ABSTRACT DIGITIZED

INTEGRATED LAND AND WATER RESOURCES DEVELOPMENT IN PIMPALGAON UJJAINI WATERSHED USING REMOTE SENSING AND GIS TECHNIQUES

by

Harshal Mahadevrao Galgale
B. Tech (Agril. Engg.)

A thesis submitted to the
MAHATMA PHULE KRISHI VIDYAPEETH,
RAHURI - 413 722 DIST - AHMEDNAGAR
MAHARASHTRA STATE (INDIA)

In the partial fulfilment of the requirements for the degree

of

MASTER OF TECHNOLOGY
(AGRICULTURAL ENGINEERING)

in

IRRIGATION AND DRAINAGE ENGINEERING

DEPARTMENT OF IRRIGATION AND DRAINAGE ENGINEERING
DR. ANNASAHEB SHINDE COLLEGE OF AGRICULTURAL ENGINEERING
MAHATMA PHULE KRISHI VIDYAPEETH,
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RAHURI, DIST. AHMEDNAGAR, M. S. (INDIA)

2000

CANDIDATE'S DECLARATION

I hereby declare that this thesis or part thereof has not been submitted by me or any other person to any other University or Institute for a Degree or Diploma.

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CERTIFICATE

This is to certify that the thesis entitled **"Integrated Land and Water Resouces Development in Pimpalgaon Ujjaini Watershed Using Remote Sensing and GIS Techniques"**, submitted to the Dr. A. S. College of Agricultural Engineering, Mahatma Phule Krishi Vidyapeeth, Rahuri, Dist. Ahmednagar, Maharashtra, in the partial fulfillment of the requirements for the degree of **Master of Technology (Agricultural Engineering)** in **Irrigation and Drainage Engineering**, embodies the results of a piece of bonafied research work carried out by **Shri. Harshal M. Galgale**, under my guidance and supervision.

The result embodies in this thesis have not been submitted to any other University or Institute for the award of degree or diploma.

The assistance and help received during the course of this investigation and source of the literature have been duly acknowledged.

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Place: M. P. K. V., Rahuri

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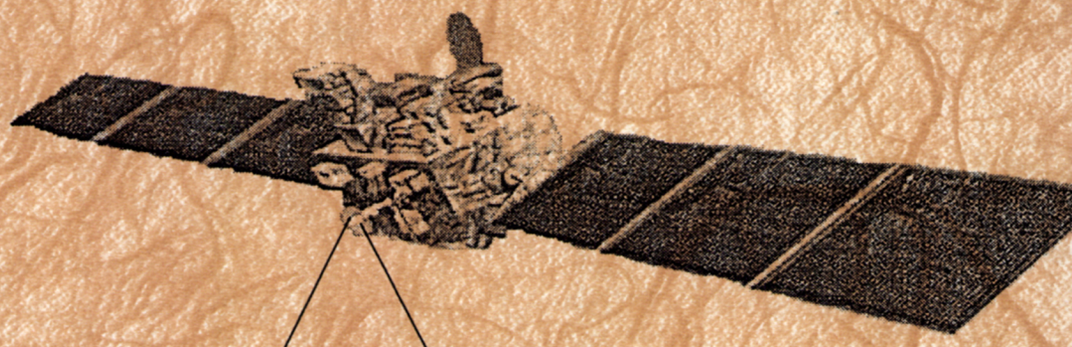
LIST OF SYMBOLS

$	=	dollars
%	=	per cent
°C	=	degree centigrade
cm	=	centimeter
gm	=	gram
ha	=	hectare
km	=	kilometer
m	=	meter
Mha	=	million hectare
mm	=	millimeter
sq. km	=	square kilometer
t/ha	=	tonnes per hectare

LIST OF ABBREVIATIONS

Abbreviations	Description
Ag.	: Agricultural
Agri.	: Agriculture
CCT	: Computer Compatible Tape
CD	: Computer Disk
Conf.	: Conference
Cons.	: Conservation
CPU	: Central Processing Unit
CRT	: Cathode Ray Tube
DEM	: Digital Elevation Model
Dept	: Department
Dist.	: District
EASI	: Environmental Analysis, System and Interface
EMR	: Electromagnetic radiation
Engg.	: Engineering
et al.	: and others
FCC	: False Colour Composite
Fig.	: Figure
GCP	: Ground Control Point
GIS	: Geographic Information System
IE	: Institution of Engineers
IMSD	: Integrated Mission for Sustainable Development
Ind.	: Indian
Intl.	: International
IR	: Infra Red
IRS	: Indian Remote Sensing Satellite
ISRS	: Indian Society of Remote Sensing
J	: Journal
LISS	: Linear Imageing Self Scanning
LRDP	: Land Resource Development Plan
Mgt.	: Management
MIR	: Middle Infra Red

M.P.	: Madhya Pradesh
M.P.K.V	: Mahatma Phule Krishi Vidyapeeth
M.R.S.A.C.	: Maharashtra Remote Sensing Application Center
M. S.	: Maharashtra State
MSS	: Multi Spectral Scanner
NIR	: Near Infra Red
NNMRS	: National Natural Resource Management System
NGO	: Non Government Organisation
No.	: Number
NRSA	: National Remote Sensing Agency
NWDPRA	: National Watershed Development Programme for Rainfed Agriculture
PACE	: Picture Analysis and Colour Enhancement
PAN	: Panchromatic
PCT	: Pseudo Colour Table
P/R	: Path/Row number
Proc.	: Proceddings
Pub.	: Published
RAM	: Random Access Memory
RMS	: Root Mean Square
ROLUFS	: Recommended Optimal Land Use and Farming Systems
RRSSC	: Regional Remote Sensing Service Centre
Rs.	: Rupees
SOI	: Survey of India
TM	: Thematic Mapper
U.P.	: Uttar Pradesh
USA	: United States of America
UV	: Ultra violet
Viz.	: Namely
VR	: Visible Red
WRDP	: Water Resource Development Plan



ABSTRACT

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INTEGRATED LAND AND WATER RESOURCES DEVELOPMENT IN PIMPALGAON UJJAINI WATERSHED USING REMOTE SENSING AND GIS TECHNIQUES

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2000

Research Guide	: Prof. L. V. Pingale
Department	: Irrigation and Drainage Engineering

The management of the natural resources such as land and water for enhancing the food production to meet the food requirement of the constantly increasing population has gained the priority in National planning. Watershed is the convenient unit over which these resources can be managed appropriately. Watershed development also includes the works pertaining to soil and water conservation, water harvesting, land use planning, horticultural development, afforestation, development of agro-based industries, community development, development of infrastructural facilities etc. Thus the watershed development will need study of all properties of watershed such as its drainage network, soils, climatic factors, socio-economic status, ground and surface water availability and present land use are necessary. The conventional methods for studying all these essential properties need lot of time and fail to give the synoptic view of the study area. Moreover, the information collected, by the time it reaches in the experts hand loses its value or may get manipulated enough due to errors in data collection and the decision/action plans suggested by the experts may vary depending on the mental condition, knowledge of the study area and conditions in which they are working.

So it is necessary to use reliable decision support system that will help both in collecting data and decision making keeping in view all the potentials and problems of the study area in short duration of time. Remote Sensing and GIS is the appropriate tool for generating action plans, evaluating and monitoring changes. Moreover, Remote Sensing gives multi temporal, synoptic, repetitive coverage of the study area. GIS in combination with Remote Sensing helps in identifying the sites for precise data collection so that it helps in developing action plans. Hence, the study entitled, "Integrated Land and Water Resource Development in Pimpalgaon Ujjaini Watershed using Remote Sensing and GIS Techniques" was under taken with the objectives to generate thematic and derived maps pertaining to the watershed, to identify potentials and problems of land, water and socio-economic conditions, to generate various thematic information and socio-economic information for generation of action plans, to generate comprehensive plan for water resources development and also to generate comprehensive plans for land resources development.

The study area, Pimpalgaon Ujjaini watershed, falls in Ahmednagar Tehsil at a distance of 15 kms from Ahmednagar city on the Ahmednagar - Aurangabad road in North-East direction. It is located about 45 kms away from M.P.K.V., Rahuri, campus.

The facilities of Remote Sensing and GIS were made available from RRSSC, Nagpur. The base maps such as watershed boundary, drainage, topography and soils were made available from respective Government. departments. These, maps were then refined with the help of Survey of India toposheet 47 I/16. The satellite data of IRS-1C/1D satellite, LISS3 and PAN cameras of months October 97, January 98 and March 98, of path 96 and row 59 were used for generating various thematic/derived maps and action plans. The satellite data was rectified with the help of base maps of watershed boundary and SOI toposheet 47 I/16. The rectified satellite image was classified. All three classified images were integrated to derive Land use / Land Cover maps. The land use / land cover map indicates that 59.77 ha (1.92%) is kharif cultivated land, 360.84 ha (11.60%) is rabi cultivated land and 345.86 ha (11.15%) is the double cropland. The scrub-land is about 1849.74 ha (59.48%) and fallow land is about

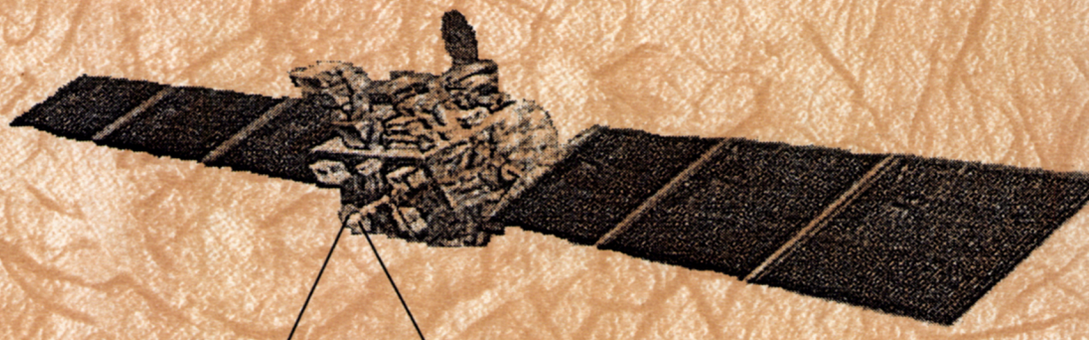
263.55 ha (8.47%), whereas only 15.25 ha (0.5%) of the area has surface water body. The soil series map shows that 1129.28 ha (36.41%) of the soil series is uncultivable while remaining is cultivable. The cultivable capable land area is about 2185.89 ha (70.3%). The high runoff potential area is about 1825.06 ha (58.69%). The area has good groundwater potential in 1078.95 ha (34.69%) and moderate ground water potential in 1283.66 ha (41.29%). The 1142.98 ha (45.5%) of land in the study area is below 3% slope while the area between 3 to 15% slope is about 786.74 ha (15.33%).

Water resources development plan prepared shows the various sites for check dams, nala bunds, K.T.weirs and Underground bandhara. Some renovations in structures are also suggested.

Land resources development plan prepared suggests 988.26 ha of Silvi-pasture, 12.54 ha Agro-horticulture, 933.15 ha horticulture, 617.62 ha of Double crop, 27.00 ha Agro-forestry, 138.61 ha of forest plantation and 355.90 ha of Intensive agriculture.

It was concluded from the study that Remote Sensing and GIS is effective and efficient tool for preparation of plans for Land and Water Resource Development.

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INTRODUCTION

1. INTRODUCTION

In 'Yajurveda' water has been described as the elixir of life, the source of energy, that sustains life on earth. Whereas land has not only been regarded as a basic resource but also a cherished asset. Land can be utilized in accordance with its suitability. Water resources have been decisive factor in the growth and development of human civilization. Soil, vegetation and water are so interdependent that one can not be managed effectively and efficiently without the other. Soil and vegetation subject them selves to an easier manipulation, water being the climatic parameter needs to be managed properly. If these interdependent resources are to be managed conveniently and effectively, collectively and simultaneously, one has to find out a suitable 'unit of management'. This unit is often "watershed" or "unit command area" depending on water resources to be managed. Watershed is defined as a catchment area of hydro-geological unit bounded by a ridgeline on three sides of a valley/stream where all the runoff passes to a common point. It becomes easier for the planners to handle the resource availability in a watershed and their conjunctive use in an integrated management set up.

For sustainable development, it is imperative to maintain equilibrium between exploitation of natural resources for human needs, economic development and the environment. For a country whose population is more than a billion and has only 2.42 per cent of global land area (Anonymous, 1999), the problem is serious. An estimated 175 Mha of land constituting about 66 per cent of her total geographical area suffers from deleterious effect of soil erosion and land degradation (Motsara, 1999). Active erosion caused by water and wind alone accounts for 150 Mha of land, which amounts to a soil loss of about 5300 million tonnes of topsoil. In addition 25 Mha have been degraded due to ravines and gullies, shifting cultivation, salinity/alkalinity, water logging etc. Mismanagement of water resources in India, a country that receives a rainfall of about 114.0 cm (Patel, 1998) annually has assumed such an alarming proportions that water table in many areas of the country is depleting at a rate faster than 10 m annually due to

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lack of any available recharge mechanism. Inspite of green revolution in India, the crop yield is one of the lowest in the World. The National average is 1.85 t/ha as against World's average of 3.2 t/ha for rice and 2.67 t/ha as against World's average of 3.7 t/ha for wheat. The average food productivity of India is just about 1.6 t/ha, as against Worlds average of 2.5 t/ha and 4.3 t/ha of Europe. Today per capita food consumption in India is 450 gm per day. The energy consumption is less than thirteenth of that in the USA and per capita annual income is 550 $ as against over 12000 $ in USA (Rai and Murali, 1998).

Thus to meet the requirement of increasing population and to achieve sustainable development, it is essential to check over exploitation of natural resources on one hand and optimal utilization of the land resource on the other hand by understanding the mutual interdependence of these resources at micro-level i.e., watershed, based on scientific approach.

Watershed is the unit of decentralization chosen by Mother Nature. It is a logical unit with a certain extent of homogeneity and uniformity. Further a watershed is limited, convenient, clearly defined and unambiguous topographic unit available in a nested hierarchy of sizes on the basis of stream ordering. Every watershed is having its own characteristics features and problems thus making it unique. In order to derive maximum benefit out of these resources in a sustainable way, it is preferable to treat the watershed as a single micro level unit. Thus watershed is manageable if dependent hydrological unit can be taken as a basic unit of development planning.

The watershed development includes the works pertaining to soil and water conservation, water harvesting, land use planning, horticulture development, pasture development, afforestation, development of industries including agro-based industries, community development, development of infrastructural facilities like roads, schools, hospitals etc. Watershed management implies rational utilization of land and water resources for sustained productivity with minimum hazard to the natural resources. It essentially relates to the soil and water conservation and water management in the watershed, which means proper land use and protection of land against all forms of deterioration. It also implies conservation of soil fertility, conserving water for farm use and to increase the

productivity of available resources. It is essential to generate comprehensive plans for land and water resources development for their sustainable use. Owing to the heterogeneity of the soil and geological formations, large amount of data needs to be collected, which should be fairly accurate over comparatively short span of time. The methods of data collection, which are presently being employed, are often subjected to errors. The appropriate land and water resources development plans may not be generated with these errors.

Conventional methods of data collection are also uneconomical, biased, time consuming and provide the information with the time lag. A small error in the data collection gets reflected in these methods and magnified in the results to be used for planning. Moreover, the synoptic/global view of the planning area is not possible using conventional methods. Thus, here comes in picture the new tool 'Remote Sensing and Geographic Information System' for preparing action plans for land and water resources development.

Remote Sensing is the science of deriving information about an object from measurements made without the sensor actually coming into contact with it. The sensors may be cameras or other energy measuring instruments that record the energy reflected from the object on the earth in the form of electromagnetic waves over the entire spectrum. The spectral response of the object class is unique to it and thus constitutes a "Signature" of its own in a particular spectral bandwidth. Thus by dividing into a number of spectral bands and separately obtaining the responses there from in each spectral band has improved the signature uniqueness and considerably the degree of confidence of recognition. The sensors are mounted on aircrafts or satellites. Satellites by virtue of its repetitivity, multi-spectral and synoptic coverage provide sequential images which enables us to evaluate for optical management of natural resources in general and monitoring and evaluation of the developmental activities which have been carried out or which have to be carried out in the watershed in particular.

GIS is a tool designed to store, manipulate, retrieve and display spatial and non-spatial data. It has become an important tool in the spatial analysis of the parameters such as land use/land cover, soils, topography, climate and hydrological conditions.

GIS has three essential characteristics:

a) Spatially referenced database,
b) Appropriate software components, and
c) Associated hardware components.

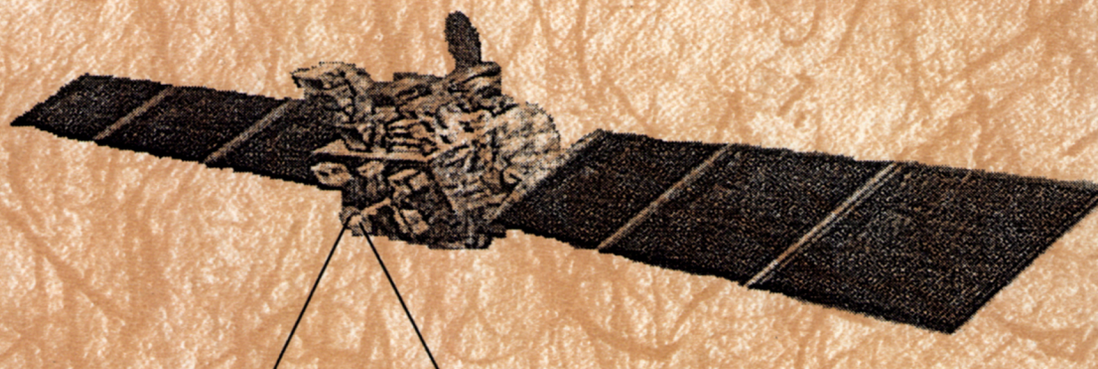
There is a varied range of GIS application such as forestry, environmental monitoring, assessment and management of water resources, change detection analysis and display of location data.

Remote sensing and GIS, two distinct technologies, are now being used in a complimentary manner. The data produced by remote sensing often requires to be integrated with the data sets acquired through fieldwork, laboratory studies etc. A GIS does this integration very efficiently.

Thus, "Remote Sensing and GIS" is viable alternative tool over conventional mode of survey of database generation that is required for formulation of action plan for land and water resource development and management. Therefore, the study entitled "Integrated Land and Water resources development in Pimpalgaon Ujjaini watershed using Remote Sensing and GIS techniques" was undertaken.

Thus the objectives of the present study are:

1) To generate thematic and derived maps pertaining to the watershed.
2) To identify potentials and problems of land, water and socio-economic conditions.
3) To generate various thematic information and socio-economic information for generation of action plans.
4) To generate comprehensive plan for water resources development.
5) To generate comprehensive plans for land resources development.



REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

During the last two decades, the applications of remote sensing in our country have shown tremendous progress and established the potential of using this technology for natural resources management and environmental monitoring and intern contributed significantly to national development. The main focus of the study was to develop Land and Water Resources Development Plans for Pimpalgaon Ujjaini watershed using Remote Sensing and GIS Techniques. In this chapter the attempt has been made to review the earlier research work pertaining natural resources management (land and water) using remote sensing and GIS techniques.

2.1 General

Beyond agricultural field, Remote Sensing and GIS have been successfully used as tool for developing Urban plans, locating problems and occurrences of insect and pest attacks, fire damage, cyclone influenced areas, environmental monitoring etc. In this section the works done previously on some of these aspects are reviewed.

Mohanty (1994) made an attempt to understand the change detection using sequential aerial photographs of 1974 and 1989, and comparison with SPOT data of 1988 with the help of 'USEMAP' GIS software package. He suggested that in order to know the trend of development and land use patterns, analysis of sequential aerial photographs and satellite imagery of different years is useful tool. He also suggested that as urban area undergoes a rapid change it would be necessary to review development and the urban plans once in five years in relation to important public and other decisions taken from time to time.

Gautam (1995) carried out geo-environmental impact analysis of G. B. Pant Sagar Reservoir (Rihand reservoir), U.P. and M.P. A comparison of aerial photo-interpreted data around G. B. Pant Sagar (Rihand reservoir) for pre dam (1994) and satellite imagery for post dam (1967) periods was carried out. Large areas show decrease in vegetation density because of deforestation while

the areas bordering the reservoir show increase in vegetation density. The area under cultivation has decreased on the western side due development of a number of coalfields in post dam period. Improper management of coal ash disposal from a thermal power plants located around the reservoir is causing siltation of the reservoir.

2.2 Land Use/Land Cover

In this section of review, the works done previously on the land use land cover resources mapping and change analysis are discussed.

Ghosh *et al.* (1996) used GIS for land use/land cover change analysis in a mountainous terrain. They carried out the integration of remote sensing data with other spatial/non-spatial data using Arc/INFO software package. A simple classification technique was adopted for land use/land cover change analysis in relation to elevation, slope, aspect and bio-climatic classes. Sustainability assessment of land where agricultural extension occurred between 1963 and 1993 was made using GIS software package. Expansion of agriculture land was found to be a maximum in 2200-2400 m elevation zone and 20-30 slope classes. When topographic expansion was considered, expansion was maximum on southeast and west facing slopes. The loss of vegetal cover is estimated to be 15 per cent between 1963-1993. However regeneration of forest was found to be maximum in elevation ranges of 1600-2000 m and mostly having 20-30 average slopes. Land deterioration over the two mapping periods was identified and strategies were suggested to mitigate the problem.

Shantakumar *et al.* (1997) applied the remote sensing technique for analysis of land use pattern. Comparative analysis and comprehensive evaluation of two period data i.e. aerial photographs of 1960 and remote sensing data of 1994 of Kunda catchment have revealed different type of changes in land use, extent of changes and their spatial distribution during the period 1960 and 1994. The plantation area (Tea) has substantially increased by 65 per cent while the cultivated area and forest area has decreased by 30 per cent and 19 per cent respectively over the statistics of 1960. The study has demonstrated and highlighted the potential of remote sensing techniques for monitoring the changes

in land use efficiently and economically. It also allows updating of information more accurately, and at faster pace with real time data without much cost.

Palaniyandi and Nagarathinam (1997) carried out the land use/land cover mapping and change detection using space borne data. Land use/land cover changes in Thiruvallur area of Chengai-MGR district in Tamilnadu during the years 1986-1990 were mapped through visual interpretation of LANDSAT-5 TM and IRS 1A LISS-II images, over space and time. In the study area, it was observed that the built up area and the agricultural land use extensions were on the upward trend, whereas the area under forest and wasteland has shown a declining trend, caused by both increasing population and related trends in other parameters. The system devised through the study has thus been able to detect the changes in land uses and land cover classes during the selected time periods.

Chaurasia *et. al.,* (1999) studied the land use through IRS-1C LISS-II data of the Saroa block in Nawanshahr district, Punjab. The drainage characteristics were studied through the interpretation of the aerial photographs of 1991. The land use of the block shows that the crop land occupied about 58 per cent area of the block, forest both in hills and plains about 28 per cent, wasteland 9.1 per cent and built-up land about 5 per cent. Major crops grown in the area according to the priority were wheat, maize, rice and sugarcane. The two sub-watersheds falling in the block covered an area of about 19.3 sq. km. with maximum length of 5.07 and 4.4 km and width 3.91 and 2.44 km respectively. Though the two sub-watersheds are adjacent but considerable difference was observed in their drainage characteristics. Most parts of the hills located in the study area were sparsely vegetated and subjected to severe gully erosion. The severity of the gully erosion along the major and minor streams poses threat to agricultural land; therefore, gully control is an imperative to conserve soil and ameliorating agricultural development.

2.3 Groundwater Potential

In this section of review the works done previously on the groundwater resources development are discussed.

Palanivel *et. al.,* (1996) studied mainly for the assessment of groundwater availability in the Upper Agniar and Vellar basins. The Remote Sensing data was used to map the geomorphological units and structural pattern. The integration of geomorphology and structural pattern with geophysical and well inventory data revealed that shallow groundwater occurrence is controlled by geomorphological characteristics whereas at intermediate depth faults/fractures control yield of groundwater. The study has also indicated that the eastern parts of the basins are more favourable for groundwater development than the western part.

Ravindran and Jeyaram (1997) conducted the experiment for finding the relevance of satellite Remote Sensing in groundwater exploration systems from the utility of satellite images in identifying and delineating various features that may serve as direct or indirect indicators of the presence of groundwater in the Shahbad Tehsil, Baran District of eastern Rajasthan. They used the IRS-1B LISS-II data for evaluation of groundwater prospects of each hydrogeomorphologic unit based on lithology, structure, landform, and available aquifer data. The study area shows the Vindhyan sandstone's (Lower Bhander) in which groundwater occurs under unconfined to confined conditions along bedding planes and fracture zones have vast potential for groundwater development through deep bore-wells or dug-cum-bore wells, while in the eastern parts where shales dominate, large diameter dug-wells are suitable to tap limited groundwater resources. Infiltration (or recharge) tube wells have been proposed to augment the sandstone aquifers.

Das *et. al.,* (1997) conducted the study for groundwater exploration and development in Keonjhar district of Orrisa. In this study air borne and space borne data was used for qualitative evaluation of groundwater resources. The study area was divided in various geomorphic units based on visual interpretation of LANDSAT (TM) false colour composite on 1:250000 scale and groundwater potential of each of the units is qualitatively assessed. Digital image processing techniques such as principal component analysis and brightness index were used for generating classified outputs. The features like valley fills, pediments etc appeared clearly on the classified image. Directional filtering brought out minor

fractures/lineaments crisply. The study has revealed the significance of different hydrogeomorphic units and lineaments in controlling groundwater potential by results of drilling and resistivity soundings.

Thomas *et. al.,* (1999) mapped the hydrogeomorphological units using IRS-1B LISS II data and evaluated groundwater prospect of each hydrogeomorphologic unit in the Lehra Gaga block of Sangrur district, Punjab. The major geomorphic units identified in the area are alluvial plain, sand dunes, palaeo channels and Ghagar flood plain. The study area being part of alluvial plain, has good groundwater prospects. Field observations showed that groundwater occurs under both confined and unconfined conditions with water table at shallow depth. The area on either side of the Ghagar river and along the major canals (about 46 per cent of the total geographical area in the block) has good quality of groundwater and is suitable for irrigation. However the water quality is marginal (Sodic) in remaining 52 per cent area of block.

2.4 Land and Water Resource Development

In this section of review the works done previously on the land and water resources development is discussed.

Rao *et. al.,* (1997[a]) studied an integrated approach for sustainable development for Banda district, U. P. Integrated study involving study of various natural resources like soils, groundwater, forest etc. was carried out in Kamasin block of Banda district, U. P. using Remote Sensing techniques. All the resources maps were prepared at 1:50000 scale and later superimposed over the other to get the complete resource information for any given location. Depending upon the combinations of resource parameters different recommendations were given as per the scheme. The action plan map indicating site specific recommendations for sustainable development was prepared. Seven action items were suggested for the block. Double cropping is recommended in single cropped areas to an extent of 42.4% of the total geographical area. Intensive agriculture, agroforestry, fodder and fuel wood plantations, silvipasture and soil conservation measures were recommended in 11.8%, 25.4%, 1.3%, 1.2% and 7.6% respectively of the total geographical area of the block. Few check dams, gully plugs and percolation tanks have been suggested.

Rao *et. al.,* (1997[b]) undertook a study in Neelkanthapuram Watershed with the objective of generating action plans for sustainable development of land and water resources through the integration of information on soils, land use/land cover, slope, hydrogeomorphology etc. using GIS approach. Thematic information was generated from remotely sensed data, SOI toposheet and ground truth. The spatial and non-spatial data are stored in Arc/INFO GIS. From basic resource data, derivative maps such as problem soils, groundwater potential and land capability are generated. For the watershed development, six action items namely Agrohorticulture, Double cropping, Afforestation, Gully control, Silvipasture, Stone terracing, Horticulture and fuel/fodder wood plantation were identified based on the resources information generated. Rules were framed to integrate different thematic maps for each action item. The study reveals that in the watershed, afforestation is needed over 56% of the total geographical area of the watershed followed by agrohorticulture, silvi pasture along with gully control measures.

Dibyendu *et. al.,* (1997) mapped various resources of Nadoti block of Sawai Madhopur district of eastern Rajasthan by employing visual interpretation technique using IRS-1B LISS II geocoded FCC along with ancillary ground based data to arrive at suitable land resources development plan for 57 microwatersheds (area varies between 500-1000 ha.) encompassing 645 sq. km. area. The maps generated on 1:50000 scale using three seasons data in a multi-thematic environment, includes slope and aspect, hydrogeomorphology, soils, drainage and watershed, land use/land cover and transport network settlement location-village boundary maps along with isohyet map in 1:250000 scale for the whole district. Based on soil and water conservation needs, microwatersheds were prioritized into 5 categories based on morphometry, drainage density, and soil erodibility, slope and land use/land cover. The analysis revealed that 8 microwatersheds are having "very high" priority followed by 10 of "high" priority category, whereas the rest 39 are in the medium to low priority category. The resources themes were integrated under GIS environment into several combinations in order to suggest optimum land use practices keeping in view the production potential of the land avoiding over utilization. Various activities were

chalked out in harmony to peoples need. The preference areas with better surface/groundwater have been recommended for agrohorticulture. In wastelands, major recommendation goes for gully plugging, stone and peripheral bunding, check dams, staggered contour trenches, grassy waterways, and revegetation in gully bed and silvipasture depending upon land capability. Under regional development plan, the levels of agricultural and infrastructural development plans were superimposed to get human resources. The regional development plan consists of 14 problem regions depending upon the similarity of the problems. For effective regional planning, this problem region could be integrated with priority watershed map, which yields socio-geophysical priority units towards phasing of land resources development plan.

Sidhu *et al.,* (1998) prepared various layers of maps viz., watershed and sub-watershed boundaries, hydro geomorphology, soil, land use/land cover, slopes by interpretation of satellite data (IRS-1B bands – 2, 3 and 4) and topographical maps were used for digitisation on Arc/INFO GIS system on a MicroVAX system and generation of data base. The GIS software package Arc/INFO version 5.0/6.0 was used to digitise, edit, build, transform, display, analyse and plot the maps. They studied this for upper Machkund Watershed (part), Visakhapatnam district, Andra Pradesh. Using the 'union' module, geomorphology, soils, land use/land cover maps were combined to generate action plan which shows the activities suggested for every parcel of land. The results showed a well-established soil-scape relationship in the area. The data revealed that major area (53.8%) of the watershed is under afforestation. The soil conservation practices followed by silvipasture are urgently required in the area, which are subjected to severe and very severe erosion on steeply sloping lands. About ¼ of the watershed can be brought under double cropping by adopting suitable soil conservation and water harvesting technology so that the irrigation can be made available during the lean period at critical stages of the crop growth in rabi season. It is also suggested that 10.2% area should be maintained as status quo with the precaution not to disturb the ecology of the area by deforestation or by man made activities. Therefore, integrated approach based on action plan generated through the union of resource data/maps in combination with the interpretation of soil based thematic maps prepared by adopting remote sensing

and GIS techniques should be utilized for sustainable development of the watershed.

Ashok Kumar (1999) studied Alunja watershed, located on 'Chotanagpur' plateau of Bihar. It was mainly under single cropping. The area receives more than 1000 mm of rainfall but it has been not utilised properly to increase the agricultural output. The Remote Sensing, geophysical DBTM (Digital Basement Terrain Model) and GIS (Geographic Information System) techniques were used for providing scientific database for sustainable utilisation of water resources in the watershed perspective. The landuse, soil and surface water body maps along with the basement information on depth derived from geophysical data was used to provide information regarding aquifer geometry, fracture zones and sub-surface basins.

Analysis indicated that surface and groundwater resources have potential to irrigate 53 per cent of geographical area of the watershed. However, at present, this available potential has been utilised only to irrigate 7.03 per cent of the watershed. Feasibility for large-scale development of groundwater through dug-well is possible only in 2 per cent area of the watershed. The available groundwater potential to irrigate 28 per cent of watershed can not be utilised through dugwells. The surface water potential is also poorly utilised. The present study also helped in prioritizing the water resource development activities.

Pandit *et.al.,* (1999) carried out a case study of Nasik Taluk, District Nasik of Maharashtra using Remote Sensing and GIS based integrated watershed development. The approach aims at generation of specific action plans for the development of area by using Remote Sensing satellite data in connection with other conventional and socio-economic data to meet the demand of present local population as well as to achieve the sustainable development. The scope of the study is to assess the natural resource potential and their spatial variability of geology, hydro geomorphology, soils, surface water resources, ground water resources, land use/land cover, climatic variations, demographic and social infrastructure resource in the Nasik Taluk using IRS LISS-II data and other collateral data. Satellite Remote Sensing technology gives systematic, synoptic, rapid, repetitive and cost effective coverage of the study area in different windows

of electromagnetic spectrum. The different thematic maps generated using Remote Sensing and other collateral data are put in GIS for analysis and preparation of action plans. Based on the potentials, problems and socio-economic constraints of the different data sets, site specific and area specific action plans of land and water resources have been drawn using GIS technique. In the water resources development plan the area of tube wells, dug cum bore wells are suggested based on the geohydrological characteristics and agriculture needs. Under ground bandhara are also suggested for the creation of ground water reservoir. The suitable sites of percolation tanks, check dams, nala bunds and minor irrigation dams are also suggested. Under the land resources development action plan afforestation, double crop, agro horticulture, horticulture, silvipasture and agro forestry are suggested as per the land capabilities and suitability. Afforestation activities are recommended in the forest blanks with gap fillings and local species. Some area under single crop is suggested to bring under double crop based on soil suitability and water availability. The silvipasture and the fast growing tree species are suggested in the upland undulating surface where highest slopes are prominent. Agro horticulture and horticulture crops are suggested as per land and water resources with specified management practice.

Murthy *et. al.,* (2000) carried out a case study of integrated watershed development planning using Remote Sensing and GIS. Uma-Gani watershed comprising of 17000 ha has been prioritized and selected based on its socio economic backwardness and resources potentials for detailed analysis and action plan generation.

The water resources development plan clearly depicts the zones of exploitation, development and conservation. The exploitation of prospective groundwater zones has been suggested through tube wells, shallow tube wells and dug wells based on the geological strata and requirements. Rainwater harvesting structures are suggested to reduce the large scale sudden runoff generated in talchir scale area and to recharge the valley fill areas. the structures suggested are stream bunding and farm ponds. The optimal utilization of the ground water and subsequent monitoring, explotary tubewells/borewells are also suggested. Desilting of existing reservoirs and tanks are also given priority.

The land resources development plan depicts alternative land use practices through double cropping, horticulture, agro-forestry, afforestation, fuel and fodder plantation and silvipasture along with appropriate soil conservation measures like nala straightening, farm bunding, trenching and khus plantations.

According to them, the suggested water and land resources development plans are expected to result in the transformation of the existing land use practices into sustainable ones that will meet the needs of the present population and future generation without endangering the environment.

The satellite data for the years 1995, 1996, and 1997 are evaluated for changes in land use/land cover and the impact. It was observed that cropping intensity (per cent), horticultural plantation (per cent), average yield of rice (t/ha), average yield of wheat (t/ha) and average yield of cotton (t/ha) increased from 107, 5, 1.6, 0.65, and 1 to 127, 6, 2.4, 1.1, and 2.2 respectively.

The ground water table has increased and the problem of drinking water was solved in the watershed using ground water conservation and recharge measures. Although, the rain input in the year 1996-97 is around 60 per cent of the average annual rainfall, the cropping intensity and yields have increased significantly showing trends of sustainable development. On a sample basis farmer level information collected to identify the trend in economic returns to the tune of 10 folds in marginal lands (100 $ to 1000 $), 4 fold in moderately developed lands (300 $ to 1200 $) and more than 2 fold in developed lands (600 $ to 1400 $).

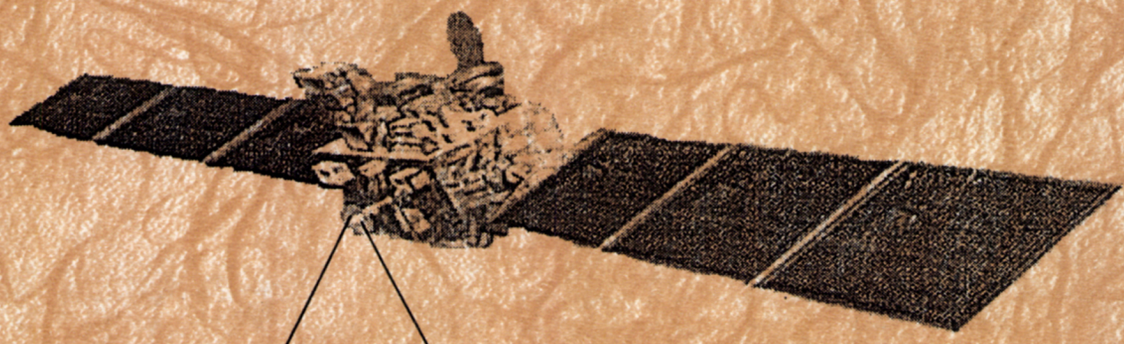
Bhagavan and Raghu (2000) adopted Remote Sensing techniques for integrated watershed management IX-plan for watersheds proposed under National Watershed Development Project for Rainfed Areas (NWDPRA). Under this project, 193 watersheds are selected in 19 districts of Andhra Pradesh. The Indian Remote Sensing Satellite (IRS-1C/1D) high resolution LISS-III and PAN merged data was used for generation of natural resources information on 1:25000 scale. Thematic maps on natural resources namely hydro-geomorphology, land use/land cover, soil erosion, soil, soil fertility, land capability, slopes are generated using Remote Sensing as well as conventional data. Ground truth information is

collected and integrated with thematic data to finalise the maps. All these maps are integrated and action plan map showing Recommended Optimal Land Use and Farming Systems (ROLUFS) and drought proofing works is prepared.

Further, the action plan and the villages included in each watershed are digitised and overlaid on each other. With the help of this map, locale-specific recommendations are given at cadastral level and effective monitoring and management of natural resources at survey number wise individual fields of the farmers is possible. Thus, integrated watershed management is adopted giving site-specific solutions with the help of Remote Sensing technology for holistic development of rainfed farming systems.

Murthy *et al.,* (2000) planned village level action plans for land and water resources development, which require higher scales for planning. The action plans generated at watershed level under various programmes like Integrated Mission for Sustainable Development (IMSD) are generally at 1:50000 scale and the action items for plan implementation are either area specific or local specific and to identify the end beneficiaries the details of land ownership, which are available on cadastral maps of 1:5000 are very essential. The merged product of IRS-1C satellite-data, generated from the Hue-Saturation-Intensity transformation of high spatial resolution panchromatic data and high spectral resolution LISS-III data, is used for referencing the cadastral maps, because the merged product precisely depicts the natural and manmade boundaries like river/stream/nala, transport network, canals, tanks, field-bunds and notified forest boundaries. The action plans are transferred on to the cadastral maps to facilitate speedy plan implementation and subsequent monitoring of the impact. The study carried out in Chimur Taluk of Chandrapur district has demonstrated that the merged product of LISS-III and PAN data is very much useful for village level development planning, i. e., Plan preparation, implementation and subsequent monitoring.

It is seen from the review of works on the application of Remote Sensing and GIS to the resource planning, the Remote Sensing and GIS is the appropriate tool for the land and water resource development plans for watershed.



SCIENCE OF REMOTE SENSING AND GIS

3. SCIENCE OF REMOTE SENSING AND GIS

In this chapter, the fundamentals of Remote Sensing and GIS (Geographic Information System) are discussed to get a brief idea about Remote Sensing and GIS. The information is gathered from "Digital Image Processing and Geographic Information System Manual" (Anonymous, 1999) and "Digital Image Processing of Remotely Sensed Data" (Jensen, 1984).

3.1 Remote Sensing

Remote Sensing is a multi-disciplinary activity, which deals with the inventory, monitoring and assessment of natural resources through the analysis of data, obtained by observations from a remote platform. In other words, remote sensing is the science of deriving information about an object from measurements made at a distance from the object without actually coming in contact with it. The observations are synoptic provide repetitive coverage of large areas and data is quantifiable. The term Remote Sensing is used more commonly to denote identification of earth features by detecting the characteristic electromagnetic radiation that is reflected/emitted by the earth's surface. Every object reflects/scatters a portion of the electromagnetic energy incident on it depending on its physical properties. In addition, objects emit radiation depending on their temperature and emissivity. The reflectance/emittance of any object at different wavelengths follows a pattern that is characteristic of that object, known as 'Spectral Signature'. Proper interpretation of the spectral signature leads to the identification of the object.

If the observation is made based on the electromagnetic radiation from the sun or the self-emitted radiance, it is called Passive Remote Sensing. It is also possible to produce the electromagnetic radiation of a specific wavelength or band of wavelengths to illuminate the terrain. The interaction of this radiation can then be studied by sensing the scattered radiance from the target. This is called "Active Remote Sensing".

3.1.1 Stages in Remote Sensing

1. Origin of electromagnetic energy (Sun, transmitter carried by the sensor).
2. Transmission of energy from the source to the surface of the earth and its interaction with the intervening atmosphere.
3. Interaction of energy with the earth's surface (reflection / absorption / transmission) or self-emission.
4. Transmission of reflected/emitted energy to the sensor placed on a suitable platform.
5. Detection of energy by the sensor converting it into photographic image or electrical output.
6. Transmission/recording of the sensor output.
7. Pre-processing of the data for generation of the data products.
8. Collection of ground truth and other collateral information.
9. Data processing and interpretation.

Thus the Remote Sensing system consists of a sensor to collect the radiation and a platform which can be a satellite, rocket, aircraft, balloon, automobiles or even a ground based stand on which a sensor can be mounted. The information received by the sensor is suitably manipulated and transported back to the earth may be through telemeter or brought back through films, magnetic tapes, etc. The data is reformatted and processed on the ground to produce either photographs or computer compatible tapes (CCT), digital analog tape (DATs), or compact discs (CDs). The photographs/computer compatible tapes are interpreted visually/digitally to produce thematic maps and other resources information.

The electromagnetic radiation spans a large spectrum of wavelengths right from very short wavelength gamma rays (10^{-10} m) to long radio waves (10^{6} m). In Remote Sensing, the most useful electromagnetic radiation regions are the visible (0.4 to 0.7 micron-meter), the reflected infra red (0.7 to 3 micron-meter), the thermal infrared (3 to 5 micron-meter and 8 to 14 micron-meter) and the microwave regions (0.3 to 300 cm). The sun is the important source of electromagnetic radiation used in conventional optical Remote Sensing. The sun's radiation covers ultraviolet, visible, infrared and radio waves. The maximum radiation occurs around 0.55 micrometer, which is in the visible region.

However, the atmospheric effects modify the solar radiation reaching the earth surface. All bodies at temperature about 0^0 absolute emit electromagnetic radiation at different wavelengths as per Planck's law.

3.1.2 Atmospheric effects

In passing through the atmosphere electromagnetic radiation is scattered and absorbed by gases and particulate. The strongest absorption occurs at wavelengths shorter than 0.3 micrometer primarily due to Ozone. On the other hand, certain spectral regions of the electromagnetic radiation pass through the atmosphere without much attenuation. These electromagnetic radiation regions are called 'Atmospheric Windows'. Remote Sensing of the earth's surface is generally confined to these wavelength regions, which are 0.4 to 1.3, 1.5 to 1.8, 2.2 to 2.6, 3.0 to 3.6, 4.2 to 5.0, 7.0 to 15.0 micrometer and 10 to 100 mm wavelength regions of electromagnetic spectrum. The atmospheric effect is very well presented in Fig. 3.1.

3.1.3 Spectral responses of some natural earth features

1) Water

Water absorbs most of the radiation in the NIR and MIR regions. This property enables easy delineation of even small water bodies. Turbidity in water generally leads to increase in its reflectance and the reflectance peak shifts towards longer wavelength. Increase in chlorophyll concentration leads to greater absorption in the blue and red regions. Dissolved gases and many inorganic salts do not manifest any change in the spectral response of the water.

2) Soil

Typical soil reflectance curve shows a generally increasing trend with wavelength in the visible and NIR regions. Some of the parameters, which influence the soil reflectance, are the moisture content, the amount of organic matter, iron oxide, relative percentages of clay, silt and sand and the roughness of the soil surface. As the moisture content of the soil increases, the reflectance in the optical IR region decreases, more significantly at the water absorption bands. In a thermal IR image, moist soil looks darker compared to dry soil. In view of the large differences in the dielectric constant of water and soil at microwave frequencies, quantification of soil moisture becomes possible.

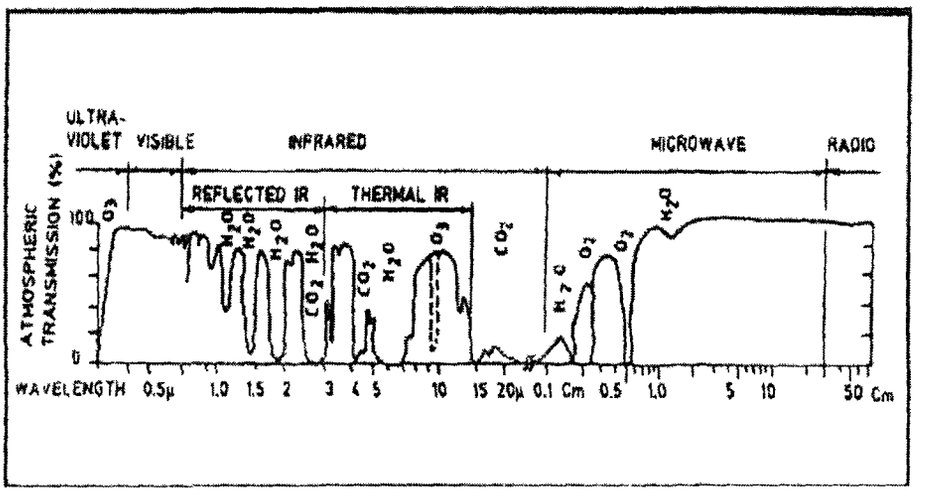


Fig. 3.1 Atmospheric windows, gases responsible for absorption

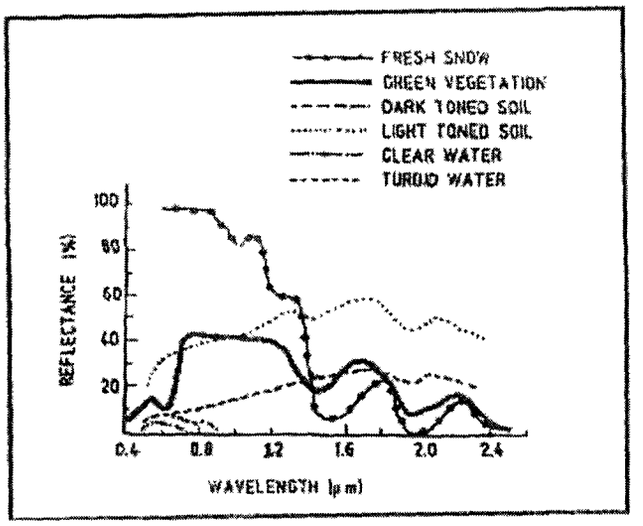


Fig. 3.2 (a) Comparison of reflectance spectra of a few land covers.

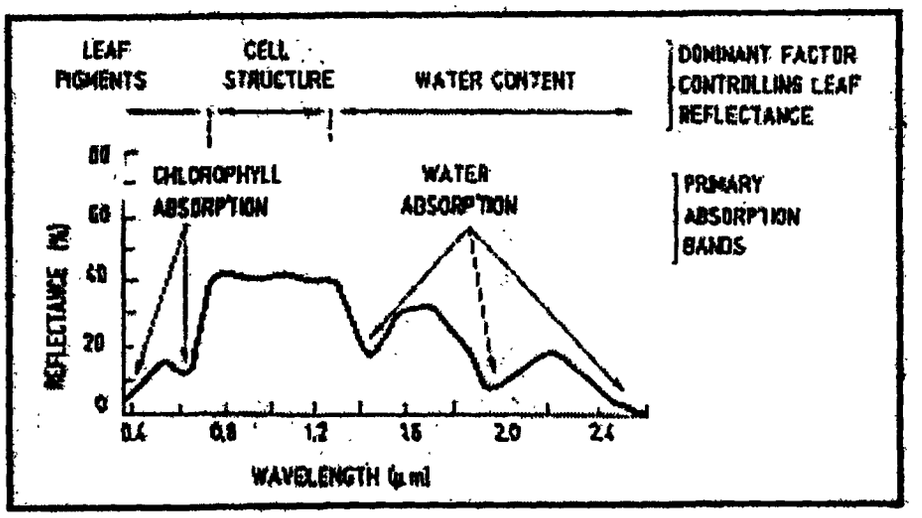


Fig. 3.2 (b) Typical vegetation reflectance spectrum.

3) Vegetation

The spectral reflectance of vegetation is quite distinct. Plant pigment, leaf structure and total water content are the three important factors, which influence the spectrum in the visible, NIR, and MIR regions respectively. Low reflectance in the blue and red regions corresponds to two chlorophyll absorption bands, centered at 0.45 and 0.65 micrometer respectively. A relative lack of absorption in the green region allows normal vegetation to look green. In the NIR, there is high (45 %) reflectance, transmittance of similar magnitude and absorption of only about 5 to 10 per cent. This is essentially controlled by the internal cellular structure of the leaves. As the leaves grow, inter cellular air spaces and the reflectance increase markedly. As the vegetation becomes stressed or senescent, chlorophyll absorption decreases and red reflectance increases accompanied by, decrease in inter-cellular air spaces. This results in decreased reflectance in the NIR. This is the reason why the ratio of the reflectance in the NIR to the red or any of the derived indices from this data are sensitive indicators of vegetation growth/vigor. In the MIR reflectance peak occurs at 1.6 and 2.2 micron-meter. It has been shown that total incident solar radiation absorbed in this region is directly proportional to the total leaf water content.

The spectral responses of these agricultural units are very well depicted in Fig. 3.2.

3.1.4 Data products generation

The data acquired by a sensor invariably suffers from a number of errors. These errors occur due to various reasons such as (i) imaging characteristics of the sensor, (ii) stability and orbit characteristics of the platform, (iii) scene surface characteristics, (iv) motion of the earth and (v) atmospheric effects. Pre-processing is carried out to correct these errors to the maximum extent so that the inherent quality of the original information of the scene (such as geometry, radiometry, and information content) is brought out in an optimal way. Pre-processing is carried out for (i) eliminating geometric distortion in the imagery, (ii) eliminating radiometric distortion in the imagery and (iii) enhancing the contrast in the data so that certain features of interest come out best in the

photograph. Normally standard data products in the digital form are generated by applying geometric and radiometric corrections only, leaving the enhancement to the application scientist.

3.1.5 Data analysis

The two major methods for data analysis for extracting resource related information from data products either independently or in some combination with other collateral information are visual interpretation and digital image processing techniques.

3.1.5.1 Visual analysis

Traditionally, visual interpretation methods have been followed for extracting information on various natural resources. Tone/Colour, Texture, Shadow, Shape, Size etc. and their association are some of the basic image characteristics on which visual interpretation is based. Some of the advantages of this approach are:

i) Familiarity of the users with the aerial photo interpretation.
ii) Images depicting the scene as though one is observing the area from a point of high altitude, and
iii) The display of spatial relations among surface features is in the same context as in maps.

However, visual interpretation techniques suffer from some shortcomings. The range of grey values recorded on a film or print is limited, the number of colour tones recognized by the human brain is quite large but still limited. The interpreter is likely to be subjective in discerning subtle differences in tones. It is difficult to be quantitative. It is also difficult to achieve precise registration of multi-band and multi-temporal images.

3.1.5.2 Digital techniques

In digital classification the computer analyses the spectral signature so as to associate each pixel with a particular feature of imagery. The reflectance value measured by a sensor for the same feature will not be identical for all pixels; such response variation within a class is to be expected for any earth surface cover

due to various reasons. Therefore, the radiance value for a class will have a mean and variance. If we use 'n' spectral bands, we get 'n' dimensional feature space. One finds a natural clustering of classes in three groups indicating the signature differences. When the clusters corresponding to different ground cover are distinct, it is easy to associated localised regions of the feature space with specific ground covers. However such distinct clustering does not always happen in real life situations and there could be some data set, which is not as obvious as others, about which class it belongs. The digital classification technique essentially partitions this feature space in some fashion so that each pixel in the feature space can be uniquely associated with one of the classes. The decision to classify a pixel into any particular class from a set of data is a statistically intelligent 'guess', which has some associated probability of error. Several classification algorithms have been developed in an attempt to minimise this error.

The digital classification techniques used can be broadly categorized into:

i) Supervised classification and
ii) Unsupervised classification.

In supervised classification, the analyst locates specific sites in the remotely sensed data (based on fieldwork, analysis of aerial data, etc.) that represent homogeneous examples of various classes (like agriculture, forest, water body, etc.). These areas are termed as 'Training Sites' because the spectral characteristics of these known areas are used to 'Train' the classification algorithm. For each training site, the statistical parameters like mean, variance, covariance, matrix etc. are generated which are used in any one of a number of different classification algorithms to decide which category an unknown pixel belongs to. Each pixel is then labeled with the name of the category it resembles or labeled 'Unclassified' if it is not similar to any category. If the training sites are not properly selected the number of miss classified/unclassified pixels increases. An output image data set is then generated using the category label assigned to each pixel. Thus, the multi-dimensional input image is used to develop a corresponding classified image of interpreted category types.

In contrast to this procedure, unsupervised classification is based on the exploitation of, the inherent tendency of different classes to form separate spectral clusters in the feature space. Unsupervised classification uses algorithms that search for natural groupings of the spectral properties of the pixels. The computer selects the class means and covariance matrix to be used in the classification. Once the data is classified into clusters, each cluster is then associated with a physical category.

3.1.6 Applications and Limitations

The applications of Remote Sensing are in:

i) Agriculture,
ii) Drought management,
iii) Forest management,
iv) Wasteland mapping,
v) Ground water potential mapping,
vi) Snow melt runoff estimates,
vii) Surface water mapping and monitoring of major reservoirs,
viii) Flood management,
ix) Mineral survey,
x) Urban sprawl mapping,
xi) Coastal and ocean resources survey,
xii) Land use mapping for agro-climatic zonal planning,
xiii) Integrated planning,
xiv) Disaster monitoring,
xv) Change detection,
xvi) Watershed management, etc.

Limitations are:

i) Data products in monsoon season have extreme cloud covers that result in fewer pictures of the earth features.
ii) High computer speeds and software needed.
iii) Skilled technical persons.

3.2 Geographic Information System (GIS)

For the users of Remote Sensing, it is not sufficient to display only the results obtained from image processing. For example, to detect land cover change in an area is not enough because the final goal would be to analyze the cause or to evaluate the impact of change. Therefore, the result should be overlaid on the maps of transportation facilities and land use zoning. In addition, the classification of Remote Sensing imagery will become more accurate if the auxiliary data contained in maps are combined with the image data.

In order to promote the integration of Remote Sensing and geographic data, Geographic Information System (GIS) should be established in which both the image and geographic data are stored in a digital form, retrieved conditionally, overlaid on each other and evaluated with the use of a model.

Thus, GIS is an organised collection of computer hardware, software, geographic data and personnel designed to efficiently capture, store, update, manipulate, analyze and display all forms of geographically referenced information.

Thus, **GIS answers,**

i) What is at .....?
ii) What has changed since .....?
iii) Where it is .....?
iv) What spatial patterns exists .....?
v) What if .....?

The following three functions are very important in GIS:

i) To store and manage geographic information comprehensively and effectively.
ii) To display geographic information depending on the purpose of use.
iii) To execute querry, analysis and evaluation of geographic information effectively.

3.2.1 Fundamental GIS concepts

All data that can be mapped has both locational (x,y) and non-locational (i.e., attribute) characteristics. In addition, the attributes at the location can be monitored through time. These three components – location, attribute and time – represent the content of most GIS. How are these data stored (encoded) digitally?

3.2.1.1 Data encoding

There are four fundamental types of geographic data to be stored in a GIS, points, lines, polygons and surfaces. These data can be stored in a number of formats, including (i) traditional Cartesian x,y coordinates (vector format), (ii) in a topological format as nodes, links (line segments) and polygons or (iii) in a grid (raster format).

1) Vector form and its data structure

Most objects on map can be represented as a combination of a point (or node), edge (or arc) and area (or polygon). The vector form is provided by the above geometric factors. The attributes are assigned to points, edges and areas.

The data structure is specified for the vector form as follows: A point is represented by geographic co-ordinates. An edge is represented by a series of line segments with a start point and an end point. A polygon is defined as the sequential edges of a boundary. The inter relationship between points, edges and areas is called a topological relationship. Any change in a point, edge and area will influence other factors through the topological relationship.

2) Raster form and its data structure

In the raster form, the object space is divided into a group of regularly spaced grids (sometimes called pixels) to which the attributes are assigned. The raster form is basically identical to the data format of Remote Sensing data. The raster form of data is usually represented in a matrix form of pixel number and line number.

ABSTRACT DIGITIZED

3.2.1.2 Data management

Once the spatial data have been encoded they must be stored, yet be ready for immediate access and manipulation. Each variable (often called a GIS layer) is archived in a computer - compatible digital format as a geographically referenced plane in a Geographic Information System database. The database can contain any type of information that is spatially distributed. When digitally registered to one another they form data bank composed of 'n' layers which can be queried to answer questions. Since each polygon can have a unique shape, its storage, retrieval and manipulation in a polygonal data structure is complex and expensive. Therefore, it is suggested that the grid is the most popular data structure, as it is cheap to store, retrieve and manipulate and can be of any dimension.

Ideally, the database files reside in the CPU memory (RAM) and are immediately accessible for computation and manipulation. However, as there is tremendous amount of information in files, they are usually stored on relatively fast hard disk drives.

3.2.1.3 Data manipulation

To extract meaningful information from a GIS database one must be able to querry it and ask logical questions, a process commonly referred as Data Manipulation.

GIS has the capability to make scale and projection changes, remove distortion and perform coordinate rotation and translation if necessary.

Once the area of interest is identified, various types of analysis may be performed. Some of the most important include map overlay, map dissolve, polygon overlay for area calculation, measurement and proximity searches.

The analysis in GIS can be done through polygon (vector format) or by grid (raster format) base. The overlay technique involves the compositing (integrating) and dissolve technique involves extracting of multiple maps in order to create new data set.

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The important grid based GIS operation is matrix analysis. This function allows the analyst to select two files that are to be combined by assigning one variable to the columns of matrix and other variable to the rows of a matrix.

Many types of data are best manipulated in grid format, especially those which are continuous over the landscape, such as elevation, slope, temperature, population density and so on. For this reason most of the GIS work performed on such surfaces required that this type of data be in a grid format. Moreover grid coding requires huge computer storage space than the polygon (vector format) coding. Thus for this purpose in GIS, raster data and vector data are frequently converted to vector data and raster data respectively which are called raster/vector conversion and vector/raster conversion respectively.

3.2.1.4 Data output

The output from GIS operations may be a hard copy display of the spatial distribution of important thematic information on a line plotter, an ephemeral display of the same data on a CRT screen or listing of statistics. Since the data were entered using known coordinate locations associated with a rigorous base map and projection, the output map files may be scaled to the desired dimensions.

3.2.1.5 Applications and Limitations of GIS

The applications of GIS are in:

1) Urban planning,
2) Regional planning,
3) District planning,
4) Wasteland development,
5) Coastal management,
6) Water resources management,
7) Crop water modeling'
8) Forestry,
9) Hill area development,
10) Watershed development, etc.

Limitations are :

1) Huge and high quality and reliability database is required for displaying querries.
2) High-speed computers and costly software required.
3) Skilled technical personnel required.

3.3 Use of Remote Sensing Data in GIS

Remote Sensing data after geometric correction can be overlaid on other geographic information/data in raster form. In GIS, there are two uses of use of Remote Sensing data as classified data and as image data.

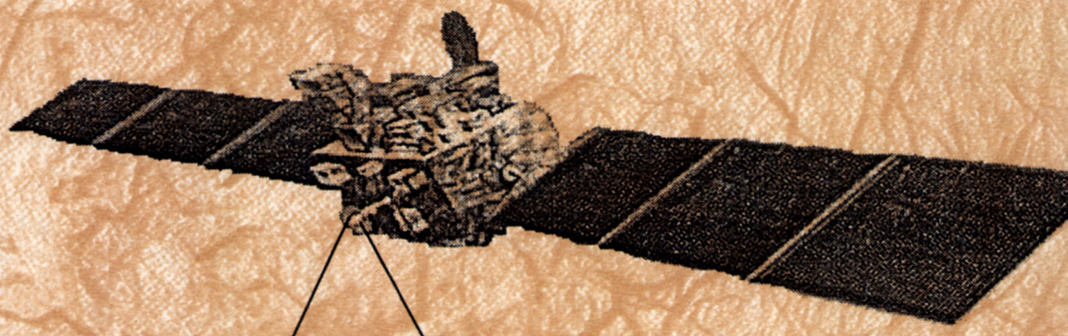
a) Use of classified data:

Land cover maps or vegetation maps classified from Remote Sensing data can be overlaid on to other geographic data, which enables analysis for environmental monitoring and its change.

b) Use of image data:

Remote Sensing data will be classified or analyzed with other geographic data to obtain a higher accuracy of classification. Image data are some times are also used as image maps with an overlay of political boundaries, roads, railways, etc. Such an image map can be successfully used for visual interpretation.

If a digital elevation model (DEM) is used with Remote Sensing data, shading corrections in mountainous areas can be made by dividing by cos q (where, q is angle between sunlight and the normal to the sloping surface).



MATERIAL AND METHODS

4. MATERIAL AND METHODS

The objective of the study was to generate land and water resource development plans on watershed basis using Remote Sensing and GIS techniques. The traditional methods of generating action plan for watershed development are quite cumbersome and time consuming. Moreover, they don't give the overall pictures of watershed regarding its potential, problems etc. The traditional methods are not area specific and don't give the synoptic view. Watershed development planning needs timely and correct information for generation of action plan. The information collected by traditional method while reaching to the experts hand becomes biased due to errors in collection of data and lose its timely value even if it may be correct.

Remote Sensing and GIS is the most appropriate tool for preparing the timely and accurate action plans. The most important aspect in Remote Sensing is the availability of a synoptic view of the target area with an up-to-date and multi-temporal coverage of various earths' features and different bands of electromagnetic spectrum. It offers a quick and efficient way to study land use and other land factors over a wide area. These information provided by the satellites in combination with other sources of information are integrated through GIS to quantify the various parameters for efficient management of land and water resources in watershed. The watershed development approach aims at optimising the use of land, water and vegetation in an area in an integrated way and thus helps alleviating drought, moderating floods, preventing soil erosion, improving water availability and increasing fuel, fodder, and agricultural production on a sustained basis.

In this chapter the approaches and methods adopted while developing the land and water resources development plans are discussed.

4.1 Materials

4.1.1 Location

The study area is watershed at Pimpalgaon Ujjaini village in Ahmednagar District of Maharashtra. The watershed is located at 15 kms from Ahmednagar on Ahmednagar-Aurangabad road in North-East direction. It is about 45 kms from the M. P. K. V., Rahuri University Campus in the East direction. The latitude and longitude of the study area are:

Longitude 74.05° to 74.10° East.

Latitude 18.15° to 18.20° North.

4.1.2 Climate

The watershed experiences a dry climate except during southwest monsoon season. The mean annual rainfall of the watershed is about 642 mm. It is relatively well distributed in four months i.e., from July to October. The winter season starts from November to February, followed by summer season from March to end of May. The mean maximum and minimum temperatures are 35°C and 10°C recorded in summer and winter, respectively. The average annual temperature is approximately 18°C.

4.1.3 Data

4.1.3.1 Socio-economic data

The socio-economic data of the watershed area is collected by taking interviews of the local farmers personally.

4.1.3.2 Field data

1.**Soil**: The soil map of the watershed was obtained from Soil Testing and Soil Survey Department, Ahmednagar. The map contained the soil series information and description of soils. The information about the potentials and problems of the different soil series was also collected.

2.**Topography**: The topography map of the watershed was prepared doing the contour survey of the study area with the help of students from Dr. Annasaheb Shinde College of Agricultural Engineering, M. P. K. V., Rahuri and Action for Food Production (AFPRO), Ahmednagar.

4.1.3.3 Satellite data

The satellite data used for the purpose of study was of path number 96 and row number 59 and is presented in Table 4.1.

Table 4.1: Details of satellite data.

Sr. no.	Satellite	Sensor	Date of pass
1.	IRS-1C	LISS-III	9th October, 1997
2.	IRS-1D	LISS-III	7th January, 1998
3.	IRS-1D	PAN	7th January, 1998
4.	IRS-1D	LISS-III	27th March, 1998

The satellite data was used for generation of thematic/derived maps.

4.1.4 Software

The computer softwares were used for the purpose of digital image processing and GIS. These are described in this section.

4.1.4.1 Digital image processing

EASI/PACE version 6.3 was used for digital image processing of remotely sensed data.

EASI stands for Environmental Analysis, System and Interface.

PACE stands for Picture Analysis, Correction and Enhancement.

In EASI/PACE software, there are mainly five modules namely IMAGE WORKS, EASI, XPACE, GCPWORKS, and FLY.

4.1.4.2 Geographic Information System

Arc/INFO software was used for GIS. Here Arc stands for spatial data i.e., it helps in creating different geometric features such as line, point, and polygon and integrate them. INFO stands for information, thus it keeps the information/description of the geometric feature i.e., Arc and helps in relating various topological features.

4.1.5 Hardware

The workstations of International Business Machines (IBM) RS6000 and SILICON Graphics SGI – OCTANE were used.

Regional Remote Sensing Service Centre (RRSSC), Nagpur, provided this computer facility for digital image processing and GIS.

4.2 Methodology

The different maps are prepared using the collateral data (data obtained from various sources) and satellite data to satisfy the objectives of the study.

These maps are:

- Base maps,
- Thematic / Derived maps and
- Action plan maps.

In this section, the procedure to generate action plans with the help of these maps is explained.

4.2.1 Base map preparation

The following base maps were prepared by the process of digitization.

- Watershed boundary: The Survey of India (SOI) toposheet 47 I/16 and reference map obtained from Taluka Agricultural Office, Dept. of Agriculture, Ahmednagar were used for the preparation of the watershed boundary map by the digitization process.
- Drainage network: The Survey of India (SOI) toposheet 47 I/16 was used for the preparation of drainage network map in the study area.
- Contour map: The Survey of India (SOI) toposheet 47 I/16 was used for the preparation of the contour map which was used for preparation of slope map.
- Built-up: The Survey of India (SOI) toposheet 47 I/16 was used for the preparation of built-up map. The map was prepared by the digitization of village boundaries, road networks etc in the watershed.

4.2.2 Thematic/Derived maps

In this section the procedure for preparation of satellite database and for generation of various thematic/derived maps in general is described. The different thematic/derived maps required for the study, the category of each thematic map etc are also explained in this section.

4.2.2.1. Satellite database

In this section the procedure for the preparation of satellite database in general and for the purpose of generating thematic/derived maps is explained.

4.2.2.1.1 Loading of satellite data

The satellite data of IRS-1C/1D, LISS-III, October 1997, January 1998, March 1998 (P/R-96/59) and IRS-1D PAN data of January 1998 (P/R-96/59 Quadrant A) were used for generation of different thematic/derived maps. The satellite data was loaded using LOAD_IRSCD program of EASI/PACE software. The details of the parameters of the program LOAD_IRSCD are given in Appendix A.

4.2.2.1.2 Rectification of satellite data

Remotely sensed data usually contain both systematic and non-systematic geometric errors. The rectification is the process by which the geometry of an image area is made planimetric. The process almost always involves GCP pixel coordinates with map coordinate counter parts. A ground control point (GCP) is a point on the surface of the earth where both image coordinates (measured in rows and columns) and map coordinates (measured in degrees of latitude and longitude, feet or meters) can be identified. This is the most precise geometric correction since each pixel can be referenced not only by its row and column in a matrix after rectification is completed, but it is also rigorously referenced in degrees, feet or meters in standard map projection. This is often referred as image to map rectification. Some times image registration might be applied, which is the translation and rotation alignment process by which two images of like geometries and of same set of objects are positioned coincident with respect to one another so that corresponding elements of the same ground

area appears in the same place on the registered images. This is called as image to image registration.

Two basic operations must be performed in order to rectify geometrically a remotely sensed image to a map coordinate system.

1) The geometric relationship between the input pixel location (row and column) and the associated map coordinate of this same point (x,y) must be identified. This will establish the nature of the geometric coordinate transformation that must be applied to rectify or relocate every pixel in the original input image (x',y') to its proper position in the rectified output image (x,y). This process is called spatial interpolation.
2) Pixel brightness values must be determined. Unfortunately there is not a direct one to one relationship between the movement of input pixel values to the output pixel locations. It will be shown that often a pixel in the rectified output image requires a value from the input pixel grid that does not fall neatly on a row – and – column coordinate. When this occurs there must be some mechanism for determining the brightness values to be assigned to the new rectified pixel. This process is called intensity interpolation.

The satellite data, which was made available from NRSA, Hydrabad was rectified with the base map. Rectification process was carried out using the module of GCPWORKS of EASI/PACE digital image processing software package. The uncorrected image (Satellite data) was loaded in uncorrected image window. The base map was taken as Geo-referenced database and loaded in Geo-referenced database window. The ground control points were selected on both corrected and uncorrected image so that a relation is established in both images after collection of three ground control points. The points were taken evenly and well distributed over the entire image so that there was good relation in both the images with the RMS error after completion of GCP collection over the entire area within the threshold specified. Then the registration of the rectified image is carried on the new PCIDSK file. The satellite images of IRS-

1C/1D, LISS-III/PAN, October1997, January 1998 and March 1998 (P/R -96/59) were rectified.

4.2.2.1.3 Adding of channels

The extra channels were added in each image data for carrying out the classification of image for preparation of Land use/Land cover map. The task was done by using program PCIMOD of EASI/PACE software. The details of the program PCIMOD are presented in the Appendix A.

4.2.2.1.4 Merged data

Using the FUSE program in EASI/PACE the merged product of LISS-III and PAN was generated for the watershed area for January 1998. The merged product helped in refining various base and thematic maps. The details of the FUSE program of XPACE module are presented in Appendix A.

4.2.2.2 Thematic/derived maps preparation

The procedure for preparation of different thematic/derived maps is explained in detail in this section.

4.2.2.2.1 Generation of Land use/Land cover map

Land use refers to "man's activities and the various use which are carried on land". Land cover refers to "natural vegetation, water bodies, rock/soil artificial cover and others resulting due to transformations".

Classification

The classification of image was done for preparation of land use/land cover map. The classification of image is the process of sorting the pixels into a finite number of individual classes, or categories of data, based on their data file values. If a pixel satisfies a certain set of criteria, it is then assigned to the class that corresponds to that criteria. The result is a thematic file whose value represent thematic categories such as land cover or vegetation types. This type of classification works best with multi-spectral data. It is helpful in land cover mapping, agricultural crop mapping, forestry inventory, water quality analysis, map revision, geologic mapping of arid lands, change detection, etc. The supervised classification was carried out for the satellite data of October1997,

January 1998 and March 1998. In supervised classification, the identity and location of some of the land cover types, such as urban, agriculture; wetland and forest are known a prior through a combination of fieldwork, maps and personal experience. Then the attempt was made to locate specific sites in the remotely sensed data that represent homogeneous examples of these known land cover types. These areas are commonly referred to as training sites because the spectral characteristics of these known areas were used to "train" the classification algorithm for eventual land cover mapping of the remainder of the image. The classification algorithm used was maximum likelihood, which is explained below:

Maximum likelihood algorithm

Every pixel both within and outside the training sites is evaluated and assigned to the class of which it has the highest likelihood of being a member. The decision rule assigns each pixel having measurements or features X to the class 'c' whose units are most probable or likely to have given rise to feature vector X. It assumes that training data statistics for each class in each band is normally distributed. In other words, training data with bi-modal or tri-modal histograms in a single band is not ideal. In such cases the individual modes probably represent individual classes that should be trained upon individually and labeled as separate classes. This would then produce unimodal, Gaussian training class statistics that would fulfil the normal distribution requirement.

The statistics already computed are used by maximum likelihood algorithm which includes mean measured vector (Mc), for each class and the covariance matrix of class 'c' for bands k through l (Vc). The decision rule applied to the unknown measurement vector (X) is: decide X is in class 'c' if and only if

Pc >= Pi where, i = 1, 2, 3, ...m possible classes.

where,

Pc = Statistics of class 'c',

Pi = Statistics of class 'i',

Mc = measured vector,

Vc = covariance matrix,

X = measured vector of unknown class.

The satellite image was classified in seven main classes.

Classification classes

1) Water: It includes those lands where there is surface water bodies used for storage, agriculture, drinking, etc.

2) Crop: It includes those lands with standing crop (per season) as on the date of the satellite imagery. The crops may be either kharif or rabi or double crop seasons.

3) Fallow: It is described as agricultural land, which is taken up for cultivation but is temporarily allowed for rest, un-cropped for one or more seasons, but not less than one year. These lands are particularly those, which are seen devoid of crops at the time when the imagery is taken of both seasons.

4) Scrub: It is described a forest where the vegetative (crown) density is less than 20 per cent of the canopy cover. It is the result of both biotic and abiotic influences. Scrub is a stunted tree or bush/scrub.

5) Plantation: It is described as an area under agricultural tree crops, planted adopting certain agricultural management techniques. It includes nilgiri, subabul, citrus, orchards, and other horticultural nurseries.

6) Barren: It is described as that piece of land, which doesn't have any agricultural or built up structures and is exposed to the atmosphere. It has normally cover of stony/rocky waste or sheet rock area, generally murumy land.

7) Built-up land: It is defined as an area of human habitation developed due to non agricultural use and that which has a cover of buildings, transport, communication, utilities in association with water, vegetation and vacant lands.

Using aggregation and referential refinement the final land use/land cover map was generated. The results were validated on ground. It was divided into classes as presented below:

Land use/Land cover Classes

1) Water: It includes those lands where there is surface water bodies used for storage, agriculture, drinking, etc.

2) Kharif: It includes those lands with standing crop in the months of June to October only as on the date of the satellite imagery.

3) Rabi: It includes those lands with standing crop in the months of November to February only as on the date of the satellite imagery.

4) Double Crop: It includes those lands with standing crop in the kharif as well as in rabi season as on the date of the satellite imagery.

5) Fallow: It is described as agricultural land, which is taken up for cultivation but is temporarily allowed for rest, un-cropped for one or more seasons, but not less than one year. These lands are particularly those, which are seen devoid of crops at the time when the imagery is taken of both seasons.

6) Scrub: It is described a forest where the vegetative (crown) density is less than 20 per cent of the canopy cover. It is the result of both biotic and abiotic influences. Scrub is a stunted tree or bush/scrub.

7) Plantation: It is described as an area under agricultural tree crops, planted adopting certain agricultural management techniques. It includes nilgiri, subabul, citrus, orchards, and other horticultural nurseries.

8) Barren: It is described as that piece of land which doesn't have any agricultural or built up structures and is exposed to the atmosphere. It has normally cover of stony/rocky waste or sheet rock area, generally murumy land.

9) Built-up land: It is defined as an area of human habitation developed due to non agricultural use and that which has a cover of buildings, transport, communication, utilities in association with water, vegetation and vacant lands.

4.2.2.2.2 Soil Map

Soils vary considerably in nature, physical, chemical and morphological characteristics and thereby play an important role in management of soil productivity and sustainable production. Hence a reliable soil resources map with scientific information about the characteristics, potentials and problems of the soils as well as their spatial distribution is indispensable for planned development of agriculture, forestry, horticulture, agro-horticulture, silvipasture and various other soil related activities.

Soil mapping of the study area was carried out to study characteristics, qualities and classes of the different soils, their location and spatial distribution. IRS-1D LISS-III data of March 1998 and Merged data of January

1998 was used along with the available soil map from Soil Testing and Soil Survey Department, Ahmednagar for this mapping purpose.

Based on the image characteristics, soil map information and collateral information like land use and vegetation a tentative relationship among image interpretation units, physiography and soils was developed and soil map was prepared.

The soil map was prepared in following three categories as they all are helpful in generation of action plans.

1) Soil Series Map,
2) Land Capability Classes Map, and
3) Hydrologic Soil Group Map.

4.2.2.2.2.1 Soil series

The soil series is the classification of the soil based on the overall parameters of the soil. The parameters include the depth, texture, slope, erosion etc. The soil series are unique in nature to that particular area. They are described particularly by the name of the region in which they found mainly in abundance. Based on the image characteristics, soil map information and collateral information like land use and vegetation a tentative relationship among image interpretation units, physiography and soils was developed and soil series map was prepared.

The Soil Series in the study area are:

Pimpalgaon Rota, Wadner, Kolgaon, Bhendwade, Malsiras, Kurkumbh, Supe, Bhamburdi, Shenwadgaon and Savedi.

i) Pimpalgaon rota: The soils with shallow depth, gravelly clay loam texture, severe erosion are included in Pimpalgaon rota soil series. The geology is of mesa type. The soils are found on gently sloping topography. The soils are cultivated

ii) Wadner: The soils with shallow depth, gravelly sandy loam texture, very severe erosion are included in Wadner soil series. The geology is of escarpment type. The soils are found on moderate strong sloping topography. The soils are uncultivated.

iii) **Kolgaon:** The soils with shallow depth, gravelly sandy clay loam texture, very severe erosion are included in Kolgaon soil series. The geology is of escarpment type. The soils are found on moderate strong to steep to moderate steep sloping topography. The soils are uncultivated.

iv) **Bhendwade:** The soils with shallow depth, gravelly sandy clay loam texture, severe erosion are included in Bhendwade soil series. The geology is of pediment type. The soils are found on gently sloping topography. The soils are cultivated.

v) **Malsiras:** The soils with shallow depth, clay texture, severe erosion are included in Malsiras soil series. The geology is of pediment type. The soils are found on gently sloping topography. The soils are cultivated.

vi) **Kurkumbh:** The soils with shallow depth, gravelly sandy loam texture, severe erosion are included in Kurkumbh soil series. The geology is of pediment type. The soils are found on gently sloping topography. The soils are cultivated.

vii) **Supe:** The soils with medium depth, clay texture, severe erosion are included in Supe soil series. The geology is of pediment type. The soils are found on gently sloping topography. The soils are cultivated.

viii) **Bhamburdi:** The soils with very deep depth, clay texture, moderate erosion are included in Bhamburdi soil series. The geology is of piedments type. The soils are found on very gently sloping topography. The soils are cultivated.

ix) **Shenwadgaon:** The soils with very deep depth, clay texture, severe erosion are included in Shenwadgaon soil series. The geology is of plains type. The soils are found on gently sloping topography. The soils are cultivated.

x) **Savedi:** The soils with very deep depth, clay texture, moderate erosion are included in Savedi soil series. The geology is of pediments type. The soils are found on very gently sloping topography. The soils are cultivated.

4.2.2.2.2.2 Land capability classes

The land capability classes are indicative of the capability of land for the cultivation purpose. There are eight land capability classes in general. The

soil map obtained from the Soil Testing and Soil Survey Department, Ahmednagar indicated that in all there are five different land capability classes in the study area. Based on the image characteristics and soil map information a tentative relationship among image interpreted units, physiography and land capability classes was developed and land capability classes map was prepared. These classes are described below,

1) Capability Class IIe

The unit comprises of very deep, clayey soils of Bhamburdi, Shenwadgaon and Savedi series developed on very gentle slopes of plains and piedments with moderate erosion hazards.

Potentials:

i. Deep to very deep soils.
ii. Less erosion.
iii. Gentle sloping.

Problems:

i. Unfavourable textures (clayey).
ii. Poor aeration.
iii. High draft requirement for the tillage operations.

Recommendations:

i. Deep summer ploughing.
ii. Application of organic manures/green manuring, if irrigated.
iii. Adoption of crop rotation with judicious use of fertilizers.

2) Capability Class IIIe

The unit comprises of medium deep, clayey soils of Supe series developed on gentle slopes of pediments with severe erosion hazards.

Potentials:

i. Medium depth soil.
ii. Gentle slopes.

Problems:

i. Unfavourable texture (clayey).
ii. Severe erosion.
iii. Poor tilth.

Recommendations:

i. Contour or graded bunding.

ii. Application of soil test based manures and fertilizers.

iii. High yielding improved crop varities.

3) Capability Class IVes

The unit comprises of shallow, gravelly clay loam to gravelly sandy loam soils of Pimpalgaon rota, Bhenwade, Malsiras and Kurkumbh series developed on gentle slopes of mesa and pediments with severe erosion hazards.

Potentials:

i. High infiltration.

ii. Cultivable lands.

Problems:

i. Severe erosion.

ii. Gravelly texture.

iii. Low water holding capacity.

Recommendations:

i. Plantations/Agro-horticulture/silvi-pasture with staggered trenches following contours.

ii. Intensive erosion control measures when in cultivation.

iii. Water conservation measures.

4) Capability Class VIes

The unit comprises of shallow, gravelly sandy loam soils of Wadner series developed on moderate strong slopes of escarpments with very severe erosion hazards.

Problems:

i. Shallow soil depths.

ii. Moderate strong sloping.

iii. Very severe erosion susceptibility.

iv. Low water holding capacity.

Recommendations:

i. Development of silvi-pasture.

ii. Control grazing.

iii. Staggered trenching.

5) Capability Class VIIes

The unit comprises of shallow, gravelly sandy loam soils of Wadner series developed on moderate strong slopes of escarpments with very severe erosion hazards.

Problems:

i. Moderate strong, steep to very steep slopes.
ii. Shallow effective depths.
iii. Very severe erosion.
iv. Gravels and stone in the soil.

Recommendations:

i. Staggered contour trenching and plantations.
ii. Introduction of suitable grasses.
iii. Afforestation and development of forests.
iv. Controlled/rotational grazing.

The soil series according to Land Capability Class is presented in Table 4.2.

Table 4.2: Soil Series according to Land Capability Class

Sr. No.	Land Capability Class				
	IIe	IIIe	IVes	VIes	VIIes
1	Bhamburdi	Supe	Pimpalgaon Rota	Wadner	Wadner
2	Shenwadgaon		Malsiras		Kolgaon
3	Savedi		Kurkhumb		
4			Bhewade		

4.2.2.2.2.3 Hydrologic soil group

Hydrologic Soil Groups are suggestive of runoff from rainfall event for hydrological studies particularly in watershed management programmes. An attempt to classify the soils into hydrological soil groups has been made on the basis of soil characteristics. These include effective depth, infiltration, permeability, soil structure, soil texture, geology, slopes, etc. Based on the image characteristics, soil map information and collateral information like land use and

vegetation a tentative relationship among image interpretation units, physiography and soils was developed and hydrologic soil group map was prepared. The following are the different hydrological soil groups:

1. Hydrologic Soil Group A (Low runoff potential)

Soils are deep to very deep, excessively drained, sands and gravels with high infiltration rates.

2. Hydrologic Soil Group B (Moderately low runoff potential):

Very deep to deep and shallow soils resting over very permeable materials, well drained, with medium or moderately coarse textures having moderately high infiltration rates.

3. Hydrologic Soil Group C (Moderately high runoff potential):

Shallow to very deep, somewhat slowly drained and moderately fine textured soils having slow infiltration rates.

4. Hydrologic Soil Group D (High runoff potential):

Clayey soils with high swell-shrink potential and imperfect drainage, high water table, and shallow soils with lithic contact or directly underlain by nearly impervious material and with very low infiltration rates.

The Soil Series according to Hydrological Soil Groups is presented in Table 4.3.

Table 4.3: Soil Series according to Hydrological Soil Groups

Sr. No.	Hydrologic Soil Group		
	B	C	D
1	Wadner	Pimpalgaon Rota	Supe
2	Kolgaon	Malsiras	Bhamburdi
3	Bhewade	Kurkhumb	Shenwadgaon
4			Savedi

4.2.2.2.3 Hydrogeomorphology and groundwater potential

The hydrogeomorphological map was prepared based on visual interpretation of the IRS-1C/1D LISS-III March 1998 and merged January 1998

data and SOI 47 I/16 toposheet and topographical maps. The geomorphic units have been classified based on the origin of the landforms and the geological process acting upon it. Further, the units have been separated based on relief altitude and structural information. The Hydrogeomorphology map has been refined and updated with the field investigation. The hydrogeomorphological set up of the area is broadly divided into two major units namely, structural and denudational origin.

1. Structural Origin:

Most of the flat topped hills and under cutting areas are classified under the structural origin. In plateaus, based on the thickness of the weathered zone and hydrologic characteristic, the structural origin units have been sub divided into A, B and C categories.

Dissected Plateau-A:

The category A is geohydrologically characterised by very thin weathered zone or outcropping of basaltic rock, very less infiltration, more runoff, having as dendritic drainage system and occupying higher altitudes with barren or waste or grass land. Generally this category has poor ground water potential

Dissected Plateau-B:

Shallow thickness of weathered zone, moderate infiltration, mostly undulating terrain, severe erosion with dominant undercutting and occupying waste land or rain fed agricultural land is characterized by category B. Generally this category has moderate to poor ground water potential

Dissected Plateau-C:

The category C is characterized by relatively more infiltration, thickness of weathered zone is more and mostly occupied by agricultural land. Generally this category has good to very good ground water potential

2. Denudational Origin :

Steep slopes and intensive erosional slopes are classified under units of denudational origin. These slopes are mostly found on the sides of the flat topped hill and plateaus. This is characterized by undulating terrain, less thickness

of weathered zone of boulders and rock fragments and occasional outcropping of basalt. The land is occupied by stony wasteland category.

4.2.2.2.4 Slope map

The digitized contour information was used for preparation of digital elevation model (DEM) and slope map. DEM and slope map give the idea about the topography of the land and its cultivability.

4.2.2.2.4.1 Digital elevation model (DEM)

The 20 m interval elevation contours and spot heights were digitized from SOI 47 I/16 toposheet map on 1:50000 scale. The digitized information was transferred to EASI/PACE on IBM RS workstation. The digitized contour information was then interpolated using GRDINT program of EASI/PACE software with the smoothest 'conic' option. Geo-referenced IRS LISS-III data was draped on digital elevation data to generate digital terrain model which provides three dimensional view of the study area for general understanding of the terrain and also for correlating the resources information with elevation data.

The details of the procedure adopted for generation of DEM is described in Appendix-A.

4.2.2.2.4.2 Slope

A slope map on 1:50000 scale was generated from the DEM. The LUT file with per cent slope range and corresponding slope code was prepared in ARC/INFO. The information of the DEM was then divided into the per cent slopes using slope code from the LUT file through the ARC command 'LATTICEPOLY'. The detail of the generation of the slope map is described in Appendix-A.

4.2.2.3 Generation of action plan

The integration of various thematic maps and attribute data, further manipulation/analysis for identifying alternatives for development have been carried out using the ARC/INFO Geographic Information System.

The digital database corresponding to hydrogeomorphology, soils, land use and their derivatives have been feature-coded and stored in the map information system. These individual maps from corresponding files have been integrated to arrive at "Composite Mapping Units" (CMUs). The socio-economic, institutional and other statistical data have been entered into the attribute database. The decision criterion was structured within the framework of resources potential and other determinants to evolve a land and water resource development alternatives/plan (i.e., pragmatic model).

4.2.2.3.1 Composite mapping unit (CMU)

It is a three dimensional landscape unit homogeneous in respect of characteristics and qualities of land, water and vegetation and separated from other dissimilar units by distinct boundaries. The CMU characteristic imply physical parameters of the component resources of a biophysical domain, whereas qualities are suggestive of their potential for specific uses under the defined sets of conditions. Based on the interaction among the basic resources of land, water and vegetation, which form the major components of primary production system, useful inferences can also be drawn about their predicted behavior in meeting the various planning goals.

The areas under agriculture, forests, grasslands and plantations, suffering from soil erosion and other forms of degradation reflect the extent of mismanaged lands for which integrated soil and water conservation measures are to be taken. The scrublands are the locked-up production potential and the appropriate reclamation has to be carried out.

Land capability based on soil, slope and meteorological factors gives optimum land use potential. Mismatch between existing and potential land use implies land use revision. Hydrologic groupings are indicative of infiltration/surface flow for soil, based entirely on its inherent characteristics. Integration of hydrologic groupings, vegetation cover complex, landform and slope permit runoff estimation from a given land system unit. Integration of hydrogeomorphological and land use data with some geophysical investigations gives around water potential. This coupled with surface water potential, when

matched against tapped water resources helps in estimating unrealized water potential to meet the primordial demands of irrigation, drinking and others.

Thus the integration of various thematic maps such as Land use/land cover, soil series, land classification classes, slope and hydrogeomorphology and ground water potential map was carried to prepare a CMU map. This CMU map was used for generating the action plan.

4.2.2.3.2 Development of land/water use alternatives

A pragmatic development model has to provide a number of alternatives in respect of each of the different landscape units or CMUs. Primarily, this is because our understanding about the interactions among the different parameters of the complex social, physical and natural system is limited to suggest a single best course of action. Furthermore, the input situation and socio-economic conditions assumed at planning stage for a particular action plan may not remain valid at the time of implementation, and thereby rendering the plan ineffective. There is also a risk factor involved in single action plan that is based almost entirely on the 'assumed best' in alliance with goals and objectives of the planning, though such an action may not necessarily agree with the individual landholder. Alternatives provide a choice to the landowners to select from amongst several recommended action plans and thus indirectly help to overcome their resistance to compliance of something that, at least some of them, may fill thrust upon them.

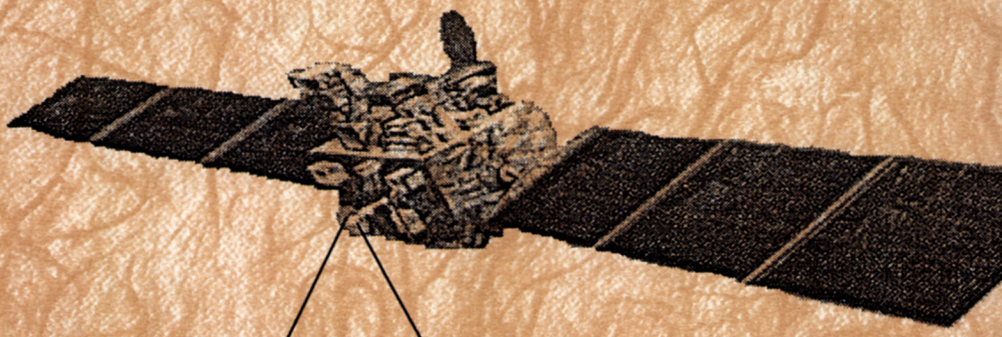
Alternatives are to be developed within the framework of optimal land use. The alternatives should be developed to cover:

- All the systems to be planned,
- All the sectors of the economy and
- All the sectors of community.

The thematic maps were derived from remote sensing techniques and collateral information was stored in Arc/INFO, a GIS package. Thus the integration of various thematic maps (spatial data) and attributing information (non-spatial data) and further analysis for suggesting developmental alternatives was carried out using Arc/INFO.

The Water Resources Development Plan showing suitable sites for rain water harvesting, groundwater recharge and groundwater exploration has been generated considering, rainfall pattern, terrain conditions, surface and groundwater availability, drainage network and problems associated with the developmental activities.

The information on soils, hydrogeomorphology, availability of surface water and groundwater, land use/land cover and slopes were integrated to develop the Land Resource Development plan giving due consideration to the Water Resource Development plan and socio-economic constraints.



RESULTS AND DISCUSSION

5. RESULTS AND DISCUSSION

Remote Sensing and GIS was used as the tool for generation of various thematic maps. The GIS was used for integration of various thematic maps for generation of action plans. In this chapter the results of various thematic maps and action plans are discussed.

5.1 Base map

The base maps were refined as discussed in Section 4.2.1. The base map pertaining to watershed boundary and drainage order/network map were prepared and were used as the base for the study. These are shown in Plate 5.1. The map pertaining to the drainage network and micro-watersheds is shown in Plate 5.2. It is seen from the Plate 5.1 that the 5^{th} order drain flows in the watershed.

5.2 Thematic Maps

5.2.1 Rectified satellite images

The rectification of the raw satellite data was carried out for the purpose of establishing the image to map relationship so that the satellite image can be used to relate the ground point accurately (georeferencly) as discussed in the Section 4.2.2.1.2. The rectified satellite FCCs of October 1997, January 1998 and March 1998 of IRS-1C/1D LISS III camera are shown in Plates 5.3, 5.4 and 5.5 respectively.

The merged satellite data product for the January 1998 of LISS III and PAN data of IRS-1D is shown in Plate 5.6. It was useful in delineating the different physiographic units of the hydrogeomorphology and soils.

5.2.2 Land use/land cover

The satellite data of October1997, January 1998 and March 1998 was classified in the classification classes as discussed in Section 4.2.2.2.1 (1). These classified maps were then integrated for the preparation of Land use/Land cover map as discussed in Section 4.2.2.2.1 (1). The land use/land cover map was classified in nine classes as described in Section 4.2.2.2.1 (1).



Plate 5.1: Watershed boundary and drainage order map.

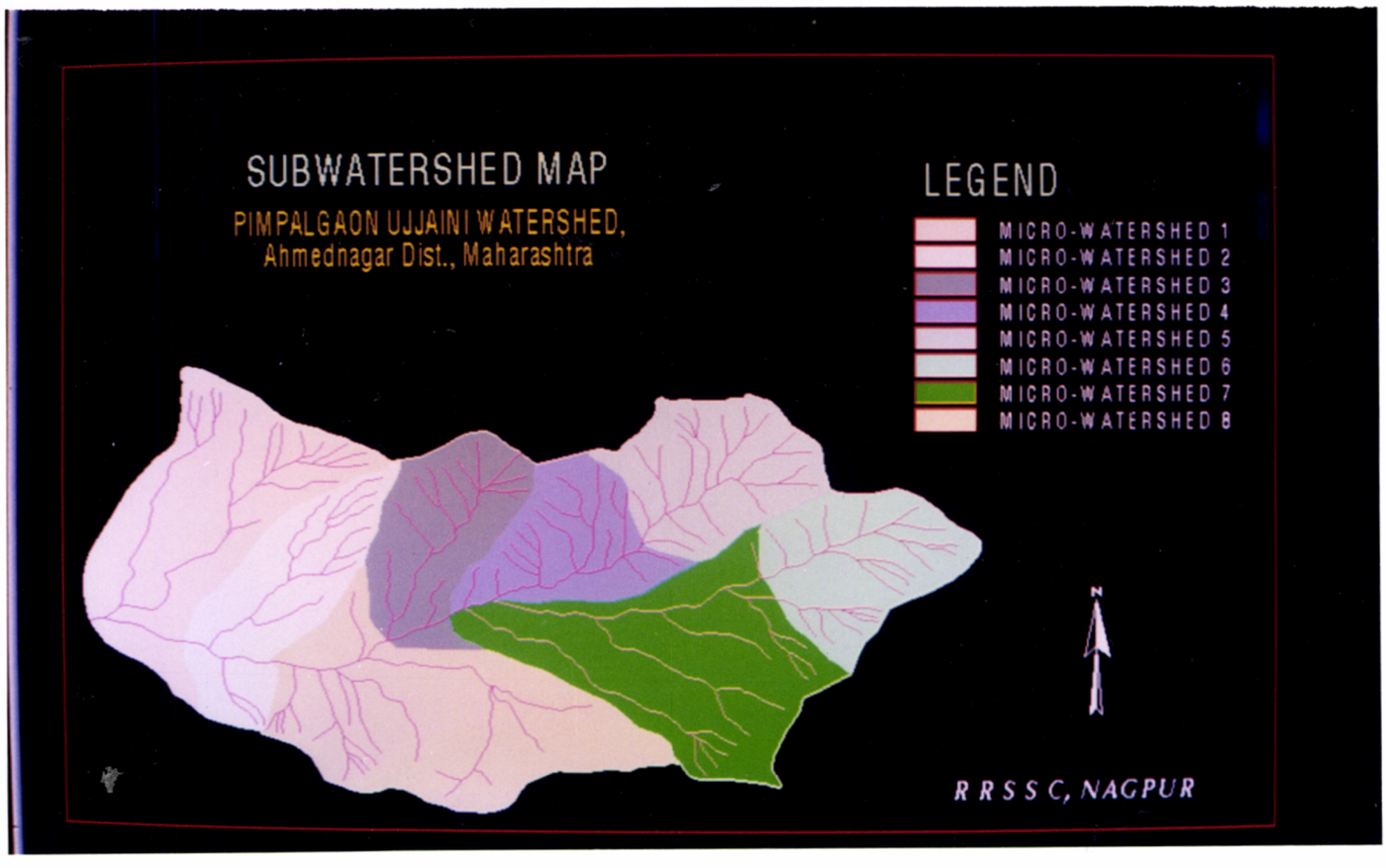


Plate 5.2 Micro-watershed boundaries and drainage network map

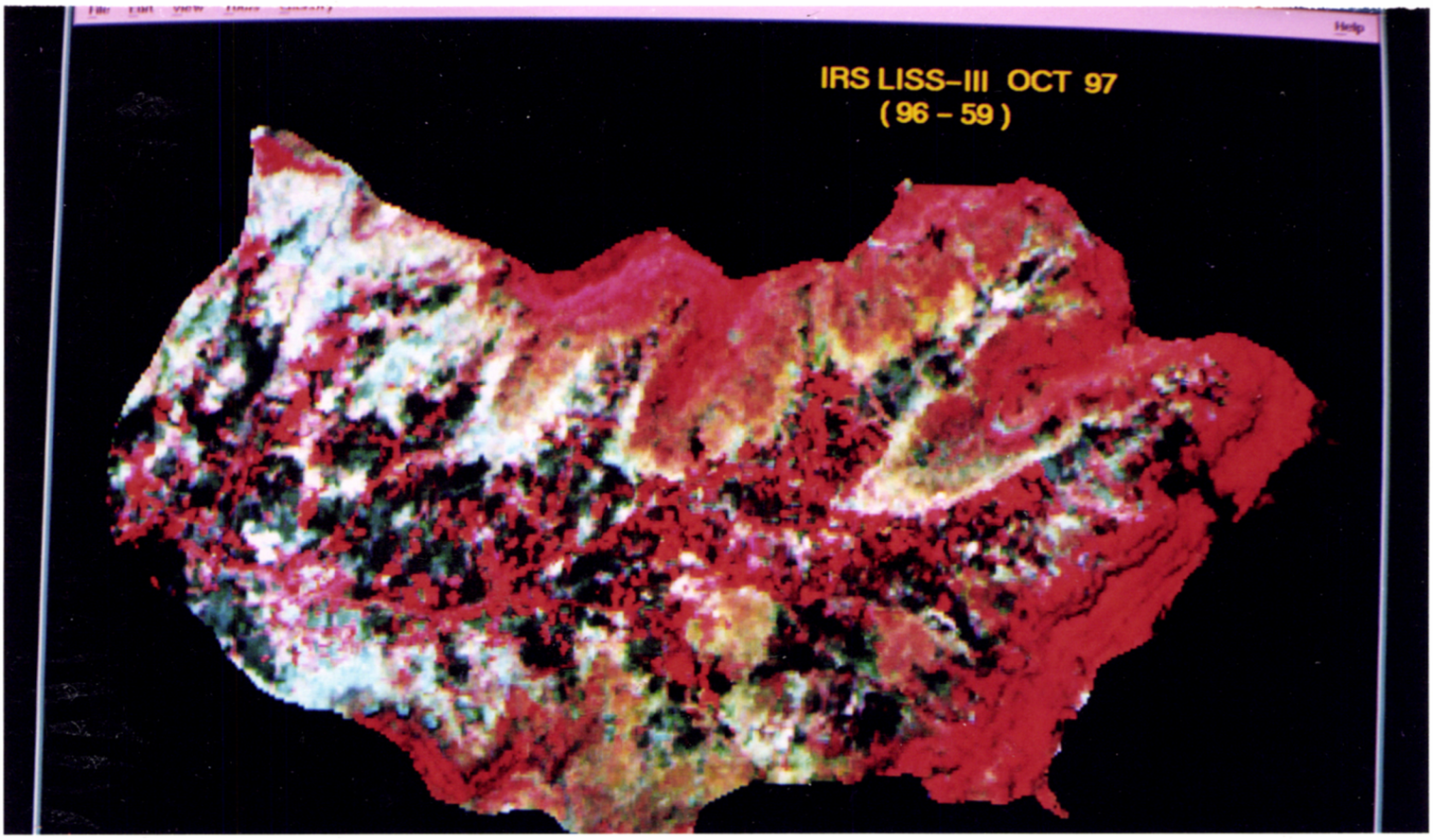


Plate 5.3 FCC of October 1997 LISS III camera

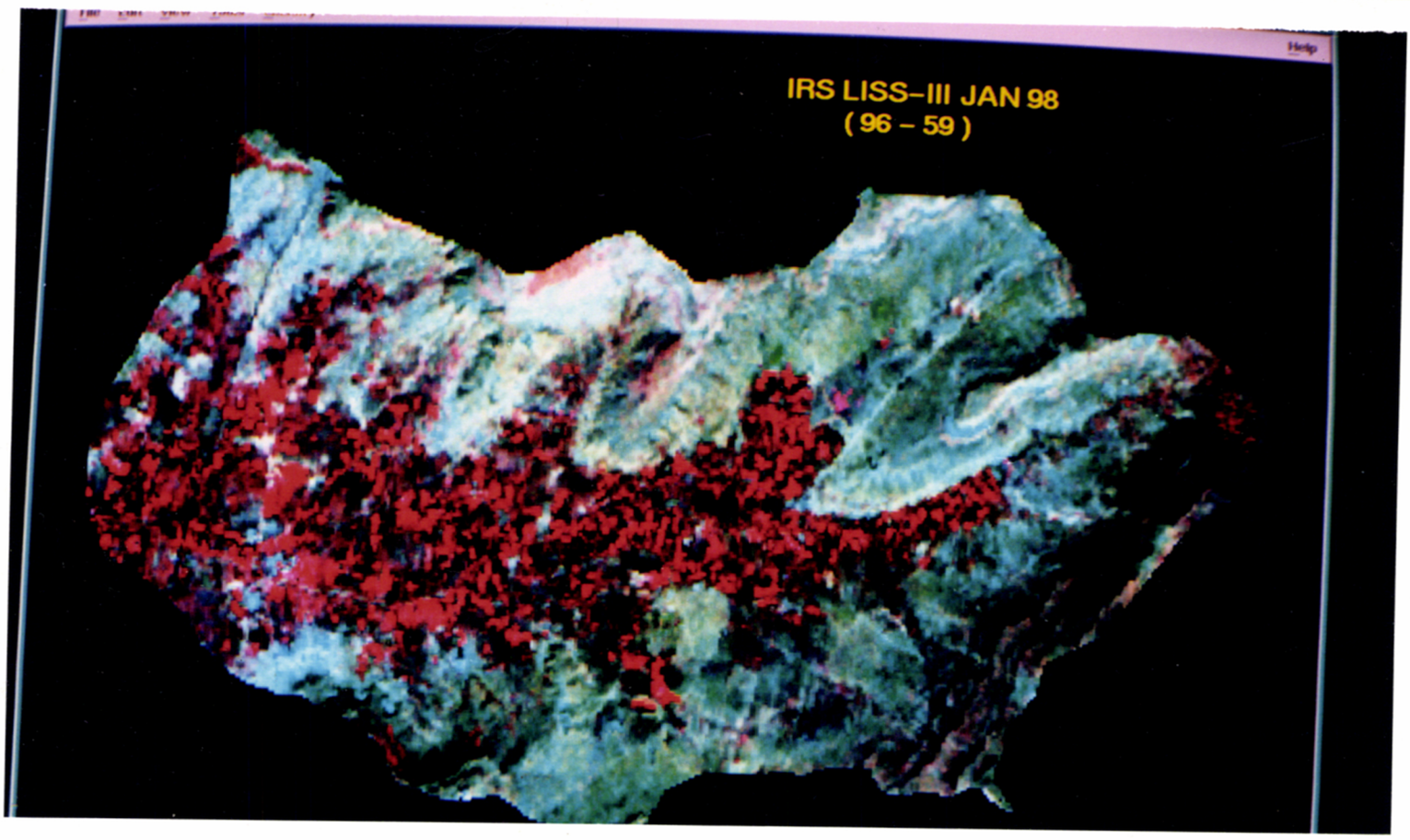


Plate 5.4 FCC of January 1998 LISS III camera

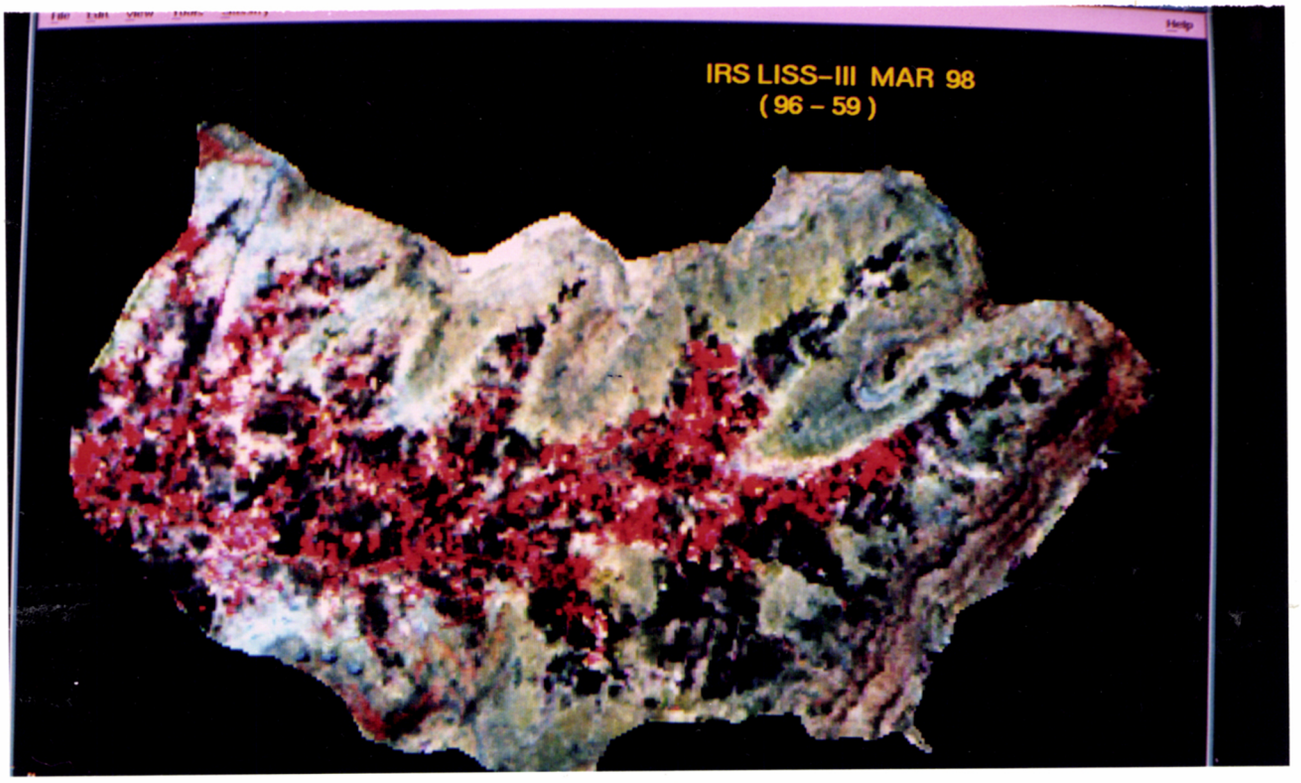


Plate 5.5 FCC of March 1998 LISS III camera

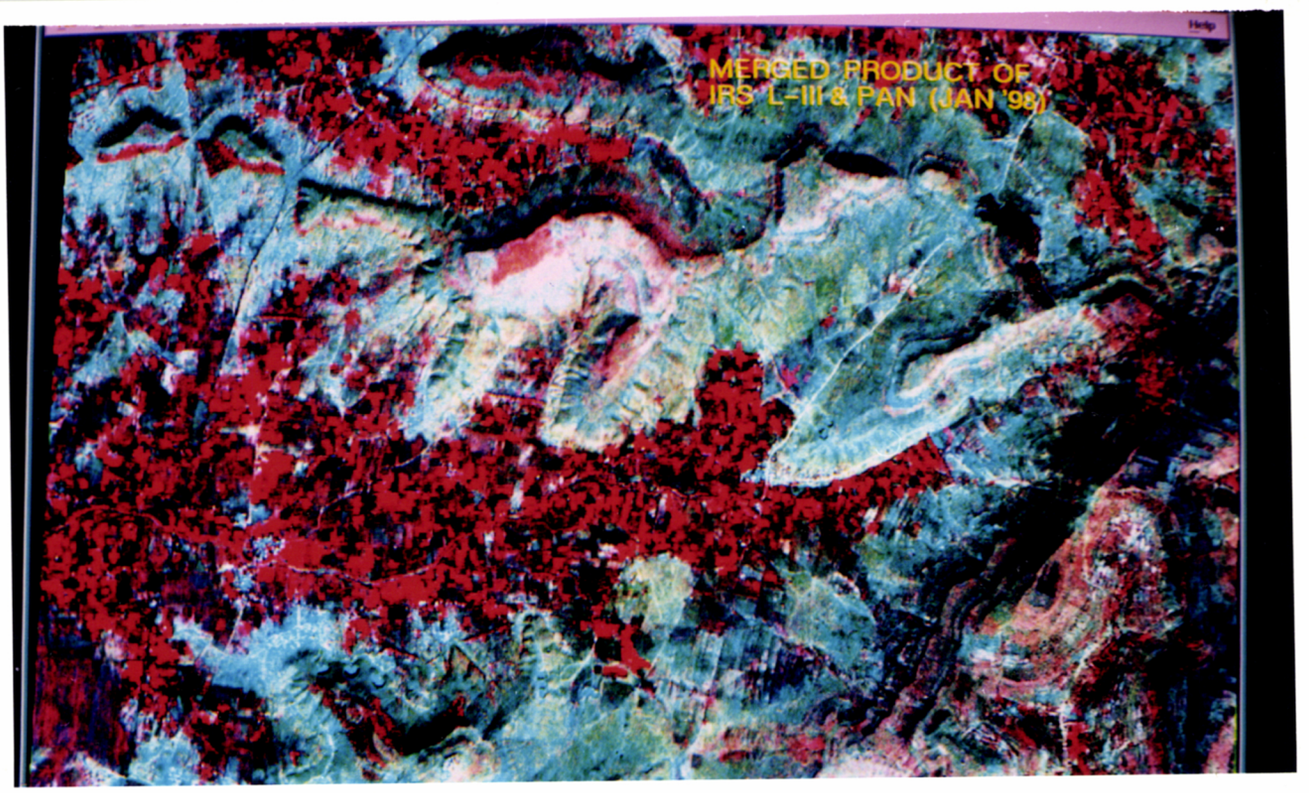


Plate 5.6 Merged product of LISS III + PAN data of January 1998



Plate 5.7 Land use / Land cover map

The area under different classes of land use/land cover are presented in Table 5.1 and the map is shown in Plate 5.7.

Table 5.1: Area under different classes of Land use/Land cover.

Sr. No.	Land use/Land cover	Area (Ha.)	Percentage %
1.	Kharif	59.77	1.92
2.	Rabi	360.84	11.60
3.	Double crop	345.86	11.15
4.	Fallow	263.55	8.47
5.	Scrub	1849.74	59.48
6.	Barren	102.29	3.28
7.	Plantations	91.75	2.95
8.	Water bodies	15.25	0.50
9.	Built-up land	20.30	0.65

It is seen from the Table 5.1 that the study area has about 24.7 per cent of cropped land. There is about 60 per cent of scrubland and 8.47 per cent of fallow land, which can be used for cultivation or plantation purpose. These scrub and fallow lands after matching with the soil types and groundwater potential are suggested for different land use activities. The built-up land in the area is about 0.65 per cent.

5.2.3 Soil map

Soils vary considerably in nature, physical, chemical and morphological characteristics and thereby play an important role in management of soil productivity and sustainable production. The soil maps were prepared as discussed in Section 4.2.2.2.2 in three main categories *viz* Soil Series, Land Capability Class and Hydrologic Soil Group.

5.2.3.1 Soil series

The Soil Series map was prepared as described in Section 4.2.2.2.2.1. The Soil Series of the study area are discussed in section 4.2.2.2.2.1.

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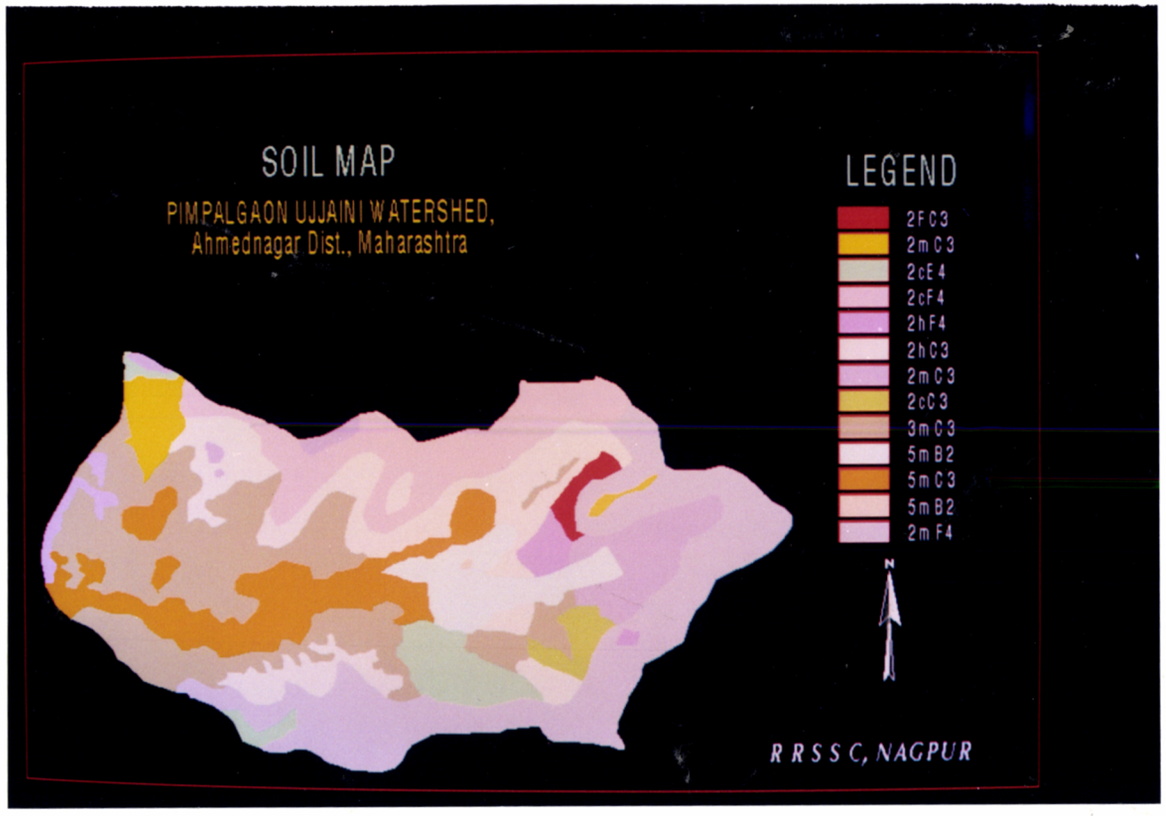


Plate 5.8 Soil series map

The area covered under different soil series of the study area is presented in Plate 5.2 and the soil series map is shown in the Plate 5.8.

Table 5.2: Area covered under different Soil Series.

Sr. No.	Soil Series	Cultivability	Area	Percentage
1.	Pimpalgaon Rota	Cultivable	109.80	3.50
2.	Wadner	Uncultivable	459.32	14.87
3.	Kolgaon	Uncultivable	669.96	21.54
4.	Bhendwade	Cultivable	442.66	14.23
5.	Malsiras	Cultivable	189.89	6.10
6.	Kurkumbh	Cultivable	45.28	1.43
7.	Supe	Cultivable	689.44	22.17
8.	Bhamburdi	Cultivable	155.24	4.99
9.	Shenwadgaon	Cultivable	346.50	11.14
10.	Savedi	Cultivable	1.22	0.03

It is seen from Table 5.2 that about 64 per cent of soil is cultivable. However Table 5.1 shows that only 25 per cent of soil is cultivated and 60 per cent is either scrub or fallow land. Thus most of the scrub and fallow lands are on the cultivable soils. These soils are not probably cultivated due to socio-economic condition and lack of awareness. Thus in land resource development plan soil factor has to play an important role.

5.3.2.2 Land capability classes

The land capability classes map was prepared as discussed in Section 4.2.2.2.2.2. The different classes potentials, problems and recommendations for each class are also discussed in Section 4.2.2.2.2.2.

The area under different Land Capability Class of the study area are presented in Table 5.3 and the map showing the Land capability classes is given in Plate 5.9.

From the Table 5.3, it is seen that the cultivable land capability class is about 65 per cent but still in the present land use scenario only 25 per cent of land is under cultivation (Table 5.1). Thus it is necessary to give due

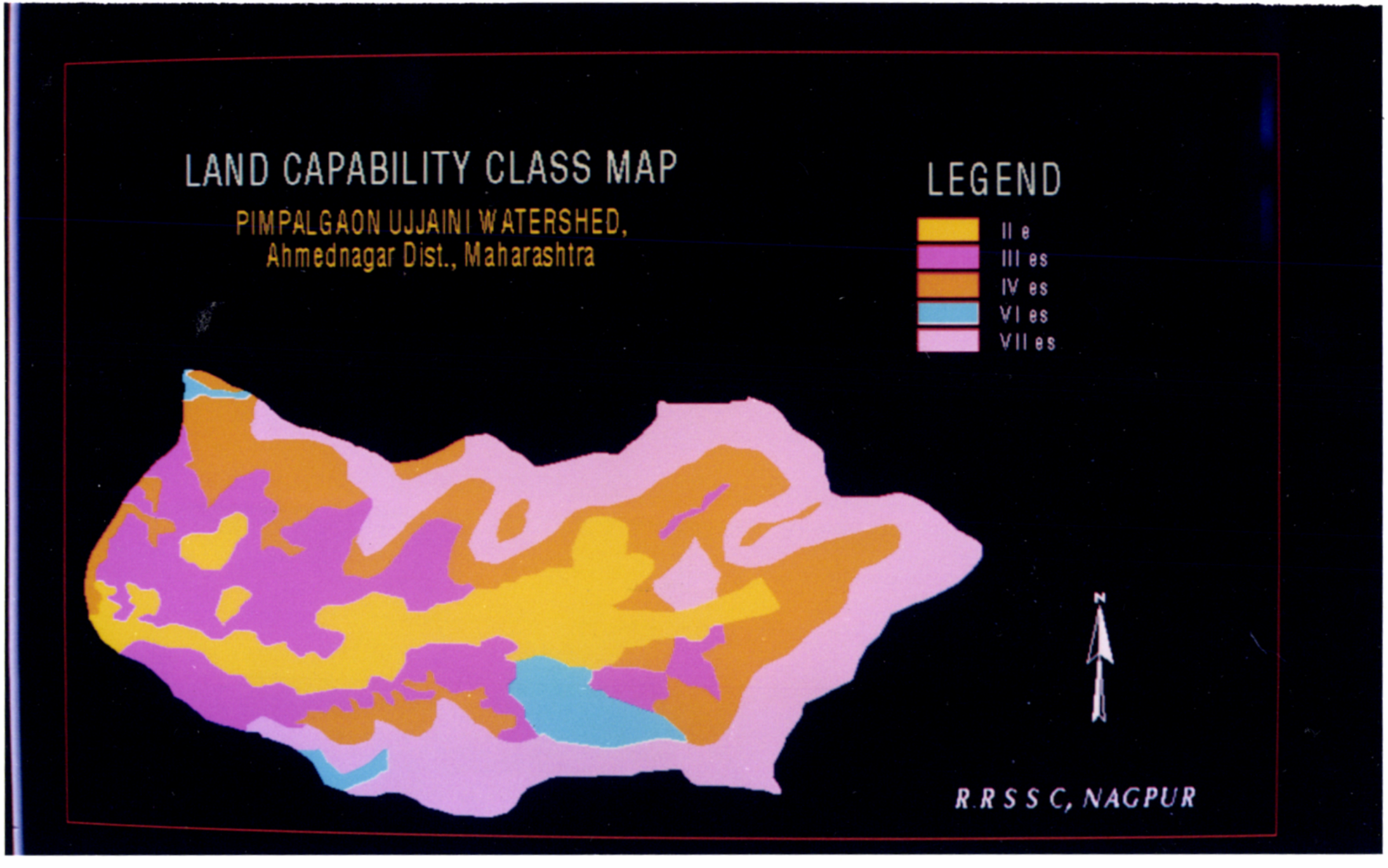


Plate 5.9 Land capability classes map

importance to Land Capability Classes while generating the Land Resource Development Plan.

Table 5.3: Area under different Land Capability Classes.

Sr. No.	Class	Cultivability	Area	Percentage
1.	IIe	Cultivable	502.97	16.17
2.	IIIes	Cultivable	689.44	22.17
3.	IVes	Cultivable	787.65	25.35
4.	VIes	Uncultivable	135.84	4.36
5.	VIIes	Uncultivable	993.48	31.95

5.2.2.3 Hydrologic soil group

Hydrologic Soil Groups map was prepared as discussed in Section 4.2.2.2.2.3. The hydrologic soil group along with the land use plays an important role in deciding the runoff from the individual storm. Thus, it helps in the design of water harvesting structure for the peak runoff rate that may occur form the single storm. The different hydrologic soil groups are also discussed in the Section 4.2.2.2.2.3.

The area under different Hydrologic Soil Group is presented in Table 5.4 and the map showing hydrologic soil groups is shown in Plate 5.10.

Table 5.4: - Area under different hydrologic soil groups.

Sr. No.	Hydrologic Soil Group	Runoff Potential	Area (ha)	Percentage (%)
1.	HSG-B	Moderate Low	939.41	30.22
2.	HSG-C	Moderate High	344.90	11.09
3.	HSG-D	High	1825.06	58.69

From the Table 5.4, it is clear that about 60 per cent of soil is having high runoff potential. Therefore, it is necessary to given attention for harvesting of the runoff water to stop erosion and to store water for drinking, irrigating and recharging purpose. Thus, the hydrologic soil group plays an important role in suggestion of the sites for water harvesting structures.

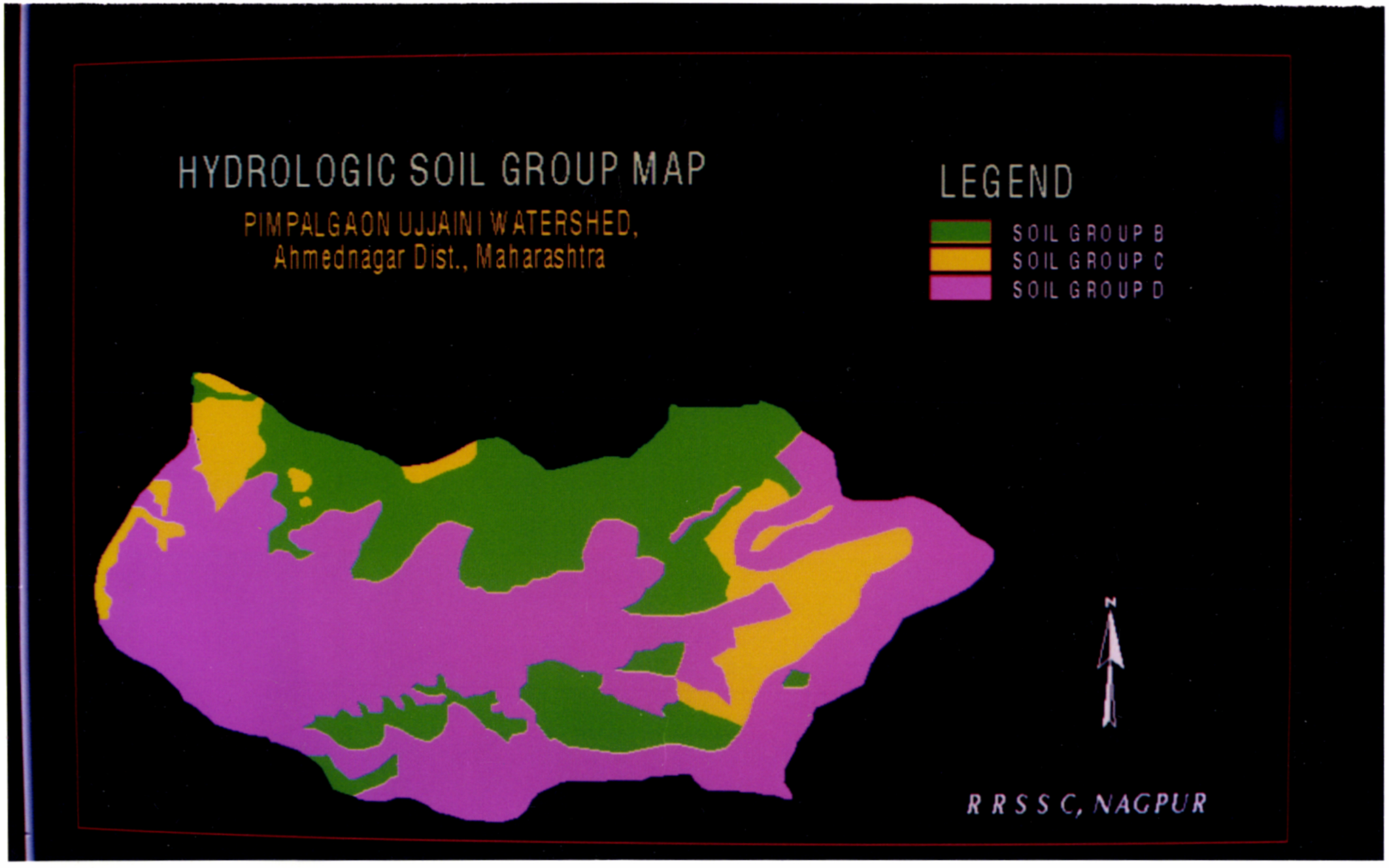


Plate 5.10 Hydrologic soil group map

5.2.4 Hydrogeomorphology and groundwater potential

The hydrogeomorphological map on 1:50000 scale was prepared based on visual interpretation of the IRS-1C/1D LISS-III March 1998 and merged January 1998 data and SOI topographical maps as discussed in the Section 4.2.2.2.3. The different classes in which the hydrogeomorphological map was divided and the characteristics of each of the class are discussed in the Section 4.2.2.2.3.

The area statistics of the Hydrogeomorphology is presented in Table 5.5 and the map showing hydrogeomorphology and groundwater potential is shown in Plate 5.11.

Table 5.5: Area under different hydrogeomorphology and groundwater potentials categories.

Sr. No.	Hydrogeo-morphology	Groundwater potential	Area (ha)	Percentage (%)
1.	Dissected Plateau - A	Poor	746.76	24.01
2.	Dissected Plateau - B	Moderate	1113.28	35.80
3.	Dissected Plateau - C	Good	1078.95	34.69
4.	Denudational Slope	Moderate	170.38	5.50

The hydrogeomorphological map gives the quantitative information for the under-groundwater potential zoning. This data when compiled with lith-log data and well water level fluctuation data will give the appropriate quantity of the under groundwater in the area. It is seen from the Table 5.5 that in the study area there is 35 per cent good groundwater potential and nearly the same per cent of moderate groundwater potential. The hydrogeomorphological map gives the spatial distribution of the groundwater potential zones in the study area. This data plays an important role in Land Resource Development Plan generation.

5.2.5 Slope map

The 20 m interval elevation contours and spot heights have been digitized from SOI topographical map on 1:50000 scale and was used for preparation of slope map as discussed in the Section 4.2.2.2.4. The slope information is very important for planning of the land and water resources

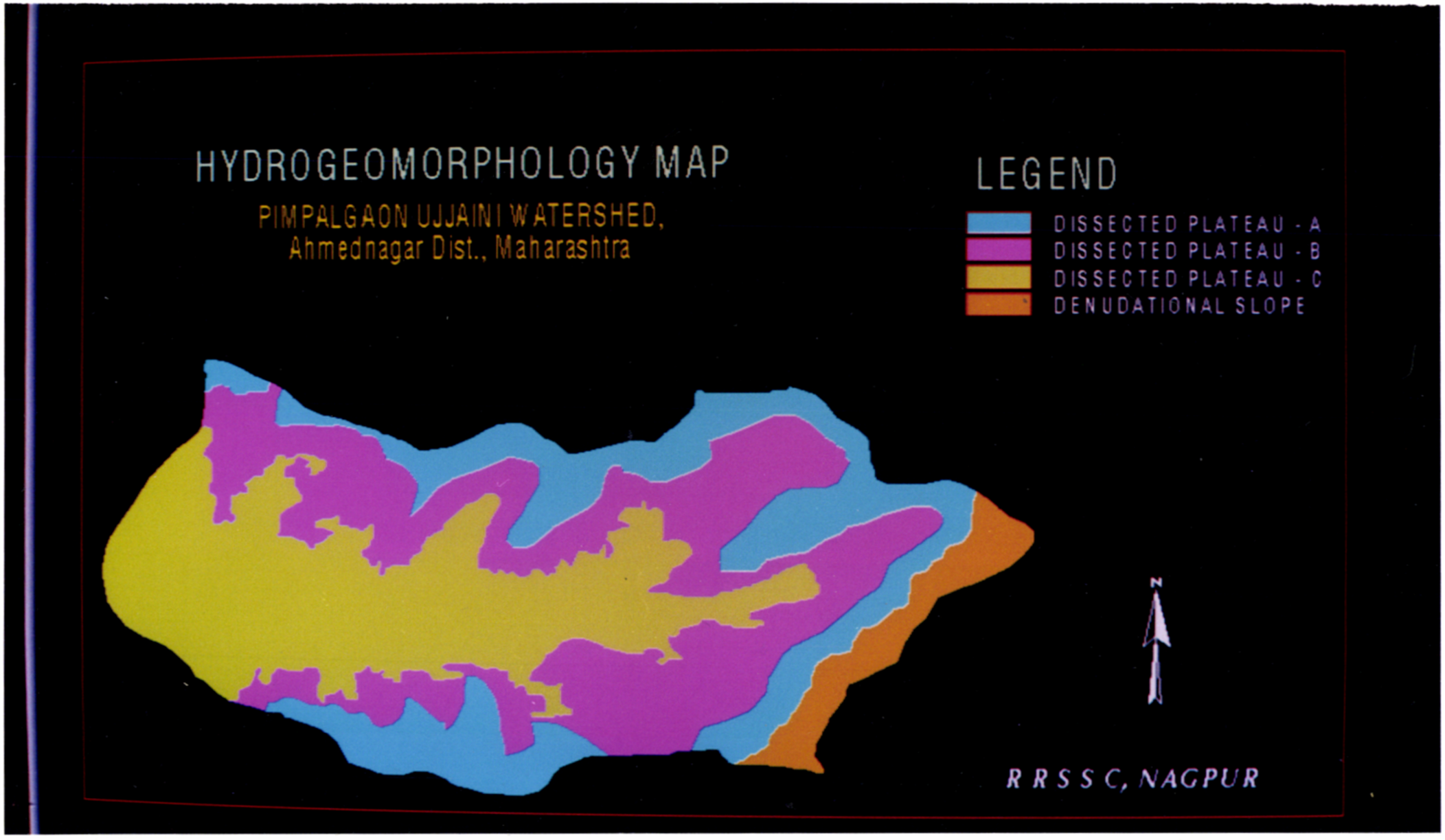


Plate 5.11 Hydrogeomorphology map

development. It gives the idea of the topography of the area. The slope map gives a clear idea about the land to be cultivated. It also gives the information regarding the land development and management practices.

The slope categories found in the study area and the area under each category is presented in Table 5.6. The DEM of the watershed is shown in Plate 5.12. The slope map is shown in the Plate 5.13.

Table 5.6: Slope Categories and the area under each category

Sr. No.	Slope Category	Area (ha.)	Percentage (%)
1.	Nearly level (less than 1 %)	562.8319	18.12
2	Very gently sloping (1 - 3 %)	580.1565	27.38
3	Gently sloping (3 - 5 %)	337.5143	10.87
4	Moderately sloping (5 - 10 %)	449.2393	14.46
5	Strongly sloping (10 - 15 %)	239.1411	7.70
6	Moderately steep to steep sloping (15 - 35 %)	574.1527	18.49
7	Very steep sloping (more than 35 %)	91.5912	2.95

Table 5.6 shows that about 55 per cent of land is having slope less than 5 per cent which should undergo cultivation. Whereas for the topography of about 21 per cent, conservation practices are necessary for cultivation purpose and on the remaining piece of land different plantations should be taken. These inferences are then matched with the groundwater potential and soil potential so as to generate both Land and Water Resource Development Plan.

5.3 Action Plans

The information generated from base map and thematic/derived maps, and the integrated map was used to generate the Water resource and Land resource development plan. These are discussed in this section.

5.3.1 Water resource development plan

The Water Resource Development Plan was prepared as discussed in Section 4.2.2.3.2. The water resource plan has been made by giving due consideration to drainage network, hydrogeomorphology and groundwater

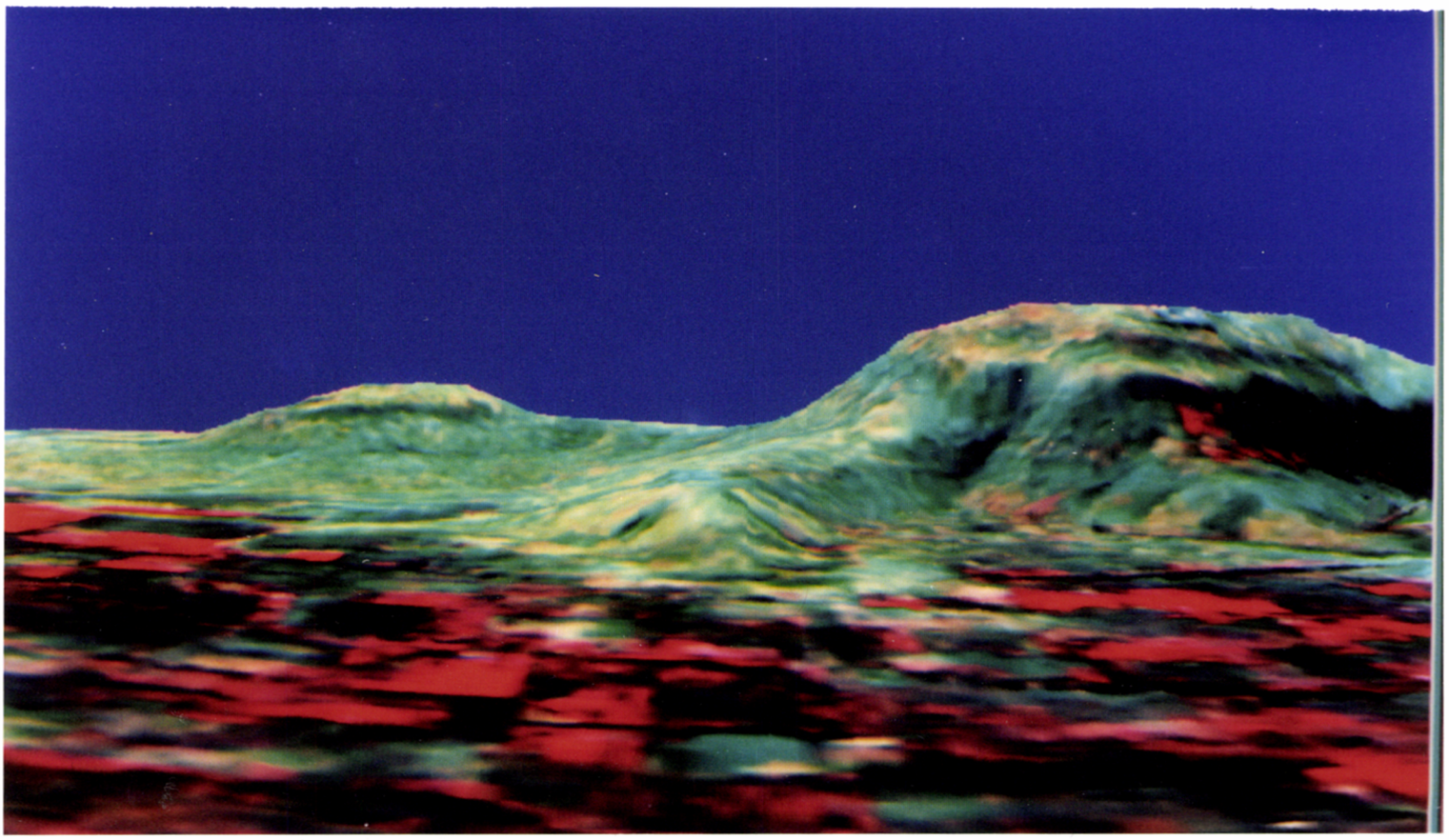


Plate 5.12 Digital elevation model

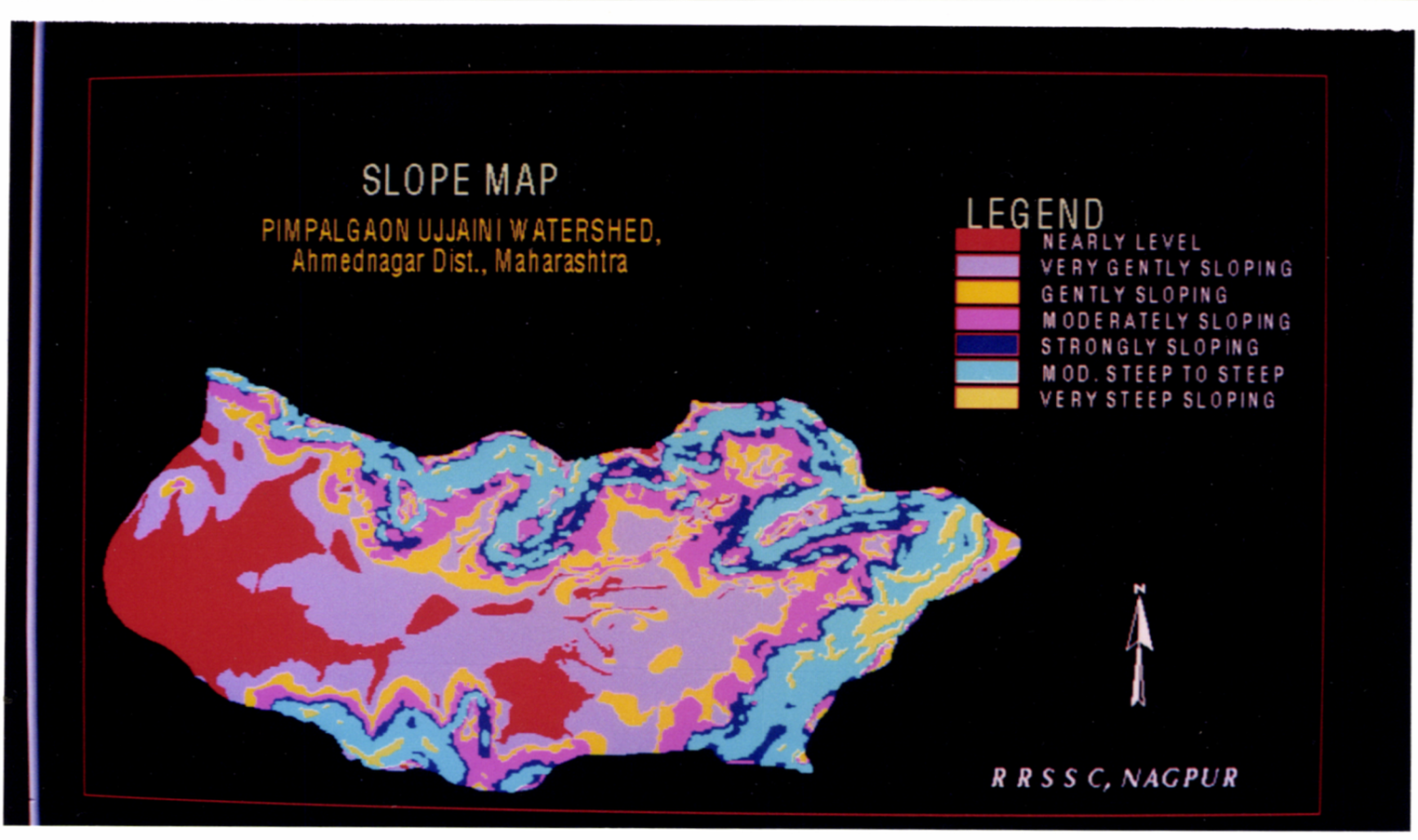


Plate 5.13 Slope map

potential. It consists of water harvesting structures and water storage structures. These structures are discussed below

5.3.1.1 Water harvesting structures

1. **Nala Bunds:** Nala bunds are bunds constructed across the nala to hold maximum runoff water, so that upstream area gets flooded temporarily for some week, with suitable arrangements to drain the water. Because of temporary storage of runoff water, silt is deposited against the bunds and water is drained off in controlled manner. The impounding water causes the percolation of water with the deeper layers of soil profile, which otherwise will flow with intense velocity causing erosion and thus siltation of down stream lakes and reservoirs. In the upstream side of bunds because of progressive silt deposition, general level will be raised. Constructions of such bunds helps in reclaiming the gullied lands and recharge the ground water, which in turn increases the availability of ground water. This will increase water levels in the wells down stream. Nala bunding is recommended in the region with annual rainfall less than 750 mm. The per cent slope of nala bund should not be more than 3 %. The nala bunds are suggested at suitable locations and are shown in the Plate 5.14.

2. **K. T. Weir:** The 'Kolhapur Type Weir' is one of the economical ways to harvest the water when compared to masonry bandharas. Instead of constructing bund all across the nala, single or multiple gates are provided which can be closed using wooden flanks. Usually first few showers of monsoon bring lot of silt along with runoff water. The runoff water from last 3-4 showers is trapped by closing the gates (wooden flanks). In the process the siltation gets reduced to certain extent and water storage can also be achieved. The K. T. Weir is proposed at the sites where there is village location so that the water stored in the Weir can be utilized by the peoples nearby. The suitable sites for K. T. Weir are shown in Plate 5.14.

3. **Underground Bandhara:** The measures for arresting sub-surface flow through suitable engineering structure such as underground bandhara is more useful. In the study area groundwater reservoir gets fully or partially recharged during monsoon period, but suffers rapid depletion due to sub-surface

leakage in the form of base flow, springs through the few reaches and extraction of water for irrigation.

Underground bandhara is an underground structure, put across a nala bed which acts like barrier to check underground water movement. The concept is on the fact that the nala course by virtue of the direction of groundwater from the surrounding areas confluences centrally towards the nala bed and provides a site for checking of the natural groundwater flow. The underground bandharas are suggested so as to develop a sort of reservoir, which will saturate the otherwise depleting aquifers and benefit the wells located in the command upstream and on its surrounding.

5.3.1.2 Water and soil conservation measures

Soil Conservation is the basic program required to be undertaken for both the development and management of resources. It provides permanent improvement in land resources, prevents further degradation of already degraded lands and helps in preserving moisture in the soil for longer period. To achieve sustained agricultural production, suitable land treatments, according to land problems/capabilities are proposed. The various conservation measures suggested for the watershed are levelling, terracing, farm bunding, strip cropping, plantation of tree and vegetal cover. By adoption of conservation methods erosion of soil, loss of nutrient, sedimentation in water storage tank and runoff will be reduced. Soil conservation preserves better moisture in the soil profile besides improving the groundwater recharge/hydrological regime.

Check dams: The main functions of check dams which is one of the water and soil conservation measures are to collect sufficient soil and water to enable the proper growth of vegetative cover, to check channel erosion and stabilize the vegetation.

5.3.1.3 Existing Structures

The existing constructed structures are located and the renovation of each structure is suggested so that these sites of water harvesting should also be helpful in future.

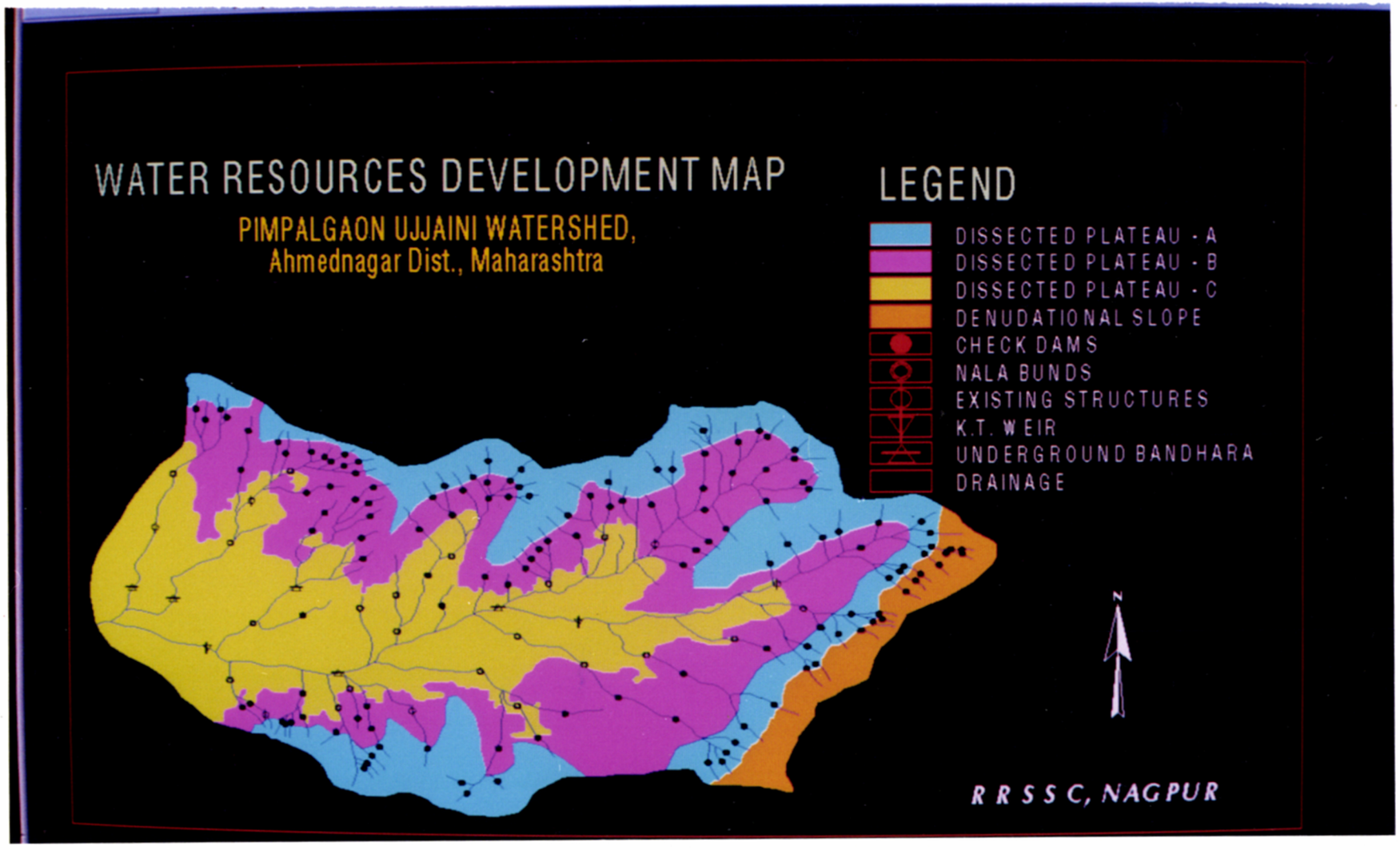


Plate 5.14 Water Resource Development map

The Water Resource Development Map is shown in Plate 5.14.

5.3.2 Land resource development plan

The Land Resource Development Plan was prepared as discussed in Section 4.2.2.3.2. The Land Resource Development Plan, is resultant of integration of soils, hydrogeomorphology, land capability classes, slopes with the present land use categories. Based on the capabilities of the composite units and other determinants like socio-economic conditions, the optimum Land Resource Development Plan has been suggested. The land use plan suggested has following categories as described below:

5.3.2.1 Intensive agriculture

The existing single crop areas under deep, fine texture soils with good ground water potentials and slope 1 to 3 per cent are suggested for intensive agriculture with conservation measures. Presently these lands are not used optimally fully due to lack of means for exploiting groundwater.

5.3.2.2 Double crop

The existing fallows under deep, fine texture soils with good groundwater potentials and slope upto 1 to 3 per cent are suggested for double crop. The existing single crop areas under deep, fine texture soils with moderate ground water potential are also suggested for double crop.

5.3.2.3 Agro-horticulture

This system of farming shows better prospects not only in terms of economy but also maintain soil fertility, prevents soil erosion and provides insurance against crop failure during drought year.

Most of the lands under current fallow and single crop area under moderate deep soil with moderately fine texture and moderate ground water potential is suggested for agro-horticulture practice. The non-availability of water for the irrigation in this area is the major constraint. Adequate water resource development and the improved irrigation mechanism like drip irrigation, sprinkler irrigation, surge irrigation is suggested. The judicial management of fruit trees and

the underneath crop results in optimal use of soil and water resources and sustainable productivity of land.

5.3.2.4 Agro-forestry

The land units under capability class IVes with shallow soils, coarse textures with moderate groundwater and surface water availability adjoining the forestland are suggested for agro-forestry along with soil conservation measures. The land units presently under plantation are suggested for agro-forestry.

5.3.2.5. Horticulture

Horticulture based farming system provides maximum economic yields besides protecting soil erosion. The existing single kharif areas under shallow soils with moderate groundwater potential with slope varying from 3 to 5 per cent are suggested for horticulture. Guava, Pomegranate and Orange crops are suggested in these areas.

5.3.2.6 Silvi-pasture

Demand for fuel wood and fodder in the area is increasing due to increase in human and livestock populations. In order to make the area sustainable there is need for silvi-pasture development.

The system has following advantages:

- Reduced soil erosion and increased moisture conservation.
- Inclusion of forage legumes and nitrogen fixing trees results in improved productivity of the soil.
- Availability of extra fuel wood, which will spare the nutrient rich animal manure for agricultural purpose instead for cooking purpose.
- The fodder requirement of the farmers is met throughout the year in general and during lean periods in particular.

5.3.2.7. Forest plantation

The land units presently under fallow, barren and forest plantation with land capability class VIIes are suggested for forest plantation as it will help in arresting runoff and preventing erosion. It will also help in solving the problem

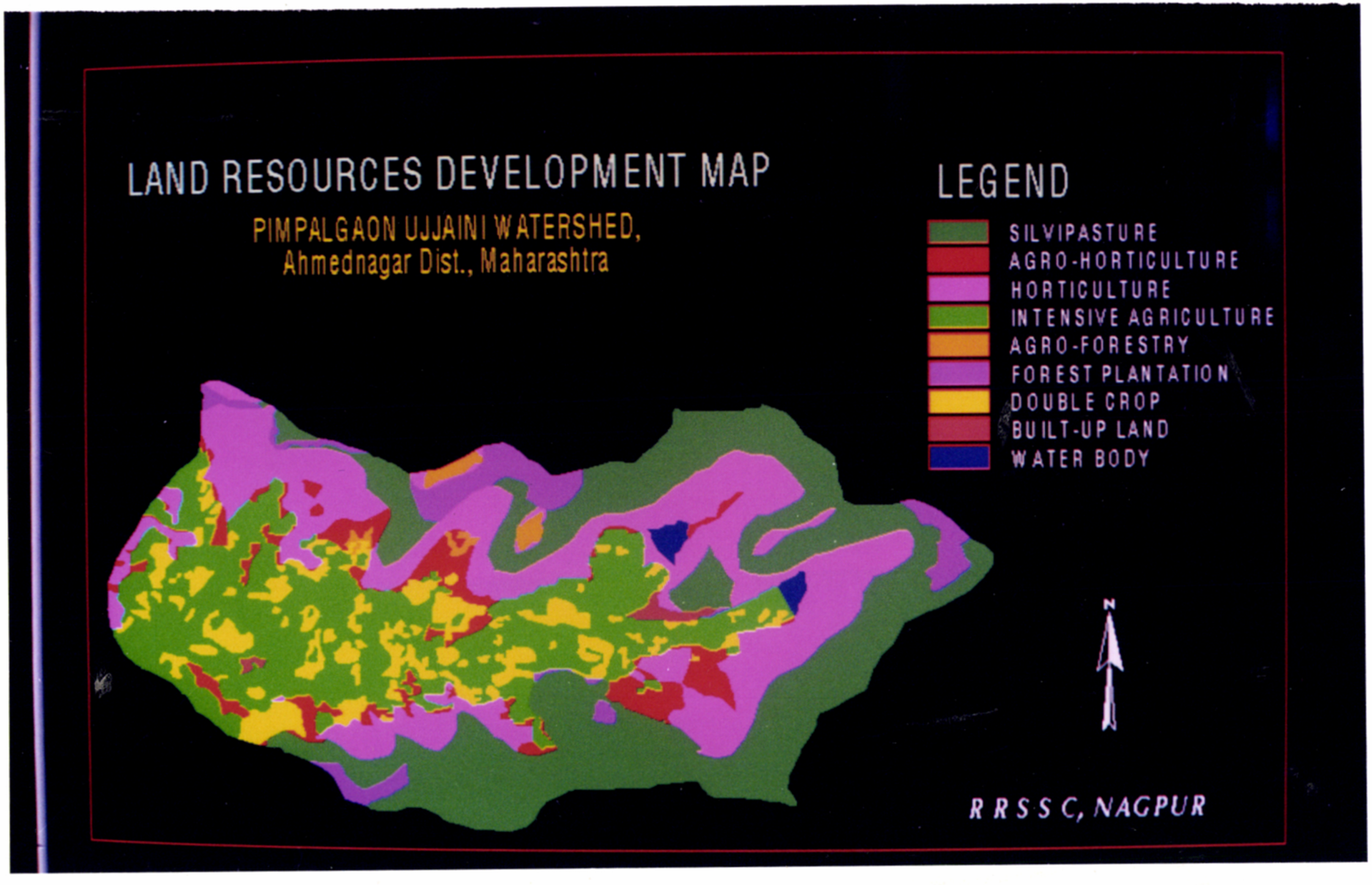


Plate 5.15 Land Resource Development map

of fuel wood to some extent in the very high periods of natural calamities. It will again conserve the ecosystem.

The Land Resource Development Map prepared according to the above considerations is shown in Plate 5.15.

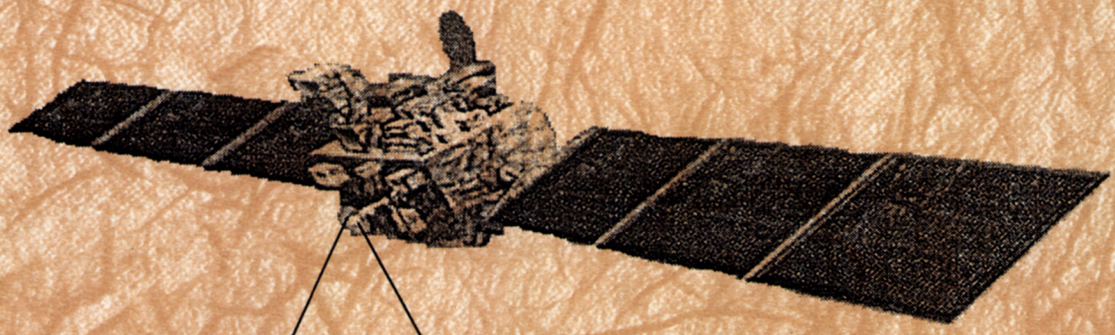
The area proposed under different land use is given in Table 5.7.

Table 5.7: Area statistics of Land Resource Development Plan

Sr. No.	Land use	Area (ha)	Percentage %
1	Silvi-pasture	988.26	31.78
2	Agro-horticulture	12.54	0.40
3	Horticulture	933.15	30.01
4	Double crop	617.62	19.86
5	Agro-forestry	27.00	0.86
6	Forest plantation	138.61	4.45
7	Intensive agriculture	355.90	11.44
8	Built-up	15.76	0.50
9	Water body	20.19	0.65

From Table 5.7, 988.26 ha (31.78%) of land is planned to be brought under Silvi-pasture thus helping in solving the problem of fodder for the cattles in the area. The 973.52 ha (31.34%) of land is brought under agriculture which was initially 766.47 ha (24.00%). About 933.15 ha (30.01%) of land is recommended for horticulture and 12.54 ha (0.41%) of land is recommended for agro-horticulture. 138.61 ha (4.45%) land is recommended for Forest plantations that will serve as fuel stock as well as medicinal and daily livelihoods of some peoples in the watershed.

The Land Resource Development Plan map is shown in Plate 5.15.



SUMMARY AND CONCLUSION

6.SUMMARY AND CONCLUSION

The effective management of natural resources such as land and water has importance in view of their limited availability against the demand. These resources are managed over the manageable unit, for sustainable development, called Watershed. In this study, the attempts were made to develop the action plans for water and land resources development using Remote Sensing and GIS techniques. The summary and conclusions derived from the study are presented in this chapter.

6.1 Summary

6.1.1 Importance of study

Soil, water and vegetation are interdependent such that one can not be managed effectively and efficiently without the other. Again, in order to sustain the high growth rate of our countries population there is need for sustainable development and optimal management of our natural resources. The preparation of appropriate action plans for the development of natural resources is necessary. The traditional methods of data collection required for preparation of action plans are time consuming and lot of errors are introduced in them by the time the information reaches in the expert hands. The Remote Sensing and GIS is the appropriate tool for collecting the data and generating action plans. Therefore, the study entitled "Integrated Land and Water Resource Development in Pimpalgaon Ujjaini Watershed Using Remote Sensing and GIS Techniques" with the objectives to generate thematic and derived maps pertaining to the watershed, to identify potentials and problems of land, water and socio-economic conditions, to generate various thematic information and socio-economic information for generation of action plans, to generate comprehensive plan for water resources development and to generate comprehensive plans for land resources development was undertaken.

6.1.2 Study area

The study area, Pimpalgaon Ujjaini watershed, falls in Ahmednagar Taluk at a distance of 15 kms from Ahmednagar city on the Ahmednagar - Aurangabad road in North-East direction. It is located at 45 kms from M.P.K.V., Rahuri, campus towards East direction.

6.1.3 Data acquisition

The facilities of Remote Sensing and GIS were made available from RRSSC, Nagpur. The satellite data was ordered through RRSSC, Nagpur from National Remote Sensing Agency, Hydrabad. The base maps such as watershed boundary, drainage, topography and soils were made available from various Government Departments. These, maps were then refined with the help of SOI toposheet 47 I/16. The satellite data of IRS-1C/1D satellite, LISS3 and PAN cameras of months October 97, January 98 and March 98, of path 96 and row 59 were used for generating various thematic/derived maps and action plans.

6.1.4 Methodology

The satellite data was rectified with the help of available base maps and SOI toposheet 47 I/16. The satellite data of all three seasons was then classified and the land use/land cover map was prepared by integration of all three classified images data. The satellite data along with base map and SOI toposheet 47 I/16 was used for refining the drainage, watershed boundary, road network and the village settlement maps of the study area. The satellite data of March 1998 and Merged data of January 1998 were used along with the soil map available from Soil Testing and Soil Survey Department, Ahmednagar, for refinement of soil maps of three categories *viz.,* Soil series, Land capability class and Hydrologic soil group. The slope map of the study area was prepared by digitizing the contour information of the SOI toposheet 47 I/16. The digital elevation model of the area was prepared by using Lattice Poly command from GIS. The digital elevetion model was also prepared from EASI/PACE Digital Image Processing software by GRDINT conic method of XPACE module. This digital elevation model was then further categorised into seven classes for which the slope map was prepared. The Hydrogeomorphology map was prepared with the help SOI toposheet and the

FCC's of January 1998 and March 1998 by identifying different physiographic units, digitizing them and coding them in GIS Arc/INFO.

The Land Resource Development Plan was prepared by integrating the present land use/land cover map with the soil series, land capability class, hydrologic soil group, hydrogeomorphology and slope map. The Water Resource Development Plan was prepared by integrating the information about drainage network in the area and hydrogeomorphology map of the area.

6.1.5 Results

The Pimpalgaon Ujjaini watershed is about 3109 ha The land use/land cover map prepared shows 59.77 ha (1.92 %) of kharif land, 360.84 ha (11.60 %) of rabi land and 345.86 ha (11.15 %) of double cropland. The land under scrub and fallow is about 1849.74 ha (59.48 %) and 263.55 ha (8.47 %) respectively. The study area has only 15.25 ha (0.50 percentage) of surface water body. The barren land is about 102.29 ha (3.28 %). Plantation land in watershed is 91.75 ha (2.95 %).

The watershed area consists of ten soil series; most of them are cultivable. The soil series Wadner and Kolgaon are uncultivable with the areas under them 459.32 ha (14.87 %) and 669.96 ha (21.54 %) respectively. Major cultivable soil series in the study are Supe, Shenwadgaon, Bhendwade and Malsiras with the areas of 689.44 ha (22.17 %), 346.50 ha (11.14 %), 442.26 ha (14.23 %) and 189.89 ha (6.10 %), respectively.

The land capability class map prepared shows land capability classes as IIe, IIIes, IVes, VIes and VIIes with areas under them 502.97 ha (16.17 %), 689.44 ha (22.17 %), 787.65 ha (25.35 %), 135.84 ha (4.36 %) and 993.48 ha (31.95 %) respectively. Land capability classes VIes and VIIes are uncultivable with the total area under them as 1129.32 ha (36.31 %).

The hydrologic soil group map prepared shows three categories of hydrologic soil group as HSG-B, HSG-C and HSG-D with areas 939.41ha (30.22 %), 344.90 ha (11.09 %) and 1825.06 ha (58.69 %), respectively.

The hydrogeomorphology map prepared shows Dissected-Plateau - A of area 746.76 ha (24.01 %) with poor ground water potential, Dissected-Plateau - B of area 1113.28 ha (35.80 %) with moderate ground water potential and Dissected-Plateau - C of area 1078.95 ha (34.69 %) with good ground water potential. In the study area Denudational Slope with moderate groundwater potential was found over the area of 170.38 ha (5.50 %).

It is seen from the slope map that the area under 3 % slope in the study area is about 1142.98 ha (45.5 %). The area between 3 to 15 % slope is about 786.74 ha (15.33 %). Remaining of the study area is having slope greater than 15 %.

Water Resources Development Plan (WRDP) shows the various sites for check dams, nala bunds, K.T.weirs and Underground bandhara. Some renovation structures are also suggested.

Land Resources Development Plan (LRDP) prepared suggests 988.26 ha area for Silvi-pasture, 12.54 ha area for Agro-horticulture, 933.15 ha area for Horticulture, 617.62 ha area for Double crop, 27.00 ha area for Agro-Forestry, 138.61 ha area for Forest Plantation and 355.90 ha area for Intensive Agriculture.

6.2 Conclusion

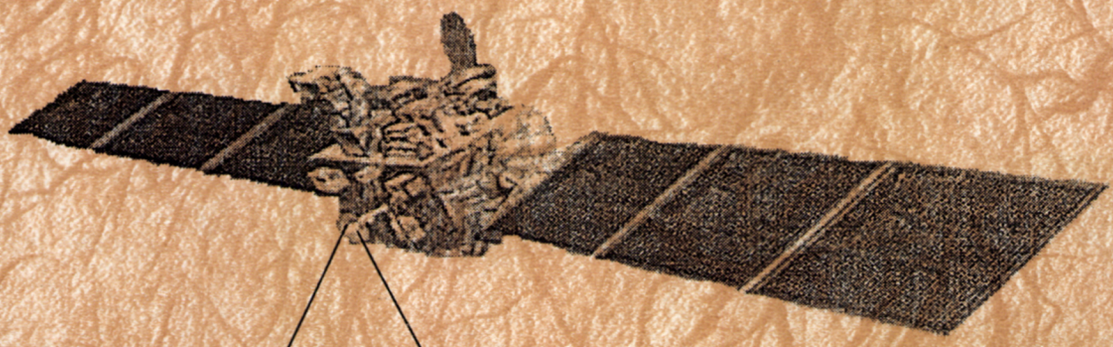
Satellite Remote Sensing technology gives systematic, synoptic, multi temporal, rapid, repetitive and cost effective coverage of the study area. GIS which has been designed to restore, manipulate, retrieve and display spatial and non-spatial data is an important tool in spatial analysis of parameters such as land use/land cover, soils, topography and hydrological conditions. The objectives of the study were to see the possibility of using Remote Sensing and GIS for preparing the Land and Water Resource Development Plan for the watershed. The Pimpalgaon Ujjaini watershed was chosen for the case study. Following conclusions were drawn from the study:

1) The Remote Sensing and GIS techniques can be effectively used for the development of Land and Water Resource

Development Plans which are necessary for efficient management of these resources in the watershed, through the preparation of thematic/derived maps such as Land use/land cover, Soil Series, Land Capability Class, Hydrologic Soil Group, Hydrogeomorphology, Slope, Drainage etc.

2) The suitable sites for check dams, nala bunds, K.T.weirs and Underground bandhara are suggested in Water Resource Development Plan to enhance the groundwater availability for the crop production.

3) The Land resource Development Plan indicated the possibility of increasing the area under double crop by 8 per cent in the present land use. It has additionally also suggested horticulture, agro-horticulture, agro-forestry and silvi-pasture over the areas of best capabilities for sustainable development.



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7. LITERATURE CITED

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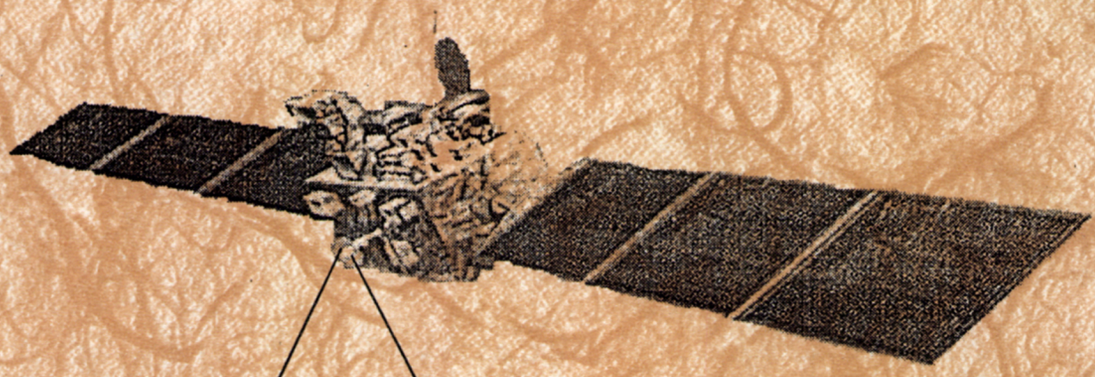
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APPENDICES

8. APPENDICES

APPENDIX A

Digital Image Processing - EASI/PACE commands

1. GRIDMAK1:

Gridmak1 is the EASI program to make grid file specifying the upper left and lower right latitudes and longitudes of the grid to be prepared. Grid is necessary for tiling of the Standard maps to use them for rectification of the raw satellite image to the corresponding mapping units of the Standard map.

Command:

Rahuri>EASI

EASI>s gridmak1

Parameter	Detail	Size	Type
FILE	File name	1-128	Char
BX1	Longitude of upper left	8	Int
BY1	Latitude of upper left	8	Int
BX2	Longitude of lower right	8	Int
BY2	Latitude of lower right	8	Int
PXYZ	12/18/24/---	4	Int
EFALSE	00 05 00	8	Int
NFALSE	00 05 00	8	Int
VALU	Grey level value	255	Int

EASI>gridmak1

EASI>r gridmak1

Example:

Rahuri>EASI
EASI>s gridmak1
FILE = "sgihome7/rahuri/galgale/pimpalgrd.pix
BX1 = "74^0 45'
BY1 = "19^0 15'
BX2 = "75^0 00'
BY2 = "19^0 00'
pxyz = "12
efalse = "00 05 00
nfalse = "00 05 00
valu = "5
EASI>gridmak1
EASI>r gridmak1

2. LOAD_IRSCD:

LOAD_IRSCD is a program to read the satellite data and write it in the specified filename. Satellite data is available in CCT or CD form. Nowadays the satellite data is mostly available in the CD's.

Commands:

rahuri>s load_irscd

Parameter	Detail	Size	Type
FILE	File name	1-128	Char
DBIC	Database input channel list	4	Int
DBOC	Database output channel list	4	Int
CDDIR	CD director	1-16	Char

rahuri>s load_irscd

rahuri>r load_irscd

Example:

rahuri>s load_irscd
FILE = sgihome7/rahuri/galgale/l3_9659_oct97.pix
DBIC = 1,2,3,4
DBOC = 1,2,3,4
CDDIR = "/mnt
rahuri>s load_irscd
rahuri>r load-irscd

3. PCIMOD:

PCIMOD is a program of XPACE to modify the PCIDSK file. These modifications include adding new channels, deleting image channels, and compressing PCIDSK files (removing deleted segments) to release disk space.

Commands: <XPACE>
<UTILITIES>
<LOCATE TASK>
PCIMOD
<STATUS>

Parameter	Detail	Size	Type
FILE	File name	1-64	Char
PCIOP	Modification option (ADD/DEL/COM)	3	Char
PCIVAL	DBNC for ADD or DBIC for DEL	4	Int

<STATUS>

<RUN>

Example:

<XPACE>
<UTILITIES>
<LOCATE TASK>
PCIMOD
<STATUS>
FILE = sgihome7/rahuri/galgale/l3_9659_oct97.pix
PCIOP = ADD
PCIVAL = 2
<STATUS>
<RUN>

4. GRDVEC:

The vector data can not be directly handled. The PACE program GRDVEC can be used to embed vector data into a image channel (layer) after which it can be used by MODEL.

GRDVEC encodes the vector segment data (DBVS) stored on the database file (FILE) on to an output image channel (DBOC), where attribute values for each vector segment are specified by the user (VALU) or by actual attribute values stored for each line and point structure in each vector segment. The user must specify either 4-connectedness or 8-connectedness (CONNECT) for line segments encoded on the image. The user has option of encoding only line structure, only point structure, or both types of structure (VTYPE).

Commands: <XPACE>
<UTILITIES>
<LOCATE TASK>
GRDVEC
<STATUS>

Parameter	Detail	Size	Type
FILV	Database Vector File Name	1-64	Char
FILE	Database File name	1-64	Char
DBVS	Database Vector Segment	1-16	Int
DBOC	Database Output Channel List	1	Int
VALU	Grey Level Value List	0-64	Real
CONNECT	Connectedness of Lines (4 or 8)	0-1	Int
VTYPE	Vector Type: (LINE/POINT/BOTH)	1-5	Char
FLDNME	Field Name to use for Elevation (ATTRIBUTE/ZCOORD)	0-64	Char

<STATUS>
<RUN>

Example:

<XPACE>
<UTILITIES>
<LOCATE TASK>
GRDVEC
<STATUS>
FILV = sgihome7/rahuri/galgale/l3_9659_oct97.pix
FILE = sgihome7/rahuri/galgale/l3_9659_oct97.pix
DBVS = 1
DBOC = 5
VALU =
CONNECT =
VTYPE = BOTH
FLDNME = ZCOORD
<STATUS>
<RUN>

5. THR:

THR creates data base threshold bitmap segments from a set of database image channels (DBIC). For each input pixel value between the minimum and maximum threshold grey level values inclusive (TVAL), corresponding bits are turned ON in the output bitmaps. For each pixel value outside this range, the corresponding bits are turned OFF. If the maximum threshold value is not specified, every pixel above minimum threshold value will be turned ON.

Commands: <XPACE>
<UTILITIES>
<LOCATE TASK>
THR
<STATUS>

Parameter	Detail	Size	Type
FILE	Database File name	1-64	Char
DBIC	Database Input Channel List	1-1024	Int
DBOB	Database Output Bitmap	0-1024	Int
TVAL	Threshold Value (min, max)	1-2	Real
COMP	Complement : ON/OFF	2-3	Char
DBSN	Database Segment Name	1-8	Char
DBSD	Database Segment Descriptor	0-64	Char

<STATUS>

<RUN>

Example:

```
<XPACE>
<UTILITIES>
<LOCATE TASK>
THR
<STATUS>
FILE = sgihome7/rahuri/galgale/l3_9659_oct97.pix
DBIC = 5
DBOB =
TVAL = 10,10
COMP = ON
DBSN = wsmask
DBSD =
<STATUS>
<RUN>
```

6. IIB:

IIB is a program of XPACE that performs transfer of specified bitmaps from the input database file to the new or existing bitmap on the output database file.

Commands:

```
<XPACE>
<UTILITIES>
<LOCATE TASK>
IIB
<STATUS>
```

Parameter	Detail	Size	Type
FILI	Database input file name	1-64	Char
FILO	Database output file name	1-64	Char
DBIB	Database input Bitmap List	1-1024	Int
DBOB	Database output Bitmap list	0-1024	Int

```
<STATUS>
<RUN>
```

Example:

```
<XPACE>
<UTILITIES>
<LOCATE TASK>
IIB
<STATUS>
FILI = sgihome7/rahuri/galgale/rl3_9659_jan98.pix
FILO = sgihome7/rahuri/galgale/rjan98_9659_pan.pix
DBIB = 1
DBOB =
<STATUS>
<RUN>
```

7. IIIBIT:

IIIBIT is a program of XPACE that performs transfer of image data between channels using a bitmap segment as a mask. This is useful in mosaicing images or extracting regions of interest.

Image pixels in the input channels (DBIC) which are under bits set ON in the bitmap segment (DBIB) are transferred to the output channels (DBOC). The bitmap segment, input and output channels must all be in the same PCIDSK database (FILE).

Commands: <XPACE>
<UTILITIES>
<LOCATE TASK>
IIIBIT
<STATUS>

Parameter	Detail	Size	Type
FILE	Database input file name	1-64	Char
DBIC	Database input channels list	1-1024	Int
DBOC	Database output channel list	1-1024	Int
DBIB	Database Input Bitmap	1	Int

<STATUS>

<RUN>

Example:

<XPACE>
<UTILITIES>
<LOCATE TASK>
IIIBIT
<STATUS>
FILE = sgihome7/rahuri/galgale/rl3_9659_jan98.pix
DBIC = 1,2,3
DBOC = 6,7,8
DBIB = 1
<STATUS>
<RUN>

8. FUSE:

FUSE is a program of XPACE that performs data fusion of a red-green-blue colour image with the resolution as the original B/W intensity image, but where the colour (hue and saturation) is derived from the resampled input RGB image.

Commands: <XPACE>
<UTILITIES>
<LOCATE TASK>
FUSE
<STATUS>

Parameter	Detail	Size	Type
FILI	Database input file name	1-64	Char
DBRGB	Database input RGB channels	3	Int
FILO	Database output file name	1-64	Char
DBINT	Database input intensity channel	1	Int
DBOC	Database output channel list	3	Int
RESAMPLE	Resample mode (Near/Bilin/Cubic)	4	Char
IHSMODEL	Intensity-Hue-Saturation model (Cylinder/Hexcone)	8	Char

<STATUS>

<RUN>

Example:

<XPACE>
<UTILITIES>
<LOCATE TASK>
FUSE
<STATUS>
FILI = sgihome7/rahuri/galgale/rl3_9659_jan98.pix
DBRGB = 1,2,3
FILO = sgihome7/rahuri/galgale/rjan98_9659_pan.pix
DBINT = 1
DBOC = 2,3,4
RESAMPLE = Cubic
IHSMODEL = Cylinder
<STATUS>
<RUN>

9. GRDINT:

GRDINT is a program of XPACE is used in gridding vector data. Gridding is the process of creating a raster image grid, given vector (line and point) data. GRDINT can interpolate or fill in elevation data between contour lines, which have been encoded into an image channel by GRDVEC.

GRDINT interpolates pixel values stored on an image channel (DBIC) on a database file (FILE), and saves results on an output image channel

(DBOC). An interpolated value is calculated for each input pixel value which is not set to the background value (BACKVAL).

Commands: <XPACE>
<UTILITIES>
<LOCATE TASK>
GRDINT
<STATUS>

Parameter	Detail	Size	Type
FILE	Database input file name	1-64	Char
DBIC	Database input channel list	1	Int
DBOC	Database output channel list	1	Int
BACKVAL	Background Grey-level value	1	Real
INTMETH	Interpolation method (CONIC/DAIG/SMOOTH)	1-5	Char

<STATUS>

<RUN>

Example:

<XPACE>
<UTILITIES>
<LOCATE TASK>
GRDINT
<STATUS>
FILE = sgihome7/rahuri/galgale/rl3_9659_jan98.pix
DBIB = 9
DBOC = 10
BACKVAL = 0
INTMETH = CONIC
<STATUS>
<RUN>

10. V6V5WRIT:

V6V5WRIT is a program of XPACE that converts one or more vector segments from EASI/PACE 6.X format to version 5.X format. That is necessary in order to use with some older PACE programs that are being phased out.

The DBVS parameter is used to indicate the V6.0 segment(s) to be converted to V5.3 format. The NEWSEG parameter indicates whether the resulting information should be written to a newly created segment (YES) or written over the existing segment (NO).

The FLDNME parameter is used to select one attribute column from the V6.0 file to assign to the single int attribute of the V5.3 segment. This should be an int or floating point attribute but not a string attribute.

Commands: <XPACE>

<UTILITIES>

<LOCATE TASK>

V6V5WRIT

<STATUS>

Parameter	Detail	Size	Type
FILE	Database file name	1-64	Char
DBVS	Database vector segment	1-1024	Int
FLDNME	Field to use as an attribute	0-64	Char
NEWSEG	Create new segment: YES/NO	0-3	Char

<STATUS>

<RUN>

Example:

<XPACE>
<UTILITIES>
<LOCATE TASK>
V6V5WRIT
<STATUS>
FILE = sgihome7/rahuri/galgale/rl3_9659_jan98.pix
DBVS = 1
FLDNME = ZCCORD
NEWSEG =
<STATUS>
<RUN>

11. VECWRITE:

VECWRITE is a program of XPACE that writes vector information held in a PCIDSK vector segment to a text file. Output formats for the text file may be TYDAC, SPANS, VEH/VEC format, ARC/INFO GENERATE format, intergraph SIF format, or AutoCAD DXF format.

VECWRIT is used to write vector (line) informaton held in a vector segment (type VEC: 116) to a text file. The use of an intemediate file to hold vector information allows vector data to be exchanged between EASI/PACE and other systems.

When running VECWRIT, the vector information held in a vector segment (DBVS) on the PCIDSK database (FILE) is written to the text file (FILV) in the specified output format (VECFORM).

Commands: <XPACE>

<UTILITIES>

<LOCATE TASK>

VECWRITE

<STATUS>

Parameter	Detail	Size	Type
FILE	Database file name	1-64	Char
DBVS	Database vector segment	1	Int
FILV	Database vector file name	1-64	Char
VECFORM	Format: SPANS/ARC/ISIF/ACAD	1-8	Char
ARCID	ARC/INFO ID: INCR/ATTR	0-4	Char
ACADATTR	AutoCAD Attributes: NUM/CHAR	0-4	Char
REPORT	Report Mode: TERM/OFF/filename	0-64	Char

<STATUS>

<RUN>

Example:

<XPACE>
<UTILITIES>
<LOCATE TASK>
VECWRITE
<STATUS>
FILE = sgihome7/rahuri/galgale/rl3_9659_jan98.pix
DBVS = 10
FILV = wsbound
VECEOFM = ARC
ARCID =
ACADATTR =
REPORT = sgihome7/rahuri/galgale/wsboundary.lin
<STATUS>
<RUN>

APPENDIX - B

Geographic Information System Arc/INFO commands

1. Starting the ARC/INFO:

For logging in the ARC/INFO license one has to execute following commands.

Login: rahuri

rahuri > {source /home1/sgiarc.csh}

sgiarc % {arc}

Arc:

2. Creating the workspace:

Workspace is the space where you will be working for doing certain tasks. It is same as directory in DOS. For creating the workspace the ARC/INFO command is:

Arc: cw {workspace_name}

Example: Arc: cw sgihome7/rahuri/galgale

3. Creating the coverage:

Coverage is the single file in the present workspace where you will be actually generating the particular theme. It is similar to file in DOS. For creating the coverage following commands have to be executed:

Arc: GENERATE {cover_name}

GENERATE: input {coverfile_name.lin}

GENERATE: lines

GENERATE: quit

Example: Arc: GENERATE soil

GENERATE: input soil.lin

GENERATE: lines

GENERATE: quit

4. Editing the coverage:

After generating the coverage it is necessary to edit it and to remove the error of different forms present in the generated cover if any. The steps and commands to be followed to edit and remove the errors in the cover generated are given below:

Arc: build {cover_name} lines

Arc: arctools

<EDIT TOOLS>
<OK>
<FILE>
<OPEN>
<ARC>
<OK>
<DISPLAY>
<DRAW ENVIRONMENT>
<GENERAL>
<NODE><DANGLE><SYMBOL>
[choose different colours and shapes for presentation of node, dangle and pseudo node]
<OK>
<APPLY>
<DISMISS>
[remove the digitisation errors]
<SAVE>
<ARCCOMMAND>
<QUIT>
<QUIT>

5. Cleaning the coverage:

After removing the digitisation errors and other sorts of errors clean the cover for building the polygon topology. Polygon topology is required for building the polygons by intersection of two crossing lines if necessary.

Arc: CEAN{input_cover} {output_cover} {dangle length} {fuzzy tolerrance} {{POLY | LINE}}

Example: Arc: CLEAN soil soil1 0.000000001 0.000000001

6. Creating the labels:

After having the topology cleaned and built for the purpose of coding it is necessary to create labels for writing the codes. The command used for creating labels in the cover is:

Arc: CREATELABELS {input_cover}

Arc: build {input_cover}

Example: Arc: CREATELABELS soil1

Arc: build soil1

7. Adding the items:

Once we have created labels it is necessary to write the users code for any particular physiographic unit that has been delineated by the process of digitisation. For having an idea and working with the codes it is necessary to add an item to the attribute table which will be displayed.

Arc: ADDITEM {in_info_file} {out_info_file} {item name} {item width} {item type} {{POLY | LINE}}

Example: Arc: ADDITEM soil1.pat soil1.pat soilcode 2 2 I

8. Coding:

After adding user defined item it is necessary to add code to each of the delineated unit otherwise default zero code is stored. For coding the delineated units the steps are as follows:

Arc: arctools

<EDIT TOOLS>
<OK>
<FILE>
<OPEN>
<POLYGON>
<OK>
<DISPLAY>
<TEXTITEM.TEXT>
<USER DEFINED ITEM>
<OK>
<APPLY>
<DISMISS>
[select the delineated unit be coded with same codes]
<TABLE EDITOR>
<CALC>
<USER DEFINED CODE>
{CODE}
<CALC>
[repeat the process till each and every unit is not coded]
<SAVE>
<ARCCOMMAND>
<QUIT>
<QUIT>

9. Creating the frequency file:

Frequency file as the name suggests it shows you the frequency of each and every code of the item choosed. The command is:

Arc: FREQUENCY {in_info_file} {out_info_file} {{case items}}

ITEM NAME (TYPE END OR BLANK ENTER TO END)

1ST ITEM NAME:

SUMMARY ITEM NAME (TYPE END OR BLANK ENTER TO END)

1ST ITEM NAME:

Arc: info

ENTER USERS NAME> ARC

ENTER COMMAND> SEL {info_cover.frq}

ENTER COMMAND>LIST

ENTER COMMAND>Q,STOP

Example: Arc: FREQUENCY soil1.pat soil1.frq

ITEM NAME (TYPE END OR BLANK ENTER TO END)

1ST ITEM NAME: soilcode

SUMMARY ITEM NAME (TYPE END OR BLANK ENTER TO END)

1ST ITEM NAME: area

Arc: info

ENTER USERS NAME> ARC

ENTER COMMAND> SEL SOIL1.FRQ

ENTER COMMAND>LIST

ENTER COMMAND>Q,STOP

10. Clipping the boundaries:

The clipping of the one theme over the other so that the input cover will have the same area as that of the clip cover. It is necessary for further processing of the themes integratedly.

Arc: CLIP {in_cover} {clip_cover} {out_cover}

Examples: Arc: CLIP soil1 wsbound finsoil

11. Creating the LUT files:

LUT files are info files necessary to store the information of different codes and their symbols to be presented in the arcplot or to be displayed on the screen.

Arc: info

ENTER USERS NAME>ARC

ENTER COMMAND>DEF {LUTfilename}

TYPE END or BLANK ENTER TO END

ITEM NAME:

INPUT WIDTH:

OUTPUT WIDTH:

ITEM TYPE:

ENTER COMMAND> ADD

TYPE END or BLANK ENTER TO END

1ST ITEM:

2ND ITEM:

ENTER COMMAND> LIST

12. Generating the DEM:

For the generation of digital elevation model and slope map it is necessary to create the DEM. The commands used in generating the DEM are:

Arc: TOPOGRID {name_demgr} {{interval}}

TOPOGRID: CONTOUR {cover_name} {item name}

TOPOGRID: END

Arc: LATTICEPOLY {name_demgr} {out_name} SLOPE {LUTfilename}

Arc: ap

ArcPlot: mape {name_demgr}

ArcPlot: shadeset contrast

ArcPlot: polygonsh {cover_name} {item name}

ArcPlot:q

Example: Arc: TOPOGRID PIMP_DEMGR 10

TOPOGRID: CONTOUR CONT CONTOURVAL

TOPOGRID:END

Arc: LATTICEPOLY PIMP_DEMGR SLOPE1 SLOPE SLP_CAT.LUT

Arc: AP

ArcPlot: mape SLOPE1

ArcPlot: shadeset contrast

ArcPlot: polygonsh SLOPE1 slope-code

ArcPlot: q

13. Integrating the themes:

The different themes are to be integrated/united for drawing out conclusion, finding the potential and problem areas and for generation of action plans. This task in GIS ARC/INFO is done using command:

Arc: UNION {in_cover} {union_cover} {out_cover}

Example: Arc: UNION soil1 slope1 unsoislo

14. More ARC/INFO Commands:

The more ARC/INFO commands are:

For listing the coverages

Arc: lc

For listing grid coverages

Arc: lg

For dropping the item

Arc: DROPITEM {item name}

For eliminating smaller area polygons

Arc: ELIMINATE {in_cover} {out_cover} {{Nokeepage | Keepage}} {{POLY | LINE}} {{selection_file}} {{BORDER | AREA}}

For listing the attribute files

Arc: LIST {in_info_file}

For generation of Statistic file

Arc: STATISTICS {in_info_file} {out_info_file} {{case item}}

Statistics:

For selecting the info file

ENTER COMMAND> SEL {info_file}

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