REMOTE SENSING AND GIS FOR ASSESSING THE IMPACT OF INTEGRATED WATERSHED MANAGEMENT

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Requirement for the award of degree of

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By

Leya Sathyan

CENTRE FOR ENVIRONMENT
Institute of Science and Technology
JAWAHARLAL NEHRU TECHNOLOGICAL UNIVERSITY
Kukatpally, Hyderabad-500 072
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ICRISAT

International Crops Research Institute for the Semi-Arid Tropics

Headquarters: Patancheru 502 324, Andhra Pradesh, India
Tel +91 40 30713071 **Fax** +91 40 30713074 +91 40 30713075 **Email** icrisat@cgiar.org
Liaison Office: CG Centers Block, NASC Complex, Dev Prakash Shastri Marg, New Delhi 110 012, India
Tel +91 11 25849552/25842553/25849554 **Fax** +91 11 25841294

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TO WHOMSOEVER IT MAY CONCERN

This is to certify that the project work entitled "**REMOTE SENSING AND GIS FOR ASSESSING THE IMPACT OF INTEGRATED WATERSHED MANAGEMENT**" is a bonafied work of **Ms. Leya Satyan** which was duly completed by her under my guidance as a part of her MASTER OF TECHNOLOGY in Environmental Management to the Jawaharlal Nehru Technological University and her work and efforts are appreciated.

Suhas P Wani
Principal Scientist (Watersheds) and
Regional Theme Coordinator

CENTRE FOR ENVIRONMENT
INSTITUTE OF SCIENCE & TECHNOLOGY
JAWAHARLAL NEHRU TECHNOLOGICAL UNIVERSITY
Kukatpally, Hyderabad – 500 072.

Dr.P.VENKATESWARLU
Ph.D.
Associate Professor

CERTIFICATE

This is to certify that the dissertation work entitled " **REMOTE SENSING AND GIS FOR ASSESSING THE IMPACT OF INTEGRATED WATERSHED MANAGEMENT** " submitted by **LEYA SATHYAN** in partial fulfillment for the award of **Master of Technology in Environmental Management** to **JAWAHARLAL NEHRU TECHNOLOGICAL UNIVERSITY, Hyderabad.** It is a record of bonafide work carried out by her under my Internal Guidance. Her work is found to be satisfactory.

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

(P.VENKATESHWARLU)

INSTITUTE OF SCIENCE & TECHNOLOGY

JAWAHARLAL NEHRU TECHNOLOGICAL UNIVERSITY

Kukatpally, Hyderabad - 500 072

CENTRE FOR ENVIRONMENT

I / We certify that the dissertation work entitled **"REMOTE SENSING AND GIS FOR ASSESSING THE IMPACT OF INTEGRATED WATERSHED MANAGEMENT"** submitted by **LEYA SATHYAN** in partial fulfillment of the Master of Technology Degree of the Department is a bonafide work, and may be placed before the Examination Board for their consideration.

Dissertation Supervisors
(Dr.SUHAS P. WANI)

Approved

External Examiner **Head of the Department**

DECLARATION

The dissertation work entitled **"REMOTE SENSING AND GIS FOR ASSESSING THE IMPACT OF INTEGRATED WATERSHED MANAGEMENT"** has been carried out by me at **ICRISAT, Patancheru,Hyderabad, India** and **NRSA, Balanagar, Hyderabad, India**. This work is original and has been submitted to any university or institute for the award of any degree.

Leya Sathyan

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ABSTRACT

The ever-growing population and the resultant demand led to over exploitation of the finite natural resources in most of the parts of India in general and in Madhya Pradesh and Rajasthan in particular. The Indian economy is largely a rural one, hence the development of rural areas depends upon the optimum management of natural resources particularly the water resources. A drainage basin or water shed can be considered as a preferable unit for initiating water conservation and management practices. Watershed management is an integration of technology with in the natural boundaries of a drainage basin for land, hydrological, biotic and vegetative resources development to fulfill the population needs on sustainable basis. In the present work an attempt is made to create resource information system and to make an impact assessment study of watershed activities in selected watersheds spread in two states of India using the satellite data interpretation technique and GIS tools. In the study area (ICRISAT) International Crop Research Institute of Semi Arid Tropics in association with (BAIF) Bhartiya Agro Industries Foundation have initiated some watershed treatment activities in the year 1998 consisting of structures like earthen check dam, permanent check dam, farm ponds and stop dams. This work created a database both spatial and non-spatial with the help of (SOI) Survey of India toposheets and Indian remote sensing satellite imageries for the period 2004.The data base consisted of drainage map (representing all the streams up to 4th order, landuse/landcover map etc. All the thematic layers are integrated with socio-economic attribute information detailing about the socio-economic status of the area. To evaluate the impact of the structures constructed the Remote Sensing technology (ERDAS Software 8.7) and GIS tools (Arc-Info 8.0) are used to create the (NDVI) Normalized Differential Vegetative Index to understand the change in terms of vegetative indices. Satellite imageries of 1997 that is before the commencement of

watershed treatment activities and imageries of 2004 that is after five years of initiation of watershed treatment, are interpreted adopting digital image processing concept to generate the NDVI. The positive and negative impacts can be clearly established with this approach. In terms of socio-economic status also the impact created is examined considering the parameter, basic amenities, literacy rate, migration of labour, per capita income etc for the same periods.

The cursory examination of the water level data along with change in number of wells says that as a whole in spite of significant increase in the number of open wells, tube wells and hand pumps from 1997-2004, there is an remarked increase in the groundwater table level though there is no considerable change in the average annual rainfall. The NDVI study also reveals that there is a significant drift towards the positive value conveying an increased greenness index. The yield impacts of certain identified crops like jowar, maize and bajara express an average increase from five to ten quintals per hectare

The impact assessment indicators developed in this study will serve as a model to adopt elsewhere under similar environments.

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1.INTRODUCTION

1. INTRODUCTION

1.1 GENERAL

World oceans cover about three fourth of earth's surface. According to the UN estimates, the total amount of water on earth is about 1400 million cubic kilometers (m.cu.km), which is enough to cover the earth with a layer of 3000 meters depth. However the fresh water constitutes a very small proportion of this enormous quantity. About 2.7 per cent lies frozen in Polar Regions and another 22.6 per cent is present as groundwater. The rest is available in lakes, rivers, atmosphere, moisture, soil and vegetation. What is effectively available for consumption and other uses is a small proportion of the quantity available in rivers, lakes and groundwater. The crisis about water resources development and management thus arises because most of the water is not available for use and secondly it is characterized by its highly uneven spatial distribution. Accordingly, the importance of water has been recognized and greater emphasis is being laid on its economic use and better management.

The importance of water resources management through adequate watershed rehabilitation and conservation is increasing. Watershed development and management is evolving as a useful mechanism to address the two most common water resource problems in India. Firstly, it aims to address the problem of water availability resulting from an increased demand on a resource rendered fragile due to irregular and erratic rainfall. However, the watershed development model also offers an effective medium to tackle larger natural resources management problems arising out of a competition for the limited resources that often results in conflict at various levels. Water is required for food production, for hydroelectric energy, and for domestic and industrial use of country's large population. Watershed management is required to mitigate the effects of flood and drought and to provide a livelihood for the large number of ethnic minority groups living in the country.

The present study signifies the effective use of Remote Sensing and GIS for watershed monitoring and impact assessment studies on the watershed program. The present approach essentially aim at understanding physical framework of watershed with the help of remote sensing data, field data and link this information to existing cadastral information in order to assess the impact of watershed program in remote villages of Madhya Pradesh and eastern Rajasthan.

1.2. WATERSHED MANAGEMENT: -

"Watershed is a geo-hydrological unit draining run-off water at a common point and it could be demarcated based on ridge and gully lines".

The term "watershed" refers to the divide separating one drainage basin from another and derived from Greek word "wacsercheid". However, over the years, the use of term watershed to signify a drainage basin or catchments area has come to stay. Hydrologically watershed could be defined as an area from which runoff drains through a particular point in a drainage system or it is also defined as a hydrologic or geomorphologic area of land that drains to a particular outlet.

Since water follows a definite flow course watershed becomes an ideally hydrologic unit for carrying out developmental activity related with water management. Watershed approach for optimal planning, development and management aims at harnessing all natural resources for sustainable development and better living. The factors that play a greater role in planning and development process of a watershed are its size, shape, physiography, slope, climate, drainage, geomorphology, soils, soil erosion zones, land use/land cover and groundwater etc.

Watershed management is an integration of technology within the natural boundaries of a drainage area for optimum development of land, hydrological, biotic, vegetative resources to meet the basic minimum needs of population in a sustainable state. Every watershed in this world is unique and shall be dealt according to its environment, natural resources and requirement. There are no hard and fast guidelines common in all for development.

Watershed management is unique approach for development of rain-fed area on sustainable basis. In India 35% of irrigated land produces 55% of total production while 65% of rained lands produce 45% food produce. Therefore it is clear indication that the rain-fed area shall be emphasized for development by watershed development management.

The watershed exists naturally and due to human intervention for agricultural purposes the changed ecology and management practices affect the well-equilibrated ecologies. If watersheds are not managed properly then natural resources are degraded rapidly and in due course cannot be used for betterment of humans. Soil water and vegetation are the most important natural resources for the survival of human beings and animals. . The poor in the rural areas, who are struggling for survival, cannot be expected to pay, adapt to conservation strategies, unless their daily needs of food, fiber and fuel are met. A still more urgent need is for assured work and full employment for all. Integration of many scattered program of soil conservation, afforestation, minor irrigation, and other development activities into well prepared micro watershed projects based on a study of climate, land, water and plant resources on the land and human and animal resources, offers scope for bringing about sustained natural resources development. ICRISAT in partnership with National Agricultural Research Systems (NARS) have developed an innovative and upscalable model of participatory integrated watershed management (Wani et al ,2002b). Thus this model convergence of different activity, community participation from planning to monitoring stage, technical backstopping by the consortium of government, non-government organization (NGO'S), national and international research institutions are important components. Further, watershed management or water management is used as an entry point activity and such programs are made as livelihood improvement program in the rural areas. (Wani et al, 2003)

The main source of water is by rain, most of it drains of and only a little percolates in ground. India receives 400 million-hectare meters (mham) of rainfall per annum, out of it only 50 mham filters down, while 115 mham are lost to sea in form of run-off and rest is evaporated. This groundwater is exploited for irrigation purposes year round for water mostly for intensive cropping. Punjab 98%, Haryana 80%, Tamilnadu 60% are in race for groundwater exploitation and its ill effect result in acute depletion of groundwater level. The groundwater is similar to bank account, unless one saves, it is not be available in hour of need. It takes years to replenish and to replace the exploited groundwater to minimum level, after following watershed management techniques. Therefore rain-fed region, planning and water management techniques can save and store water resource during rainy season for optimal utility and which also increases groundwater aquifer level.

India has 15% of world's cattle population, 46% of world's buffalo 17% of goat and first largest producer of milk in the world But average Indian child suffer from mal-nutrition, even the per capita milk consumption is very less while compared to few under developed countries. The resource management is just going in unorganized and neglected. The contribution of livestock-based activity to economy is far less compared to small countries of that of, New Zealand, Switzerland and other countries in pastoral and dairy produce.

The natural resources in the semi-arid tropics (SAT) are the "life line" of rural livelihood, the key occupation being agriculture. These dry eco-regions are predominantly rain-fed, marginal and fragile and prone to severe land degradation. Unpredictable weather, limited and erratic rainfall with long intervals of dry spells, and intense rainfall causing runoff and severe soil erosion characterize these dry regions. The over exploitation and reduced recharge of groundwater, along with low rainwater use efficiency is another serious threat to scarce water resource in dry regions. Low level of soil organic matter, accompanied by high rates of organic matter degradation aggravated by low literacy and poverty are the major cause of low productivity and depleting natural resource base in the dry regions (Wani et al 2003). The challenge, therefore, is to develop sustainable and environmental friendly option to manage natural resources in this fragile ecosystem to increase the productivity and incomes of millions of poor farmers who are dependent on the natural resources for their survival. The way forward to address this gigantic task is by sustainable management of natural resources in a manageable land unit, which is a watershed.

1.3. BASIC DATA NEEDS FOR WATERSHED MANAGEMENT

- Physical data such as location, physiography, drainage, soil, vegetation, geology, and climate, hydrologic and other relevant site characteristics.
- Watershed is a basic unit of management, a proper framework of delineation of watershed at macro and micro level.
- Present land use, nature and extent.
- Socio-economic, cultural and traditional system.
- Land tenure systems, legislation, by-laws, land facets and its problems (arable, non-arable and drainage line etc.)
- Existing stage of development and infrastructure.,
- Economics of development activities, rates of return, willingness and acceptance of program by local people, any impediments to implementation, operational conveniences and difficulties etc.
- Technology available on conservation and production and its application.
- The above information ought to be collected for identified watershed

area by undertaking various types of land resources and socio-economic surveys.

1.4. WATERSHEDS IN INDIA

Approximately 170 million hectares in India are classified as degraded land, roughly half of which falls in undulating semi-arid areas where rain-fed farming is practiced. Long- term experiments by a number of research organizations in India in the 1970s and 1980s confirmed that the introduction of appropriate physical barriers to soil and water flows, together with re vegetation, could generate considerable increases in the resource productivity. These, in turn, stimulated the formulation of a number of government projects, schemes and programmes in support of micro-watershed development.

In India, micro-watersheds are generally defined a falling in the range 500-1000 ha. A macro-watershed is equivalent to a river basin and may encompass many thousands of hectares. The micro-watershed concept aims to 'establish an enabling environment for the integrated use, regulation and treatment of water and land resources of a watershed-based ecosystem to accomplish resource conservation and biomass production objectives' (Jensen et al.1996)

Although a macro-watershed may be a sensible planning unit from a biophysical perspective, many would argue against the appropriateness of such a unit for rural development. Social institutions to promote cooperation-needed to protect and rehabilitate private and common-pool resources-are usually village based. Often, however, biophysical and socio-political boundaries do not coincide. The majority of project does not, therefore, strictly entail the development of 'a watershed'; rather they adopt an approach to rural development incorporating principles from the watershed approach.

1.5. WATERSHED PROGRAMMES IN INDIA AND OTHER ASIAN COUNTRIES

In India about 35 percent of the agricultural land is under assured irrigation while remaining 105 million hectares are depended on rainfall. It is estimated that generally about 30-35 percent of the rainwater is being utilized for crop production, while the remaining 65-70 percent is lost as runoff, deep drainage and evaporation. In this process of water runoff, a huge volume of topsoil is also washed away. The estimated annual loss of fertile soil in India is 1.2 billion tones. With this over 8.9 million tones of mineral nutrients are also lost from the field annually, which is equivalent to the total quantity of fertilizer produced in the country. Hypothetically, our agricultural production can be managed without any chemical fertilizer, if we can prevent soil erosion. This can be achieved by watershed management. (Hegde et al., 1998)

Central and state governments, donors and NGOs have all been involved in implementing watershed programmes in India. Although the details vary with different projects, the basic institutional structures are similar. Money flows to a project implementing agency (either a government or non-government organization) which works closely with a village-level body, a watershed committee- to design and implement project activities.

Natural resources through out the world, particularly in Asia where demographic pressures are veiy high, are under severe threat. The need to improve the management of natural resource for meeting the food, feed and fuel needs of the ever-increasing population is urgent.

ICRISAT along with its stakeholders have established benchmark watersheds in India, Thailand, Vietnam and China.

The stakeholders include scientific organization, agricultural universities, non-government organizations and farmers.

1.6. ASSESSMENT OF THE WATERSHED MANAGEMENT PRACTICES

The watershed programs are undertaken for managing natural resources and improving agricultural productivity thereby improving the rural livelihoods. However, the expected benefits from these investments are not realized most of the times which is mainly due to lack of peoples participation (as people and livestock are an integral part of watershed community and should be given utmost importance.), lack of scientific inputs, compartmentalized approach with maximum emphasis on construction of rainwater harvesting structures (many of which are of poor quality) lack of tangible economic benefits to individuals, involvement of contractors for executing works, and non involvement of landless families and marginal land holders.(Farrington and Lobo 1997,Kerr et al 2000, Wani et al.2002a, 2002b).

1.7. IMPACT ASSESSMENTS AND IMPLEMENTATION IN PROJECT

"Environmental impact assessment" can be defined as the systematic identification and evaluation of the potential impacts (effects) of proposed projects, plans, programs or legislative actions relative to the physical, biological, cultural and socioeconomic components of the total environment (Lauy W.Canter Environmental impact assessment).

Soon after the implementation of the suggested project or action plan, the area undergoes transformation, which is monitored regularly. Such an exercise not only helps in studying the impact of the program, but also enables resorting to mid-course corrections, if required. Parameters included under monitoring activities are land use / land cover, extent of irrigated area, vegetation density and condition, fluctuation of groundwater level, well density and yield, cropping pattern and crop yield, occurrence of hazards and socioeconomic conditions.

The major concern of watershed development efforts has been attaining sustainable impacts on poverty and the environment after the end of interventions. For sustaining the benefits of convergence through watershed management approach beyond the project period, it is essential to identify the mechanisms that build the capacity of the community for self-regulation and management.

The need for project monitoring and impact assessment becomes clear as it helps in mid-course corrections. The project strategy being evolutionary and based on lessons learned during implementation, experience from current project would benefit other parallel projects working in the same mode. Also cross-site lessons can be learned and experiences would benefit to improve project implementation. Project monitoring and impact assessment will assist decision makers and policy makers to evaluate the project objectively.

The strategic approach for project monitoring and impact assessment begins with the preparation of inventory baseline data covering socioeconomic, natural resource base, and inputs and outputs for each watershed. This is followed by continuous monitoring and documentation by the Project Implementing Agencies (PIAs). The approach also encompasses impact assessment before project completion and process documentation. The key instruments are participatory rapid appraisals, stratified sampling, detailed surveys, objective verifiable indicators (qualitative and quantitative), GIS based analysis, feedback from the PIAs through regular reports, tour notes from project staff, feedback evaluation from experts/visitors, and impact assessment reports.

1.8. REMOTE SENSING

Remote sensing is broadly defined as collecting and interpreting information about a target without being in physical contact with the object. (Sabins, 1987). Remote sensing is the examination of, obtaining information about an object or phenomena at a distance from it, without physical contact with it, particularly by a device based on the ground, by sensors carried aboard ships or aircrafts or spacecrafts or satellites orbiting the earth, which gather data at a distance from there source (landsat, Skylab, space shuttle spot)(Clark, 1989)

Remote sensing is a science and art of obtaining information about an object, area or phenomena through the analysis of data acquired by a device that is not in contact with the object area or phenomena under investigation. (Lilesand and Kiefer, 1994), Demus (1997) also defined Remote sensing as 'the observation of objects or group of objects, normally at a distance, most often with the use of some form of mechanical or electronic device for later retrieval. All such methods often relay on sensing devices far removed from the observer and are therefore collectively called Remote sensing.

Remote sensing has become an integral part of information technology and provides solution to facilitate sustainable development of especially the natural resources and conservation of environments at varying scales. The greater distance between the sensing platforms and its objects allow the satellite to view large area synoptically at each instant. In addition, because satellite-sensing devices are orbiting the earth, they are able to sense much of the planets in fraction of time that would be needed by a conventional air borne sensing devices.

For optimal utilization of natural resources, information on their nature, extent and spatial distribution is a prerequisite. Until the 1920s such information had been collected by conventional surveys, which are labour-intensive, cost- prohibitive and are impractical in the inhospitable terrain. During the 1920s and early 1970s, aerial photographs were used for deriving information on various natural including land subject to degradation by various processes (Bushnell1929, USDA 1951, Howard 1965, Iyer et.al.,1975).

Since the launch of the Earth Resource Technology Satellite (ERTS-1), later renamed as LandSat-1 in 1972, followed by Landsat-2, 3,4 and5, SPOT -1, 2, 3and 4 and the Indian Remote Sensing Satellites (IRS1A, 1B, 1C and 1D) with linear Imaging Self-Scanning sensors (LISS-I, II, III and IV), space borne multispectral data collected in the optical region of the electromagnetic spectrum have been extensively used in conjunction with the aerial photograph and other relevant information supported by ground truth, for deriving information on geological, geomorphological and hydro-geomorphological features (Rao et al,1996a, Reddy et al.1996); soil resources (Singh and Dwivedi 1986) landuse/landcover (Landgrebe 1979, Raghavaswamy etal.1992, Rao,et al.1996b);forest resources (Dodge and Bryant 1976, Unni 1992, Roy et al 1996)

Furthermore, space borne multispectral data has been operationally used for integrated assessment of natural resources and subsequent generation of action plans for land and water resources development and for assessment of the impact of their implementation.

Biomass has been used as a surrogate measure to evaluate the impact of the implementation of action plan for land and water resources development. High absorption of incident sunlight in the visible red (600-700 nm) portion and strong reflectance in the near infrared (750-1350 nm) portion of electro magnetic spectrum has been used to derive vegetation indices, which indicate the abundance and condition of biomass. The index is typically a scene, difference ratio, or other linear combination of reflectance factor or radiance observations from two or more wavelength intervals. The vegetation indices thus developed are highly correlated with the vegetation density or cover, photo synthetically active biomass (Tucker 1979, Wiegand and Richardson 1984); leaf area index (Weigand et al.1979) Greenleaf density (Tucker et al.1985); photosynthesis rate (Sellers 1987); and amount of photo synthetically active tissue (Wiegand and Richardson 1987, Dwivedi et. al., 2003)

Indian Remote Sensing Satellite IRS-1D, 1C, P6, LISS III and LISS IV data have been used for deriving NDVI and Differential NDVI to assess the impact in the watersheds.

National Remote Sensing Agency (NRSA), Hyderabad, India provided the Indian Remote Sensing Satellite (IRS-1C, 1D,P6) data for developing and managing watershed efficiently as well as for monitoring the impact of various interventions made in the watershed.

IRS-1C/1D-Sensors and Characters:

IRS 1C and 1D are characterized by improved spatial resolution, extended spectral bands, stereo viewing and faster re-visit capability.

IRS 1C/1D satellite operates in a circular, sun synchronous, near polar orbit with an inclination of 98.96 degrees, at an altitude of 817 km in the descending node. The satellite takes 101.35 minutes to complete one revolution around the earth and completes about 14 orbits per day. The entire earth is covered by 341 orbits during a 24-day cycle.

The mean equatorial crossing time in the descending node is 10.30 hrs ± 5 minutes. The orbit adjust system is used to attain the required orbit initially and is maintained throughout the mission period. The ground trace pattern is controlled with ± 5 km of the reference ground trace pattern.

Sensor Characteristics:

IRS-1C/1D satellite carries three sensors, which are characterized by enhanced resolution and coverage capabilities with a repeatability period of 22 days. Table shows the specification and resolution of all the three sensors.

Table 1.1 IRS-1C/1D Sensor Characters and Specifications

Sensor No.	IRS-1C/1D Sensors	Sensor Characters and Specifications		
		Spatial resolution (m)	Swath (Km)	Spectral Bands (μm)
Sensor-I	Panchromatic (PAN)	5.8	70	0.5-0.75
Sensor-II	Linear Imaging Self-scanner-III (LISS-III)	23.5	141	Visible & NIR 1.55-1.70
Sensor-III	Wide Field Sensor (WiFS)	188.3	810	0.62-0.68 0.77-0.86

Resourcesat-1 / IRS P6 Sensors and Characters

Resourcesat-1 is conceptualized and designed to provide continuity in operational remote sensing with its superior capabilities. The main objective of Resourcesat-1 is not only to provide continued remote sensing data for integrated land and water management and agricultural and it's related applications, but also to provide additional capabilities for applications. Apart from making data available in real time to Ground Stations in its visibility area Resourcesat-1 with it's ability to record data anywhere in the world with its advanced On Board Solid State Recorder (OBSSR), has entered into new dimensions of meeting the requirements of Resource Managers globally.

Table 1.2 IRS-P6 Sensor Characters and Specifications

ORBIT AND COVERAGE DETAILS	
Orbits / cycle	341
Semi major axis	7195.11
Altitude	817 Km
Inclination	98.69 deg
Eccentricity	0.001
Number of orbits/day	14.2083
Orbit period	101.35 minutes
Repetitivity	24 days
Distance between adjacent paths	117.5 Km
Distance between successive ground tracks	2820 Km
Ground trace velocity	6.65 Km / sec
Equatorial crossing time	10.30 +_ 5 min A.M (at descending node)

Sidelap and overlap between scenes						
Payload	Resolution Meters	Swath kms	Revisit	Image Size kms x kms	Overlap Kms	Sidelap Equator kms
LISS III						
Visible	23.5	141	24 days	142 x 141	7	23.5
SWIR	23.5	141	24 days	142 x 141	7	23.5
LISS IV						
Mono	5.8	70	5 days	70 x 70	2.5	5 (with in L3)
Mx	5.8	23	5 days	23 x 23	14.2	
AwiFS						
	50 (Nadir)	737	24 days	738 x 737	82 %	84 %
	70 (End Pixel)					

1.9. ROLE OF GEOGRAPHIC INFORMATION SYSTEM IN WATERSHED APPLICATIONS

Geographic Information System is a system for capturing, storing, checking, manipulating, analyzing and displaying data, which are spatially referenced to the earth. (DOE, 1987,P-132). GIS is any manual or computer based set of procedures used to store and manipulate geographically referenced data. (Aronoff, 1989,P-39)

GIS can play an important role in inventory and data handling activities of land use and land cover. A GIS accepts, organize, analyze statistically and display various types of spatial information. These variables are achieved in a computer compatible digital formula as a reference or database. Database represents various kinds of aerial information e.g.; terrain description, soil and lithology types, land cover and land use, population density and climate etc.

Elements: There are five basic technical elements in a GIS, viz., encoding, data input, data management, manipulative operations and output products.

The spatial information is encoded as points, lines or polygons. These indexing systems are called as (i) grid cell or raster coding and (ii) polygon or vector coding. The former is basically a matrix system where the information can be collected by a systematic array of grid square or grid cells. Their grid cells are functionally identical to the pixels or picture elements, which compose a digital image. In the second system (vector coding) each aerial unit containing the desired attribute data is digitally encoded and stored. This is also known as polygon coding.

There is a digitizer that converts the map data (analog information) to digital number. Data management helps in the successful operation of a variety of data in GIS. The data management system performs data entry, storage, retrieval and maintenance through its computer.

GIS are capable of performing the surface analysis and overlay analysis. Surface analysis for instance, comprises of the inclusion of soil categories, their analysis and labeling according to agricultural value. In the automated overlay analysis, the GIS overlay two or more data plains and explicit their relationships. Finally the GIS can retrieve and display data in tabular or graphic form or both. The system can produce hard copies, charts, scatter diagram, tables and maps.

1.10. OBJECTIVE OF THE STUDY

The overall goal of this study is to enhance the benefits of integrated watershed management programs by using GIS and Remote Sensing data for assessing the impact. The specific objectives are:

1. To prepare spatial database and attributes for the selected three micro watersheds viz; Bundi watershed in Rajasthan and Lalatora in Vidisha and Guna watersheds in Madhya pradesh.
2. To apply GIS and satellite imageries for assessing impact of various interventions in the watershed on vegetation, water availability and groundwater quality.

2.REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

The impact assessment studies of a particular watershed to answer the following:

- What has been the role of watershed projects in achieving the objectives of improving natural resource management, agricultural development and livelihoods of different groups of rural people?
- What approaches to watershed development have worked best to achieve these objectives?
- What other factors besides watershed projects help determine the achievement of these objectives?

Assessing the performance of watershed projects requires examining the determinants of agricultural and rural development from a broader perspective. Regardless of the efforts of any given development project, conditions in rural areas are determined by a variety of other factors, such as infrastructure, access to markets, social institutions in the villages, and agro-ecological conditions. Because watershed projects do not operate in isolation from other forces.

2.1 NORMALIZED DIFFERENTIAL VEGETATION INDEX (NDVI)

The NDVI is commonly used vegetation index in remote sensing studies because it is roughly correlated with green plant biomass. The NDVI is based on the relative spectral (i.e., height) reflectance values in the red and near infrared (NIR) wavelengths.

$$NDVI = \frac{IR - RED}{IR + RED}$$

Vegetation indices are commonly used to reduce effects of atmospheric conditions or different soil backgrounds on spectral reflectance values. The amount of red solar energy reflected by vegetation cover depends primarily on chlorophyll content, whereas the amount of near infrared energy reflected by vegetation is affected by the amount and condition of green biomass, leaf tissue structure and water content. (Jensen, 1996)

The remote sensing data is used extensively for large area vegetation monitoring. Typically the spectral bands used for this purpose are visible and near IR bands. Various mathematical combinations of these bands have been used for the computation of NDVI, which is an indicator of the presence and condition of green vegetation. These mathematical quantities are referred to as Vegetation Indices. There are three such indices, Simple Vegetation Indices, Rational Vegetation Indices, and Normalized Differential Vegetation Indices.

These indices are computed from the equations

$$VI = NEAR\ IR - RED$$

$$RVI = RED / NEAR\ IR$$

$$NDVI = (NEAR\ IR - RED) / (NEAR\ IR + RED)$$

Land surfaces are characterized by a high degree of spatial heterogeneity of surface cover. These types have associated references in emissivity, thermal properties and reflectance characteristics (Mathews and Rossow, 1987). Satellite studies show that the soil moisture and vegetation parameter like vegetation status, leaf area density and photosynthetic activity are not independent. Naturally, vegetated surfaces can fill moisture from within the soil and may show signs of stress rather than adjacent arable land. Therefore there is close relationship between meteorological drought indicators and satellite based indices of vegetation activity (Walsh, 1987).

Photosynthetically active vegetation typically has a reflectance of < 205 in the narrow band visible (0.5- 0.7μm) but a much higher reflectance up to 60% in the near IR (0.7 –1.3mm).

The NDVI is bounded ratio that ranges between –1 to +1.clouds, snow, and water have the negative NDVI since they are more reflective in visible than near IR wavelengths. Soil and rock have a broadly higher reflectance giving NDVI close to '0'. Only active vegetation has a positive NDVI typically between about 0.1 and 0.6 values at a higher end of the range indicating increased photosynthetic activity and a greater density of the canopy (Tarpley et al 1984).

Musa et.al., (1998) used integration of R.S and GIS to produce map that classified groundwater potential zone to either very high, high, moderate, low or very low in terms of groundwater yield in Langat Basin. It was concluded that almost all alluvial plains have a high potential for groundwater occurrence. Meanwhile in the hard rock area groundwater potential is in the high-density lineament zones.

Rasmussen (1998) developed simple operational, consistent NDVI-Vegetation models by applying environmental and climatic information. Millet yield was assessed using AVHRR NDVI data. Two years data showed that on linear regression line between grains yield and integrated NDVI could be statistically justified.

Khan et.al (1999) in their case study "Watershed prioritization using remote sensing and geographical information system, worked on of selecting watersheds to under take soil and water conservation measures using remote sensing and Geographical Information System (GIS) techniques. Using the terrain information derived from geocoded satellite data and 1:50,000 topographic maps, 68 watersheds were assessed on the basis of their erosivity and sediment-yield index values. Thematic maps of landform, land-use and land-cover, and slope were digitized using ARC/INFO. On the basis of sediment yield index values the watersheds were grouped into very high, high, moderate and low priorities. High priority watersheds with very high SYI value (>150) need immediate attention for soil and water conservation whereas, low priority watershed having good vegetative cover and low SYI value (<50) may not need immediate attention for such treatments

Dwivedi et.al., (2001) in their case study "evaluation of impact of implementation of soil conservation measure in Ghod catchments, Maharastra" discussed the changes in biomass of the catchments over a period of time by generating temporal NDVI for kharif and rabi seasons. Discussed the changes in the agricultural land use, crop cover, cropping pattern, crop production etc as well as change in soil erosion, land degradation, change in groundwater table, irrigation area etc. The study has vividly brought out the impact of soil conservation measures employed in the catchments in terms of development of biomass changes in agricultural land use by improvement in eroded lands and groundwater recharge.

Dwivedi et al.,(2001) carried out resource inventory for Adarsh watershed, impact assessment using temporal satellite data.

Khan and Moharana (2002) conducted studies to delineate and characterize groundwater prospect zones using R.S and GIS. The information on lithology, structure, geomorphology and hydrology were generated and integrated to prepare groundwater map for a region in western Rajasthan. The information on nature and type of aquifer, type of wells, depth range, yield range, success rate and sustainability were supplemented to form a good database for identification of favorable zones. GIS was used to prepare database on the above layers. Four categories of groundwater prospect zones high, moderate, low and very low are delineated.

Jayakumar and Arocklasamy (2002) made an attempt to study the land use/ land cover and change detection analysis in Kolli hill, part of Eastern Ghats of Tamil Nadu using R.S and GIS. They observed 467 ha increase in single crop category and 434 ha decrease in the land with or without scrub category. Lesser changes were noticed in double crop plantation and barren/ rocky categories. Suggestion was given to use the identified wasteland for agriculture, to improve the economy of the people.

Lim and Kafatos (2002) developed new methods to study and monitor changes in the distribution of vegetation in North America. NDVI, which is a level 3 data product from channel 1 and 2 of NOAA/AVHRR pathfinder, was used. Frequency analyses for uniformly divided NDVI range was used to study inter annual trends in vegetation greenness levels and Southern Oscillation Indices (SOIS). Long term increase in vegetation greenness on decadal time scale for some region in North America is suggested.

Jaiswal et.al. (2003) in their case study " Role of R.S. and GIS techniques for the generation of groundwater prospect zones towards rural development....an approach" extracted information on lithology, geological structures, land forms, landuse/landcover from remotely sensed data and drainage networks. Soil characteristics and slope of the terrain using conventional methods and then integrated in a GIS environment to depict village wise groundwater prospect zones. This study was carried for the Gorna sub-basin a part of the Son watershed, Madhya Pradesh, India.

Tottrup and Rasmussen(2002) did study for mapping long-term changes in savannah crop productivity in Senegal through trend analysis of time series of remote sensing data. Implementation of the United Nations Convention on Combating Desertification (CCD) requires an identification of areas where vegetative production is consistently declining. Time series of remote sensing data are well suited to this task, and methods have been developed for assessing long-term trends in savannah net primary production (NPP) or biomass and crop yields, using time series of NOAA AVHRR normalized difference vegetation index (NDVI) data. In this study, trend analysis is used to identify areas within the Peanut Basin in Senegal with apparent positive or negative trends in agricultural productivity. Having identified such areas, in-depth analysis is undertaken to determine whether long-term changes in agricultural productivity are mainly a function of rainfall patterns or are due to anthropogenic influences. The trends observed cannot be solely explained by rainfall data, and there seems to be a significant correlation with changes in land cover and land use. It is concluded that NDVI trend analysis may be used to investigate long-term and wide-scale environmental changes, and that by pinpointing areas of major change it can serve as a starting point for local-level analysis or action.

Dwivedi et al, (2004) carried out the impact assessment of soil and water conservation method using temporal data in kothapally watershed / Adarshwatershed, Rangareddy Dist, Andhra Pradesh.

Gundimeda (2004) worked on how 'sustainable' is the 'sustainable development objective' of CDM in developing countries like India? The rural poor and landless require resilient, sustainable livelihood systems that are flexible in the short term due to dependence on multiple products. The Kyoto Protocol requires that Clean Development Mechanism (CDM) projects result in long-term benefits related to the mitigation of climate change. This long-term requirement to keep carbon in storage may conflict with the short-term needs of the poor. The objective of this paper is to examine the potential implications of the Land use change and forestry (LUCF) projects to the rural livelihoods in India. For this purpose the paper uses a linearised version of the almost ideal demand system (LA-AIDS) to analyse data collected from 69 206 rural households in India. Based on the analysis, the paper concludes that for CDM to be sustainable and result in sustainable development of the local people, three important criteria should be satisfied: (1) Integrating the energy substitution possibilities in the objectives of carbon sequestration; (2) Management of the CPR lands by the rural poor through proper design of the rules for sustenance of user groups; and (3) Ensuring that the maximum revenue from carbon sequestration is channeled to the rural poor. Otherwise CDM would just result in either leakage of carbon benefits or have negative welfare implications for the poor.

2.2. INTEGRATED WATERSHED MANAGEMENT: ICRISAT'S INNOVATIVE CONSORTIUM MODEL

ICRISAT'S 'small is beautiful' approach and partnership methodology have sown seeds of agrarian renewal in many semi-arid regions of India and elsewhere. Most of the rain-fed areas in developing countries suffer from one or another form of land degradation. Due to variation in seasonal rains during the crop-growing period, crop may face drought and sometimes water logging due to torrential down pours causing runoff. In order to conserve the rainwater, minimize land degradation, improve rainwater recharge, and increase crop intensity and crop productivity a watershed management approach is adopted. (Kerr et al.2000; Samra 1997;Wani et al.2002)

Watershed programs in India so far have mainly focused on natural resource conservation and interventions such as soil and rainwater conservation and to some extent afforestation in the government forestlands. Sufficient emphasis and efforts were not targeted to build up stakes of the community for sustainable development of the natural resources and issues of gender equity have not been addressed adequately. Natural resource management progress has largely remained a water storage structure-driven investment giving only wage labor benefits to deprived sections of the society which is of a very transient nature. Emphasis on efficient water management, sustainability, monitoring and evaluation has not been adequate. However, it is a well-known fact that watershed projects should move from purely soil and moisture conservation and water harvesting interventions to a wholesome community-based integrated watershed management approach, which creates a voice and stake for the landless, poor and women. Poverty alleviation through processes that evolve and empower the poor and women will sustain. People-centered development requires convergence of initiatives and efforts to be accompanied by decentralization of decision-making (Wani et al. 2003). For establishing a successful watershed program it is necessary to involve the primary stakeholders right from the beginning and build up their capacities to take the program towards a sustainable initiative. The interventions in the project design should aim at empowerment of the community.

A new farmer participatory consortium model for efficient management of natural resource emerged from the lessons learnt from long-term watershed based research led by the ICRISAT and national partners. The important partners are the Central Research Institute for Dryland Agriculture (CRIDA), National Remote Sensing Agency (NRSA), and District Water Management Agency (DWMA) in Hyderabad, Andhra Pradesh. The important components of the new model, which are distinctly different from earlier models, are described by Wani et al. (2002, 2003). The new model is distinctly different model as it has brought the farmer in the center of the initiative. This farmer-centric integrated watershed management model has the components of use of new science tools for development where there is effective continuous transfer of knowledge and technology from on-station to on-farm. The approach is holistic participatory based on farming systems and diversified livelihood opportunities to cater to the needs of socially marginalized and landless along with dryland farmers. The interventions are so designed recognizing the needs of individual farmers. The in situ conservation that brings tangible benefits to farmers precedes the community-based interventions, which enhance the scope of participation. Continuous monitoring and evaluation provides space for reflection, refinement and development of need based, concurrent technologies that aims at the empowerment of community and stakeholders. Hence, on the institutional front a consortium is put in place comprising research organizations, university, development workers, policy makers and farmers. This vehicle provides the required technical backstopping in the model.

The new science-based farmer participatory consortium model for efficient management of natural resources and for improving the livelihood of poor rural households was evaluated in Adarsha watershed, Kothapally, Rangareddy District, Andhra Pradesh, by ICRISAT and partners. The salient impacts that resulted due to the implementation of this model were substantial reductions in runoff and soil loss, improvement in groundwater levels, reduction in pesticide usage, improvement in land cover, increase in productivity and high incomes to the farmers. Compared to the pre-project situation, average household incomes from crop production have doubled. The drivers of this success were:

- Selection of the watershed on a demand driven basis
- Higher farmer participation in the watershed program
- Good local leadership
- Integrated approach to watershed management
- Team effort and collective action by the consortium partners
- Social vigilance and transparency in financial dealings
- Increased confidence of the farmers
- Choice of low-cost conservation structures that provide benefits to large segments of the community
- Constant participatory monitoring
- Knowledge-based entry point activity and
- Concerted local capacity building efforts by all the partners.

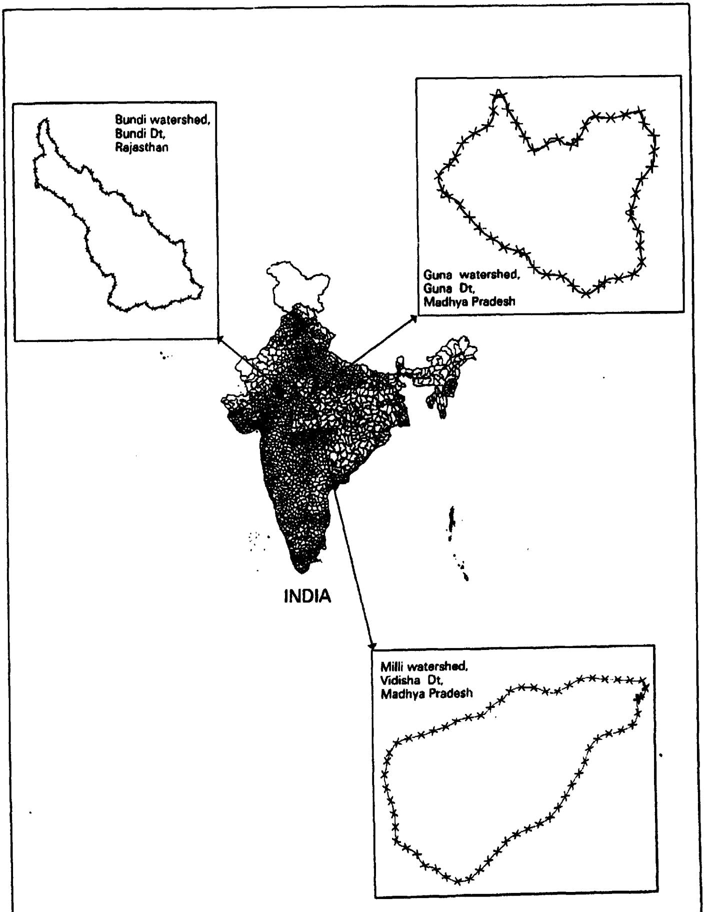


Fig 3.1. Location Map of the Study Area

3.STUDY AREA DISCRIPTION

3. STUDY AREA DESCRIPTION

The present study is comprises of three different watershed areas named BUNDI, MADHUSUDHANGADH (GUNA), LALATORA (MILLI).

3.1 DESCRIPTION OF BUNDI WATERSHED STUDY AREA: -

The present study area is located in the Bundi district of Rajasthan at 24^0 16′00″N and 77^0 30′ 15″E covering a total area of 4,500 ha. Bundi district is situated in the southeastern part of Rajasthan. It is bounded in the north by Tonk, in the west by Bhilwara and on the southwest by Chittorgarh districts.

Bundi district comprises of four Tehsils named as Bundi, Keshoraipatan, Nainwa and Hindoli. The river chambal forms the southern and eastern boundaries separating the Bundi and Kota territories. The southern tehsils of Bundi forms a wedge between Bhilwara and Kota and also touches Chittorgarh district. The study area comprises of two villages named as Thana and Goverdhanpuraa under Hindoli Tehsil of Bundi District.

The Bundi watershed is extended between two villages; Thana (250 32′ 21.40″N and 770 27′37. 85″E) with an area of 1347 hectares and the other one is Goverdhanpuraa (250 33′ 22.28″N and: 75^0 23′ 58.04″E) with an area of 409 hectares.

3.1.1 Historical Background of Bundi: -

The region of Bundi has a glorious past with the inception of the princely state In Bundi by Hades, a branch of celebrated Shawnees, Rajput monuments in the form of fort and palaces came into existence. Bundi artists have played a prominent role in the evolution of early Rajasthani paintings.

Bundi is located in a narrow valley called Bandu-Ka- Naal and is said to be have been named after Bundu, a Meena chieftain. Around 1342 Ad.Rao Dewa (Devi

Singh) Hada is reported to have conquered this territory from Meenas and named it "Hadoti"(Haroti). He established his Kingdom here by erecting the city of Bundi in the center of the valley. Rao Dewa (Devi Singh) was founder of the present Bundi, who was followed by 24 rulers in the erstwhile princely state who ruled over the territory.

3.1.2. Topography:

The topography of the present watershed study area is gently undulating. And two major soil types are found in the region viz; silt clay and sandy clay. The soil depths found in the study are ranged from 30 to130.

3.1.3.Crops: -

Since these lands are shallow/poor having low moisture retention capacity, with scanty rains, mostly poor type of vegetation is observed. Agriculture lands too became unproductive, as results of edaphic factors and biotic-interference, resulting into continuos process of erosion.

Kharif crops	Maize, Jawar, bajara, and seasame
	Black gram and green gram
Rabi	Wheat, chickpea, mustard and Safflower.

3.1.4.Demography particulars:

It is estimated that the population in Bundi District is 7,70,248 and in the two villages Thana and Goverdhapura (where the watershed situated) are respectively 1,333 and 3,921 as per District Statistical abstract, 2001.

3.1.5.Climate and rainfall:

The climate in the Bundi District can be considered as arid. The study area experience rain during monsoon or in winter season, and annual average rainfall is 600 mm.

Summer Season: The skies are mostly clear, highest temperature records in summer season during March to May. Tanks, nearly dry up during summer season. Temp varies from 35^0-48^0c.

Winter Season: The cold winter season during December to February has scanty precipitation and only dew in early hours support vegetative and vegetable crops. Temperature varies from 4^0 - 8^0c.

The region in total gets average rainfall of 60 cms per annum

3.2 DESCRIPTION OF LALATORA WATERSHED STUDY AREA: -

The present study area is located in Vidisha District of Madhya Pradesh at 24^0 16′00″N and 77^0 30′ 15″E covering a total area of 10,525 ha. The district extends between Latitude 23^0 21′ and24^0 22′ North and Longitude 77^0 15′ 30″ and 78^0 18′ East with an area of 7371 sq kms.

The watershed includes ten different villages namely Bandipur, Rajpur, Lalatora, Anandpur, Shapur, Kolapur, Fazalpur, Khaitkhedipathar, Khairkhedi and Gotkhed. The study area comprise of one village named Lalatora, which is about 725 ha in area and is sub-watershed of Milli watershed having total area of about 10525 ha.

Vidisha district is situated in the eastern part of the fertile Malwa Region. The shape of the district is more or less Elliptical and the longer axis lies from North West to South East with slight projections on the North, Northwest, South and Southwest. Its greatest length from Northwest to Southeast is about 133.6 km and the greatest width from Northeast to Southwest is about 96 km. The tropic of Cancer passes through the Southern stretch of the district about 2 km south of the district head quarters. It is bounded in the North by Guna district in the south by Raisen district and in the east by Sagar district.

3.2.1. Historical back ground of Vidisha:

The District derives its name from the head quarter's town of Vidisha .The earliest reference of Vidisha is contained in Ramayana by Valmiki. It is stated that Shstrughana's son Shatrughati was placed in charge of Vidisha. Later it was ruled by the Mauryas, the Sungas, the Kanvas, the Nagas, the Vakatakas, the Guptas, the Kalchuris of Mahishmati the Parmars, the Chalukyas, the Mugals, Marathasand Peshwas and thereafter became a part of the Sciendia's Gwalior State.

In 1904 Vidisha was raised to a district having two tehsils of Vidisha and Basoda till the formation of Madhya Bharat in 1948. The district was enlarged in 1949 by the merger of small states of Kurwai. The Sironji Sub division, which was formerly in Kota district of Rajasthan state and small pargana of Piklone belonging to the Bhopal state, were added to the District with the formation of new Madhya Pradesh. At the same time, the town and the district were renamed as Vidisha.

3.2.2. Topography:

The topography of the present watershed study area is gently undulating. And the major soil found in the region is Vertisol with poor internal drainage.

3.2.3. Crops: -

Kharif crops: The major crops taken in kharif season are soyabean and jowar .

Rabi crops: The major crops taken in Rabi season are Wheat and Chickpea.

3.2.4. Demographic particulars:

As per 1991 census, the district Vidisha had a population of 9.70388 lakh's with an area of 7371sq kms. And the total population in the given watershed area (Lalatora village) is 360 only.

3.2.5. Climate and rain fall:

The climate in the Vidisha District can be considered as arid. The study area is experience rain during southwest monsoon or in winter season.

3.2.6.Monsoon season:

The monsoon is generally during June and continues till the end of September. The total year is divided into four seasons. The cold season from December to February is followed by hot season till mid-June. The period from mid-June to about the end of September constitutes the southwest monsoon. October and November considered as the post monsoon or retreating monsoon. The maximum temperature is noticed 41^{0}C during summer and the minimum temperature is noticed as 24^{0}C during winter.

The average rainfall ranging from 1028mm.

3.3. DESCRIPTION OF MADHUSUDHANGADH (GUNA) WATERSHED

The present study area is located in Guna district of Madhya Pradesh at 23⁰ 57′ 48.50′′N and 79⁰ 16′ 06.99′′E. And the district extends between Latitude of 23⁰ 53′ and25⁰ 6′55′′ North and Longitude of 76⁰ 48′ 30′′ and 78⁰ 16′70′′ East with an area of 6484.63 Sq.Km.

The watershed includes three different villages namely Bajaribarri (23⁰ 57′ 48.50′′N 79⁰ 16′ 6.99′′ E), Kailaspura (23⁰ 58′ 50.03′′N and 79⁰ 16′ 26.03′′E), and Barodakalan (23⁰ 58′ 29.13′′N and 23⁰ 58′ 29.13′′N).

Guna gateway of Malwa and Chambal is located on the north-eastern part of Malwa Platue, between Parbati and the Betwa. The western boundary of the district is well defined by the river. The Parbati is the main river flowing along the western boundary touching Rajgarh district of Madhya Pradesh and Jhalawarh and Kota districts of Rajasthan.Shivpuri and Kota are located in north where as Vidisha, Bhopal and Rajgarh lies to the south.

3.3.1.Topography:

The topography of the present watershed study area is gently undulating. And the major soil groups found in the region are Vertisols with poor internal drainage.

3.3.2.Crops: -

Since these lands are shallow/poor having low moisture retention capacity, with scanty rains, mostly poor type of vegetation is observed. Agriculture lands too became unproductive, as results of edaphic factors and biotic-interference, resulting into continuous process of erosion.

Kharif crops: The major crops taken in kharif season are Soyabean, Maize, jowar, Sesame.

Rabi crops : The major crops taken in Rabi season are Wheat and Chickpea.

3.3.3.Climate and rain fall: -

The climate in the Bundi District can be considered as arid. The study area is experience rain during monsoon or in winter season.

Summer Season: The skies are mostly clear, highest temperature records in summer season during March to May. The tanks, nearly dry up during summer season. Temp varies from 35^0-41^0c.

Winter Season: The cold winter season during December to February has scanty precipitation and only dew in early hours support vegetative and vegetable crops. Temperature varies from 18^0-24^0c.

The average rainfall in the study area ranges from 839 mm.

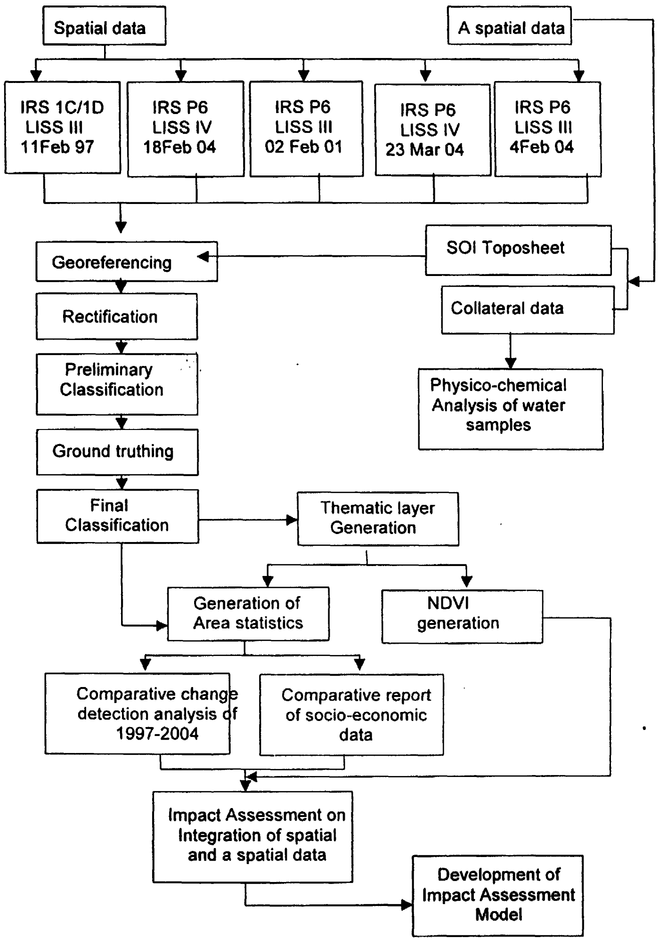
3.3.4.Demographic particulars: -

The present water shed study area extends over three villages namely Bajaribarri with an area of 300 ha, Kailsapura with an area of 500 ha and the third village Braodakalan with an area of 500 ha. As per census 1991, the population in Guna district was estimated as 83,8926 and in Guna block it was 1.34314 lakhs .

3.3.5.Disaster Vulnerability:

As mentioned above the soil groups in the study area have less poor internal drainage and the watershed area fully depends upon southwest monsoon. So, this area can be considered as disaster prone area.

METHODOLOGY FLOWCHART



4.MATERIALS AND METHODS

4. MATERIALS AND METHODS

4.1 DATA BASE:

4.1.1. Satellite data

The satellite data used in the study is acquired from the various satellites and sensors and were used in the form of digital as well as geo-coded false color paper prints at 1:50,000 scale. For Lalatora watershed, Madhya Pradesh. IRS-P6 LISS III data of 4th February 2004 covered by path- 97 and row- 55 was procured in the form of digital data. For Bundi watershed, IRS P6 data of 18th February 2004 covered by path- 202 and row- 083 was used. Where as, IRS P6 LISS IV data covered by path- 202 and row- 079, acquired on 23 rd March 2004 was used to derive the spatial information of Guna watershed.

Table 4.1 The Details of Remote Sensing Data Used

S.NO	Satellite/Sensor	Path/Row No.	Date of acquisition
1	IRS 1C/1D LISSIII	96-56	11 Feb 1997
2	IRS P6 LISSIV	202-083	18 Feb 2004
3	IRS P6 LISS III	97-55	02 Feb 2001
4	IRS P6 LISSIV	202-079	23 Mar 2004
5	IRS P6 LISSIII	97-55	04 Feb 2004

4.1.2. Ancillary Data

Survey of India (SOI) toposheets 55 E/5, 45 O/6 and 54 H/8 of 1:50,000 to prepare base map, settlement map, drainage layer and also for field work and ground truth verification.

4.1.3.Instrument and Materials

- GARMIN-12 global positioning system (GPS)

4.1.4.System and Software

- Pentium 4 PC.
- Window NT operating system.
- ERDAS IMAGINE 8.7 & Arc/Info 8.0 software.
- MS office with word, Excel and power point.
- DeskJet printer and other required material.

4.1.5.Generation of Digital Data Base

Data input is the operation of encoding the data and writing them to the database. The creation of a clean digital database is the most important at the complex task upon which the usefulness of GIS depends. Two aspects of the data need to be considered separately for the GIS, these are first the positional or geographical data necessary to define where the graphic or cartographic features occur and second, the associated attributes that records what the cartographic features represents.

Data input to a geographical information system can be best described under three categories.

- Entering the spatial data (digitizing)
- Entering the non-spatial, associated attributes and
- Linking the spatial to non- spatial data.

At each stage there should be necessary and proper data verification and checking procedure to ensure that the resultant database is as free as possible from error.

The spatially registered set of data constitutes a spatial database in addition; each spatial object has an associated attribute. This could be a name, a number, a range of values, etc., for example, contour has a number, and a road has a name. Such attributes also form a part of database. Further, there may be other data sets associated with the demographic data.

Geographical data deals primarily with two types of data:

Spatial data- The descriptive information about the objects or features present on the surface of the earth pertaining to space i.e., location as well as physical properties of the objects.

Non-spatial data – The descriptive information about the objects or features present on the surface of the earth not pertaining to the space is known as non-spatial data.

4.2. METHODOLOGY

In the present study, ARC/INFO GIS package and ERDAS package has been used as the core of spatial and non-spatial database. ARC/INFO is a modular, vector based package, and is versatile for creation, organization, storage, retrieval, analysis, display and query for making cartographic quality output in the form of maps and generation of statistical tabular reports. The spatial data is organized using topographical data model while the non-spatial attribute data is stored using a data base management package.

4.2.1.Design aspect of the study

The database consisting of both maps and socio-economic data designed, to be flexible enough to handle these datasets and also to allow future updation and extension.

The following aspects of design have been considered as spatial data domain.

4.2.2.Data Source

The spatial data is mainly from R.S data and other convincible sources. Most of these spatial data sets follow the (SOI) latitude-longitude graticules. Thus, the spatial database needs to follow the standards of SOI mapsheets. The database created on 1:50000 scale.

4.2.3.Coordinate system for database:

The coordinate system needs to be in appropriate units that represent geographic features in their shape and size. Since the 1:50,000-scale toposheet is used as in the case of survey of India.

4.2.4.Spatial Data Base Organization

The IRS 1D/1C LISS-III and LISS IV and IRS P6 LISS III and LISS IV data covering the study area were radiometrically normalized and mosaiced using ERDAS IMAGINE version 8.7, image-processing software. To begin with, the topographic maps at 1:50,000 scale were scanned on a contex FSS-800 system. The digital outputs thus obtained were rectified for scanning errors and were projected on to the co-ordinate system by specifying the projection details. The individual rectified digital topographical maps were mosaiced and were used as a reference image for geometric correction of satellite data acquired during 1997 and 2004. Ground control points (GCPs) identifiable both on reference image as well as on the IRS data were precisely located with the help of cursor, after displaying them on to a color monitor. Subsequently the digital IRS satellite data was registered to reference map with a sub-pixel accuracy using first order polynomial transform and was resampled using nearest neighbour algorithm. Later the digital data of the year 1997 was co-registered to LISS IV data using image-to-image registration algorithm. The primary elements of spatial database are as follows:

4.3. THEMATIC MAPS

Maps illustrating the theme behind them are called thematic maps. Various thematic maps depict various surface features of the land. A thematic map contain only identical features through out the map ignoring all the other features, thus reducing the confusion prevailing because of other features. Thematic maps are prepared for specific purpose.

4.3.1.Preparation of Base Map:

Base map is an outline map on which thematic details are incorporated. The nature of thematic map will not be the same; it depends on the purpose of map. Toposheet will act as one of the input in the base map preparation, especially in the use of remote sensing data. In the process of preparation of base map, the scanned toposheets that cover the study area are required. Placing the trace paper on the toposheet, the major features like settlements, roads, rivers, water bodies, forest boundaries etc are traced out. Thus, traced out sheet was considered as base map.

The base map thus prepared from toposheet was used for overlaying on the satellite imagery in order to prepare various thematic maps.

The base maps for the three watersheds Bundi, Guna, Lalatora (Milli) are shown in fig 4.1, 4 2 and 4.3.

4.3.2.Preparation of Drainage Map:

Drainage map comprises of various streams and rivers that are flowing in the area. Drainage patterns and textures are dissection signatures and very important terrain recognition elements, used as criteria for identification of geological and geomorphological phenomena.

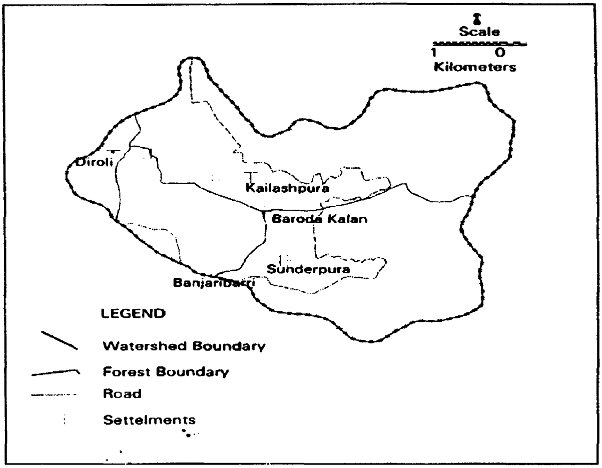


Fig 4.1 Base Map of Guna Watershed

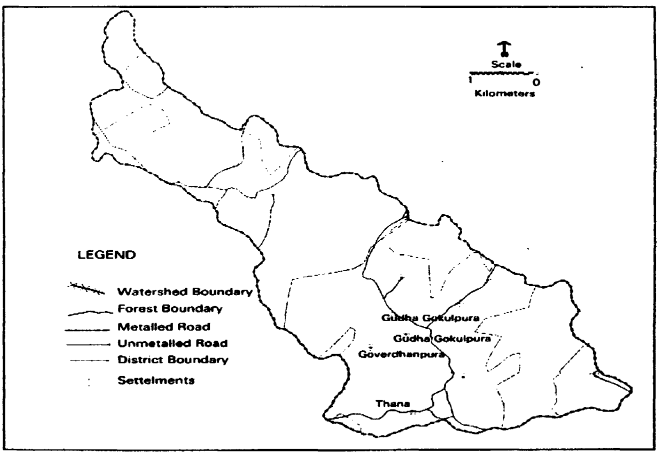


Fig 4.2 Base Map of Bundi Watershed, Rajasthan

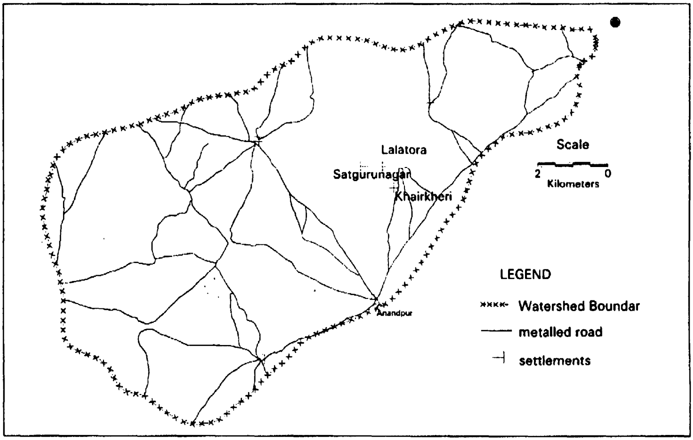


Fig 4.3 Base Map of Milli Watershed, Vidisha District, Madhya Pradesh

The drainage pattern truly reflects the hidden structural characteristics and points out the tectonic history of an area. Various landforms and bedrocks depict six most common drainage patterns. Drainage pattern is usually classified as

- Dendritic
- Rectangular
- Trellis
- Parallel
- Sub parallel
- Radial
- Centripetal and
- Deranged.
- Stream order

The first step in drainage basin analysis is order designation. The smallest finger-type tributaries are designated order1; where two first order channels join, a channel segment of order 2 is formed; where two channels of order 2 join, a segment of order 3 is formed and so forth. When a higher order stream joins with a lowest order streams, the order of resulting stream is same as that of higher order stream. The trunk stream through which all discharge of water and sediment passes is therefore the stream segment of higher order.

4.3.2.1.Stream number (Nu)

The number of stream segments present in each order is counted and recorded. Graphical presentation of this data on semi-log paper yields straight-line plots.

4.3.2.2.Bifurcation ratio (Rb)

The ratio between the number of stream segments of a given order (Nu) to the number of segments of the next higher order (Nu+1) is termed as bifurcation ratio.

$$Rb = \frac{Nu}{(Nu+1)}$$

The bifurcation ratio is not same from one order to the next order because of possibility of changes in the watershed geometry and lithology, but tends to be consistent through out the series. Bifurcation ratio characteristics range between 3 and 5 for watersheds in which the geologic structures do not distort with drainage pattern. High bifurcation ratio expected in the regions of steeply dipping rock, strata where narrow strike valleys are confined between ridges.

The drainage layer of the study area was prepared by digitizing the streams from the Survey of India (SOI) toposheets of 1:50000 scale. The drainage pattern of the study area is dendritic to sub-dendritic.

The drainage network map for the three watersheds Bundi, Guna and Lalatora(Milli) are shown in fig 4.4, 4.5 and 4.6.

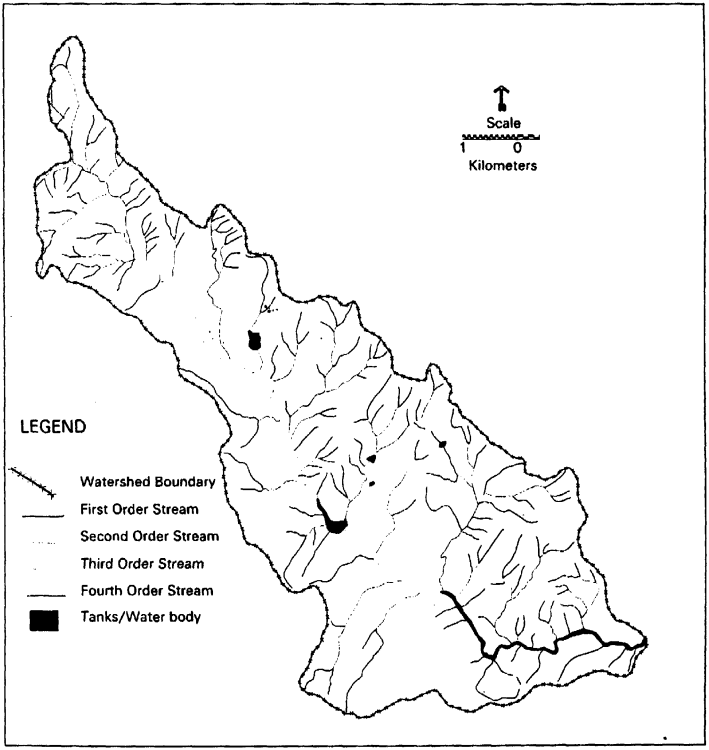


Fig 4.4 Drainage Network Map of Bundi Watershed

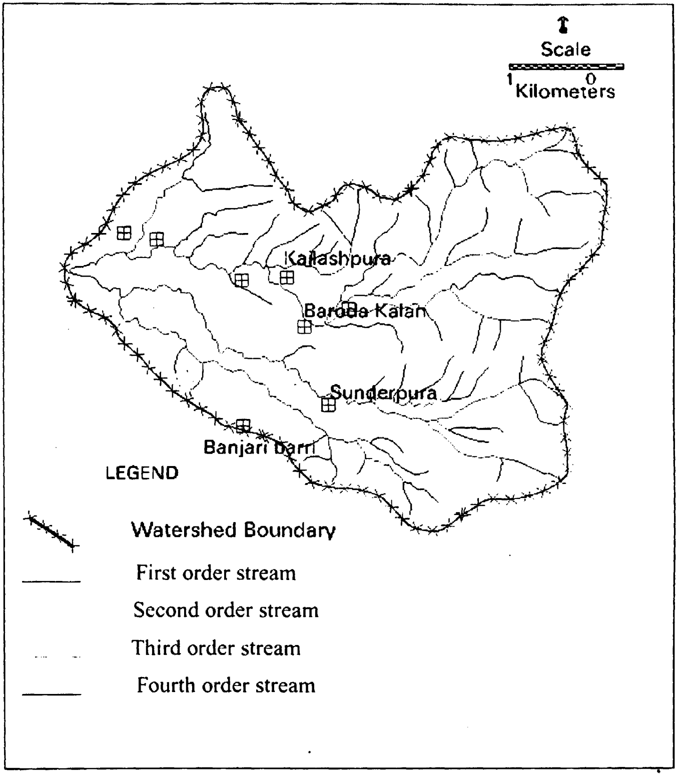


Fig 4.5 Drainage Map of Guna Watershed

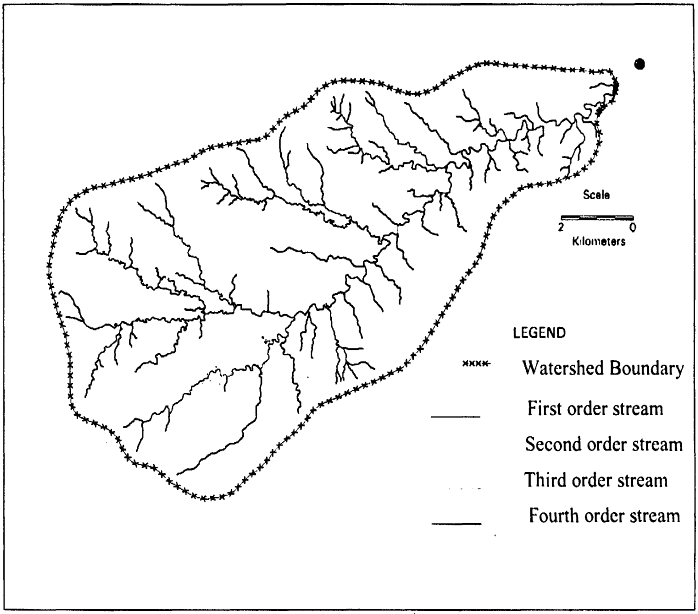


Fig 4.6 Drainage Map of Milli (Lalatora) Watershed

4.4. PREPARATION OF LANDUSE / LANDCOVER MAP

Satellite remote sensing techniques are of immense value for preparing accurate landuse/landcover map and monitoring changes at regular provided intervals of time.

Digital interpretation: Image classification is the process of categorizing (all pixels in an image into land cover classes or themes) the remotely sensed data into land cover classes or information. Normally, multi-spectral data are used to perform the classification i.e., different feature types manifest different combinations of (DN values) Digital Numbers based on their inherent spectral reflectance and emittance properties. Spectral pattern recognition refers to the family of classification procedures that utilizes this pixel-by -pixel spectral information as the basis for automated land cover classification.

4.4.1.Supervised classification

In this classification the image analyst "supervises" the pixel categorization process by specifying, to the computer algorithm, representative sample sites of known cover type, called training areas, as used to compile a numerical "interpretation key" that describes the spectral attributes for each feature type of interest. Each pixel in the data set is then compared numerically to each category in the interpretation key and labels with the name of the category it "look most like".

4.4.2.Basic steps involved in supervised classification.

The analyst identifies representative training areas and develops a numerical description of the spectral attributes of each land cover type of interest in the stage.

Each pixel in the image data set is categorized in to land cover class, it most closely resembles. If the pixel is insufficiently similar to the training dataset it is usually labeled 'unknown'.

Being digital in character, the result may be used in a number of different ways. Output products are thematic maps; tables of full scenes or sub scene are a statistics for various land cover classes, and digital data files amenable to inclusion in a GIS. In the later case the classification "output" becomes a GIS input

The training stage: the training effort required in supervised classification is both an art and science. It requires close interaction between the image analyst and the image data. It also requires substantial reference data and a through knowledge of the geographic area to which the data apply. Most importantly the quality of the training processes determines the success of the classification stage and therefore the value of information generated from the entire classification effort.

The overall objective of the training process is to assemble a set of statistics that describe the spectral response pattern for each land over type to be classified in an image.

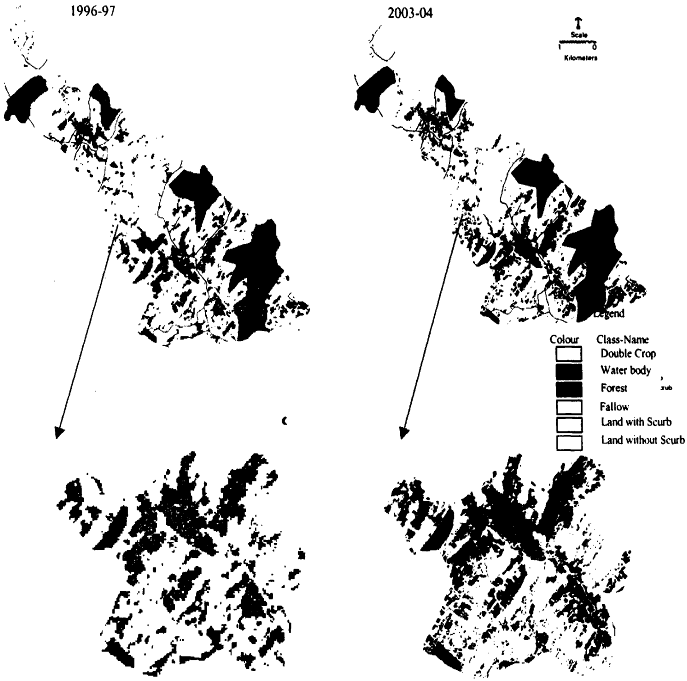
4.4.3.Unsupervised classification

The fundamental difference between these techniques is that supervised classification involves a training step followed by classification step. In the unsupervised approach the image data are first classified by aggregating then into the natural spectral grouping or clusters present in the scene. Then, the image analyst determines the land cover identity of these spectral groups by comparing the classified data to ground reference data.

Table 4.2 Land use/Land cover classification system

Level-I	Level -II	Level III
1.Built-up land	1.1 Towns/Cities	
	1.2 Villages	
2. Agricultural Land	2.1 Crop Land	2.1.1 Kharif
		2.1.2 Rabi
		2.1.3 Kharif+Rabi (double crop)
	2.2 Fallow Land	
	2.3 Plantations	
3. Forest	3.1 Evergreen/Semi-evergreen	3.1.1 Dense
		3.1.2 Open
	3.2 Deciduous (moist and dry)	3.2.1 Dense
		3.2.2 Open
	3.3 Scrub forest	
	3.4 Forest blank	
	3.5 Forest plantations	
	3.6 Mangrove	
4. Waste Lands	4.1 Salt Affected Land	
	4.2 Waterlogged Land	
	4.3 Marshy/Swampy Land	
	4.4 Gullied/Ravinous Land	
	4.5 Land with Scrub	
	4.6 Land without Scrub	
	4.7 Sandy area	
	4.8 Mining/ Industrial waste land	
	4.9 Barren Rocky/Stony waste/ Sheet Rock Area	
5. Water Bodies	5.1 River/Stream	
	5.2 Canals	
	5.3 Lake/Reservoirs/Tanks	

Classification of watershed: classification of watershed unto level -III of land use/land cover classification system was carried out based on key elements and tonal variations of various features of the imagery. The comparative landuse/ landcover map of Bundi and Milli watershed for the year 1997 and 2004 are shown in fig 4.7 and 4.8. Fig 4.9 shows the landuse/landcover map of Guna watershed during the year 2004.



Area of Watershed interventions

Class Name	1997	2004
DoubleCrop	460.32	634.22
Waterbody	4.60	3.56
Forest	80.60	78.36
Fallowland	112.19	68.54
Land without Scurb	420.18	133.50
Land with scurb	480.43	640.14

Fig 4.7. Landuse / Landcover Map of Bundi Watershed

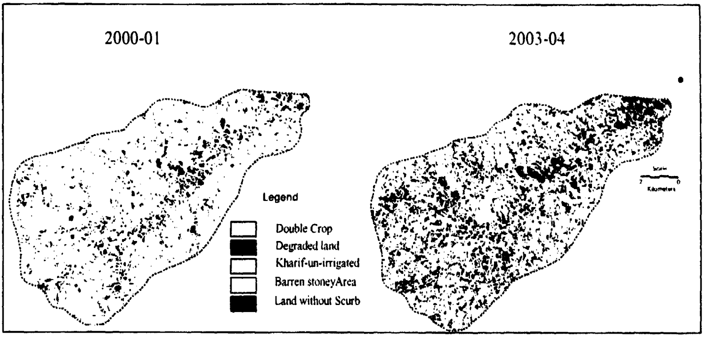


Fig4.8. Land use/Land cover Map of Milli Watershed

Comparative Spatial Extent of Various Land use/Land cover classes of Milli Watershed

LU/LC Classes	LISS-III(1997)Area in Ha	LISS-IV(2004)Area in Ha
Double Crop	1062.259	2956.44
Degraded Land	126.66	0
Kharif-Un-irrigated	158.17	796.44
Barren Stony Area	3925.56	2481.81
Land without Scrub	4451.9	3489.87
TOTAL	9724.55	9724.55

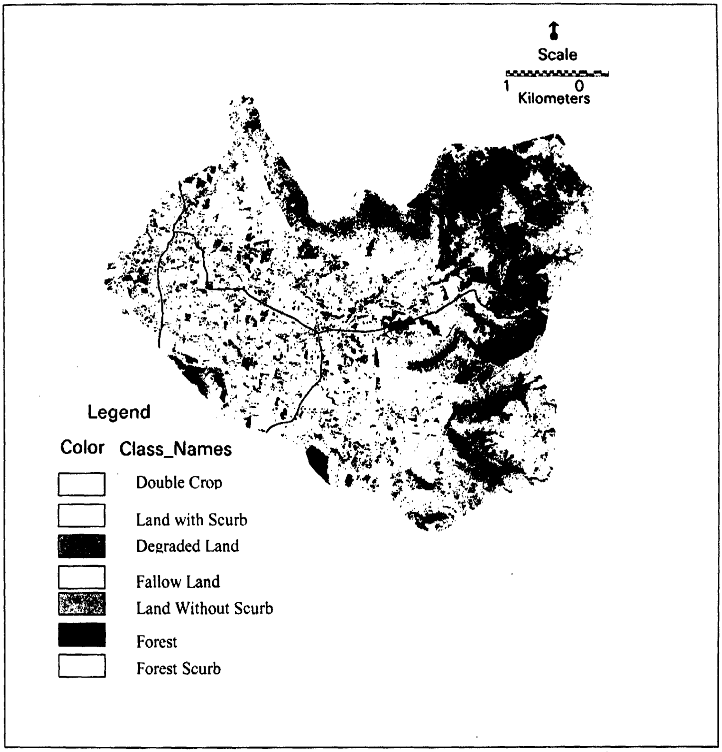


Fig 4.9 Landuse/Landcover Map of Gona Watershed

4.5. GENERATION OF NDVI MAP

The major changes in the catchments due to implementation of watershed development program are reflected in the development of vegetation cover and agriculture land use, crop yield etc. the Normalized Difference Vegetation Index (NDVI) is the difference of near infrared (NIR) and visible red (R) reflectance values normalized over total reflectance. IRS 1C/1D LISS III and IRS P6 LISS IV data for 1997 and 2004 were generated on a silica graphic workstation as follows.

$$NDVI = \frac{IR - RED}{IR + RED}$$

the equation produces NDVI values in the range of –1.0 to 1.0, where negative values generally represents clouds, snow, water and other non-vegetated surfaces, and positive values represent vegetative surfaces. The NDVI relates to photosynthetic activity of living plants. The higher the NDVI values, the more "green" the cover type. It implies that the NDVI increases as the green biomass increases.

Fig 4.10a shows the satellite imagery of Bundi watershed of 11 Feb 1997 and 18 Feb 2004 Fig 4.10b shows the NDVI map of the same area.Fig 11a shows the satellite imagery of Milli watershed of 2 Feb 2001 and 4 Feb 2004 and fig 4.11b shows the NDVI map of the same area.Fig 4.12 shows the satellite image of Guna watershed of 23 Mar 2004.

4.6. TEMPORAL CHANGES IN THE GROUNDWATER LEVELS IN THE WATERSHED AND WATER QUALITY

Water is an essential resource for all living things. Rainwater is the primary source for water resource. Rainfall is not uniformly distributed in different months of the year in India. During monsoon period major part of rainwater go as runoff. Some

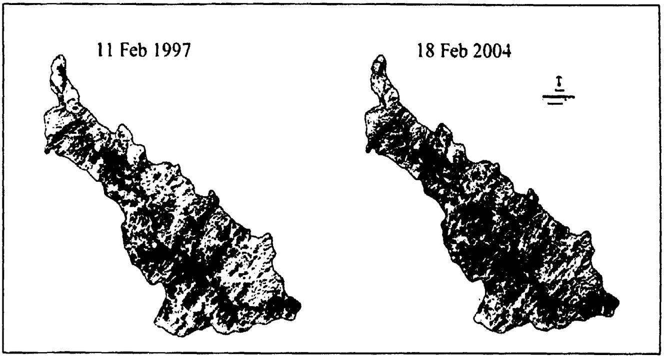


Fig 4.10a Satellite Image of Bundi Watershed

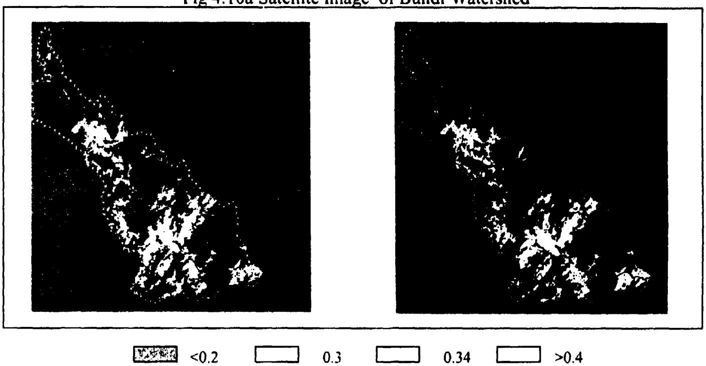


Fig 4.10b NDVI Image of Bundi Watershed

Spatial Extend of Various NDVI Categories (Area in Ha)

NDVI Category	1997	2004
0.00 – 0.20	3265	2234
0.20 – 0.30	545	2616
0.30 – 0.34	25	32
> 0.40	1563	2058
Total	5398	6940

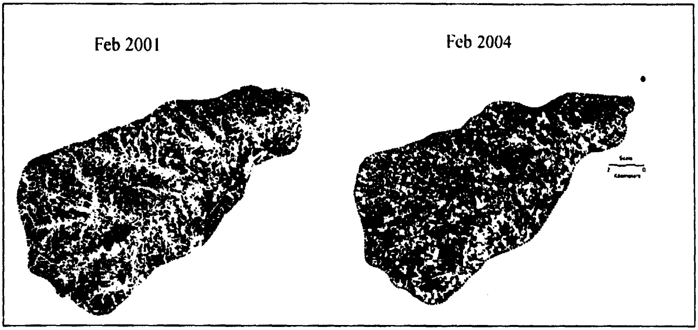


Fig 4.11a .Satellite Images of Milli (Lalatora) Watershed

Fig4.11b. NDVI Image of Milli (Lalatora) Watershed

Spatial Extend of Various NDVI Categories (Area in Ha)

NDVI Category	2001	2004
0.00 – 0.30	3178	2645
0.30 – 0.40	362	1575
0.40 – 0.50	124	855
> 0.50	8	579
Total	3672	5654

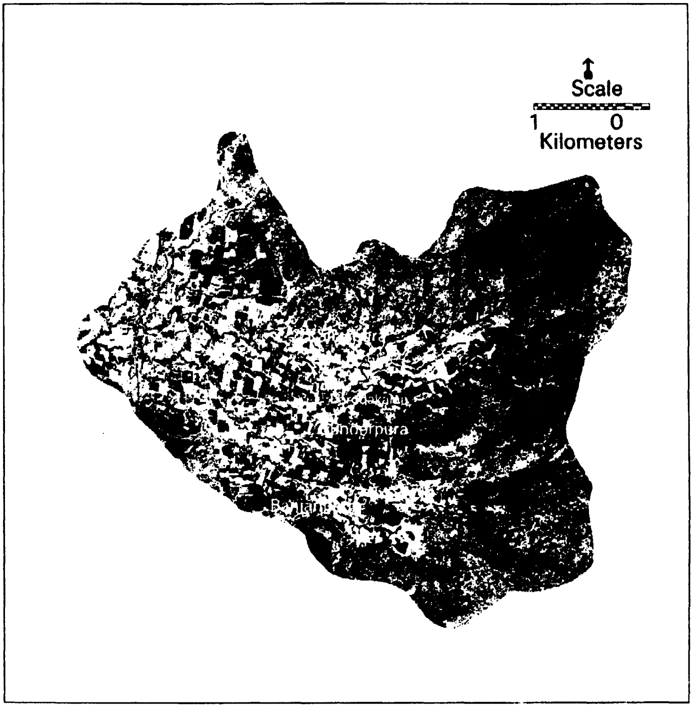


Fig 4.12. Sateellite Imagery of Guna Watershed

quantity of water goes as recharge in to the ground wherever favorable aquifer conditions are available. The study of historic groundwater level data is important in the evaluation, development and management of groundwater. These data are used to assess the changes in groundwater storage and its response to rainfall, evaporation, pumpage, surface irrigation etc.

Historic water levels are essential for forecasting future trends of water levels in response to the adoption of modern concept s in groundwater reservoir operation.

4.6.1.Water table fluctuation data

Water table fluctuation data is prepared on the basis of monthly water levels measured from the existing observation wells averaged over five years. These hydrographs not only show the monthly water level fluctuation in the shallow aquifer but also give the long term trend of the water levels to infer the groundwater balance in the area.

Fig 4.13,4.14 and 4.15 shows the well location map of the three watersheds viz; Bundi, Guna and Milli.

4.6.2.Depth of water level

Depth to water level data will give an idea about the level of water table in different landforms and in different rainfall regions.

4.6.3.Groundwater Quality

In the groundwater assessment studies, evaluation of the quality of the groundwater available is as important as quantity. The usability of available groundwater is determined by its chemical, physical and biological properties. Detailed chemical analysis is done in the laboratory for six parameters.

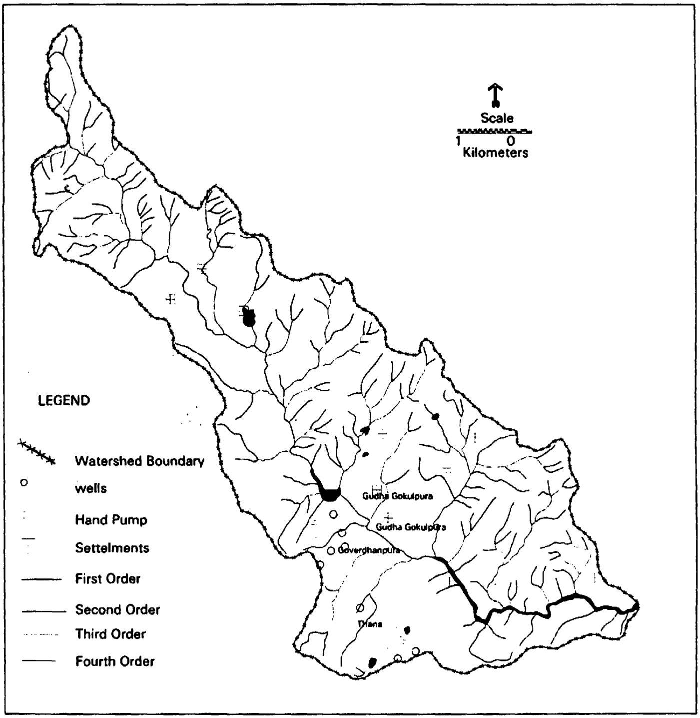


Fig 4.13.Well Location Map of Bundi Watershed

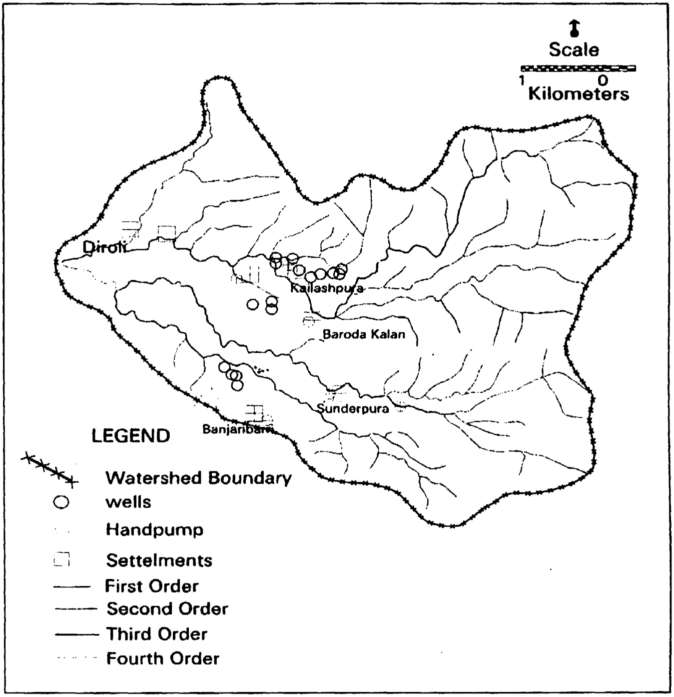


Fig 4.14.Well Location Map of Guna Watershed

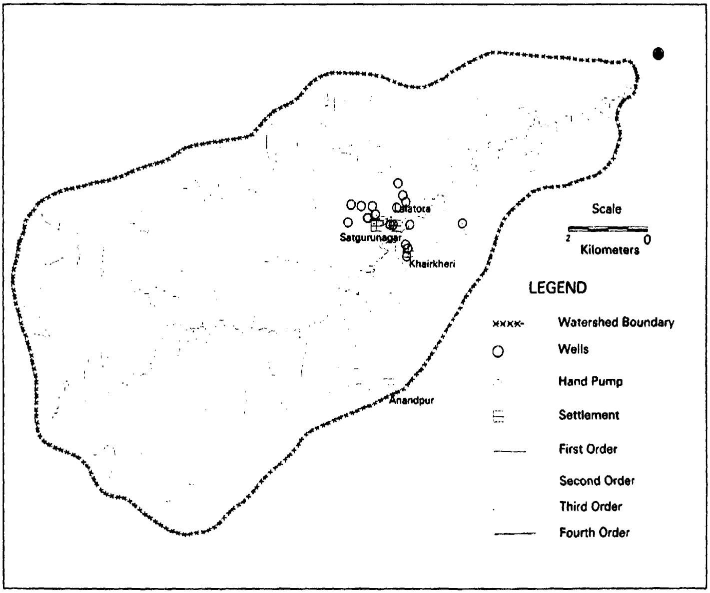


Fig 4.15.Well Location Map of Milli Watershed

Groundwater is used for irrigation, drinking (human & livestock) and industrial purposes. Certain quality standards have been established for evaluating suitability of water for drinking, other domestic usage, irrigation and industrial use.

The suitability of water for irrigation has been based on electrical conductivity (EC) and TDS. For various crops different proportion of EC and TDS are classified based on tolerance capacity of different crops and soil types.

For the purpose of drinking water, WHO standards are referred.

pH

pH is negative logarithm of hydrogen ion concentration. Fresh distilled water has a pH of 7.Acidic water have a pH of 0 to 7, where as alkaline water have pH ranging from 7 to 14.pH meter is calibrated using distilled water and further calibrated using the standard buffer solution of pH 4 and 7.The pH electrode is washed with distilled water after calibration and then dipped into the beaker containing sample water, whose pH is to be found .

Electric Conductivity

Conductivity is the capacity of the water to carry an electrical current and varies both with number and types of ions the solution contains, which in turn is related to the concentration of ionized substance in the water. Conductivity meter is calibrated using distilled water and further calibrated using 0.1M Potassium Chloride. The electrode is washed with distilled water after calibration and then dipped into the beaker containing sample water, whose conductivity is to be found.

Phosphates

Phosphates present in water under acidic conditions react with ammonium molybdate to form molybdophosphoric acid .This is reduced to molybdenum blue by adding reducing agent such as stannous chloride. The intensity of blue colored complex is measured which is directly proportional to the concentration of phosphate present in the sample.

Fluoride

Fluorides present in water under acidic condition react with zirconium SPADNS solution and the color of SPADNS reagent gets bleached due the formation of zirconium hexa fluoride and this result in bleaching of the reddish color of zirconium and alizarian combination. The decrease in intensity of color is directly proportional to fluoride concentration.

Nitrate

Nitrate is the most highly oxidized form of nitrogen compounds commonly present in natural waters, because it is the product of the aerobic decomposition of organic nitrogenous matter. Water sample with boric acid and Devarda's alloy is distillated in Kjdledal distillation unit and it is further titrated with sulphuric acid in auto titrator.

Total Dissolved Solids

TDS in water sample is found by mixing the waters sample thoroughly and filtering the sample through Wattman filter paper. The filtered sample is evaporated on a hot plate. The hot dried sample is dried in a desicator.The weight of the sample is measured.

5.RESULTS AND DISCUSSIONS

5.RESULTS AND DISCUSSION

5.1 INTRODUCTION

The major changes in the catchments due to implementation of integrated watershed development programs are having reflections in the development of vegetation cover agricultural land use, groundwater table and crop yield

Proper utilization and management of natural resources depends on the development of effective resource information database and remote sensing and GIS are one of the key tools which have capability to provide real time information that makes it possible to have meaningful repetitive surveys which can show the changes that have taken place. Satellite image interpretation has enabled to use an objective assessment of monitoring of agricultural land use and vegetation.

5.2 RESULTS OF THEMATIC MAPPING

All the resource themes generated by the thematic mapping are discussed below:

The drainage network map with the water bodies and streams are identified for the three watersheds.The drainage pattern and streams are identified for the three watersheds Bundi, Guna, and Milli and are found to be dendritic pattern and coarse texture.

The dendritic pattern is the most common type of pattern found by a main stream with tributary branching and rebranching truly in all the possible directions. It is generally developed up on homogenous rocks of uniform resistance such as horizontally bedded sedimentary rocks, massive igneous rocks and completely metamorphosed rocks.

In the three watersheds Bundi, Guna and Milli (Lalatora) the drainage network is coming up to 4th order stream the bifurcation ratio is below 4. This indicates less soil erosion in these areas and the geological formation is not disturbed.

In order to study the change in biomass and its temporal behavior in the watershed NDVI images are generated for the two watersheds (Lalatora and Bundi) from satellite data.

For Bundi watershed NDVI images from satellite data of 11 Feb 1997 and 18 Feb 2004 are generated to study the impact of watershed development programs on the study area. Fig 4.10a shows the satellite data of the watershed during the period and fig 4.10b shows the corresponding NDVI images. Change in colours indicates an increasing trend in NDVI values from 0.05 to 0.4 and above.

Fig 5.1 shows improved vegetation cover in Bundi watershed as seen under temporal satellite data. Fig 5.1a. shows the efforts which have been made by the implementing agency to educate the people to minimize the human and livestock interference with the natural species as seen in the satellite data, bunding has been carried out and allowed the natural species to restore/maintain the biodiversity of the region. Fig 5.1b.improved vegetation cover seen in different crowns of red colour, can be observed in the year 2003.Similarly in the Fig 5.1c and 5.1d to the south -west of the image improved vegetation cover can be seen.

Similar NDVI images were generated for Lalatora (Milli) watershed .Fig 4.11a shows satellite image of Lalatora watershed for 2 Feb 2001 and 4 Feb 2004 and fig 4.11b shows NDVI images for same data. Progressive development in biomass cover in terms of NDVI could be seen as yellow, Magenta, Red, Green and dark green colour indicating an increasing trend in NDVI values from 0.05 to 0.4 and above.

For Guna watershed comparative NDVI image could not be generated due to non-availability of data. Fig 4.12 shows the Satellite data of Guna watershed of 23 Mar 2004.

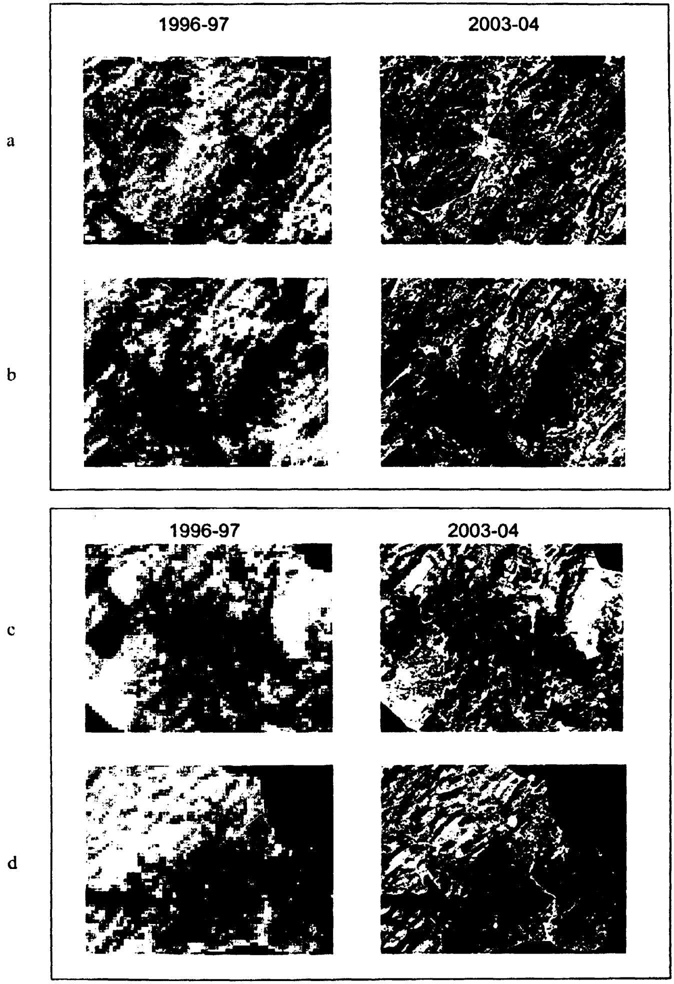


Fig 5.1.Bundi Watershed Comparative Approach at Various Locations

1996-97 IRS P6 LISS III
2003-04 IRS P6 LISS IV

A comparison of biomass for Bundi and Lalatora Watersheds during the years 1997-2004 and 2001-2004 clearly brings out positive changes that have taken place during the last seven years.

Preliminary interpretation of satellite data has been carried out using visual interpretation. Apart from NDVI, a change in agricultural landuse has been used to study the impact of watershed program.

The various landuse/landcover classes delineated in these watersheds include agricultural land, wastelands, water bodies, forests etc.

Comparative landuse/landcover map for Bundi and Lalatora are shown in Fig 4.7 & 4.8 and watershed wise area statistics is furnished. Land Use/land cover map of Guna watershed for 2004 is shown in Fig 4.9

During the process of well inventory water quality monitoring was carried out on selected wells in the three watersheds (Bundi, Guna and Lalatora)

The locations of these wells are mapped. Fig 4.13, 4.14&4.15 shows the well location map of these watersheds. Only those wells are shown in the map from which the water samples were collected. Table 5.5 shows the details of number of wells present in the watershed. The geographic coordinate's latitude/longitude of all wells of Guna & Milli watershed is given in table 6 for further Study.The location of wells are coordinated with stream order and land use/land cover pattern of the particular watersheds.For Guna and Milli watershed the wells are mainly located on second, third and fourth order streams .Where as in Bundi the sample wells are located inside the village away from the stream. The bifurcation ratio is below 4 in the three watersheds.

Water quality analysis was carried out for four months February, April, July and October 2004 from selected wells in the three watersheds. The groundwater levels of these wells were also monitored. Ten samples from Bundi watershed, twenty samples from Guna watershed and sixteen samples from Lalatora watershed were analysed.

Table 17, 18, 19 & 20 shows the water Quality analysis result for February, April, July & October. The results were compared with the standards for domestic water quality given in table 15. All the parameters analyzed that is pH, Conductivity, Fluorides, Total Dissolved Solids, Phosphates and Nitrate is found to be in permissible limits.The trend in the six parameters during the analysis period(Feb, April, July and Oct 2004) is plotted in fig 5.2.

Table 7, 8, 9, & 10 shows the groundwater level of the three watersheds.Trend in water level in the three watersheds is plotted in fig 5.3

The three watersheds show different trend, which can be related to the different climatic conditions of the watersheds. For Guna watershed the water level remains almost equal in the first three months and the level has gone down by October. In Milli watershed July and October months show good results in water level. In Bundi watershed all the wells had water through out the four months and there is only slight variation in the water level.

Results of watershed Interventions like building of rain water harvesting structures, can be easily identified from the following table showing the statistics obtained from Kailaspura Village (Guna Watershed).

Table 5.1Mean Water Column (m) in the wells

(Mean Depth of Wells 9m)

Season	Before Intervention	After Intervention
Kharif	5	7.5
Rabi	2.5	3
Zaid	0.5	1.5
Mean Water Column (m)	2.7	4

Table 5.2Mean Pumping Duration (hour) from the wells

Season	Before Intervention	After Intervention
Kharif	3	6
Rabi	1	3.12
Zaid	0	1.5
Mean	1.3	3.54

Table 5.3Effects of Watershed Interventions during different seasons

Season	Pumping duration (h)		Recharge /recovery period in well (h)		Area irrigated by one well (ha)	
	Before watershed interventions	After watershed interventions	Before watershed interventions	After watershed interventions	Before watershed interventions	After watershed interventions
Rainy	4	11	13.5	10	1	2.5
Post-rainy	1.5	6.5	21	16	0.5	1.5
Summer	0	1	30	21	0	0.2

The above table indicates the positive changes in the watershed after intervension.The water column in the wells have increased in all three seasons (Kharif, Rabi, Zaid) compared to the before intervention statistics. Mean water column has raised by 1.3m after the watershed interventions. Similarly the pumping duration has also increased in all three seasons. The mean pumping duration has increased to 2.24 hours compared to the earlier pumping hours.

5.3 COMPARITIVE STUDY OF WATERSHEDS OF MADHYA PRADESH AND EASTERN RAJASTHAN

5.3.1. GENERAL CHARACTERISTICS

Table 5.4 General Description

Watershed		Village		Latitude/Longitude	Annual rainfall (mm)	Mean Temperature.	Soil type
Name	Area (ha)	Name	Area (ha)				
Lalatora (Vidisha District)	10,525	Lalatora	725	$77^0 30' 15''$E $24^0 16'00''$N	1028	Max-41^0 Min-24^0	Vertisols
Madhusudhangadh (Guna District)	2260	Bajaribarri	300	$79^0 16' 06.99''$E $23^0 57' 48.50''$N	839	Max-41^0 Min-24^0	Vertisols
		Kailaspura	500	$79^0 16' 26.03''$E $23^0 58' 50.03''$N	839	Max-41^0 Min-24^0	Vertisols
		Barodakalan	500	$79^0 16' 33.03''$E $23^0 58' 29.13''$N	839	Max-41^0 Min-24^0	Vertisols
Bundi	4500	Thana	1347	$75^0 27' 37.85''$E $25^0 32'' 21.40''$N	525	Max-48^0 Min-8^0	Siitclay/sandy clay
		Goverdhanpuraa	409	$75^0 23' 58.04''$E $25^0 33' 22.28''$N	525	Max-48^0 Min-8^0	Siitclay/sandy clay

5.4. WATER RESOURCE INFORMATION

A comparative study (1997-2004) was carried out to analyze the impact of watershed programmes in the village.

During 1997 number of wells were ten and there were no tube wells in Lalatora. By 2004 the number of wells increased to sixteen and there are about thirty-three tube wells.

In Bajaribarri out of the nine wells six wells used to dry up in summer in 1997. In the present situation i.e.; (2003-2004) there are 14 wells, out of which 9 wells contain water through out the year.5 wells get dried in summer.

There were 19 wells in Kailaspura in 1997, out of which 16 used to dry up in summer. Only 3 wells were there in which water was available through out the year. In the present situation there are 37 wells, out of which 25 wells contain water through out the year.

In Barodakalan out of the 17 wells, 13 wells used to dry up in summer in 1997.In the present situation there are 26 wells, out of which 17 wells contain water through out the year. And the remaining 9 wells dried up during summer.

One of the major causes for the wells to get dried up was pumping of water from wells.

Table 5.5 Different Sources of Water

	Lalatora		Bajaribarri		Kailaspura		Barodakalan		Thana		Govardhanapura	
	1997	2004	1997	2004	1997	2004	1997	2004	1997	2004	1997	2004
Open wells	10	16	9	14	19	37	17	26	128	132	41	44
Tube wells	0	33	Nil	Nil	Nil	Nil	Nil	Nil	Nil	1	Nil	Nil
Hand pump	5	30	2	4	3	4	3	6	5	17	2	7

(ICRISAT and Ground Survey)

5.4.1.SOURCE OF IRRIGATION

Wells and Nala (small streams) were the main source of irrigation. But almost all wells dry-up in summer. To overcome this drawback water harvesting structures were constructed (Check Dam and Farm Pond) which in turn increased the groundwater level.

Table 5.6 Source of Irrigation

	Lalatora	Bajaribarri	Kailashpura	Barodakalan	Thana	Goverdhanpuraa
Open well	16	14	37	26	132	44
Check dam	10	2	4	5	3	4
Farm pond	6	7	10	3	Nil	Nil
Stop dam	Nil	Nil	1	1	Nil	Nil
Tube well	33	Nil	Nil	Nil	1	Nil

5.4.2.PUMP USED AND PUMPING HOURS

LALATORA

The pumps that are generally being used are Sagar pumps. The general supply of electricity is about 6 hours in a day out of which 4 hours are used for irrigation purposes. In Lalatora no well irrigation. There are 33 tube wells and pumping capacity is 8 hours

MADHUSUDHANGADH

Diesel pump sets are used in Guna for pumping. Maximum pumping hours are 4-5. There are no tube wells in Guna.

5.5 CROP

Table 5.7 Types of Crop

Villages	Types of crop			
	Kharif		Rabi	
	1997-98	2003-04	1997-98	2003-04
Lalatora	Jawar ,Maize	Jawar, Maize, Soyabean	Wheat, Chick pea	Wheat, Chick-pea
Bajaribarri	Jawar, Maize, Soyabean	Maize, Soyabean	Wheat, Chickpea.	Wheat, Chickpea, Coriander
Kailaspura	Jawar, Maize, Soyabean	Maize, soyabean	Wheat, chickpea	Wheat, Chickpea, Coriander
Barodakalan	Jawar, Maize, Sesame	Jawar, Maize, Sesame, Soybean	Wheat, Chickpea.	Wheat, Chickpea, Coriander
Thana	Jawar, Maize, Sesame	Paddy, Maize, Jawar, Bajra, arhar.	Mustard, Wheat, Chickpea, Gram.	Wheat, Chickpea, Gram, Safflower.
Goverdhanpura	Maize, Sesame	Maize, Sesame, Black gram, Pigeon pea, Jawar	Wheat, Chickpea, Mustard.	Wheat, Chickpea, Mustard, Safflower.

(Ground survey)

Table 5.8Yield from crop (Quintal/ Hectare)

Villages	Season	Crop	1997-98	2003-04
Lalatora	Kharif	Jowar	20	11 to 12
		Maize	15-16	10
		Soyabean	0	20
	Rabi	Wheat irrigated	10	20
		Wheat unirrigated	5 to 6	10
		Chickpea irrigated	12 to 13	15
		Chickpea unirrigated	7	8
Guna				
Banjaribarri	Kharif	Jowar+Maize+Soyabean	7 to 9	15 to 17
	Rabi	Wheat+Chickpea	18 to 20	27 to 29
	Zaid(Summer)		3 to 5	7 to 9
Kailashpura	Kharif	Jowar+Maize+Soyabean	8 to 10	17 to 19
	Rabi	Wheat+Chickpea	20 to 22	31 to 33
	Zaid(Summer)		5 to 6	8 to 10
Barodakalan	Kharif	Jowar+Maize+Sesame	9 to 11	18 to 20
	Rabi	Wheat+Chickpea	21 to 23	30 to 32
	Zaid(Summer)		5 to 6	7 to 9
Bundi				
Thana	Kharif	Maize	12	42
		Sesame	120kg	240kg
		Paddy	0	30
	Rabi	Wheat	36	48
		Chickpea	18	24
		Masoor	12	14
Goverdhanpura	Kharif	Maize	12	25
		Sesame	90	3
		Blackgram	0	5
		Pigeonpea	0	5
	Rabi	Wheat	25	60
		Chickpea	6	24
		Mustard	6	24

(Ground Reported)

Table 6. Well Location of Milli and Guna Watersheds Lalatora(Milli)

	Well Location	
Farmer Name	Latitude	Longitude
Ajeet Singh	24º12' 17.0"	77º 26' 32.2"
Bhupat Singh	24º12' 18.8"	77º 26' 29.9"
Harnath Singh	24º12' 20.4"	77º 26' 26.4"
Laxman Singh	24º12' 31.1"	77º 26' 30.8"
Beeren Singh	24º12' 37.8"	77º 26' 30.6"
Jandelrimla	24º12' 44.3"	77º 26' 29.8"
Pahelvan Singh	24º12' 38.2"	77º 26' 24.8"
Jandel Singh	24º12' 38.8"	77º 26' 17.6"
Shambu Singh	24º12' 34.5"	77º 26' 18.4"
Laxman Singh	24º12' 26.8"	77º 26' 19.7"
Bhagat Singh	24º12' 17.8"	77º 26' 20.4"
Bishan Singh	24º12' 18.4"	77º 26' 15.6"
Daryav singh	24º12' 25.4"	77º 26' 11.3"
Raghunath Singh	24º12' 28.4"	77º 26' 32.2"
Baldev Singh	24º12' 21.5"	77º 26' 01.8"
Ramesh	24º12' 22.0"	77º 26' 26.3"
Gajraj singh	24º12' 18.2"	77º 26' 08.8"
Narayan singh	24º12' 15.5"	77º 26' 07.0"
Bhujbal singh	24º12' 16.5"	77º 26' 06.1"
Kamal Singh	24º12' 17.8"	77º 26' 01.8"
Bane Singh	24º12' 18.1"	77º 25' 48.4"
Hari Singh	24º12' 16.1"	77º 25' 35.8"
Pal Singh	24º12' 14.1'	77º 25' 43.7"
Chandan Singh	24º12' 12.2"	77º 25' 42.9"
Kundan Singh	24º12' 10.9"	77º 25' 47.5"
Harnath Singh	24º12' 13.8"	77º 25' 52.0"
Mansingh	24º12' 11.5"	77º 25' 59.7"
Chand singh	24º12' 07.4"	77º 26' 01.3"
Bhairav Singh	24º12' 11.2"	77º 26' 10.5"
Baldev singh	24º12' 08.7"	77º 26' 12.4"

Bajaribarri (Guna)

Farmer Name	Latitude	Longitude
Babulal	23°57' 49.4"	77° 15' 53.7"
Sanman Dayaram	23°57' 29.8"	77° 16' 03.9"
Kailash Champalal	23°58' 01.2"	77° 15' 55.8"
Common Well(Dhokapur)	23°57' 59.4"	77° 15' 54.2"
Gendalal	23°58' 04.5"	77° 15' 54.8"
Laxman/Mansingh	23°58' 08.6"	77° 15' 50.3"
Sanman	23°58' 13.5"	77° 15' 53.7"
Mangilal Banjara	23°58' 09.1"	77° 16' 00.1"
Kaniram	23°58' 08.7"	77° 16' 01.9"
Dayaram Banjara	23°58' 08.8"	77° 16' 06.0"
Mannulal Deva	23°58' 07.1"	77° 16' 09.2"
Narayan Singh	23°58' 16.7"	77° 16' 05.8"
Baseta Dhobi	23°58' 19.6"	77° 15' 57.6"
Khanna	23°58' 26.1"	77° 15' 54.7"
Jaisingh/Khanna	23°58' 27.6"	77° 15' 51.5"
Hajari Prasram	23°58' 31.7"	77° 15' 54.1"
Asaram Mansingh	23°58' 26.4"	77° 15' 59.2"
Megha Khanna	23°58' 26.5"	77° 15' 57.2"
Fatesh Singh	23°58' 12.7"	77° 15' 59.9"
Hira Mansingh	23°58' 03.9"	77° 16' 10.2"
Nannu	23°58' 02.8"	77° 16' 10.6"
Nandram Bhairav	23°57' 58.6"	77° 16' 07.6"
Dharma Kaniram	23°58' 00.8"	77° 16' 12.7"
Panna Hema	23°57' 54.9"	77° 16' 11.5"
Dera	23°57' 53.1"	77° 16' 13.2"
Ghirdari Krishna	23°57' 53.4"	77° 16' 15.8"
Ratan Krishna	23°57' 57.0"	77° 16' 16.3"
Balaji Manna	23°57' 59.4"	77° 16' 18 4"
Dhannalal Tulsiram	23°57' 55.0"	77° 16' 18.8"
Gangaram Gulab	23°57'54.3"	77° 16' 22.7"
Handpump	23°57'49.7"	77° 16' 17.0"
Bhura Mansingh	23°57' 49.8"	77° 16' 20.8"
Dharma Kaniram	23°57' 49.9"	77° 16' 27.1"
Khusal Mansingh	23°57' 54.8"	77° 16' 28.5"

Kailashpura (Guna)

Farmer Name	Latitude	Longitude
Khailiram Patel	23°58' 46.8"	77° 17' 22.3"
Gajraj Singh	23°58' 46.8"	77° 17' 38.2'
Khailiram Patel	23°58' 51.8"	77° 17' 41.0"
Karan Singh	23°58' 55.3"	77° 17' 33.6"
Bapulal Vijayram	23°59' 00.6"	77° 17' 31.4"
Pyara Singh	23°58' 38.1"	77° 17' 27.9"
Mansingh/Chanda	23°58' 46.8"	77° 16' 28.6"
Megha/Ramsingh	23°58' 48.9"	77° 16' 21.8"
Phulsingh/Deepa	23°58' 51.8"	77° 16' 24.6"
Ramlal/Khushal	23°58' 51.8"	77° 16' 23.1"
Raghunath/Nanda	23°58' 59.4"	77° 16' 30.1"
Mangilal/Daula	23°59' 00.3"	77° 16' 15.6"
Navalsingh/Hajari	23°58' 56.0"	77° 16' 13.1"
Bhama/Pannalal	23°58' 51.8"	77° 16' 04.3"
Amra/Bhavsingh	23°59' 00.4"	77° 16' 04.8"
Bhima I/Deva	23°58' 50.2"	77° 16' 06.9"
Mangilal/Moti	23°58' 48.8"	77° 16' 02.7"
Mansingh/Moti	23°58' 50.1"	77° 16' 02.4"
Gulaba/Nathu	23°58' 51.0"	77° 16' 02.7"
Babulal/Peeru	23°58' 48.8"	77° 15' 58.5"
Peeru/Bhavsingh	23°58' 47.1"	77° 16' 05.4"
Bharosa/Matarlal	23°58' 41.0"	77° 16' 07.6"
Bhima II/Deva	23°58' 39.9"	77° 16' 08.8"
Sanman/Kesiya	23°58' 42.5"	77° 16' 12.5"
Mangilal/ Khemaji	23°58' 28.8"	77° 16' 03.1"
Mansingh/Ganaram	23°58' 31.4"	77° 16' 05.5"

Barodakalan(Guna)

Farmer Name	Well Location	
	Latitude	Longitude
Chetan Singh	23° 58' 49.1"	77° 16' 16.7"
Amar Singh	23° 58' 36.2"	77° 16' 02.7"
Rupsingh Chauhan(I)	23° 58' 31.6"	77° 16' 16.4"
Rupsingh Chauhan(II)	23° 58' 28.8"	77° 16' 19.7"
Saudan Singh	23° 58' 26.2"	77° 16' 17.2"
Ratan Singh(Tube well)	23° 58' 24.5"	77° 16' 18.3"
Bhagawat	23° 58' 23.2"	77° 16' 18.4"
Umraosingh/Baldev	23° 58' 24.3"	77° 16' 13.8"
Halkuram/Girdhan	23° 58' 16.1"	77° 16' 13.8"
Gaturam/Khaimchand	23° 58' 14.1"	77° 16' 21.7"
Hariram/Diroli	23° 58' 26.1"	77° 16' 02.4"
Nanjiram/Asharam	23° 58'44.0"	77° 16' 57.8"
Arjun/Deva	23° 58' 42.3"	77° 15' 56.2"
Mangilal/Moti	23° 58' 36.9"	77° 15' 55.4"

Table 7. Groundwater Level Observation (February 2004)
(Guna) Madhusudangad

S.No.	NAME OF FARMER	TOTAL DEPTH(m)	GROUNDWATER LEVEL(m)
1	Komal singh/umrao singh	9.25	6.75
2	Khuman/laxman	10	6.75
3	Ramlal/khusal	13	7.75
4	Nannu/hajari	9.75	6.25
5	Bhama/karan singh	11.25	7.50
6	Deepa/khusal	9.25	6.00
7	Megha/ram singh	10.75	6.50
8	Mangilal/umrao singh	6.75	3.50
9	Laxman/nanda	6.5	4.25
10	Jai singh	5.25	3.50
11	Man singh/chanda	6.75	3.25
12	Khaima/daula	6.25	4.50
13	Hajari/chanda	7.25	4.00
14	Kamal singh / samandar singh	12.25	10.00
15	Rodya/nathu	14.25	9.50
16	Hajari/Pannalal	12.5	11.00
17	Ramlal/Bhawarlal	8	7.25
18	Kaniram/Ramlal	9	7.25
19	Mangilal/Ramlal	9	6.75
20	Nannu/Ramlal	8.75	5.50

(Milli) Lalatora

S.NO	NAME OF FARMER	TOTAL DEPTH (m)	GROUNDWATER LEVEL (m)
1	Govt	12.00	10.05
2	Govt	15.00	7.06
3	Mangaliya	10.50	7.45
4	Babulal	12.00	10.95
5	Bhairav singh	12.00	9.36
6	Kripal singh	13.50	Dry
7	Pahalwan singh	13.50	10.50
8	Bhujbal singh	9.50	Dry
9	Bhishan singh	-	Dry
10	Bane singh	12.00	Dry
11	Dal singh	12.00	Dry
12	Gajraj singh	13.50	10.36
13	Govt	7.50	Dry
14	Kailash singh	150	Dry
15	Adivasi Tapara	10.50	Dry
16	Lakhapat singh	10.00	10.90

(Bundi) Thana

S.NO	NAME OF FARMER	TOTAL DEPTH(m)	GROUNDWATER LEVEL(m)
1	Shivaraj singh / Sardar singh	17.00	12.65
2	Ramkishan/Baldev	15.60	10.75
3	Moti/Nanda	25.95	25.55
4	Soji/Savula	25.90	22.00
5	Permeshwar/Ramrai	19.60	14.50

(Bundi) Goverdhanpura

S.NO	NAME OF FARMER	TOTAL DEPTH(m)	GROUNDWATER LEVEL(m)
1	Chithar/Bura	12.80	4.70
2	Rameshwar/Savuta	18.90	5.10
3	Khana/Gulaba	18.65	7.50
4	Madunath/Sivanath	25.00	12.80
5	Gunsham/Gemmala	19.00	5.60

Table 8. Groundwater Level Observation (April 2004)
(Guna) Madhusudangad

S.NO	NAME OF FARMER	TOTAL DEPTH(m)	GROUNDWATER LEVEL(m)
1	Komal singh/umrao singh	9.25	7.5
2	Khuman/laxman	10.00	7
3	Ramlal/khusal	13.00	7
4	Nannu/hajari	9.75	6
5	Bhama/karan singh	11.25	8
6	Deepa/khusal	9.25	6.75
7	Megha/ram singh	10.75	7.25
8	Mangilal/umrao singh	6.75	4.1
9	Laxman/nanda	6.50	4.75
10	Jai singh	5.25	2.75
11	Man singh/chanda	6.75	4.25
12	Khaima/daula	6.25	4.25
13	Hajari/chanda	7.25	4.7
14	Kamal singh/samandar singh	12.25	10.15
15	Rodya/nathu	14.25	9.25
16	Hajari/Pannalal	12.50	10.75
17	Ramlal/Bhawarlal	8.00	Dry
18	Kaniram/Ramlal	9.00	7.5
19	Mangilal/Ramlal	9.00	7.3
20	Nannu/Ramlal	8.75	6.75

(Milli) Lalatora

S.NO	NAME OF FARMER	TOTAL DEPTH (m)	GROUNDWATER LEVEL(m)
1	Govt	12.00	10.05
2	Govt	15.00	7.06
3	Mangaliya	10.50	7.45
4	Babulal	12.00	10.95
5	Bhairav singh	12.00	9.36
6	Kripal singh	13.50	Dry
7	Pahalwan singh	13.50	10.50
8	Bhujbal singh	9.50	Dry
9	Bhishan singh	-	Dry
10	Bane singh	12.00	Dry
11	Dal singh	12.00	Dry
12	Gajraj singh	13.50	10.36
13	Govt	7.50	Dry
14	Kailash singh	150	Dry
15	Adivasi Tapara	10.50	Dry
16	Lakhapat singh	10.00	10.90

(Bundi) Thana

S.NO	NAME OF FARMER	TOTAL DEPTH (m)	GROUNDWATER LEVEL (m)
1	Shivaraj singh/Sardar singh	17.00	14.85
2	Ramkishan/Baldev	15.60	12.5
3	Moti/Nanda	25.95	22.3
4	Soji/Savula	25.90	18.2
5	Permeshwar/Ramrai	19.60	13.1

(Bundi) Goverdhanpura

S.NO	NAME OF FARMER	TOTAL DEPTH (m)	GROUNDWATER LEVEL (m)
1	Chithar/Bura	12.80	11.00
2	Rameshwar/Savuta	18.90	7.25
3	Khana/Gulaba	18.65	7.25
4	Madunath/Sivanath	25.00	6.75
5	Gunsham/Gemmala	19.00	5.50

Table 9. Groundwater Level Observation (July 2004)
(Guna) Madhusudangad

S.NO	NAME OF FARMER	TOTAL DEPTH(m)	GROUNDWATER LEVEL(m)
1	Komal singh/umrao singh	9.25	6.70
2	Khuman/laxman	10.00	6.30
3	Ramlal/khusal	13.00	6.30
4	Nannu/hajari	9.75	6.00
5	Bhama/karan singh	11.25	8.00
6	Deepa/khusal	9.25	7.00
7	Megha/ram singh	10.75	7.20
8	Mangilal/umrao singh	6.75	4.00
9	Laxman/nanda	6.50	4.60
10	Jai singh	5.25	2.20
11	Man singh/chanda	6.75	3.20
12	Khaima/daula	6.25	3.00
13	Hajari/chanda	7.25	3.20
14	Kamal singh/samandar singh	12.25	8.10
15	Rodya/nathu	14.25	7.70
16	Hajari/Pannalal	12.50	8.10
17	Ramlal/Bhawarlal	8.00	Dry
18	Kaniram/Ramlal	9.00	5.90
19	Mangilal/Ramlal	9.00	5.30
20	Nannu/Ramlal	8.75	4.90

(Milli) Lalatora

S.NO	NAME OF FARMER	TOTAL DEPTH(m)	GROUNDWATER LEVEL(m)
1	Govt	12.00	Dry
2	Govt	15.00	10.65
3	Mangaliya	10.50	9.30
4	Babulal	12.00	Dry
5	Bhairav singh	12.00	7.30
6	Kripal singh	13.50	8.00
7	Pahalwan singh	13.50	9.00
8	Bhujbal singh	9.50	9.00
9	Bhishan singh	-	Dry
10	Bane singh	12.00	8.20
11	Dal singh	12.00	9.00
12	Gajraj singh	13.50	9.10
13	Govt	7.50	Dry
14	Kailash singh	150	9.00
15	Adivasi Tapara	10.50	9.00
16	Lakhapat singh	10.00	5.35

(Bundi) Thana

S.NO	NAME OF FARMER	TOTAL DEPTH(m)	GROUNDWATER LEVEL(m)
1	Shivaraj singh/Sardar singh	17.00	14.80
2	Ramkishan/Baldev	15.60	13.35
3	Moti/Nanda	25.95	22.20
4	Soji/Savula	25.90	12.58
5	Parmeshwar/Ramrai	19.60	10.80

(Bundi) Goverdhanpura

S.NO	NAME OF FARMER	TOTAL DEPTH(m)	GROUNDWATER LEVEL(m)
1	Chithar/Bura	12.80	9.25
2	Rameshwar/Savuta	18.90	10.10
3	Khana/Gulaba	18.65	12.38
4	Madunath/Sivanath	25.00	16.50
5	Gunsham/Gemmala	19.00	9.25

Table 10. Groundwater Level Observation (October 2004)
(Guna) Madhusudangad

S.NO	NAME OF FARMER	TOTAL DEPTH(m)	GROUNDWATER LEVEL(m)
1	Komal singh/umrao singh	9.25	4.20
2	Khuman/laxman	10.00	3.40
3	Ramlal/khusal	13.00	2.60
4	Nannu/hajari	9.75	1.90
5	Bhama/karan singh	11.25	3.80
6	Deepa/khusal	9.25	2.60
7	Megha/ram singh	10.75	3.80
8	Mangilal/umrao singh	6.75	0.90
9	Laxman/nanda	6.50	1.10
10	Jai singh	5.25	0.10
11	Man singh/chanda	6.75	1.40
12	Khaima/daula	6.25	1.30
13	Hajari/chanda	7.25	1.60
14	Kamal singh/samandar singh	12.25	3.70
15	Rodya/nathu	14.25	3.40
16	Hajari/Pannalal	12.50	3.20
17	Ramlal/Bhawarlal	8.00	3.00
18	Kaniram/Ramlal	9.00	1.70
19	Mangilal/Ramlal	9.00	1.20
20	Nannu/Ramlal	8.75	1.10

(Milli) Lalatora

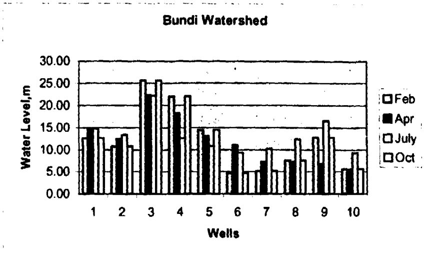
S.NO	NAME OF FARMER	TOTAL DEPTH(m)	GROUNDWATER LEVEL(m)
1	Govt	12.00	4.40
2	Govt	15.00	3.50
3	Mangaliya	10.50	1.70
4	Babulal	12.00	3.35
5	Bhairav singh	12.00	5.00
6	Kripal singh	13.50	4.90
7	Pahalwan singh	13.50	4.00
8	Bhujbal singh	9.50	4.15
9	Bhishan singh	-	5.00
10	Bane singh	12.00	4.40
11	Dal singh	12.00	4.60
12	Gajraj singh	13.50	4.80
13	Govt	7.50	9.00
14	Kailash singh	150	5.10
15	Adivasi Tapara	10.50	3.10
16	Lakhapat singh	10.00	1.25

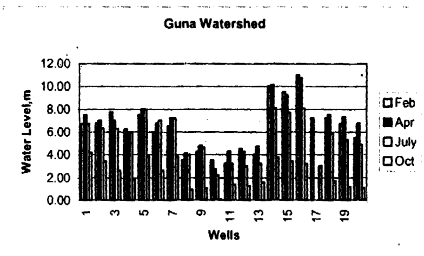
(Bundi) Thana

S.NO	NAME OF FARMER	TOTAL DEPTH (m)	GROUNDWATER LEVEL(m)
1	Shivaraj singh/Sardar singh	17.00	12.65
2	Ramkishan/Baldev	15.60	10.75
3	Moti/Nanda	25.95	25.55
4	Soji/Savula	25.90	22.00
5	Permeshwar/Ramrai	19.60	14.50

(Bundi) Goverdhanpura

S.NO	NAME OF FARMER	TOTAL DEPTH(m)	GROUNDWATER LEVEL(m)
1	Chithar/Bura	12.80	4.70
2	Rameshwar/Savuta	18.90	5.10
3	Khana/Gulaba	18.65	7.50
4	Madunath/Sivanath	25.00	12.80
5	Gunsham/Gemmala	19.00	5.60





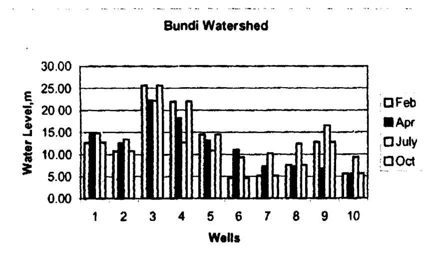


Fig5.3.Trend In Water Level In The Three Watersheds

Table 11. Water Quality Analysis For The Month Of February

(Guna) Madhusudangadh

S.no	Farmer name	pH	E.CdS/m	Total dissolved solids	Fluoride mg/l	PO4-P mg/l	Nitrate mg/l
1	Komal singh	7.45	0.6	400	0.4	Nil	0.16
2	Khuman	7.62	0.61	407	0.4	Nil	3.95
3	Madhan	7.23	0.59	393	0.4	Nil	0.10
4	Nannu	7.28	0.58	387	0.3	Nil	0.35
5	Bhammakaran	7.75	0.63	418	0.3	Nil	0.16
6	Deepa/kushal	7.73	0.60	400	0.3	Nil	0.18
7	Mega/ram singh	7.52	0.65	430	0.3	Nil	0.15
8	Mangilal	7.45	0.51	340	0.3	Nil	0.27
9	Laxman	7.65	0.49	327	0.3	Nil	0.18
10	Jaisingh	7.77	0.52	347	0.3	Nil	0.16
11	Mansingh chanda	7.85	0.62	413	0.4	Nil	0.25
12	Khuman/dola	7.45	0.65	433	0.4	Nil	0.15
13	Hajari/pannalal	7.65	0.79	527	0.5	Nil	0.32
14	Kamalsingh	7.25	0.64	423	1.0	Nil	0.68
15	Rodiya/nathu	7.32	0.66	440	0.5	Nil	0.38
16	Hajari/pannalal	7.42	0.64	427	1.2	Nil	0.67
17	Ramlal/bhawanlal	7.32	0.63	420	0.6	Nil	0.22
18	Kaniram/ramlal	7.45	0.64	427	0.5	Nil	0.33
19	Mangilal/ramlal	7.21	0.65	440	0.5	Nil	0.31
20	Nannu/ramlal	7.20	0.65	433	0.4	Nil	0.17

(Milli) Lalatora

S.no	Name of farmer	pH	E.CdS/m	Total dissolved solids	Fluoride mg/l	PO4-P mg/l	Nitrate mg/l
1	Govt	7.89	0.77	520	0.4	Nil	1.23
2	Govt	7.85	0.77	515	0.5	Nil	0.27
3	Mangaliya	7.77	0.52	347	0.4	Nil	0.38
4	Babulal	7.95	0.61	407	0.5	0.03	0.85
5	Bhairav singh	7.64	0.62	413	0.4	Nil	0.59
6	Kripal singh	-	-	-	-	-	-
7	Pahalwan singh	7.55	0.57	380	0.5	Nil	0.71
8	Bhujbal singh	-	-	-	-	-	-
9	Bishan singh	-	-	-	-	-	-
10	Bane singh	-	-	-	-	-	-
11	Dall singh	7.57	0.66	440	0.4	0.03	1.86
12	Gajraj singh	-	-	-	-	-	-
13	Govt	-	-	-	-	-	-
14	Harlal singh	-	-	-	-	-	-
15	Adiwasi tapara	-	-	-	-	-	-
16	Lakhapat singh	7.43	0.46	307	0.6	Nil	-

(Bundi) Thana

S.No	Name of farmer	pH	E.CdS/m	Total dissolved solids	Fluoride mg/l	PO-4-P mg/l	Nitrate mg/l
1	Shivaraj / sardar singh	7.75	0.54	360	0.5	0.05	0.30
2	Ram Kishan/Baldev	7.60	0.52	348	0.4	Nil	5.30
3	Moti/Nanda	7.55	0.65	435	0.5	Nil	1.89
4	Soji/Savula	7.84	0.73	487	0.6	Nil	2.47
5	Permeshwar	7.60	0.74	493	0.4	Nil	0.36

(Bundi) Goverdhanpura

S.NO	Name of farmer	pH	E.CdS/m	Total dissolved solids	Fluoride mg/l	PO4-P mg/l	Nitrate mg/l
1	Chittar /Bura	7.65	0.78	520	0.9	Nil	0.70
2	Rameshwar /savuta	7.7	0.80	533	0.6	Nil	1.11
3	Khana/gulaba	7.45	0.71	473	0.6	Nil	1.49
4	Madunath	7.83	0.70	467	0.9	Nil	0.71
5	Gunsham	7.65	0.77	513	0.8	Nil	3.01

Table 12.Water Quality Analysis For The Month Of April

Bundi (Thana)

S.NO	FARMER NAME	pH	E.C dS/m	TDS mg/l	FLUORIDE mg/l	PO4-P mg/l	NITRATE mg/l
1	Shivaraj singh/Sardar singh	7.72	0.47	310	0.4	Nil	0.58
2	Ramkishan/Baldev	7.64	0.56	370	0.3	Nil	1.07
3	Moti/Nanda	7.89	0.73	480	0.4	0.01	1.38
4	Soji/Savula	7.78	0.67	440	0.4	0.03	1.66
5	Permeshwar	7.78	0.85	560	0.5	Nil	2.62

Bundi (Goverdhanpura)

S.NO	FARMER NAME	pH	E.C dS/m	TDS mg/l	FLUORIDE mg/l	PO4-P mg/l	NITRATE mg/l
1	Chithar/Bura	7.78	0.56	370	0.7	Nil	0.56
2	Rameshwar/Savuta	7.66	0.72	480	0.6	Nil	0.86
3	Khana/Gulaba	7.58	0.75	500	0.4	Nil	0.89
4	Madunath/Sivnath	7.98	0.65	430	0.7	Nil	0.50
5	Gunsham	7.60	0.71	470	0.7	Nil	3.26

(Milli) Lalatora

S.NO	FARMER NAME	pH	E.C dS/m	TDS mg/l	FLUORIDE mg/l	PO4-P mg/l	NITRATE mg/l
1	Govt	7.73	0.72	480	0.3	Nil	0.48
2	Govt	7.78	0.67	440	0.3	Nil	2.89
3	Mangaliya	7.72	0.51	340	0.3	Nil	0.30
4	Babulal	7.85	0.61	400	0.3	Nil	0.60
5	Bhairav Singh	7.09	0.53	350	0.3	Nil	1.38
6	Kripal Singh	-	-	-	-	-	-
7	Pahalwan Singh	7.42	0.55	360	0.3	Nil	0.69
8	Bhujbal Singh	-	-	-	-	-	-
9	Bishan Singh	-	-	-	-	-	-
10	Banc Singh	7.12	0.64	420	0.3	Nil	0.21
11	Dall Singh	7.38	0.54	360	0.3	Nil	1.31
12	Gajraj Singh	7.39	0.55	360	0.3	Nil	0.64
13	Govt	-	-	-	-	-	-
14	Harlal Singh	-	-	-	-	-	-
15	Adiwasi Tapar	-	-	-	-	-	-
16	Lakhapat Singh	7.15	0.44	290	0.3	Nil	1.99

(Guna) Madhusudhangadh

S.NO	FARMER NAME	pH	E.C dS/m	TDS mg/L	FLUORIDE mg/l	PO4-P mg/l	NITRATE mg/l
1	Komal Singh	7.32	0.59	390	0.3	Nil	1.16
2	Khuman	7.40	0.45	300	0.3	Nil	0.36
3	Madhan	7.20	0.54	360	0.3	Nil	0.34
4	Nannu	7.32	0.53	350	0.3	Nil	0.42
5	Bhammakaran Singh	7.28	0.49	320	0.3	Nil	0.36
6	Deepa/Kushal	7.72	0.56	370	0.3	Nil	0.31
7	Mega/Ram Singh	7.28	0.55	360	0.3	Nil	0.35
8	Mangilal	7.43	0.50	330	0.3	Nil	0.40
9	Laxman	7.39	0.47	310	0.3	Nil	0.34
10	Jai Singh	7.52	0.56	370	0.3	Nil	0.43
11	Mansingh Chanda	7.63	0.47	310	0.3	Nil	0.38
12	Khuman/Dola	7.42	0.46	300	0.3	Nil	0.40
13	Hajari/Chanda	6.92	0.70	460	0.3	0.01	0.27
14	Kamal Singh	7.08	0.61	400	0.3	Nil	0.57
15	Rodiya/Nathu	7.36	0.59	390	0.3	Nil	0.77
16	Hajiri/Pannalal	7.41	0.65	430	0.3	Nil	0.63
17	Ramlal/Bhawanlal	-	-	-	-	-	-
18	Kaniram/Ramlal	7.22	0.68	450	0.3	Nil	1.05
19	Mangilal/Ramlal	7.23	0.64	420	0.3	Nil	0.45
20	Nannu/Ramlal	7.30	0.71	470	0.3	Nil	0.40

Table 13.Water Quality Analysis For The Month Of July
Bundi (Thana)

S.NO	FARMER NAME	pH	EcdS/m	TDS mg/l	FLUORIDE mg/l	PO4-P mg/l	NITRATE mg/l
1	Shivaraj singh/Sardar singh	7.75	0.42	280	0.3	Nil	0.73
2	Ramkishan/Baldev	7.5	0.54	360	0.1	Nil	1.86
3	Moti/Nanda	765	0.71	473	0.3	Nil	1.08
4	Soji/Savula	7.8	0.64	427	0.3	Nil	0.50
5	Permeshwar	7.76	0.74	493	0.2	Nil	1.88

Bundi (Goverdhanpura)

S.NO	FARMER NAME	pH	E.C dS/m	TDS mg/l	FLUORIDE mg/l	PO4-P mg/l	NITRATE mg/l
1	Chithar/Bura	7.75	0.47	313	0.7	Nil	0.6
2	Rameshwar/Savuta	7.6	0.65	433	0.5	Nil	3.90
3	Khana/Gulaba	7.58	0.68	453	0.3	Nil	0.88
4	Madunath/Sivnath	7.85	0.64	427	0.5	Nil	0.27
5	Gunsham	7.6	0.64	427	0.5	Nil	1.29

(Milli) Lalatora

S.NO	FARMER NAME	pH	E.CdS/m	TDS mg/l	FLUORIDE mg/l	PO4-P mg/l	NITRATE mg/l
1	Govt	7.57	0.69	460	0.1	Nil	1.27
2	Govt	-	-	-	-	-	-
3	Mangaliya	7..70	0.24	160	0.1	Nil	0.17
4	Babulal	-	-	-	-	-	-
5	Bhairav Singh	6.57	0.33	220	0.1	Nil	0.69
6	Kripal Singh	7.39	0.49	327	0.1	Nil	0.88
7	Pahalwan Singh	-	-	-	-	-	-
8	Bhujbal Singh	7.54	0.51	340	0.1	Nil	1.11
9	Bishan Singh	-	-	-	-	-	-
10	Bane Singh	7.12	0.53	353	0.1	Nil	0.72
11	Dall Singh	-	-	-	-	-	-
12	Gajraj Singh	-	-	-	-	-	-
13	Govt	-	-	-	-	-	-
14	Harlal Singh	7.3	1.16	773	0.2	0.39	7.4
15	Adiwasi Tapar	7.35	0.53	353	0.1	Nil	1.05
16	Lakhapat Singh	7.15	0.31	207	0.3	Nil	1.02

(Guna) Madhusudhangadh

S.NO	FARMER NAME	pH	E.C dS/m	TDS mg/L	FLUORIDE mg/l	PO4-P mg/l	NITRATE mg/l
1	Komal Singh	7.32	0.54	360	0.1	Nil	0.01
2	Khuman	7.40	0.46	307	0.1	Nil	Nil
3	Madhan	7.20	0.48	320	0.1	Nil	3.44
4	Nannu	7.32	0.43	287	0.1	Nil	Nil
5	Bhammakaran Singh	7.28	0.22	147	0.1	Nil	Nil
6	Deepa/Kushal	7.72	0.39	260	0.1	0.13	0.79
7	Mega/Ram Singh	7.28	0.48	320	0.1	Nil	Nil
8	Mangilal	7.43	0.33	220	0.1	Nil	0.06
9	Laxman	7.39	0.4	267	0.1	Nil	0.06
10	Jai Singh	7.52	0.44	293	0.1	Nil	3.32
11	Mansingh Chanda	7.63	0.48	320	0.1	Nil	5.68
12	Khuman/Dola	7.42	0.51	340	0.1	Nil	Nil
13	Hajari/Chanda	6.92	0.57	380	0.1	Nil	Nil
14	Kamal Singh	7.08	0.54	360	0.2	Nil	0.50
15	Rodiya/Nathu	7.36	0.46	307	0.2	Nil	0.01
16	Hajiri/Pannalal	7.41	0.54	360	0.2	Nil	0.01
17	Ramlal/Bhawanlal	-	-	-	-	-	-
18	Kaniram/Ramlal	7.22	0.51	340	0.2	Nil	Nil
19	Mangilal/Ramlal	7.23	0.61	407	0.2	Nil	Nil
20	Nannu/Ramlal	7.30	0.59	393	0.2	Nil	Nil

Table 14. Water Quality Analysis For The Month Of Oct
Bundi (Thana)

S.NO	FARMER NAME	pH	EcdS/m	TDS mg/l	FLUORIDE mg/l	PO4-P mg/l	NITRATE mg/l
1	Shivaraj singh/Sardar singh	7.76	0.67	447	0.5	Nil	0.65
2	Ramkishan/Baldev	7.60	0.54	360	0.5	Nil	1.63
3	Moti/Nanda	7.5	0.88	587	0.5	Nil	0.89
4	Soji/Savula	7.8	0.70	467	0.6	Nil	0.45
5	Permeshwar	7.50	0.75	500	0.5	Nil	1.35

Bundi (Goverdhanpura)

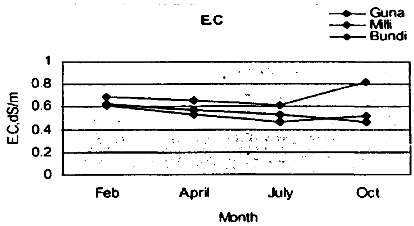
S.NO	FARMER NAME	pH	E.C dS/m	TDS mg/l	FLUORIDE mg/l	PO4-P mg/l	NITRATE mg/l
1	Chithar/Bura	7.77	1.50	1000	0.7	Nil	0.54
2	Rameshwar/Savuta	7:62	0.91	607	0.5	Nil	2..86
3	Khana/Gulaba	7.49	0.91	607	0.5	Nil	0.78
4	Madunath/Sivnath	7.90	0.67	447	0.6	Nil	0.20
5	Gunsham	7.60	0.70	467	0.7	Nil	1.14

(Milli) Lalatora

S.NO	FARMER NAME	pH	E.CdS/m	TDS mg/l	FLUORIDE mg/l	PO4-P mg/l	NITRATE mg/l
1	Govt	7.69	0.70	467	0.7	Nil	1.22
2	Govt	7.7	0.70	467	0.3	Nil	
3	Mangaliya	7.68	0.30	200	0.3	Nil	0.15
4	Babulal	7.78	0.30	200	0.3	Nil	
5	Bhairav Singh	7.0	0.46	307	0.3	Nil	0.59
6	Kripal Singh	7.43	0.37	247	0.3	Nil	0.78
7	Pahalwan Singh	7.38	0.24	160	0.3	Nil	
8	Bhujbal Singh	7.20	0.43	287	0.3	Nil	1.0
9	Bishan Singh	7.38	0.24	160	0.3	Nil	
10	Bane Singh	7.00	0.36	287	0.3	Nil	0.66
11	Dall Singh	7.26	037	160	0.4	Nil	
12	Gajraj Singh	7.30	0.37	240	0.4	Nil	
13	Govt	7.00	0.85	247	0.4	Nil	
14	Harlal Singh	7.23	0.83	247	0.3	Nil	6.99
15	Adiwasi Tapar	7.35	0.39	567	0.5	0.08	0.93
16	Lakhapat Singh	7.11	0.64	553	0.3	0.02	0.90

(Guna) Madhusudhangadh

S.NO	FARMER NAME	pH	E.C dS/m	TDS mg/l	FLUORIDE mg/l	PO4-P mg/l	NITRATE mg/l
1	Komal Singh	7.28	0.58	353	0.3	Nil	0.01
2	Khuman	7.18	0.62	387	0.3	Nil	Nil
3	Madhan	7.25	0.53	413	0.3	Nil	3.40
4	Nannu	7.18	0.44	353	0.3	Nil	Nil
5	Bhammakaran	7.22	0.55	293	0.3	Nil	Nil
6	Deepa/Kushal	7.68	0.43	367	0.3	Nil	0.70
7	Mega/Ram Singh	7.19	0.55	287	0.3	Nil	Nil
8	Mangilal	7.33	0.44	367	0.3	Nil	0.06
9	Laxman	7.29	0.50	293	0.3	Nil	0.06
10	Jai Singh	7.45	0.58	333	0.3	Nil	3.29
11	Mansingh Chanda	7.51	0.56	387	0.3	Nil	5.50
12	Khuman/Dola	7.38	0.66	373	0.3	Nil	Nil
13	Hajari/Chanda	6.88	0.55	440	0.4	Nil	Nil
14	Kamal Singh	6.9	0.34	367	0.4	Nil	0.43
15	Rodiya/Nathu	7.25	0.56	227	0.4	Nil	0.01
16	Hajiri/Pannalal	7.32	0.47	373	0.3	Nil	0.01
17	Ramlal/Bhawanlal	7.32	0.40	313	0.4	Nil	Nil
18	Kaniram/Ramlal	7.18	0.57	267	0.4	Nil	Nil
19	Mangilal/Ramlal	7.15	0.53	380	0.3	Nil	Nil
20	Nannu/Ramlal	7.2	0.55	353	0.3	Nil	Nil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Guna
Milli
Bundi
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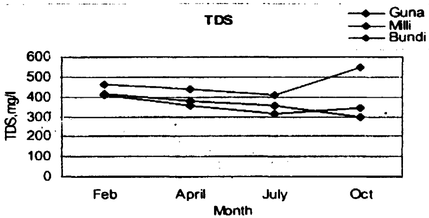
E.C,dS/m
Feb
April
July
Oct
Month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Milli
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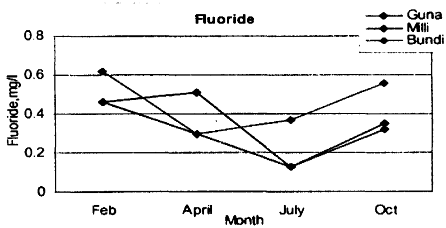
TDS,mg/l
Feb
April
July
Oct
Month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Milli
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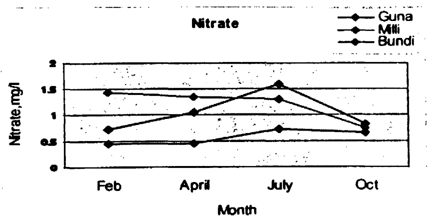
Fluoride,mg/l
Feb
April
July
Oct
Month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Feb
April
July
Oct
Month

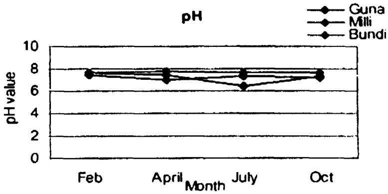

Fig5.2. Trend in Water Quality in the Three Watersheds

Table 15. Standards For Domestic Water Quality

Classification of impurities	Impurity	Max.permissible limit in ppm or mg/litre
Physical	1.Colour	15-25
	2.Turbidity	10-May
	3.Temperature	10^{0}-15.6^{0}c
	4.Taste & Odours	Nil
Biological	1.M.P.N.of coliform bacteria	Not more than one coliform colony per 100 ml of water sample
Chemical	1.pH-value	6.6 to 8.0
	2.Total solids	500-600
	3.Hardness	75-115(hardness expressed as CaCO3 equivalent)
	4.Barium	1
	5.Cadmium	0.01
	6.Chromium	0.05
	7.Selenium	0.05
	8.Arsenic	0.05
	9.Manganese	0.05
	10.Iron	0.3
	11.Lead	0.05 to 0.10
	12.Copper	1.04 to3.00
	13.Zinc	15
	14.Silver	0.05
	15.Fluoride	1.5
	16.Cyanide	0.2
	17.Phenolic substance	0.001(as phenol)
	18. Sulphate	250
	19.B.O.D.	Nil
	20. Nitrate	45
	21.Chloride	250

Table 16.Pumping Capacity And Pumping Hours Of Wells
Guna

Village Name	Farmer's Name	Pumping hours per day
Banjaribarri	Kaniram/Ramlal	2.0
	Mangilal/Ramlal	3.0
	Nannu/Ramlal	5.0
Kailashpura	Komal Singh	3.5
	Khuman Singh	2.5
	Ramlal	3.0
	Nannu	3 0
	Bhamakaran Singh	2.0
	Deepa	3.5
	Mega/Ramsingh	3.0
	Mangilal	4.0
	Laxman	3.5
	Jai Singh	4.0
	Mansingh/Chanda	3.5
	Hema/Dola	3.0
	Hajari/Chanda	2.5
Bardodakalan	Kamal Singh	3.5
	Rodiya/Nathu	2.5
	Hajari/Pannalal	4.5
	Ramlal/Bhuvanlal	1.0

Bundi(Thana)

List of Farmers	Pumping Capacity(HP)	Pumping Hours
1	8	5
2	8	5
3	8	4
4	8	3
5	8	4
6	8	4
7	8	3
8	8	3
9	8	2
10	8	2
11	8	3
12	8	2
13	8	2
14	8	2
15	8	3
16	8	3
17	8	2
18	8	3
19	8	5
20	8	3
21	8	4
22	8	2
23	8	5
24	8	2
25	8	2
26	8	4
27	8	4
28	8	4
29	8	4
30	8	3
31	8	4
32	8	4
33	8	8
34	8	4
35	8	4
36	8	4
37	8	24
38	8	8
39	8	24
40	8	5
41	8	5
42	8	10
43	8	10

44	8	7
45	8	24
46	8	5
47	8	6
48	8	5
49	8	7
50	8	4
51	8	4
52	8	2
53	8	5
54	8	7
55	8	2
56	8	7
57	8	7
58	8	6
59	8	3
60	8	2
61	8	3
62	8	5
63	8	7
64	8	5
65	8	4
66	8	7
67	8	10
68	8	0
69	8	7
70	8	10
71	8	12
72	8	14
73	8	8
74	8	14
75	8	14
76	8	12
77	8	24
78	8	7
79	8	7
80	8	24
81	8	14
82	8	14
83	8	14
84	8	2
85	8	5
86	8	5
87	8	4
88	8	8
89	8	5

90	8	6
91	8	5
92	8	5
93	8	4
94	8	5
95	8	2
96	8	5
97	8	3
98	8	4
99	8	6
100	8	6
101	8	6
102	8	2
103	8	5
104	8	2
105	8	10
106	8	2
107	8	4
108	8	4
109	8	2
110	8	3
111	8	5
112	8	5
113	8	8
114	8	6
115	8	6
116	8	3
117	8	2
118	8	2
119	8	8
120	8	6
121	8	2
122	8	8
123	8	2
124	8	2
125	8	2
126	8	2
127	8	2
128	8	2
129	8	2
130	8	3

C.Bundi (Goverdhanpuraa)

List of farmers	Pumping Capacity(HP)	Pumping Hours
1	5	4
2	10	4
3	8	4
4	8	4
5	8	4
6	8	4
7	8	4
8	8	4
9	8	4
10	8	3
11	8	3
12	8	3
13	10	4
14	8	4
15	8	4
16	8	4
17	8	4
18	8	4
19	8	4
20	5	4
21	8	4
22	8	4
23	8	4
24	8	4
25	8	4
26	8	4
27	8	4
28	8	4
29	8	4
30	8	4
31	8	4
32	8	4
33	8	4
34	8	4
35	8	4
36	8	4
37	8	4
38	8	4
39	8	4
40	8	4
41	8	4
42	8	4
43	8	4
44	8	4

6.CONCLUSION

6. CONCLUSIONS

In view of the global village concept the responsibilities of the governance and the civic of the developing countries have increased to ensure the proper, scientific use of the limited financial resources to maintain and monitor the natural resources in general and the water resources in particular to emulate the living standards of its countrymen.

Governments have been spending crores of rupees to conserve and augment the water resources. There is every need to have a rational and scientific approach to measure the impact of the steps taken.

Since the better advantages in terms of spatial and temporal aspects of Remote Sensing Technology aided with GIS tool can be preferred as a substitute for the time taking, harduous, high cost, traditional/conservative approaches.

In the development of performance indicators to assess the impact the approach adopted in this study is by considering the vegetative change through the measurement of Infra Red and Red band signals (NDVI) besides the Socio-economic components may be considered as a scientific and rational approach towards the impact assessment of integrated watershed management.

The model developed in this study may be applied elsewhere under similar environments for impact assessment of watersheds.

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