Estimation of Runoff from Small Agricultural Watershed Using Remote Sensing and GIS

A dissertation submitted in partial fulfillment of the requirement for the award of the degree

Master of Technology

In

Environmental Geo-Informatics

By

B.H. Sandhya Rani

ICRISAT
LIBRARY

Center for Environment
Institute of Science and Technology
Jawaharlal Nehru Technological University
Hyderabad-500028

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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

Science with a Human Face

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TO WHOMSOEVER IT MAY CONCERN

This is to certify that the project work entitled **"ESTIMATION OF RUNOFF FOR SMALL AGRICULTURAL WATERSHEDS USING REMOTE SENSING AND GIS** is a bonafied work of **MS. B.H. SANDHYA RANI** which was duly completed by her under my guidance as a part of her MASTER OF TECHNOLOGY in Environmental Geo-Informatics to the Jawaharlal Nehru Technological University and her work and efforts are appreciated.

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

A CGIAR Center

ICRISAT-Bamako
BP 320
Bamako
Mali
Tel +223 2223375
Fax +223 2228683
Email icrisat-w-mali@cgiar.org

ICRISAT-Bulawayo
Matopos Research Station
PO Box 776,
Bulawayo, Zimbabwe
Tel +263 83 8311 to15
Fax +263 83 8253/8307
Email icrisatzw@cgiar.org

ICRISAT-Lilongwe
Chitedze Agricultural Research Station
PO Box 1096
Lilongwe, Malawi
Tel +265 1 707297/071/067/057
Fax +265 1 707298
Email icrisat-malawi@cgiar.org

ICRISAT-Maputo
c/o INIA, Av. das FPLM No 2698
Caixa Postal 1906
Maputo, Mozambique
Tel +258 1 461657
Fax +258 1 461581
Email icrisatmoz@panintra.com

ICRISAT-Nairobi
(Regional hub ESA)
PO Box 39063, Nairobi,
Kenya
Tel +254 20 524550
Fax +254 20 524001
Email icrisat-nairobi@cgiar.org

ICRISAT-Niamey
(Regional hub WCA)
BP 12404
Niamey, Niger (Via Paris)
Tel +227 722529, 722725
Fax +227 734329
Email icrisatsc@cgiar.org

Visit us at www.icrisat.org

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Abstract

The present study titled "Estimation of Runoff from Small Agricultural Watersheds using Remote Sensing and GIS (Geographical Information Systems)". In this study Remote Sensing technology (ERDAS Software 8.7) and GIS tools (Arc-Info 8.0) are used to estimate the runoff. The base maps, slope maps, drainage maps were prepared from SOI (Survey of India) toposheets, land use land cover maps which is an important input for SCS (Soil Conservation Service) model were prepared from IRS P6-LISS IV satellite images and GIS, which has been designed to restore, manipulate, retrieve and display spatial and non-spatial data, is an important tool in analysis of parameters such as land use/ land cover, soils, topographical, hydrological conditions. The DEM (Digital Elevation Model)were generated in this study with the topographic information at 20 m interval contours has been used.

The type of the soil present in Lalatora (Milli) and Guna watersheds Vertisols and Bundi watershed Consists of silt clay/sandy clay. With the help of SCS model, in conjunction with Remote Sensing and GIS it is possible to make management plans for usage and development of a watershed.

Runoff and consequent soil erosion are inevitable under a tropical monsoon. These need quantification for the design and adaptation of control measures, these can be done by monitoring the soil and runoff losses on watershed basis. Watershed is an area that drains to a common point. It may be managed for various objectives, depending on local needs, including capturing runoff, minimizing erosion and reducing non point source pollution.

In the present study the runoff is modeled using SCS (Soil Conservation Service) Curve Number is best estimated for agricultural watersheds.

This study area reveled predicted runoff values are under-estimated compared to the observed values in the three watersheds (Bundi. Guna and Lalatora) for normal green cover. The predicted runoff values are from smaller area. ranges from 20 to 500 ha. The measured runoff value is for larger area (9000ha).

Remote Sensing and GIS are used to spatially visualize the runoff estimates over the whole watershed. Using conventional methods. it's become highly difficult to collect the data remote and inaccessible places. Remote sensing and GIS provides an alternative.

Black soils are more prone to runoff compared to red soils; hence effort should be made to take up short duration cover crops so as to minimize the raindrop impact or runoff in the kharif season.

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1.INTRODUCTION

1.1 General

Water is the most critical resource and constraint in the semi-arid tropics (SAT). To minimize the land degradation and sustain crop productivity in the SAT, management and efficient utilization of rainwater is important. Watershed based resource utilization involves the optimum use of area's precipitation for the improvement and stabilization of agriculture on the watershed through better water, soil, and crop management. More effective utilization of water for the production of crops can be facilitated by

i) in situ conversation of moisture ,of rainwater

ii) proper drainage , collection ,storage, and reutilization of runoff.

iii) ground water recovery from wells

Water can be managed if watershed is taken as a unit.

1.2 WATERSHED

A watershed is a hydrologically defined area that is drained by a network of streams, which meet together in such a way that the water leaves through a common point. The characteristics of the drainage network play a great part in determining how the water moves through the basin and consequently impacts on the issues such as water quality and quantity in given place.

Estimation of runoff is of prime importance in hydrological studies. Design of hydraulic structure necessitates the estimation of runoff. Various linear as well as non linear models have been developed for the estimation of runoff

Throughout the world the need for hydrological studies results from engineering problems encountered by man, such as flooding, design of bridges and dams, soil erosion, design of storm water drains. Most environmental process show complicated interrelations, both time and space, leading to numerical models with a complex mathematical structure. Also environmental models require huge amount of data often coming from many sources like remote sensing.

In the present study direct runoff is computed using soil conservation service (SCS) model, an empirical equation that requires rainfall and watershed coefficient as inputs. The watershed coefficient is called the curve number (CN), which represents the runoff potential of the land cover – soil complex. One of important models for estimation of runoff is the soil conservation service (SCS) runoff curve number model, which has had wide acceptance in engineering practice due to its simplicity, easy predictability, and stability of the solution and reliability of the results.

The major problem in testing these models is the generation of spatial input data. With the advent of Remote Sensing technology, deriving the spatial information on input parameters has become more handy and cost effective. Besides with the powerful spatial processing capabilities of Geographic Information System (GIS) and its compatibility with the remote sensing, runoff modeling approaches have become more comprehensive and robust.

1.3 Model Watershed Programme by ICRISAT Consortium

Land degradation in arid and semi-arid environment if not checked leads to desertification resulting in reduced crop production, poverty, starvation and migration of people and animals. In order to arrest land degradation and increase the productivity in Madhya Pradesh and Eastern Rajasthan Sir Dorabji Tata Trust has supported ICRISAT- led consortium through a project "combating Land Degradation and

Increasing Productivity in Madhya Pradesh and Eastern Rajasthan". The overall objective of the project is to minimize land degradation and to improve food security and livelihood opportunities for rural people through management and conservation of natural resources. The approach adopted in the project is a consortium approach for technical backup through convergence of all development activities in a benchmark watershed. The benchmark watershed will be used as sites of learning and through capacity building the benefits of integrated watershed management will be scaled- up to other watersheds in the target districts.

The considerable progress is achieved for this project. The main aim was to involve all concerned people (policy makers, researchers, and development departments in the region) to scale up the findings from the benchmark project in respective regions. A multi disciplinary team was constituted which consisting of members from consortium partners selected watersheds in Guna (Kailaspura, Baroda Kalan, and Banjari Bardi), Milli watershed (Lalatora) and Bundi (Thana and Govardhanapura) districts.

1.4 Objectives of Study Area

- The scope of the present study is to map the watershed area in respect the current land use/land cover pattern, soil map, soil depth, cadastral map and drainage map.
- To prepare different thematic maps including base map, drainage map, contour map, soil map by using Remote Sensing and GIS.
- To find out the Runoff in the given watershed areas by using Remote sensing and geographical Information systems

2. REVIEW OF LITERATURE

2. LITERATURE REVIEW

2.1 Watershed Management

Water, the very basis of life and the single most important feature of our planet, is the most threatened resource today. In rainfed areas watershed management is the approach used for conservation of water and other natural resources as well as for sustainable management of natural resources. A watershed is made up of soil, vegetation and water along with the people and animals who are the integral part of the system.

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.

Sustainable management of a watershed thus entails the rational utilization of land and water resources for optimum production but minimum hazard to natural and human resources. Therefore, watershed management is the process of guiding and organizing land use and use of other resources in a watershed to provide desired goods and services to people while enhancing the resource base without adversely affecting natural resources and the environment (Wani et al. 2001). Embedded in this concept is the recognition of the interrelationships among land use, soil and water, and the linkages between uplands and downstream areas.

Watershed management approaches are evolving throughout the country and are being used to solve tough problems.

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. (Wani et al, 2002b).

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 aforestration 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. The 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 (Wani et al. 2003).

2.2 Runoff

Runoff is the residual precipitation remaining after the interception and evapotranspiration losses have been deduced. It appears in surface channels, natural or manmade, whose flow is perennial or intermittent. Classified by the path taken by channel, runoff may be surface, subsurface, or ground water flow.

Surface runoff = {Precipitation} - {evaporation + interception + infiltration + Surface detention + storage

2.3 Factors Affecting Runoff

2.3.1 Rainfall

Precipitation, whether it occurs as rain or snow, is the potential source of water that may run off the surface of small watersheds. The extent of the storm and the distribution of rainfall during the storm are two major factors, which affect the peak rate of runoff.

2.3.2 Antecedent Moisture Condition

The runoff from a given storm is affected by the existing soil moisture content resulting from the amount of precipitation occurring during the preceding five days (antecedent moisture condition).

2.3.3 Watershed Area

The watershed area or area draining water to the point of interest is usually determined from a topographic map or scaled aerial photograph accompanied by a field review locating manmade features that have diverted the flow of water.

2.3.4 Soils

In general, the higher the rate of infiltration, the lower the quantity of stormwater runoff. Fine-textured soils such as clay produce a higher rate of runoff than do course-textured soils such as sand. Sites having clay soils may require the construction of more elaborate drainage systems than sites having sandy soils.

2.3.5 Surface Cover

The type of cover and its condition affects runoff volume through its influence on the infiltration rate of the soil. Fallow land yields more runoff than forested or grass land for a given soil type. The foliage and its litter maintain the soil's infiltration potential by preventing the sealing of the soil surface from the impact of the raindrops. Some of the raindrops are maintained on the surface of the foliage, increasing their chance of being evaporated back to the atmosphere. Some of the intercepted moisture is so long draining from the plant down to the soil that it is withheld from the initial period of runoff. Foliage also transpires moisture into the atmosphere thereby creating a moisture deficiency in the soil, which must be replaced by rainfall before runoff occurs. Vegetation, including ground litter, forms numerous barriers along the path of the water flowing over the surface of the land, which slows the water down and reduces its peak rate of runoff. Covering areas with impervious material reduces surface storage and infiltration and thus increases the amount of runoff.

2.3.6 Time Parameters

Time is the parameter that is used to distribute the runoff into a hydrograph. The time is based on the velocities of flow through segments of the watershed. The slope of the land in the watershed is a major factor in determining the velocity. Two major parameters are time of concentration (Tc) and travel time of flow through the segments (Tt).

2.3.7 Storage in the Watershed

On very flat surfaces where ponding or swampy areas occur throughout the watershed, a considerable amount of the surface runoff may be retained in temporary storage, thus reducing the rate at which runoff will occur. Storage areas may be created to reduce the rate of runoff in an urbanizing area. These can be effective sediment traps as well as flood detention structures if left permanently in the watershed. (Nation Engineering Hand book, 1993)

2.4 Hydrologic Cycle

The basic components of the hydrological cycle include precipitation, evaporation, evapotranspiration, infiltration, overland flow, stream flow and ground water flow. The hydrologic cycle is very complex but under certain well-defined conditions, the response of watershed to rainfall, infiltration and evapotranspiration can be estimated under realistic assumptions. The components of water balance in a watershed in unit of depth, may be written as

Rainfall = Surface runoff+ Ground water flow+ Interception losses+
Depression storage + Evapotranspiration+ Change in soil water
Storage.

Information on surface runoff volume and its peak intensity is needed for several purposes in soil and water management. For eg: it is needed in the design of soil and water conservation structures, for studying the effect of land treatment and planning supplemental irrigation. Information on other components of hydrological water balance is also needed for various purposes for management of soil and water management.

2.4.1 Evapotranspiration

Evapotranspiration (ET) is the conversion of water to vapor and the transport of that vapor away from the water surface in to the atmostsphere. Only unrestricted moisture conditions evapotranspiration taken place at a potential rate. evapotransspiration flux moves large quantities of soil moistures back to atmosphere.Spatial and temporal estimation of actual evapotranspiration (ET) is required for continuous models which simulate hydrologic process that occur between storms as well as during the storm. The estimation of evapotranspiration may be approached in many ways depending upon the data available.

PATHAK (1989) at ICRISAT Hyderabad computed the evaporation and transpiration separately for his runoff model as below.

$E^* = \beta E_0 / t^*$

$T = (1-\beta) E_0$

Where,

E_0=daily pan evaporation

E*=daily evaporation from the soil

β=light interception coefficient (range from 1 to 0)

T=daily transpiration

t*=time factor

The value of time factor depends on the frequency of soil wetting. when soil is wetted either by rainfall of irrigation* for the first non day is 1,for the second non rainy day it is 2,for the third non rainy day it is 3 and so on through out the rain free days. On a rainy day t* is taken as 2 except in situations where is rainfall greater than the open pan evaporation during the previous day in which case t* starts at 1 again. The same empirical equations are use in the present model to simulate evaporation and transpiration.

HASHMI et al.(1994),developed a model to estimate crop evapotranspiraion(ET),the prime variable in estimating irrigation demand. They computed spatial variability of evapotranspirayion using GIS. Nonspatial models are based on the concept that a measured value represents a homogeneous area around the measured point, which is generally not true in areas with large climate or topological variation. This model uses the spatial databases that are developed for agricultural land use ,climate parameters and topographic data using GIS. This model is best used to characterize the factors that affect the accuracy of regional evapotranspiration.

2.4.2 Infiltration

Infiltration is the process through which water enters the soil. It replenishes the soil moisture deficiency and the excess moves downward by the force of gravity until it reaches the ground water. The infiltration rate of water increases with temperature

(Duke, 1992). Infiltration of water in to soil influences profoundly the soil water regime and inturs its availability to plants evaporation and transpiration and ground water recharge (Hirkurubav, 1993).

2.4.3 Soil Moisture

It is desirable to have accurate prediction of soil moisture before a rainfall event because of its effect on infiltration and the surface runoff.

PHATAK (1989) at ICRISAT Hyderabad computed soil moisture on daily basis using soil moisture accounting procedure. It is based on an assumption that whenever there is rainfall or irrigation the upper layer is fully recharged before any moisture is transmitted to the lower layer. This method is reasonably accurate and use simple water balance equation.

NGARA (1993) conducted soil moisture studies in some soils around Harare (Zimbabwe). Accounting to him, the amount of water is a sail is itself no effective indication of its availability. A better indicator is the force with which the water is held in to the soil. Field capacity is said to be upper limit and wilting point, the lower limit of plant available water. Actually field capacity is the soil dependent and is influenced by soil permeability. Well drained sandy soils have a FC value of 1/10 atm while well drained clayey soils have a FC value 1/3 atm.

ALTENDORS et al . (1999), developed a set of neural networks, that predicts soil water content at given dep6th as a function of soil temperature .the model developed to predict the moisture at a depths 0.15m, 0.3 m, 0.6m and 1.2m. the input data consists of soil co-efficient describing soil type and soil temperature measured at depths above and below the desired depth. The model will predicts the variation in water content with time and its performance increased as depth is deeper. This is simple and potential model performs better than the linear regression models.

2.5 Methods of Determining Runoff

Many different methods of computing runoff have been developed. Some of the methods and limitations of each are listed below.

1.The Rational Method establishes an empirical formula, Q=CiA, for computing peak rates of runoff that is commonly used in urban areas.

"Q" is the peak runoff rate in cfs,
"C" is a runoff coefficient,
"i" is the average rainfall intensity in in./hr. and
"A" is the drainage area in acres.

It is useful for estimating runoff on relatively small areas such as rooftops, parking lots, or others
The most serious drawback of the Rational Method is that it gives only peak discharge and provides no information on the time distribution of the storm runoff.
Furthermore, the choice of "C" and Time of Concentration "Tc" when choosing "i" in the Rational Method is more an art of judgment than a precise account of the antecedent moisture or a real distribution of rainfall intensity. .

2. Computer Program for Project Formulation--Hydrology, SCS-TR-20, utilizes hydrologic soil-cover complexes to determine runoff volumes and unit hydrographs to determine peak rates of discharge. Factors included in the method are 24-hour rainfall amount, a given rainfall distribution, runoff curve numbers, time of concentration, travel time, and drainage area. It is very useful for large drainage basins, especially when there are a series of structures or several tributaries to be studied. The program h as the capability of routing storm volumes through road culverts and storm detention basins.

3. The SCS-TR-55 tabular method is an approximation of the more detailed SCS-TR-20 method. The tabular method can be used for watersheds where hydrographs are needed to measure non-homogeneous runoff, i.e., the watershed is divided into sub-areas. It is especially applicable for measuring the effects of changed land use in a part of the watershed. It can also be used to determine the effects of channel modifications, at different locations in a watershed. The tabular method should not be used when large changes in the curve number occur among sub-areas within a watershed or when the drainage areas of the sub-areas differ by a factor of 5 or more. For most watershed conditions, however, this procedure is adequate to determine the effects of urbanization on peak rates of discharge for sub-areas with "Tc" less than two hours.

4. The SCS-TR-55 Graphical Peak Discharge Method calculates peak discharge from hydrograph analyses using TR-20 Computer Program for Project Formulation. This method demonstrates a procedure for estimating depth and peak rates of runoff from small watersheds. The watershed must be hydrologically homogeneous, that is land use, soils and cover area distributed uniformly throughout the watershed. The time of concentration for the watershed is estimated using the computed flow velocities for the sheet flow, shallow concentrated flow and channel flow. These values may range from 0.1 to 10 hours.

In India, the availability of accurate information on runoff is scarcely available in few selected sites. However, quickening of the watershed management programme for conservation and development of natural resources management has necessitated the runoff information. Advances in computational power and the growing availability of spatial data have made it possible to accurately predict the runoff. The possibility of rapidly combining data of different types in a Geographic Information System (GIS) has led to significant increase in its use in hydrological applications. The curve number method (SCS, 1972), also known as the hydrologic soil cover complex method, is a versatile and widely used procedure for runoff estimation.

2.6 Concepts of Remote Sensing and GIS in Watershed Management

Watershed management requires exhaustive data and information, which are dynamic in nature and temporarily change over time and space due to natural and external influences an agro-climatic environment. Using conventional methods, it becomes highly difficult to collect the data from remote and inaccessible areas. More over the collected data are often inadequate, outdated and time consuming besides being more expensive. By the time one planning process is completed based on a set of information, the regime of watershed undergoes drastic changes rendering the plan worthless. Under these circumstances, more emphasis is required to be given to develop watershed models, which can quickly analyses the changing parameters. Remote Sensing technology has immense contribution towards this in providing synoptic and unbiased information on large area sat periodic intervals.

2.7 Role of Remote Sensing and GIS in Runoff Modeling

Remote sensing and GIS techniques are being increasingly used for planning, development management of natural resources. GIS technologies in particular help in integrating various datasets and perform various spatial analysis for decision making. GIS and remote sensing are presently being used for solving environment problems like degradation of land by water logging, soil erosion, contamination of surface and ground water resources, deforestation, changes in ecological parameters and many more.

Recently GIS technique has been interfaced with some standard hydrological models either distributed type or hydrologic parameters type, to capture the variation in computed quantities.

2.8 Principles of Remote Sensing

"Remote sensing is a science and art of obtaining useful information about an object or phenomenon, from a distance, without actually coming into physical contact with the target."

The main means of remote sensing is to measure the Electro-Magnetic Energy (EME) coming from sun and which is reflected, scattered or emitted by the surface features/objects using passive or active sensors onboard airborne and space-borne earth resources observation platforms. Examples of former are LANDSAT, SPOT and IRS series of satellites, while that of latter is of ERS-1, RADARSAT and RISAT missions. (M Amji Reddy, 2001)

Different objects on the surface of the earth reflect different amounts of energy in different wavelengths of the Electromagnetic Spectrum (EMS) Detection and measurement of these spectral responses and spectral signatures enable identification and classification of surface objects through visual interpretation techniques and/or digital analysis using computers. But often, similar spectral response from objects creates spectral inseparability causing misinterpretation and misclassification. This is overcome by systematic ground verifications/ measurements and thereby improving the accuracy of thematic content of the maps. "Satellite remote sensing provides multi-spectral, multi-spatial, multi-temporal and multi-sensor data, which can be meaningfully used in resources inventory, mapping, monitoring and their management." IRS 1C/1D satellite offers "3D - Stereo - viewing" capability for better understanding of the terrain and its cover, whereas microwave satellite offers cloud free images, which are vital for areas, which are persistently under cloud.

Remotely sensed data is compatible and can be integrated with most of the other data generated from conventional and ground measurement systems, using Geographic

Information Systems (GIS) technologies for finding optimal solutions for effective management of earth resources and environment for sustainable development.

2.9 Applications of Remote Sensing

Remote sensing methods have great promise as technique for both reconnaissance and detailed exploration of both renewable and non-renewable resources such as mineral exploration, mapping hydrothermal rocks, oil exploration and rural- urban exploration. This technology finds also application in several areas such as agriculture, forestry, surface and ground water, soils classification, land use, pollution monitoring and cartography. Remote sensing is a valuable source of environmental information on regional scale and repetitive schedule about the atmosphere, continents and oceans. With faster rate of increase of population there is great changes in land use / land cover. Agriculture areas are being converted according to necessities and utility irrespective of their impact on ecology and environment. Forestlands are being stripped of for timber or conversion into agriculture. Although many changes are detrimental to the environment, it's unlikely that the process will halt. The alternative is to plan and regulate the changes to minimize negative impacts on environment. Planning requires an accurate inventory of existing patterns of land use / land cover. Remote sensing images provide a database for such inventories at scales ranging from regional to local. It also can utilize in estimation and alert of natural hazards e.g. drought, flood, pest impacts. Thus remote sensing techniques are helpful in carrying out rescue, relief and rehabilitation efforts. With the experience gained so far in mapping and monitoring the natural resources it is accepted by one and all that no single system provides all the needed information about an area. So the investigator shall select images types based on sensor capability, climate condition and objective of the investigation.

Remote sensing techniques provide quick reliable and repetitive database at economic rates compared to other conventional methods. It is advantageous particularly to inaccessible and inhospitable areas. Remote sensing is an initial step that must be followed by field checking, sampling field surveys. Drought prone areas are to be tackled by integrated strategies to over come impact of drought and mitigate the effects like shortage of food grains, fodder and depletion of water resources.

Remote sensing can be utilized in warning scarcity of resources and help in providing relief, reducing lag time in supply of required inputs for agriculture, fodder for cattle and in planning contingency plan. Conventional early warning systems can be complemented supplemented with remote sensing inputs derived from satellite data. In Fodder management there seems to overlapping among the information packages for water, agriculture land and fodder resources. The optimal use and inter linkage among the resources essential for maximum utility. While the required data is obtained from conventional resources, the data gaps can be filled by remote sensing technology.

Monitoring is required for taking corrective measures at appropriate times, through cropping system. On term basis its helps in accessing the performance of suggest measure of land, water, forest, conservation and related treatments.

Remote sensing technique is handy in drought management. Management of drought needs special attention towards evolving a strategic management plan to tackle the problem both in short term and long term. Remote sensing technology allows the speedy collection of data on land, water resources and their spatial distribution. Thus this database help the scientists / planners / organizing agents to design the program according to the target.

Thus the scope of application of remoter sensing and GIS is vast in management of land resources in more scientific way so as to get the optimal utilization of natural resource without of degradation of lands, water, forest resources and better environmental protection

2.10 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 817km in the descending node. The satellite takes 101.35 minutes to complete one revolution around the earth and completes about 14 orbits per day. 341 orbits cover the entire earth 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.

2.10.1 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. Specifications and resolution of all the three sensors is given in table 1.

2.10.2 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 Resorcesat-1 with it's ability to record data anywhere in the world with its advanced On Board Solid State Recorder, has entered into new dimensions of meeting the requirements of Resource Managers globally. Specifications of IRS P6 are given in table 2.

Leuder (1959) was of the opinion that mapping of certain phases like slope, erosion, stoniness ad drainage can be accomplished with minimum of field checking, kamphrost and iyer(1972) used aerial photos to differentiate four ravine and classes based on depth and other morphomertric features perceived through interpretation and parallax bar measurements. Latz et al (1984) found that eroded aflisols are to have higher spectral reflectance as compared to normal soils due to exposure of B horizon with higher iron content and low organic matter. A review of the spectral reflectance data for soil erosion investigations has provided by Wiesmiller et al., (1985).

Dwivedi et al.,(2001)using temporal Remote Sensing data studied the land use/land cover changes in the part of Anantapur district.

Dwivedi et al (2004) using Remote Sensing and GIS generated baseline information on natural resources and degradable lands for comprehensive developments of watershed.

Using remote sensing and GIS McCloy(1995) evaluated the risk of soil erosion for the harbour creek cathcmant in New south wales, Australia. Kumar et al (1997) observed the maximum spectral response from severely eroded black soils followed by moderately erode and nil to slightly eroded soils, while studying the spectral of pattern of eroded black cotton soils of the Indianan peninsula in the Landsat MSS, TM and SPOT HRV MLA spectral bands .Wu et al (1997) used Landsat TM data and GIS to evaluate and monitor the impact of soil conservation measures in Finney country, Kansas, USA. Other IRS IC PAN data was used for mapping and monitoring ravenous lands in western Uttar Pradesh (Singh et al ,1998). A pilot study on the reclamative grouping of ravines was made using IRS ID LISS --III data(NRSA, 2000).

2.11 Geographic information system technology

GIS is a "system of hardware, software, data, people, organization and institutional arrangement for collecting, storing, analyzing, and disseminating information about areas of the earth" (Dueker and Kjerne, 1989). GIS are computer-based systems that can deal with virtually any type of information about features that can be referenced by geographical location. These systems are capable of handling both location data and attribute data about such features. Along with the automated mapping or display of locations of features, but also these systems provide a capability for recording and analyzing descriptive characteristics about features. The most important benefits of GIS is the ability to spatially interrelate multiple types of information stemming from a range of sources. The manipulation and overlay of various thematic maps such as e.g. land use / land cover with soil map for future prediction of land use. The analysis of cadastral map with all other thematic maps of the region for statistical data, are few examples of watershed management by application in GIS. Thus the number, form and complexity of other data analysis is possible with a GIS are virtually limitless. Such procedures can operate on system's spatial data, the attribute data or both that permits combing detailed map categories to create new less detailed categories for easy analysis. (Heidke 1993).

Several constrains need to be considered when combining data from multiple sources in a GIS. The data layers of cover same geographic location or overlap. The data layers must share one coordinate system to other. The spatial scale at which each original source maps compiled must be compatible with that of others. Last but not the least, the important constrain is that the compilation time of different source map must be reasonably close in time. Example, if the source data of Landuse is few years old, then it would result in wrong statistics and present trend shall be missed, there by result in wrong conclusion. (Lillesand & Kiefer – 2000).

2.11.1 Spatial Data Models

The spatial data is represented in two types: the raster model and the vector model. In raster model the data stored in the form of a rectangular array of picture elements or pixels. The area that each pixel represents defines the spatial resolution. In the raster structure a value for the parameter of interest of like land use class, soil type etc. is given to each pixels in an array. Operation on raster involves files involve the retrieval and processing of the data in all pixels.

The vector model represents an object an object means of points, lines and polygons, i.e .as sets of vectors. The fundamental primitive in the vector model is the point object. Line are created by connecting points with straight lines, areas are defined by a set of lines .The position of each object is defined by its placements in a map space, with respect to a coordinate reference system. The spatial entities in the vector model corresponding more or less to the spatial entities in the vector model corresponding more or less to the spatial entities in the real world which they represent.

Haan et al (1995) distinguished four levels linkage of hydrological model with GIOS. These levels vary from essentially considering GIS and the model as separate systems in fully integrating the model and GIS. The lowest level of integration consists of using GIS as an aid in porting the spatial input data required for a model. The next level of integration is to use an interfacing program specifically written to communicate between the GIS and the model. The interface program may serve as control program in issuing commands to the GIS. A third level of integration occurs when the interface program is interoperated in to the model. This requires modification to the input/output routines of existing models is developing special input/output routines for new models.

The highest level of integration occurs when the model and GIS is essentially a single, integrated union. One way of achieving this is by programming the model using the programming language appropriate to the GIS being employed.

Lopez and Zinck(1991) could establish cause-effect relationships responsible for mass movement using GIS analysis techniques. Vieux (1991) integrated a distributed finite element process model of overland flow and the ARC/INFO GIS software. His model represents overland flow as sheet flow and is modeled as such over each finite element. GIS is utilized to provide topographic information for modeling overland flow in small catchment.. Vogt and Gomer (1992).

Sharada at al (1993) have successfully used the GIS technique prioritize the watersheds of Musi catchment by employing Sediment Yield Index method

Saha and pande(1994) have used GIS and remote sensing techniques to assess the soil erosion suspecability in Sitla Rao watershed, west Doon valley, India and found out that remote sensing and GIS are very useful tools in assessment and mapping the soil erosion suspectability.

He et al (1993) integrated GIS and computer model to evaluate the impacts of agricultural runoff on water quality. Various management scenarios were explored to minimize sedimentation and nutrient loading. The scenarios included variations in crop cover tillage methods and other agricultural management practices.

Savabi et al (1996) made study o9n using GRASS GIS together with WEPP. The GIS package was used to obtain many of the needed input parameters for WEPP. Annual WEPP simulated and measured storm runoff amounts were compared. The results indicated that DEM and GRASS GIS technique are powerful tools and can used to parameteriz3d the WEPP model. Mitasova et al (1996) could model the erosion-deposition process in GIS using high resolution DEM data.

2.12 INTROCUTION TO DIFFERENT TYPES OF MODLES

Models can be classified as stochastic or Deterministic models.

1. Stochastic models: - In which the variables included in the model are Considered as random variables having distributions in probability.
2. Deterministic models: - Where in all variables are regarded as free from Random variation

The classi. cation of the models can be summarized as below:

Physical: - A prototype built in a laboratory to assume dynamic similitude between model and real world

Analogue:- Such as flow of electricity used to simulate the flow of water in soils.

Mathematical: In which the behavior of the response of the system to various inputs is represented by a set of equation together with logical statements expressing relationships between variables and parameters.

Lumped models: -Neither takes into account the spatial/temporal distribution in the input variables, nor the spatial/temporal variation in parameters characterizing the physical processes acting upon unit.

Distributed models: - Have concern about the spatial distribution of variables together with computational algorithms while evaluating the influence on simulated behavior.

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Models can be conceptual or empirical

Conceptual: - if the physical process relating the input variables to produce the output variables is considered in terms of physical laws.

Empirical: - models are by strict definition based on observation and experiment but not o any theory. Regression models are empirical, being based on observation and not on understanding process.

The term "physically based models are generally being used to replace conceptual distributed model. Because if models are physically based, meaning firmly based in our understanding of the physics of the processes, they are necessarily distributed because the equations on which they are defined generally involve one or more space coordinates. (Beven,1985). Physically based hydrological models thus have the capability of forecasting the spatial pattern of hydrological conditions with in catchments as well as simple outflows and storage volumes.

It is not strange to see the conceptual, or physically based models using empirical processes description.

The hydrological models can be also categorized as event based models or continuous models.

Event Model: - which predicts the output for a single rainfall event occurring over a period of time ranging from an hour to several days.

Continuous Model: - Is the one that operates over an extended period of time determining flow rates and conditions. It keeps predicting the output during rainfall events as well as periods with out rain.

Though the output of the process predicted from a model is exactly equal to the measure output, it is worthwhile to try to model a certain process because the process of model development contributes to improved understanding of the process.

DeCoursey (1991) had described the utility of a model in the following ways

1) Hypothesis expressed in mathematical terminology can provide a quantitative description and understanding of chemical, biological and hydrological; processes and interaction
2) complete mathematical model can provide a conceptual framework which will help to pin point the area were knowledge is lacking and might stimulate new ideas and experimental approaches.
3) Mathematical models are a good way disseminating research knowledge in an easy to use form to the user
4) The economic benefits of methods suggested by research can often be investigated and highlighted by a model, thus stimulating the adoption of improved methods of prediction.
5) Modeling may lead to less ad hoc experimentation
6) Models sometimes make it easier to design experiments to answer specific questions or to discriminate between several alternatives.
7) Model integrates the knowledge about various parts in a system with several components, there by giving coherent view of the behavior of the whole system
8) Modeling can help provide strategic and tactical support to a research program, motivating scientists and encouraging collaboration

9) A model may provide a powerful means of summarizing the data and also a method for interpolation and cautious extrapolation
10) Model forms a good tool of understanding the behavior of an area where real data collection forms a tedious and expensive

11) A successful model will have a predictive power which may be used in playing "what if games" in assigning priorities in research and development, management and planning

12) Models validated by data from experimental catchments provide a mechanism it transfer data from study areas to other area s where fewer data may be available.

2.12.1 Model Selection

Selection of the model depends up on the available input and output .The Soil Conservation Service Number (USDA-SCS, 1972) is one of the most widely used methods for runoff estimation for small watersheds. for example, it has been used in large more complex models like CREAMS and EPIC to calculate runoff, in order to assess nutrient loss and effect of soil erosion on soil productivity. The curve number (CN) method is simple and provides reasonably accurate results under certain conditions. Its biggest advantage is that it requires few inputs.

2.12.2 The advantages with specific SCS method are:

a) SCS model parameters are defined with respect to soil, land use, land treatment, and antecedent soil moisture which could be derived easily through remote sensing data, published soil maps and reports.
b) Easily adaptable to mathematical formulation of a distributed model
c) SCS model parameters can easily be altered in response to anthropogenic activities and cover types that occur in a watershed
d) The curve number provided could explain most of the possible activities and cover types that could occur in a watershed.
e) It is simple and computationally efficient.

2.12.3 Digital elevation Model (DEM)

Digital Elevation Model is a raster representation of a continuous surface, usually referring to the surface of the earth. The accuracy of this data is determined primarily by the resolution (the distance between sample points). Other factors affecting the accuracy are the data type (integer or floating point) and actual sampling of the surface when creating the original DEM. It is a digital representation of continuous variable over a two – dimensional surface by regular array of z values referenced to a common datum. Digital Elevation Models are typically used to represent terrain relief. Also referred to as digital terrain model (DTM)

2.12.4Applications of DEM

DEMs have several geomorphological and hydrological applications.

- Computing the terrain properties (e.g: slope and aspect)
- Selecting the alignment of roads and settlements
- Analyzing and comparing the different types of terrain
- Ascertaining the invisibility between the two points
- Cut and fill problems in engineering projects
- Site selection for engineering project
- Displaying the landforms in three dimension for the design and planning of landscape
- Sorting elevation data for digital topographic map on rational data bases

3. STUDY AREA DESCRIPTION

3. STUDY AREA DESCRIPTION

The present study is comprises of three different watershed areas named BUNDI, MADHUSUDHANGADH (GUNA), LALATORA (VIDISHA). Fig 1 shows the location map of Bundi, Lalatota(Milli) and Guna Watershed.

3.1 Bundi Watershed

Bundi watershed is located in Nainwa Taluk, Bundi district in the north eastern region of Rajasthan state at 24^0 16'00''N and 77^0 30' 15''E covering a total area of 4,500 ha.. the topography is undulating with a slope of 10 to 15%. The soil type ranges from sandy clay to silt clay type with a soil depth of 30 to 130 cm. The Ph of the soil ranges 8.07 to 8.25. this is a rainfed region with a temperature as low as 8 ^{0}C and the maximum rising up to 48^0C the rainfall received from this region ranges between 450 to 600 mm.

Land use pattern and major crops: the land use pattern in the location proposed had a total area of 1,15,000 ha with 20% under forest cover, 58% under cultivable area, 14% under non-cultivable wasteland and 8% under pasture and follow land. The major crops grown up in the rainy season are maize, sesame, groundnut, black gram and green gram. The crops taken up in the post rainy season are wheat, mustard, gram and lentil. Fig 2 shows satellite imagery of Bundi Watershed.

3.2 Lalatora watershed

Lalatora watershed is located at about 135 km from Bhopal in northeastern part of vidisha district, Madhya pradesh. The watershed area is about 725 ha and is a sub-watershed of milli watershed having total area of about 10525 ha and lying between latitude 24^0 16'00''N, longitude 77^0 30' 15''E at an altitude of 415 m above the mean sea level

The topography of the present watershed study area is gently undulating. The soils are mostly vertisols and associated soils with poor internal drainage. The major crops grown are Maize, Sorghum rainy season and Wheat, chicpea in the postrainy season. Some pulses, vegetables, paddy and spices are also grown in small quantities in both the season. In spite of high rainfall, very large areas are kept fallow during the rainy season and crops are taken during the post rainy season on stored moisture in the soil profile. The climate of the study area is mainly sub humid during monsoon period. Summer is very hot where as winter is mild. The maximum and the minimum temperatures are 31.5^{0}C and 8.5^{0}C. The average annual rainfall ranges from 757-1300mm. Fig 3 shows satellite imagery of Lalatora (Milli) Watershed.

3.3 MADHUSUDHANGADH (GUNA) WATERSHED

The present study area is located in Guna district of Madhya Pradesh at 23^{0} 57' 48.50''N and 79^{0} 16' 06.99''E. The watershed includes three different villages namely Banjariberi (23^{0} 57' 48.50''N 79^{0} 16' 6.99'' E), Kailaspura (23^{0} 58' 50.03''N and 79^{0} 16' 26.03''E),and Barodakalan (23^{0} 58' 29.13''N and 23^{0} 58' 29.13''N).

The topography is undulating terrain with moderate slopes. The prevalent soil types are medium black and red soils with a soil depth of about 150 cm. This is predominantly a rainfed area covering 80 percent and the rainy season extends from July to September. The average rainfall received is 1070 mm. Minimum temperature of 6^{0}C is recorded in the month of January and maximum temperature goes up to 44^{0}C in June the crops grown in rain season are soybean, maize and jowar. Wheat and gram are the post rainy season crops in the region.Fig 4 shows satellite imagery of Guna Watershed.

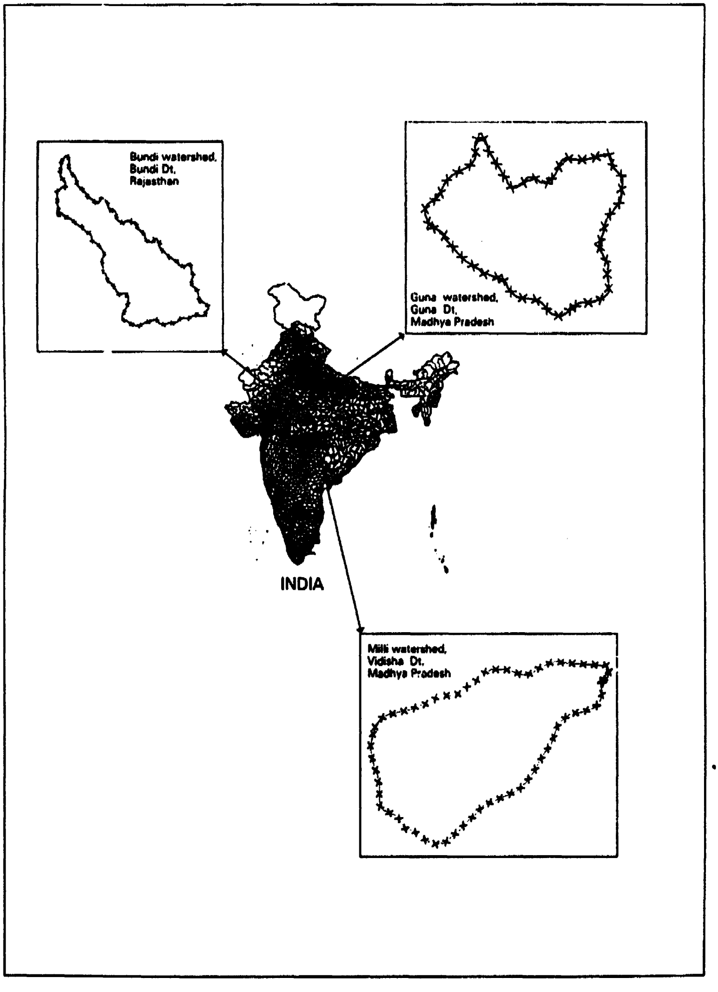


Fig 1: Location Map

4.MATERIALS AND METHODOLOGY

4. MATERIALS AND METHODOLOGY

4.1 Materials

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 4 th February 2004 covered by path- 97 and row- 55 was procured in the form of digital data. For Bundi watershed, IRS P6 data of 18 th 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. Details of Remote Sensing Data Used are shown in the tale 3.

GARMIN-12 global positioning system (GPS) has been used for Geo-referencing
Of Satellite images.

4.1.2 Collateral Data

Survey of India (SOI) toposheets on 1:50,000 scales (55 E/5, 45 O/6 and 54 H/8) were used in the current study for the preparation of base map, drainage and contour maps. And the SOI toposheets were referred for geo-referencing the satellite data, ground truth collection, beside generation of DEM.

4.1.3 Software Utilized

- ERDAS IMAGINE 8.7 for Vectorization and Map composition.
- ARCGIS 8.3.1 for rectification of errors, data in putting.
- MS Excel 2000 for additional feature handling and other computations & MS Word 2000 for Report presentation and final presentation.

4.1.4 Scale of Mapping

The scale of the final maps prepared is on 1: 50,000.

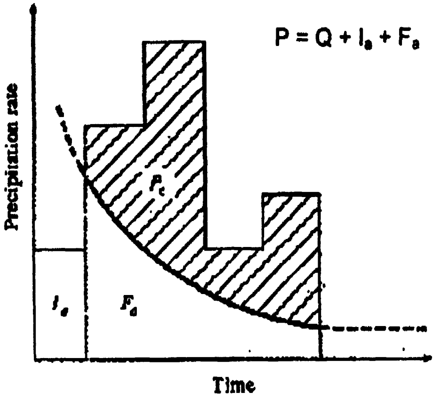
4.2 Methodologies and Approach

4.2.1 SCS Runoff Curve Number Method

The principle behind this methodology is that, the depth of excess precipitation or direct runoff is always less than or equal to the depth of precipitation, likewise after runoff begins the additional depth of water retained in the watershed is less than or equal to some potential maximum retention. There is some amount of rainfall Ia for which no runoff will occur, so the potential runoff is (P - Ia). According to the SOIL CONSERVATION SERVICE (1972) hypothesis the ratios of the two actual to the two potential quantities are equal that is

$(F_a / S) = (Q / (P - I_a))$ ...... (1) From continuity principle

$P = Q + I_a + F_a$ ....(2)



Combining equations (1) and (2)

$Q = ((P - I_a)^2) / (P - I_a + S)$ ....(3)

This is the basic equation for computing the depth of excess rainfall or direct runoff from a storm .

By study of results from many small experimental watersheds, an empirical relation was developed that is

$I_a = 0.2S.$ ....(4)

then $Q = ((P - 0.2S)^2) / (P + 0.8 S)$ ....(5)

Where,

Q = runoff (mm)

P = precipitation (mm)

S = potential maximum retention after runoff begins (mm), and

Ia = initial abstraction (mm).

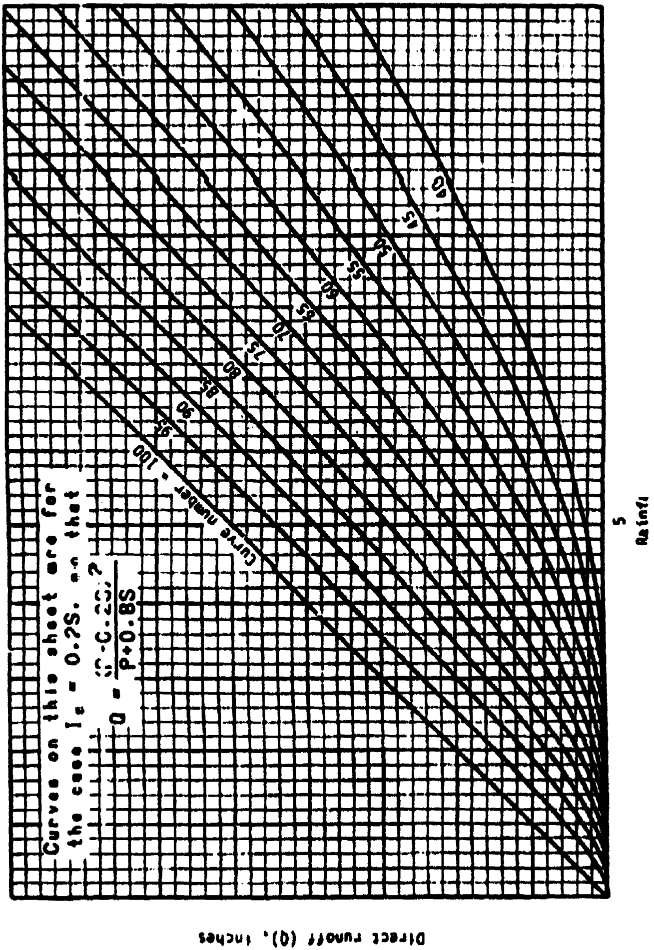


Fig 5. Relation between Rainfall and Runoff

Plotting the data for P and Q from many watersheds the SCS found curves of the type shown in fig 5.

To standardize these curves, a dimensionless curve number CN is defined such that 0 £ CN £ 100. For impervious surface and water surface CN = 100; for natural surfaces CN 100. The curve number and S are related by

$$S = ((1000 / CN) - 10) \quad \ldots\ldots\ldots\ldots\ldots\ldots (6)$$

Where S is in inches.

$$S = (25400/CN) - 254$$

Where S is in mm.

The curve is for normal antecedent moisture conditions (AMC II). For dry condition (AMC I) or wet condition (AMC III) equivalent curve numbers can be calculated as follows. (Jakeman A.J, and Hornberger, G.M., 1993)

$$CN\text{-}I = 0.3358 * 1.009^{CN\text{-}II} * CN\text{-}II^{1.038} \qquad r^2 = 0.9998$$

$$CN\text{-}III = 3.5610 * 0.9961^{CN\text{-}II} * CN\text{-}II^{0.8101} \qquad r^2 = 0.9999$$

4.3 Factors Considered in Estimating Runoff Curve Numbers

The major factors that determine CN are the hydrologic soil group (HSG) cover type, treatment, hydrologic condition, and antecedent runoff condition (ARC). Another factor considered is whether impervious areas outlet directly to the drainage system (connected) or whether the flow spreads over pervious areas before entering the drainage system (unconnected).

4.3.1 Hydrologic Soil Groups (HSG)

Infiltration rates of soils vary widely and are affected by subsurface permeability as well as surface intake rates. Soils are classified into four HSG's (A, B, C, and D). Most urban areas are only partially covered by impervious surfaces; the soil remains an important factor in runoff estimates. Urbanization has a greater effect on runoff in watersheds with soils having high infiltration rates (sands and gravels) than in watersheds predominately of silts and clays, which generally have low infiltration rates. Any disturbance of a soil profile can significantly change its infiltration characteristics. With urbanization, native soil profiles may be mixed or removed or fill material from other areas may be introduced.

4.3.2 Definitions of the classes

a) The soils have a high infiltration rate even when thoroughly wetted. They chiefly consist of deep, well drained to excessively drained sands or gravels. They have a high rate of water transmission.

b) The soils have a moderate infiltration rate when thoroughly wetted. They chiefly are moderately deep-to-deep, moderately well drained to well-drained soils that have moderately fine to moderately coarse textures. They have a moderate rate of water transmission.

c) The soils have a slow infiltration rate when thoroughly wetted. They chiefly have a layer that impedes downward movement of water or have moderately fine-to-fine texture. They have a slow rate of water transmission.

d) (High runoff potential). The soils have a very slow infiltration rate when thoroughly wetted. They chiefly consist of clay soils that have a high swelling potential, soils that

have a permanent water table, soils that have a clay pan or
clay layer at or near the surface, and shallow soils over nearly impervious material. They have a very slow rate of water transmission.

4.3.3 Cover Type

Table 4 addresses most cover types such as vegetation, bare soil, and impervious surfaces. There are a number of methods for determining cover type. The most common are field reconnaissance, aerial photographs, and land use maps.

4.3.4 Treatment

Treatment is a cover type modifier to describe the management of cultivated agricultural lands. It includes mechanical practices, such as contouring and terracing, and management practices, such
crop rotations and reduced or no tillage.

4.3.5 Hydrologic Condition

Hydrologic condition indicates the effects of cover type and treatment on infiltration and runoff and is generally estimated from density of plant and residue cover on sample areas. Good hydrologic condition indicates that the soil
usually has a low runoff potential for that specific hydrologic soil group, cover type, and treatment. Some factors to consider in estimating the effect of cover on
infiltration and runoff are

(a) canopy or density of lawns, crops, or other vegetative areas; (b) amount of year-round cover; (c) amount of grass or close-seeded legumes in rotations; (d) percent of residue cover; and (e) degree of surface roughness.

4.3.6 Antecedent Soil Moisture

The amount of soil moisture present in the soil at the time of interception of rain will influence the detachment of particles through influencing the runoff volume generated when the soils are near saturation the total amount of rainfall could lead to generation of runoff.

4.3.7 Urban Impervious Area Modifications

Several factors, such as the percentage of impervious area and the means of conveying runoff from impervious areas to the drainage system, should be considered in computing CN for urban areas. For example, do the impervious areas connect directly to the drainage system, or do they outlet onto lawns or other pervious areas where infiltration can occur?

4.3.8 Connected Impervious Areas

An impervious area is considered connected if runoff from it flows directly into the drainage system. It is also considered connected if runoff from it occurs as concentrated shallow flow that runs over a pervious area and then into a drainage system. Urban CN's, Table 4.2a on Page 4.6, were developed for typical land use relationships based on specific assumed percentages of impervious area. These CN values were developed on the assumptions that (a) pervious urban areas are equivalent to pasture in good hydrologic condition and (b) impervious areas have a CN of 98 and are directly connected to the drainage system.

4.4 Maps Generated to Compute the Runoff

4.4.1 Base Map

The base-map is referred to a gratitude map containing the basic reference details of topography, drainage and cultural details, which act as points of reference while transferring the thematic details. The reference details include Reserved Forest (RF) and Protected Forest boundaries that are transferred from a Survey of India (SOI) topographical map in the scale of 1:50,000.

4.4.2 Contour Map

All the contours confined to watersheds at 20 m in travel and the spot heights available at 1:50,000 scale toposheets are digitized.

4.4.3 Slope map

Slope is the measure of the amount of rise divide by the amount of horizontal distance traveled. Slope, aspects and altitude are important terrain parameters from land utilization point of view. Slope is the vital one for the land irrigation and land capabilities assessment. The density of contours on map is used for preparing slope map that gives various groups are categories of slopes. The topographic characteristics of an area are one of the most determinants of the suitability of the area for development.

Slope map is used to know the terrain properties like steep slopes and plains. The speed and the extent of runoff depend on the slopes. The velocity of the flow of runoff varies and increases with increase of slope. The preparation of slope map is very useful for watershed management, ground water resources, land use and land cover. Slope classification: slope levels are broadly classified into 7 types based on the USGS method of classification as shown in the table 5.

Slope map showing the slope categories at 1:50,000 scale was derived from contour and spot heights (elevation map) taken from the SOI toposheets using the grid tools in ARC/INFO.

4.4.4 Land use/ Land cover Classification

Land use/Land cover information is the basic pre-requisite for land, water and vegetation resources, utilization, conversation and management.
Land use is referred to " Man's activities and the various use which are carried on land", Land cover is referred to " Natural vegetation, water bodies, rock/soil, artificial cover and other noticed on the land".

4.4.4.1 Classification system

The current land use/ land cover maps can be prepared adopting the following classification system shown in table 6.

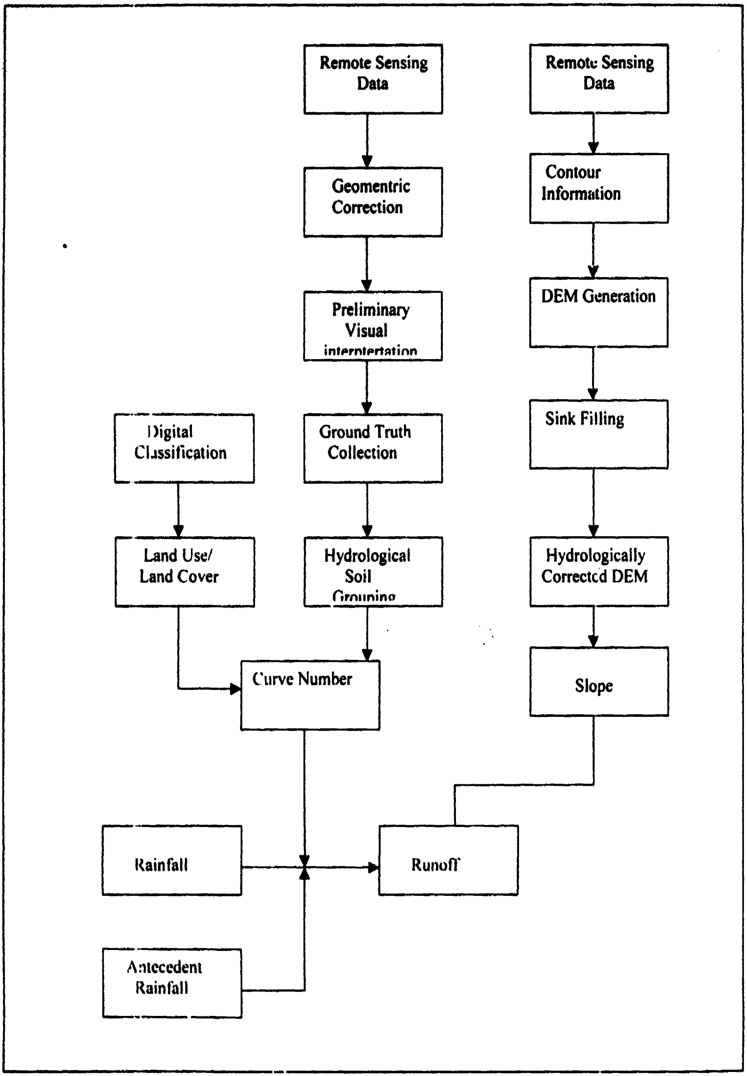
Category of land use/land cover in a study area, which is not covered under the purview of the classification system, can be put under the category of "others". The land use/land cover maps have to be prepared adopting visual or digital interpretation techniques in conjunction with collateral data such as topo maps and census data. If the digital method is followed then digital output is converted into line maps with corresponds to other theme maps. The total numbers of classes are would vary from area to area. The imagery has to be interpreted and ground checked for corrections.

4.4.5 Development of Interpretation Key

It essentially consists of a set of image elements or characteristics, which help in the recognition or identification of various land use/land, cover classes systematically on the satellite imagery during visual interpretation. The preliminary interpretation key prepared for IRS data has been finalized after the ground truth whenever it was found necessary. However, the interpretation key may differ with the change in type of satellite data, band combination, season, scale etc.

4.5 Ground Truth Data Collection and Verification

The doubtful areas identified during the preliminary interpretation were marked on the Survey of India topographical maps for planning the traverse and checking the details on the ground. These were physically verified and field observations during April 2004, about the terrain conditions and land use patterns and were noted for use in the modification of the thematic details. . This aided in increasing the reliability of remotely sensed data by enabling verification of interpretation details and enhanced the interpretation accuracy, supplementing it with the information that cannot be obtained from satellite imagery. Also, these visits enabled interaction with various officials and village people to infer better information and overall understanding. Thus ground truth verification of doubtful areas and ground measurements form an important component of satellite-based remote sensing studies.


Remote Sensing Data
Remote Sensing Data
Geomentric Correction
Contour Information
Preliminary Visual interpretation
DEM Generation
Digital Classification
Ground Truth Collection
Sink Filling
Land Use/ Land Cover
Hydrological Soil Grouping
Hydrologically Corrected DEM
Curve Number
Slope
Rainfall
Runoff
Antecedent Rainfall

Flow Chart

5. RESULTS AND DISCUSSIONS

5.0 RESULTS AND DISCUSSIONS

Runoff is the important hydrological factor in the watershed management. Any rainfall based planning and design activity require quantification of water yield in the form of runoff resulting from the interaction between rainfall and the land features. By making models, we can see what would occur in a system if we changed certain characteristics of it, without actually making the changes

5.1 Computing Runoff using Remote Sensing and GIS

IRS P6 LISS III and LISS IV data covering the study area were radio metrically normalized and mosaic can be done using ERDAS IMAGINE version 8.7, image-processing software. To begin with, the topographic maps at 1:50,000 scales 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 mosaic 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 resampling using nearest neighbor algorithm. The geo-coded data was converted to radiance image using gain or offset provided in the header information.

5.2 Results of Thematic Mapping

5.2.1 Base Map:

The base maps of the three watersheds (Bundi, Lalatora (Milli), Guna) were derived from the SOI toposheets on 1:50000 scale.. The different features roads, railway network, district highways, settlements water bodies etc. were observed. The figure 6,7,8 shows the base map of Bundi, Lalatora (Milli) and Guna watersheds.

5.2.2 Drainage Map:

The drainage maps of the three watersheds were prepared from the SOI toposheet and the satellite imageries. The drainage pattern of Bundi, Guna, Lalatora (Milli) watersheds are found to be dentric pattern and course texture. The dentric pattern is the most common type of pattern formed by mainstream with tributaries branching and re branching freely in all possible directions. It generally develops upon the homogeneous rocks of unformed resistance such as horizontally bedded sedimentary rocks and completely metamorphosed rocks.

In Bundi, Lalatota (Millli) watersheds, the drainage network contain up to 4th order stream. The bifirucation ratio is less than 4 hence the soil erosion is less in this area. The drainage maps of the three watersheds are shown in fig 9,10,11.

5.2.3 Contour map

The contour maps of the three watersheds, which were used to generate the Digital Elevation Model, are shown in the figures 12,13,14. The contour maps of the three watersheds were derived from the SOI toposheet.

5.2.4 Slope map

Slope maps of the three watersheds which is one of the input to predict the runoff were derived from the Survey of India toposheets. The spatial extent of various slope classes of Bundi, Lalatora and Guna are shown in table 7a, 7b. and 7c. Slope maps are prepared from the DEM.Slope maps of Bundi, Lalatora (Milli), Guna are shown in the figure 14,15,16. In Bundi 56.06% area is under Nearly Level Sloping, 19.38% of area is under Very Gentle Sloping, 11.47 % is under Gentle Sloping and 13.09% is under Moderately Sloping. In Guna 54.92% is under Nearly Level Sloping,15.66% is under Very Gentle Sloping, 3.76 is under Gentle Sloping, 22.71 is under Moderately Sloping and 2.95 Moderate to Steep Slope. In Lalatora (Milli), 56.06% is under Nearly Level Sloping, 19.38% is under Very Gentle Sloping, 11.47 is under Gentle Sloping and 13.09% is under Moderately Sloping

5.2.5 Land use/Land Cover

The spatial information on the land use/land cover forms an important input for the subsequent analysis for the generations of derivative information like curving numbers and covering factor. Satellite data found to be very useful and economical way to extract curve numbers compared to conventional way of curve numbers derivation (slack and Welch, 1979, Ragan and Jackson, 1980 and Kumar et al, 1994). The spatial extent of land use/ land cover classes of Bundi, Lalatora (Milli) watersheds are shown in table 8a, 8b, and 8c. The land use and land cover maps are shown in the figure 17, 18 and 19.

5.2.6 DEM Generation

The contour and drainage information derived from the SOI toposheets at 1:50,000 scale was used in the generation of DEM. Initially the arcs direction of drainage network were aligned to the natural flow of the stream. Besides the height information of the contours was stored as an attribute in arc attribute table (AAT). The drainage network was used to force the DEM to follow natural drainage course. Other wise the routing of fluxes will not be correct. Using the both the coverage's along with watershed boundary, the DEM was generated with TOPOGRID command. In spite of aligning the DEM to drainage network there will be sinks or depressions in the DEM, where the flow are get trapped table 9. Hence these sinks are to be filled so as to get a continuous flow of flux till the far end of watershed. Using fill command these sinks are filled and thus, hydro logically corrected DEM was generated. The DEM map of the three watersheds is shown in the figure 20,21,22.

5.3 SOIL AND TERRAIN PROPERTIES

5.3.1 Bundi Watershed

The soils of Bundi watershed are shallow to medium deep clay. Because of the sloppy terrain the soils are degraded due to wind and water erosion. These soils come under the hydrological soil group c. The topography is undulating with a slope of 10 to 15%. The area has slope ranging from 0.05% to 15%. The area wise statistics of various slope classes is given in table 7a.

5.3.2 Lalatora watershed

The soils of Lalatora watershed are vertisols and associated soils with poor internal drainage. The topography is gently undulating. The slope ranges from 3 to 8%. These soils come under soil group B. The area wise statistics are of various slope classes is given in table 7b.

5.3.3 Guna watershed

The prevalent soil types are medium black and red soils with a soils depth of about 150 cm. The topography is undulating terrain with moderate slopes. The area wise statistics are of various slope classes is given in table 7c.

5.4 RUNOFF ESTIMATION

To compute the Runoff, various land use/ land cover in a particular watershed were assigned the curve numbers as per table 4, considering the hydrological properties of underneath soil. The curve numbers are for antecedent soil moisture condition-2 and will vary with respect to 5- day antecedent rainfall received prior to runoff event.
First of all overlays for land use and soil is generated from Remote Sensing data for the three watersheds(Bundi,Guna Lalatora(Milli)). Based upon rainfall during the five days preceding the storm shown in the table 10. Changes in AMC are reflected through changes in the Curve Number. The CN value is obtained for the different land covers from the Table 4 This CN value is used in equation

$S = (25400/CN) - 254$

By using this value of S in equation

$$Q = \frac{(P-0.2*S)^2}{(P+0.8*S)} \quad \text{if } P>(0.2*S)$$

$$Q = 0 \quad \text{if } P<(0.2*S)$$

Direct runoff is calculated.

To compute the total runoff over the grid cell, in cubic meters,

$Q=(Q'/1000)*\text{cell area (in } m^3)$

Runoff values were measured for four events for Bundi watershed during August-2004 and our events for Madhusudhangadh (Guna) watershed during august – 2004 and three events for Lalatora watershed. Rainfall as well as five-day antecedent rainfall were also measured and are presented in table. The runoff computed using curve number grid was compared with insitu measurements .the curve number for a grid cell varied in accordance with date of event in relation to land use/land cover dynamics with in a watershed are shown in the table 11.

The runoff values were under estimated for Bundi and Guna watersheds as the predicted runoff values are from smaller area, ranges from 20 to 500 ha. The measured runoff value are for larger area (9000ha).

6. SUMMARY AND CONCLUSIONS

6. SUMMARYAND CONCLUSIONS

Water is the most critical resource and constraint in the semi-arid tropics (SAT). To minimize the land degradation and sustain crop productivity in the SAT, management and efficient utilization of rainwater is important. Watershed based resource utilization involves the optimum use of area's precipitation for the improvement and stabilization of agriculture on the watershed through better water, soil, and crop management. More effective utilization of water for the production of crops can be facilitated by

i) in situ conversation of moisture ,of rainwater

ii) proper drainage , collection ,storage, and reutilization of runoff.

iii) ground water recovery from wells.

Water can be managed if watershed is taken as a unit.

In the present study the runoff was estimated using SCS Curve Number. the major problem in testing these models is the generation of spatial input data. With the advent of Remote Sensing technology, deriving the spatial information on input parameters has become more handy and cost effective. Besides with the powerful spatial processing capabilities of Geographic Information System (GIS) and its compatibility with the remote sensing, runoff modeling approaches have become more comprehensive and robust.

Conclusions

- Predicted values are closed to the observed values. The model used for the prediction of runoff how ever needs to be validated for different soils and crop cover conditions.
- Remote sensing and GIS are used for spatial interpretation and runoff estimation.
- Black soils are more prone to runoff compared to red soils; hence effort should be made to take up short duration cover crops so as to minimize the raindrop impact or runoff in the kharif season.
- On very flat surfaces where ponding or swampy areas occur throughout the watershed, a considerable amount of the surface runoff may be retained in temporary storage, thus reducing the rate at which runoff will occur. Storage areas may be created to reduce the rate of runoff in an urbanizing area

Table 1: Specification and Resolution of All The Three Sensors.

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	0.5-0.59 Visible 0.62-0.68 & 0.77-0.86 NIR 1.55-1.70 (SWIAR)
Sensor-III	Wide Field Sensor (WiFS)	188.3	810	0.62-0.68 0.77-0.86

Table 2: Specifications of IRS-P6

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
Repetivity	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)

Table 3. Details of Remote Sensing Data Used

S.NO	Satellite/Sensor	Path/Row No.	Date of acquisition
1	IRS P6 LISSIV	202-083	18-Feb-04
2	IRS P6 LISSIV	202-079	23-Mar-04
3	IRS P6 LISSIII	97-55	4-Feb-04

Table 4.Curve Numbers Assigned to Various Land Use/Land Cover Classes

S.NO.	LAND USE/ COVER	HYDROLOGICALSOIL GROUP			
		A	B	C	D
1	Fallow	77	86	91	94
2	Fallow (polughed)	75	84	89	92
3	Maize (Early stage)	72	81	88	91
4	Maize (Mid stage)	70	80	87	90
5	Maize (Peak Growth Stage)	67	78	85	89
6	Small grains (Early Stage)	65	76	84	88
7	Small grains (Mid Stage)	64	75	83	87
8	Small grains (Peak Growth stage)	63	75	83	87
9	Vegetables (terraced)- early stage	66	74	80	82
10	Vegetables (terraced)- Peak Growth Stage	62	71	78	81
11	Paddy	95	95	95	5
12	Forest Dense	30	55	70	77
13	Forest Moderate Dense	36	60	73	79
14	Forest - Degraded/open	45	56	77	83
15	Scrub - Poor	48	67	77	83
16	Scrub - Dense	30	48	65	73
17	Settlements (Rural)	77	86	91	94
18	Gullied Land	77	86	91	94

Table 5. Slope Classification

S.No	Classification of slope	Lower and upper limits of slope percentage	Lower and upper limits of contour spacing
1	Nearly level	0-1%	More than 4 cm
2	Very Gently sloping	1-3%	1.33- 4 cm
3	Gently sloping	3-5%	0.8- 1.33 cm
4	Moderate sloping	5-10%	0.4 –0.8 cm
5	Strongly sloping	10- 15%	0.26- 0.4 cm
6	Moderate steep to steep sloping	15- 35%	0.11- 0.26
7	Very steep sloping	>35%	<0.11 cm

Table 6. Land Use/ Land Cover Classification

Sl No.	LEVEL - I	LEVEL –II	LEVEL - III
1	BUILT UP LAND	Built up (rural)	Rural
			Urban
		Built up (urban)	Brick klin /Mud quarry
			Industrial
			Institution
		Transportation	Sheds (poultry /others)
			Vacant land
2	AGRICULTURAL LAND	Cropland	Double crop (Kharif Rabi)
			Kharif (paddy area)
			Kharif (other crop)
			Current fallow
		Plantations	Grape
			Guava
			Mango
		Fallow	Teak
			Sweet orange
			Mixed plantation
3	FOREST	Forest /	Forest plantation
		Forest Plantations	Scrub Forest
4	WASTE LAND	Land with /without scrub	Land with scrub
			Land with out scrub
		Barren rocky/ Stony waste	Barren rocky/Stony waste
5	WATER BODIES	Tank/Reservoir	Tank/Reservoir
		Dry Tank	Dry Tank

Table 7 a Area Under Various Slope Categories in Bundi Watershed

SL NO.	Slope Class	Area in ha	Area %
1	Nearly Level Sloping	2137.95	46.83
2	Very Gentle Sloping	1637.64	35.87
3	Gentle Sloping	412.92	9.05
4	Moderately Sloping	376.74	8.25
5	Total	4565.25	100

Table 7 b. Area under Various Slope Categories in Lalatora (Milli) Watershed

SL NO.	Slope Class	Area in ha	Area %
1	Nearly Level Sloping	1283.75	56.06
2	Very Gentle Sloping	443.68	19.38
3	Gentle Sloping	262.62	11.47
4	Moderately Sloping	299.88	13.09
5	Total	2289.93	100

Table 7 c. Area Under Various Slope Categories in Guna Watershed

Sl. NO.	Slope Class	Area in ha	Area %
1	Nearly Level Sloping	5352.93	54.92
2	Very Gentle Sloping	1526.49	15.66
3	Gentle Sloping	366.12	3.76
4	Moderately Sloping	2213.46	22.71
5	Moderate to Steep Slope	286.2	2.95
6	Total	9745.2	100

Table 8a Spatial Extent of Various Land use/Land cover classes of Bundi Watershed

LU/LC LISS-IV	Area in Ha
Double Crop	634.22
Water Body	3.56
Forest	78.36
Fallow	68.54
Land Without Scrub /Fallow	133.5
Land With Scrub	640.14

Table 8b Spatial Extent of Various Land use/Land cover classes of Lalatora (Milli) Watershed

LU/LC	Area in Ha
Double Crop	2956.44
Kharif- Crop Land	796.44
Barren Stony Area	2481.81
Land without Scrub/Fallow	3489.87

Table 8c. Spatial Extent of Various Land use/Land cover classes of Guna Watershed	
LU/LC	Area in Ha
Class Name	
Double Crop	611.23
Forest	102.06
Fallow	71.19
Land Without Scrub	168.83
Land With Scrub	329.13

Table 9. Sample DEM data showing a sink

305	308	312	307	304
307	304	303	306	308
310	308	**275**	305	309
312	307	304	303	306
308	306	305	308	311

Central Cell of a Sample DEM Window after Filling Sink

305	308	312	307	304
307	304	303	306	308
310	308	**303**	305	309
312	307	304	303	306
308	306	305	308	311

Central Cell of a Sample DEM Window after Filling Sink

Table 10. Antecedent soil Moisture (ASM) conditions for Curve Number Method.

ASM CONDITIONS	5-DAY ANTICEDENT RAINFALL (mm)	
	Dormant Season	Growing Season
ASM-I	<13	>36
ASM-II	13-28	36-53
ASM-III	>28	>53

Table11. Runoff Prediction Using Curve Number Method

Event No.	Event	Rainfall	5-day Antecedent Rainfall	Measured Runoff	Predicted Runoff
	Bundi				
1	10-Aug-04	34	66	1.8	1.57
2	12-Aug-04	28.5	130	0.8	0.58
3	14-Aug-04	40	107	2.9	2.05
4	15-Aug-04	34	136	1.5	0.93
	Madhusudhangadh				
5	14-Aug-04	105.5	20.5	47.9	31.69
6	21-Aug-04	29.6	27.6	10.9	14.95
7	22-Aug-04	90.2	50.4	33.9	29.78
8	23-Aug-04	24.8	140.6	4.5	3.84
	Lalatora				
9	1-Aug-04	47.4	45.2	-	22.17
10	6-Aug-04	152	25	-	18.42
11	22-Aug-04	104	41	-	10.48

(- not available)

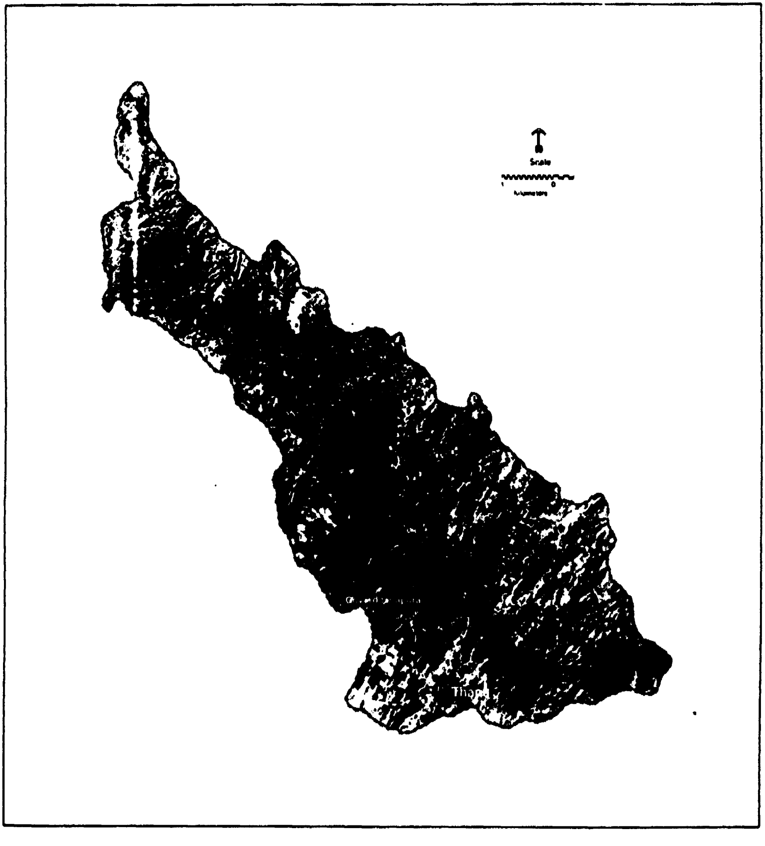


Fig2. Satellite Imagery of Bundi Watershed during the Year 2003-04

Fig 3. Satellite Imagery of Lalatora(Milli) Watershed during the Year 2003-04

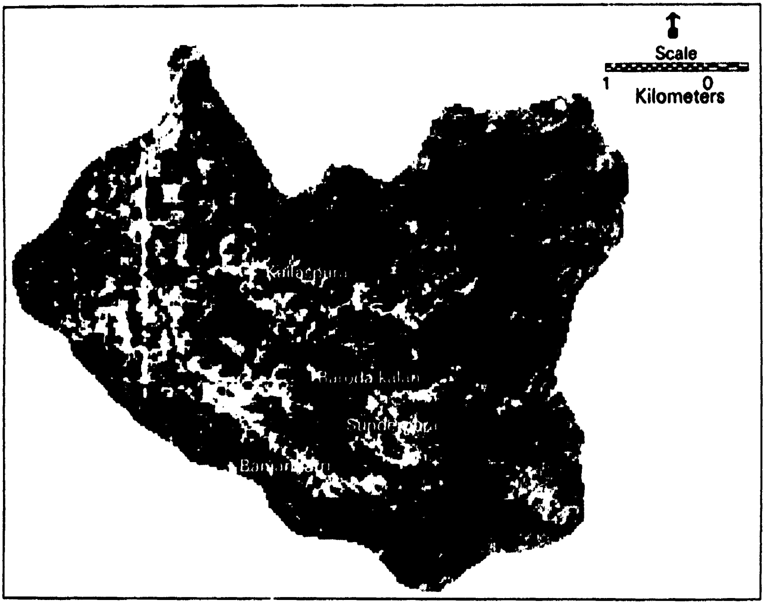


Fig 4. Satellite Image of Guna Watershed during the Year 2003-04

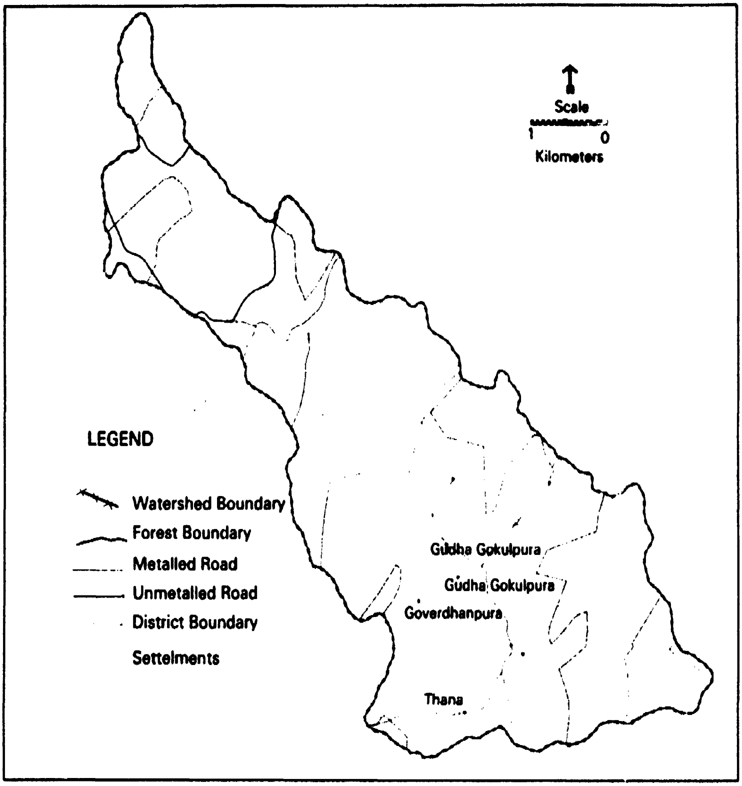


Fig 6. Base Map of Bundi Watershed

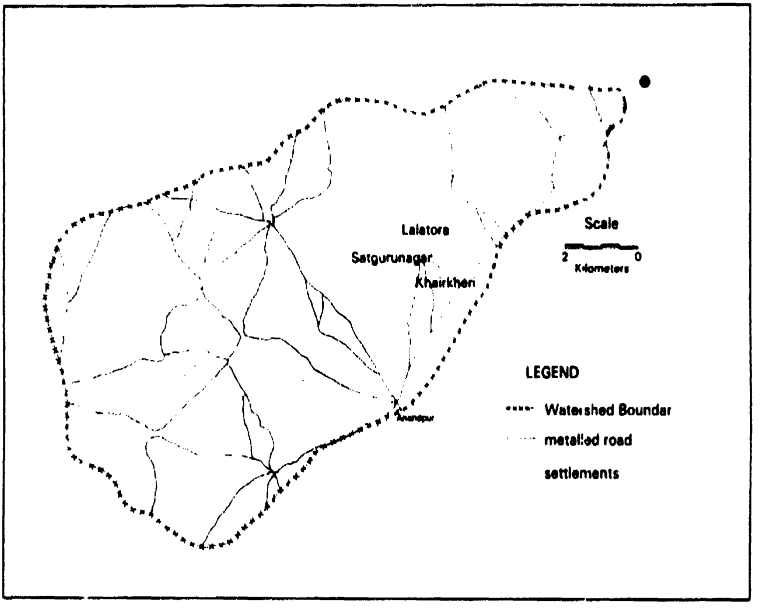


Fig 7. Base Map of Milli Watershed, Vidisha District, Madhya Pradesh

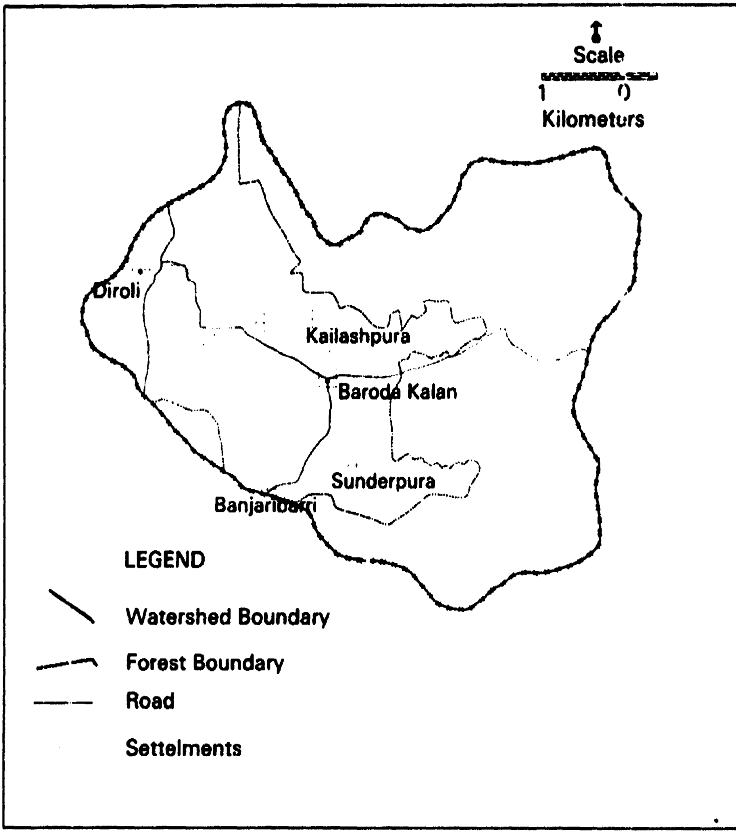


Fig 8. Base Map of Guha Watershed

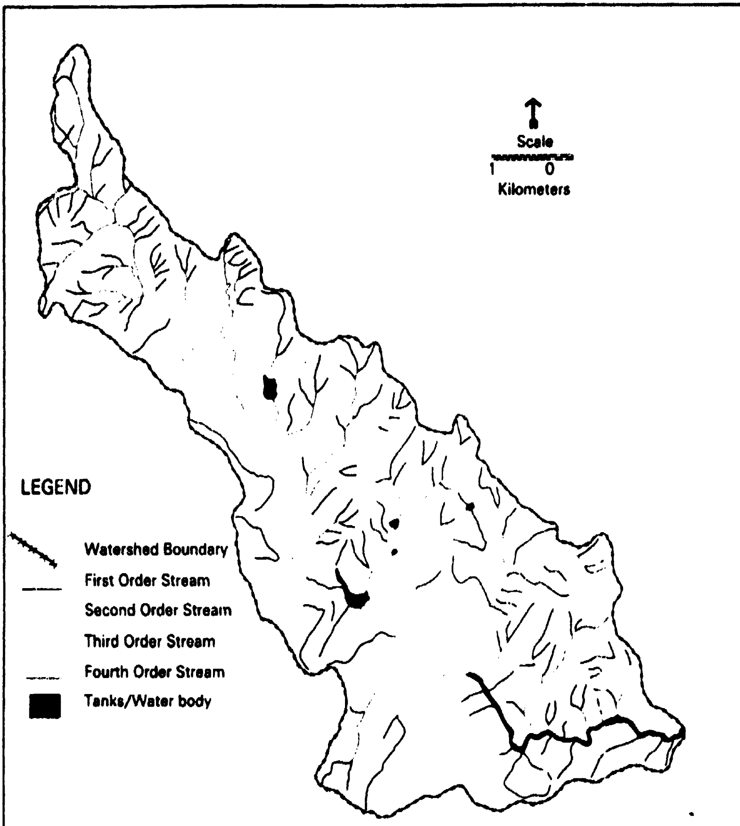


Fig 9. Drainage Network Map of Bundi

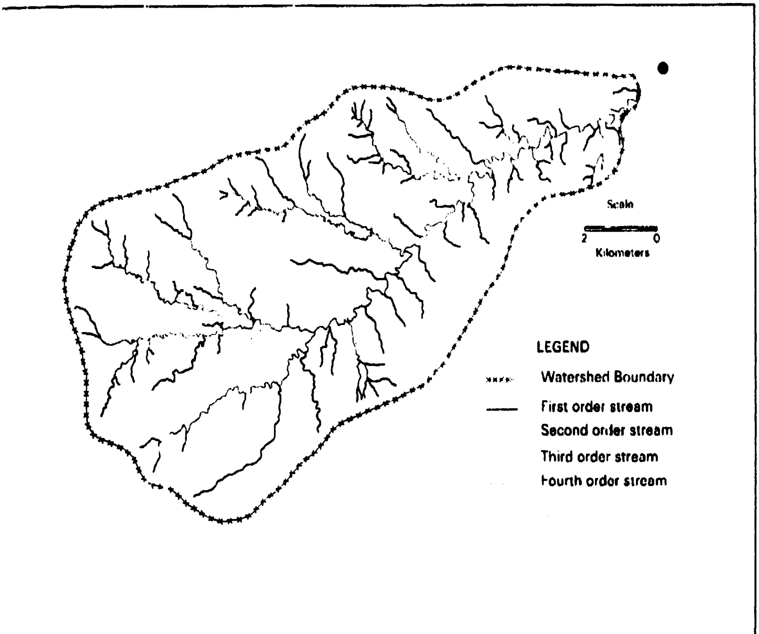


Fig10 Drainage Map of Milli (Lalatora) Watershed

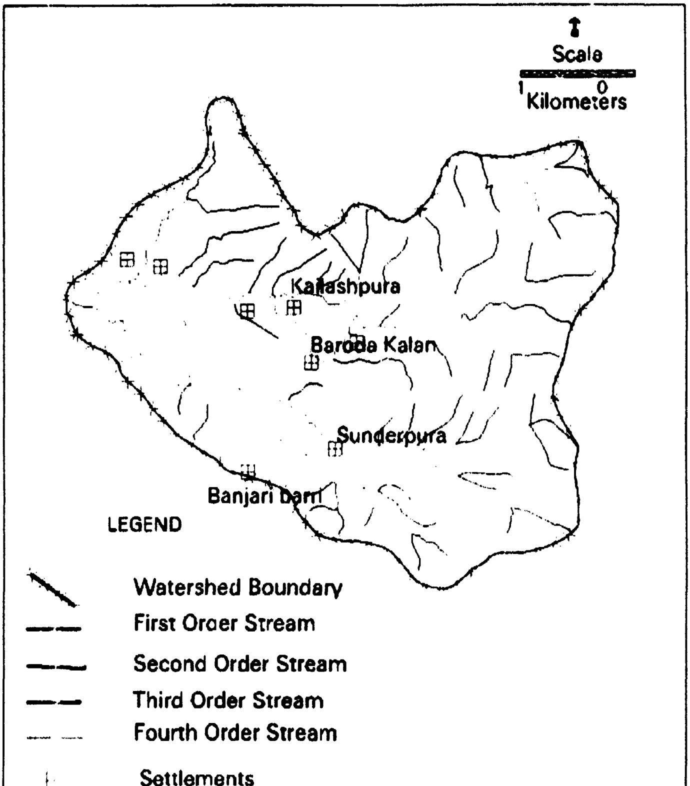


Fig , Drainage map of Guna Watershed

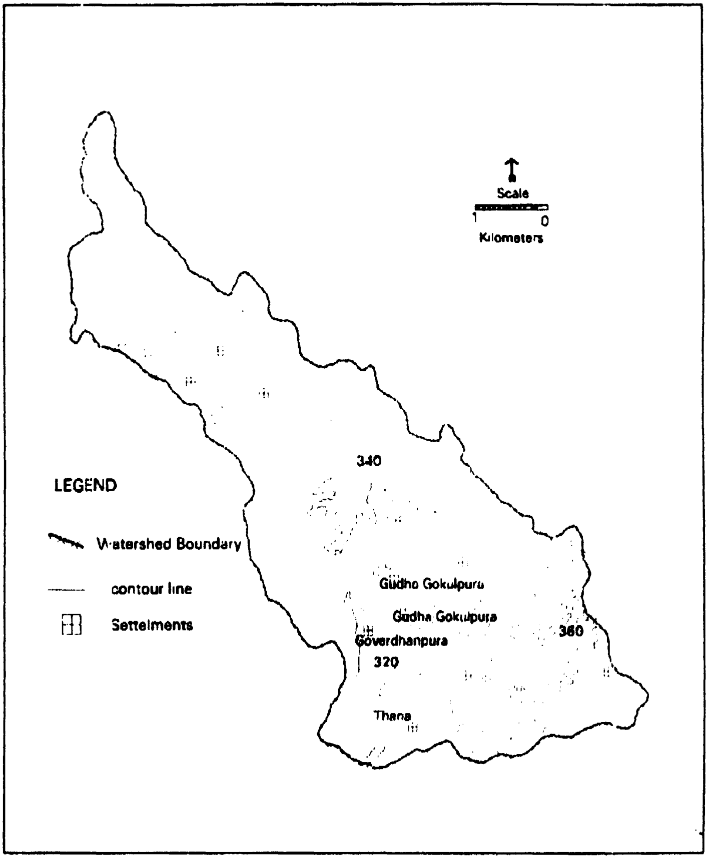


Fig12. Contour Map of Bundi Watershed

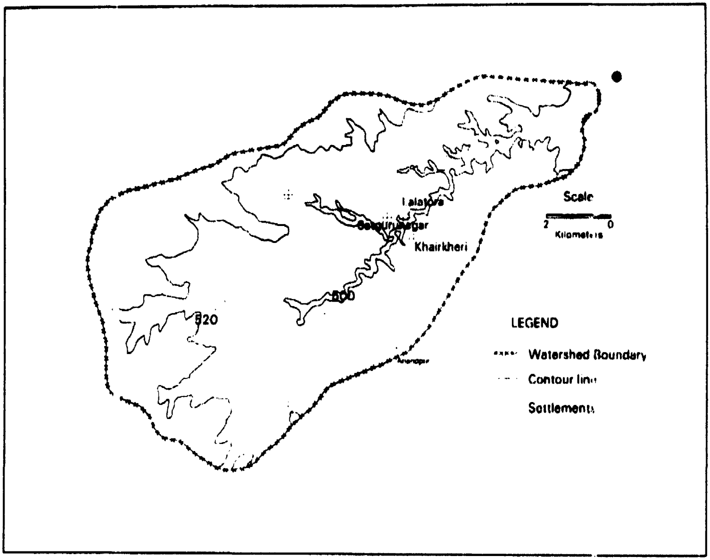


Fig13 Contour Map of Milli Watershed

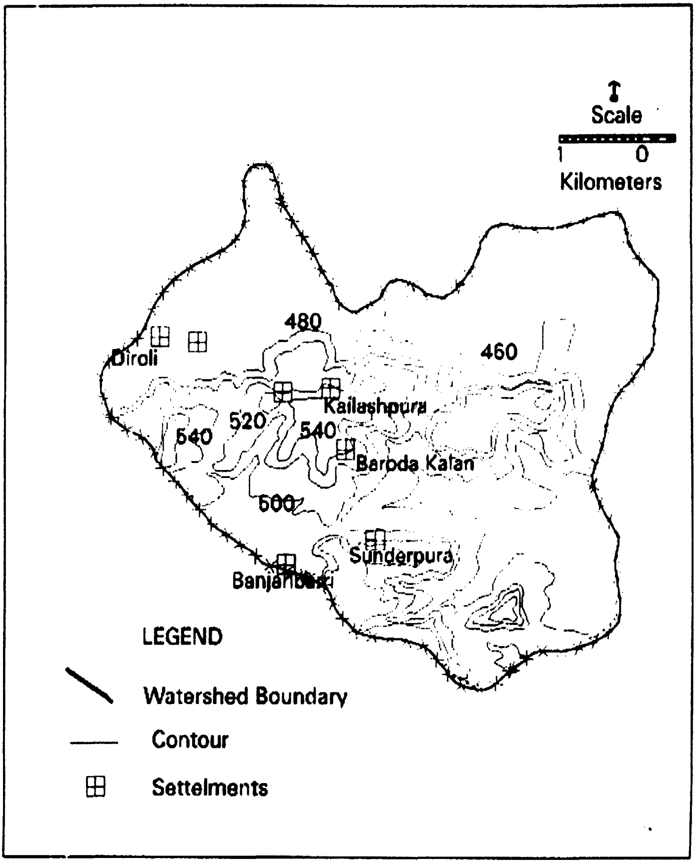


Fig14.Contour Map of Guna Watershed

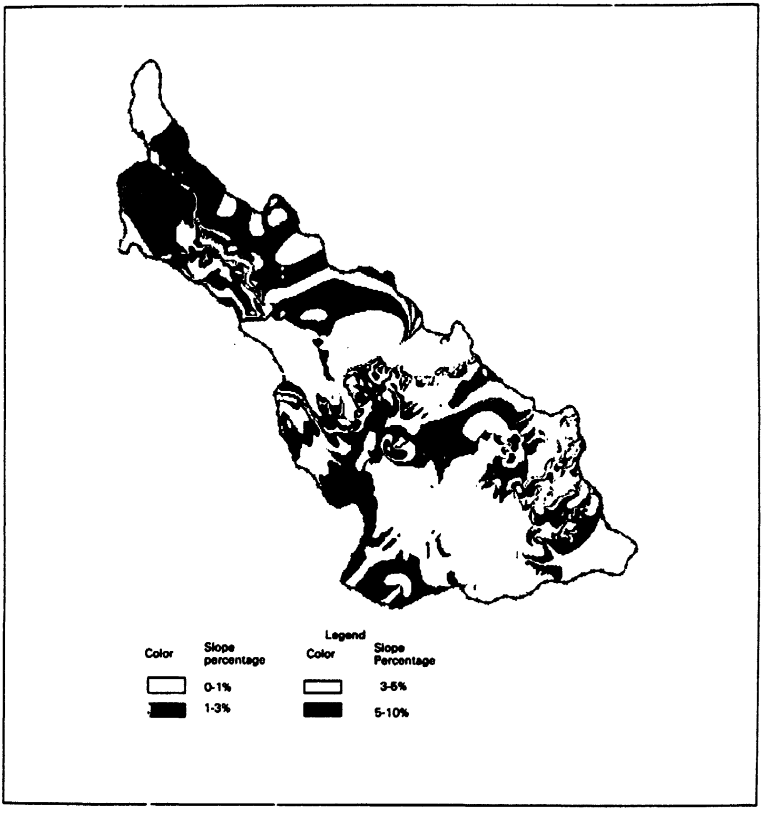


Fig15 Slpoe Map of Bundi Watershed

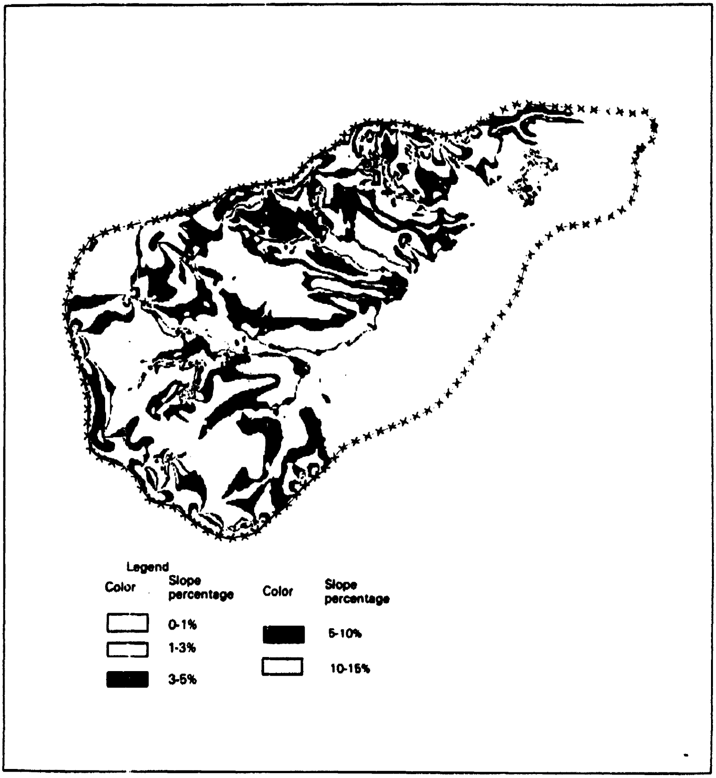


Fig 16 Slope Map of Milli Watershed

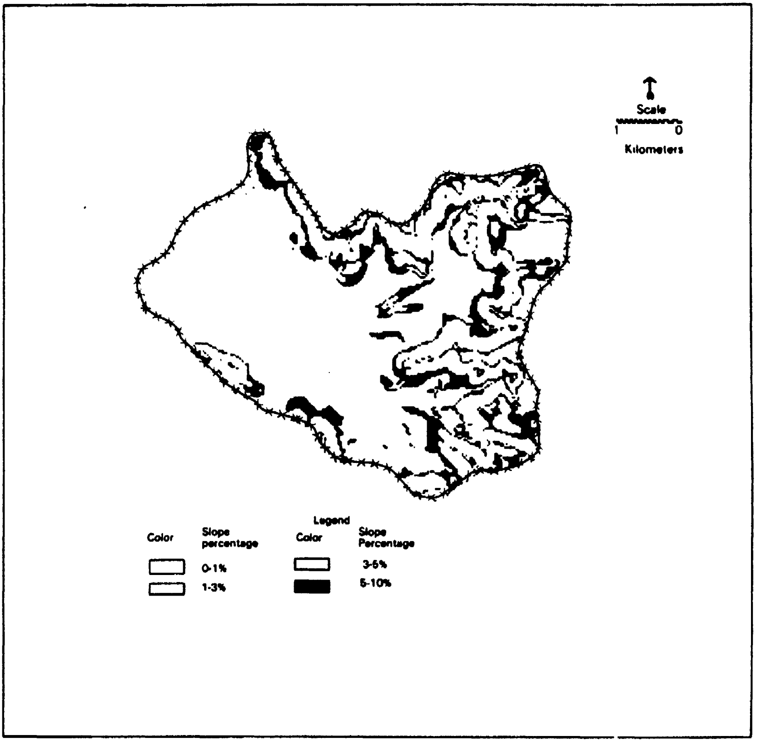


Fig 17 Slope Map of Guna Watershed

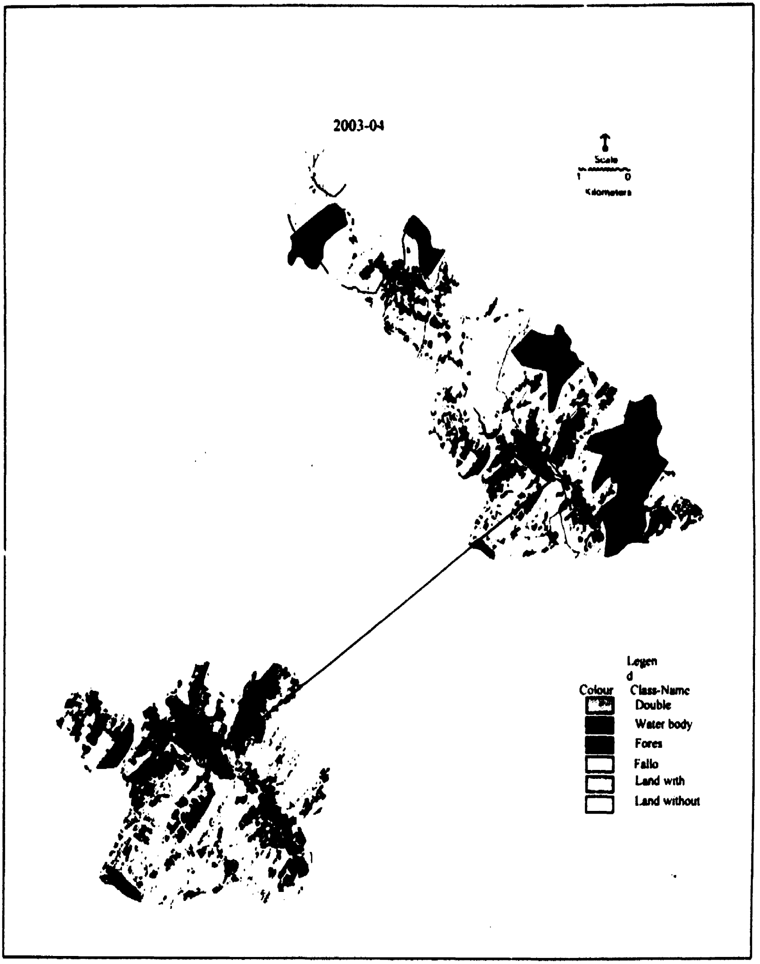


Fig 18. Land use/Land cover Map of Bundi Watershed

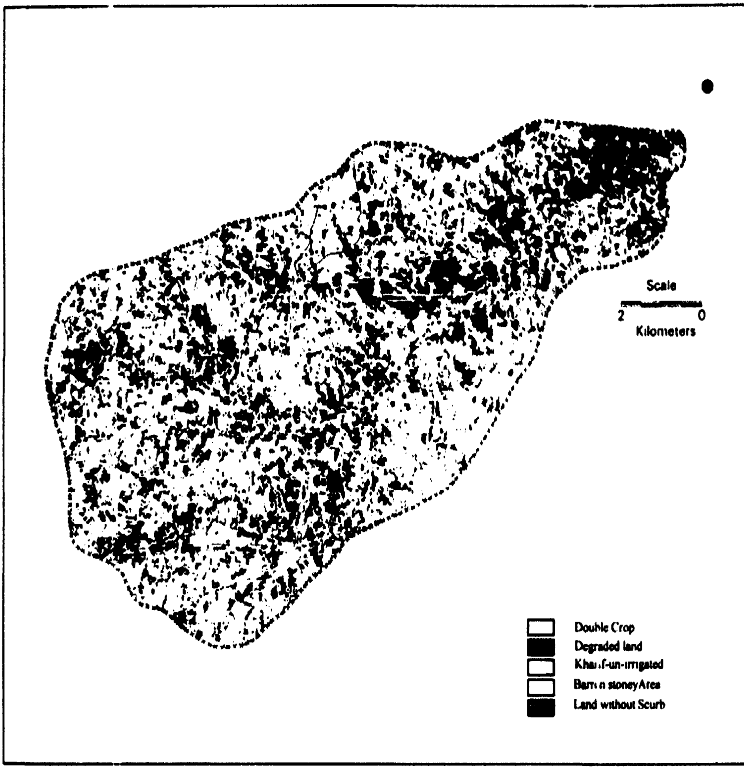


Fig19. Land use/Land cover Map of Milli Watershed

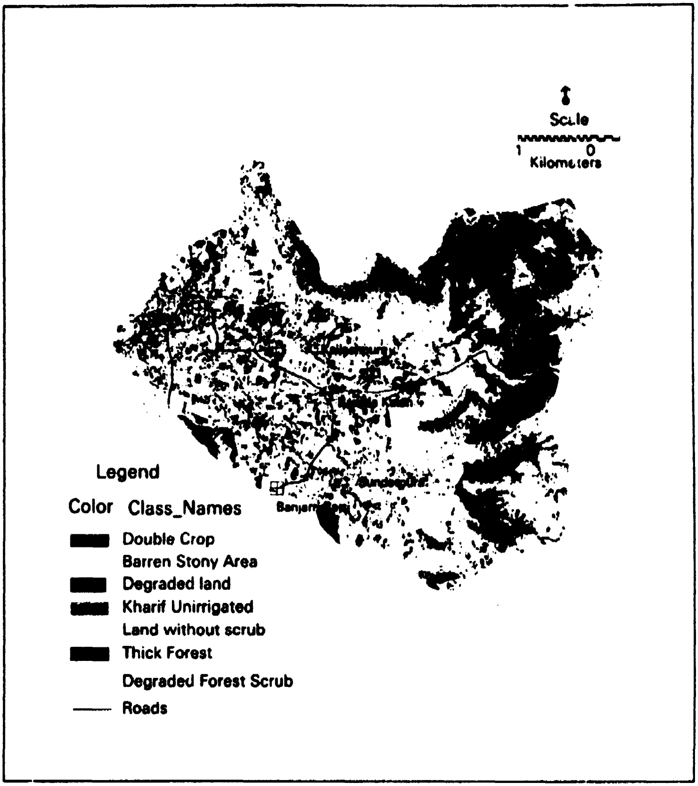


Fig 20 Landuse /Landcover Map of Guna

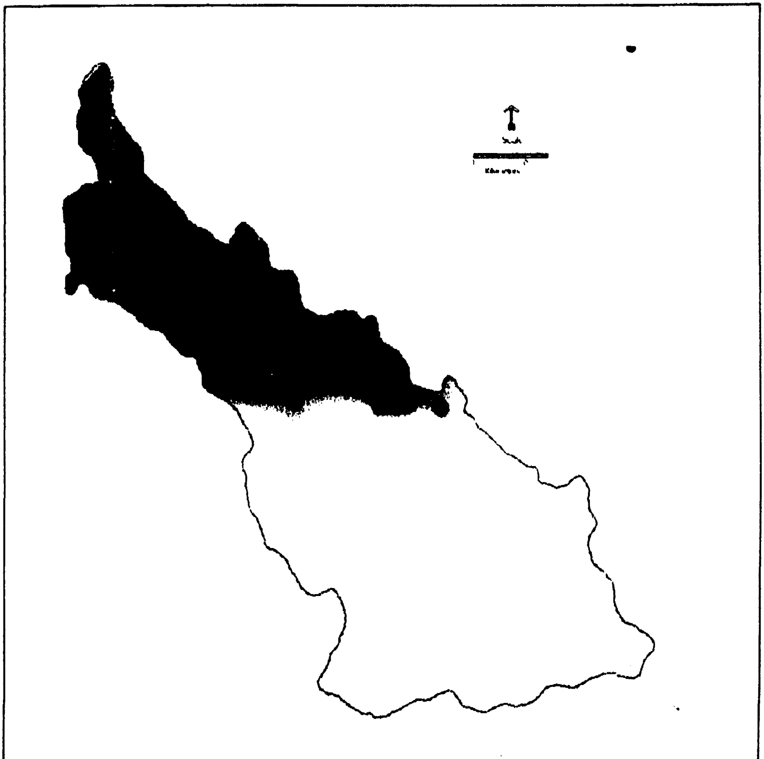


Fig:21 Digital Elevation Model of Bundi Watershed

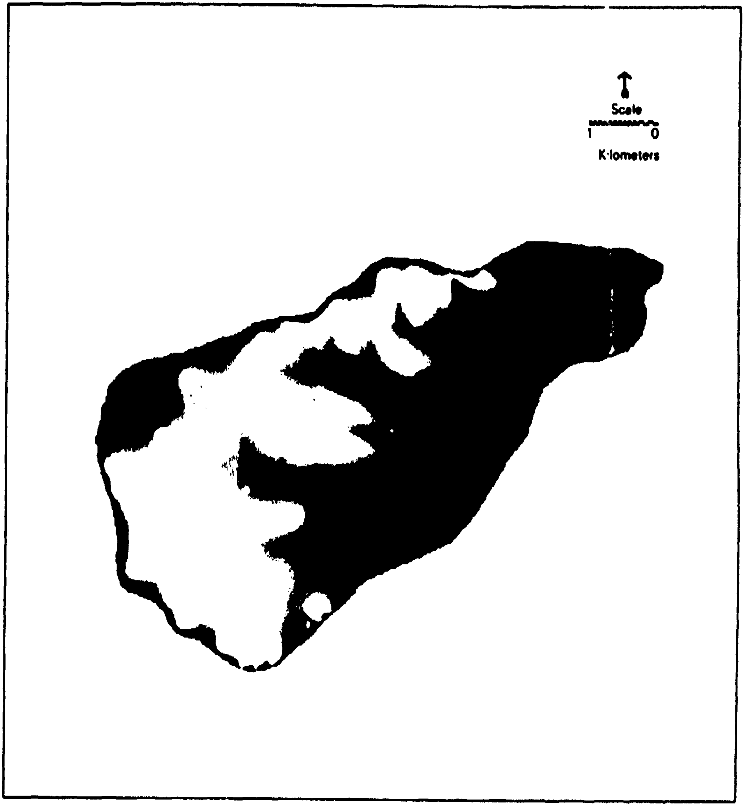


Fig:22 Digital Elevation Model of Milli Watershed

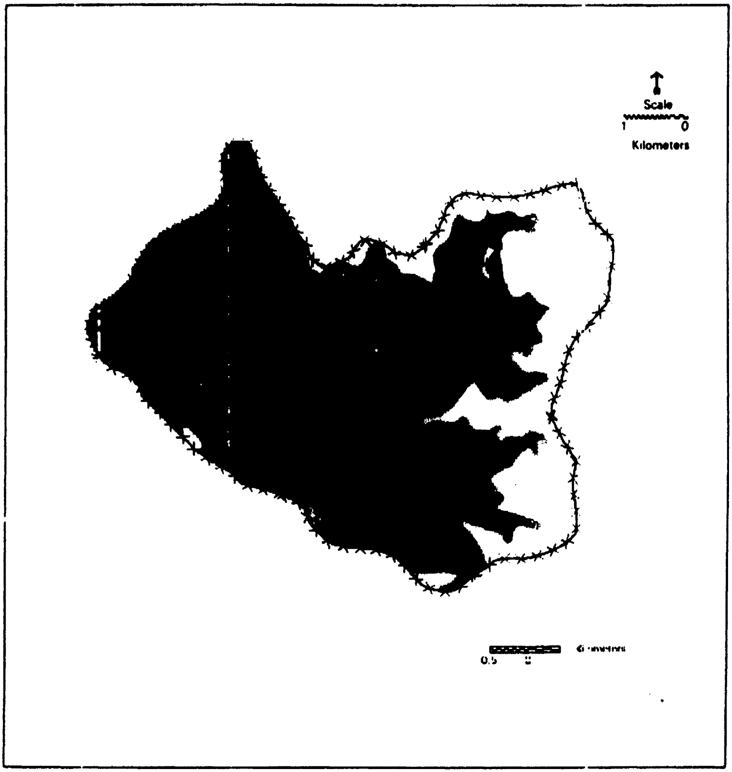


Fig:23 Digital Elevation Model of Guna Watershed

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