STUDIES ON THE IMPACT OF WATERSHED DEVELOPMENT PROGRAMME USING REMOTE SENSING AND GIS TECHNIQUE

By

Suhas Kalchandra Upadhye
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

SOIL AND WATER CONSERVATION ENGINEERING

DEPARTMENT OF SOIL AND WATER CONSERVATION ENGINEERING,
Dr. ANNASAHEB SHINDE COLLEGE OF AGRICULTURAL ENGINEERING,
MAHATMA PHULE KRISHI VIDYAPEETH,
RAHURI, DIST. AHMEDNAGAR, M. S. (INDIA)

2000

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FACULTY OF AGRICULTURAL ENGINEERING,
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RAHURI-413 722

2000

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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 Degree or
Diploma.

(S. K. Upadhye)

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

Dated : 12 / 7 / 2000

****

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Mahatma Phule Krishi Vidyapeeth,
Rahuri-413 722 (Maharashtra)

CERTIFICATE

This is to certify that the thesis entitled, "STUDIES ON THE IMPACT OF WATERSHED DEVELOPMENT PROGRAMME USING REMOTE SENSING AND GIS TECHNIQUE" submitted to the Faculty of Agricultural Engineering, Mahatma Phule Krishi Vidyapeeth, Rahuri, Dist. Ahmednagar (M. S.) in partial fulfilment of the requirements for the award of the degree of MASTER OF TECHNOLOGY (AGRICULTURAL ENGINEERING) in SOIL AND WATER CONSERVATION ENGINEERING, embodies the results of a bonafide research work carried out by Shri. Suhas Kalchandra Upadhye at M. P. K. V., Rahuri and RRSSC, Nagpur under my guidance and supervision of myself and Er. D. S. Pandit at Nagpur.

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

The assistance and help received during the course of this project work and source of literature referred to have been duly acknowledged.

Place: M. P. K. V., Rahuri (A. A. Atre)

Dated: 12/7 / 2000

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Dean,
Faculty of Agricultural Engineering,
Mahatma Phule Krishi Vidyapeeth,
Rahuri-413 722 (Maharashtra)

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

(P. S. Pampattiwar)

Dated: 12/ 7/ 2000

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

Dated: 12 / 7 */2000*

(Suhas K. Upadhye)

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LIST OF SYMBOLS

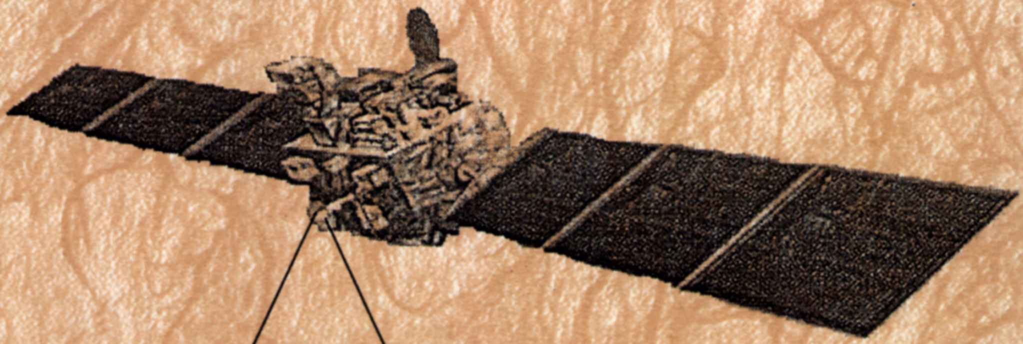
Symbols		Description
$	:	dollars
Q	:	Runoff depth
P	:	Storm Rainfall
Ia	:	Initial abstraction
S	:	Maximum potential retention

LIST OF ABBREVIATIONS

Abbreviations	Description
Ag.	: Agricultural
Agri.	: Agriculture
AMC	: Antecedent Moisture Condition
Bk	: Budaruk
°C	: degree centigrade
CCT	: Computer Compatible Tape
CD	: Computer Disk
cm	: centimeter
CN	: Curve Number
Conf.	: Conference
Cons.	: Conservation
CPU	: Central Processing Unit
CRT	: Cathode Ray Tube
DEM	: Digital Elevation Model
Dept	: Department
Dist.	: District
Div.	: Divisional
DOP	: Date of Pass
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
gm	: gram
ha	: hectare
IE	: Institution of Engineers
Ind.	: Indian
Intl.	: International

IR	: Infra Red
IRD	: Irrigation Research Development
IRS	: Indian Remote Sensing Satellite
ISRS	: Indian Society of Remote Sensing
J	: Journal
Kd.	: Khurda
kg/ha	: kilogram per hectare
km	: kilometer
LISS	: Linear Image Self Scann
m	: meter
Mgt.	: Management
Mha	: million hectare
MIR	: Middle Infra Red
Mm	: millimeter
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
Mt	: metric tonne
NIR	: Near Infra Red
NNMRS	: National Natural Resource Management System
NGO	: Non Government Organisation
No.	: Number
Nov.	: November
NDVI	: Normalised Difference Vegetation Index
NRSA	: National Remote Sensing Agency
NWDPRA	: National Watershed Development Programme for Rainfed Agriculture
Oct.	: October
PACE	: Picture Analysis and Colour Enhancement
PAN	: Panchromatic
PCT	: Pseudo Colour Table
P/R	: Path/Row number

Proc.	: Proceddings
Pub.	: Published
q/ha	: quintal per hectare
RAM	: Random Access Memory
r.m.	: Running meter
RMS	: Root Mean Square
RRSSC	: Regional Remote Sensing Service Center
Rs.	: Rupees
SCS	: Soil Conservation Service
SHGs	: Self Help Groups
Suptd.	: Superintendent
t/ha	: tonnes per hectare
TM	: Thematic Mapper
U.P.	: Uttar Pradesh
USA	: United States of America
USLE	: Universal Soil Loss Equation
UV	: Ultra violet
WGDP	: Western Ghat Development Programme
Viz.	: Namely
VR	: Visible Red



ABSTRACT

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STUDIES ON THE IMPACT OF WATERSHED DEVELOPMENT PROGRAMME USING REMOTE SENSING AND GIS TECHNIQUE

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Research Guide	:	Er. A. A. Atre
Department	:	Soil and Water Conservation Engineering

The watershed development includes the works pertaining to conservation, water harvesting, land use planning, horticulture development, afforestation, development of industries including agro based industries, community development, development of infrastructure facilities like roads, schools, hospitals, etc. This development should be on sustained basis with minimum hazard to natural resources like soil and water. This can be achieved by 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.

The evaluation and monitoring of watershed development programme is of prime importance to assess the conservation of natural resources and efficacy of its utilization. The conventional methods of watershed evaluation are cumbersome and time consuming. Moreover they do not give synoptic view of the study area. So Remote Sensing and GIS is the appropriate tool for evaluating and monitoring the changes in the watershed due to development programme. We get repetivity as well as we can compare both, pre and post development situation of watershed for change detection.

Considering these points study was undertaken to generate various thematic maps of watershed and to evaluate the watershed development programme based on change in land use pattern, vegetation index, runoff and socio-economic status of the watershed.

The study area was Sawarde Bk. watershed (14/08/01 KR 69/2) of Kagal Taluk, Dist. Kolhapur. It is about 45 km. from Kolhapur and is situated in South West direction of Kagal. The study area comprises of ten villages. The watershed was developed under the centrally sponsored scheme of National Watershed Development Programme for Rainfed Agriculture (NWDPRA) project carried out by Dept. of Agriculture, during 1991 to 1996.

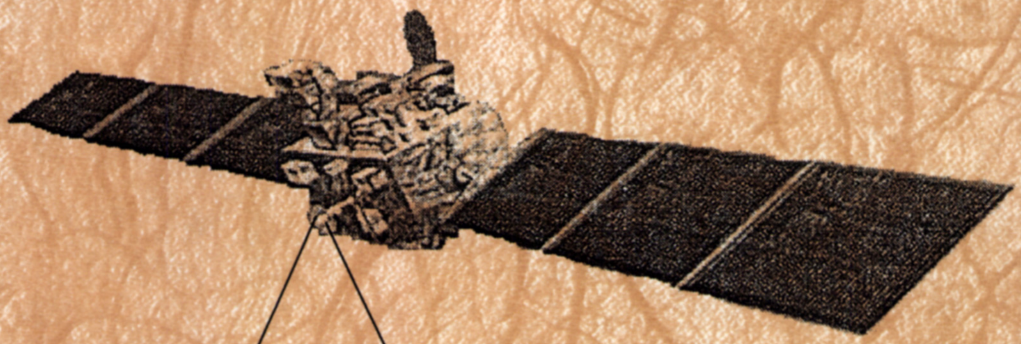
The data sets used for evaluation of the watershed development programme were obtained from IRS-1A and IRS-1C satellites for October, 1989 and November 1998 as pre and post development scenario, respectively. The facilities of Regional Remote Sensing Service Centre, Nagpur for Remote Sensing and GIS were used. The data were then rectified using the watershed base map. For better evaluation of the programme a buffer area of 2 km around the watershed was considered. The watershed boundaries, five sub-watershed units, roads, village boundaries and forest boundaries were digitized. The image under buffer boundary mask was then extracted and classified under eight different classes. For determining the vigour of the vegetation, the Normalised Difference Vegetation Index MODEL was applied. By identifying different sub-watershed units and with the help of soil map available from Soil Survey Division, Irrigation Research Department, Pune, the hydrologic soil group map was prepared. Since runoff from a watershed can be estimated with the help of SCS-CN model, this map was integrated with land use/land cover map of pre and post treatment to determine the weighted curve numbers. The socio-economic status of the farmers in the watershed was evaluated by conducting field visits and interviews with the farmers and field level and supervisory officials.

The area under water bodies increased from 31 (0.60%) to 34 ha (0.66%) in the watershed and from 97 (1.17%) to 98 ha (1.18%) in buffer, respectively. This indicates the marginal increase in water spread area and water availability. The cropped area in the watershed increased by 302 ha and by 896 ha in buffer over the pre treatment area of 1088 and 2178 ha, respectively. The area under dense forest and plantation also increased by 100 per cent and 2.16 per cent in the watershed over the pre treatment area of 5 and 370 ha The increase of 21 43 per cent and 39.69 per cent in area of dense forest and plantation was observed in the buffer, respectively The fallow land decreased to 885 ha (17 08%) and 1329 ha (16 06%) in the post treatment period in the watershed and buffer The pre treatment areas under fallow land in the watershed and buffer were 1176 ha (22 70%) and 1959 ha (23 68%) This indicates that fallow land might have been brought under cultivation. The wasteland decreased by 22 ha and 448 ha in the watershed and buffer, respectively

The NDVI categories, dense and open vegetation increased by 362 ha and 49 ha in the watershed This increase in the buffer was 949 ha and 490 ha, respectively However, the area under blank and degraded vegetation decreased by 178 and 236 ha, respectively in the watershed and by 952 and 488 ha in buffer, respectively

The weighted curve numbers for the sub watershed unit 1, 2 and 3 have decreased from 74 77, 75 95 and 74 97 to 73.21, 73 95 and 74 39, respectively So the maximum potential retention for the sub watershed units 1, 2 and 3 have increased from 85.70, 80 39 and 84 77 mm to 92.42, 89 44 and 87 41 mm, respectively This indicates the decreased runoff from these three sub watershed units Whereas the weighted curve number for sub watershed unit 4 and 5 have increased and so the maximum potential retention decreased This might be attributed to introduction of agricultural crops in both seasons having more runoff potential than natural vegetation Even then the overall weighted curve number for entire watershed decreased from 74 58 to 74 20 This definitely suggests reduced runoff from the watershed

The area under agriculture in the watershed has increased and the fallow land has decreased after the watershed development programme The area under blank vegetation and degraded vegetation has decreased and that under open vegetation and dense vegetation has increased The watershed development works have resulted in the decrease in the runoff from the watershed and slight increase in water harvesting On the socio economic front the literacy and the level of education of the people in the watershed has increased All these favour in uplifting the economic standard of the people in the watershed In all the effect of watershed development programme under NWDPRA at Sawarde Bk (14/08/01 KR 69/2)watershed is positive



INTRODUCTION

1. INTRODUCTION

For a country like India which supports 16 per cent of world population on 2.42 per cent of global land area (Manorama Yearbook 2000), the problem of food supply to all is serious. An estimated 175 Mha of land constituting about 66 per cent (Motsara, 1998) of total geographical area suffers from deleterious effect of soil erosion and land degradation. Active erosion caused by water and wind alone accounts for 150 Mha of land, which accounts to a soil loss of about 5300 million tonnes of top soil. In addition 25 Mha have been degraded due to ravines and gullies, shifting cultivation, salinity/alkalinity, water logging etc. The growing pressure on land for food, fuel, fibre fodder and industrial expansion and consequent need for infrastructural facilities due to ever increasing population has given rise to competing and conflicting demands on finite land and water resources. Soil and water conservation on a watershed basis can play a prominent role in the integrated and comprehensive land and water management strategy.

A watershed is an area from which runoff resulting from precipitation flows past a single point into a large stream, a river, a lake or an ocean. Catchment and watershed are same by definition, the term catchment is often used to refer that area which drains into a reservoir. The area downstream of the reservoir that is irrigated using water from the same either by gravitational flow or by lift irrigation or by any other method is termed as command area.

At present the population of India has turned over a billion, demanding over 250 Mt of foodgrain (Swaminathan, 1998). To achieve this, the annual growth rate of 6 per cent that has achieved during the period of green revolution is required to be doubled. Presently 67 per cent of the agricultural land is rainfed which produces only 4 per cent of total food grain production (Singh and Venkateswarlu, 1998). The limited per capita land, of about 0.15 ha in 2000 (Motsara, 1998) will further be reduced to 0.07 ha in 2020 (Virmani, 1998), is getting degraded because of non agricultural practices followed. Extreme pressure on land has resulted in large scale depletion of forest with the result that the closed forest have reduced from 14 per cent to 11 per cent of the India's total area in less than a decade.

Mismanagement of water resources in India, a country which receives a bountiful amount of annual rain of about 114.0 cm (Patel, 1998) 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 because of lack of any available recharging mechanism. Inspite of green revolution the crop yield in India is one of the lowest in the world. The National average is about 1.85 t/ha as against the world average of 3.2 t/ha for rice and 2.67 t/ha as against a world average of 3.7 t/ha for wheat. The average total food productivity in India is just about 1.6 t/ha as against the world's average of 2.5 t/ha and 4.3 t/ha achieved in Europe. Today per capita food consumption in India is just about 450 gm per day. The energy consumption is less than thirtieth of that in the USA and per capita annual income is just about 550 $ as against over 12000 $ in USA (Rai and Murali, 1998).

Watershed is the unit decentralisation chosen by Mother Nature. It is a natural geological 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 characteristic 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 unit. Thus a 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 conservation, water harvesting, land use planning, horticulture development, afforestation, development of industries including agro based industries, community development, development of infrastructure 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 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.

Evaluation and monitoring of watershed development programme is of prime importance to assess the conservation of natural resources and efficacy of its utilization. Similarly the upliftment of the inhabitants of the watershed from socio-economic point is also important.

Remote sensing is the science of deriving information about an object from measurements made at a distance from the object, and without the sensors actually coming in contact with it. The sensors may be cameras or other energy measuring instruments, 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. By dividing it into a number of bands and separately obtaining the responses therefrom, the uniqueness of signature is improved and so also considerably the degree of confidence of recognition. This concept of multi-spectral characteristic response forms the basis of many remote sensing systems. The sensors are mounted on aircrafts or satellites. Satellites enable large area coverage at frequent intervals in uniform solar illumination conditions and are highly suited for applications based on synoptic measurements.

Geographic Information System (GIS) designed to restore, manipulate, retrieve and display spatial and non spatial data has become an important tool in the spatial analysis of parameters such as land use / land cover, soil types, topography, climate and hydrological conditions. Thus its application is being extended to a variety of thrust areas such as forestry, environmental monitoring, assessment and management of water resources, change detection analysis and display of locational data. GIS has three essential characteristics: - spatially referenced data base, appropriate software components and associated software components.

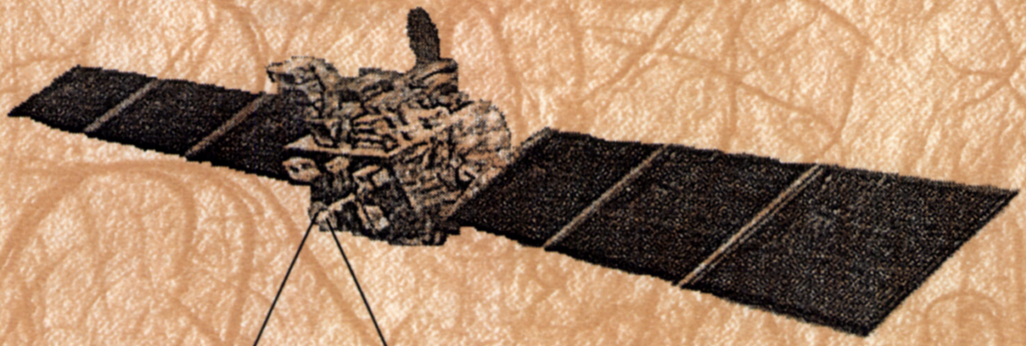
Remote sensing and GIS, two distinct technologies, are now being used in a complimentary manner. The data produced by remote sensing often requires to be integrated with the data sets acquired through field surveys and laboratory studies, which is done efficiently by GIS.

Conventional methods of data collection are uneconomical, biased, time consuming and provide the information with time lag. A small error in the data collection gets magnified in the conventional methods of evaluation. Remote sensing and GIS techniques have capability of providing information about the environment parameters. These parameters provide basic data bank for evaluation of vital resources of the watershed. The analysis of the data using Remote sensing and GIS techniques gives more accurate results, which provide decision makers with the kinds of information that can not be effectively provided by conventional methods.

To carry out resource monitoring and assessment of area of interest, information derived through remote sensing data has to be merged or integrated with databases in GIS. Thus the remote sensing together with GIS application aids to collect, analyse and interpret the data rapidly on large scale intermittently and is very much useful for planning and evaluation purpose. With this view the present project work with the following specific objectives was undertaken.

Objectives: -

1. To generate thematic and derived maps pertaining to watershed before and after development.
2. To evaluate the watershed development programme based on the following indicators:
    a. Change in land use pattern
    b. Vegetation index
    c. Runoff
    d. Change in socio-economic status.



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 which has contributed significantly to national development in various sectors. The main focus of the study was to evaluate the watershed development programme based on vegetation index, change in land use pattern, runoff and change in socio-economic status using remote sensing and GIS technique. The attempt has been made to review the research work done in respect of change detection monitoring and evaluation using remote sensing and GIS technique.

Mohanty (1994) carried out the analysis of urban land use change for North Bhubaneswar, Orissa using sequential aerial photographs and SPOT data. In order to know the trend of development and land use patterns, analysis of sequential aerial photographs and satellite imagery of different years can be a useful tool for interpretation of various land use and their comparison. In the present study an attempt has been made 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 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.

Sebastian *et al.* (1994) used the approach of Remote Sensing for land use change monitoring. Remote Sensing gives timely and reasonably accurate information in a less tedious way. It can be effectively used for monitoring the land use/land cover changes. In this study, index of crowding of pixels within a cluster and index of patchiness of the pattern of clusters, derived from Landsat TM and IRS-1A FCC, are used to monitor the changes that had taken place in two blocks of the Kangsabati command area in West Bengal, from 1985 to 1988. The two land use classes taken for analysis are agriculture and forests. The study shows an increase in the area of agriculture and forests.

Gautam (1996) 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 (1944) and satellite imagery for post dam (1967) periods was carried out. Large areas show decrease in vegetation density as a result of deforestation while the areas bordering the reservoir show increase in vegetation density. The area under cultivation has decreased on the western side due to development of a number of coal fields in post dam period. Improper management of coal ash disposal from a thermal power plant located around the reservoir is causing siltation of the reservoir.

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 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 per cent average slopes. Land deterioration over the two mapping periods was identified and strategies were suggested to mitigate the problem.

Jain *et al.* (1996) used GIS for estimation of Direct Runoff Potential. Due to the geographic nature of factors of SCS runoff model it can easily be modelled into Geographic Information System (GIS). In this study, Kolar sub basin of Narmada has been chosen for carrying out runoff potential estimation using Integrated Land and Water Information System (ILWIS).

Dwivedi *et al.* (1997) used the approach of Remote Sensing for inventorying and monitoring of eroded lands. In the study, Landsat MSS, TM and IRS-1A LISS-II data have been visually interpreted to derive information on both eroded lands and shifting cultivation areas. Three categories of eroded lands, namely nil to slight, moderate and severe to very severe were delineated. Optical-cum-digital enlargement of LISS-II data helped to pick up small pockets of eroded lands and shifting cultivation areas that were not discernible at a 1:250000 scale.

Temporal variation observed in the extent and distribution of eroded lands is also discussed in detail.

Dwivedi *et al.* (1997 a) studied the utility of multisensor data for mapping eroded lands. The availability of remote sensing data with improved spatial, spectral and radiometric resolution is now available to fully exploit their potential for specific application subject to the relative merits and limitations of each sensors data. In this case study, Landsat MSS and TM; and SPOT MLA data for part of the Bijapur district, Southern India, which were acquired on the same day, have been evaluated for mapping eroded lands. The approach involves the geometric registration of all three data to a common map grid using tie points and third order polynomial transform; and resampling the MSS and TM data to a 20 m by 20 m pixel dimension and radiometric normalisation. Thematic maps showing eroded lands were generated on a micro-vax-based DIPIX system using a maximum likelihood classifier. Accuracy estimates were made for the thematic maps following stratified unaligned random sampling technique, and subsequently, computing overall accuracy and Kappa coefficient. Spectral separability and classification accuracy was maximum from SPOT MLA data followed by a combination of Landsat MSS band 1, SPOT MLA band 2 and Landsat TM band 4; Landsat TM, a combination of Landsat MSS, TM and SPOT MLA; and Landsat MSS data.

Nagarajan and Purnendu (1997) carried out the assessment of Dudhganga river catchment before and after the construction of dam using remote sensing and ancillary data. Rapid assessment of spatial distribution of various hydrological and vegetation cover features at various stages of water resources project from the beginning is taken into consideration for environmental auditing. This study aims at collection of such information for a certainly completed Dudhganga reservoir / dam at Asangaon across Dudhganga river using high ground resolution temporal orbital satellite (SPOT 1 and IRS 1B / 1C) images corresponding to various stages of water storage and season (May 1988, March 1992, and October 1996). Dudhganga drainage basin characteristics such as compactness, circularity ratio etc. have been computed. Area of water spread and submergence of upstream (including villages) have been demarcated. Considering the high-energy streams of this catchment and water spread, a debris control measure is suggested.

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.

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 has revealed 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.

Biswas and Aggarwal (1998) used GIS to assess the pre and post treatment scenario of Baramasia micro watershed with respect to soil loss. The Soil Conservation Department of Damoder Valley Corporation planned Baramasia watershed in the district of Giridih, Bihar with an integrated watershed development approach. During the planning stage itself, proper estimation of technical aspects and active peoples participation was emphasised. Micro level analysis was made to pin point the appropriate measures along with fast availability of water resources through the construction of water harvesting structures. After almost all the schemes were implemented successfully, it was observed in the year 1997, that a drastic change has occurred with respect to land use pattern in the watershed and also in the per capita income. ILWIS version of GIS has been used to ascertain reduction in annual and per hectare soil loss through Universal Soil Loss Equation (USLE) method. IRS-1C PAN data along with many basic maps have been used for the analysis. The result obtained is fascinating that is 56 per cent annual soil loss reduction in the watershed, thus amply showing the effect of soil and water conservation programmes.

Brahmabhatt *et al.* (1998) used the approach of Remote Sensing and GIS to study the development of watersheds in part of Bhavnagar and Ahmedabad districts of Gujrat. The study discusses the planning, implementation and impact assessment components. Developmental plan details prepared using satellite data were transferred onto village maps for implementation purpose for selected villages falling in seven taluka of Bhavnagar and two taluka of Ahmedabad district. Implementation of some of these plans in selected micro watersheds by NGOs has been possible through funding by state agency. The implementation during 1994-98 in about 40 villages of Viramgam and Dhandhuka taluka of Ahmedabad district comprises construction of 17 sub surface dykes, 1 new tank, 31 nala bunds, 2 farm ponds, 3 diversion of nala, 5 recharge wells, deepening of 10 existing tanks for rain water harvesting and ground water recharge. Land development activities comprise farmyard building in 3325 ha, farmyard tree plantation in 206 ha, agro horticulture in 267 ha, agro forestry in 7.5 ha and afforestation in 22 ha of wasteland. Initial results of ground based monitoring in Ahmedabad district indicate improvement of water quality and check in declining rates of ground water levels in wells.

Dogra *et al.* (1998) carried out the study for preparation of base map for catchment area treatment. Mountainous and hilly watersheds are often prone to soil erosion on account of their geomorphologic aspect. The most appropriate management measure in this context is catchment area treatment. The assessment of potential for catchment area treatment is part of watershed management planning and also a component of impact assessment of water resource projects. The need and choice of type of treatment is in general evaluated through the terms of USLE in its basic or modified form. All the terms of USLE are geophysical and geographically linked. The geographically linked data obtained and analysed through remote sensing techniques can be effectively combined with attribute data by using GIS software. A sub Himalayan catchment is analysed using modern techniques of GIS and remote sensing in an integrated manner. Demographic analysis of the area points to population increase at the rate of 25 per cent per decade indicating that the pressure on land may increase by way of more settlements, increased farming activities and higher level of deforestation. Soil erosion is also expected due to proneness of some part of area to landslides and due to erosion along roadsides. Further more, the major river draining area, the Sutlej, has been identified as one of the major source of hydroelectric power. Several sites have been identified on the Sutlej and its tributaries. From the point of controlled sedimentation in the reservoir, catchment area treatment takes priority. A base map is generated by first building a topology in GIS software using a contour map of the study area. The slope map and three-dimensional views are generated and analysed along with land use pattern of study area obtained using remote sensing techniques. A watershed of 25 sq. km. has been analysed and categorised based on susceptibility to soil erosion.

Durga Rao and Pradhan (1998) used Remote Sensing and GIS in the hydrological modeling of ungauged watershed. The present investigation is in Bandal watershed, a tributary of Song River in Doon valley. It emphasized on computing daily runoff using Thornthwaite and Matther model and Soil Conservation Service model and to compare the results obtained in each method. The methodology indicates preparation of land use map by applying digital image processing techniques using Remote Sensing satellite IRS-1C, LISS-III digital data coupled with ground truth data. Various resource maps such as digital elevation model, aspect, classified height map, soil map have been created in GIS environment. Integrating these maps with meteorological data and ground truth data, various resources maps such as actual evapotranspiration, potential evapotranspiration, surface runoff, and curve number map have been created. Computed daily runoff using Thornthwaite and Matther model and Soil Conservation Service model has been compared with each other. A unit hydrograph has been generated using SCS dimensionless hydrograph and the outputs from the Remote Sensing and GIS. It has been observed that the lag time of peak flood is very short; it may be due to steep slope and shape of the watershed. Any change in the land use or meteorological data can be incorporated in the spatial and non-spatial database to monitor the change in the scenario.

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 part of upper Machkund Watershed, 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.

Gonsalves and Vatkar (1999) carried out a case study of integrated watershed development programme in Aagadgaon watershed. The attempt has been made to evaluate the impact of integrated watershed development programme (1994-98) in Aagadgaon watershed. The impact of various soil and water conservation measures, viz. contour bunding, farm bunding, gully plugs, nala bunds, gabion structures, check dams resulted in overall increase of 40 to 60 per cent in the yield levels of crops like pearl millet, sorghum, wheat, green gram, tur in the watershed. The number of wells in the project area increased from 83 to 88 and showed ground water recharge during the operational period. The area under cultivation in Kharif, Rabi and Summer increased. The cropping intensity increased from 57 to 65 per cent. At first time two SHGs activities with involvement of 46 women are started. A significant increase of live stock population was also noticed.

Jaiswal *et al.* (1999) used the remote sensing technology for land use / land cover change analysis. Land use / land cover changes over a period of 30 years were studied using remote sensing technology in a part of Ghoparu block, Shahdol district of M. P. Land use/land cover maps were prepared by visual interpretation of two periods remotely sensed data. Post classification comparison technique was adopted for this purpose. The loss of vegetation cover was estimated to be 22 per cent and 14 per cent of land was found to have been transformed into wasteland between 1967 and 1996. Overall rate of change was found to be 1.8 per cent per year during this period.

Minakshi *et al.* (1999) carried out a case study of Dehlon block, District Ludhiana, Punjab regarding land use/land cover mapping and change detection using satellite data. The land use information collected for Dehlon block from the analysis of the IRS 1B LISS-II data for the year 1993 and IRS PAN data for the year 1997 and Survey of India topographical maps for 1964 revealed a large change in the area of different land use categories during the period from 1964 to 1997. The agricultural land covering an area of about 94.14 per cent in 1964 reduced to 90.26 per cent in 1997 while the area under rural settlements increased from 312 ha in 1964 to 1102 ha in 1997. An extra area of about 169 ha under wasteland was added during the period under study making total wasteland area to about 400 ha in 1997. However, the block lacks the forest cover of the required limit. The considerable change in living environment was observed in the block. The number of persons per unit settlement area (ha) being 213.3 in 1964 reduced to 97.1 in 1991; it indicate that the living standard of the people has improved with the changed cropping pattern and increased agricultural production during the period from 1964 to 1991.

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, hydrogeomorphology, 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 The different thematic maps generated using Remote Sensing and other collateral data were 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 were drawn using GIS technique In the water resources development plan the construction of tube wells, dug cum bore wells are suggested based on the geohydrological characteristics and agriculture needs Underground 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.

Mishra (2000) studied the human factor in watershed management Watershed development projects have been taken up under different programmes launched by the Govt of India The Drought Prone Area Programme (DPAP) and the Desert Development Programme (DDP) adopted the watershed approach in 1987. The Integrated Watershed Development Projects (IWDP) scheme taken up by the National Watershed Development Board in 1989 also aimed at developing wastelands on watershed basis This programme has now been brought under the administrative jurisdiction of the Department of Wastelands Development in the Ministry of Rural Development The fourth major programme based on the watershed concept is the National Watershed Development Programme for Rainfed Agriculture (NWDPRA) under the ministry of Agriculture

While the focus of these programmes may have differed, the common theme amongst these programmes has been their basic objective of land and water resource management for sustainable production This objective can not be materialized without sustained community participation

Experience has shown that watershed development projects under different programmes often fails to achieve their physical and financial targets on account of inappropriate administrative arrangements or inadequate management skill of the project staff Even in cases where progress has been satisfactory, the development has not been sustainable in terms of operation and maintenance of assets created and common property resources because of inadequate participation of village communities and user groups While the programme guidelines do emphasise the importance of peoples participation in the developmental programmes, most successful experiments, largely of voluntary agencies and a few from the governmental agencies indicate that success is achieved through Government's/VA's participation in the people's programme rather than the other way around

The planning and implementation of watershed development projects involve the project staff of the implementing agencies, whether governmental or non-governmental and the village community that is directly dependent on the natural resources in the watershed area, sufficient care needs to be bestowed on their orientation, skill upgradation and motivation The project staff needs training in technical content as well as the skill to recognize and improve upon indigenous technical knowledge They also need to be trained in the tools and techniques of project management, Participatory Rural Appraisal (PRA) methods, community organization and other administrative and accounting procedures

The villagers need training and exposure to modern scientific and technical methods, entrepreneurial skills to identify and exploit opportunities, community organization and team building to work in user groups So there is a need to provide institutional arrangement and funding for community organization and training components

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.

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.

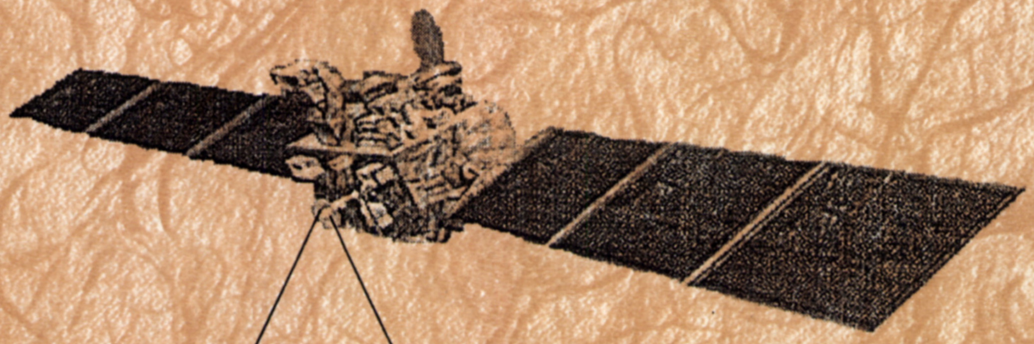
In the study area the cropping intensity, ground water level, average yields of crops, horticulture plantation and economic returns to the farmer are considered as indicators of development. The data are collected from Remote Sensing inputs and field validation of different farmers.

An awareness programme of all the State officers (Officers involved in the plan preparation/implementation and monitoring, non-government organization, women organizations, gram sevaks and farmers) involved in the project has been carried out through village level meetings and the block level interactions. The watershed is being monitored using satellite data for change detection in terms of land use/land cover and field studies to establish the increase in the yield of crops, status of ground water and reduction of runoff.

So far, an amount of $ 0.2 million has been spent for the implementation in selected villages, on priority basis. The results are quite encouraging. It was observed that the runoff has decreased and the ground water reserve and consumptive use increased.

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 in addition 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 was around 60 per cent of the average annual rainfall, the cropping intensity and yields 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 $)



BASIC PRINCIPLES OF REMOTE SENSING AND GIS

3. BASIC PRINCIPLES OF REMOTE SENSING AND GIS

In this chapter the fundamentals of Remote Sensing and GIS (Geographic Information System) are discussed so as to get a brief idea about Remote Sensing and GIS. The information is gathered from Digital Image Processing and GIS manual published by RRSSC, Nagpur.0

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 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 surface features

3.1.3.1 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.

3.1.3.2 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.

3.1.3.3 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 intra-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 of Remote Sensing

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).

3.2.1.1.1 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.

3.2.1.1.2 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.

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. But 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.

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 quarries.
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 Remote Sensing data as classified data and as image data.

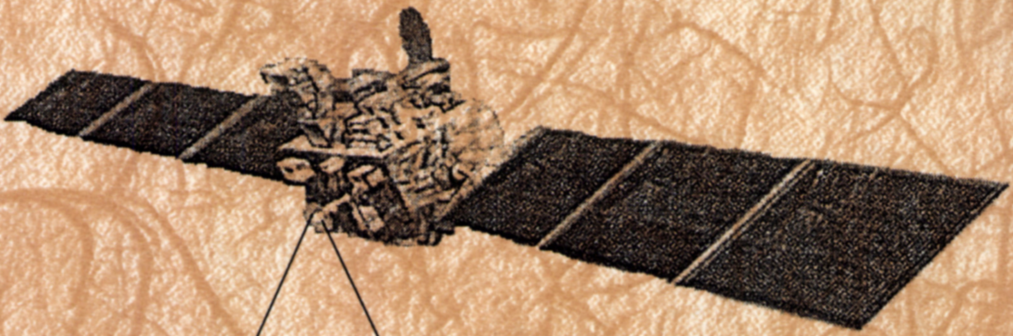
3.3.1 Use of classified data

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.

3.3.2 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 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 cos q (where, q is angle between sunlight and the normal to the sloping surface).



MATERIAL AND METHODS

4. MATERIAL AND METHODS

Since 1983, the concept of comprehensive watershed development programme was introduced in Maharashtra state so as to integrate all soil conservation and crop production activities on the basis of watershed. The centrally sponsored scheme of National Watershed Development Programme for Rainfed Agriculture (NWDPRA) is being implemented in the state of Maharashtra since 1987-88. For implementation of this scheme in eighth five year plan, the Government of India has restructured NWDPRA by adopting farming system approach on watershed management principles in order to conserve precious rain water and equally precious top fertile soil. According to the criteria for implementation of the NWDPRA, micro watershed Sawarde Bk. (14/08/01KR69/2) Tal. Kagal, Dist. Kolhapur was selected and development work was undertaken by Agriculture Department during the period 1991-1992 to 1995-1996.

For evaluation of the watershed development programme, it is necessary to study the pre-treatment and post-treatment scenario. For post-treatment scenario we can judge or see the impact by conducting field visits. However, for pre-treatment we can't do it at this stage and thus application of Remote Sensing is necessary. Remote Sensing and GIS are the appropriate tools for evaluation studies. The most important aspect of Remote Sensing is the availability of synoptic view of the target area with an up-to-date and multi-temporal coverage of various earth features in different bands of electromagnetic spectrum. It offers a quick and efficient way to study land use and other land features 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 watershed. The watershed development approach aims at optimizing 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. Thus evaluating the changes in the above parameters for pre and post treatment of the watershed help in justifying the watershed development programme.

4.1 Watershed

4.1.1 Location

The Sawarde Bk Watershed is located in Kagal Taluk of Kolhapur District It is about 45 km from Kolhapur and lies towards southwest of Kagal. The watershed area is located between $16^0 20'$ to $16^0 30'$ N latitude and $74^0 07'$ to 74°15' E longitude The watershed area comprises of ten villages viz Sawarde Bk . Sawarde Kd . Sonali. Pirachi wadi. Pimpalgaon Kd , Bange, Malge Kd . Chaundal. Kurni and Nidhori The watershed occupies an area of 5180 ha In addition, 2 km buffer occupying an area of 8274 ha surrounding the watershed covering parts of Kagal Block in Kolhapur district was considered for the study The study area is covered in Survey of India topographical map numbered 47 L / 3 on 1 50000 scale

4.1.2 Climate

The watershed experiences a dry climate except during southwest monsoon season. The mean annual rainfall of the watershed is about 706 5 mm It is relatively well distributed in five months i.e June to October [E4 (A3 B1) D1 E3] The duration of winter season is 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 mean annual temperature is approximately 18°C

4.1.3 Socio-economic data

The data regarding the socio-economic status of the ten villages in the watershed were collected from District Statistics Department. Kolhapur for the year 1981 and 1991 The data are presented in Table 5 13 The status of the watershed before and after development and the changes in crop yield in the watershed collected from Taluk Agril Office, Kagal and Dist Supt Agril Office, Kolhapur are presented in Table 5 14 and 5 15 respectively

4.1.4 Activities of NWDPRA in the watershed

The physical and financial targets and achievements regarding the activities carried in the watershed are presented in Table 4.1 and 4.2, respectively.

4.1.5 Satellite Data

The Remote Sensing data used for the study are presented below

Sr. No.	Purpose	Sensor	Path	Row	Date of Pass
1.	Pre treatment	IRS-1A LISS II	29	57	Oct. 1989
2.	Post treatment	IRS-1C LISS III	96	61	Nov. 1998

Using the remotely sensed digital data the base maps were prepared.

4.2 Software

The software packages, which were used for the purpose of digital image processing and GIS are:

4.2.1 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.

4.2.2 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 integrates 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.

Table: 4.1 Activities of NWDPRA in the watershed (Physical targets and achievements)

Items	Unit	Physical Target	Physical Achivement
Arable Land			
Contour Vegetative Hedges 0 to 4 per cent slope	ha	550	550
Contour Vegetative Hedges 4 to 8 per cent slope	ha	1111	1111
Vegetative filter strips	r.m.	3000	2108
Repairs to existing conservation measures	ha	482	282
Gull y control measures	Nos.	500	1052
Non arable Land			
Live Fencing	r.m.	7137	6399
Vegetative filter strips in place of diversion drain	r.m.	6300	6305
Contour vegetative hedges with furrows	ha	700	699
Gull y control measures	Nos.	2910	3477
Over seeding of grasses	ha	706	706
Planting of trees alongwith drainageline	Nos.	58573	58542
Gull y Control Measures			
Nala bank stabilisation	r.m.	5686	5686
Live check dam	Nos.	500	500
Brush wood dam	Nos.	176	176
Loose boulder structures (small)	Nos.	1176	1176
Earthen structure	Nos.	250	240
Loose boulder structures (big)	Nos.	501	514
Limited number of dug out sunken for runoff management	Nos.	45	45
Basic Activity			
Khas nursery	ha	2.10	-
Barani Chetna Kendra	Nos	1	1
Cattel Care Center	Nos.	1	1
Farmers Hostel	Nos.	1	1

(Source: Office of District Supt. Agricultural Officer, Kolhapur)

Table: 4.2 Activities of NWDPRA in the watershed (Financial targets and achievements)

Activity	Financial Target (Rs. In Lacks)	Financial Achivements (Rs. In Lacks)
• Basic Activity Extension, Training, Management, Research & Innovative support, Khus Nursery, etc.	11.89	8.56
• Arable Land		
-Conservation Measures	14.09	13.01
-Production System	14.50	14.04
• Non-Arable Land		
-Conservation Measures	18.89	19.49
-Production System	2.97	2.97
• Drainage Line Treatment	31.86	28.76
• Animal Husbandry	1.00	0.97
Total	95.15	87.80

(Source: Office of District Supt. Agricultural Officer, Kolhapur)

4.3 Hardware

The workstations of International Business Machines (IBM) RS6000 and SILICON Graphics SGI – OCTANE were used. This computer facility was provided by RRSSC, Nagpur

4.4 Methodology

4.4.1 Base map preparation

The watershed boundary was digitized on the toposheet with the help of the reference map obtained from Kagal Taluk Agriculture Office. A buffer area of 2 km around the watershed was also prepared with the help of ARC/INFO GIS package, to study the effect of watershed development programme in adjoining areas. The drainage network, road network, forest boundaries and location of villages were digitized. The five sub-watershed units were digitized with the help of drainage network and contours and used only for detecting change in runoff pattern during the pre and post treatment periods of the watershed.

4.4.2 Loading of satellite data

The satellite data of IRS-1A, LISS-II, October 1989 (P/R-29/57) was used for getting pre-treatment scenario of the watershed. For the post-treatment scenario of watershed the satellite data of IRS-1C, LISS-III, November 1998 (P/R-96/61) was used. The satellite data were loaded using LOAD_IRSCD program of EASI/PACE software.

4.4.3 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-

1A, LISS-II, October1989 (P/R – 29/57) and of IRS-1C, LISS-III, November 1998 were rectified.

The rectified FCC's of October 1989 and November 1998 are shown in Plates 1 and 2, respectively.

4.4.4 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.

4.4.5 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". The classification of image was done for preparation of land use/land cover map.

4.4.5.1 Classification

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, then the pixel is 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 October1989 and November 1998. In supervised classification, the identity and location of some of the land cover types, such as urban, agriculture, wet land 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

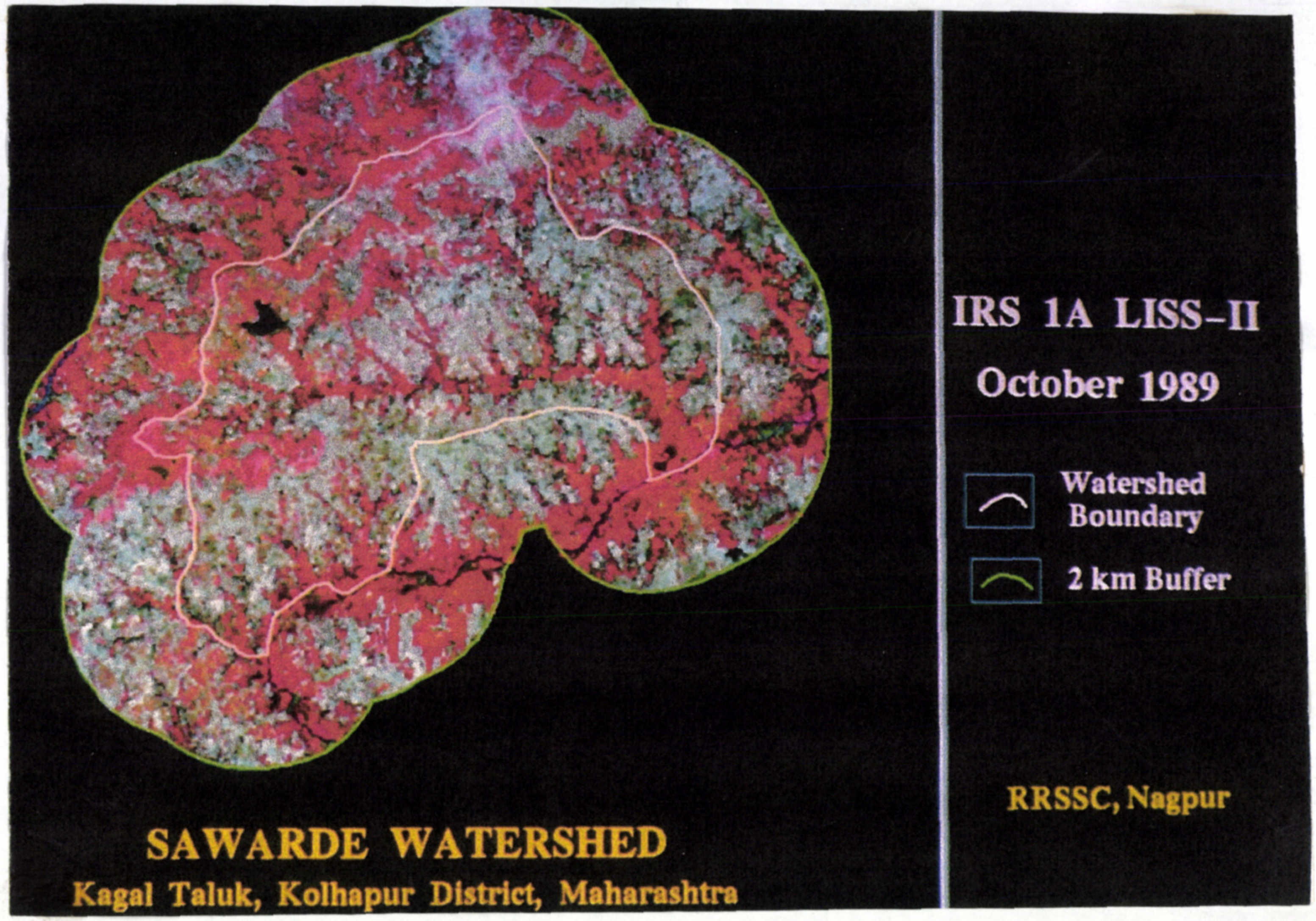


Plate 1: False Colour Composite (FCC) of study area during October 1989.

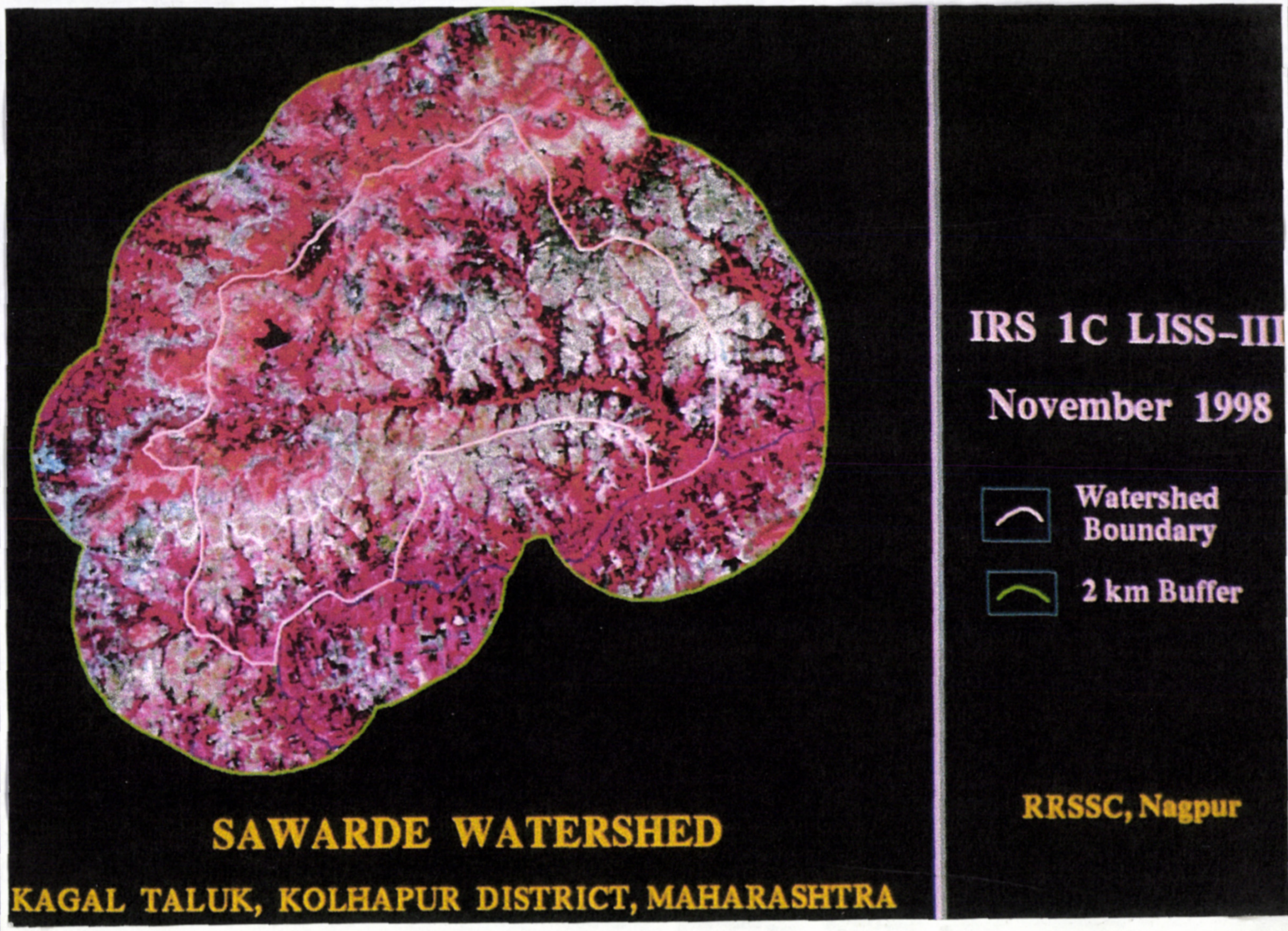


Plate 2: False Colour Composite (FCC) of study area during November 1998.

cover mapping of the remainder of the image. The classification algorithm used was maximum likelihood.

4.4.5.2 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 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

$$P_c >= P_i \text{ where, } i = 1, 2, 3, \ldots m \text{ possible classes.}$$

The satellite images were classified in eight different classes as below

Classes:

1) Water: It includes those lands having surface water bodies 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 of either kharif or rabi or kharif + rabi 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) Forest blank: It is described as openings amidst forests without any tree cover. It includes openings of assorted size and shapes as seen on the imagery.

5) Degraded forest/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.

6) Open forest: It is described a forest where the vegetative (crown) density is 40 to 60 per cent of the canopy cover.

7) Dense forest: It is described a forest where the vegetative (crown) density is more than 60 per cent of the canopy cover.

8) Plantation: It is described as an area under agricultural tree crops, planted adopting certain agricultural management techniques. It includes tea, coffee, rubber, coconut, citrus, orchards, and other horticultural nurseries.

4.4.6 Change detection of land use/land cover

The classified images having different land use/land cover categories pertaining to pre and post treatment periods have been compared to derive information on changes. The land cover transformation in terms of increase in vegetation cover, area under forest, plantations etc. were derived. The changes with respect to spatial extent of wastelands, fallow, number and spread of water bodies were also obtained in order to quantify the extent of changes in the watershed, buffer and total area.

4.4.7 Normalised difference vegetation index

Normalised difference vegetation index is the ratio of the difference in near infra red and visible red to the sum of near infra red and visible red reflectance. It is represented mathematically as

$$NDVI = \frac{NIR - VR}{NIR + VR}$$

where,

NDVI = Normalised Difference Vegetation Index.

NIR = near infra red reflectance, and

VR = visible red reflectance.

This index gives the values in the range, which can not be displayed on the monitor. Generally 8-bit data is used to retrieve and store the information, which has range from 0 to 255 values. Thus for the purpose of displaying the data and distinguishing different vegetation categories Normalised Difference Vegetation Index is represented mathematically as follows:

$$NDVI = \frac{NIR - VR}{NIR + VR} \times 128 + 127.5$$

The reflectance of vegetation in NIR region is high due to high chlorophyll content in leaf where as there is higher absorption of EMR in VR region thus giving the high value of NDVI, which is best, suited for comparison. If the chlorophyll content in leaves is less then the reflectance in NIR region will be less and absorption in the VR region is more thus less value of NDVI (may be negative) is obtained which is best suited for comparison. Only green vegetation has positive NDVI values. High values of NDVI being associated with higher densities / vigour of any given healthy phytomass.

For Normalised Difference Vegetation Index the program MODEL of EASI/PACE, software was used. MODEL implements a high level modeling language that can be used for GIS and imagery applications. MODEL is generalised image processing and raster GIS tool. Using a special programming language, the user enters a set of equations (MODEL) describing how channels of imagery data and attribute data should be combined. The result can be new channels of data and/or a text report. The MODEL is applied to both the pre-treatment and post-treatment images.The details of MODEL parameters are given in Appendix B.

4.4.8 Runoff analysis

The runoff estimation was done by SCS-CN method.

The basic equation for computing the depth of excess rainfall or direct runoff from a storm by the SCS method is

$$Q = \frac{(P - Ia)^2}{(P - Ia + S)}$$

where,

Q = Direct runoff depth, mm

P = Storm rainfall, mm

Ia = Initial abstraction, mm and

S = Maximum potential retention, mm.

The maximum potential retention depends on curve number The relation between curve number and maximum potential retention is given as

$$S = \frac{25400}{CN} - 254$$

where,

CN = curve number

Thus from above the equation it is clear that S depends on the values of CN Higher the value of CN, lower will be S which in turn means that higher will be the runoff The CN and S can also be used indirectly for comparing the runoff independent of the storm (precipitation)

The value of CN depends on the Hydrologic Soil Group, treatment, land use/land cover, hydrologic condition and antecedent moisture condition There is very less chance of altering the soil group The antecedent moisture condition depends on five day antecedent rainfall and hence is independent of watershed development However, due to watershed development there is every chance of altering the land use, treatments and thereby hydrologic condition of the watershed The entire watershed was divided in five sub watershed units for development of curve number Plate 3 shows the five sub watershed units.

The major input parameters land use/land cover and hydrologic soil group maps derived were used for the runoff estimation. The hydrologic soil group map was prepared as described below

4.4.8.1 Hydrologic Soil Group

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

The Hydrologic Soil Group plays an important role in the determination of runoff depth using SCS-CN method Hydrologic Soil Groups are suggestive of runoff from rainfall event to hydrological studies particularly in watershed management programmes An attempt to classify the soils into

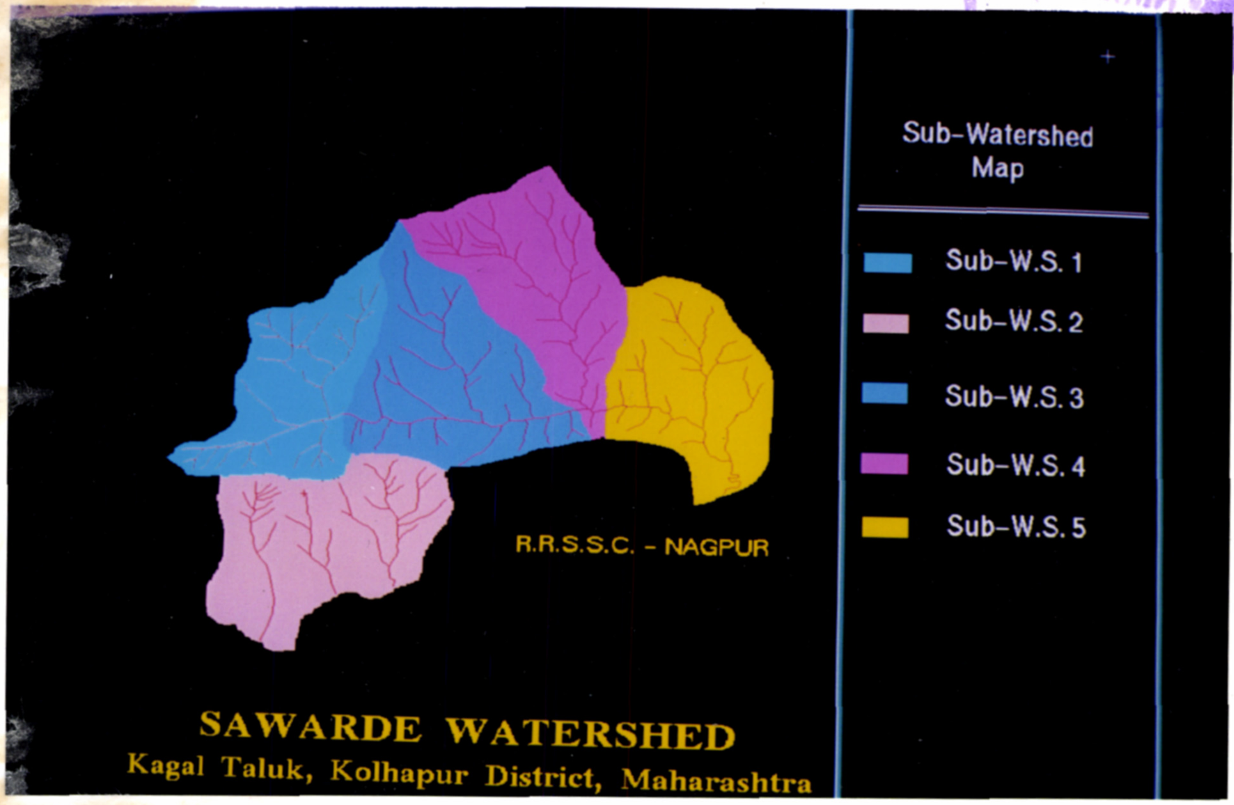


Plate 3: Sub watershed units map

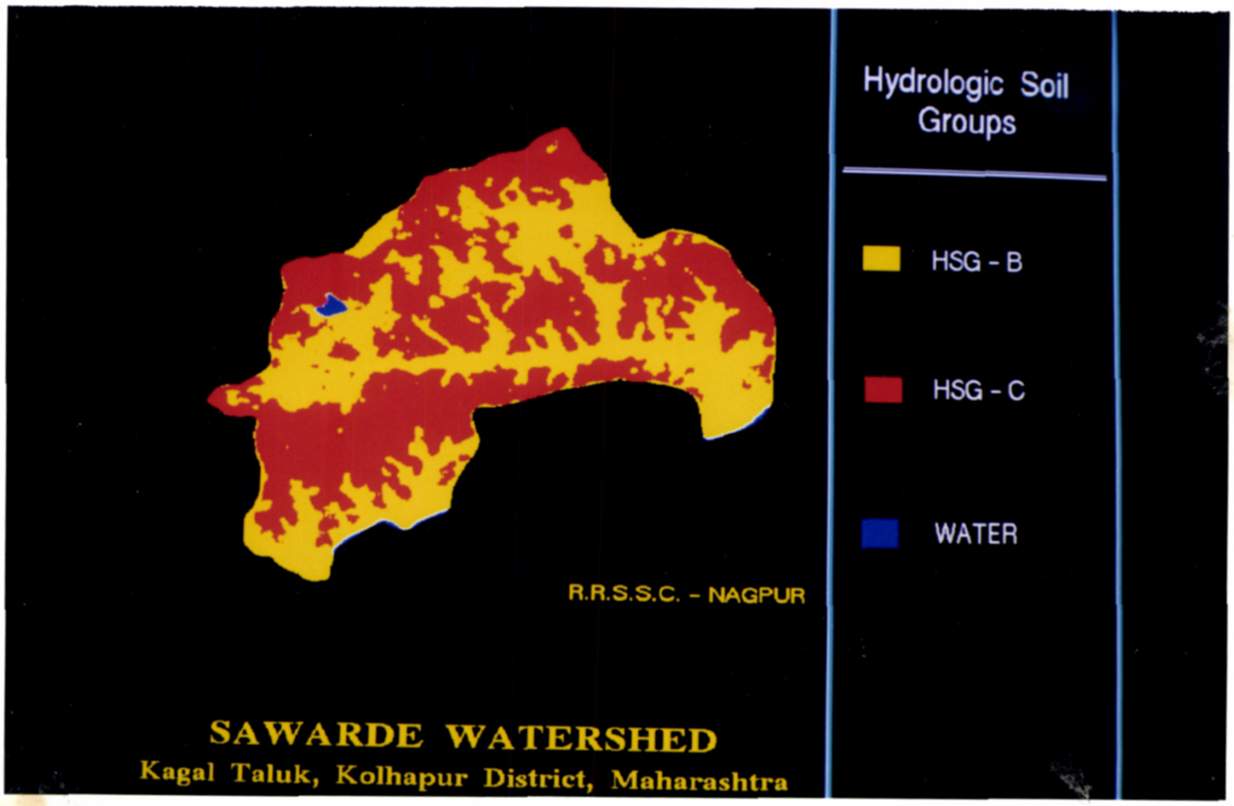


Plate4: Hydrologic Soil Group map

hydrological soil groups has been made on the basis of soil characteristics. These include effective depth, infiltration, permeability, soil structure, depth to impermeable layer etc.

Based on the collateral information of land use/land cover, land form, land capability class map obtained from Kagal Taluk Agriculture Office, soil map obtained from Divisional Soil Survey Office, IRD, Pune and the image characteristics, a relationship among image interpretation units, physiography and soils was developed and Hydrologic Soil Group map was prepared. The hydrologic soil group map was kept same for runoff analysis of both pre-treatment and post-treatment images.

The area statistics regarding Hydrologic Soil Group is presented in Table 4.3 and the map showing Hydrological Soil Groups is shown in Plate 4.

The hydrologic soil groups are described below:

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.

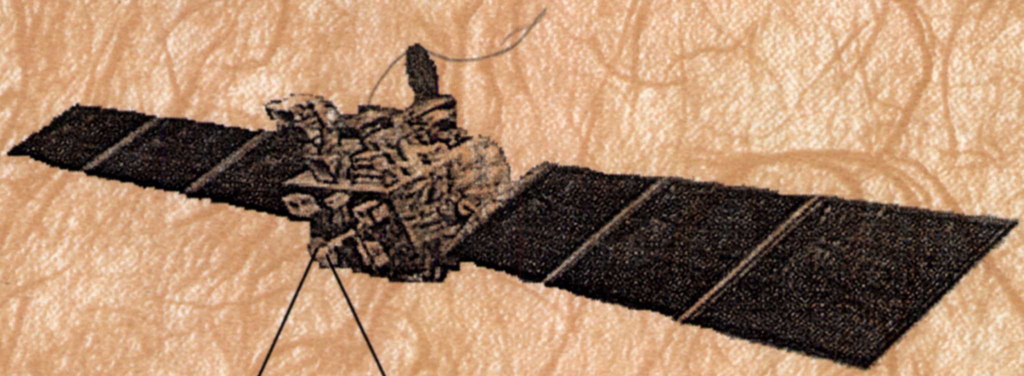
For the area under study there were only two hydrological soil groups namely B and C.

Table 4.3: Area under different hydrologic soil group in watershed.

Hydrological Soil Group	Area (Ha.)
B	2202
C	2945
Water	33

4.4.8.2 Generation of curve numbers

The five sub-watersheds were used for determination of runoff pattern in pre and post treatment periods separately. The thematic maps of land use/land cover and hydrologic soil group was integrated and corresponding CN values were read from the text file for preparation of CN map. The details of programs used for integration and derivation of CN map are presented in Appendix C. The curve numbers for different land use categories and hydrologic soil groups obtained for AMC II are also presented in Appendix C.



RESULTS AND DISCUSSION

5. RESULTS AND DISCUSSION

Remote sensing and GIS was used as the tool for generation of various thematic and derived maps pertaining to the evaluation of watershed development programme. The results obtained are discussed below.

5.1 Land Use/Land Cover

The classification of the images was done for preparation of land use/land cover map.

The satellite data of October 1989 and November 1998 was classified in eight different classes as described in 4.4.5.1.

The pre and post development classified scenario is depicted in Plate 5 and 6 respectively. The areas under different classes of land use/land cover in October 1989 and November 1998 are given in Table 5.1 and 5.2 respectively.

The agricultural land comprises of the area under crop and fallow land. The total area under the agriculture was 6401 ha of which 2264 ha was in watershed and 4137 ha was in the buffer area in the year 1989-90 (pre-treatment). The cropped area under the watershed, buffer and total area was 1088 ha, 2178 ha, and 3266 ha respectively whereas the fallow lands in watershed, buffer and total area was 1176 ha, 1959 ha, and 3135 ha respectively. The forest land comprises of degraded forest/forest blank, open forest and dense forest. The total area under forest land was 195 ha out of which 17 ha was in watershed and the remaining 178 ha was in the buffer area. The total area under degraded forest/forest blank was 24 ha out of which 4 ha was in watershed and 20 ha was in the buffer area whereas the total area under open forest and dense forest was 82 ha and 89 ha respectively. The open forest area in the watershed was 8 ha and it was 74 ha in the buffer area whereas the dense forest area in the watershed was 5 ha whereas it was 84 ha in the buffer area. The wasteland comprises of the upland with or without scrub. The total area under wasteland was 5848 ha out of which 2456 ha was in watershed and 3392 ha was in the buffer area. The water bodies comprises of the river or tank. The total area under water bodies was 128 ha out of which 31 ha was in the

Table: 5.1 Area statistics- Land use/Land cover map (Pre-treatment)

WATERSHED	:	SAWARDE	BLOCK	KAGAL
DISTRICT		KOLHAPUR	STATE	MAHARASHTRA
SATELLITE DATA		IRS LISS-II 29-57-B1	DOP	OCTOBER 1989

Sr. no.	Land use/Land cover category	Watershed		Buffer		Total	
		Area.ha	%	Area.ha	%	Area.ha	%
1.	Agriculture	2264	43.71	4137	50.00	6401	47.58
	Crop	1088	21.00	2178	26.32	3266	24.28
	Fallow	1176	22.70	1959	23.68	3135	23.30
2.	Forest land	17	00.33	178	02.15	195	01.45
	Deg. Forest/forest	4	00.08	20	00.24	24	00.18
	Open forest	8	00.15	74	00.89	82	00.61
	Dense forest	5	00.10	84	01.02	89	00.66
3.	Waste land	2456	47.41	3392	41.00	5848	43.47
	Upland with or without scrub	2456	47.41	3392	41.00	5848	43.47
4.	Water bodies	31	00.60	97	01.17	128	00.95
	River/tank	31	00.60	97	01.17	128	00.95
5.	Built-up	42	00.81	14	00.17	56	00.42
6.	Others	370	07.14	456	05.51	826	06.14
	Plantations	370	07.14	456	05.51	826	06.14
	Total	5180	100.00	8274	100.00	13454	100.00

Table: 5.2 Area statistics- Land use/Land cover map (Post-treatment)

WATERSHED	:	SAWARDE	BLOCK	KAGAL
DISTRICT		KOLHAPUR	STATE	MAHARASHTRA
SATELLITE DATA		IRS LISS-III 96-61	DOP	NOVEMBER 1998

Sr. no.	Land use/Land cover category	Watershed		Buffer		Total	
		Area.ha	%	Area.ha	%	Area.ha	%
1.	Agriculture	2275	43.92	4403	53.21	6678	49.64
	Crop	1390	26.83	3074	37.15	4464	33.18
	Fallow	885	17.08	1329	16.06	2214	16.46
2.	Forest land	17	0.33	178	2.15	195	1.45
	Deg. Forest/forest	1	0.02	17	0.21	18	0.13
	Open forest	6	0.12	59	0.71	65	0.48
	Dense forest	10	0.19	102	1.23	112	0.83
3.	Waste land	2434	46.99	2944	35.58	5378	39.97
	Upland with or without scrub	2434	46.99	2944	35.58	5378	39.97
4.	Water bodies	34	0.66	98	1.18	132	0.98
	River/tank	34	0.66	98	1.18	132	0.98
5.	Built-up	42	0.81	14	0.17	56	0.42
6.	Others	378	7.30	637	7.70	1015	7.54
	Plantations	378	7.30	637	7.70	1015	7.54
	Total	5180	100.00	8274	100.00	13454	100.00

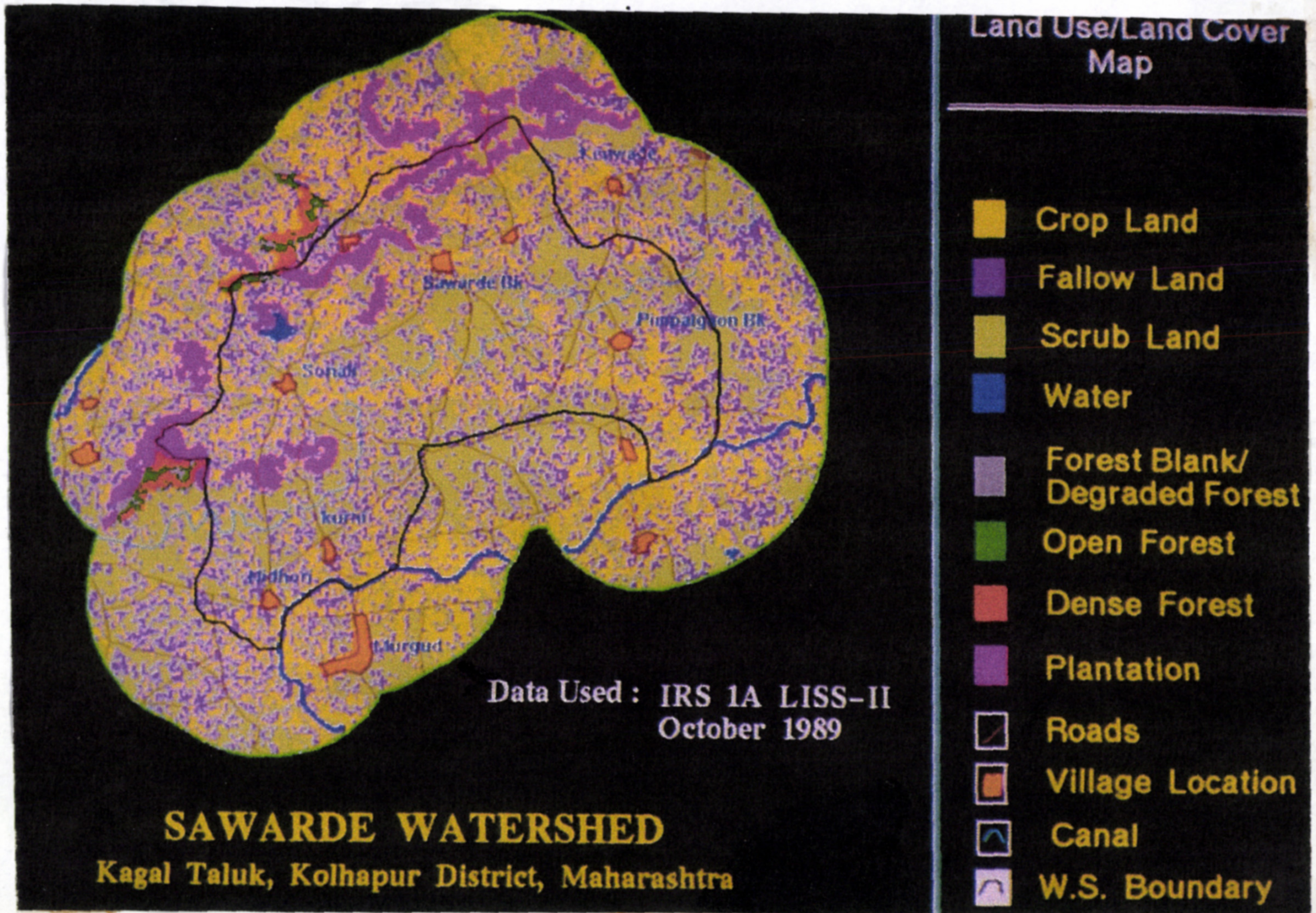


Plate 5: Land use/Land cover map (October 1989).

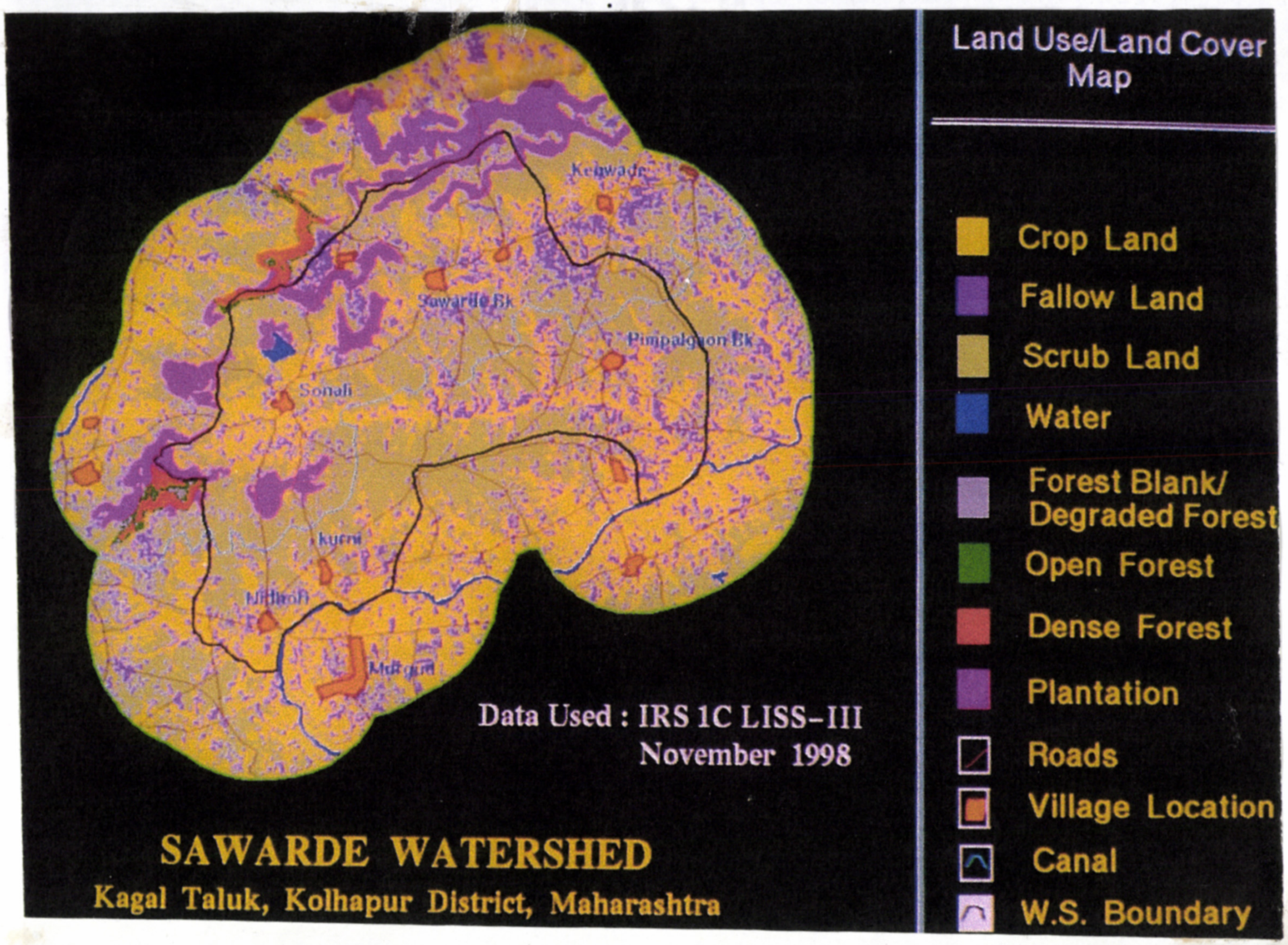


Plate 6: Land use/Land cover map (November 1998).

watershed and 97 ha was in the buffer area. The area under plantation in the watershed was 370 ha and that in the buffer was 456 ha having the total area as 826 ha.

In year 1998-99 the total area under the agriculture was 6678 ha out of which 2275 ha was in watershed and 4403 ha was in the buffer area (post-treatment). The cropped area under the watershed, buffer and total area was 1390 ha, 3074 ha, and 4464 ha respectively whereas the fallow land in watershed, buffer and total area was 885 ha, 1329 ha, and 2214 ha respectively. The total area under forest land was 195 ha out of which 17 ha was in watershed and the remaining 178 ha was in the buffer area. The total area under degraded forest/forest blank was 18 ha out of which 1 ha was in watershed and 17 ha was in the buffer area whereas the total area under open forest and dense forest was 65 ha and 112 ha, respectively. The open forest area in the watershed was 6 ha and it was 59 ha in the buffer area whereas the dense forest area in the watershed was 10 ha whereas it was 102 ha in the buffer area. The total area under wasteland was 5378 ha of which 2434 ha was in watershed and 2944 ha was in the buffer area. The total area under water bodies was 132 ha of which 34 ha was in the watershed and 98 ha was in the buffer area. The area under plantation in the watershed was 378 ha and that in the buffer was 637 ha.

5.2 Change Detection of Land Use/Land Cover

Detecting the changes in land use/land cover over the area can indicate the impact of the developmental activities in the watershed. Comparison of the pre-treatment and post-treatment classified images reveals the changes. The area statistics showing change in land use/land cover is presented in Table 5.3. It can be observed that the total area under agriculture in the watershed has increased by 11 ha over the pre-treatment area (1989-90) of 2264 ha and 266 ha in the buffer area over the pre treatment area (1989-90) of 4137 ha. In the watershed area, the cropped area has increased by 302 ha and the area under fallow land has decreased by 291 ha over the pre treatment area of 1088 ha and 1176 ha whereas the cropped area in the buffer has increased by 896 ha over the pre treatment area of 3074 ha and the area under fallow land has decreased by 630 ha. Thus it can be observed that the total area under the agriculture in the buffer has increased by 266 ha. The area under wasteland has decreased by 22 ha in the watershed and

TABLE 5.3: Change Detection in Land use / Land cover.

Watershed	:	Sawarde	Block	:	Kagal
District	:	Kagal	State :	:	Maharashtra
First Season	:	IRS LISS-II	Second Season:		IRS LISS-III
Satellite Data	:	(29-57-B1, OCT. 89)	Satellite Data	:	(96-61, NOV. 98)

Sr. No.	Land Use/Land Cover	Watershed Area(ha.)			Buffer Area (ha.)			Total Area (ha.)		
		Oct. 89	Nov. 98	Change	Oct. 89	Nov. 98	Change	Oct. 89	Nov. 98	Change
1.	Water Bodies	31	34	(+)3	97	98	(+)1	128	132	(+)4
2.	Agriculture	2264	2275	(+)11	4137	4403	(+)266	6401	6678	(+)277
	Crop	1088	1390	(+)302	2178	3074	(+)896	3266	4464	(+)1198
	Fallow	1176	885	(-)291	1959	1329	(-)630	3135	2214	(-)921
3.	Waste Land	2456	2434	(-)22	3392	2944	(-)448	5848	5378	(-)470
4.	Forest	17	17	0	178	178	0	195	195	0
	Deg. Forest	4	1	(-)3	20	17	(-)3	24	18	(-)6
	Open Forest	8	6	(-)2	74	59	(-)15	82	65	(-)17
	Dense Forest	5	10	(+)5	84	102	(+)18	89	112	(+)23
5.	Plantation	370	378	(+)8	456	637	(+)181	826	1015	(+)189
6.	Built-up	42	42	0	14	14	0	56	56	0
	Total	5180	5180	0	8260	8260	0	13454	13454	0

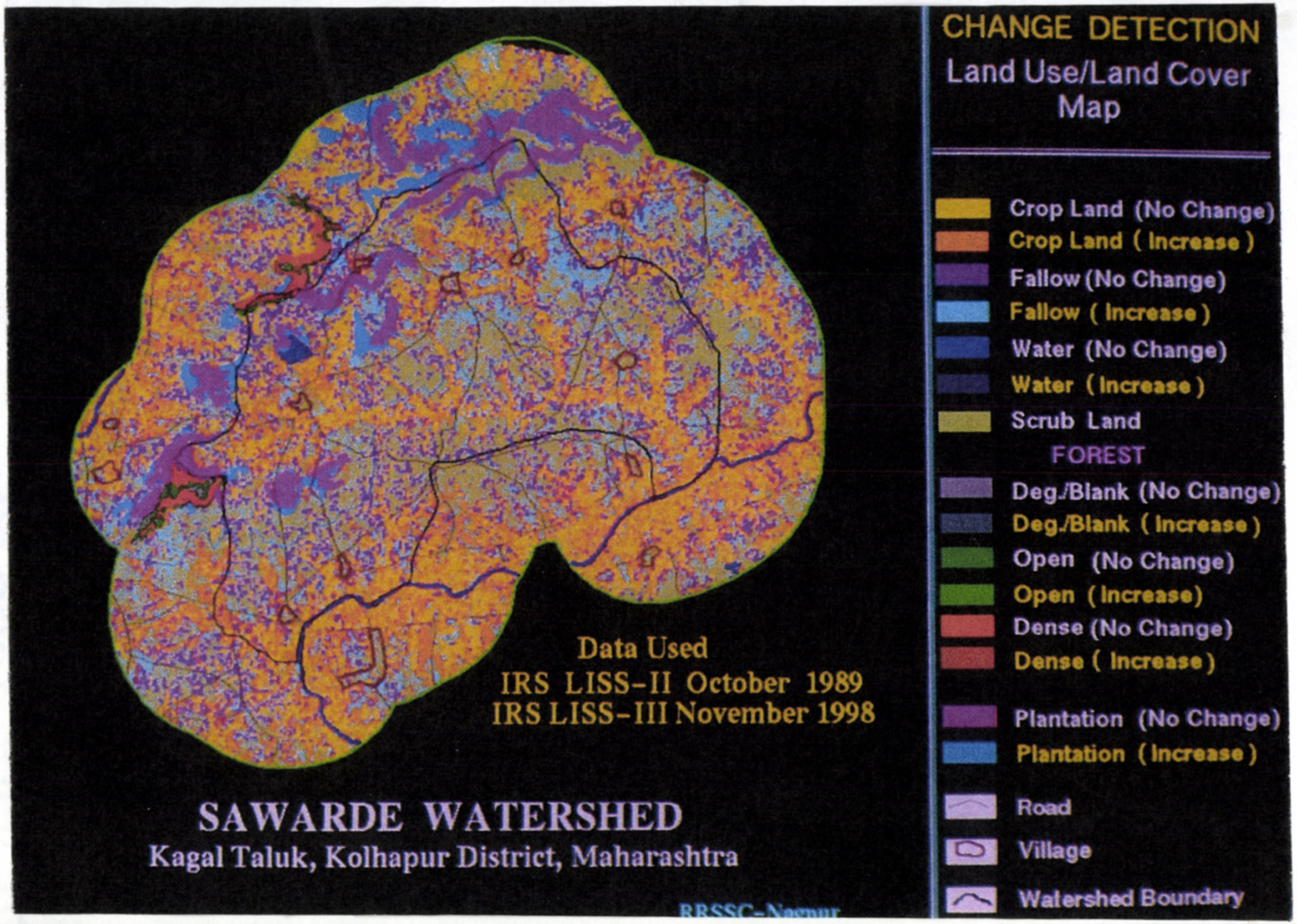


Plate 7: Change Detection- Land use/Land cover map.

488 in the buffer area. In the watershed, the area under dense forest has increased by 5 ha and that under degraded forest and open forest has decreased by 3 ha and 2 ha respectively. In the buffer area, the area under dense forest has increased by 18 ha and that under degraded forest and open forest has decreased by 3 ha and 15 ha respectively. The area under plantation in the watershed has increased by 8 ha over the pre treatment area of 370 ha whereas that in the buffer has increased by 181 ha over the pre treatment area of 456 ha. It can be observed that the area under built-up land has remained same in both watershed as well as buffer area. The change detection image is presented in Plate 7.

5.3 Normalised Difference Vegetation Index

The NDVI was applied to the images using the program MODEL. The details of the program are given in the Appendix B and the procedure is described in 4.4.7. The total area is divided in five NDVI groups namely water, blank vegetation, degraded vegetation, open vegetation and dense vegetation.

The NDVI map showing the pre-treatment and post-treatment vigour condition of the watershed and the buffer is shown in Plate 8 and 9, respectively.

The area under each group for both the pre-treatment and post-treatment condition is given in Table 5.4 and Table 5.5, respectively.

The area statistic showing changes in the NDVI category is given in Table 5.6. It is observed from this table that area under water body has increased by 3 ha, area under open vegetation and dense vegetation has increased by 49 and 362 ha, respectively. Whereas, the area under blank vegetation and degraded vegetation in the watershed has decreased by 178 ha and 236 ha, respectively. In the buffer area, the area under water body has increased by 1 ha; area under open vegetation and dense vegetation has increased by 490 and 949 ha, respectively. Whereas, the area under blank vegetation and degraded vegetation in the buffer area has decreased by 1157 ha and 2634 ha, respectively.

Table: 5.4 Normalised Difference Index (NDVI) area before treatment.

WATERSHED :	SAWARDE	BLOCK	KAGAL
DISTRICT	KOLHAPUR	STATE	MAHARASHTRA
SATELLITE DATA	IRS LISS-II 29-57-B1	DOP	OCTOBER 1989

Sr. No.	Description	Watershed		Buffer		Total Area	
		Area, ha	%	Area, ha.	%	Area, ha	%
I.	NDVI Category						
1.	Water Bodies	31	0.60	97	1.17	128	0.95
2.	No Vegetation	1092	21.08	2109	25.49	3201	23.79
3.	Degraded Vegetation	2375	45.85	3122	37.73	5497	40.86
4.	Open Vegetation	1100	21.24	1619	19.57	2719	20.21
5.	Dense Vegetation	582	11.24	1327	16.04	1909	14.19
	Total	5180	100.00	8274	100.00	13454	100.00

Table: 5.5 Normalised Difference Index (NDVI) area after treatment.

WATERSHED :	SAWARDE	BLOCK	KAGAL
DISTRICT	KOLHAPUR	STATE	MAHARASHTRA
SATELLITE DATA	IRS LISS-III 96-61	DOP	NOVEMBER 1998

Sr. No.	Description	Watershed		Buffer		Total Area	
		Area, ha	%	Area, ha	%	Area, ha	%
I.	NDVI Category						
1.	Water Bodies	34	0.66	98	1.18	132	0.98
2.	No Vegetation	914	17.64	1157	13.98	2071	15.39
3.	Degraded Vegetation	2139	41.29	2634	31.83	4773	35.48
4.	Open Vegetation	1149	22.18	2109	25.49	3258	24.22
5.	Dense Vegetation	944	18.22	2276	27.51	3220	23.93
	Total	5180	100.00	8274	100.00	13454	100.00

TABLE 5.6: Change Detection in Normalised Difference Vegetation Index (NDVI) area.

Watershed	:	Sawarde	Block	:	Kagal
District	:	Kagal	State	:	Maharashtra
First Season	:	IRS LISS-II	Second Season:		IRS LISS-III
Satellite Data		(29-57-B1, OCT. 89)	Satellite Data		(96-61, NOV. 98)

Sr. No.	NDVI Category	Watershed Area(ha.)			Buffer Area (ha.)			Total Area (ha.)		
		Oct. 89	Nov. 98	Change	Oct. 89	Nov. 98	Change	Oct. 89	Nov. 98	Change
1.	Water	31	34	(+)3	97	98	(+)1	128	132	(+)4
2.	Blank Vegetation	1092	914	(-)178	2109	1157	(-)952	3201	2071	(-)1130
3	Degraded Vegetation	2375	2139	(-)236	3122	2634	(-)488	5497	4773	(-)724
4	Open Vegetation	1100	1049	(+)49	1619	2109	(+)490	2719	3258	(+)539
5	Dense Vegetation	582	944	(+)362	1327	2276	(+)949	1909	3220	(+)1311
	Total	5180	5180	0	8274	8274	0	13454	13454	0

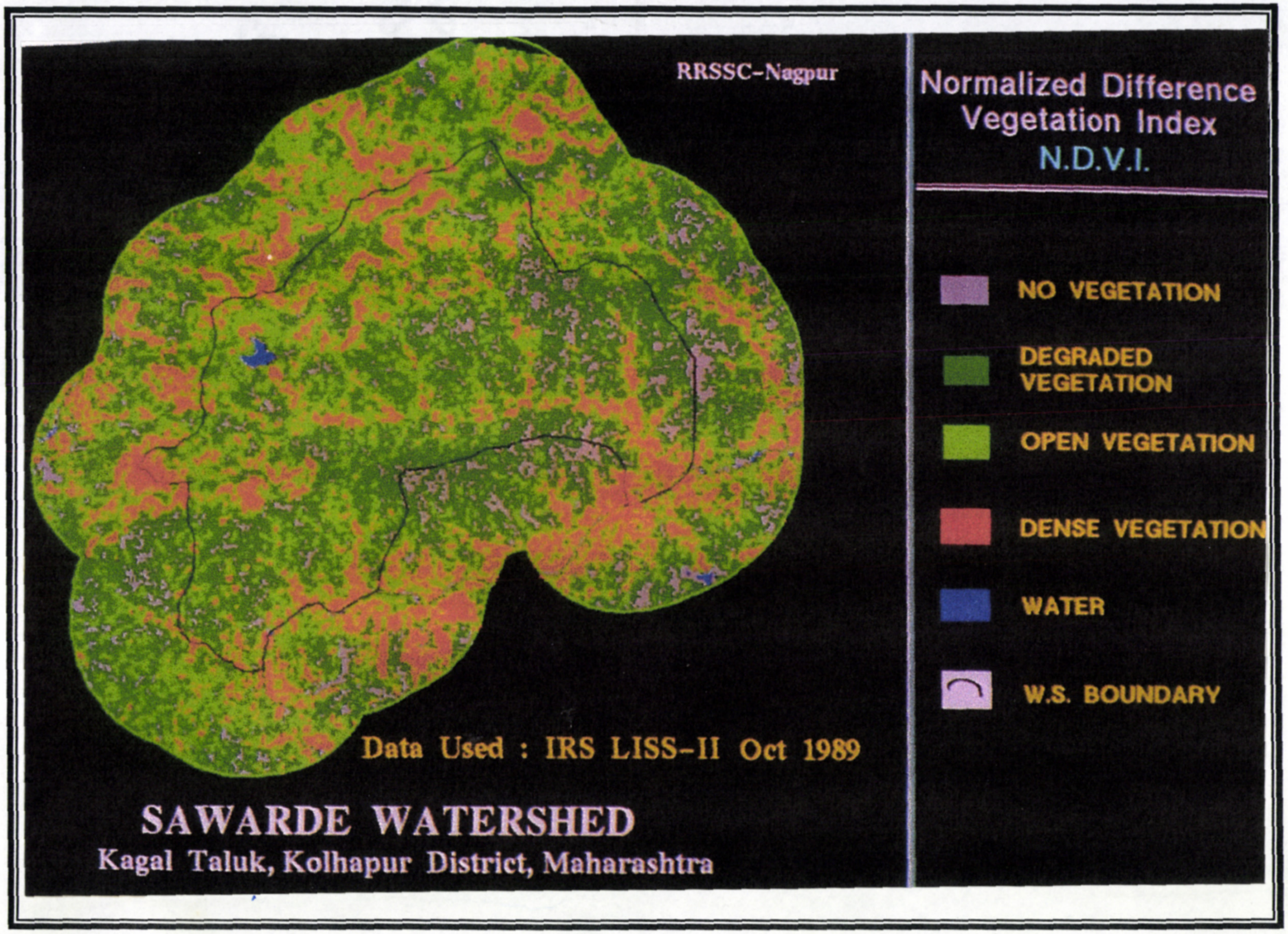


Plate 8: Normalised Difference Vegetation Index map during October 1989.

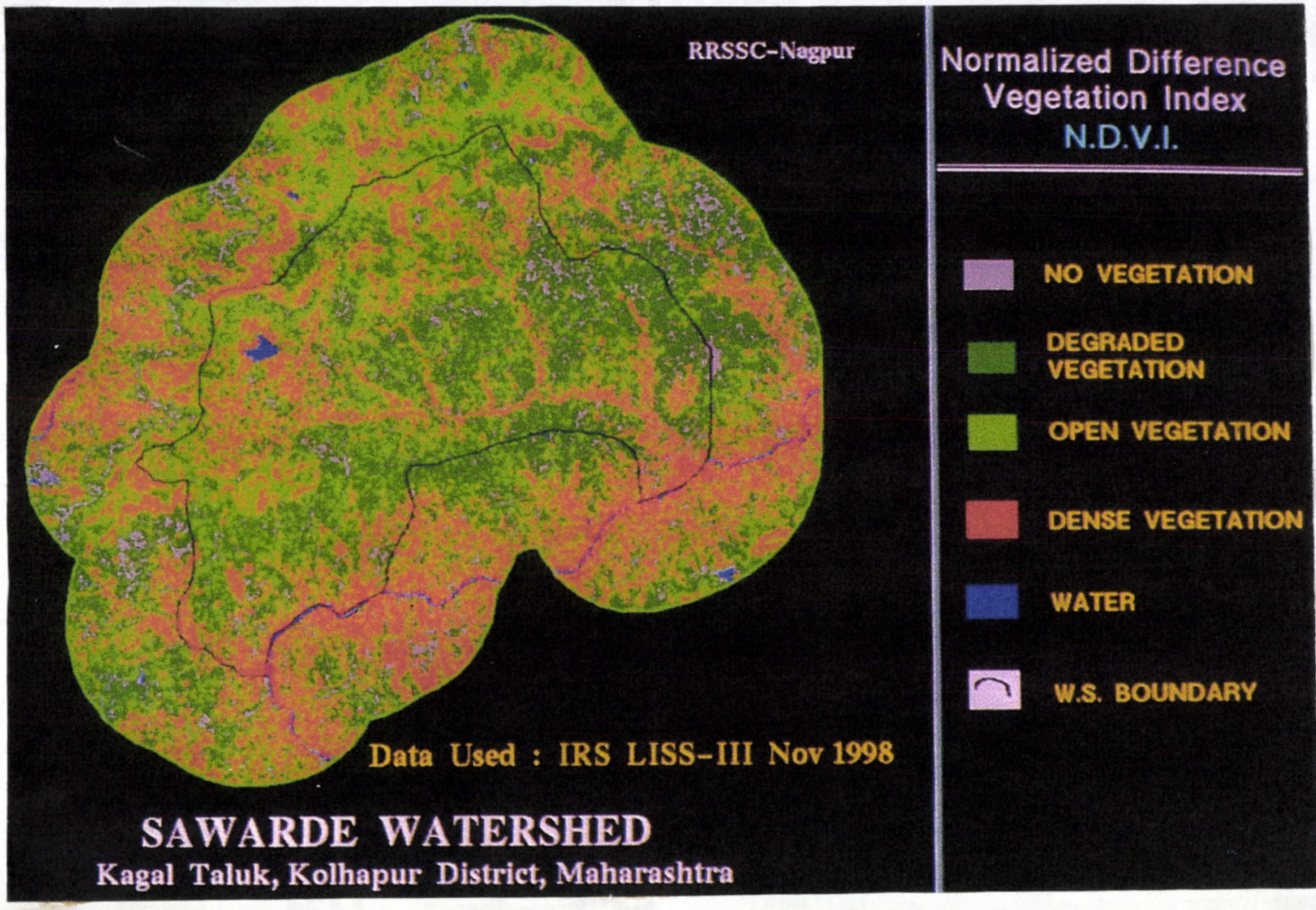


Plate 9: Normalised Difference Vegetation Index map during November 1998.

5.4 Change Detection in Runoff Curve Numbers

The analysis was done as described in 4.4.8 and weighted curve numbers for five sub watersheds were determined for pre and post treatment. Plates 10 and 11 depict the Curve Number distribution in entire watershed for pre and post treatment. Based on these curve numbers the maximum potential retention (S) was computed. The changes in curve number and maximum potential retention are given in Table 5.7 to 5.11 for five sub watersheds.

It is seen from the Tables 5.7 to 5.11 that the CN before the watershed development programme for the five sub watersheds (i.e. sub watershed No.1, 2, 3, 4 and 5) is 74.77, 75.96, 74.98, 72.75, and 74.31 respectively and for the post-treatment period the curve numbers are 73.32, 73.96, 74.40, 74.37 and 74.94 for the sub watershed No.1, 2, 3, 4 and 5, respectively. It is observed that the curve number in the first three sub watersheds decreased from 74.77 to 73.32, 75.96 to 73.96 and 74.98 to 74.40 respectively. But it increased from 72.75 to 74.37 and 74.31 to 74.94 in sub watershed 4 and 5, respectively. This might have happened due to the introduction of agricultural crop in both seasons having more values of curve number than natural vegetation.

The weighted CN for entire watershed for AMC II before development was found to be 74.74, which was reduced to 74.35 after treatment. The reduction is of the magnitude of 0.52 per cent. This has resulted in an increase of 2.07 per cent in maximum potential retention.

5.4 Socio-Economic Status and Changes

The demographical details of the villages included in the watershed were collected from Kolhapur District Statistical Department for the years 1981 and 1991. The data includes total population and number of male, female, SC, ST and literate. The data are extended for the year 2001.

The socio-economic status of the farmers was assessed by conducting field visits and interviews with the farmers. The questionnaire used for conducting the interviews is given in the Appendix D.

Table 5.7: Weighted Curve Number and Maximum Potential Retention for Sub Watershed No. 1 (AMC II)

	Oct. 89			Nov. 98		
CN values	No. of pixels	Area, ha	A x CN	No. of pixels	Area, ha	A x CN
55	187	9.8923	544.0765	26	1.3754	75.6470
60	3063	162.0327	9721.9620	1602	84.7458	5084 7480
70	2278	120.5062	8435.4340	2931	155.0499	10853.4930
71	2659	140.6611	9986.9381	4792	253.4968	17998 2728
73	2618	138.4922	10109.9306	4426	234.1354	17091.8842
77	70	3.7030	285.1310	22	1.1638	89.6126
78	1667	88.1843	6878.3754	928	49.0912	3829.1136
86	2298	121.5642	10454.5212	1786	94.4794	8125.2284
91	2108	111.5132	10147.7012	447	23.6463	2151 8133
100	353	18.6737	1867.3700	341	18.0389	1803 8900
Total =	17301	915.2229	68431.4400	17301	915.2229	67103.7029
Weighted CN			74.77			73.32
S =			85.71			92.43

Table 5.8: Weighted Curve Number and Maximum Potential Retention for Sub Watershed No. 2 (AMC II)

	Oct. 89			Nov. 98		
CN values	No. of pixels	Area, ha.	A x CN	No. of pixels	Area, ha.	A x CN
55	18	0.9522	52.3710	9	0.4761	26.1855
60	2675	141.5075	8490.4500	1339	70.8331	4249.9860
70	1160	61.364	4295.4800	1053	55.7037	3899.2590
71	2644	139.8676	9930.6000	4898	259.1042	18396.4000
73	7259	384.0011	28032.0800	10237	541.5373	39532.2200
77	0	0	0	3	0.1587	12.21990
78	1526	80.7254	6296.5810	731	38.6699	3016.2520
86	2472	130.7688	11246.1200	1756	92.8924	7988.7460
91	3128	165.4712	15057.8800	1048	55.4392	5044.9670
100	397	21.0013	2100.1300	205	10.8445	1084.4500
Total =	21279	1125.6590	85501.6900	21279	1125.6590	83250.6900
Weighted CN =			75.96			73.96
S =			80.39			89.43

Table 5.9: Weighted Curve Number and Maximum Potential Retention for Sub Watershed No. 3 (AMC II)

	Oct. 89			Nov. 98		
CN values	No. of pixels	Area, ha	A x CN	No. of pixels	Area, ha	A x CN
0	7	0.3703	0	7	0.3703	0
55	34	1.7986	98.9230	2	0.1058	5.8190
60	2445	129.3405	7760.4300	1229	65.0141	3900.8460
70	1204	63.6916	4458.4120	1416	74.9064	5243.4480
71	2650	140.1850	9953.1350	3778	199.8562	14189.7900
73	9350	494.6150	36106.9000	11071	585.6559	42752.8800
77	0	0	0	0	0	0
78	1557	82.3653	6424.4930	1023	54.1167	4221.1030
86	1993	105.4297	9066.9540	2113	111.7777	9612.8820
91	2847	150.6063	13705.1700	1448	76.5992	6970.5270
100	0	0	0	0	0	0
Total =	22080	1168.032	87574.4200	22080	1168.0320	86897.3000
Weighted CN =			74.98			74.40
S =			84.76			87.43

Table 5.10: Weighted Curve Number and Maximum Potential Retention for Sub Watershed No. 4 (AMC-II)

CN values	Oct. 89			Nov. 98		
	No. of pixels	Area, ha	A x CN	No. of pixels	Area, ha	A x CN
55	344	18.1976	1000.8680	1	0.0529	2.9095
60	3760	198.904	11934.24	1598	84.5342	5072.0520
70	2089	110.5081	7735.5670	1818	96.1722	6732.0540
71	2674	141.4546	10043.28	4370	231.1730	16413.28
73	5784	305.9736	22336.0700	7037	372.2573	27174.78
77	0	0	0	0	0	0
78	1194	63.1626	4926.6830	637	33.6973	2628.3890
86	2275	120.3475	10349.89	3084	163.1436	14030.3500
91	1456	77.0224	7009.0380	1031	54.5399	4963.1310
100	0	0	0	0	0	0
Total	19576	1035.5704	75335.6300	19576	1035.5704	77016.9500
Weighted CN =			72.75			74.37
S =			95.14			87.54

Table 5.11: Weighted Curve Number and Maximum Potential Retention for Sub Watershed No. 5 (AMC-II)

CN values	Oct. 89			Nov. 98		
	No. of pixels	Area, ha	A x CN	No. of pixels	Area, ha	A x CN
55	0	0	0	0	0	0
60	3450	182.5050	10950.3000	1397	73.9013	4434.0780
70	0	0	0	0	0	0
71	3013	159.3877	11316.5300	4656	246.3024	17487.4700
73	5623	297.4567	21714.3400	6842	361.9418	26421.75
77	0	0	0	0	0	0
78	720	38.088	2970.8640	369	19.5201	1522.5680
86	2469	130.6101	11232.4700	2911	153.9919	13243.3000
91	1885	99.7165	9074.202	1017	53.7993	4895.7360
100	145	7.6705	767.0500	113	5.9777	597.7700
Total =	17305	915.4345	68025.7500	17305	915 4345	68602.6800
Weighted CN =			74.31			74.94
S =			87.81			84.94

Table 5.12: Changes in Curve Number (CN) and Maximum Potential Retention (S)

Sub watershed No.	Curve Number (CN)			Maximum Potential Retention (S), mm			Signs
	Oct. 89	Nov. 98	Change	Oct. 89	Nov. 98	Change	
1.	74.77	73.31	(-)1.46	85.70	92.42	(+)6.72	
2.	75.95	73.95	(-)2.00	80.39	89.44	(+)9.05	+ = Increase
3.	74.97	74.39	(-)0.58	84.77	87.41	(+)2.64	- = Decrease
4.	72.74	74.37	(+)1.63	95.15	87.52	(-)7.63	
5.	74.30	74.94	(+)0.64	87.81	84.93	(-)2.88	

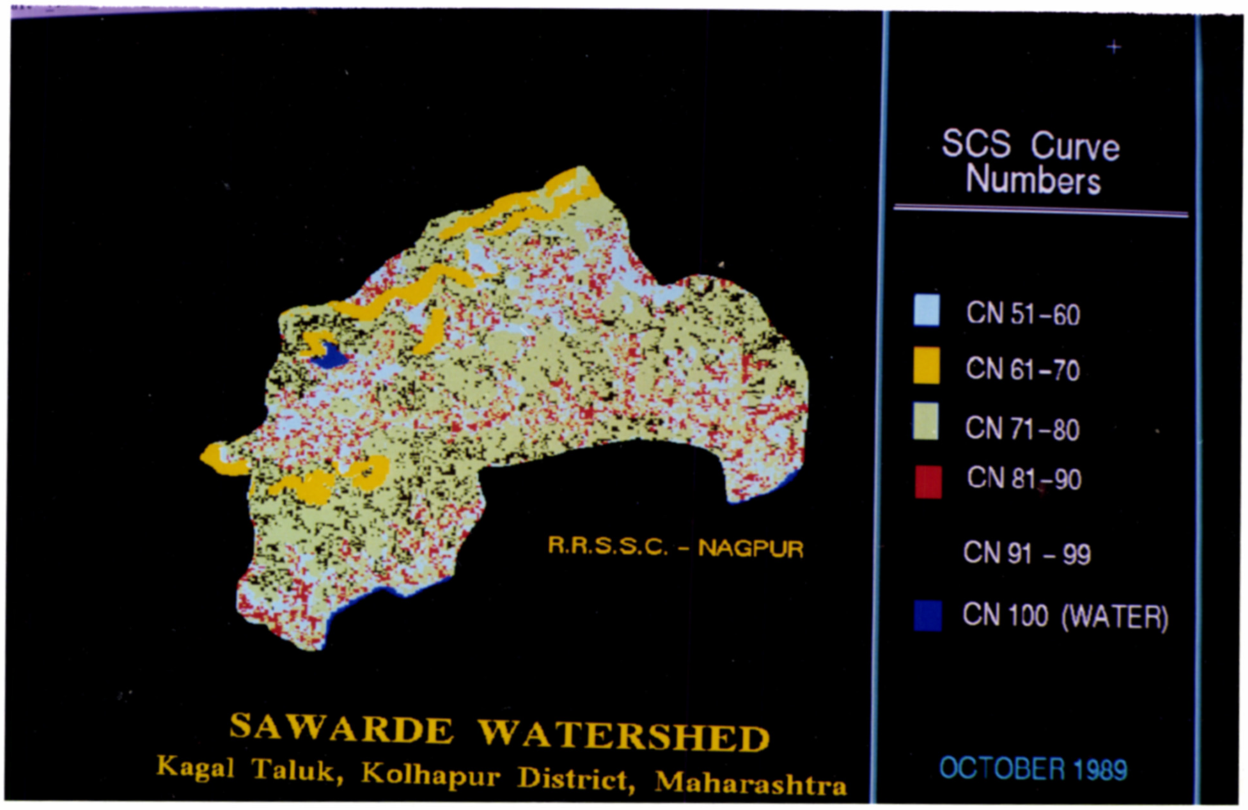


Plate 10: Curve Number map of watershed for pre treatment condition.

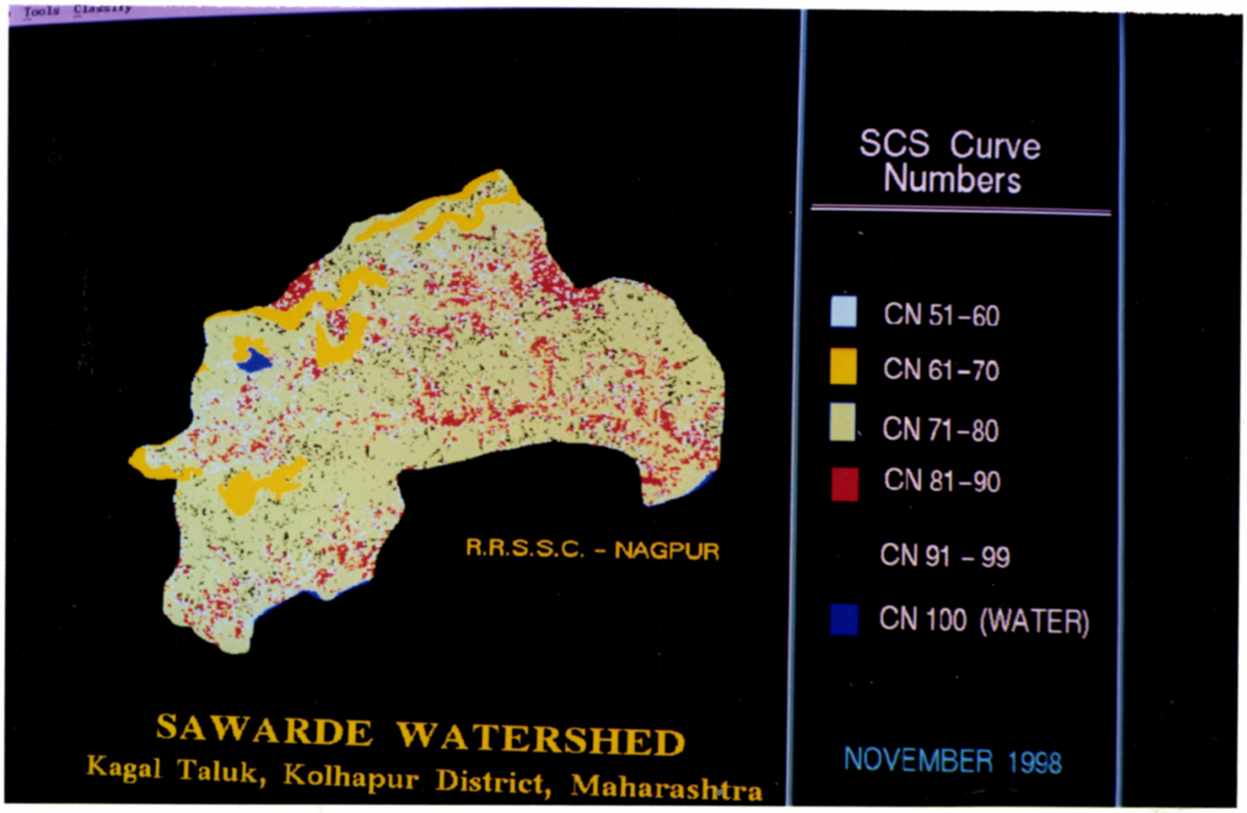


Plate 11: Curve Number map of watershed for post treatment condition.

5.5.1 Status of watershed before and after development

The total population of the watershed in the year 1981 and 1991 was 19125 and 21949, respectively and the estimated population for the year 2001 is around 25266 The demographic details of the watershed for the years 1981, 1991 and estimated for the year 2001 which includes total population, SC, ST, main workers, cultivators, agricultural labours is presented in Table 5 13

The cattle population like cows and buffaloes, other animals like goats and poultry birds have increased by 417, 2346, 1118 and 2686 over the pre treatment numbers of 425, 1000, 200 and 5000 respectively Similarly there is increase in number of wells, which were only 76 before development and are now increased to 320 These are helpful in solving the problem of drinking water, domestic use and irrigation This has lead to changes in cropping pattern and intensity Table 5 14 shows the changed scenario of cattle population and cropping pattern

The tractors, motor cycle and jeeps in the watershed have increased to 43, 169 and 26 respectively This indicates that the farmers have increased their income so as to invest it in farm related as well as other allied activities

In the watershed the level of education has increased, which could be known by the number of persons possessing higher secondary and graduate level education The change can very well be appreciated from the data presented in Table 5 14

With the watershed development programme there was also introduction of improved package of practices and this has led to increased crop yield for most of the important crops of the area Table 5 15 shows changes in yield levels of important crops

5.5.2 Remarks of beneficiaries in the watershed

Farmers in the watershed receiving benefits of different activities of watershed development were interviewed personally The changes observed by them as well as their remarks are given in Appendix E The most pertinent and common remarks are shortlisted here

1) The rabi jowar is introduced due to construction of different water harvesting structures like cement bandhara, earthen embankment, diversion dam, etc

Table 5.13: Demographical details of the watershed.

	Year		
	1981	1991	2001*
Population			
Male	9756	11058	12565
Female	9369	10891	12701
Total	19125	21949	25266
Scheduled Caste			
Male	1234	1362	1732
Female	1218	1302	1538
Total	2452	2664	3270
Scheduled Tribe			
Male	5	12	29
Female	6	22	81
Total	11	34	110
Main Workers			
Male	5699	5904	8054
Female	2684	3724	7168
Total	8383	9628	15222
Cultivators			
Male	3923	3777	3778
Female	1909	2880	6076
Total	5832	6657	9854
Agril. Labours			
Male	290	606	3534
Female	318	509	1764
Total	608	1115	5298

(Source: District Statistical Office, Kolhapur [1981 & 1991])
(* Estimated)

Table: 5.14 Status of watershed before and after development.

Items	Before Treatment.	After Treatment	Change	% Change
Literate				
Primary (No.)	3504	6769	3265	93.17
Secondary (No.)	910	3057	2147	235.93
Higher Secondary (No.)	315	805	490	155.55
Graduate (No.)	190	221	31	16.31
Cows (No.)	425	842	417	98.11
Buffaloes (No.)	1000	3346	2346	234.60
Goats (No.)	200	1318	1118	559.00
Poultry Birds (No.)	5000	7686	2686	53.72
No. of Wells	76	320	244	321.05
Tractors (No.)		43		
Motor Cycle (No.)		169		
Jeep (No.)		26		
Sugarcane (ha)	86	405	319	370.93
Paddy (ha)	903	2099	1196	132.44
Groundnut (ha)	532	901	369	69.36
Nachani (ha)		89	89	
Jowar (ha)	489	384	-105	-21.47
Soyabean (ha)	33	236	203	615.15

(Source: Office of Taluk Agriculture Officer, Kagal)

Table: **5.15** Changes in crop yield in the watershed.

Crop	Yield, q/ha (Pre-treatment)	Yield, q/ha (Post-treatment)	% Change
Rice	16	19	18.75
Nachani	5	6	20.00
Groundnut	11	14	27.27
Soyabean	9	14	55.55
Tur	2	3	50.00
Rabi Sorghum	8	10	25.00
Green Gram	7	9	28.57

(Source: Office of District Supt. Agriculture Officer, Kolhapur)

2) The water level in the wells has increased That has satisfied the drinking water need and application of two or three irrigations during rabi season

3) The farmers preferred switching to agro-horticulture by introducing mango and sapota provided under NWDPRA project

4) The yield of various crops increased due to improved varieties and new package of practices These were advocated in the NWDPRA project This resulted in uplifting the socio-economic status of the farmers

5) The Cattle Care Center constructed under NWDPRA in the village Pirachi wadi is useful for the farmers for getting valuable guidance and treatments to the cattle from the veterinary doctor visiting weekly This has resulted in increase in cattle population

6) The Farmers' Hostel constructed under NWDPRA in the village Pirachi wadi is used for conducting meetings of farmers, lectures of experts and agricultural scientist The meetings and lectures are useful for the farmers for solving their personal, social and field problems

5.6 Problems Encountered by the Implementing Agency

Discussions were held with the executing field level and supervisory officials in the Department of Agriculture regarding their experiences in NWDPRA project implementation Based on these discussions the problems faced by the implementing agency during the implementation of the National Watershed Development Programme for Rainfed Agriculture (NWDPRA) project are enumerated below

5.6.1 Problems

1) Due to restrictions on the expenditure in NWDPRA some suitable sites for water harvesting structures could not be developed The cost norms pose problems in execution as the cost may vary with site

2) Unawareness amongst inhabitants of watershed regarding the programme causes delay and less utilization of funds This also causes the problem of maintenance of Soil and Water Conservation works

3) Interference of local politicians causes delay in programme implementation

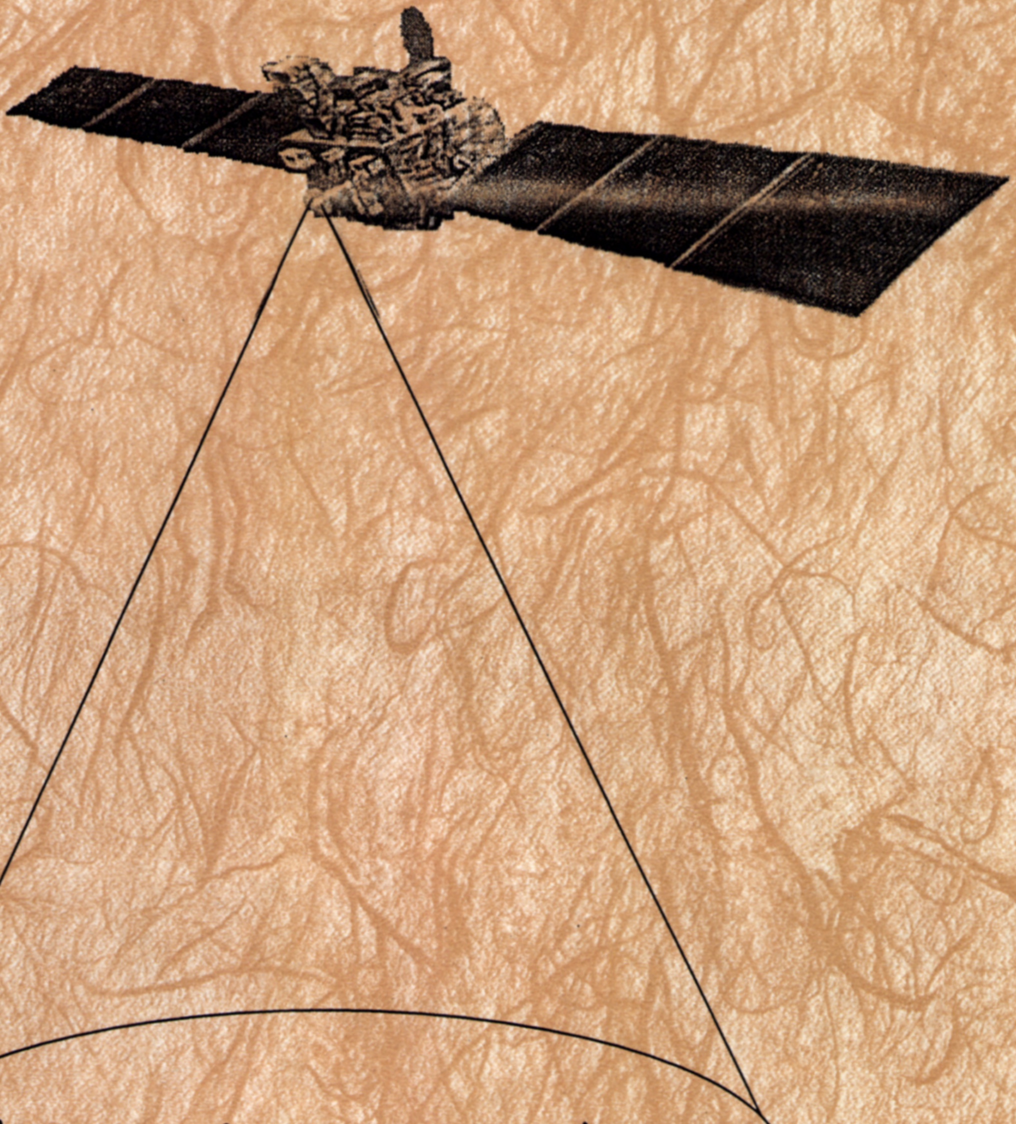
4) The concept of self-help group is difficult to implement

5) Pertaining research and guidance is lacking

5.6.2 Suggestions

Considering above problems, the views of field level officials, supervisory officials of Government department, remarks and views of the farmers and beneficiaries in the watershed following suggestions are made

1) There should be diagnostic approach instead of fixed cost norms A Division may be formed which will look after the design and estimation of various soil and water conservation structures
2) The disparity in norms posed as a problem can be removed by adopting above approach
3) The inhabitants must be educated and motivated first to obtain their full support and patronage to watershed development programme This will also eliminate the problem of forming SHGs and care and maintenance of Soil and Water Conservation works
4) Sufficient provision of funds under Research and Development should be made in the project itself to have need based solutions
5) The areas under forest and social forestry department also need to be developed in the watershed in order to accomplish this all such departments should be included in the watershed development programme
6) Improvement in participation and co-operation from all developmental departments in watershed development programme is necessary
7) Since all activities in watershed development can not be run simultaneously the headwise expenditure should be tallied at least after a year
8) There should not be disparity in norms of various projects of watershed development e g NWDPRA, WGDP, State programmes



SUMMARY AND CONCLUSION

6. SUMMARY AND CONCLUSIONS

The watershed, Sawarde Bk. (14/08/01 KR 69/2) was developed during the period of 1991-96 under the centrally sponsored scheme of NWDPRA. The development works were carried out by Soil Conservation wing of Department of Agriculture. The studies regarding the impact of watershed development activities were undertaken by using the Remote Sensing and GIS technique. The evaluation of watershed development programme was done based on four indicators, viz. change in land use pattern, vegetation index, runoff and socio-economic status. The first three indicators were studied using Remote Sensing and GIS technique whereas the fourth indicator, socio-economic status was studied by conducting field visits and interviews with the farmers and field level and Supervisory Officials.

The results of this study are summerised below.

6.1 Summary of Results

There is marginal increase (0.06 and 0.01 %) in the spread of water body in the watershed as well as in the buffer area.

There is 0.21 % increase in area under agriculture and 0.16 % increase in the area under plantation in the watershed. Mainly the fallow land has been converted into cropped land. The wasteland in the watershed has also decreased by 0.42 %.

The area under degraded forest and open forest in the watershed has decreased by 0.06 % and 0.03 % respectively and that under dense forest has increased by 0.09 %.

This has been clearly seen from the Normalised Difference Vegetation Index, which shows that the area under open vegetation and dense vegetation in the watershed has increased and the area under blank and degraded vegetation has decreased by 0.94, 6.98, 3.44 and 4.56 % respectively.

The weighted curve numbers in the sub watershed units 1, 2 and 3 have decreased by 1.94, 2.63 and 0.77 % and so the maximum potential retention has increased. Whereas the weighted curve numbers in the sub watershed unit 4 and 5 has increased by 2 24 and 0 86 % However the entire watershed shows lowering of weighted curve number from 74 74 to 74 35 thereby increasing the maximum potential retention from 85 85 to 87 63 mm

There is an increase in cropped land and average crop yields This has resulted in increase in income of the farmers There was increase in literacy percentage in the watershed

6.2 Conclusions

Based on the results of this study the author arrived at the following conclusions

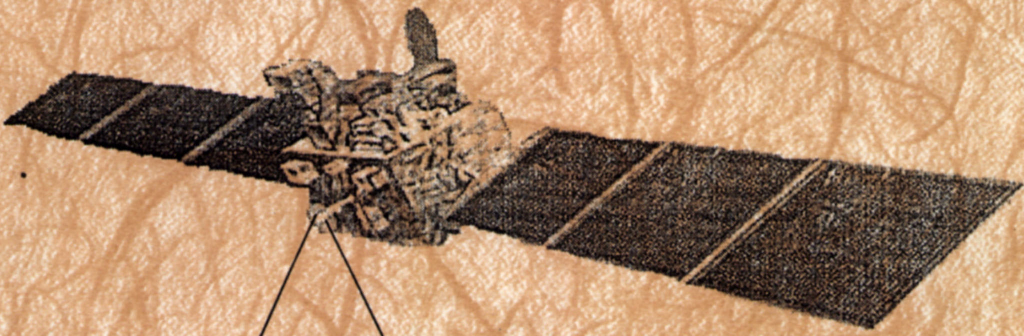
1 The area under agriculture in the watershed has increased and the fallow land has decreased after the watershed development programme

2 The area under blank vegetation and degraded vegetation has decreased and that under open vegetation and dense vegetation has increased

3 The watershed development has resulted in the decrease in the runoff from the watershed and slight increase in water harvesting

4 On the socio economic front the literacy and the level of education of the people in the watershed has increased

All these favour in uplifting the economic standard of the people in the watershed In all the effect of watershed development programme under NWDPRA at Sawarde Bk (14/08/01 KR 69/2)watershed is positive



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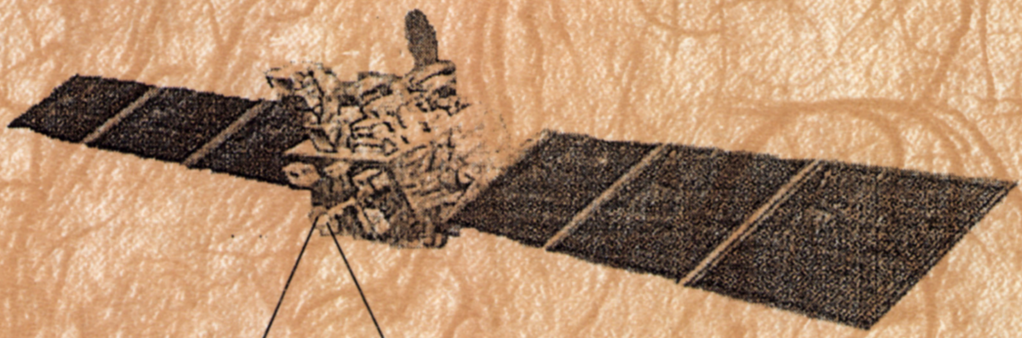

APPENDICES

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/upadhye/nkolgrd.pix

BX1 = "74^0 00'

BY1 = "16^0 15'

BX2 = "74^0 15'

BY2 = "16^0 30'

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 = sgihome5/rahuri/upadhye/l3_9661_nov98.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 = sgihome5/rahuri/upadhye/rsawarde_13_nov98.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 an 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 = sgihome5/rahuri/upadhye/rsawarde_13_nov98.pix

FILE = sgihome5/rahuri/upadhye/ rsawarde_13_nov98.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 = sgihome5/rahuri/upadhye/ rsawarde_13_nov98.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 = sgihome5/rahuri/upadhye/ rsawarde_13_nov98.pix

FILO = sgihome5/rahuri/upadhye/ rsawarde_13_nov98.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 = sgihome5/rahuri/upadhye/ rsawarde_13_nov98.pix

DBIC = 1,2,3

DBOC = 6,7,8

DBIB = 1

<STATUS>

<RUN>

8. 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 = sgihome5/rahuri/upadhye/ rsawarde_13_nov98.pix

DBVS = 1

FLDNME = ZCOORD

NEWSEG =

<STATUS>

<RUN>

9. 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) information held in a vector segment (type VEC: 116) to a text file. The use of an intermediate 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 = sgihome5/rahuri/upadhye/ rsawarde_13_nov98.pix

DBVS = 10

FILV = wsbound

VECEOFM = ARC

ARCID =

ACADATTR =

REPORT = sgihome5/rahuri/upadhye/wsboundary.lin

<STATUS>

<RUN>

APPENDIX – B

MODEL – Modelling Program

MODEL implements a high level modelling language, which can be used for GIS and imagery applications. MODDEL is a generalised image processing and raster GIS tool. Using a special programming language, the user enters a set of equations (MODEL) describing how channels of imagery data and attribute data should be combined. The result can be new channels of data and/or a text report.

Following global parameters controls MODEL:

Name	Prompt	Count	Type
FILE	Database File Name	1-64	Char
SOURCE	Source of model		
UNDEFVAL	Value for undefined operations		
REPORT	Report Mode:TERM/OFF/FILENAME		

FILE : specifies the name of the PCIDSK file to be used in modelling.

SOURCE : specifies the one of the three sources for the text holding the model equations.

"n" = number of text segment

"filespec" = name of the text file on disk

"text" = single line model to use directly

UNDEFVAL : optionally specifies the value that should be used for the result of numeric expressions which contain an undefined operation (such as division by zero or the logarithm of the negative value).

REPORT : species the text file to append any generated reports to.

The modelling program used for the present study is Normalised Difference Vegetation Index (NDVI). It is given by the equation:

$$NDVI = \frac{NIR - VR}{NIR + VR} \times 128 + 127.5$$

where,

NDVI= Normalised Difference Vegetation Index

NIR = Near Infrared Reflectance

VR = Visible Red Reflectance

(Only green vegetation has positive NDVI values. High values of NDVI being associated with higher densities /vigour of any given healthy phytomass.)

the NDVI model is applied to both pre and post treatment images by activating and running the MODEL program.

The source of model used for pre treatment image (File name: rsawarde_l2_oct89.pix) is:

source = % 6 = ((%4 - %3) / (%4 + %3)) * 128 + 127.5

where,

% 6 = the number of channel in which the model results are to be stored.

% 4 = Near Infra red band

% 3 = Infra Red band.

The source of model used for post treatment image (File name : rsawarde_l3_nov98.pix) is:

source = % 5 = ((%3 - %2) / (%3 + %2)) * 128 + 127.5

where,

% 5 = the number of channel in which the model results are to be stored.

% 3 = Near Infra red band

% 2 = Infra Red band.

NDVI Image Differencing:

The differencing of NDVI images generated for both pre and post treatment periods has been carried out to derive information on changes with reference to vigour/biomass. The resultant difference image was suitably scaled and colour coded highlighting the changes under significant, moderate and marginal categories. NDVI image differencing of two dates for forest vegetation is also done to derive progressive /retrogressive transformation details like open to closed, degraded to open categories etc.

In imaging applications, input is usually image channels containing raw imagery. In GIS, applications, input usually is attribute data and image channels containing data 'layers'. Layers may include raw imagery, elevation, classification themes, digitized maps and proximity maps.

A single PCIDSK database (FILE) is assumed to contain all the image channels/layers. Attribute data may be held in text files or as segments in the PCIDSK file. The text describing the model (SOURCE) is read in and the equations are applied to each pixel in the PCIDSK database. If the model specifically generates a report, then this is sent to the current report file (REPORT). Since imagery is often of unpredictable quality, it is possible to specify the results of undefined operations (UNDEFVAL) rather than have the MODEL program terminate immediately upon the detection of such an operation.

APPENDIX-C

Runoff Estimation

The different steps involved in determining runoff from the watershed are described below.

1) Preparation of Sub watershed units:

While determining the runoff from the watershed, the watershed was divided in five sub watershed units. The sub watershed units were made considering the stream network and contour network of the area. These five sub watershed units were used to determine the runoff in each unit.

2) Preparation of Land use/Land cover map

3) Preparation of Hydrologic Soil Group map

4) Matrix of Land use/Land cover and Hydrologic Soil Group

The program MAT was used to determine the different combinations of land use/land cover and the hydrologic soil group. The watershed comprises of eight land use/land cover classes and three hydrologic soil groups so in all 24 combinations are found by matrix analysis.

MAT creates a coincidence (intersection) matrix for the classes of two images and an image of the coincidence values. Classes within the input images can be recorded by MAT using tables created with REC. MAT is intended for use with thematic imagery of upto 256 classes (0-255). Channels other than 8 bits will be truncated. MAT is controlled by the following global parameters:

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

Parameter	Detail	Size	Type
FILE	Database File name	1-64	Char
DBIC	Database Input Channel List	2	Int
DBLUT	*Database Look Up Table Segments*	*0-2*	*Int*
DBOC	Database Out put Channel List	1	Int
MRV1	Matrix Column Recoded Values, Image 1	1-16	Int
MRV2	Matrix Column Recoded Values, Image 2	1-16	Int
REPORT	Report Mode:TERM/OFF/FILENAME	1-64	Char

<STATUS>

<RUN>

Example:

<XPACE>

<UTILITIES>

<LOCATE TASK>

MAT

<STATUS>

FILE = sgihome5/rahuri/upadhye/rsawarde_13_nov98.pix

DBIC = 10,1

DBLUT = 2

DBOC =

MRV2 = 1,2,3

REPORT = NOV98.MAT

<STATUS>

<RUN>

MAT creates a coincidence matrix for two images, with optional recording using a look up table created with REC. A cell in the i th column and j th row in the matrix represents the overlap of class I (or all classes that are recoded to class i) from image 1 and class j (or all that are recoded to class j) from image 2. Statistics are collected for each unique combination, and a report is generated. Note that the coincidence matrix is created for the recorded values of the images if the recode look up tables are specified. This recoding is done as part of the matrix analysis.

Each cell in the matrix is assigned a value depending upon its matrix address. An output image is created using, for each output pixel , the value in the matrix cell corresponding to the coincidence of the two recoded input classes (One from each of the input images). The maximum number of cells in the matrix is 256;since each cell maps onto one gray level (0-255), the maximum product of the number of entries in MRV1 and MRV2 is 256. Class (0) is reserved for "unclassified" areas; that is, the combination at that point is not in the cross product of MRV1 and MRV2. The last two "classified" cells in the matrix will have the same class of 255 ONLYIF there are sixteen entries in both MRV1 and MRV2.

The number of values in MRV1 determines the number of columns in the matrix. All recoded image values for DBIC (1) should be listed here; any recoded image values that are not in MRV1 will be shown as 'UNCLASSIFIED' in the matrix analysis.

The maximum product of MRV1 X MRV2 is 256, for 256 cells in the coincidence matrix.

MRV2: Specify the recoded values from DBIC (2) to be used in the (upto) 16 rows in the matrix.

The number of values in MRV2 determines the number of rows in the matrix. All recoded image values for DBIC (2) should be listed here; any recoded image values that are not in MRV2 will be shown as 'UNCLASSIFIED' in the matrix analysis.

REPORT: Specify the file to which the generated report will be appended.

5) Determination of curve numbers (CN) for different combinations of Land use/Land cover and Hydrologic Soil Group:

The different combinations obtained using matrix analysis were then used to determine the curve numbers from the standard table. The table showing CN values for different combinations of land use/land cover and hydrologic soil group is presented below

Table: Curve Number values for different Land use/Land cover and Hydrologic Soil Groups (AMC II)

Sr. No.	Land use/Land cover	Hydrologic Soil Group			
		A	B	C	D
1	Agriculture without conservation practices	72	81	88	91
2	Agriculture with conservation practices	62	71	78	81
3.	Pasture Land				
	Poor	68	79	86	89
	Fair	49	69	79	84
	Good	39	61	74	80
4.	Levelled pasture land Good condition	30	58	71	78
5.	Forest				
	Degraded	45	66	77	83
	Open	36	60	73	79
	Dense	25	55	70	77
6.	Fallow	77	86	91	94
7.	Land without scrub/forest blank	45	66	77	83
8.	Land with scrub	36	60	73	79
9.	Settlements	57	72	81	86
10.	Industrial district (72 % Impervious)	81	88	91	93
11.	Roads – DIRT	72	82	87	89
12.	Roads – Hard surface	74	84	90	92
13.	Roads – Gravel	76	85	89	91
14.	Water	100	100	100	100

6) Preparation of Text File (cnlut.txt):

A text file of the curve numbers for the different combination obtained by matrix analysis was prepared by using 'vi' editor. The file is then used for the preparation of look up table.

7) Preparation of LUT (Look up Table)

LUT enhances imagery on disk by passing it through 8 bit LUT segments and writing the resulting imagery back to disk. This allows bulk radiometric enhancement of the image data. LUT is controlled by the following global parameters:

Commands: <XPACE>

<UTILITIES>

<LOCATE TASK>

LUT

<STATUS>

Parameter	Detail	Size	Type
FILE	Database File name	1-64	Char
DBIC	Database Input Channel List	1-1024	Int
DBLUT	Database Look Up Table Segments	1-1024	Int
DBOC	Database Out put Channel List	1-1024	Int
MASK	Area mask (window or bitmap)	0-4	Int

<STATUS>

<RUN>

Example:

<XPACE>

<UTILITIES>

<LOCATE TASK>

LUT

<STATUS>

FILE = sgihome5/rahuri/upadhye/rsawarde_13_nov98.pix

DBIC = 10

DBLUT = 4

DBOC =12

MASK =

<STATUS>

<RUN>

8) LUTREAD

LUTREAD reads look up table data from the text file and write it to a look up table segment on a database file. MAT is controlled by the following global parameters:

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

Parameter	Detail	Size	Type
FILE	Database File name	1-64	Char
DBLUT	Database Look Up Table Segments	0-1	Int
DBSN	Database Segment Name	0-8	Char
DBSD	Database Segment Description	0-64	Char
LUTFORM	LUT Text form: ATT/INOUT/OUT	3-5	Char
TFILE	Text file	1-64	Char

<STATUS>
<RUN>

Example:

<XPACE>
<UTILITIES>
<LOCATE TASK>
LUTREAD
<STATUS>
FILE = sgihome5/rahuri/upadhye/rsawarde_13_nov98.pix
DBLUT =
DBSN = cnlut
DBSD =
LUTFORM = INOUT
TFILE = /sgihome5/rahuri/upadhye/cn.txt
<STATUS>
<RUN>

9) Determination of number of pixels under each CN for the five sub watershed units (HSTMASK):

The program HSTMASK was used to determine the number of pixels under each CN value under each sub watershed unit.

10) Determination of area from the pixel numbers:

The pixel numbers obtained by HSTMASK were converted to area by multiplying with 0.23 x 0.23. The area obtained was in hectares.

11) Weighted CN for the each sub watershed units:

The weighted curve number was obtained by taking the summation of the product of particular area and its CN value and dividing this sum by the total area of the sub watershed unit.

12) Calculation of maximum potential retention:

The maximum potential retention was calculated by the formula given below:

$$S = \frac{25400}{CN} - 254$$

where,

CN = Curve Number

13) Calculation of runoff depth using SCS-CN method:

The runoff depth was calculated by using SCS-CN method. The formula used is given below

$$Q = \frac{(P - Ia)^2}{(P - Ia + S)}$$

where,

Q= Runoff Depth, mm

P = Storm Rainfall, mm

Ia= Initial Abstraction, mm

S= Maximum Potential Retention, mm

The same procedure was followed for both the pre-treatment and post-treatment conditions and the runoff was estimated for both the conditions.

APPENDIX – D

Questionnaire

Activity:

Name:

Village:

Survey No.:

Area:

Before Implementation			After Implementation		
Crop	Area, ha	Yield, t/ha	Crop	Area, ha	Yield, t/ha

Farmers Remark:

APPENDIX – E

Changes in Socio-Economic Status and Remarks of Beneficiaries

Activity: Cement Bandhara

1) Name: Ramchandra Dhondi Malvekar.
Village: Sawarde Kd.
Survey No.: 296
Area: 2.19 ha

Before Implementation			After Implementation		
Crop	Area, ha	Yield, t/ha	Crop	Area, ha	Yield, t/ha
Ground nut	0.15	11.0	Ground nut	0.20	14.0
Tur	0.20	2.0	Sugar cane	0.80	-
Jowar	0.15	7.0	Jowar	0.20	9.0
Plantation			Mango	900 Nos.	

Farmer's Remark: Increase in .well water level. The water from the well is now sufficient for drinking, domestic, irrigating mango trees and half area of sugar cane. The water in the well is available upto the month of April-May, which usually get dried in the month of Jan-Feb before implementation of watershed development programme. Technical guidance is available from Field Supervisor from time to time. A try of 'Earthworm Culture' is also carried out but it might not be successful due to birds. Bench terracing works should be included in the developmental programme.

2) Name: Akaram Dattu Malvekar
Village: Sawarde Kd.
Survey No.: 696
Area: 6.0 ha

Before Implementation			After Implementation		
Crop	Area, ha	Yield, t/ha	Crop	Area, ha	Yield, t/ha
Ground nut	3	9.5	Ground nut	2.0	12.0
Tur	2	1.5	Rabi Jowar	3.0	3.0
			Sugar cane	1.0	
Plantation			Mango	175 Nos.	

Farmer's Remark: Increase in well water level after the construction of cement bandhara. In all 175 mango seedlings were received under NWDPRA in the year 1993-94 and the survival percentage of the plantation is 100 %. Their yield may start from this year. The second crop rabi Jowar is now possible due to construction of bandhara.

3) Name: Jagdish Sattaparao Kamble.
Village: Sawarde Kd.
Area: 3 ha

Before Implementation			After Implementation		
Crop	Area, ha	Yield, t/ha	Crop	Area, ha	Yield, t/ha
G. nut	3.0	12.0	G. nut	3.0	15.0
			Horse Gram	1.0	8.0

Farmer's Remark: Three acres of land came under double cropping. The new crop horse gram is introduced.

4) Name: Ramchandra Bandu Kamble
Village: Sawarde Kd.
Area: 2 ha
New crop: Rabi Jowar

Farmer's Remark: Two acres of land come under double cropping.

5) Name: Ganpati Aba Devadkar.

Village: Sawarde Kd.

Farmer's Remark: Double crop (rabi Jowar) is introduced after the construction of cement bandhara.

6) Name: Sadu Hari Malvekar

Village: Sawarde Kd.

Farmers Remark: Double crop (rabi Jowar) is introduced after the construction of cement bandhara.

7) Name: Keshba Krishna Tambekar

Village: Sawarde Bk.

Survey No: 429

Area: 2.5 ha

Before Implementation			After Implementation		
Crop	Area, ha	Yield, t/ha	Crop	Area, ha	Yield, t/ha
Ground nut	1.0	9.0	Ground nut	2.0	12.0
Jowar	1.0	7.5	Jowar	1.0	10.0
Tur	1.0	2.0	Tur	1.0	3.0
			Horse gram	1.0	8.0

Farmers Remark: Double crop (rabi Jowar) is introduced. Four acres of field can be cultivated in rabi season.

Activity: Diversion Dam

Village: Sonali

The total area benefited from this diversion drain is 12 ha. the farmers put gate during the last showers of rainy season and store the run off water. The stored water is used by them during rabi season or dry spells of the rainy season.

The farmers getting benefit from this structure are;

Sr.No.	Name	Area (ha)
1	Madhukar Sakharam Chougale	1.4
2	Dashrath Sakharam Chougale	1.4
3	Pandurang Sakharam Chougale	1.4
4	Narayan Sakharam Chougale	1.4
5	Balu Bhau Chougale	1.8
6	Bapu Tukaram Chougale	1.8
7	Shankar Bhau Chougale	2.0
8	Rambhau Dhondiram Chougale	0.8

9) Name: Tukaram Pandurang Malvekar
Village: Sawarde Kd.
Survey No: 279
Area: 0.62 ha

Farmers Remark: the water level in the well is increase and double crop (rabi Jowar) is possible after the construction of diversion drain.

10) Name: Bali Aba Patil
Village: Sawarde Bk.

Farmer's Remark: The water level in the well is increased. The water in the structure is used during dry spell. Initially the yield of paddy was 14 q/ha and now it is about 19 q/ha

11) Name: Tukaram Mane
Village: Sawarde Bk.

Farmer's Remark: The water in the structure is used during dry spell. Increment in yield.

12) Name: Namdevrao Rau Parit.
Village: Sawarde Bk.

Farmer's Remark: It is useful in dry spell. Four ha of area can be commanded.

13) Name: Chandu Rama Patole

Village: Sawarde Bk.

Farmers Remark: Double crop (rabi Jowar) is introduced. The water in the structure can be used during dry spell. Increment in the yield.

Before Implementation			After Implementation		
Crop	Area, ha	Yield, t/ha	Crop	Area, ha	Yield, t/ha
Ground nut	1.0	11.5	Ground nut	1.5	14.0
Soybean	1.5	12.0	Soybean	1.5	15.0
Nagali	0.5	4.0	Nagali	0.5	5.5
			Rabi Jowar	1.0	9.0

Activity: Check Dam

Village: Chaundal

Numbers : Two

The soil loss is reduced. The stored water can be used for irrigation.

Initially there were no double crops. Now the double crops introduced are maize, wheat, and horse gram. The sugarcane id also now tried successfully. At least 50% increase in yield is occurred.

The farmers getting benefit from these structures are

Sr. No.	Name	Area (ha)
1	Mahadev Bhagoji Repe	2.5
2	Dadu Yesba Repe	2.3
3	Dinkar Aba Repe	2.6

4) Name: Pandurang Dattu Mahatugade

Village: Sawarde Bk.

Farmers Remark: Double crop (rabi Jowar) is introduced. The water level in the well is increased.

5) Name: Tukaram Sakaram Chavan

Village: Sawarde Bk.

Farmer's Remark: Initially the yield of wheat was 11 q/ha and now it is about 16 q/ha.

6) Name: Anandrao Gopalrao Parit.

Village: Sawarde Bk.

Farmer's Remark: Double crop (six acre) come under irrigation. The water level in the well is increased.

7) Name: Baburao Gangaram Parit.

Village: Sawarde Bk.

Farmer's Remark: Double crop (three acre) come under irrigation. Two irrigations during rabi season can be possible from check dam.

8) Name: Shivaji Joti Parit.

Village: Sawarde Bk.

Farmer's Remark: Four acre of crop land came under double cropping. Two irrigation during rabi season can be possible from check dam.

9) Name: Kundlik Rama Kesarkar.

Village: Sawarde Bk.

Farmer's Remark: Double crop (wheat) is introduced. Increment in the yield.

10) Name: Dev Parsu Kashid

Village: Sawarde Bk.

Farmer's Remark: Rabi crops are benefited.

11) Name: Ganpati Bala Patil

Village :Sawarde Bk.

Farmer's Remark: Rabi crops are benefited.

12) Name: Shankar Sambha Patil

Village: Pimpalgaon

Farmer's Remark: Double crops are benefited and show increment in yield.

13) Name: Pappalal Keraba Kamble

Village : Pimpalgaon

Farmer's Remark: Double crops are benefited.

14) Name: Sanjay Babu Patil.

Village : Pimpalgaon

Farmer's Remark: Double crops are benefited.

15) Name: Ananda Sambha Patil

Village : Pimpalgaon

Farmer's Remark: Double crops are benefited two to three irrigation can be possible from check dam.

Activity: Plantation

1) Name: Tukaram Gundu Shinde

Village: Sawarde Kd.

Farmer's Remark: Fifteen Sapota (Chikku) and 25 coconut seedlings were received under NWDPRA. Yet the income from them has not been started but he is sure to get benefit from them.

2) Name: Ramchandra Dhondi Malvekar.

Village: Sawarde Kd.

Farmers Remark: Total 900 mango seedlings have been received under NWDPRA out of which 100 trees are of 5 years of age and their yield may start from this year.

3) Name: Akaram Dattu Malvekar

Village: Sawarde Kd.

Farmer's Remark: Under NWDPRA 175 mango seedlings were received in the year 1993-94 and the survival percentage of the plantation is 100 %. Their yield may start from this year.

Activity: Cattle Care Center

Village: Pirachi wadi

Under NWDPRA, Cattle Care Center is constructed in year 1995-96. The veterinary doctor visits the Cattle Care Center weekly and gives valuable guidance to the farmers.

Activity: Farmer's Hostel

Village: Pirachi wadi

Under NWDPRA, Farmer's Hostel is constructed in year 1995-96. The farmers' Hostel is used for conducting meetings of farmers, lectures of experts or agricultural scientists.


VITA

9. VITA

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SUHAS KALCHANDRA UPADHYE

A candidate for degree of

MASTER OF TECHNOLOGY

(Agricultural Engineering)

in

SOIL AND WATER CONSERVATION ENGINEERING

2000

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Title of the thesis : Studies on the impact of watershed development programme using Remote Sensing and GIS technique.

Major Field : Soil and Water Conservation Engineering.

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