloping, Clay , Shallow, Strongly Acidic, Moderate Erosion | Fine loamy Typic Humudepts |
| 41 | PTD1A54e1 | Phodtdei1, Nearly Level to Gently Sloping, Sandy Loam, Moderately Deep, Strongly Acidic, Nil to Slight Erosion | Fine loamy Ultic Hapludalfs |
| 42 | PTD2A24e2 | Phodtdei2, Nearly Level to Gently Sloping, Sandy Clay Loam, Very Shallow, Strongly Acidic, Moderate Erosion | Loamy Skeletal Typic Dystrudepts |

| Mapping Unit | Soil Code | Description of the Soils | Taxonomic Class |
|---|---|---|---|
| 43 | DWNA65e1 | Diwian, Nearly Level to Gently Sloping, Sandy Clay Loam, Deep, Very Strongly Acidic, Nil to Slight Erosion | Fine loamy Ultic Hapludalfs |
| 44 | NGS1A55e2 | Nongshillong1, Nearly Level to Gently Sloping, Clay Loam, Moderately Deep, Very Strongly Acidic, Moderate Erosion | Fine loamy Humic Dystrudepts |
| 45 | MRS3A55e3 | Marshillong3, Nearly Level to Gently Sloping, Clay Loam, Moderately Deep, Very Strongly Acidic, Severe Erosion | |
| 46 | PTD3B74e2 | Phodtdei3, Gently Sloping, Clay, Very Deep, Strongly Acidic, Moderate Erosion | Fine Typic Dystrudepts |
| 47 | MWHB64e1 | Mawroh, Gently Sloping, Sandy Clay Loam, Deep, Strongly Acidic, Nil to Slight Erosion | Fine loamy Typic Dystrudepts |
| 48 | PPL1B35e2 | Pawphlang1, Gently Sloping, Sandy Clay Loam, Shallow, Very Strongly Acidic, Moderate Erosion | Loamy Skeletal Typic Humudepts |
| 49 | PTD4B34e1 | Phodtdei4, Gently Sloping, Sandy Clay Loam, Shallow, Strongly Acidic, Nil to Slight Erosion | Fine loamy Typic Dystrudepts |
| 50 | PPL2B64e2 | Pawphlang2, Gently Sloping, Sandy Clay Loam, Deep, Strongly Acidic, Moderate Erosion | Fine loamy Typic Dystrudepts |
| 51 | PPL3B63e3 | Pawphlang3, Gently Sloping, Clay Loam, Deep, Moderately Acidic, Severe Erosion | Fine Typic Hapludalfs |
| 52 | WHJ5C54e2 | Wahsiej5, Moderately Sloping, Sandy Clay Loam, Moderately Deep, Strongly Acidic, Moderate Erosion | Loamy Skeletal Typic Dystrudepts |
| 53 | WHJ9C54e1 | Wahsiej9, Moderately Sloping, Loam, Moderately Deep, Strongly Acidic, Nil to Slight Erosion | Fine loamy Humic Dystrudepts |
| 54 | MWG1C64e2 | Mawiong1, Moderately Sloping, Sandy Loam, Deep, Strongly Acidic, Moderate Erosion | Fine loamy Typic Hapludults |
| 55 | MRS2C65e1 | Marshillong2, Moderately Sloping, Sandy Clay Loam, Deep, Very Strongly Acidic, Nil to Slight Erosion | Fine loamy Typic Dystrudepts |

| Mapping Unit | Soil Code | Description of the Soils | Taxonomic Class |
|---|---|---|---|
| 56 | WHJ7C64e2 | Wahsiej7, Moderately Sloping, Sandy Clay Loam, Deep, Strongly Acidic, Moderate Erosion | Fine loamy Typic Dystrudepts |
| 57 | WHJ4C54e3 | Wahsiej4, Moderately Sloping, Loam, Moderately Deep, Strongly Acidic, Severe Erosion | Coarse loamy Typic Dystrudepts |
| 58 | WHJ3D44e2 | Wahsiej3, Moderate to Steeply Sloping, Sandy Clay Loam, Moderately Shallow, Strongly Acidic, Moderate Erosion | Coarse loamy Typic Humudepts |
| 59 | WHJ10D45e1 | Wahsiej10, Moderate to Steeply Sloping, Sandy Clay Loam, Moderately Shallow, Very Strongly Acidic, Nil to Slight Erosion | Fine loamy Typic Humudepts |
| 60 | MRS1D45e2 | Marshillong1, Moderate to Steeply Sloping, Sandy Clay Loam, Moderately Shallow, Very Strongly Acidic, Moderate Erosion | Fine loamy Typic Dystrudepts |
| 61 | SKW2D44e1 | Sakwang2, Moderate to Steeply Sloping, Sandy Clay Loam, Moderately Shallow, Strongly Acidic, Nil to Slight Erosion | Fine loamy Typic Humudepts |
| 62 | WHJ1D44e3 | Wahsiej1, Moderate to Steeply Sloping, Sandy Clay Loam, Moderately Shallow, Strongly Acidic, Severe Erosion | Loamy Skeletal Typic Dystrudepts |
| 63 | NGS4B64e1 | Nongshillong4, Gently Sloping, Clay Loam, Deep, Strongly Acidic, Nil to Slight Erosion | Fine loamy Ultic Hapludalfs |
| 64 | SKW1B45e2 | Sakwang1, Gently Sloping, Loam, Moderately Shallow, Very Strongly Acidic, Moderate Erosion | Fine loamy Mollic Hapludalfs |
| 65 | MWG2B45e1 | Mawiong2, Gently Sloping, Sandy Clay Loam, Moderately Shallow, Very Strongly Acidic, Nil to Slight Erosion | Fine loamy Typic Humudepts |
| 66 | PTW5B64e3 | Pathew5, Gently Sloping, Sandy Loam, Deep, Strongly Acidic, Severe Erosion | Fine loamy Typic Haplohumults |
| **Note:** The family level mineralogy class is mixed and temperature class is thermic for all the above soils | | | |

## 13.9. Map Composition:

Soil map has been composed in GIS environment along with proper legend, scale bar, north arrow, source and base information. Each soil unit has been labeled with numeric number to identify easily in the map. Soil map prepared for Cluster-2 is shown in the Figure-61 and for a grid is shown in the Figure-62.

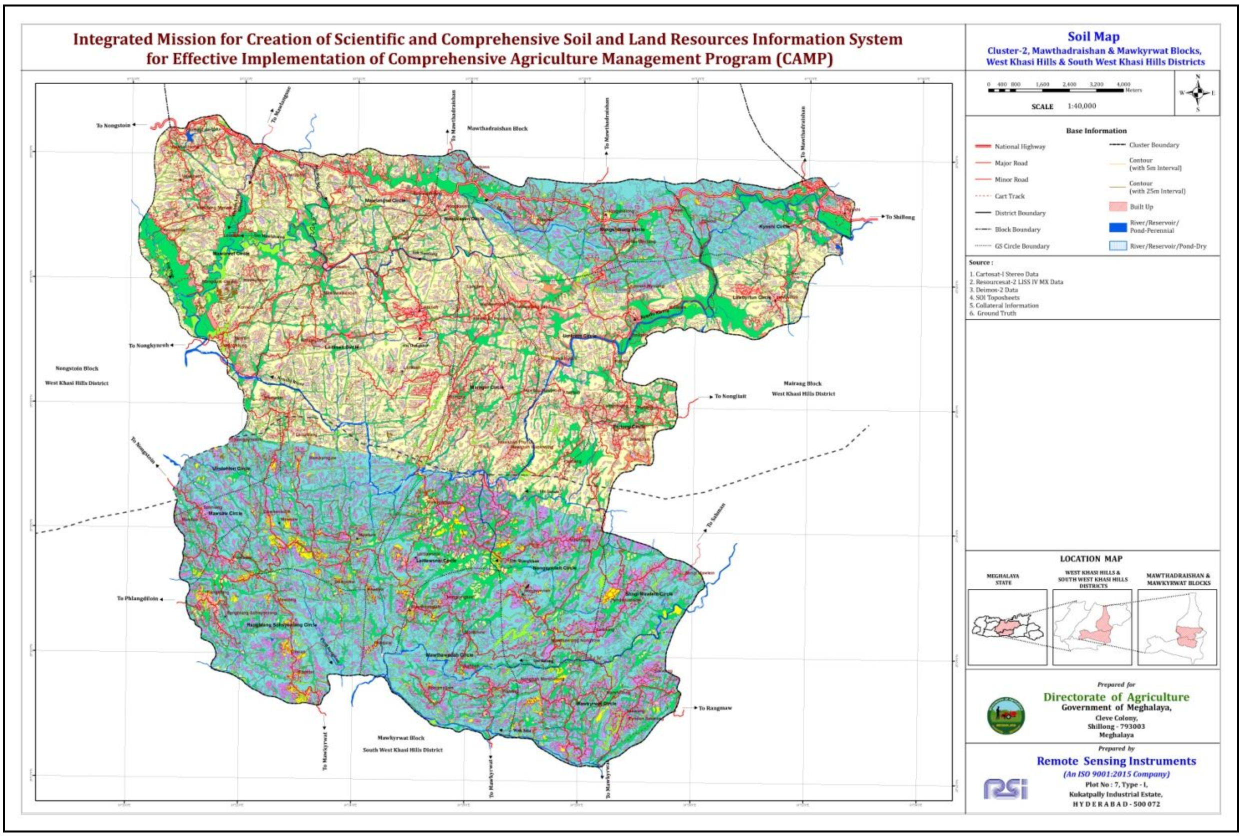



**Figure-61: Soil Map of Cluster-2**

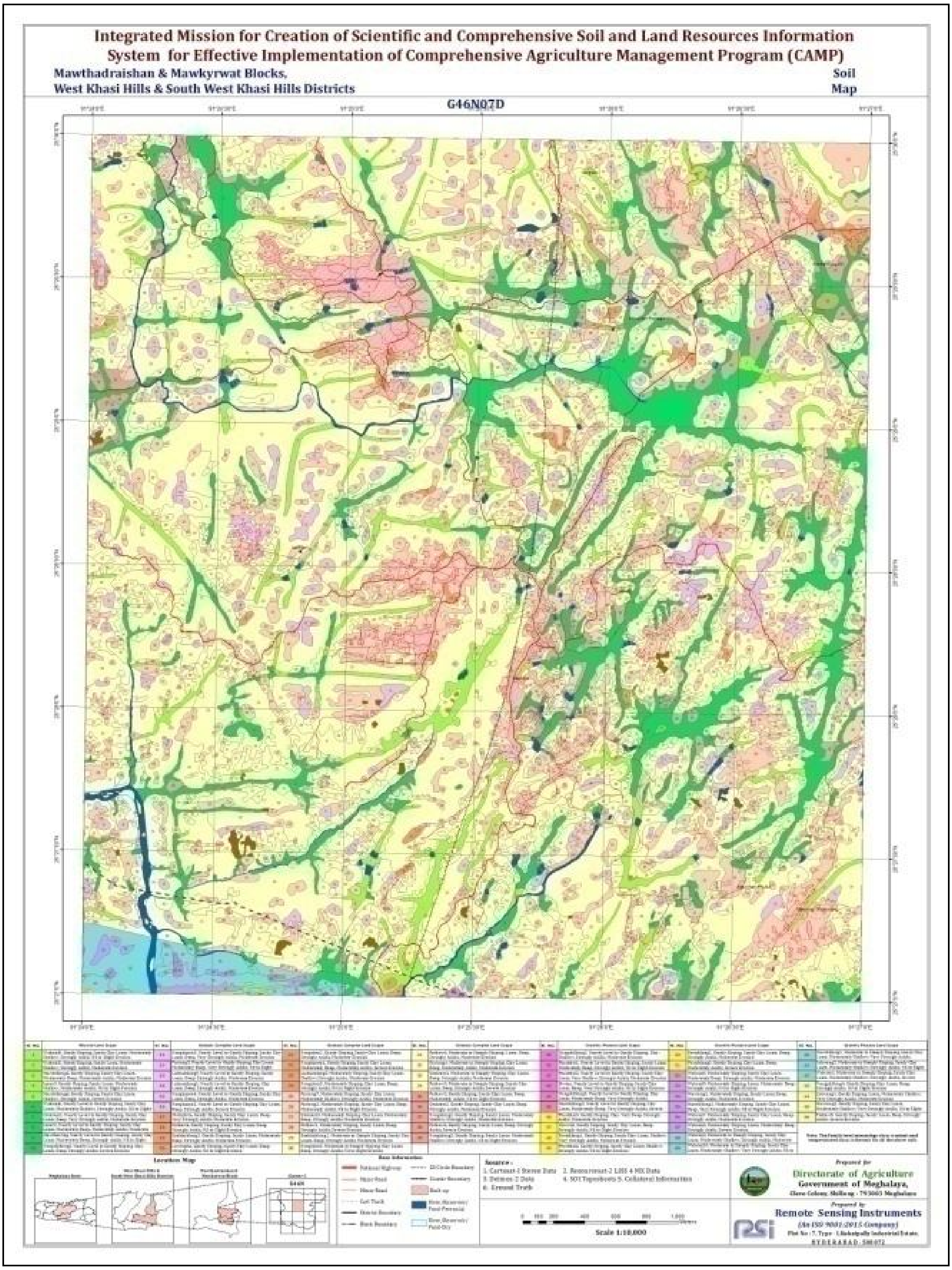



**Figure-62: Soil Map of a Grid**

# CHAPTER -14

# PREPARATION OF LAND DEGRADATION MAP

## 14.1. Introduction:

Land degradation is the deterioration of soil, severely reduced productivity of desirable plants and declining diversity of flora and fauna because of the activities of both people and livestock. Population growth and unscientific land utilization incompatible with its carrying capacity has accelerated land degradation. The information on land degradation is needed for a variety of purposes like planning reclamation programs, rational land use planning, for bringing additional areas into cultivation and also to improve productivity levels in degraded lands. Land degradation has numerous environmental, economic, social and ecological consequences. In general, it implies temporary or permanent regression from a higher to a lower status of productivity through deterioration of physical, chemical and biological aspects. The physical processes which contribute to land degradation are mainly water and wind erosion, compaction, crusting and water logging. The chemical processes include salinisation, alkalisation, acidification, pollution and nutrient depletion. The biological processes, on the other hand are related to the reduction of organic matter content in the soil, degradation of vegetation and impairment of activities of micro-flora and fauna. Generally, it is defined as a human-induced or natural process that negatively affects the land to function effectively. It is the temporary or permanent lowering of the productive capacity of land. It thus covers the various forms of soil degradation, adverse human impacts on water resources, deforestation, and lowering of the productive capacity of rangelands.

## 14.2. Methodology:

Mapping of various degraded land classes has been carried out by on-screen visual interpretation of multi spectral and multi temporal satellite imagery with ground truth as per the classification system using Remote Sensing and GIS techniques in Arc GIS environment. Statistically sound sample points were identified for various Land degradation types from interpreted map for ground truth collection. Field work was carried out to confirm the land degradation types identified in the pre-field interpretation map. During the field work the relationship between image elements and tentatively identified soil types was established that are delineated during preliminary interpretation. The sample points were readjusted depending upon the variability in the field and sufficient points were collected for finalization of maps. The preliminarily interpreted land degradation map was finalized in light of ground truth data.

### 14.3. Classification System:

Land Degradation has been classified based on land degradation process, land degradation type and degree of problem.

**Land Degradation Process:** The physical processes which contribute to land degradation are mainly water erosion, wind erosion, glacial, anthropogenic and others. The chemical processes include salinisation, alkalization and acidification. In which only water erosion, acidification and anthropogenic others are observed.

**Degree of Problem:** The degree of land degradation problem has direct bearing on the management of these soils either to work out for cost of reclamation or for adopting package of practices for cultivation of crops / trees. The degree of problem in each type of land degradation is categorized into nil to slight, moderate, severe/strong, very severe/strong and extreme class

- **Water Erosion (W):** It is the most widespread form of degradation and occurs widely in all agro-climatic zones. The soil erosion is initiated when rain drops fall onto the bare soil surface. The impact of raindrops breaks up the surface soil aggregates and splashes particles into the air. On sloping land relatively more of the detached material will fall down slope resulting in runoff. This subsequently lead to different types of water erosion depending on the gravity of the problem, susceptibility of land and continuity of the process. This category includes processes such as splash erosion, sheet erosion, rill and gully erosion. In these, only sheet erosion is observed.

  - **Sheet Erosion (Wsh):** It is a common problem resulting from loss of top soil. The soil particles are removed from the whole soil surface on a fairly uniform basis in the form of thin layers. Based on degree of problem, sheet erosion is further classified in to following three categories.

- Wsh1- Nil to slight erosion
- Wsh2- Moderate erosion
- Wsh3- Severe erosion

- **Acidification (A):** pH is one of the most-important soil property that affects the nutrient uptake by plants and there by influencing the crop productivity. Acidity occurs when base cations such as Calcium, Magnesium, Potassium and Sodium are lost from the soil leading to high hydrogen ion concentration. This results in decrease of soil pH below 6.5. The soils respond to lime application, which results in improvement of crop productivity. If the pH is 4.5 to 5.0, then they are called strongly acidic and if the pH is < 4.5, then they are called very strongly acidic. Based on degree of problem, acidification is further classified in to following four categories.

    - Aac1- Slightly Acidic
    - Aac2- Moderately Acidic
    - Aac3- Strongly Acidic
    - Aac4- Very Strongly Acidic

- **Anthropogenic (H):** Mining, brick kiln activities, industrial effluent affected areas etc. related to the man made activities are included under this type of degradation. In these, following classes are observed.

    - **Mine/Quarry (Hmd):** These are the areas subject to removal of different earth material on surface by manual and mechanized operations.
    - **Road Cutting (Rc):** These are the areas subject to cutting of earth material and forming the road by manual and mechanized operations. They will be located beside the roads constructing in hills and undulating terrain.

- **Others (T):** Mass movement, barren rocky, reverine sand etc. related to the natural activities is included under this type of degradation. In these, following classes are observed.

  - **Barren Rocky (Bs):** These are the contiguous rock exposure on surface.
  - **Rock Outcrop (Roc):** These are the rock exposure on surface covered with stones and scrub.

## 14.4. Legend:

Legend for land degradation map has been prepared with different colours and labeled with numeric number for all the land degradation units as shown in the Table-19, to identify each unit easily. Code of land degradation category, land degradation process and degree of problem has been mentioned in the legend, for each unit.

**Table-19: Legend of Land Degradation Map with Classification System**

| Mapping Unit | Unit Code | Land Degradation Process | Degree of Problem |
|---|---|---|---|
| 1 | Wsh1&Aac2 | Water Erosion (W) & Acidification (A) | Nil to Slight Erosion-Moderately Acidic |
| 2 | Wsh1&Aac3 | | Nil to Slight Erosion-Strongly Acidic |
| 3 | Wsh1&Aac4 | | Nil to Slight Erosion-Very Strongly Acidic |
| 4 | Wsh2&Aac2 | | Moderate Erosion-Moderately Acidic |
| 5 | Wsh2&Aac3 | | Moderate Erosion-Strongly Acidic |
| 6 | Wsh2&Aac4 | | Moderate Erosion-Very Strongly Acidic |
| 7 | Wsh3&Aac2 | | Severe Erosion-Moderately Acidic |
| 8 | Wsh3&Aac3 | | Severe Erosion-Strongly Acidic |
| 9 | Wsh3&Aac4 | | Severe Erosion-Very Strongly Acidic |
| 10 | Hmd | Mine/Quarry | - |
| 11 | Hrc | Road Cutting | - |
| 12 | Bs | Barren Rocky | - |
| 13 | Roc | Rock Outcrop | - |

### 14.5. Distribution of Land Degradation Categories:

From the land degradation map prepared, it has been observed that 94.3% of the area is affected by water erosion and acidification. In case of intensity of water erosion, 48% of the area is affected by nil to slight erosion, 30% of the area is affected by moderate erosion and 16% of the area is affected by severe erosion. In case of intensity of acidification, 71.7% of the area is strongly acidic, 18.1% of the area is very strongly acidic and only 4.5% of the area is moderately acidic. In combination of water erosion and acidification, 33.6% of the area is strongly acidic with nil to slight water erosion. Land degradation categories wise area covered is given in the Table-20 and shown in the Figure-63.

**Table-20: Details of Land Degradation Status**

| Sl. No. | Land Degradation Category | Degree of Problem | Area (in hectares) | Percentage to Cluster-2 Area |
|---|---|---|---|---|
| 1 | Wsh1&Aac2 | Nil to Slight Erosion - Moderately Acidic | 580.26 | 2.30 |
| 2 | Wsh1&Aac3 | Nil to Slight Erosion - Strongly Acidic | 8,465.62 | 33.57 |
| 3 | Wsh1&Aac4 | Nil to Slight Erosion - Very Strongly Acidic | 3,070.94 | 12.18 |
| 4 | Wsh2&Aac2 | Moderate Erosion - Moderately Acidic | 448.37 | 1.78 |
| 5 | Wsh2&Aac3 | Moderate Erosion - Strongly acidic | 5,688.44 | 22.56 |
| 6 | Wsh2&Aac4 | Moderate Erosion- Very Strongly acidic | 1,410.68 | 5.59 |
| 7 | Wsh3&Aac2 | Severe Erosion - Moderately Acidic | 114.46 | 0.45 |
| 8 | Wsh3&Aac3 | Severe Erosion - Strongly acidic | 3,919.33 | 15.54 |
| 9 | Wsh3&Aac4 | Severe Erosion-Very Strongly acidic | 77.98 | 0.31 |
| 10 | Hmd | Mine/Quarry | 19.81 | 0.08 |
| 11 | Hrc | Road Cutting | 66.05 | 0.26 |
| 12 | Bc | Barren Rocky | 31.06 | 0.12 |
| 13 | Roc | Rock Outcrop | 74.17 | 0.29 |
| 14 | Built-up | | 788.84 | 3.13 |

| Sl. No. | Land Degradation Category | Degree of Problem | Area (in hectares) | Percentage to Cluster-2 Area |
|---|---|---|---|---|
| 15 | Aquaculture | | 67.90 | 0.27 |
| 16 | Water Bodies | | 391.92 | 1.55 |
| | | | **25,215.83** | **100.00** |

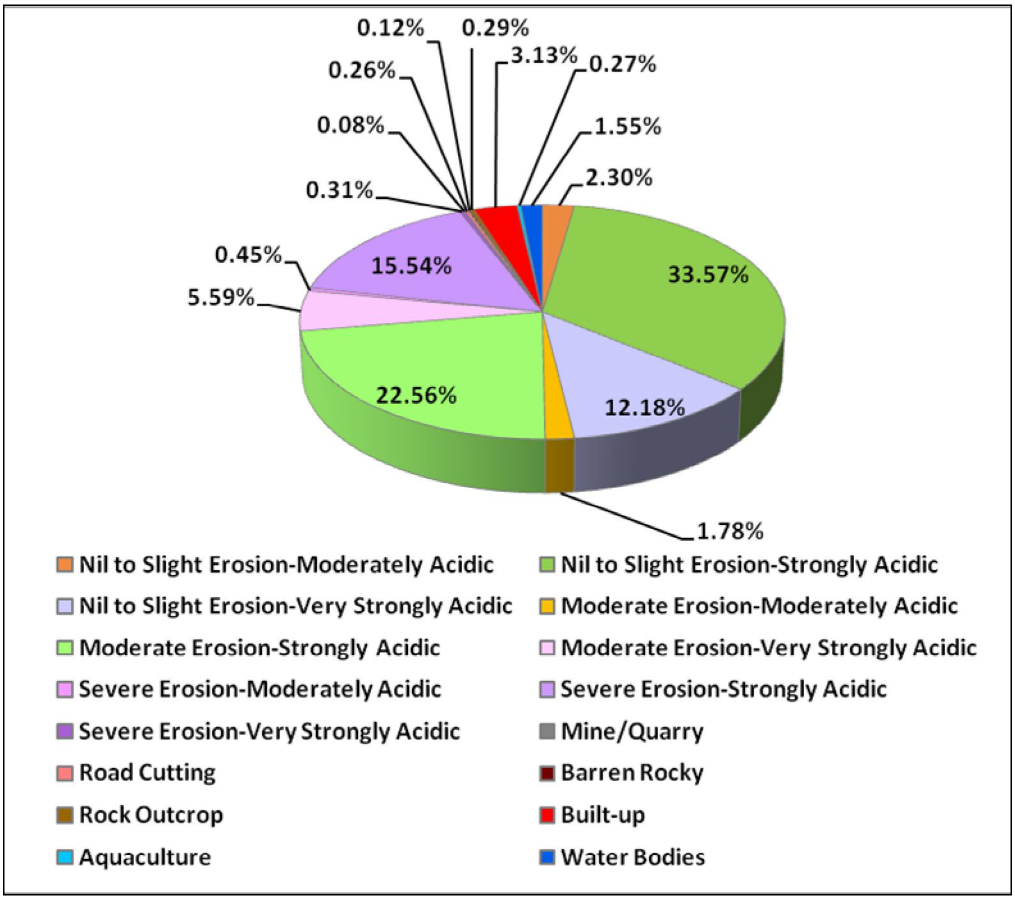



**Figure-63: Distribution of Land Degradation Status**

## 14.6. Map Composition:

Land degradation map has been composed in GIS environment along with proper legend, scale bar, north arrow, source and base information. Each land degradation unit has been labeled with numeric number to identify easily in the map. Land degradation map prepared for a grid is shown in the Figure-64 and for Cluster-2 is shown in the Figure-65.

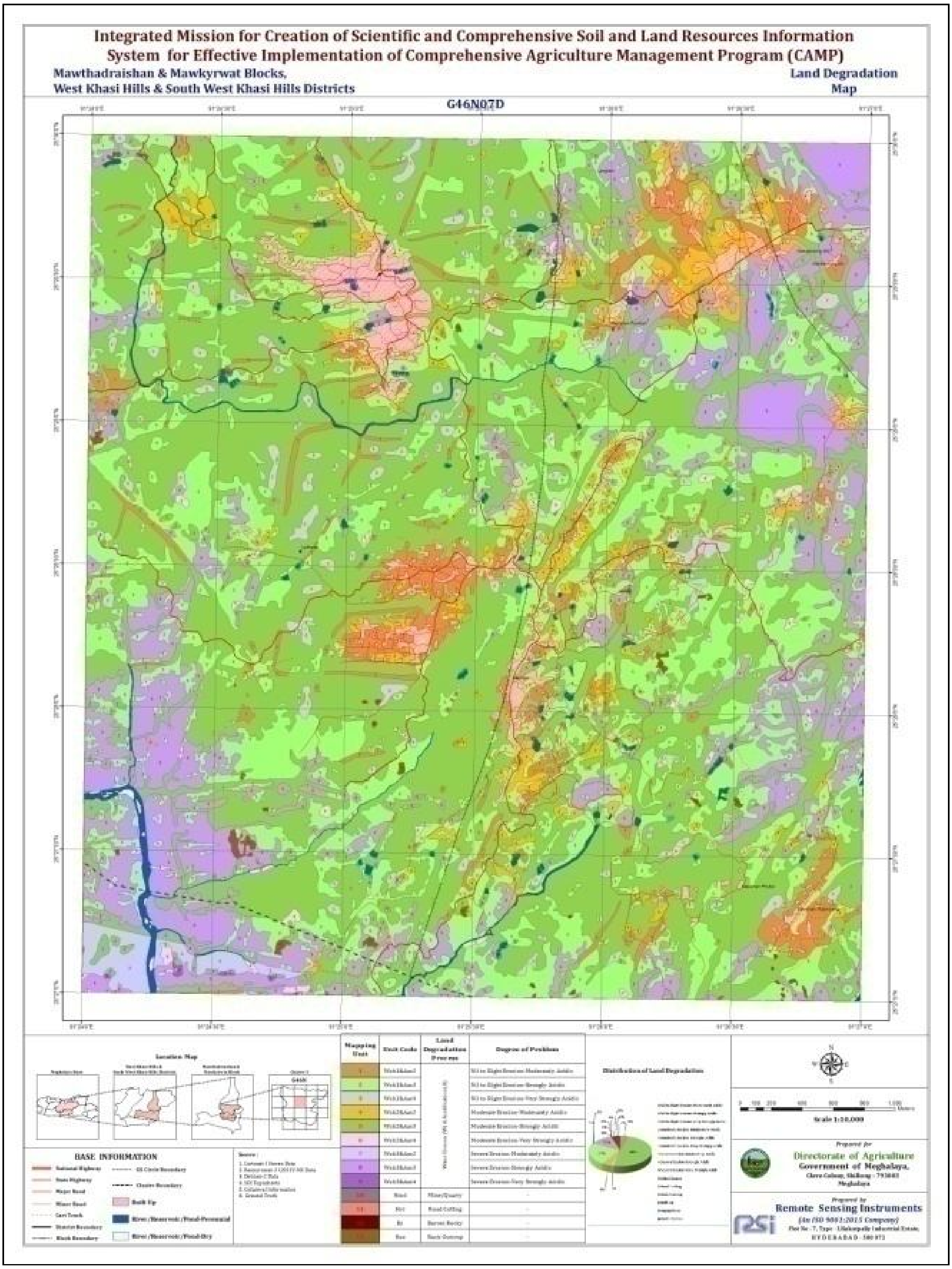



Figure-64: Land Degradation Map of a Grid

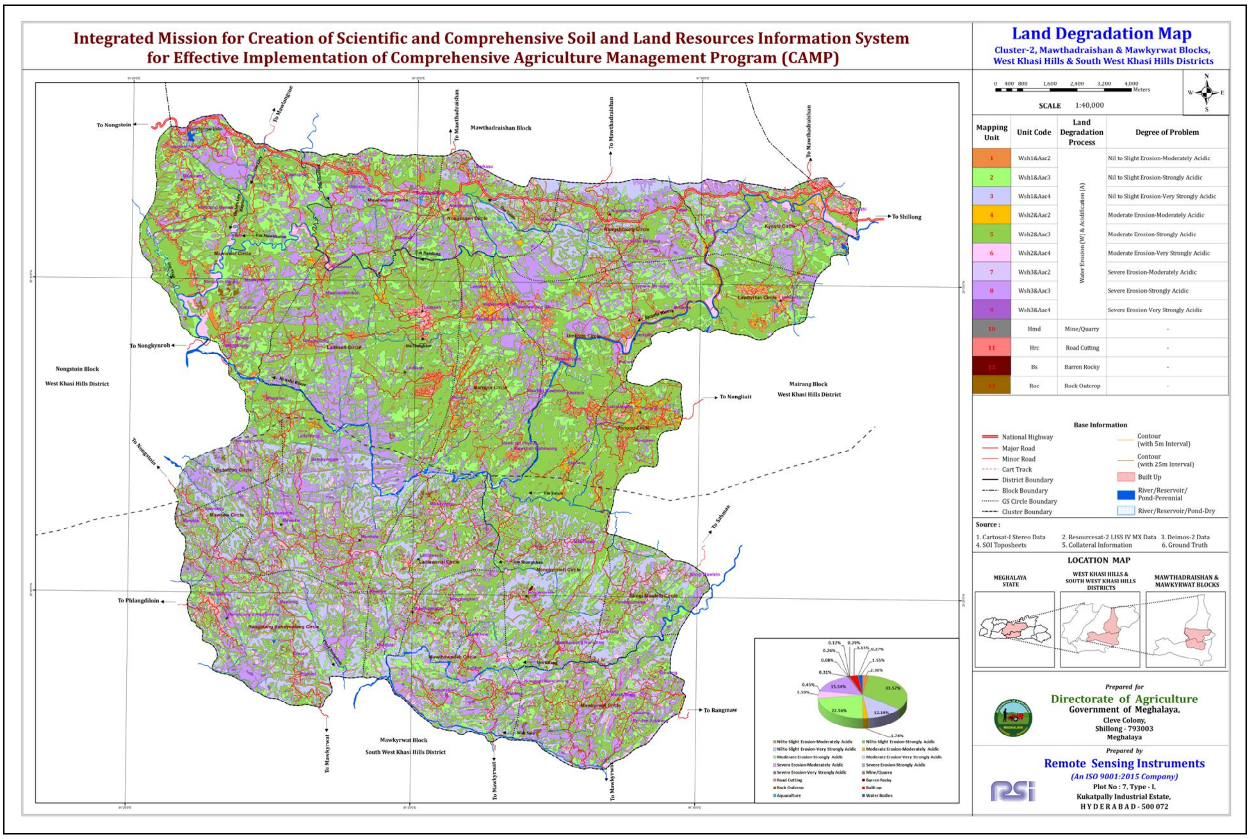



**Figure-65: Land Degradation Map of Cluster-2**

# CHAPTER-15

# PREPARATION OF LAND CAPABILITY MAP

## 15.1. Introduction:

Land Capability classification is an interpretative grouping of soils mainly based on inherent soil characteristics, external land features, environmental factors that limit the use of land Information on the first two items provided by standard soil survey. The classification of soil units provide information on soil characteristics like colour, texture, structure, consistence, permeability, soil depth, soil reaction, type of clay mineral. Each of the above factors play an important role in behavior of the soil and its management. Besides the above inherent soil characteristics, landscape features like slope and erosion may also limit the safe and productive use of soil.

The land capability classes are meant to give a broad idea of limitations which are suggestive of management needs. The management needs suggested are broad and indicative in nature. Precise recommendations could follow from farm level detailed investigations.

## 15.2. Methodology:

The land capability class is the highest level of generalization and indicates the intensity of limitations. The land capability classes have been derived for each mapping unit using the respective morphological, physical, chemical characteristics of the soils along with the land characteristics and climatic parameters.

## 15.3. Land Capability Classification:

Land capability classification is an interpretative grouping of soils mainly based on

a) Inherent soil characteristics
b) External land features and
c) Environmental factors that limit the use of land for agriculture, pasture, or other uses on a sustained basis.

Information on the first two items is provided by standard soil survey. The classification of soil units provide information on soil characteristics like colour, texture, structure, consistence, permeability, soil depth, soil reaction, type of clay mineral. Each of the above factors play an important role in behavior of the soil and its management. Besides the above inherent soil characteristics, landscape features like slope, erosion may also limit the safe and productive use of soil. One unfavorable feature of sufficient intensity in the soil may limit its use and would call for extensive treatment. Several minor unfavourable features may also collectively become a major problem and thus limit the use of soil.

In land capability classification each of the factors like, soil, land features and climate may be considered separately, independent of each other. While considering soil, each soil type may be considered according to the morphology and physic-chemical properties of soil profile and capability rating may accordingly be assigned. The final land capability class may be decided after considering the land features and effect of climate. The capability class of a land decreases with the increase in limitations.

Classification of soil units into capability grouping enables one to get a picture of:

a) The soil hazards which cause soil deterioration

b) Its potentiality for production

The various factors mentioned above individually and collectively control the placement of a soil in a particular class.

In all there are eight land capability classes. Soils in class-I to IV are considered suitable for agriculture, whereas those in class-V to VII are not suitable for cultivation and are recommended for silvi-pasture and other uses whereas soils of class-VIII are not suitable for any cultural use.

- **Class-I:** These lands have few or no limitations and are suitable for intensive cultivation under variety of crops. They are very deep nearly level, well drained soils of favourable texture and structure. They are fertile and free from salinity and alkali hazards.

- **Class-II:** These lands have moderate limitation. They are gently to moderately sloping lands with deep soils of favourable texture and structure, but they are susceptible to moderate erosion. These lands may have slight drainage impedence, seasonal wetness which is easily correctible, and also slightly affected by salinity and or acidity.

- **Class-III:** These lands have moderate to severe limitations due to strong slopes, subject to severe erosion, moderate soil depths, and problems of wetness /impeded drainage, presence of harmful factors including salinity or alkalinity, high water table. Soils of heavy texture with expanding type of clay minerals with gentle slopes are included in this class.
- **Class-IV:** These lands have severe limitations due to steep slopes subject to very severe erosion. They have shallow depth and are severely affected by salinity or alkalinity and have severe root zone limitations.
- **Class-V:** Lands that have all characteristics of class I lands except for locally severe limitations of stoniness, rockiness or extremes of climatic conditions.
- **Class-VI:** These are not arable lands due to severe limitations of very shallow soil depth on steep slopes subjected to very severe erosion with gravels and stones on the surface and affected by extreme salinity and alkali, and have very low moisture holding capacity.
- **Class-VII:** These are also non-arable lands having increasing limitations of depth, erosion, texture, drainage and which are affected by salinity and alkali hazard.
- **Class-VIII:** These are Bad Lands and rock outcrops. They have very stony, very shallow soil interspersed with sheet rock.

These land capability class are further sub divided into land capability sub-class. Capability subclasses are soil groups within one class. They are designated with e, w, s, or c. The letter

- "e" indicates the risk of erosion
- "w" indicates the limitation of wetness
- "s" indicates the soil limitations
- "c" indicates the climatic limitations.

These letters are suffixed to the main class. For example "IIIe" shows class III lands with limitation of soil erosion, "IIIw" indicates class III lands with limitation of wetness.

## 15.4. Legend:

Legend for land capability map has been prepared with different colours and labeled with alpha numeric code for all the land capability class as shown in the Table-21, to identify each unit easily. Land capability class code with description and land capability sub-class code with description have been mentioned in the legend, for each unit.

**Table-21: Legend of Land Capability Map with Land Classification System**

| Land Capability Legend | | | | |
|---|---|---|---|---|
| Map Unit | Land Capability Class | | Land Capability Sub-Class | |
| | Code | Description | Code | Description |
| II-es | II | Soils have moderate limitations that restrict the choice of plants or that require moderate conservation practices | es | Erosion & Soil limitations |
| III-es | III | Soils have severe limitations that restrict the choice of plants or that require special conservation practices or both | es | Erosion & Soil limitations |
| III-sw | III | Soils have severe limitations that restrict the choice of plants or that require special conservation practices or both | sw | Soil & excess water limitations |
| IV-es | IV | Soils in this class have very severe limitations that restirct the choice of plants or require very carefull management practices for production | es | Erosion & Soil limitations |
| VI-es | VI | Soils have severe limitations that make them generally unsuitable for cultivation and restrict their use mainly to pasture, rangeland, forest land or wildlife habitat. | es | Erosion & Soil limitations |

## 15.5. Distribution of Land Capability Class:

From the land capability map prepared, it has been observed that, most of the area (i.e., 54%) is of Class-VI in which soils are having severe limitations and not suitable for cultivation and 37% of the area is of Class-III in which soils are having severe limitations that restrict choice of plants or that require special conservation practices or both. In respect of sub class, 76.4% of the area is having erosion and soil limitations. 54% of the area is having erosion and soil limitations under Class-VI. Land capability class wise area covered is given in the Table-22 and shown in the Figure-66.

**Table-22: Details of Land Capability Status**

| Sl. No. | Land Capability Class | Area (in Ha.) | Percentage to Cluster-2 Area |
|---|---|---|---|
| 1 | IIes | 93.58 | 0.37 |
| 2 | IIIes | 4,814.86 | 19.09 |
| 3 | IIIsw | 4,511.51 | 17.89 |
| 4 | IVes | 739.52 | 2.93 |
| 5 | VIes | 13,616.60 | 54.00 |
| 6 | Built-up | 788.84 | 3.13 |
| 7 | Road Cutting | 66.05 | 0.26 |
| 8 | Mine/Quarry | 19.81 | 0.08 |
| 9 | Barren Rocky | 105.24 | 0.42 |
| 10 | Aquaculture | 67.90 | 0.27 |
| 11 | Water Bodies | 391.92 | 1.55 |
| | **Total Area** | **25,215.83** | **100.00** |

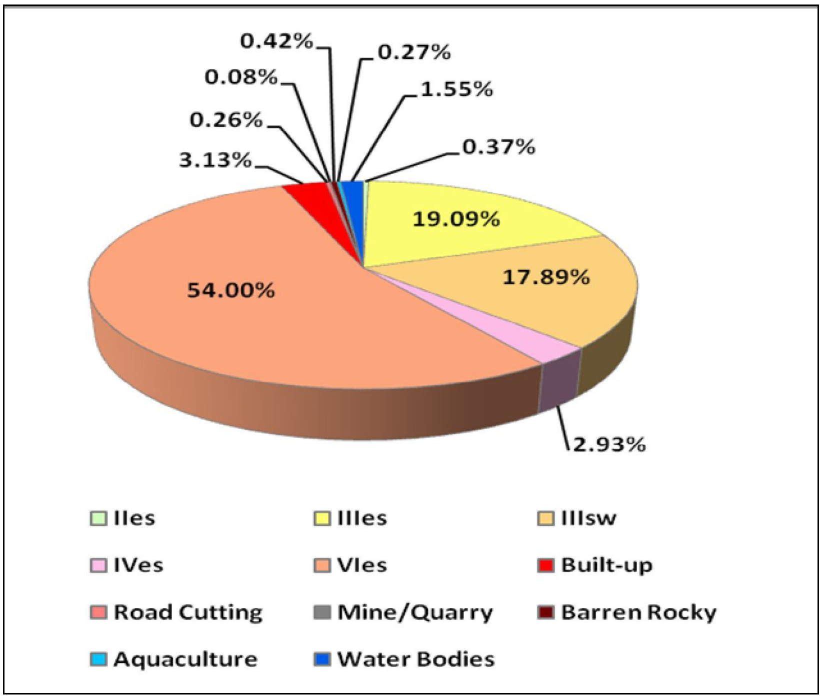



**Figure-66: Distribution of Land Capability Status**

## 15.6. Map Composition:

Land capability map has been composed in GIS environment along with proper legend, scale bar, north arrow, source and base information. Each unit has been labeled with alpha numeric codeto identify easily in the map. Land capability maps prepared for Cluster-2 is shown in the Figure-67 and for a grid is shown in the Figure-68.

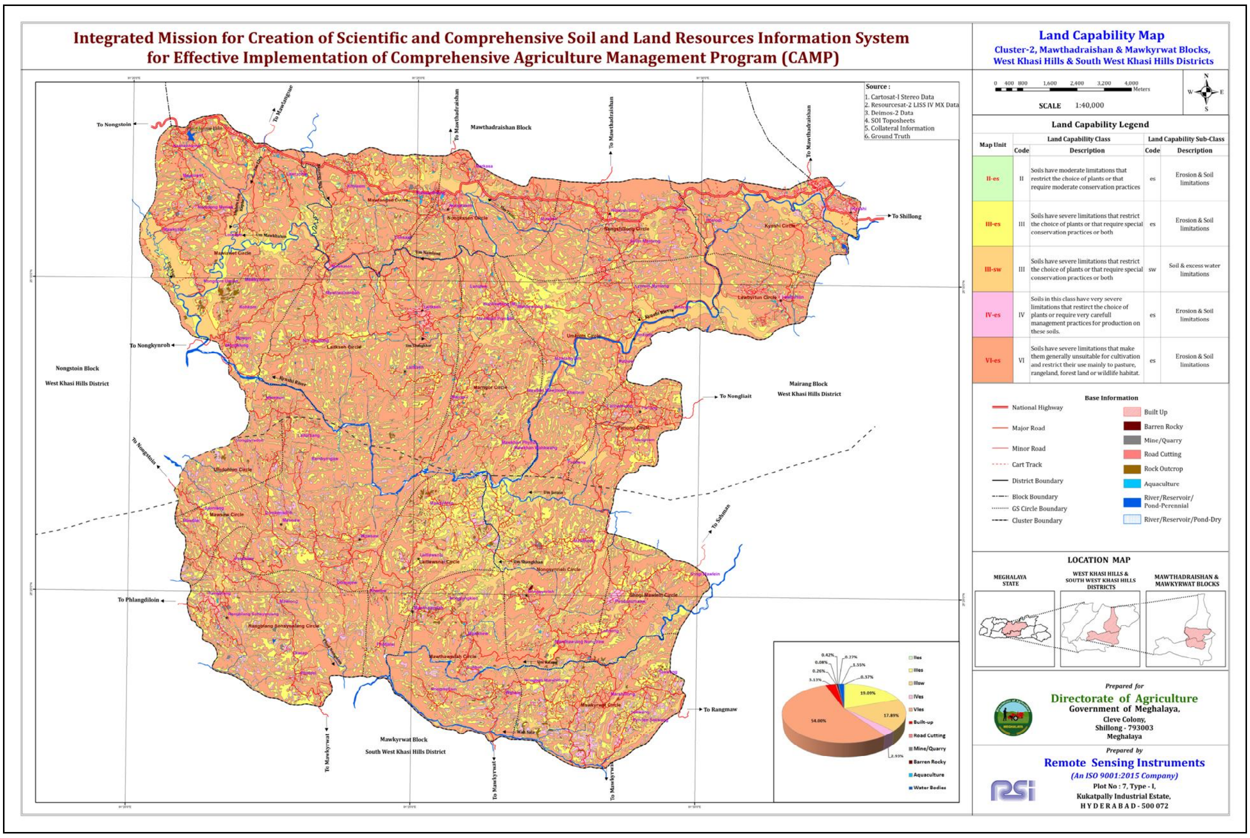



**Figure-67: Land Capability Map of Cluster-2**

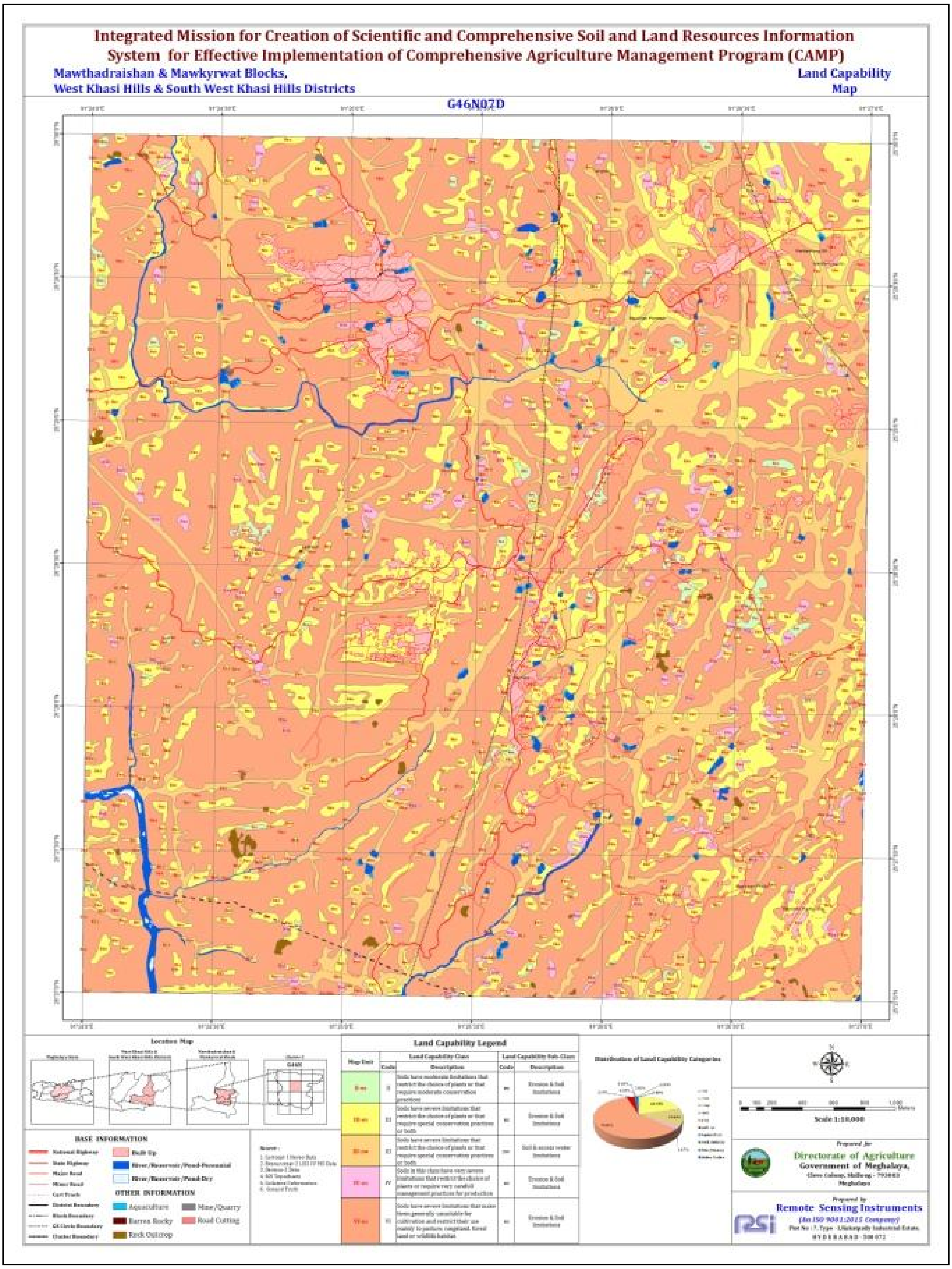



**Figure-68: Land Capability Map of a Grid**

# CHAPTER-16

# PREPARATION OF LAND IRRIGABILITY MAP

## 16.1. Introduction:

Land irrigability classification is an interpretative grouping based on soil and land characteristics which indicate relative suitability of land for irrigation and predicted behavior of soil under irrigation. The concept of soil as used in the irrigability classification is that of a natural three dimensional body which provides medium for plant growth. Soil with its observable and measurable characteristics and qualities is part of land. Thus irrigability classification is a combine effect and reciprocal influence of the soil and land characteristics. Several factors have been considered in deciding the irrigability class which are as fallow:

- Effective soil depth
- Texture
- Moisture holding capacity
- Soil surface cover (occurrence of gravels, cobbles and stones)
- Soil permeability
- Soil salinity and alkali hazard
- Drainage
- Soil erosion
- Ground water table
- Land form, relief and slope

The land irrigability classification also helps in predicting behavior of the soils and land under sustained irrigation conditions. This classification will help to avoid certain kinds of soils for irrigation purpose. For example, irrigating the sandy soils will result in huge percolation losses of irrigation water. Similarly irrigating black soils may result in water logging and salinity problems.

## 16.2. Methodology:

The soil irrigability classification has been done by considering the soil properties of each mapping unit as shown in the soil map. The land irrigability classification has been arrived at by considering soil irrigability class, land development cost, topography, internal drainage conditions of the land etc. The data obtained from soil survey has been used to indicate relative suitability of soil and land for irrigation.

**16.3. Soil Irrigability Classification:**

This classification is made by considering only the soil characteristics for sustained irrigation purpose. The criteria for soil irrigability classification are quantitatively defined and are exclusive in that a soil can qualify for only one class. The most limiting factor determines the classification. For practical reasons irrigation suitability is determined by first grouping the soil into:

a) Soil irrigability class according to their sustained use under irrigation

b) Then grouping the irrigable soils into land irrigability class.

The land classes are based on needs of land development, ground water conditions and drainability of the lands. Soil irrigability class are established without regard to availability of irrigation water, water quality, land preparation costs, availability of drainage and other non-soil related factors. The soil irrigability classes are:

- **Class-A:** Nil to slight soil limitations for sustained use under irrigation
- **Class-B:** Moderate soil limitations for sustained use under irrigation
- **Class-C:** Severe soil limitations for sustained use under irrigation
- **Class-D:** Very severe soil limitations for sustained use under irrigation
- **Class-E:** Un-suitable for irrigation under prevailing conditions but may be brought under irrigation by reclamation and management at high cost
- **Class-F**: Not suited for irrigation or non-irrigable soils class

**16.4. Land Irrigability Classification:**

The land irrigability classification has been arrived at by considering soil irrigability class, land development cost, topography, internal drainage conditions of the land etc. Out of 6 classes, Class-1 to class-4 are suitable for irrigation and class-5, class-6 are not suitable for irrigation.

- **Class-1:** Lands that have few limitations for sustained use under irrigation. Land included in this class is capable of providing sustained and relatively high yields for a wide range of crops at reasonable cost. The soils in this class are nearly level, have deep rooting zone, good permeability, favourable texture and available moisture holding capacity.
- **Class-2:** Lands that have moderate limitations for sustained use under irrigation, limitations may include singly or in combination with the effects of very gentle slopes; less than ideal soil depth, texture, permeability; moderate salinity/alkalinity when in equilibrium with irrigation water, and somewhat unfavourable topography or drainage condition.
- **Class-3:** Lands that have severe limitations for sustained use under irrigation. Limitations may include singly or in combination the effects of gentle slopes; unfavourable soil depth, texture permeability; moderately severe salinity/alkalinity when in equilibrium with the irrigation water, and unfavourable topography or drainage conditions.
- **Class-4:** Lands those are marginal for sustained use under irrigation because of very severe limitations. Limitations may include singly or in combination the effects of moderate steep slopes; very unfavourable soil depth, texture, permeability; severe salinity/alkalinity when in equilibrium with the irrigation water, and unfavourable topography or drainage conditions.
- **Class-5:** Lands that are temporarily classed as not suitable for sustained use under irrigation pending further investigations.
- **Class-6:** Lands not suitable for sustained use under irrigation. The lands of this class are non-arable.

Each Land Irrigability class is further sub-divided based on parameters like topography, drainage conditions and soil limitations. They are designated with t, d, or s. The letter

- "t" indicates the topogarhy limitations
- "d" indicates the drainage limitations

- "s" indicates the soil limitations

These letters are t, d, or s is suffixed to the irrigability class to indicate respective limitation in the land irrigability class.

## 16.5. Legend:

Legend for land irrigability map has been prepared with different colours and labeled with alpha numeric code as for all the land irrigability class as shown in the Table-23, to identify each unit easily. Land irrigability class code with description and land irrigability sub-class code with description have been mentioned in the legend, for each unit

**Table- 23: Legend of Land Irrigability Map with Classification System**

| Map Unit | Land Irrigability Class | | Land Irrigability Sub-Class | |
|---|---|---|---|---|
| | Code | Description | Code | Description |
| 3d | 3 | Land that has severe limitations for sustained use under irrigation | d | Drainage limitations |
| 3ts | | | ts | Topography and Soil limitations |
| 4ts | 4 | Land that is marginal for sustained use under irrigation because of very severe limitations | ts | Topography and Soil limitations |
| 6ts | 6 | Land not suitable for sustained use under irrigation | ts | Topography and Soil limitations |

## 16.6. Distribution of Land Irrigability Class:

From the land irrigability map prepared, it has been observed that, 54% of the area is of class-6, where land is not suitable for sustained use under irrigation due to steep slopes, 25% of the area is of class-3 where land has moderate limitations for sustained use under irrigation and 15% of the area is of class-4 where land is marginal for sustained use under irrigation because of very severe limitations.

In respect of sub class, 77.3% of the area is having topography limitations and soil limitations and 17% of the area is having drainage limitations. Land irrigability class wise area covered is given in the Table-24 and shown in the Figure-69.

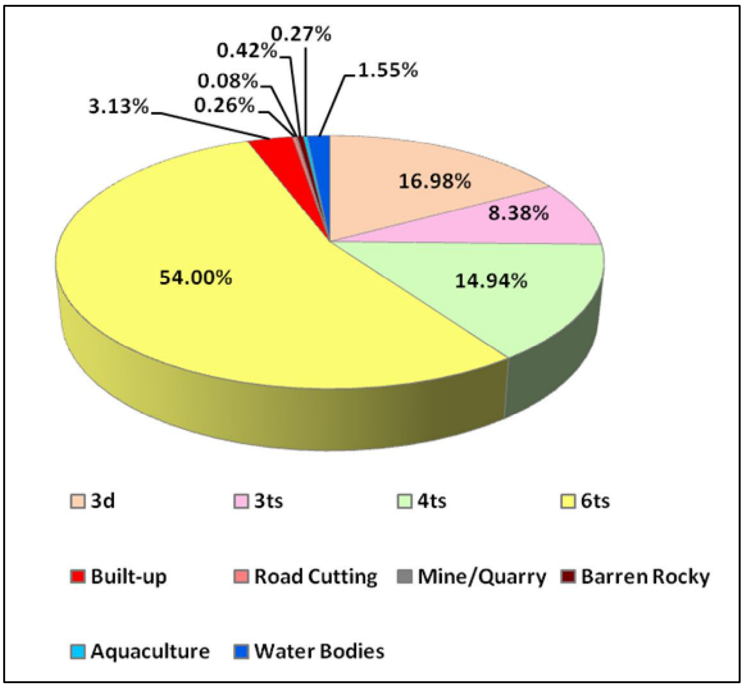



**Figure-69: Distribution of Land Irrigability Status**

**Table-24: Details of Land Irrigability Status**

| Sl. No. | Land Irrigability Class | Area (in Ha.) | Percentage to Cluster-2 Area |
|---|---|---|---|
| 1 | 3d | 4,280.42 | 16.98 |
| 2 | 3ts | 2,112.29 | 8.38 |
| 3 | 4ts | 3,767.77 | 14.94 |
| 4 | 6ts | 13,615.59 | 54.00 |
| 5 | Built-up | 788.84 | 3.13 |
| 6 | Road Cutting | 66.05 | 0.26 |
| 7 | Mine/Quarry | 19.81 | 0.08 |
| 8 | Barren Rocky | 105.24 | 0.42 |

| Sl. No. | Land Irrigability Class | Area (in Ha.) | Percentage to Cluster-2 Area |
|---|---|---|---|
| 9 | Aquaculture | 67.90 | 0.27 |
| 10 | Water Bodies | 391.92 | 1.55 |
| | **Total Area** | **25,215.83** | **100.00** |

## 16.7. Map Composition:

Land irrigability map has been composed in GIS environment along with proper legend, scale bar, north arrow, source and base information. Each unit has been labeled with alpha numeric code to identify easily in the map. Land irrigability map prepared for Cluster-2 is shown in the Figure-70 and for a grid is shown in the Figure-71.

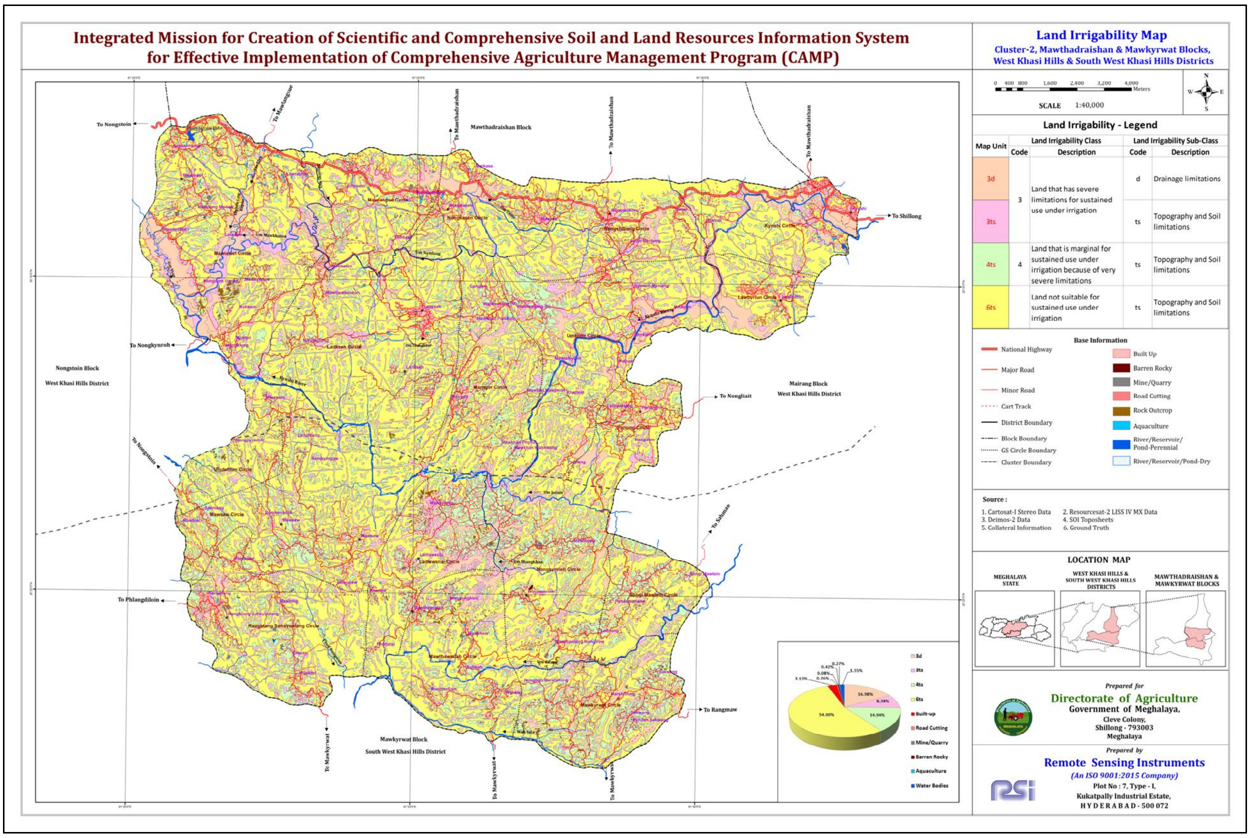



**Figure-70: Land Irrigability Map of Cluster-2**

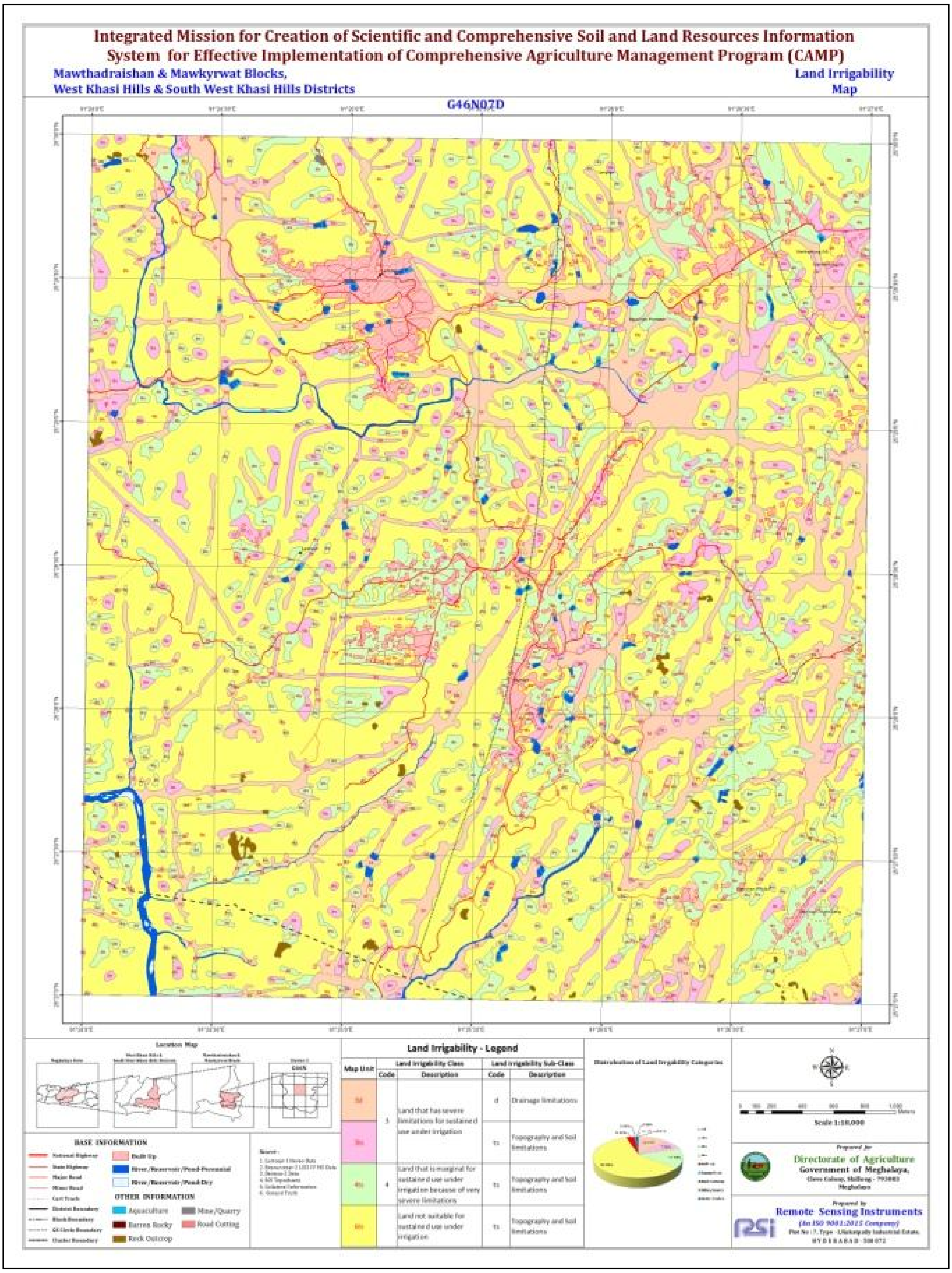



**Figure-71: Land Irrigability Map of a Grid**

# CHAPTER-17

# PREPARATION OF ACTION PLAN MAPS FOR LAND AND WATER RESOURCES DEVELOPMENT

## 17.1. Introduction:

Generation of action plan is very important for improving lands on scientific basis. Action plan for land and water resources development has been prepared based on soil properties including nutrient status, land use/land cover, land degradation status and physiography.

## 17.2. Action Plan for Land Resources Development:

Action plan for land resources development has been suggested by considering problems and potentials of soils, slope, existing land use, soil erosion, nutrient deficiencies, and soil acidity problems. The problems associated with the area include steep slopes, moderate to severe soil erosion due to heavy rains and slopy terrain, strong to very strong acidity problems due to heavy leaching of soils, deforestation, over glazing of lands, along slope cultivation of crops causing severe erosion, presence of underutilized scrub lands, fallow lands, etc.

Paddy cultivation is mostly restricted to valleys with bunding. Overflow of these areas is a recurring problem in rainy season due to heavy rains. To control over flooding of these paddy areas, runoff disposal channels have been suggested.

The farmers are cultivating crops in gentle and moderate slopes by raising field beds along the slopes. This is causing severe soil erosion especially in the rainy season. To control this, contour bunding is suggested. Bench terracing is suggested especially in moderate slopes with deep soils.

This cluster has large area under scrub lands in different physiographic conditions and slopes. The scrub land areas with nearly level to gently sloping areas have been recommended for cultivation of crops by clearing the bushes, leveling and making field bunding/contour bunding. In moderate slopes with scrub lands bench terracing is suggested, wherever the soils are deep and cultivation of annual crops/horticulture is suggested. In steep slopes with scrub forest, half-moon terracing with horti-silvi pasture is recommended.

In gently sloping fallow lands, strengthening of field bunds and cultivation of crops is suggested. In moderate slopes with fallow lands bench terracing and cultivation of crops is recommended, wherever the soils are deep.

In steeply sloping open forest areas staggered trenching and gap afforestation is recommended, where as in lower slopes gap afforestation is recommended in the open forest areas.

Acidity is one of the serious problems in the area. The soil acidity ranges from moderately acidic to very strongly acidic, and nutrient availability to many crops is a problem in such acidic conditions. Therefore, the pH of the soil has to be increased at least up to 6.4. The lime requirement to bring the soils to that pH level has been estimated. The lime requirement is found to be varying based on the pH of the soil.

The action plans have been suggested individually or in combination of soil and water conservation measures, lime requirement and application of deficient nutrients. Recommendation for nutrient applications is not given for the forest areas.

Legend for Action Plan for Land Resources Development has been prepared with different colours and labeled with numeric number for each action plan suggested individually or in combination to identify each unit easily, as given in the Table-25.

**Table-25**

**Legend for Action Plan for Land Resources Development**

| Sl.NO. | Action Plan for Land Resource Development |
|---|---|
| 1 | Construction of run off disposal channels; application of 10.2 tonne of lime and application of P&Mo |
| 2 | Strenghthening of field bunds and cultivation of crops; application of 10.7 tonne of lime and application of N,K,Mn&Mo |
| 3 | Convert to agriculture land by levelling and bunding; application of 6.7 tonne of lime and application of N |
| 4 | Gap afforestation |
| 5 | Convert to agriculture land by field levelling and bunding; application of 8.2 tonne of lime and application of N |
| 6 | Construction of run off disposal channels; application of 10.2 tonne of lime and application of B |

| Sl.NO. | Action Plan for Land Resource Development |
|---|---|
| 7 | Strenghthening of field bunds and cultivation of crops; application of 10.7 tonne of lime and application of N,P,K&Zn |
| 8 | Convert to agriculture land by clearing bushes, levelling and bunding; application of 6.7 tonne of lime |
| 9 | Gap afforestation |
| 10 | Levelling and bunding and cultivation of deep rooted crops; application of 10.2 tonne of lime and application of Mn&Zn |
| 11 | Gap afforestation |
| 12 | Protection and monitoring |
| 13 | Convert to agriculture land by clearing bushes, levelling and bunding; application of 10.7 tonne of lime and application of N&Zn |
| 14 | Strenghthening of field bunds; application of 10.2 tonne of lime and application of N&Mn |
| 15 | Strenghthening of field bunds, cultivation of crops; application of 10.7 tonne of lime and application of N,K,Mn&Zn |
| 16 | Convert to agriculture land by levelling and bunding and cultivation of deep rooted crops; application of 10.7 tonne of lime and application of N,K,Mn&Zn |
| 17 | Gap afforestation |
| 18 | Protection and monitoring |
| 19 | Contour bunding and cultivation of crops; application of 10.7 tonne of lime and application of P,K&ZN |
| 20 | Strenghthening of field bunds; application of 9.7 tonne of lime and application of P,Zn&Mo |
| 21 | Contour bunding and cultivation of deep rooted horticulture crops including fruit crops; application of 10.2 tonne of lime and application of Mn&Zn |
| 22 | Contour bunding, cultivation of crops; application of 10.2 tonne of lime and application of B&Mo |
| 23 | Staggered trenching and gap afforestation |
| 24 | Protection and monitoring |
| 25 | Development of horti-silvi pastural system; application of 9.7 tonne of lime and application of N |
| 26 | Bench terracing and cultivation of crops; application of 7.7 tonne of lime and application of S |
| 27 | Bench terracing and cultivation of deep rooted horticulture crops including fruit crops; application of 8.2 tonne of lime |

| SI.NO. | Action Plan for Land Resource Development |
|---|---|
| 28 | Bench terracing and cultivation of deep rooted horticulture crops including fruit crops; application of 10.2 tonne of lime and application of Mn,Zn&Mo |
| 29 | Staggered trenching and gap afforestation |
| 30 | Protection and monitoring |
| 31 | Half-moon terracing, development of horti-silvi pastural system; application of 10.2 tonne of lime and application of N,K,S,B&Mo |
| 32 | Bench terracing and cultivation of deep rooted horticulture crops including fruit crops; application of 10.2 tonne of lime and application of Mn&S |
| 33 | Half-moon terracing and development of horti-silvi pastural system; application of 7.2 tonne of lime and application of P,Mn,Zn,S&B |
| 34 | Staggered trenching and development of horti-silvi pastural system; application of 10.2 tonne of lime and application of N&Mn |
| 35 | Contour bunding and cultivation of crops; application of 10.2 tonne of lime and application of N,P&Mn |
| 36 | Contour bunding and cultivation of crops; application of 5.7 tonne of lime and application of N,Mn&Zn |
| 37 | Clearing the bushes, contour bunding and cultivation of crops; application of 10.7 tonne of lime and application of N,K,Mn,Zn&S |
| 38 | Contour bunding and cultivation of root crops/vegetable crops; application of 9.7 tonne of lime and application of N,K,Zn&B |
| 39 | Gap afforestation |
| 40 | Gap afforestation |
| 41 | Protection and monitoring |
| 42 | Clearing the bushes, levelling, bunding and cultivation of crops; application of 10.7 tonne of lime and application of N,P,K,Mn,Zn&B |
| 43 | Strenghthing of field bunds and development of horticulture system; application of 10.7 tonne of lime and application of N,P,K,Mn&Zn |
| 44 | Strenghthing of field bunds and cultivation of crops; application of 10.7 tonne of lime and application of N,P&Mo |
| 45 | Levelling, bunding and cultivation of crops; application of 10.7 tonne of lime and application of N,Zn&S |
| 46 | Gap afforestation |
| 47 | Protection and monitoring |
| 48 | Clearing the bushes, contour bunding and cultivation of crops; application of 10.7 tonne of lime and application of N,P&Zn |
| 49 | Strenghthing of field bunds and cultivation of deep rooted horticulture crops including fruit crops; application of 10.7 tonne of lime and application of N,P,K&Mo |
| 50 | Strenghthing of field bunds and cultivation of deep rooted horticulture crops including fruit crops; application of 10.7 tonne of lime and application of N,K,Mn,Zn,B&Mo |
| 51 | Contour bunding and development of horticulture/fruit crops; application of 10.7 tonne of lime and application of Mo |

| Sl.NO. | Action Plan for Land Resource Development |
|---|---|
| 52 | Staggered trenching and gap afforestation |
| 53 | Protection and monitoring |
| 54 | Contour bunding, development of horti-silvi pastural system; application of 10.7 tonne of lime and application of N,B&Mo |
| 55 | Bench terracing and cultivation of crops; application of 8.7 tonne of lime and application of P,Mn&Zn |
| 56 | Bench terracing for cultivation of deep rooted crops including fruit crops; application of 10.7 tonne of lime and application of N,K,S&Mo |
| 57 | Bench terracing for cultivation of crops; application of 10.7 tonne of lime and application of N,K,B&Mo |
| 58 | Staggered trenching and gap afforestation |
| 59 | Protection and monitoring |
| 60 | Half-moon terracing, development of horti-silvi pastural system; application of 10.7 tonne of lime and application of S&Mo |
| 61 | Strenghthing of field bunds; application of 10.7 tonne of lime and application of N,Mn,S&Mo |
| 62 | Half-moon terracing, development of horti-silvi pastural system; application of 10.2 tonne of lime and application of N,Mn,B&Mo |
| 63 | Contour bunding and cultivation of deep rooted crops including fruit crops; application of 10.7 tonne of lime and application of N,P,K&Mn |
| 64 | Contour bunding and cultivation of crops; application of 10.2 tonne of lime and application of N,Mn,Zn,S,B&Mo |
| 65 | Gap afforestation |
| 66 | Contour bunding and cultivation of root crops/vegetable crops; application of 9.7 tonne of lime and application of N,K,Zn&B |
| 67 | Quarring with environmental protection |
| 68 | Quarring with environmental protection |

During the study, it has been observed that, N, P and K are deficient. So, application of N, P & K is suggested in 28.1%, 8.5% and 10% areas, respectively. Micro nutrients are also deficient. So, application of Boron (B), Molybdenum (Mo), Manganese (Mn), Sulphur (S) and Zinc (Zn) are suggested in 28.1%, 24.7%, 24.7%, 16.1 and 9.6% areas, respectively. Application of lime is suggested in 56.9% area. Application of 10.7 tonnes of lime is suggested in 14.4% area and application of 10.2 tonnes of lime is suggested in 34.3% area. Application of 8 to 10 tonnes of lime is suggested in 3.8% area and application of 5 to 8 tonnes of lime is suggested in 4.4% area. Staggered trenching is suggested in 17.2% area, construction of run-off disposal channel is suggested in 15.7% area, half-moon terracing is suggested in 14.7% area, bench terracing is suggested in 8.4% area, contour bunding is suggested in 3.9% area and strengthening of existing field bunds is suggested in 5.7% area.

Protection and monitoring of forest is suggested in 24.7% area and gap afforestation is suggested in 12.7% area. Development of horti-silvi-pastoral system is suggested in 22.6% area and cultivation of crops is suggested in 14.8% area. The details of action plan suggested are given in the Table-26.

**Table-26: Details of Action Plan Suggested**

| Sl. No. | Action Plan Suggested | Area (in Ha.) | Percentage to Cluster-2 Area |
|---|---|---|---|
| 1 | Bench Terracing | 2,115.93 | 8.39 |
| 2 | Half-moon Terracing | 3,709.57 | 14.71 |
| 3 | Construction of run-off disposal channel | 3,969.89 | 15.74 |
| 4 | Contour Bunding | 989.16 | 3.92 |
| 5 | Clearing the bushes | 174.52 | 0.69 |
| 6 | Staggered Trenching | 4,327.07 | 17.16 |
| 7 | Strengthening of existing field bunds | 1,443.89 | 5.73 |
| 8 | Gap Afforestation | 3,208.45 | 12.72 |
| 9 | Protection and monitoring of forest | 6,216.47 | 24.65 |
| 10 | Converting to agriculture land by leveling and bunding | 456.77 | 1.81 |
| 11 | Cultivation of crops | 2,114.47 | 8.39 |
| 12 | Cultivation of deep rooted crops including fruit crops | 303.07 | 1.20 |
| 13 | Cultivation of deep rooted horticulture crops including fruit crops | 1,028.02 | 4.08 |
| 14 | Cultivation of root crops/vegetable crops | 156.54 | 0.62 |
| 15 | Cultivation of deep rooted crops | 130.59 | 0.52 |
| 16 | Development of horti-silvi pastural system | 5,575.75 | 22.11 |
| 17 | Development of horticulture system/ fruit crops | 114.39 | 0.45 |
| 18 | Quarrying with environmental protection | 98.60 | 0.39 |
| 19 | Application of N | 7,088.25 | 28.11 |
| 20 | Application of P | 2,135.95 | 8.47 |
| 21 | Application of K | 2,511.15 | 9.96 |

| Sl. No. | Action Plan Suggested | Area (in Ha.) | Percentage to Cluster-2 Area |
|---|---|---|---|
| 22 | Application of B | 7,077.94 | 28.07 |
| 23 | Application of Mn | 6,215.83 | 24.65 |
| 24 | Application of Mo | 6,220.74 | 24.67 |
| 25 | Application of S | 4,062.60 | 16.11 |
| 26 | Application of Zn | 2,413.51 | 9.57 |
| 27 | Application of 5.7 tonnes of lime | 154.79 | 0.61 |
| 28 | Application of 6.7 tonnes of lime | 158.41 | 0.63 |
| 29 | Application of 7.2 tonnes of lime | 561.14 | 2.23 |
| 30 | Application of 7.7 tonnes of lime | 235.37 | 0.93 |
| 31 | Application of 8.2 tonnes of lime | 245.24 | 0.97 |
| 32 | Application of 8.7 tonnes of lime | 372.49 | 1.48 |
| 33 | Application of 9.7 tonnes of lime | 336.15 | 1.33 |
| 34 | Application of 10.2 tonnes of lime | 8,651.87 | 34.31 |
| 35 | Application of 10.7 tonnes of lime | 3,627.97 | 14.39 |

### 17.3. Action Plan for Water Resources Develpment:

In order to improve the water resources, obstructing the run-off and sufficient recharge is essential. In case the natural recharge is not sufficient, it has to be met through artificial recharge. Many times the sites for the constructing reservoirs and recharge structures are selected based on administrative grounds. As a result, proper recharge does not take place leading to waste of money. So, generation of action plan is very important for improving water resources on scientific basis.

**Figure-72: Field Photograph of Water Harvesting Structures**

The action plans for water resource development will help in soil and water conservation with reducing of runoff and erosion. They will also help in controlling floods and improvement of waste lands.

The action plan for development of water resources have been suggested by considering physiography, slope of the land, soil erosion, surface runoff, internal drainage, current land use etc. obtained from the thematic maps prepared.

Senior Scientists of RSI visited the field to study the area for action plan generation. In the field, they observed some water harvesting structures and one of them are shown in the Figure-72.


**Figure-73: Discussions with AS&WCO, Soil and Water Conservation, West Khasi Hills, Nongstoin**

Later on RSI scientists met AS&WCO, Soil and Water Conservation, West Khasi Hills, Nongstoin and their subordinates and discussed about the soil and water conservation measures followed in West Khasi Hills District.

Construction of water harvesting structures like check dams, nallah bunds and percolation tanks with diversion canals, have been suggested for water resources development. Check dams have to be constructed on the lower order streams with gentle slopes, where as percolation tanks have to be constructed on the lower order streams in plains and valleys having sufficient weathered zone / loose material.

Action plan map has been prepared with locations of the suggested water harvesting structures across the streams and watershed boundaries. Action plan map for water resources development along with legend is shown in the Figure-74.

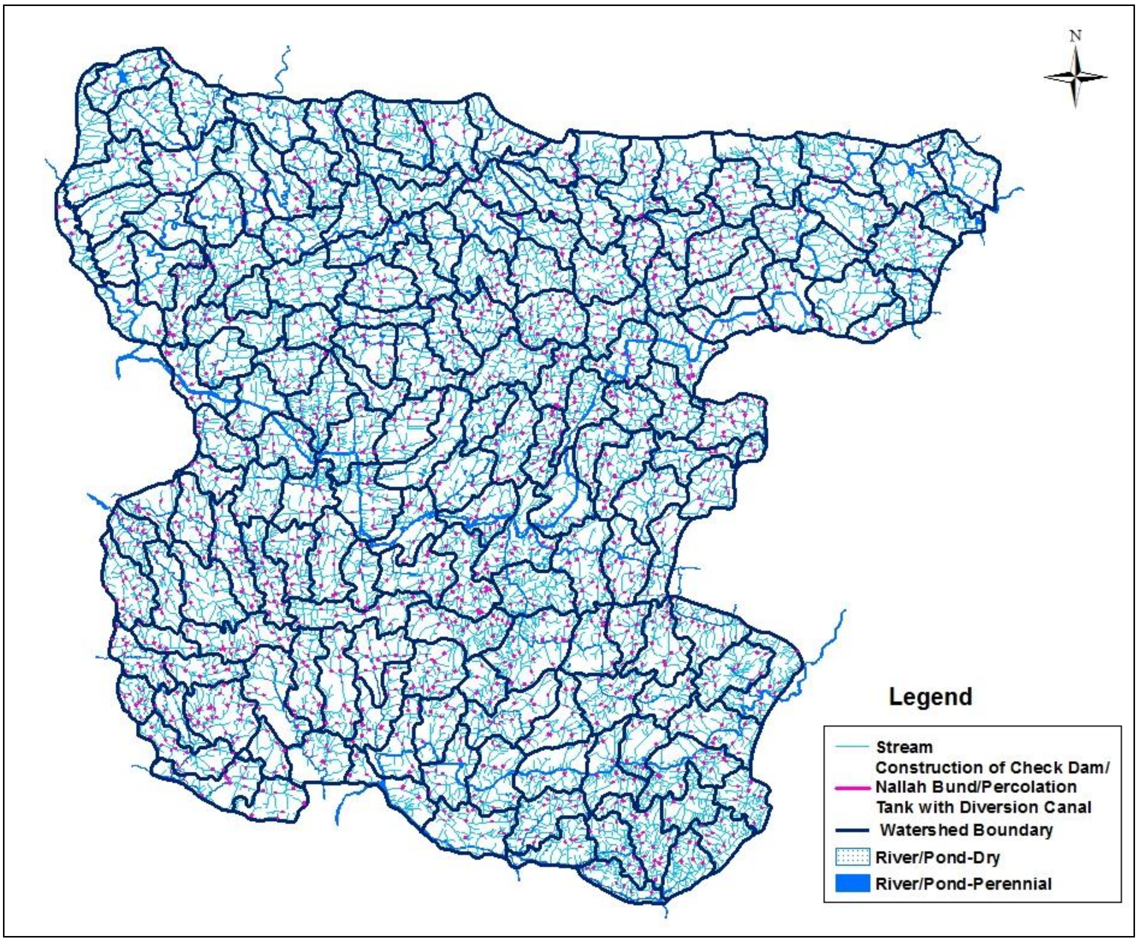



**Figure-74: Action Plan Map for Water Resources Development**

## 17.4. Action Plan Map for Land and Water Resources Develpment:

Action plan map for land and water resources development was generated by combination of action plans for land resources development and action plans for water resources development. It has been composed in GIS environment along with proper legend, scale bar, north arrow, source and base information. Each unit has been labeled with numeric number to identify easily in the map. Action plan map for land and water resources development prepared for a grid is shown in the Figure-75 and for Cluster-2 is shown in the Figure-76.

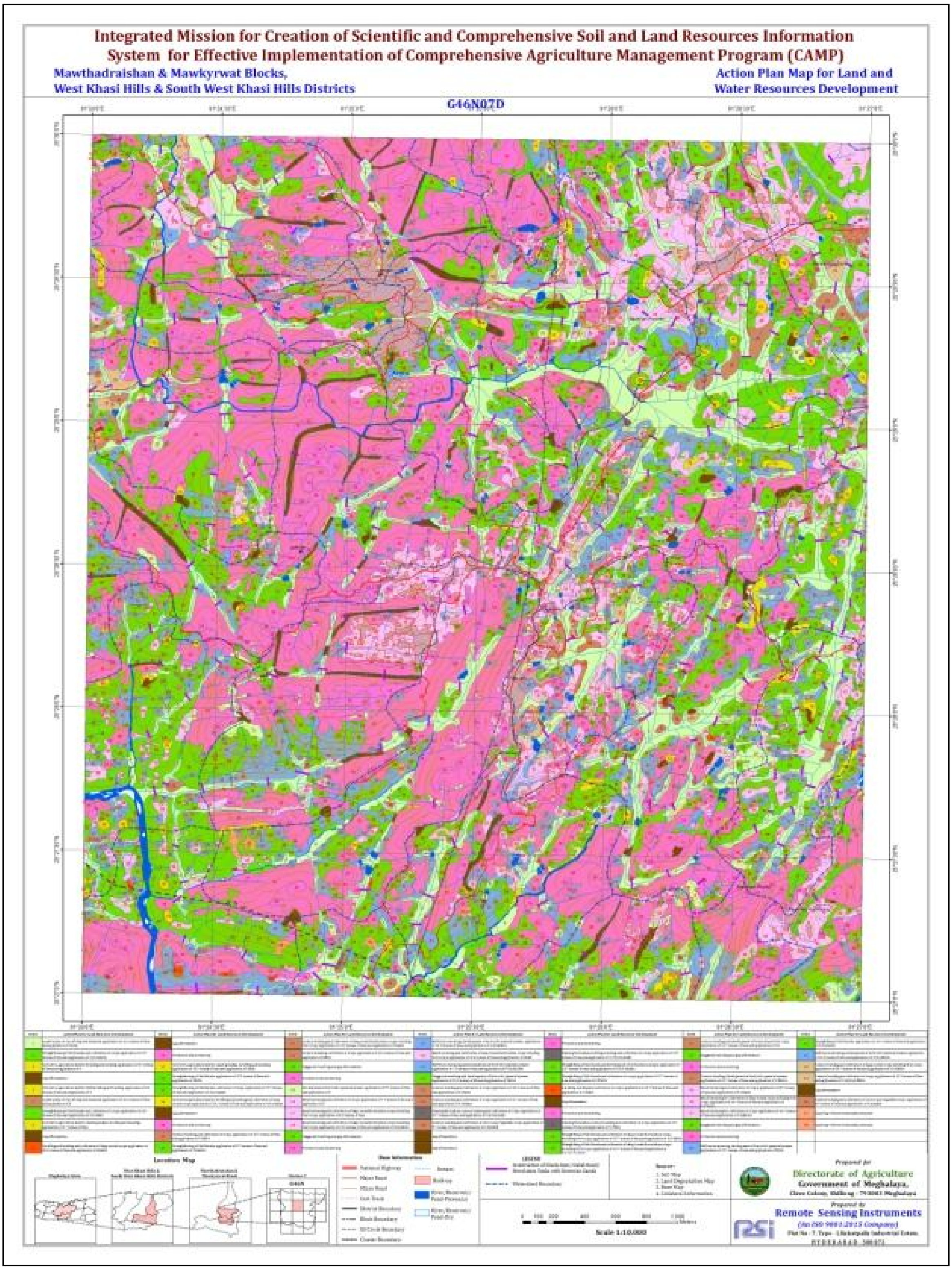



**Figure-75: Action Plan Map for Water and Land Resources Development of a Grid**

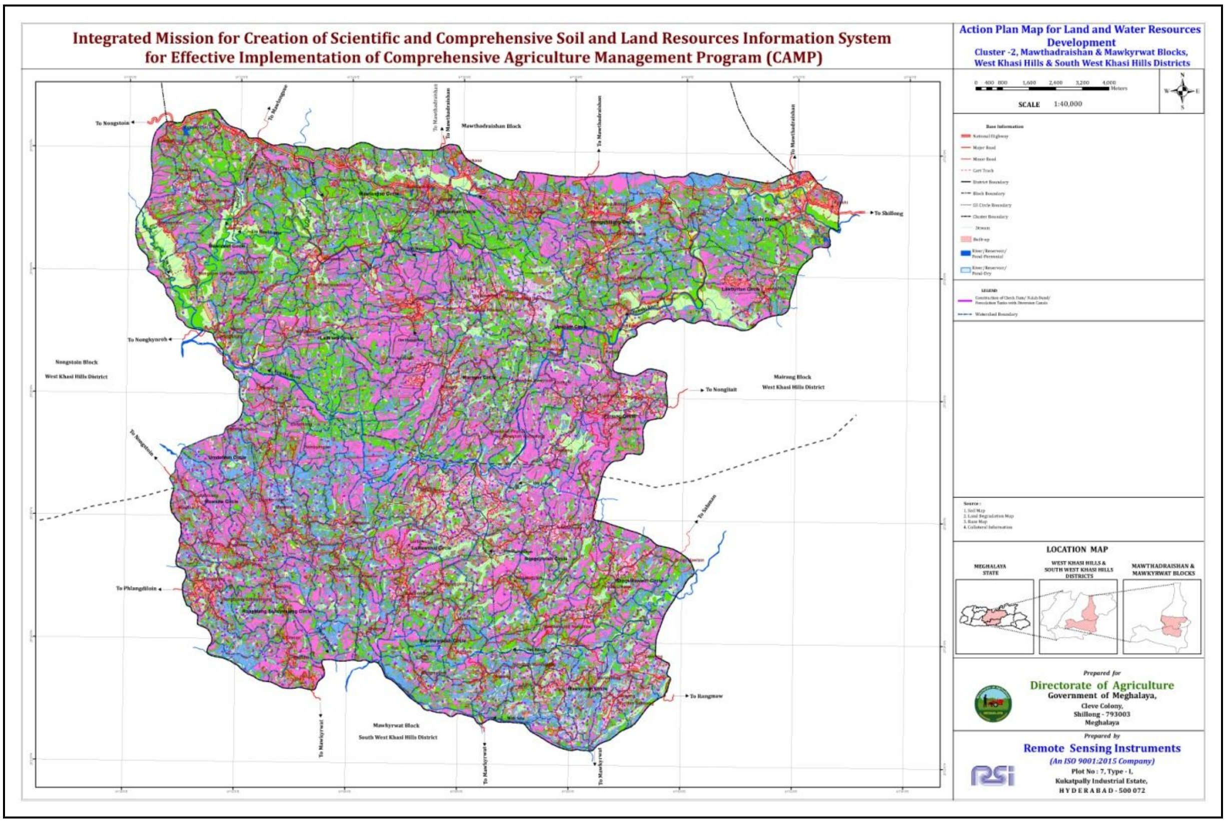



**Figure-76: Action Plan Map for Water and Land Resources Development of Cluster-2**

# CHAPTER-18

# PREPARATION OF CROP SUITABILTY MAP

## 18.1. Introduction:

Land suitability for the crops is the ability of a land to tolerate the production of crops in a sustainable manner. It is an assessment of soils and associated climatic conditions for their suitability for major crops in this cluster. The analysis allows identifying the main limiting factors of a particular crop production and enables decision makers to develop a crop management system for increasing the land productivity. Analysis of land for its suitability for different crops is a prerequisite to achieve optimum utilization of available land resource for agricultural production in a sustainable manner. The aim of this approach is to provide more flexible and superior mechanism to the decision makers for selecting the suitable crop. This research work provides information at local level which could be utilized by farmers for selecting the proper cropping pattern to overcome the major pedological constraints.

## 18.2. Methodology:

The land suitability classification has been carried using the guidelines of FAO (1976) and Sys et.al (1993). The methodology involves mapping of soils at 1:10000 scale. By considering climatic conditions, physical, chemical and inherent fertility of soils and other parameters like soil reaction, threshold values of each soil, site and climatic parameters have been fixed for grouping into different crop suitability class.

## 18.3. Crop Suitability Classification:

The crop suitability has been categorized into five suitability classes, namely Highly Suitable (S1), Moderately Suitable (S2), Marginally Suitable (S3), Currently Not Suitable (N1) and Permanently Not Suitable (N2). The details of the same are given below.

- **Highly Suitable (S1):** Lands having no significant limitations or only have minor limitations to sustain a given land utilization type without significant reduction in productivity or benefits and will not require major inputs above acceptable level.

- **Moderately Suitable (S2):** Lands having limitations which in aggregate are moderately severe to sustain a given land utilization type; the limitations will reduce productivity or benefits and increase required inputs to the extent that the overall advantage to be gained from the use, although still attractive, will not be as appreciable compared to that expected from Class S1 land.
- **Marginally Suitable (S3):** Lands having limitations which in aggregate are severe to sustain a given land utilization type and so will reduce productivity or benefits, or increase required inputs, that any expenditure will only be marginally justified.
- **Currently Not Suitable (N1):** The land is not suitable at present, due to some problems, which can be addressed latter.
- **Permanently Not Suitable (N2):** The land is permanently not suitable as the range of inputs required is unjustifiable.

### 18.4. Land Suitability Assessment for Crops:

The analysis of soil and site conditions along with the climatic conditions helps in identifying most suitable crops for given land. Similarly the study also helps in identifying alternate cropping suitable for particular piece of land. The suitability criteria for each crop/plantation have been adopted from a standard reference. By considering climatic conditions, physical, chemical and inherent fertility of soils and other parameters like soil reaction, threshold values of each soil, site and climatic parameters has been fixed for grouping into different crop suitability class. By comparison of the soil and land parameters, associated climatic conditions with the adaphic requirements of different crops, the suitability rating has been assigned for different crops. The details of the parameters considered for the suitability analysis are given below.

- **Climatic Parameters:** average rainfall and average temperature of growing period for crops selected for analysis.
- **Physical Conditions of the Soil:** Soil Texture, Water availability, Gravel/Stonines, Availability of foot-hold for (Surface and subsoil) root

development, Soil Depth, Availability of foot-hold for plant growth, Calcium Carbonate, Nutrient availability, Gypsum, Source of nutrient Sulphur.

- **Soil Fertility (f) (Not readily correctable):** Organic matter, Cation Exchange Capacity (CEC), Base Saturation, Nutrient availability.
- **Soil Reaction:** Soil acidity, alkalinity etc.

## 18.5. Field Study for Crops:

Senior Scientists of RSI visited the field to study the crops grown in Cluster-2. In the field, they observed that paddy is mostly cultivated in valleys. Potato is grown on raised beds. Maize and Squash are observed in the uplands with gentle slopes. The crops observed in the field are shown in the Figure-77.

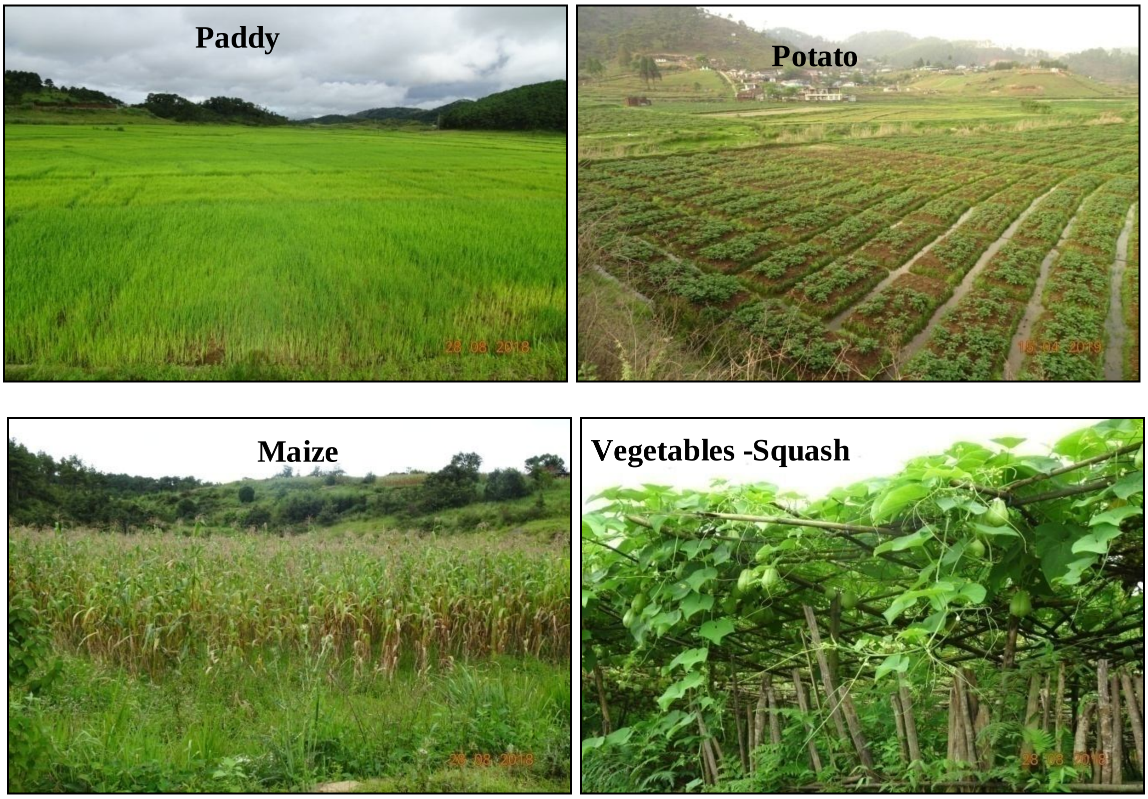



**Figure-77: Field Photographs of Crops Observed**

Later on RSI scientists met Shri Pynshai N Wahlang, DAO, Shri Shanbor Lyngdoh, DHO, West Khasi Hills, Nongstion and their subordinates and discussed about the agricultural and horticultural practices being adopted in this area.

**Figure-78: Discussions with Shri Pynshai N Wahlang, DAO, West Khasi Hills, Nongstion**

**Figure-79: D Discussions with Shri Shanbor Lyngdoh, DHO, Khasi Hills, Nongstion**

### 18.6. Crops Selected for Suitability Analysis:

The crop suitability has been prepared for Rainfed Bunded Rice, Maize, Sweet Potato, Banana, Citrus, Turmeric, Ginger, Potato, Millets, Tobacco, Pine Apple, Soybean, Areca nut and Black Pepper which are mainly cultivated in this area.

### 18.7. Crop Suitability Analysis:

The crop suitability analysis has been made for each soil unit for the selected crops. From the analysis, it has been observed that, maize is highly suitable in 6% of the cluster area, whereas soybean in 2% area, potato in 0.9% area, sweet potato and tobacco in 0.5% area. Millets are moderately suitable in 39.7% area, whereas banana in 34.8% area. Rainfed bunded rice, sweet potato, tobacco, pine apple and soybean are moderately suitable from 20% to 22% area, maize, citrus and potato are moderately suitable from 16% to 18% area, turmeric and ginger are moderately suitable from 6% to 8% area. The details of the crop suitability analysis are given in the Table-27.

**Table-27: Details of Crop Suitability**

| Sl. No. | Crop | Highly Suitable (S1) | | Moderately Suitable (S2) | | Marginally Suitable (S3) | | Currently Not Suitable (N1) | | Permanently Not Suitable (N2) | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Area (in Ha.) | % | Area (in Ha.) | % | Area (in Ha.) | % | Area (in Ha.) | % | Area (in Ha.) | % |
| 1 | Rainfed Bunded Rice | - | - | 5,069.93 | 20.1 | 16,791.61 | 66.6 | - | - | 1,914.53 | 7.6 |
| 2 | Maize | 1,525.34 | 6.0 | 4,436.93 | 17.6 | 13,590.98 | 53.9 | 2,971.99 | 11.8 | 1,250.83 | 5.0 |
| 3 | Sweet Potato | 116.46 | 0.5 | 5,456.56 | 21.6 | 16,951.62 | 67.2 | - | - | 1,251.43 | 5.0 |
| 4 | Banana | - | - | 8,775.73 | 34.8 | 13,749.60 | 54.5 | - | - | 1,250.73 | 5.0 |
| 5 | Citrus | - | - | 4,075.87 | 16.2 | 6,911.85 | 27.4 | - | - | 12,788.34 | 50.7 |
| 6 | Turmeric | - | - | 2,017.65 | 8.0 | 9,664.78 | 38.3 | - | - | 12,093.63 | 48.0 |
| 7 | Ginger | - | - | 1,688.07 | 6.7 | 6,135.26 | 24.3 | - | - | 15,952.74 | 63.3 |
| 8 | Potato | 238.77 | 0.9 | 4,059.57 | 16.1 | 16,586.85 | 65.8 | - | - | 2,890.88 | 11.5 |
| 9 | Millets | - | - | 10,012.76 | 39.7 | 12,512.58 | 49.6 | - | - | 1,250.73 | 5.0 |
| 10 | Tobacco | 116.46 | 0.5 | 5,456.56 | 21.6 | 12,330.60 | 48.9 | - | - | 5,872.45 | 23.3 |
| 11 | Pine Apple | - | - | 5,294.43 | 21.0 | 12,609.19 | 50.0 | - | - | 5,872.45 | 23.3 |
| 12 | Soybean | 499.52 | 2.0 | 5,073.50 | 20.1 | 16,952.32 | 67.2 | - | - | 1,250.73 | 5.0 |
| 13 | Areca nut | - | - | - | - | 21,936.52 | 87.0 | - | - | 1,839.55 | 7.3 |
| 14 | Black Pepper | - | - | - | - | 22,722.60 | 90.1 | - | - | 1,053.47 | 4.2 |

## 18.8. Legend:

Legend for crop suitability map has been prepared with different colours and labeled with numeric number for each unit to identify easily in the map as given in the Table-28. The crop suitability classes for the selected 14 crops have been mentioned in the legend, for each unit.

## Table-28: Legend of Crop Suitability Map Generated

| Mapping Unit | Soil Code | RainfedBunded Rice | Maize | Sweet Potato | Banana | Citrus | Turmeric | Ginger | Potato | Millets | Tobaco | Pine Apple | Soya Bean | Arecanut | Black Pepper |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 001 | WHJ8B44e1 | S3 | N1 | S3 | S3 | N2 | S3 | S3 | S3 | S3 | N2 | N2 | S3 | S3 | S3 |
| 002 | JSR1B54e2 | N2 | N2 | N2 | N2 | N2 | S3 | S3 | N2 | N2 | N2 | N2 | N2 | N2 | S3 |
| 003 | MRS4B53e2 | S3 | S3 | S3 | S3 | N2 | S3 | S3 | S3 | S2 | N2 | N2 | S3 | S3 | S3 |
| 004 | JSR3B43e1 | S3 | S3 | S3 | S3 | N2 | S3 | S3 | S3 | S2 | N2 | N2 | S3 | S3 | S3 |
| 005 | MRS5B34e3 | N2 | S3 | S3 | S3 | N2 | S3 | S3 | N2 | S3 | N2 | N2 | S3 | N2 | S3 |
| 006 | WHJ6A44e1 | S2 | S3 | S3 | S2 | N2 | S3 | S3 | S3 | S2 | N2 | N2 | S3 | S3 | S3 |
| 007 | UKM1A65e2 | S2 | S3 | S3 | S2 | N2 | S3 | S3 | S3 | S2 | N2 | N2 | S3 | S3 | S3 |
| 008 | JSR2A53e2 | S3 | N1 | S3 | S3 | N2 | S3 | S3 | S3 | S3 | N2 | N2 | S3 | S3 | S3 |
| 009 | MTWA54e1 | N2 | S3 | S3 | S3 | N2 | S3 | S3 | N2 | S3 | N2 | N2 | S3 | S3 | S3 |
| 010 | NGS3A64e3 | S2 | S3 | S3 | S2 | N2 | S3 | S3 | S3 | S2 | N2 | N2 | S3 | S3 | S3 |
| 011 | NGK3A65e2 | S3 | S2 | S2 | S2 | S2 | S3 | S2 | S3 | S2 | S2 | S3 | S2 | S3 | S3 |
| 012 | PRG3A55e1 | S3 | S1 | S2 | S2 | S3 | S3 | S2 | S2 | S2 | S2 | S3 | S2 | S3 | S3 |
| 013 | LTG3A64e2 | S3 | S2 | S2 | S3 | S2 | S2 | S2 | S2 | S2 | S2 | S2 | S2 | S3 | S3 |
| 014 | LTG1A64e2 | S2 | S1 | S2 | S2 | S2 | S2 | S2 | S2 | S2 | S2 | S2 | S2 | S3 | S3 |
| 015 | NGK4A64e2 | S2 | S1 | S2 | S2 | S2 | S2 | S2 | S2 | S2 | S2 | S2 | S2 | S3 | S3 |
| 016 | NGK2A64e3 | S3 | N1 | S3 | S3 | S2 | S3 | S3 | S3 | S3 | S3 | S3 | S3 | S3 | S3 |
| 017 | SHPB65e2 | S3 | S1 | S2 | S2 | S2 | S2 | S2 | S2 | S2 | S2 | S2 | S2 | S3 | S3 |
| 018 | PTW6B64e1 | S2 | S1 | S2 | S2 | S2 | S2 | S2 | S2 | S2 | S2 | S2 | S2 | S3 | S3 |
| 019 | KSKG2B54e2 | S2 | S1 | S2 | S2 | S3 | S2 | S2 | S2 | S2 | S2 | S2 | S2 | S3 | S3 |
| 020 | LRPB64e1 | S2 | S1 | S2 | S2 | S2 | S2 | S2 | S2 | S2 | S2 | S2 | S2 | S3 | S3 |
| 021 | NGD1B64e2 | S2 | S1 | S2 | S2 | S2 | S2 | S2 | S2 | S2 | S2 | S2 | S2 | S3 | S3 |
| 022 | NGK1B53e3 | S3 | S3 | S3 | S3 | S3 | S3 | S2 | S3 | S2 | S3 | S3 | S3 | S3 | N2 |
| 023 | LTG2C34e2 | S3 | S3 | S3 | S3 | N2 | S3 | S3 | S3 | S3 | S3 | S3 | S3 | N2 | S3 |
| 024 | NGD3C64e1 | S3 | S2 | S2 | S2 | S2 | S3 | N2 | S3 | S2 | S2 | S2 | S2 | S3 | S3 |
| 025 | PRG7C44e2 | S3 | S2 | S2 | S2 | N2 | S3 | N2 | S2 | S2 | S2 | S2 | S2 | S3 | S3 |
| 026 | PRG2C63e1 | S3 | S2 | S2 | S2 | S2 | S3 | N2 | S2 | S2 | S2 | S2 | S2 | S3 | S3 |
| 027 | UKM3C54e2 | S2 | S1 | S2 | S2 | S3 | S2 | S3 | S1 | S2 | S2 | S2 | S1 | S3 | S3 |
| 028 | PRG8C34e3 | S3 | N1 | S3 | S3 | N2 | S3 | N2 | S3 | S3 | S3 | S3 | S3 | N2 | S3 |
| 029 | KSKG1D64e2 | S3 | S2 | S2 | S2 | S3 | N2 | N2 | S2 | S2 | S2 | S2 | S2 | S3 | S3 |
| 030 | NGD2D64e1 | S3 | S3 | S3 | S3 | S3 | N2 | N2 | S3 | S3 | S3 | S3 | S3 | S3 | S3 |
| 031 | PTW4D64e2 | S3 | S3 | S3 | S3 | S3 | N2 | N2 | S3 | S3 | S3 | S3 | S3 | S3 | S3 |
| 032 | PRG1D63e2 | S3 | N1 | S3 | S3 | S3 | N2 | N2 | S3 | S3 | S3 | S3 | S3 | S3 | S3 |
| 033 | UKM4D64e2 | S3 | S2 | S2 | S2 | S3 | N2 | N2 | S2 | S2 | S2 | S2 | S2 | S3 | S3 |

| Mapping Unit | Soil Code | RainfedBunded Rice | Maize | Sweet Potato | Banana | Citrus | Turmeric | Ginger | Potato | Millets | Tobaco | Pine Apple | Soya Bean | Arecanut | Black Pepper |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 034 | PRG5D64e3 | S3 | N1 | S3 | S3 | S2 | S3 | N2 | S3 | S3 | S3 | S3 | S3 | S3 | S3 |
| 035 | PTW2B63e1 | S2 | S1 | S2 | S2 | S2 | S2 | S2 | S2 | S2 | S2 | S2 | S2 | S3 | S3 |
| 036 | UKM2B64e2 | S2 | S1 | S2 | S2 | S2 | S2 | S2 | S2 | S2 | S2 | S2 | S2 | S3 | S3 |
| 037 | NGL1B44e2 | S3 | S2 | S3 | S3 | N2 | S3 | S2 | S3 | S2 | S3 | S3 | S3 | S3 | S3 |
| 038 | PTW5B64e3 | S2 | S1 | S2 | S2 | S2 | S2 | S2 | S2 | S2 | S2 | S2 | S2 | S3 | S3 |
| 039 | NGL2B44e1 | S2 | S1 | S2 | S2 | S3 | S2 | S2 | S2 | S2 | S2 | S2 | S2 | S3 | S3 |
| 040 | NGS2A34e2 | S2 | S3 | S3 | S3 | N2 | S3 | S2 | S2 | S2 | S3 | S2 | S3 | N2 | S3 |
| 041 | PTD1A54e1 | S3 | S2 | S2 | S2 | S3 | S2 | S2 | S3 | S2 | S2 | S2 | S2 | S3 | S3 |
| 042 | PTD2A24e2 | N2 | N2 | N2 | N2 | N2 | N2 | S2 | N2 | N2 | N2 | N2 | N2 | N2 | N2 |
| 043 | DWNA65e1 | N2 | S3 | S3 | S3 | S3 | S3 | S2 | N2 | S3 | S3 | S3 | S3 | S3 | S3 |
| 044 | NGS1A55e2 | S3 | S1 | S2 | S2 | S3 | S2 | S2 | S2 | S2 | S2 | S2 | S1 | S3 | S3 |
| 045 | MRS3A55e3 | S3 | S2 | S2 | S2 | S3 | S3 | S2 | S3 | S2 | S2 | S2 | S2 | S3 | S3 |
| 046 | PTD3B74e2 | S3 | S2 | S2 | S2 | S2 | S3 | S3 | S2 | S2 | S2 | S2 | S1 | S3 | S3 |
| 047 | MWHB64e1 | S2 | S1 | S2 | S2 | S2 | S2 | S2 | S3 | S2 | S2 | S2 | S2 | S3 | S3 |
| 048 | PPL1B35e2 | N2 | N1 | S3 | S3 | N2 | S2 | S2 | N2 | S3 | S3 | S3 | S3 | S3 | S3 |
| 049 | PTD4B34e1 | S2 | S2 | S2 | S2 | N2 | S3 | S2 | S2 | S2 | S2 | S2 | S2 | S3 | S3 |
| 050 | PPL2B64e2 | S2 | S1 | S1 | S2 | S2 | S2 | S2 | S2 | S2 | S1 | S2 | S1 | S3 | S3 |
| 051 | PPL3B63e3 | S2 | S1 | S2 | S2 | S2 | S3 | S3 | S2 | S2 | S2 | S2 | S1 | S3 | S3 |
| 052 | WHJ5C54e2 | N2 | S3 | S3 | S3 | N2 | S3 | N2 | N2 | S3 | S3 | S3 | S3 | S3 | S3 |
| 053 | WHJ9C54e1 | S3 | S2 | S2 | S2 | S3 | S3 | N2 | S2 | S2 | S2 | S2 | S2 | S3 | S3 |
| 054 | MWG1C64e2 | S3 | S2 | S2 | S2 | S2 | S3 | N2 | S3 | S2 | S2 | S2 | S2 | S3 | S3 |
| 055 | MRS2C65e1 | S3 | S2 | S3 | S3 | S2 | S3 | N2 | S3 | S2 | S3 | S3 | S3 | S3 | S3 |
| 056 | WHJ7C64e2 | S2 | S1 | S2 | S2 | S2 | S2 | S3 | S2 | S2 | S2 | S2 | S2 | S3 | S3 |
| 057 | WHJ4C54e3 | S3 | S2 | S2 | S3 | S3 | S2 | S3 | S3 | S2 | S2 | S2 | S2 | S3 | S3 |
| 058 | WHJ3D44e2 | S3 | S3 | S3 | S3 | N2 | N2 | N2 | S3 | S3 | S3 | S3 | S3 | S3 | S3 |
| 059 | WHJ10D45e1 | S3 | S3 | S3 | S3 | N2 | N2 | N2 | S3 | S3 | S3 | S3 | S3 | S3 | S3 |
| 060 | MRS1D45e2 | S3 | N2 | N2 | N2 | N2 | N2 | N2 | N2 | N2 | N2 | N2 | N2 | N2 | N2 |
| 061 | SKW2D44e1 | S3 | S3 | S3 | S3 | N2 | N2 | N2 | S3 | S3 | S3 | S3 | S3 | S3 | S3 |
| 062 | WHJ1D44e3 | N2 | S3 | S3 | S3 | N2 | N2 | N2 | N2 | S3 | S3 | S3 | S3 | S3 | S3 |
| 063 | NGS4B64e1 | S2 | S1 | S1 | S2 | S2 | S2 | S2 | S2 | S2 | S1 | S2 | S1 | S3 | S3 |
| 064 | SKW1B45e2 | S3 | S2 | S2 | S2 | N2 | S2 | S2 | S2 | S2 | S2 | S3 | S2 | S3 | S3 |
| 065 | MWG2B45e1 | S3 | S2 | S2 | S2 | N2 | S2 | S2 | S3 | S2 | S2 | S3 | S2 | S3 | S3 |
| 066 | PTW5B64e3 | S2 | S1 | S2 | S2 | S2 | S2 | S2 | S2 | S2 | S2 | S2 | S2 | S3 | S3 |

Suitability Classification : S1 = Highly Suitable, S2 = Moderately Suitable, S3 = Marginally Suitable, N1 = Currently not Suitable, N2 = Permanently not Suitable

## 18.9. Map Composition:

Crop suitability map has been composed in GIS environment along with proper legend, scale bar, north arrow, source and base information. Each unit has been labeled with numeric number to identify easily in the map. Crop suitability map prepared for a grid is shown in the Figure-80 and for Cluster-2 is shown in the Figure-81.

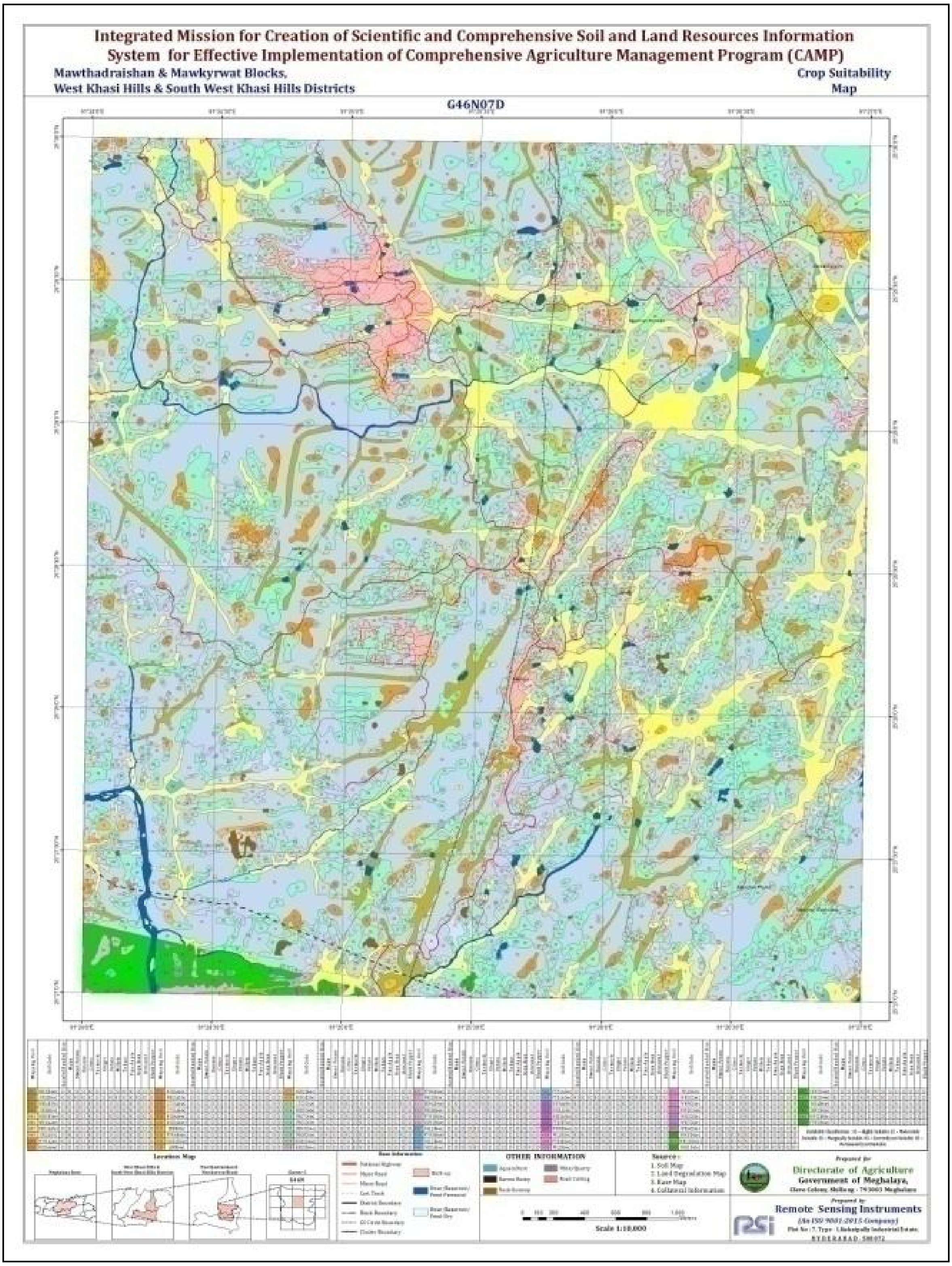



**Figure-80: Crop Suitability Map of a Grid**

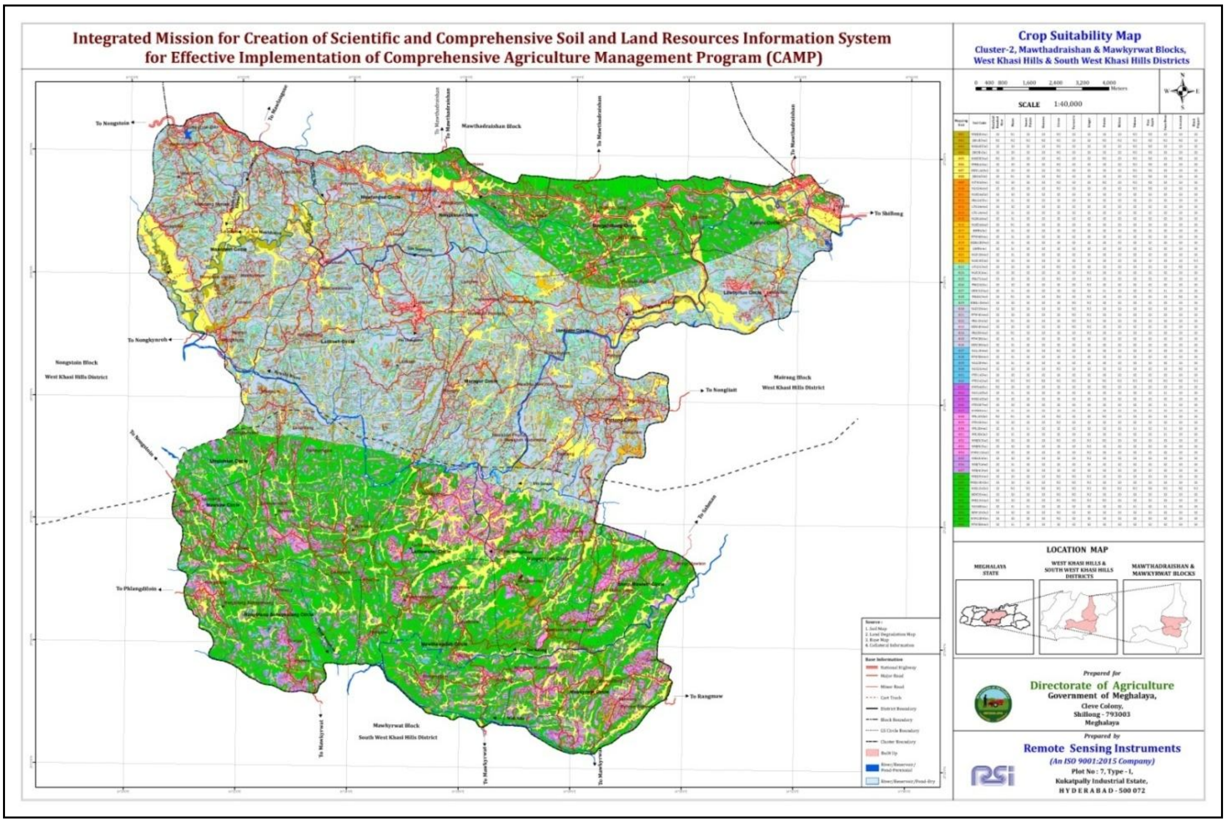



**Figure-81: Crop Suitability Map of Cluster-2**

# CHAPTER-19

# DEVELOPMENT OF SOIL AND LAND RESOURCES INFORMATION SYSTEM

## 19.1. Introduction:

Web based user friendly Soil and Land Resources Information System has been developed for usage of the data prepared in this study. This web based application supports - management, processing, analysis, modeling of soil and land resources data generated in the study. Using this application farmer/user can obtain a report on soil and land status of his land with reference to the grid information available in their soil health cards using available Map tool.

The main role of this system is to migrate soil and land resources data generated to geospatial platform and to generate, manage user friendly reports and data visualizations.

## 19.2. Development and Installation:

Soil and Land Resources Information System has been developed by using the technologies of PHP, GeoServer, Ajax, Open layers, PostGIS. All basic maps function such as zoom-in, zoom-out, pan, legend, co-ordinates tool etc. has been combined with the Shape file data so that number of layers on map is managed efficiently.

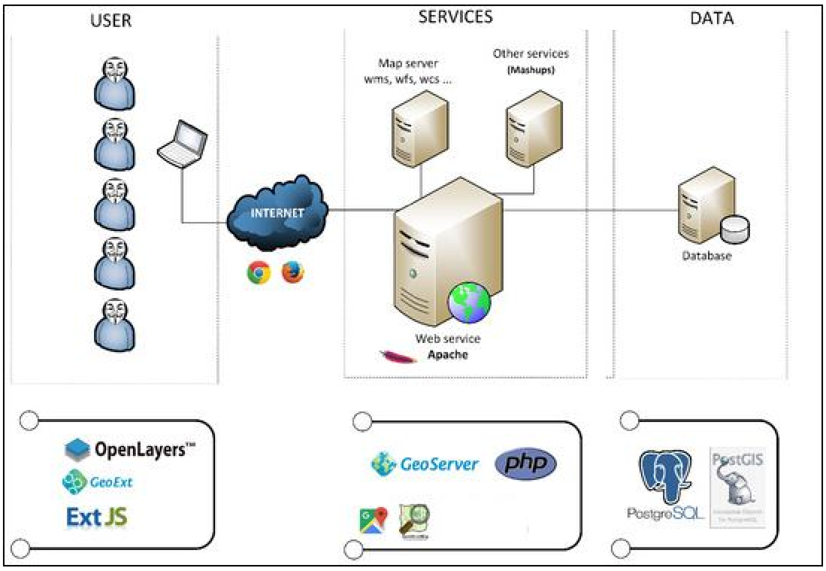



**Figure-82: System Architecture Overview**

**PHP:** PHP (Hypertext Preprocessor) is a powerful server-side scripting language for web programming to create customizable web applications. This language provides cross-platform usability, easy and fast development advantage. It is a very stable and Open Source tool with large support community. It can interact with many different database languages including MySQL, Postgres and PostGIS.

**GeoServer:** GeoServer is an OGC (Open Geospatial Consortium) compliant standard comprises standards for delivering maps and spatial data online (WMS, WFS, WCS, WPS, KML), styling of spatial data (SLD) and sharing of metadata catalogues (CSW) etc. It is a web based API that can be easily embedded into the application and customization can be accomplished. Complex features that contain properties that can contain further nested properties to arbitrary depth can be easily handled. Complex features can be used to represent information not as an XML view of a single table, but as a collection of related objects of different types. Visualization of properties and features can be globally handled either using Java Script or XML configurations.

**Ajax:** AJAX (Asynchronous JavaScript and XML) the basic idea is for dynamic web Portlet/content/page/Map URL rendering with loading the complete page. Whole process is asynchronously processed in the background, while renewing only the part of the page that needs updating.

**OpenLayers:** OpenLayers used is suited for putting a dynamic map in any web page. It can display map tiles, vector data and markers loaded from any source. It is completely free, Open Source and JavaScript compliant framework best suited for handling map objects and Url's.

**PostGIS**: It is a spatial extension of PostgreSQL, an object relational database management system aptly suited for building GIS based web applications.

### 19.3. Application:

**Layer Selection from Landing Page:** User can select any of the layer information that needs to be viewed from landing page as shown in the Figure-83.

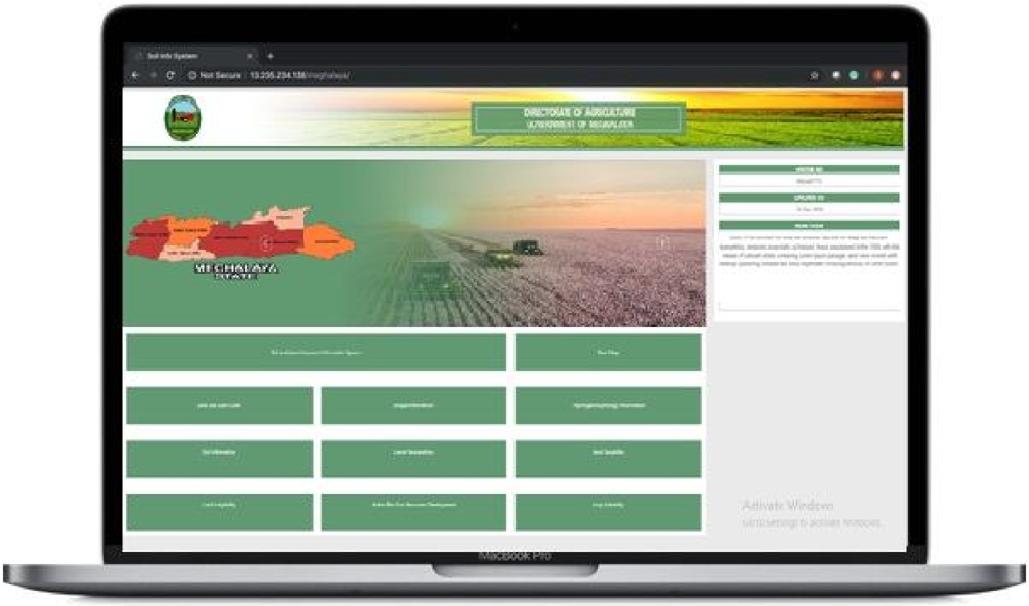


**Figure-83: Soil and Land Resources Information System**

**Selection Criteria:** As this is a customized application, user is driven by selection of options through drop-down menus map will be displayed as shown in the Figure-84.

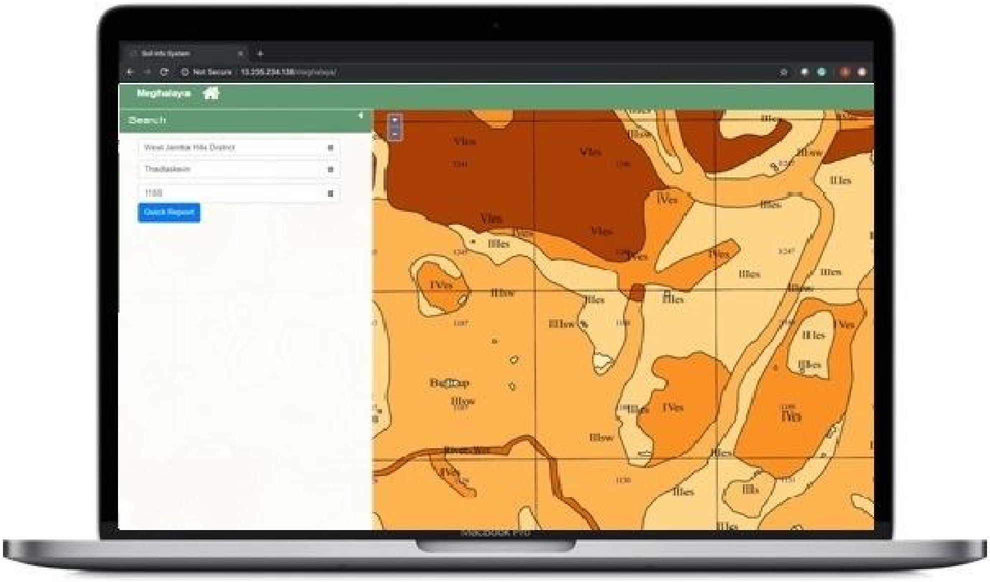


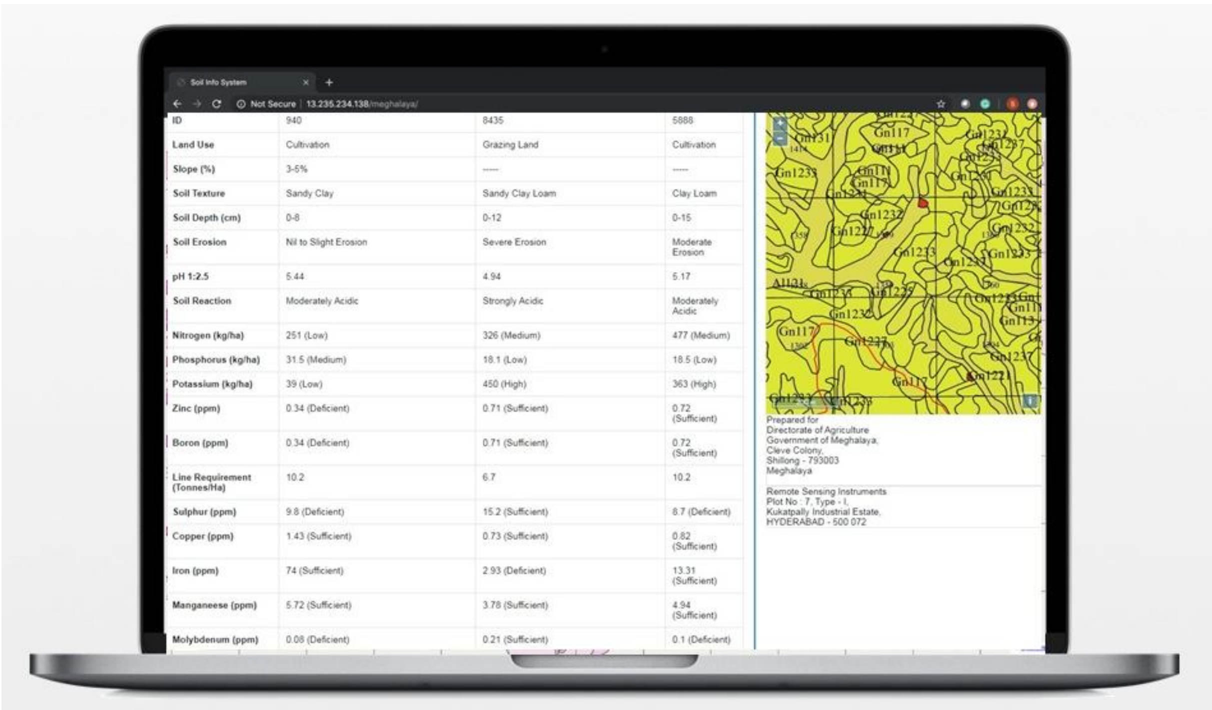
**Figure-84: Selection Criteria**

Step-by-step procedure is detailed below.

- Drop-down list for Select District shows District names.

- Select West Khasi Hills District or South West Khasi Hills District
- Drop-down list for Select Block shows Block names.
- Select Mawthadraishan/ Mawkyrwat Block.
- Drop-down list for Select Grid shows Grid numbers.
- Select desired Grid number as in soil health card.
- Map canvas displays respective Grid Map as shown in the Figure-85.

**Report Generation:** Once the user is zoomed into a particular Grid, user can click directly on the selected grid on the map. Then soil report button will be appeared. Here on clicking Soil Report button a report will be generated with soil and land resources information pertaining to the respective grid number as shown in the Figure-85. In case the respective grid number comprises of more than three types of soils, first three major types (sorted in descending area order) are depicted in a tabular form as well as a map form as shown in the Figure-85. The layout thus generated can be "Printed" on connected printer or can be saved as a file which can be printed later.



| ID | 940 | 8435 | 5888 |
|---|---|---|---|
| Land Use | Cultivation | Grazing Land | Cultivation |
| Slope (%) | 3-5% | ----- | ----- |
| Soil Texture | Sandy Clay | Sandy Clay Loam | Clay Loam |
| Soil Depth (cm) | 0-8 | 0-12 | 0-15 |
| Soil Erosion | Nil to Slight Erosion | Severe Erosion | Moderate Erosion |
| pH 1:2.5 | 5.44 | 4.94 | 5.17 |
| Soil Reaction | Moderately Acidic | Strongly Acidic | Moderately Acidic |
| Nitrogen (kg/ha) | 251 (Low) | 326 (Medium) | 477 (Medium) |
| Phosphorus (kg/ha) | 31.5 (Medium) | 18.1 (Low) | 18.5 (Low) |
| Potassium (kg/ha) | 39 (Low) | 450 (High) | 363 (High) |
| Zinc (ppm) | 0.34 (Deficient) | 0.71 (Sufficient) | 0.72 (Sufficient) |
| Boron (ppm) | 0.34 (Deficient) | 0.71 (Sufficient) | 0.72 (Sufficient) |
| Line Requirement (Tonnes/Ha) | 10.2 | 6.7 | 10.2 |
| Sulphur (ppm) | 9.8 (Deficient) | 15.2 (Sufficient) | 8.7 (Deficient) |
| Copper (ppm) | 1.43 (Sufficient) | 0.73 (Sufficient) | 0.82 (Sufficient) |
| Iron (ppm) | 74 (Sufficient) | 2.93 (Deficient) | 13.31 (Sufficient) |
| Manganeese (ppm) | 5.72 (Sufficient) | 3.78 (Sufficient) | 4.94 (Sufficient) |
| Molybdenum (ppm) | 0.08 (Deficient) | 0.21 (Sufficient) | 0.1 (Deficient) |



\ **Figure-85: Report on Soil and Land Resources Information**

# CHAPTER-20

# FINDINGS OF THE STUDY

Theme wise findings of the study are as given below.

## 20.1. Land Use Land Cover:

Forest cover, grazing land and cultivation are mostly observed in this cluster. Regarding the forest cover, moderately dense to dense forest is covering 28% of the cluster area, open forest covers 9% and scrub forest covers 10% of the cluster area. In respect of cultivation, paddy cultivation is in 16% of the cluster area, cultivation of other crops is in 6% area and fallow land is in 8% area. Other than these, grazing land is prominent and it covers 17% of the cluster area.

## 20.2. Slope:

As this area is made of hilly terrain, >15% slopes is covering half (i.e., 51%) of the cluster area. Moderately steeply sloping ground of 15-35% slope is covering 25.8% area and steeply sloping ground of 35-70% slope is covering 25.6% area. Slopes of < 3% are covering 25.5% area. In which, level to nearly level of 0-1% slope is covering 15.3% area and very gently sloping of 1-3% slope is covering 10.2% area. Other than these, gently sloping area (3-5% slope) is covering 7.2% area, gently to moderately sloping area (5-10% slope) is covering 9.4% area and moderately sloping area (10-15% slope) is covering 6.2% area.

## 20.3. Hydro-geomorphology:

This area is mainly covered by highly/moderately/less dissected upper plateau with valley fills, valleys and piedmont slopes. It has been found that highly dissected upper plateau is covering 27% of the cluster area and it is having nil to poor ground water prospects, moderately dissected upper plateau is covering 18% area and having poor to moderate ground water prospects and less dissected upper plateau is covering 20% area and having moderate ground water prospects. Valley fill is covering 17% area and having good and good to very good ground water prospects. Valleys are covering 7.6% area and having good ground water prospects. Piedmont slope is covering 6.4% area and having good ground water prospects.

### 20.4. Soils:

Soils of this cluster are found that they are moderately acidic to strongly and very strongly acidic and pH is less than 6 with a minimum value of 4.2. These soils have high organic matter content especially in the surface horizon. Exchangeable bases and base saturation are low as the soils are acidic and CEC is moderate. Nitrogen is deficient in 48.5% of surface samples collected, whereas phosphorus is deficient in 19.7% surface samples. Among micro-nutrients, boron is deficient in 25.4% surface samples, molybdenum in 43.7% surface samples and sulphur in surface 25.4% samples. However, iron and copper are sufficient in 100% of surface samples collected, whereas potassium is sufficient in 83.3% surface samples, zinc in 87.9% surface samples and manganese in 80.3% surface samples.

### 20.5. Land Degradation:

Water erosion and soil acidity (acidification) are the major land degradation problems found in this cluster. In case of intensity of water erosion, 48% of the cluster area is affected by nil to slight erosion, 30% area is affected by moderate erosion and 16% area is affected by severe erosion. In case of intensity of acidification, 71.7% area is strongly acidic, 18.1% area is very strongly acidic and only 4.5% area is moderately acidic. In combination of water erosion and acidification, 33.6% area is strongly acidic with nil to slight water erosion.

### 20.6. Land Capability:

Erosion, soil and excess water limitations have been found under class–2/class–3/ class–4/class–6 in this cluster. Class-II land is covering only 0.37% of the cluster area, where the land is suitable for agriculture with moderate limitations. Class-III land is covering 37% area, where soils are having moderate to severe limitations that restrict choice of plants or that require special conservation practices or both. Class-IV land is covering 3% area, where soils are having severe limitations that restrict choice of plants or require very careful management practices for production on these soils. Class-VI land is covering nearly 54% area, where soils are having severe limitations and not suitable for cultivation. In respect of sub class, 76.4% area is having both erosion and soil limitations and 17.9% area is having both soil and excess water limitations

## 20.7. Land Irrigability:

Topography, soil and drainage limitations have been found under class-3/class–4/ class–6 in this cluster. Class-3 land is covering 25% of the cluster area, where land has moderate limitations for sustained use under irrigation. Class-4 land is covering 15% area, where land is marginal for sustained use under irrigation because of severe limitations. Class-6 land is covering 54% area, where land is not suitable for sustained use under irrigation. In respect of sub class, both topography and soil limitations are found in 77% area and only drainage limitations is found in 17% area.

## 20.8. Crop Suitability:

Crop suitability has been analyzed for prominent crops grown in the area namely, for rainfed bunded rice, maize, sweet potato, banana, citrus, turmeric, ginger, potato, millets, tobacco, pine apple, soybean, areca nut and black pepper. Each crop has been classified into highly/moderately/marginally suitable or currently/permanently not suitable for all the 66 soil mapping units delineated. From the analysis it has been observed that, maize is highly suitable in 6% of the cluster area, whereas soybean in 2% area, potato in 0.9% area, sweet potato and tobacco in 0.5% area. Millets are moderately suitable in 39.7% area, whereas banana in 34.8% area. Rainfed bunded rice, sweet potato, tobacco, pine apple and soybean are moderately suitable from 20% to 22% area, maize, citrus and potato are moderately suitable from 16% to 18% area, turmeric and ginger are moderately suitable from 6% to 8% area.

# CHAPTER-21

# ACID SOILS AND THEIR RECLAMATION

## Origin and Classification:

In the regions of high rainfall, soils are acidic in their reaction because of the facts that soluble basic salts such as those of Ca, Mg, K, Na, are leached away by drainage water and insoluble acidic **residues composed chiefly of oxides and silicates of iron, silicon, aluminum are left which accumulate in** pretty high amount. These salts are acidic in reaction, hence the soils are acidic. Besides that reason, there may be other causes also which produce acidity in the soil.

Important factors which produce acidity in soil are as follows:

- Continuous removal of lime and other base elements by crops and accumulation of acids contained in the manures.
- Application of acid forming fertilizers in the soil.
- Microbial action.
- Formation of soil on the acidic rocks.

**Classification of Acid Soils:** According to the intensity of acidity, the acid soils are classified into the following categories in the study areas.

- Normal (pH 6.5-7.5)
- Slightly acidic (pH 5.5-6.5)
- Moderately acidic (pH 5-5.5)
- Strongly acidic (pH 4.5-5)
- Very strongly acidic (pH below 4.5)

Acid soils occurring in temperate climate are categorized as podzol, brown podzol, grey brown podzol, brown forest soils, and grey forest soils based on their variations in their soil conditions.

**Effects of Soil Acidity on Plants:**

Soil acidity affects the plants both directly and indirectly. These effects are briefly mentioned below:

**Direct Effects:** Direct effects are as follows:

- Toxic effects of low H+ ion concentrations on root tissues.
- Influence of soil acidity on the permeability of the plasma membrane for cations.
- Disturbance in the balance between basic and acid constituents through roots.
- Affects enzymatic processes since enzymes are particularly sensitive to pH changes different crop plants have their specific optimum pH requirement. Rice, oat and linseed can endure a fairly acidic reaction (pH = 5.0) while barley, sugar-beet, lucerne etc. can tolerate a fairly alkaline reaction (pH = 8.0)

**Indirect Effects:** Indirect Effects are as follows:

- Availability of various nutrients, e.g., phosphorous, copper, and zinc.
- High solubility and availability of elements like aluminium, manganese and iron in toxic amount due to high acidity in the soil.
- Deficiency of some nutrients such as calcium and potassium due to soil acidity.
- Prevalence of plant diseases.
- Beneficial activities of soil microbes are adversely affected.

**Reclamation of Acid Soils or Correction of Soil Acidity:**

Acidity of soil is due to predominance of H+ ions over OH– ions, the bulk of H+ ions being held in close association with clay-organic colloid complex. Strong acid soils are not much productive. The soils which are less productive owing to high degree of acidity can be made mo

When lime is added to moist soil, the soil solution becomes charged with cations and the exchangeable hydrogen and aluminum ions on clay-organic colloid complex as well as the H+ ionsm soil solution are displaced by calcium ions. Hydrogen combines with OH– to form neutral water or with CO3 or HCO3– to form unstable H2CO3, which readily dissociates to form CO2 and water.

Acidity of soil can also be corrected by adding exchangeable Mg++ to exchange complex. But addition of or Mg++ or both to the soil will not necessarily solve the problem of soil acidity.

The important points to be considered in liming are:

- The salts of these elements which are going to supply these ions (Ca++ or Mg++) and the overall reactions of salts in the soils.
- Salts of strong acids as gypsum (CaSO4) or calcium chloride (CaCl2) can be applied to supply calcium ions to the soils but it is worth considering what will be the effects of these salts on soil acidity. The application of these salts will indeed increase the acidity in the soil, instead of decreasing it. Therefore, it is suggested that calcium salts of strong acids must not be applied for correcting the acidity of soils.

**Liming Materials:**

More than 90 per cent of the lime used in agriculture for reclamation of acid soils is generally in the form of calcium carbonate, some in calcium and magnesium carbonates, and much smaller quantity in the form of calcium oxide or calcium hydroxide. To a chemist lime is calcium oxide but to a farmer, agronomist or soil scientist lime usually means calcium carbonate or calcium carbonate equivalents.

The common liming materials used for reclamation of acid soils are as follows:

- Calcic limestone (CaCO3) which is ground limestone.
- Dolomite (CaCO3, MgCO3).
- Quick lime (CaO) which is burnt limestone.

- Hydrated (slaked) lime [Ca (OH) 2].
- Coral shell lime.
- Marl or chalk (CaCO3).
- Slags obtained as by-products from iron and steel plants, slags are used in agriculture for reclaiming acid soils. The slags are of three types:
  - Blast furnace slags,
  - Basic slag and
  - Electric furnace slag.

  These slags are rich in phosphorus and mixture of CaO and CaCOH)2. Besides, Ca, Mg, Al, silicates are also present in them.
- Press-mud. It is obtained from carbonation plants of sugar mills. Press mud and some other matters containing calcium are used to decrease acidity in the soils.
- Miscellaneous sources of lime, such as, wood ash, ground oyster shells, by-product lime resulting from paper mills, tanneries, water softening plants, and by product CaCO3 form fertilizer factories using gypsum process (such as Sindri Fertilizer Factory, Bihar, India).

The rate of lime application should always be determined after soil testing. The lime requirement has been calculated based on soil pH and buffering capacity of soils. Soil acidity changes from slight to very strong in the study areas. The lime requirement has been calculated to bring the pH to a level of 6.4. The lime requirement was found to vary from 5.7 tonnes for hectare to 10.7 tonnes for hectare in this cluster.

# CHAPTER-22

# NUTRIENT/FERTILISER APPLICATIONS

## 22.1. Supplementing Deficient Nutrients with Organic Manures in Place of Inorganic Fertilizers:

The use of chemical fertilizer is increasing day-by day for the sake of increasing production. By excess use of it, the fertility of soil and health also deteriorate. Therefore, the use of organic manure is one of the alternative ways for enhancing production and improves the soil health. It is not only cheaper; easily available and ensures sustainable agriculture too.

**Organic Mnnures:** Organic manures are natural products used by farmers to enhanced sustainable crop production. There are a number of organic manures like farm yard manure, green manures, compost prepared from crop residues and other farm wastes, vermi compost, oil cakes, and biological wastes-animal bones, slaughter house refuse.

Organic manures comprise a variety of plant-derived materials that range from fresh or dried plant material to animal manures and litters to agricultural by-products. The nutrient content of organic manures varies greatly among source materials, and readily biodegradable materials make better nutrient sources. Nitrogen and phosphorus content is lower, often substantially lower, in organic fertilizers compared to chemical fertilizers. However, use of locally available sources is perfectly reasonable if its use is consistent with the production strategy.

Nutrient value of animal manures is more variable than that of agricultural by-products. However, it always is advisable to analytically determine the nutrient content of the organic fertilizer. The organic carbon content of organic fertilizer can be of equal or greater importance than its nitrogen and phosphorus contents.

**Advantages of Organic Manures**:

- Organic manure provides all the nutrients that are required by plants but in limited quantities.

- It helps in maintaining C:N ratio in the soil and also increases the fertility and productivity of the soil.
- It improves the physical, chemical and biological properties of the soil.
- It improves both the structure and texture and water holding capacity of the soils.
- Due to increase in the biological activity, the nutrients that are in the lower depths are made available to the plants.
- It acts as mulch, thereby minimizing the evaporation losses of moisture from the soil.
- It reduces the cost of agricultural production and also improves the soil health.
- It has been noticed plant products and animal products (milk, meat etc.) produced from organic farming are substantially better in quality.
- The underground water of such farming system are found to be free from toxic elements.

**Disadvantage of Organic Manures**:

- The continuous use of organic manures alone might result in asynchronicity between N supply and demand by crops, which may lead to a greater potential of nitrate leaching, especially under wet/humid conditions as in this cluster.
- Repeated excessive applications of animal manures were observed to adversely affect soil quality and crop yield (Chang et al., 1990), increase accumulation of P in soil (Zhang et al., 2004) and nitrate leaching (Yuan et al., 2000), and lead to high gaseous N losses and ammonia volatilization (Beauchamp et al., 1982).
- Nutrients are so low that a huge quantity of manure has to be added for the desired dose of nutrients.
- Transport of a huge quantity of manure to the site of application is difficult especially in hilly areas as this cluster. It increases the cost also.
- The rate of mineralization and the rate of release of nutrients, particularly of the nitrogen, are slow.

**Inorganic Fertilizers**: Inorganic fertilizer, also referred to as synthetic fertilizer, is manufactured artificially and contains minerals or synthetic chemicals. For example, synthetic nitrogen fertilizers are typically made from petroleum or natural gas. Phosphorus, potassium and other trace elements in inorganic fertilizers are often mined from the earth.

Balanced inorganic fertilizers, high in all three macronutrients, commonly include products like ammonium nitrate, ammonium sulfate, potassium chloride (potash), triple superphosphate, and magnesium sulfate (Epsom salts). Inorganic fertilizers provide this nutrition in plant-ready form immediately. The concentration of nutrients increases the risk of burning the plant, and the rapid release of nutrients may leach them deeply into the soil and water table where plants can't access them.

**Advantages of Inorganic Fertilizers**:

- You can use inorganic fertilizer to rescue dying plants immediately, because of it releases nutrients easily into the soil and absorbed by the plants.
- It is easily available in almost all agro-input outlets. This makes it very convenient.

**Disadvantages of Inorganic Fertilizers**:

- The cost is relatively much higher than organic fertilizers.
- Besides the essential nutrients available for plants' use in inorganic fertilizers, they also contain other compounds and salts. Plants are unable to absorb these compounds and salts, and so are left in the soil. Over time, these compounds build up in the soil and change the soil chemistry. This creates soil problems, making it less ideal to work with.
- Applying too much, at an instance, tends to burn the plant and can even destroy it. You need to strictly follow the recommended rates.
- Moreover, leaching occurs easily when you over water or when there is too much rainfall as in this cluster.

- In cases of heavy rains or overwatering, the nutrients and other compounds wash into nearby water bodies. They pollute and render them unhealthy for consumption by human or livestock.

Continual application of the fertilizer disturbs the natural biotic environment and affects the soil structure. Most soil organisms do not survive in areas of consistent application of inorganic fertilizers.

**Conclusions on usage of Organic Manures in place of Inorganic Fertilizers:**

- Organic manure provides all the nutrients that are required by plants but in limited quantities.
- Usage of organic manure reduces the cost of agricultural production and also improves the soil health.
- Plant products and animal products (milk, meat etc.) produced from organic farming are substantially better in quality.
- The continuous use of organic manures alone might result in asynchronicity between N supply and demand by crops, which may lead to a greater potential of nitrate leaching, especially under wet/humid conditions as in this cluster.
- Repeated excessive applications of animal manures were observed to adversely affect soil quality and crop yield (Chang et al., 1990), increase accumulation of P in soil (Zhang et al., 2004) and nitrate leaching (Yuan et al., 2000).
- Nutrients are so low that a huge quantity of manure has to be added for the desired dose of nutrients which increases manure and its transport cost substantially especially in hilly areas as this cluster.
- The nutrient content in inorganic fertilizers is high and releases nutrients easily into the soil and absorbed by the plants which saves even dying plants.
- The cost of inorganic fertilizers is relatively much higher than organic fertilizers.
- In case of heavy rains, the nutrients and other compounds in inorganic fertilizers will washout into nearby water bodies. They pollute and render them unhealthy for consumption by human or livestock.

- In view of the above, an optimum combination of organic and inorganic fertilizers is recommended for sustainable agriculture.

## 22.2. Nutrient-Fertilizer Recommendations for Major Crops:

Nutrient fertilizer Recommendations depend on number of parameters such as nutrient content of the soils, type of crop and variety grown. In the present study, nutrients present in different soils indicating the sufficiency/deficiency of the different nutrients including micronutrients have been studied. For major nutrients like N, P, K their status is indicated by low, medium, or high, based on the quantitative analysis of the nutrients. The fertilizer recommendation may be given by the agriculture department based on the field trials on soil test/crop response/fertilizer recommendations keeping in view the fertility status of the soils, crops and their varieties grown and the farming practices being adopted.

However, we are giving nutrient-fertilizer recommendations for major crops grown in this cluster based on the available information. If required, the department of agriculture can conveniently modify the recommendations suitable to the local conditions.

The fertilizer recommendations are made combining organic manures with inorganic fertilizers for the following crops.

**Paddy**: Nutritional requirement should be assessed based on the soil analysis of the crop field. In absence of soil analysis, application of 60-40-40 kg N ha-1 , 60 kg $P_2O_5$ ha-1and 40 kg $K_2O$ ha- 1 is recommended. 50% dose of nitrogen and 100% dose of phosphorus and potassium should be applied at the time of sowing (basal). The remaining 50% dose of nitrogen should be given in two splits vis. 30 and 60 days after sowing (DAS). If available it is also recommended to apply 5 ton FYM/ha during land preparation (20 days before sowing).

As most of the soils of Meghalaya are acidic in nature lime should be applied as recommended in the report at the time of land preparation once in three year. Apply manure and fertilizers in the following split doses.

Green manuring Dhaincha (Sesbania aculeate) or Crotolaria sp. can be grown between two lines of rice and after 30 days after sowing (DAS), these plants can be cut and used as mulch between the rice 13 lines. It increases the soil fertility as well as reducing soil erosion and moisture evaporation from the field. As the soils are acidic, application of recommended dose of lime may increase the yields.

**Potato:** FYM 15-20 t/ha should be applied in the furrows before planting. Fertilizer dose of 120 kg N, 120 P2O5, 60 kg K2O is recommended. Entire quantity of mixed fertilizer should be applied in furrows as basal application and covered with a thin layer of soil so that tubers do not come into contact with the fertilizer. As the soils are acidic, application of recommended dose of lime may increase the yields. Micronutrients may be applied based on the sufficiency/deficiency of particular nutrients in the soil based on the soil test data provided in this study.

**Sweet Potato:** FYM 15 t/ha is applied at the time of field preparation. In addition to that 190kg Urea, 375kg SSP and 150kg MOP is also applied per hectare. One third of Urea and full dose of SSP and MOP is to be applied at the time of land preparation and the remaining dose of Urea should be applied in three equal splits at 30, 45 and 60 days after planting. Excessive nitrogen in the soil delays the tuber formation. As the soils are acidic, application of recommended dose of lime may increase the yields. Micronutrients may be applied based on the sufficiency/deficiency of particular nutrients in the soil based on the soil test data provided in this study.

**Maize:** For maize, 10-15 tonnes of farmyard manure, cow dung or compost are required for hectare, which should be incorporated into the soil at the time of ploughing. It is also recommended to apply 175 kg of Urea, 375 kg of SSP and 50 kg of MOP for providing N:P:K::80:60:40. However, for local varieties 130 kg of N, 250 kg of SSP and 50 kg of MOP recommended.

One third the quantity of Urea and the whole quantity of SSP and MOP should be applied at sowing time or just before sowing. The remaining quantity of urea should be applied as top-dressing, in two equal split doses, 30-45 days (knee height stage) and 60-75 days (tassel initiation stage) after sowing. Micronutrients may be applied based on the sufficiency/deficiency of particular nutrient in the soil.

Soils however, should be tested regularly as the recommendations will differ from region to region, and will also depend on other factors related to previous crop grown, soil management, pH, etc. As the soils are acidic, application of recommended dose of lime may increase the yields.

**Orange:** Citrus trees require heavy manuring, but in the north eastern region, it is very much neglected. Lack of proper manuring in mandarin orange plantations is one of the main reasons for low production as well as decline of orchards. Organic manuring is a better way of feeding the citrus plants than chemical fertilizers. A balanced dose of nutrients should be given to bearing trees (400-600 g of nitrogen, 350-400 g of phosphorous and 400-600 g of potassium along with 25-30 kg of farm yard manure per tree around the base for average production of 400-500 fruits per tree of mandarin orange and sweet orange depending upon the nutrients status of the soil). Farm yard manure and fertilizers should be applied in March-April, provided sufficient moisture is present in the soil. Chemical fertilizers with half dose of nitrogen and full dose of potassium and phosphorous is mixed in the soil after 15-20 days of farm yard manure application. In high rainfall areas, it is advisable to apply the fertilizers at least in two spilt doses, one in February-March and another in August-September.

Similarly, the response of micro-nutrients on the declined trees is also found to be encouraging in this region. Therefore, regular spraying of micro-nutrients is essential for normal growth and production of citrus fruits, especially of those nutrients which are deficient in acid soils. These micro-nutrients can be applied in April-May along with half dose of nitrogen in spray form at the rate of 2 percent urea, 0.5 percent zinc sulphate, 0.1 percent boric acid, 0.2 percent magnesium sulphate, 0.3 percent copper sulphate and 0.2 percent sodium molybdate.

A smaller dose of these nutrients (250-300 g N, 200-250 g $P_2O$ and 250-300 g $K_2O$) are required for other citrus fruits also. Liming is also beneficial to citrus, especially in this region because of its acidic soil. Lime can also be sprayed along with other nutrients but in the long run basal application is more beneficial at the rate of 500-800 g per plant or the recommended dose of lime.

**Ginger:** At the time of planting, well decomposed cattle manure or compost @ 10 tonnes/ha has to be applied either by broadcasting over the beds prior to planting or applied in the pits at the time of planting. Application of neem cake @ 2 tonnes/ha at the time of planting helps in reducing the incidence of rhizome rot disease/ nematode and increasing the yield.

As the soil fertility will be varying with the soil type, agro ecological conditions or management systems, site specific nutrient management based on the soil test results for major nutrient is advocated. The recommended dose of nutrients for varying soil test values of N, P and K is given in the table below. The fertilizers are to be applied in 2 - 3 split doses. Full dose of phosphorus is applied as basal at the time of planting. Equal split doses of N and K is top dressed at 45, 90 (and 120) DAP. As the soils are acidic, application of recommended dose of lime may increase the yields. Micronutrients may be applied based on the sufficiency/deficiency of particular nutrients in the soil based on the soil test data provided in this study.

Soil test based fertilizer recommendations for fresh rhizome yield target levels of 25 and 30 tons/ha.

**Table-29: Fertilizer/Nutrient Recommendations**

| Soil test value for available Nutrients (kg/ha) | Fertilizer Recommended for yield targets 25 t/ha | Nutrient (kg/ha) 30 t/ha |
|---|---|---|
| Nitrogen | | |
| < 150 | 250 | 340 |
| 150-250 | 180 | 270 |
| 250-400 | 90 | 175 |
| > 400 | - | 50 |
| Phosphorus(P2O5) | | |
| < 10 | 55 | 75 |
| 10-30 | 35 | 55 |
| 30-50 | 15 | 25 |
| > 50 | - | 5-10 |
| Potassium(K2O) | | |
| < 110 | 100 | 130 |

| Soil test value for available Nutrients (kg/ha) | Fertilizer Recommended for yield targets 25 t/ha | Nutrient (kg/ha) 30 t/ha |
|---|---|---|
| 110-300 | 75 | 100 |
| 300-500 | 35 | 50 |
| > 500 | 5 | 15 |

In Zinc deficient soils, basal application of zinc fertilizer up to 6 kg zinc/ha (30 kg of zinc sulphate/ha) gives good yield. Foliar application of micronutrient mixture specific to ginger is also recommended (dosage @ 5 g/L) twice, 60 and 90 DAP, for higher yield.

### 22.3. Organic Manuring System:

In the earlier chapter, discussions are made in detail about the advantages and disadvantages of using organic manures or inorganic fertilizers. Considering the benefits and disadvantages of using nutrients in single form, combined use of organic and inorganic fertilizers has been recommended. The above nutrient recommendations given for different crops are also showing the combination of organic and inorganic fertilizers. A list of organic manures and inorganic fertilizers with their nutrient contents are given below Tables-30 to 32.

**Table-30: NPK content in different Organic Manures**

| Name of the Manure | N% | $P_2O_{5\%}$ | $K_2O$% |
|---|---|---|---|
| Animal Refuse | 0.3-0.4 | 0.1-0.2 | 0.1-0.3 |
| Cattle Dung (Fresh) | 0.4-0.5 | 0.3-0.4 | 0.3-0.4 |
| Poultry Manure (Fresh) | 1.0-1.8 | 1.4-1.8 | 0.8-0.9 |
| Sewage Sludge (Dry) | 2.0-3.5 | 1.0-5.0 | 0.2-0.5 |
| Rural Compost (Dry) | 0.5-1.0 | 0.4-0.8 | 0.8-1.2 |
| Urban Compost (Dry) | 0.7-2.0 | 0.9-3.0 | 1.0-2.0 |
| Farmyard Manure (Dry) | 0.4-1.5 | 0.3-0.9 | 0.3-1.9 |
| Banana (Dry) | 0.61 | 0.12 | 1.00 |

**Table-31: NPK content in different Fresh Green Manures**

| Fresh Green Manures | N% | $P_2O_{5\%}$ | $K_2O$% |
|---|---|---|---|
| Cowpea (Vigna Unguiculata) | 0.71 | 0.15 | 0.58 |

| **Fresh Green Manures** | **N%** | **$P_2O_{5\%}$** | **$K_2O\%$** |
|---|---|---|---|
| Sesbania Aculeata | 0.62 | - | - |
| Cluster-bea (Cyamopsis Tetragonoloba) | 0.34 | - | - |
| Horse-gram (Dolichos Biflorus) | 0.33 | - | - |
| Mothbean | 0.80 | - | - |
| Green gram (Vigna Radiate) | 0.72 | 0.18 | 0.53 |
| Sunnhemp (Crotalaria Juncea) | 0.75 | 0.12 | 0.51 |
| Blackgram (Vigna Mungo) | 0.85 | 0.18 | 0.53 |

**Table-32: Micro Nutrient Status of Farm Yard Manure (FYM)**

| **Micro Nutrient** | **FYM (in %)** |
|---|---|
| Sulfur | 0.0200 |
| Zinc | 0.0040 |
| Copper | 0.0003 |
| Manganese | 0.0070 |
| Iron | 0.4500 |

**Major Nutrient Contents of Inroganic Fertilizers**: Major nutrients contents such as nitrogen, potassium and phosphorus in inorganic fertilizers are given the Table-33, 34 and 35, respectively

**Table-33: Nitrogen percentage in different Nitrogenous Fertilizers**

| **Inorganic Fertilizer** | **Nitrogen%** |
|---|---|
| Ammonium Sulphate | 20.6-21.0 |
| Urea | 44.0-46.0 |
| Ammonium Chloride | 25+ |
| Ammonium Nitrate | 32-35 |
| Ammonium Sulphate Nitrate | 2.6 |
| Calcium Ammonium Nitrate (CAN) | 25.0 |
| Sodium Nitrate | 16.0 |

| Inorganic Fertilizer | Nitrogen% |
|---|---|
| Calcium Nitrate | 15.6-21.6 |
| Potassium Nitrate | 13.0 |
| Calcium cynamide | 212.0 |

**Table-34: Potassium percentage in different Potassic Fertilizers**

| Inorganic Fertilizer | $K_2O$% |
|---|---|
| Murate of potash | 50.0-60.0 |
| Potassium sulphate | 48.0-52.0 |

**Table-35: Phosphorus percentage in different Phosphatic Fertilizers**

| Inorganic Fertilizer | $P_2O_5$% |
|---|---|
| Single Superphosphate | 16.1-20+.0 |
| Double Superphosphate | 30.1-35.0 |
| Triple Superphosphate | 45.0-50.0 |
| Basic Slage (India) | 3.0-8.0 |
| Dicalcium Phosphate | 35.0-40.0 |
| Rock Phosphate | 20.0-25.0 |

The nutrient Recommendations given for different crops in the above paragraphs show the combination of organic and inorganic fertilizers. However, the above tables-33 to 35 shows the nutrient contents of different organic manures and inorganic fertilizers.

Based on the policy of Department of Agriculture, if the Agriculture Department wants to use only organic farming, they have to apply huge quantities of organic manures available locally to compensate the nutrient content of inorganic fertilizers to get maximum yields. The above tables help in converting inorganic component of nutrients to organic component of manures.

The continuous use of organic manures alone may lead to a greater potential of nitrate leaching, especially under wet/humid conditions. Nutrients are so low in organic manures that a huge quantity of manure has to be added for the desired dose of nutrients which may increase the cost of manure and transportation charges in the hilly terrain.

# CHAPTER-23

# RECOMMENDATIONS

Action plan for land resources development has been suggested by considering problems and potentials of soils, slope, existing land use, soil erosion, nutrient deficiencies, and soil acidity problems. The action plans consist of soil and water conservation measures, lime requirement and addition of deficient nutrients. To control over flooding of the paddy areas, construction of runoff diversion channels have been suggested. To control soil erosion in cultivated areas on gentle and moderate slopes, contour bunding with diversion drains are suggested. Bench terracing is also suggested especially in moderate slopes with deep soils. The scrub land areas with nearly level to gently sloping areas have been recommended for cultivation of crops by clearing the bushes and making field bunding/contour bunding. In moderate slopes with scrub lands bench terracing is suggested wherever the soils are deep and cultivation of annual crops/horticulture is suggested. In steep slopes with scrub forest, half-moon terracing with horti-silvi pasture is suggested. In gently sloping fallow lands, strengthening of field bunds and cultivation of crops is suggested. In moderate slopes with fallow lands, bench terracing and cultivation of crops is suggested, wherever the soils are deep. In steeply sloping open forest areas staggered trenching and gap afforestation is recommended, where as in lower slopes gap afforestation is recommended in the open forest areas.

Staggered trenching is suggested in 17.2% area, construction of run-off disposal channel is suggested in 15.7% area, half-moon terracing is suggested in 14.7% area, bench terracing is suggested in 8.4% area, contour bunding is suggested in 3.9% area and strengthening of existing field bunds is suggested in 5.7% area. Protection and monitoring of forest is suggested in 24.7% area and gap afforestation is suggested in 12.7% area. Development of horti-silvi-pastoral system is suggested in 22.6% area and cultivation of crops is suggested in 14.8% area of Cluster-2.

Construction of water harvesting structures like check dams, nallah bunds and percolation tanks with diversion canals, have been suggested for water resources development. Check dams have to be constructed on the lower order streams with gentle slopes, where as percolation tanks have to be constructed on the lower order streams in plains and valleys having sufficient weathered zone / loose material.

The soil acidity ranges from moderately acidic to very strongly acidic, and nutrient availability to many crops is a problem in such acidic conditions. The lime requirement to bring the soils pH level up to 6.4 has been estimated and recommended. The lime requirement is found to vary based on the pH of the soil. Application of lime is suggested in 56.9% area. Application of 10.7 tonnes of lime is suggested in 14.4% area and application of 10.2 tonnes of lime is suggested in 34.3% area. Application of 8 to 10 tonnes of lime is suggested in 3.8% area and application of 5 to 8 tonnes of lime is suggested in 4.4% area.

Application of N, P & K is suggested in 28.1%, 8.5% and 10% areas, respectively where N, P and K are deficient. Application of Boron (B), Molybdenum (Mo), Manganese (Mn), Sulphur (S) and Zinc (Zn) are suggested in 28.1%, 24.7%, 24.7%, 16.1 and 9.6% areas of this cluster, respectively where micro nutrients are also deficient.

There are advantages and disadvantages in usage of organic manure and inorganic fertilizers. In view of this, an optimum combination of organic and inorganic fertilizers is recommended for compensation of deficient nutrients for sustainable agriculture in major crops grown in this cluster.

Rainfed bunded rice, maize, sweet potato, banana, citrus, turmeric, ginger, potato, millets, tobacco, pine apple and soybean are found high/moderately suitable in some of the areas in this cluster. They can be recommended for cultivation in those areas. Liming may improve the suitability. Marginally suitable areas are not recommended as they are not economical.

# CHAPTER-24

# TRAINING

Customized training programme will be provided to the officials of Agriculture Department and related user agencies with the thematic experts as well as GIS experts on how the data has been generated, utilization of the thematic maps and data prepared, usefulness and utilization of Soil and Land Resources Information System.

Training progromme will be conducted by delivering lectures and presentations, by conducting on hand live training programme, by clearing doubts and by taking feedback etc.

**Figure-86: Presentation on Thematic Maps generated**

# CHAPTER-25

## DELIVERABLES

All the satellite images procured from NRSC namely Deimos-2, Cartosat-1, Resourcesat-2 LISS-IV MX covering the study area and their rectified images have been submitted in digital in a hard disk. DEM generated for contour generation and details of Ground Control Points (GCP's) collected by DGPS survey have been submitted in digital format as DGPS Library. Base map, agriculture and other land use / land cover (ALULC) map, slope map, hydro-geomorphology map, soil map, land degradation map, land capability map, land irrigability map, action plan map for land and water resources development and crop suitability map have been composed for entire cluster and submitted in hard copies and in soft copies as .pdf format. These maps have also been composed in 10k grid wise on 1;10,000 scale and submitted. Database generated for preparation of all these maps have been submitted in soft copy as geo-database/.shp file format. Technical report has also been prepared and submitted.

# CHAPTER-26

# CONCLUSIONS

Natural resources like land use/land cover, geomorphology, lithology, slope, soils etc. have been mapped by application of Remote Sensing and GIS. Soil profile points have been dug and soil samples have been collected at different depths and analyzed for different soil parameters like pH, EC, Organic Carbon, CEC etc., available major and micro nutrients such as Nitrogen, Phosporus, Potassium, Sulphur, Boron, Copper, Zinc, Iron, Manganese and Molybdenum. Mechanical analysis of the soil samples has also been carried. The results indicate that the textures are mostly sandy clay loams and clay loams. The pH is less than 6 with a minimum value of 4.2 indicating the soils vary from moderately acidic to strongly and very strongly acidic. From the analysis of surface soil samples, it has been observed that the major deficiencies are in nitrogen, molybdenum, boron, sulphur and phosphorus. However, iron, copper, zinc, potassium and manganese are sufficient in most of the surface soil samples.

Crop suitability has been analyzed for prominent crops grown in this area namely, rainfed bunded rice, maize, sweet potato, banana, citrus, turmeric, ginger, potato, millets, tobacco, pine apple, soybean, areca nut and black pepper. The study area has been classified into highly/moderately/marginally suitable and currently/permanently not suitable for these crops.

Action plan for land resources development has been suggested by considering problems and potentials of soils, slope, existing land use, soil erosion, nutrient deficiencies, and soil acidity problems. To control over flooding of the paddy areas runoff disposal channels have been suggested. To control soil erosion in cultivated areas on gentle and moderate slopes, contour bunding is suggested. Bench terracing is also suggested especially in moderate slopes with deep soils. The scrub land areas with nearly level to gently sloping areas have been recommended for cultivation of crops by clearing the bushes and making field bunding/contour bunding. In moderate slopes with scrub lands bench terracing is suggested, wherever the soils are deep, cultivation of annual crops/horticulture is suggested.

In steep slopes with scrub forest, half-moon terracing with horti-silvi pasture is suggested. In gently sloping fallow lands, strengthening of field bunds and cultivation of crops is suggested. In moderate slopes with fallow lands bench terracing and cultivation of crops is suggested, wherever the soils are deep. In steeply sloping open forest areas staggered trenching and gap afforestation is recommended, where as in lower slopes gap afforestation is recommended in the open forest areas.

Acidity is one of the serious problems in the area. The soil acidity ranges from moderately acidic to very strongly acidic, and nutrient availability to many crops is a problem in such acidic conditions. The lime requirement to bring the soil pH level up to 6.4 has been estimated and recommended. The lime requirement is found to vary based on the pH of the soil. Application of N, P & K is suggested in deficient areas. Application of micro nutrients such as zinc, molybdenum, sulphur, boron, copper and manganese are suggested in deficient areas.

There are advantages and disadvantages in usage of organic manure and inorganic fertilizers. In view of this, an optimum combination of organic and inorganic fertilizers is recommended for sustainable agriculture.

Rainfed bunded rice, maize, sweet potato, banana, citrus, turmeric, ginger, potato, millets, tobacco, pine apple and soybean have been suggested in high and moderately suitable areas. Liming may improve the suitability. Nutrient/fertilizer recommendations are given for the major crops.

Construction of water harvesting structures like check dams, nallah bunds and percolation tanks with diversion canals, have been suggested for water resources development. Check dams have to be constructed on the lower order streams with gentle slopes, where as percolation tanks have to be constructed on the lower order streams in plains and valleys having sufficient weathered zone / loose material.

Web based user friendly Soil and Land Resources Information System has been developed in GIS for usage of the data prepared in this study. The data can be retrieved by the farmers with reference to the grid information available in their soil health cards.

# CHAPTER-27

## WAY AHEAD / FUTURE STUDIES

In the present study, problems and potentials of the area have been identified by systematic study of various natural resources like land use/land cover, slope, physiography, soils, etc. Various problems like availability of limited land for agriculture and irrigation is noticed as it is a hilly terrain with moderate to steep slopes. Occurrence of underutilized lands like grazing lands, scrub forest and fallow lands are also noticed. In addition, highly acidic soils affecting the availability of nutrients to crops, their productivity and soil erosion problems due to heavy rains and steep slopes are noticed.

The remedial measures suggested include various land and water resource development programmes like soil and water conservation measures, liming to decrease the soil acidity for improving nutrient availability and application of deficient nutrients. The study also reveals deficiency of some major and micro nutrients which may be compensated by application of organic manures in optimum combination with inorganic fertilizers to have sustainable crop production.

Now focus should be made on implementation of these recommendations at grid level. For implementing the development of programmes, grid may be used as a basic unit in the absence of a cadastral base. The implementation of action plans may be taken up in a phased manner as it requires huge financial support from state and central government agencies as the farmers are poor to invest in the developmental programmes. However, the farmers can take up action items like clearing the bushes/field bunding for cultivation of crops, application of deficient nutrients and liming of soils with government subsidies.

The present study involves only part of Mawthadraishan and Mawkyrwat blocks of West Khasi Hills and South West Khasi Hills Districts. This type of studies should be extended to other parts of the district, so that basic data can be generated, characterization of various natural resources can be carried out and problems and potentials of the natural resources can be identified for the entire district. This will help in suggesting remedial measures in the form of action plans for development of land and water resources, reducing the soil acidity and application of deficient nutrients and growing of suitable crops for achieving the following goals for entire district on an uniform basis.

- Attaining Food Security and Sustainable Growth by increasing production of food grains and improving productivity.
- Augment Farmer's Income through growing of suitable horticultural crops.
- Promote Commercial Agriculture through low volume high value crops.