ICRISAT

A Project Report on

Sustainable Integrated Watershed Management by using Remote sensing and GIS

Submitted in Partial fulfilment of requirement
for the award of the degree of

MASTER OF TECHNOLOGY
(Environmental management)

by
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TO WHOMSOEVER IT MAY CONCERN

This is to certify that the project work entitled "Sustainable Integrated Watershed Management by using Remotesensing and GIS is a bonafied work of Ms. K.Samatha, Regd No: 01031D3137, 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.

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CERTIFICATE

This is to certify that the project entitled **Sustainable Integrated Watershed Management by using Remotesensing and GIS** that is being submitted by **K.Samatha**, Regd no: 01031D3137 during the year 2002-2003 in Partial fulfillment for the award of the degree **MASTER OF TECHNOLOGY in Environmental management** to the Jawaharlal Nehru Technological University is a record of bonafide work carried out by her under our guidance and supervision.

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

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Abstract

The study deals with the sustainable management of Malleboinpalli watershed, a part of drought prone area of Mahaboobnagar district using the resource data base aquiring from IRS-1D PAN and LISS-III merged data, drainage morphometry, hypsometry and the quantity of sediment yield and socio-economic data from survey of the Malleboinaplli of this watershed. Base map , contour map, slope map, drainage network and watershed boundary are prepared from Survey of India toposheet. The remotely sensed data in the form of geocoded false colour composite of IRS -1D PAN and LISS-III satellite sensing system, obtained from National Remote Sensing Agency is used to prepare thematic maps of drainage network and watershed boundary, slope, land use/ land cover, geology, hydrogeomorphology, groundwater prospect, soil, land capability and land irrigability and transport network and settlements and village boundaries by using ARC/GIS 8.1.2. The drainage morphometry including hypsometric analysis is applied on the study area and derived the erodability characteristics of the watershed. The acquiring of the erodability characteristics from Hypsometric analysis is based on the contour map and drainage map. The sediment yield is computed for the watershed by using Garde's formula. An attempt is also made in this research work to study the status of groundwater potentiel by the success of wells in contraction with slope and hydrogeomorphology of the Malleboinpalli suffering from drought during the summer season. This can be achieved by constructing the suggested water harvesting structures for the augmentation groundwater potential. The integrated study of all these leads to the preparation erosion intensity zone map. Finally master action plan is prepared for both land and water resources development by integrating all the theme maps in conjunction with the results aquired from drainage morphometry, hypsometry, sediment yield and socio-economic data of the Malleboinpalli village.

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1. Introduction

1.1 General

Over exploitation of available natural resources for meeting the ever increasing demand for food, fuel and fiber has led to serious environmental degradation. Globally, an estimated 1,965 million ha of land is subjected to one or other kind of degradation out of which soil erosion by water and wind accounts for 1,904 million ha. In India alone, 6000 million tonnes of soil is lost through erosion by water annually (Rao.,2002). Altogether 175 million hectares of vegetative land is degraded in some form or other (DST Report.,1990).

The estimated crop losses due to pests, flood and drought disasters account more than 2000 million dollars every year. Based on statistics of over 170,000 borewells dug with the help of countrywide Hydrogeomorphological maps, it has been observed that the success rate of finding water has gone upto 92% compared to 45-50 percent using conventional methods(Rao.,2000). In India drought is a resultant of deficient rainfall due to spatial and temporal variations of monsoon. Drought conditions prevail whenever there is a deficiency of 15-35 % of a normal rainfall. Generally about 100 to 160 districts in India are affected by drought every year.The loss in terms of human sufferings is unaccountable economic losses including crop losses reach upto 1500 crores each year typically (Kondawar., 2000).

Poverty and land degradation

"Poverty limits the opportunities for protecting and enhancing the environment because poor people have few options but to exploit the natural resource base in order to attain food security, and sometimes even to survive. Poverty also hinders efforts to manage population growth because for poor people, children represent additional sources of income. The way forward is through sustainable and economic development. Aimed at broadly based poverty alleviation" (CGIAR., 1994)

Watersheds are natural hydrologic entities that cover a specific arial extent of land from which rainwater flows to a defined gully, river at any particular point.

Watershed is a planning unit for development of land and water resources. Soil, water and vegetation are the most vital resources and a wide range of effect on the lives of the people at large.Judicious and effective management of soil, water and vegetation can ensure the sustained productivity of food, fuel, fodder, forage, fiber, fruit and small timber.

Water resources delineation started with water resources regions (WRRs) into basins, then to the catchments .These catchments are further delineated into watersheds macro level and micro level basing on their size(Watershed Atlas., 1990). In this present study main focus is towards sustaining natural resources at village level micro-watershed a Nucleus watershed serving as a benchmark site in district.

Watershed management is the integration of technologies within the natural boundaries of a drainage area for optimum development of land, water and plant resources to meet the basic needs of people and animals in a sustainable manner. Sustainable Integrated watershed management is a pre-requisite not only for land, water, and biomass management of degraded areas but also for improving the livelihood of farmers as well as for conservation of areas so that biodiversity is protected for future generations (Wani.,2002)

The present study deals with Integration of socio-economic database with natural resource data which is a pre-requisite to prepare action plan keeping in view the underlying concept of sustainability of Malleboinpalli watershed in Mahaboobngar district. The available literature on various aspects of Mahaboobnagar district drafted by earlier investigators revealed that area is affected with degradation of natural resources, poverty and low crop yields.

1.2. Concept of sustainable integrated watershed management

Integrated area planning and management of any watershed involved in developmental activities using the natural resources available in

accordance with socio-economic conditions prevailing in that area for sustainable development is referred as integrated sustainable watershed management.

Naturally resources are generally land, it's related resources, surface and subsurface water resources which could be managed sustainably.

Socio-economic conditions namely demographic details, details of cultivation and other infrastructure facilities affect the sustainable development of natural resources. Sustainable utilization of natural resources is the driving force behind the present planning process, since it is now widely accepted that the future generations also have an equal claim over the use of finite resources of the planet earth. In this context, the concept of "Sustainable development". has gained importance. The essence of this concept is to maintain development in a way that will not damage our environment and could fulfill the demand of present and future generations also.

This project work aims at developing the action plan for these resources of watershed using GIS and Remote sensing for meeting the needs of the people through sustainable development.

1.3 Study objectives

For any developmental activities proper planning and management of the watershed is a must. Keeping this in view an atternpt is made at watershed scale to prepare an action plan for sustainable development of land and water resources by applying the Remote sensing and GIS techniques and related conventional methods.

The specific objectives of the present investigation are

(1) To assess the socioeconomic profile alongwith the natural resource base and climatic parameters.

(2) Preapare an action plan using satellite imageries and GIS for sustainable management of natural resources in the Malleboinpalli watershed.

These are mainly based on

(1) Creation of spatial and non spatial data-base for the watershed area.

(2) Quantitative analysis of drainage basin.

(3) Estimation of sediment yield for the watershed

(4) Hypsometry analysis for the determination of geomorphic stage of development of the watershed

(5) Identification of groundwater potential zones

(6) Integration of the information obtained from the analysis of satellite data, results of hypsometry, quantity of sediment yield and socio-economic conditions with in the watershed area.

(7). To promote the economic development of the village community, which is directly or indirectly dependent on the watershed through

a. Optimum utilization of the watershed's natural resources like land,Water, vegetation etc, that will mitigate the adverse effects of drought and prevent further ecological degradation

b. Employment generation and development of the human and other economy resources of the village in order to promote savings and income generation activities.

(8) To suggest measures for the restoration of ecological balance in the study area.

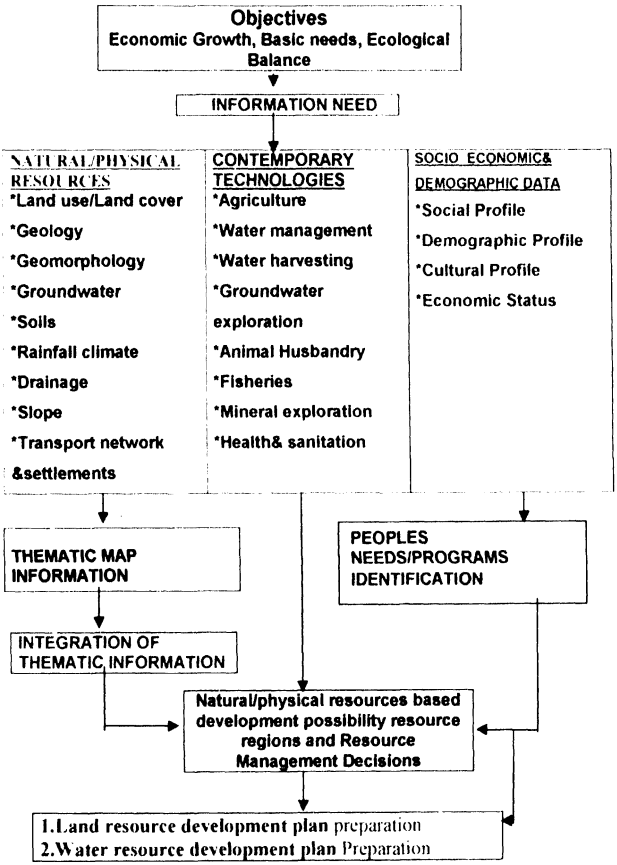
(9) To envisage plans to improve the economic and social conditions of the resource poor and disadvantaged sections of the watershed community with due consideration to social justice.

1.4 Conceptual frame work of the project

The study addressing the above issues needs elaborate data base on natural resources, physical/terrain parameters , climate, contemporary technology and socio-economic profile of the study area. Analysis of the data and integration of the same with contemporary technology will help in arriving at the action plan for sustainable development. The conceptual frame work for action plan preparation is given Figure No:1.1

Figure 1.1

Conceptual frame work of the project



Location map of Malleboinpalli watershed area

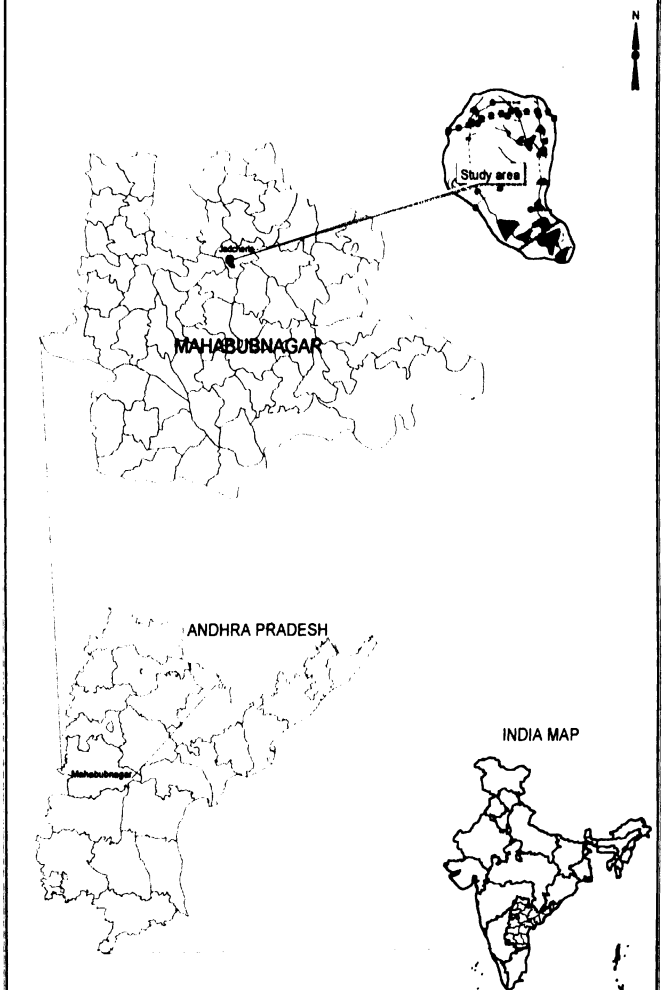


Plate .No: 1.1

1.5 Study area (Malleboinpalli) Description

1.5.1 Location

Longitude : 16^0 44'33.44"N to 16^0 46'29.08"N

Latitude : 78^0 05'20.35"E to 78^0 07'50.03"E

Jedcharla mandal, Mahaboob nagar District of A.P, India which is spread Over 15.05 Sq.km.Location map of the study area is shown in Figure1.1

1.5.2 Physiography:

The physiography of the study area is very gentle to gentle sloping. The drainage basin having a tributary of Krishna.General gradient of the watershed extends from north-west to the south-east.The altitudes of the plains vary from 520m to 580m above mean sea level (msl), while the hilly region vary from 560m to 620m above msl .

1.5.3 Geographical distribution.

Geographical Area	:15.0597 Sq.km
Double cropped area	: 1.4091 Sq.km
Kharif Unirrigated area	: 11.1437 Sq.km
Fallow lands	: 0.1648 Sq.km

1.5.4 Rainfall

Receives on an average of 670 mm of rainfall annually.

1.5.5 Geology

The study area mainly consists of Granites in different forms.

1.5.6 Geomorphology

The geomorphic evolution of an area is the result of interaction between the different elements like lithology, structure,climate etc involved in the various endogenic and exogenic processes operating from time to time.The study area is mainly covered by different geomorphic units such as Pediplains, Pediplain with shallow and moderate weathering, inselberg etc.

1.5.7 Demography

Study area comprises of Malleboinpalli panchayat, Esaikunta tanda and Nakkalabanda tanda,

1.5.8 Cropping pattern

Farmers diversify their cropping pattern through number of crops grown in the two seasons main rainy season(kharif), post rainy season (rabi). These are rice, sorghum, maize, castor are main crops along with these cotton, pigeon pea, millet, horse gram, sunflower and vegetables are also cultivated in few hectares.

1.5.9 Farmers categorization

The total households are of 539.Farmers are classified into 382 small land holding farmers, 85 medium land holding farmers, 52 large land holding farmers.

1.5.10 Pedology

Soils in the Malleboinpallli watershed predominantly consists of red clay loam soils, red sandy soils, saline and alkaline soils and light black soils having the fertility varying from good to poor.

1.5.11 Geomorphic characteristics

The geomorphic characteristics of a watershed significantly effect the entire hydrologic cycle, which includes total run off volume, peak run off rate, runoff duration and other hydrologic parameters. Geomorphologic analysis is the systematic description of the watershed geometry and its stream channel

to measure the linear aspects of drainage network, Arial aspects of drainage basin and relief aspect of channel network are discussed in the chapter Drainage Morphometry of results and discussions

1.5.12 Streams and water bodies

Watershed consists of two streamlets one flowing from north to south and another flowing from north east to south direction. Along the stream path there are 7 tanks as follows

Naganna kunta

Singayya kunta

Nallakunta

Rekulakunta

Komanu kunta

Papanna kunta

All these for the purpose of irrigation

Ura kunta in village for domestic purpose.

1.5.13 Transport network

Through the study area two state highways are passing from Hyderabad to Kurnool and Mahaboobnagar. One railway broad guage is also passing from Secunderabad to Kurnool

1.6 Data base

Four types of data mainly used remotesensing data, topographical data, socio-economic data and climatological data are used. The data sources are detailed in the table No: 1.1

Table No:1.1 **Sources and utility of data types**

S.No	Data type	Source of collection	Utility
1	Remote sensing data	Indian Remote sensing Satellite(IRS-ID) panchromatic (PAN) and Linear imaging self scanner–III(LISS-III) satellite imagery	1. Thematic mapping, vegetative cover factor for sediment yield estimation Erosion –intensity zoning.
2	Topographical data	Survey of India Top sheets of 1:50,000 and 1:25,000 scale (No 56L/1,56L/2)	Basemap preparation, Slope map, Drainage network, Drainage optometry, Contour map for Hypos merry.
3	Socio economic data	Ground truth survey	Analysis of socio-economic conditions for the development of master action plan
4	Rain fall data	Agro – climatology, GIS units of GT-3, ICRISAT	Sediment Yield estimation

1.7 Research approach

The entire thesis work is divided into land management and water management coupled with socio-economic aspects

The step wise procedure is as follows.

1. Drainage map is used to know the *drainage pattern* and for finding out the *drainage density* and *stream slope*. Basin characteristic features are also evaluated to know the hydrologic performance of the watershed.
2. Landuse/Land cover map is prepared to know the various uses which are carried out for the land and vegetation, water bodies, rock/soil, artificial cover and others resulting due to land transformations. This landuse/land cover map is also used to find the areas of cropland, forest, wasteland etc, in order to calculate the *vegetative cover factor.*
3. Slope map is used as an aid for mapping *erosion-intensity units.*
4. Hydrogeomorphology map and geology map are used to finding out *groundwater prospects* to suggest water-harvesting structures such as percolation tanks, Check dams etc. Erosion intensity map is used to find the erosion prone areas so that necessary control measures may be taken up in preventing sediment Transport.
5. Contour map is used for Hypsometric Analysis.
6. A GIS digital system ARC/GIS version 8.1.2 is using for input and manipulation of maps which are readily retrievable in future on a scale of 1:50,000.
7. Rain fall data is collected from the Malleboinapalli weather station for the last 18 months and for the last 30 years from the nearest Mahaboobnagar weather station at the diastance of 6km to the Malleboinapalli.Temperature data of Palem weather station is collected for last 10 years

   Average annual precipitation and average annual temperature are used to compute *Runoff*
8. Sediment yield is computed using the Garde's equation.

9. Well data is used to prepare the graphs for % of success of wells in different slope categories and in different geomorphological units.
10. All the required socio economic dataand de collected household GPS survey is conducted to collect the data from each and every family.
11. Socio-economic data on integration with resource is used as an aid in preparation of action plan for land and water resources development

1.8 Organization of thesis

The present thesis is organized into six chapters .in the chapter-I *Introduction*, the concept of sustainability, objectives of the study and research approach discussed here. In chapter-II - *Review of Literature: concepts and advances* of *Remote sensing and GIS , soil erosion, run off estimation, sediment yield computation using remote sensing and GIS, Soil conservation measures* are discussed. Preparation of Thematic maps is discussed in Chapter-III- Materials and Methodology. In chapter-IV *Results and discussions, Results of thematic mapping, Drainage morphometry, Hypsometric analysis, Sediment yield computation, Integration of Themes, Preparation of erosion intensity zoning map and Generation of action plan.* Chapter-V deals about the *Summary and conclusions* . Finally in the chapter- VI - *References are given.*

2. Review of Literature

2.1 Introduction

The watershed development approach in India was first adopted in 1974 when the Govt, of India enforced the scheme for "Soil Conservation in the watershed of river valley projects". In 1982 Govt of India launched another ambitious programme for the development of dryland Agriculture on watershed basis under which 47 Model watersheds were identified under different Agro-climatic zones all over the country.

The acceptance of watershed as a natural hydrologic unit for multi-resources development planning stems from the fact that sustainability of development based on soil and land use depends on their interaction with water in all the activities that takes place through out the watershed. Soil, water and land use constitute natural resource base vital for human sustenance. All forms of life derive their nutritional and other needs from the soils or soil based other life supporting systems. The unique assemblage of soil together with water and other resources determine developmental potential of an area /region.

In this chapter review of literature available from the previous work done on Integrated watershed management, soil erosion intensity zones, computation of run off, estimation of sediment yield and delineation of groundwater potential zones by using Remote sensing and GIS and concepts of Remote sensing, GIS, Soil erosion and Soil conservation measures are discussed.

2.1. Remotesensing and GIS applications in watershed.

Krishna(1996) in his case study of *"Remote sensing Approach for Watershed-based Resources Management in the Sikkim Himalaya"* discussed the usefulness of remotely sensed data for watershed management .In these biophysical conditions were assessed based on field experience. Land use/land cover categories, soil-physiographic unit's identified from the satellite imagery. Analysis of micro-climatic variations, cropping pattern and associated parameters for the preparation of action plan. Considering the socio-economic needs and

environmental conservation two tier land resource management approach is proposed.

Varma et al.,(1998) conducted *"Integrated resource study for conservation and management for Ropar wetland ecosystem"*. It was undertaken to analyze physiographic, drainage, land use, and vegetation status. Various thematic maps have been prepared using black and white aerial photographs on 1:20,000 scale and IRS-IA LISS-II False Color Composite(FCC) on 1:50,000 scale. The water spread and qualitative turbidity level is also monitored. Keeping in view threats of the notified area as anthropogenic pressure, industrial pollution, sedimentation, eutrophication, illegal fishing and flooding, etc. conservation measures were suggested.

Nag(1998) carried out *"Morphometric analysis using remote sensing techniques in the drought affected Chakra-river basin of West Bengal"*. Using satellite imageries of LANDSAT and IRS, different hydrogeomorphological units have been delineated. Drainage details have been prepared from toposheet and satellite imagery. The parameters worked out here included bifurcation ratio(Rb), stream length (Lu), form factor (Rf), circulatory ratio (Rc) and drainage density This morphometric analysis suggests that the area is covered by fractured, resistant , permeable rocks, the drainage network not so affected by tectonic disturbances.

Rana(1998) applied *"Directional filtering in lineament Mapping for groundwater prospecting around Bhinmal -a semi arid part of Thar desert"*. The application of Directional filtering procedures on IRS LISS I bands 4 digital image of the study area revealed NE-SW, NW-SE and E-W trending lineaments which are very subtle. The use of exploratory borehole litho logs and field evidences indicated that the lineaments are long rectilinear buried and partly exposed channels and the intersection zones are characterized by thick lenses of coarse sand and gravel. These buried channels and zones of coarse

sediments thus represent potential sites for the accumulation of freshwater during rain.

Kumar and Tomar(1998) studied *"Groundwater assessment through hydrogeomorphological and geophysical survey- A case study in Godavari Sub watershed, Giridih,Bihar"*. In this remotely sensed data has been further sub-divided based on the tone, texture and pattern. These units were analyzed by electrical resistivity method. Correlation between different sub-units, hydro geomorphic unit and top soil resistivity were attempted. The correlation and integration of resistivity map with geomorphologic map were carried out through "GRAM" Geographic Information system. This has helped in better understanding the surface resistivity pattern. These sub divisions were different geohydrological and recharge characteristics.Resistivity zonation map prepared on the basis of limited field data and through interpolation /extrapolation can be modified / corrected with the help of information derived from remotely sensed data to obtain more realistic picture.

Biswas et al.,(1999) worked on *"Prioritization of sub watersheds based on morphometric analysis of drainage basin by using remote sensing and GIS for Nayagram block Midnapore district "*. They studied morphometric parameters-stream length, bifurcation ratio, drainage density, stream frequency, texture ratio, form factor, circulatory ratio, and elongation ratio, estimation of sediment yield by Sediment yield index (SYI) method and prioritized all the sub watersheds under study area .

Pal (2000) studied on *"Evaluation of water discharge and sediment budget in the lesser Himalaya"*. Based on the morphometric and drainage analysis, the water discharge, suspended load yield and rainfall has been computed. Automatic water stage recorder with horizontal axes (float types) equipment being used for water discharge during rainy season. The water samples collected during peak runoff were analyzed to evaluate sediment

yield daily. Drainage pattern in three catchments was mapped through the interpretation of aerial photographs. After detailed analysis of the above factors concluded that most of the suspended load was transported between June and September and during rest of the months the concentration of sediment load was close to zero.

Pratap et al.,(2000) studied on *"Groundwater prospect zoning using remote sensing and GIS in Dala-renukoot Area,Uttar Pradesh"*. Thematic maps in respect of geology, geomorphology, slope, drainage, land use/land cover, lineament and lineament intersection frequency were prepared on 1:50,000 imagery by remote sensing and GIS. Each theme was assigned a weightage depending on its influence on the movement and storage of groundwater and each unit in every theme map is assigned a knowledge based ranking from 1 to 5 depending on its significance of groundwater occurrence.

Subbarao et al.,(2001) studied in the identification of groundwater potential zones using Remote sensing techniques in and around Guntur Town, Andhra Pradesh. Identified units and features by remote sensing technology with the integration of conventional information and limited ground truths are shallow weathered Pedi plain(PPS), moderately weathered Pedi plain(PPM), deeply weathered Pedi plain(PPD), residual hills(RH), and lineaments The results show that the PPD, PPM, PPS are good, good to moderate, moderate to poor promising zones respectively. The RH is a poor geomorphologic unit in respect to prospective zone as groundwater resource. Lineaments parallel to the stream courses and intersecting-lineaments are favorable indicators for groundwater development. They can also be utilized to augment groundwater resource.

Sarkar et al.,(2001) studied on *"A geographic Information system approach to evaluation of groundwater potentiality of Shamri micro-watershed in the Shimla taluk, Himachal pradesh"*. The role of various parameters namely,

drainage, lineaments, lithology, slope and landuse have been emphasized for delineation of groundwater potential zones. IRS-1C PAN and LISS –III FCC merged satellite image on 1:25,000 scale and topographic maps together with field traverses have been used as data source. A multi criteria evaluation following probability weighted approach has been applied for overlay analysis that allows a linear combination of weights of each thematic map with the individual capability value. The resultant map indicates a high groundwater potentiality in the flood plains, river terraces and river channels I the vicinity of the Shamri nala.Other sites of high potentiality include places showing break in slopes and criss- crossing of lineaments

Carios et al.,(2001) used "*Remote sensing data, GIS and Universal Soil loss Equation (USLE) model for developing maps of erosion risk in Piracicaba river basin, south eastern Brazil*". Soil erosion losses were simulated with the GIS-USLE technique for January 1978-1993.A series of thematic maps (one for each equation factor) are created processed and analyzed using Arc-Info/GIS. Basing on this erosion risk zonation is mapped. Soil and water conservation practices are developed, especially for the areas of heightened erosion risk identified.

Chakrabarthy and Datta(2001) observed the indicators of land use of watershed in arid region, Western Rajasthan using remote sensing and GIS. Finally concluded that there is marginal improvement or land use/land cover and vegetation vigor or biomass deteriorated over the years.

Durbude and Purandara(2001) in their case study of *"Estimation of surface runoff potential of a watershed in semi arid environment"* analyzed the study area using IRS-IB LISS-II satellite imagery for estimating the runoff potential under geomorphic set-up. After the analysis of satellite imagery topographical maps, ground truth data verification and runoff calculation by SCS method, different water harvesting as well as storage structures are

proposed and the future scope for irrigation on full water irrigation are calculated. Check dams, lift irrigation systems and storage tanks are proposed.

Wani et al.,(2002) conducted a study on "*Spatial distribution Rainy season Fallows in Madhya pradesh: Potential for increasing Productivity and minimizing land degradation*". It's a deductive approach including delineation of agricultural land and forests from temporal satellite data was employed to identify kharif fallow. Three sets of satellite data correspondin to three periods, namely mid-kharif, late kharif, and rabi season were used. Finally it was estimated that 2.02 million ha accounting for 6.57% of the total area of the state were under fallowing. Madhya pradesh is endowed with well distributed rains ranging from 700-1200mm. Vertisols with good moisture holding capacity can be used to grow short duration soyabean by adopting sound land management practices.This will help increase income to the farmers besides preventing land degradation due to runoff erosion.

Tripati and Panda(2002) conducted a study for the Nagwan watershed of the Damodar valley Corporation, Bihar to prepare Runoff modeling. GIS is used to extract the hydrologic parameters of the watershed from the remote sensing and field data. DEM (Digital elevation model) for the preparation of Contour map and Easi/Pace GIS software was used to extract the topographic features and to delineate watershed and overland flow patns from the DEM. Land use classification generated from data of Remote Sensing Satellite (IRS- IB and LISS-II). Drainage characteristics derived from toposheet and relief of study area. Hypsometric analysis procedure is used to determine the geomorphic stage of development of watershed. Data extracted from all these is used in the preparation empirical model for the surface runoff prediction. This is helpful in the designing of conservation structures and evaluating the effect on these structures.

Mohan and Dilip(2002) studied on "*Estimation the soil erosion potential using Universal soil loss equation for the catchment in Yelberg of Karnataka*". In

to automize the estimation of USLE parameters, a geographical information system Integrated land and Water Information systems was used. by this method annual and seasonal soil erosion rates were estimated for the study area. The gentle sloping topography and the soil types resulted in low erosion rates from major portion of the watershed. Erosion potential map and rain fall station point map is used for calculating erosion from rain fall events of particular interest. This is useful in the evaluation of various types of management and surface practices.

Srinivas et al.,(2002) studied on *"Assessment of soil erosion using remote sensing and GIS in Nagapur district, Maharastra for prioritization and delineation of conservation units"*. The rate of soil loss is estimated by USLE method is helpful to evaluate the influence of different land cover and sol management factors in quantitative estimations of soil loss of the district. The physical and chemical data of different soil series of Nagpur district are used for the estimation of soil erodability. Implementation of Universal Soil Loss Equation using integration procedures of GIS enabled the prediction of potential and actual conditions respectively. Nine units with unique combinations of soil erosion and site characteristics are identified for conservation using multi criteria analysis in GIS. Suitable agronomic and mechanical measures are suggested for soil conservation based on the above characteristics in each unit.

Mani et al,(2003) studied on *"Erosion study of apart of Mahuji river-Island using Remote sensing data"*. In this study Image processing of digital data has been done in ILWIS software. Supervised for delineation of river from land and then image change detection analysis has been done to find out changes in river course from 1991 to 1997 and further from 1997 to 1998. Erosion and deposition maps of the area have been prepared and the erosion of island is measured at various sections at 1 km interval. Erosion of 1900 ha has been observed during the period of six years.

2.3 Model Watershed Programme by ICRISAT Consortium

Adarsha watershed, Kottapalli, Rangareddy district, Andhra pradesh

Before giving the focus on this Nucleus watershed Maleboinpalli ICRISAT-led consortium which is to provide technical backstopping to The United Kingdom's Department for International Development (DFID)-Andhra Pradesh Rural livelihoods Programme (APRLP) to scale up the benefits of holistic watershed management approach through convergence for improving the livelihoods of the rural poor, had developed and evaluated an innovative farmer participatory consortium model for watershed management in Kothapalli watershed to achieve sustainable development.(Wani. et al.,(2001)(2002))

A participatory watershed research at Kothapalli having an area of 465 ha was taken in the ICRISAT-led consortium of watershed committee which involves farmers, NGOs, Women's Self Help Groups(SHGs), Drought Prone Area Programming(DPAP), Central research Institute for Dryland Agriculture(CRIDA), National Remote sensing agency (NRSA) and National Agricultural Research System members(NARS)

The major outputs of the programme are

(1)Improved natural resources management options evaluated and refined in farmer fields

(2) Evaluated suitable cropping systems based in the agro ecological potential of the region.

(3) Increased system productivity through adoption of improved soil, water, nutrient and pest management technologies.

(4) Better land treatment

A major part of the land treated with various soil & water conservation measures yielded promising results. Among these the impact of check dams, sunken pits are significant.

(5) Farmers experienced improved groundwater level in their wells through increased recharge using harvest. In the watershed runoff soil loss measurements are recorded using automatic hydrological gauzing stations.

(6) Vermicomposting an eco-friendly technology is suggested for them to improve availability of nutrient rich compost and for providing employment opportunities.

(7) Increased the awareness of the People about the alternative lively-hood options.

(8) Increased cropping intensity & introduction of new crops.

With the availability of irrigation water, fertile soil, improved quality of seed& fertilize, a major extent of land has been brought into double cropping there by increasing the intensity of crop.

(9) The various land treatment measures adopted for run off control have helped in the rise of groundwater table. The area under well irrigation boosted up by 2-3 fold.

(10) Increased productivity of crops

The use of improved seed, fertilizer, plant protection measures, timely operations and soil and water conservation has boosted the productivity of different crops .

2.4.Concepts of Remote sensing and GIS

2.4.1 Introduction

Watershed management requires exhaustive data and information, which are dynamic in nature and temporally change over time & space due to natural & 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, out dated 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 analyze the changing parameters. Remote sensing technology has immense contribution towards this in providing synoptic and unbiased information on large areas at periodic intervals.

The technology of remote sensing has developed most rapidly when people perceived the need to strike the appropriate balance between resource development and environmental preservation. Today remote sensing affords a practical means for frequent and accurate monitoring of the earth's resources globally. The remote sensing data have been providing information necessary for making sound decisions and policy formulations in a host of resource development and land-use applications. The other areas of remote sensing applications like locating forest fires, monitoring population growth and distribution, detecting diseased crops, geological investigations, determining location and extent of water pollutants, oil spill, ice bergs etc., have benefited the mankind.

There are two basic processes involved in electromagnetic Remote Sensing of earth resources which are data acquisition and data analysis.

A Remote Sensing System using electromagnetic radiation has four components

1.Source:

The source of electromagnetic radiation may be natural like the Sun's reflected light or the Earth's emitted heat on man-made microwave radar.

2.Earth's surface interactions:

The amount of characteristics of radiation emitted or reflected from the earth's surface is dependent upon the characteristics of the objects on the earth's surface.

3.Atmospheric interaction:

Electromagnetic energy passing through atmosphere is distorted and scattered.

4.Sensors:

The electromagnetic radiation that has interacted with the surface of the earth and the atmosphere is recorded by a sensor.

Remote sensing provides a reliable base for generating information on natural resources(Rao.,2002). The information on nature, extent, spatial

distribution, and potential and limitations of natural resources is a pre-requisite for planning the strategy for sustainable development .In addition socio-economic and meteorological and other related ancillary information is also required while recommending area specific prescriptions for taking up curative or preventive measures. By virtue of synoptic view of the study area at regular interval, space borne multi-spectral data have been used for generating base line information on mineral resources, soils, groundwater and surface water, land use/ land cover, forest etc. At scales ranging from regional to micro level.

Beginning with the Landsat -MSS data with 60X80 m spatial resolutions and four spectral bands spanning from green to near infrared in early 1970s' the natural resources scientists had access to Landsat-(Thematic mapper)TM data with a 30m spatial resolution and seven spectral bands spread over between blue and thermal infrared region of the electromagnetic spectrum in early 1980s which helped further refinement and generation of thematic information at large scale.

Further development in the sensor technology indigenously resulted in the launch of the state-of-the-art satellite (IRS-IC) in December, 1995 and IRS-ID later with the following three unique sensors.

I. Wide field sensor (Wifs) with 188 spatial, two spectral bands red and near infrared, 180 km swath and a repetitivity of 5 days.

II. Linear Imaging Self scanning sensor (LISS-III) with 23.5m spatial resolution in the green red and near infrared region, and 70.5 in the middle infrared region and, 140km swath.

III.Panchromatic (PAN) camera with 5.8m spatial resolution, 70km swath and stereo capability.

Imaging sensor characteristics of the IRS-ID PAN and LISS-III are given in the table 2.1

Table2.1 **IRS-1D (PAN &LiSS-III) Imaging sensor characteristics**

Panchromatic(PAN)	
Spatial Resolution	5.8
Swath(Km)	70
Spectral band(μm)	0.5 – 0.75
CCD Device	4096 elements
Linear array	
Device size(micron)	7*7
No of Quantisation levels(bit)	6
SNR(at saturation Radiance)	>64
SWR(0 at Nyquist frequency)	0.20
Integration time(m sec)	0.883
Data rate(Mbps)	84.903

Linear Imaging Self-Scanner(LISS-III)		
	Visible&NIR	SWIR
Spatial Resolution (m)	23.5	70.5
Swath(Km)	1.42	148
Spatial bands(m)	0.52-0.59 0.62-0.68 0.77-0.86	1.55-1.70
CCD Device	6000 elements	2100 elements
Device size(micron)	1087	30*30
No of Quantisation levels(bit)	7	7
SNR(at saturation Radiance)	>128	>128
Band to Band registration (pixels)	±0.25	
SWR(0 at Nyquist frequency)	>0.40(0.52-0.59μm) >0.40(0.62-0.68μm) >0.40(0.77-0.86μm)	>0.30
Integration time(m sec)	3.5528	10.6584
Data rate(Mbps)	35.790	1.3906

For visual interpretation the standard false color composite (FCC) prints generated from green, red and near infrared bands have been used. How ever special products with varying combination of spectral bands have also been tried out for specific applications.

Integration of information on natural resources, socio-economic, climatic conditions and other related ancillary information in a holistic manner for preparing localtion specific intervention for a given area is very crucial.

2.4.2 Basic Elements of Visual Interpretation

The satellite imagery of IRS-1D PAN and LISS-III merged image is visually interpreted using six basic elements of image interpretation namely

1. Tone/color
2. Texture
3. Shape
4. Size
5. Pattern
6. Association.

Due to the effect of no terrain related factors, image interpretation is based on relative tonal values rather than absolute tonal values. Tone or hue refers to the relative brightness of color of objects on an image. Texture, which shows the frequency of tonal change, is produced by the overall reflectance of the constituents of the object. It determines the smoothness or roughness of the object. Shape is an indicator of boundary geometry. Size of an object is a functional scale of the image. Pattern refers to the alignment and spatial dispersion of objects. Association is a parameter that defines the occurrence of certain features in relation to others.

2.5.Remote sensing advances in watershed

The various applications of remote sensing in watershed management are described here

2.5.1 Surface water inventories

High resolution and near infrared sensors such as those on IRS and LANDSAT can be used to measure the extent of surface water because of strong near infrared contacts between water and adjacent land .Numerous results from these satellite studies indicate the water bodies as small as 0.01sq.km that can be delineated with ease. This makes the monitoring of surface water using repetitive remote sensing data feasible, even on small inaccessible watersheds

2.5.2 Flood Assessment and Plain mapping

IRS/LANDSAT data are the most pertinent kinds of satellite information for flood observations because of relatively high resolution cartographic fidelity,and the near infrared sensors. Areas inundated are detected in the near infrared bands as areas of reduced reflectivity due to standing water, excessive soil moisture and vegetation moisture stress. Most important is the fact that observations as late as two weeks after the flood crest will still show the characteristic reduced near infrared reflectivity of the previously inundated areas, which essentially reduces the need for obtaining satellite observations at the time of peak flooding. Other investigations have shown that areas likely to be flooded, known as flood prone areas, tend to have multispectral signatures which are at times different than the signatures of surrounding non flood prone areas .

2.5.3 Snow Mapping

The extraction of snow covered area from satellites using visible and near infrared imagery has been tested successfully. The extraction of snow covered area from satellites using visible and near infrared imagery has been tested

successfully. The extraction of other more meaningful snow pack parameters such as water equivalent and depth is still in research stage, although water equivalent values obtained by measuring the snow's attenuation of natural gamma radiation from extremely low altitude aircraft have been very promising.

2.5.4 Hydrologic Land use Analysis

Knowledge of watershed land use is important because a record of surface cover characteristics can be used to refine estimates of the quantity, quality and timing of water yield in response to a particular precipitation event or watershed treatment. Various watershed models require up-to-date land use inputs for calibration purposes and hence, better stream flow simulations. These land use requirements can be met by various levels of sensing data.

2.5.5 Physiographic Characterization

Physiographic observations such as basin area and shape ,stream network organization, drainage density and pattern and specific channel characteristics can enable an investigator to estimate the mean annual discharge and mean annual flood flows from a watershed, as well as the rapidity of watershed response to a particular rainfall event. In general the kind of dynamic hydrologic information available from the respective coverage of satellite images cannot be obtained from topographic maps. Further, in same areas single satellite images offer more geographic information than is available on comparable scale map.

2.5.6 Watershed models

Much of the information capable of being extracted with the Remote sensing approaches mentioned previously can be used in the calibration or operation of numerical watershed models, especially in data sparse regions .the suitable data include land use classification, stream channel and other physiographic parameter consists of a combination of specific land uses

including urban development, streets, Parking lots, roof tops and construction site. IRS/LANDSAT gives automatic classification of impervious area and the agreement with the conventional method was excellent.

2.6 Resource mapping in watershed

Remote sensing technique in evolving characteristics of the watershed has demonstrated that this medium is very useful in providing applicable hydrological information in spatial and temporal scale. The synoptic coverage of satellite imagery permits fairly easy identification of basin extent, and broad physical features such as stream network, land use, vegetation, surface water bodies, etc. Hydrologists and water resources engineers were long handicapped with reliable survey data of mapping of watershed characteristics. Satellite remote sensing now enables easy, accurate , time and cost effective mapping and updating of several resources information of the watershed such as stream network map, land use/land cover map, soil map, land irritability map, land capability map, erosion intensity map, hydro geomorphology map, groundwater prospect map etc. These maps and information can be geo referenced with conventionally measured topographic maps through Geographic Information system (GIS) for meaningful synthesis of the watershed.

2.7.Role of Geo-graphic Information Systems (GIS)

2.7.1 Introduction

Over the past two decades it has become increasingly apparent that resources are becoming more scarce, the effect of human activities more pervasive and the recognition and the prediction of causes and effects more complex. It has also been recognized that better resource assessment and planning methods yield direct benefits in improved resource management and ultimately in improved quality of life. Georeferenced information has always been

critical to the welfare of the country, it is the technology and methods such as computer based information systems and remote sensing that can provide the means to prepare resource inventory and model process from the local to global scale. The need for a computer based information system that efficient handling analysis of geo referenced data has evolved Geographical Information System (GIS). The GIS is collection of computer hardware, software, experienced personnel for input management data storage and retrieval, manipulation and output of geo graphically referenced data and the corresponding attributes. A GIS is generally designed for the collection, storage and analysis of objects and phenomenon where geo graphical location is an important characteristics or critical to the analysis. In other words a GIS may be defined as computer based information system which attempts capture, store, manipulate, analysis, and display spatially referenced and associated tabular attribute data, for handling efficient research, planning and management problems. Such as system will normally embody.

- A database of spatially referenced data consisting of location and associated tabular database.

- GIS provides an ideal environment for integration of information on natural resources and ancillary information and generation of action plan taking into account social, cultural, and economic needs of the people(Rao.D.P., 2003).

- Appropriate software components encompassing procedures for interrelated transactions from input via storage and retrieval, and the adhering manipulation and spatial analysis facilities to output (including specialized algorithms for special analysis and specialized computer languages for special queries) and associated hardware components including high-resolution graphics display, large capacity electronic storage devices which are organized and

interfaced in an efficient and effective manner to allow rapid data storage , retrieval and management capabilities and facilitate the analysis.

2.7.2 Components of GIS

A GIS maybe considered as a subsystem of an information system which it self has five major component subsystems including:

- Data input processing
- Data storage, retrieval and database management
- Data manipulation and analysis.
- Display and product generation
- A user interface

These main components are summarized in data input which covers all aspects of transforming spatial and non–spatial (textural or feature attribute) information from both printing and digital files into a GIS database. To capture spatially referenced data effectively, a geographical information system should be able to provide alternative methods of data entry. These usually include digitizing (both manual and automatic), satellite images, and scanning and keyboard entry. The data may come from many sources such as existing analogue maps, aerial photographs, and remote sensing surveys and other information systems. Often the data require operations of manual or automated processing prior to encoding, including format conversion, data reduction and generation of data, error detection and editing, merging of points into lines, edge matching, rectification, registration and interpolation etc. The level of measurement of these data may very and range from categorical to ratio data and from fuzzy and stochastic information to precisely measured data.

Database management functions control the creation of and access to the database it self. For the storage, integration and manipulation of large volumes of different data types at a variety of spatial scales and levels of resolution, a GIS

has to provide the facilities available with in a Database Management System (DBMS). Most commercial GIS (such as, for example: ARC/INFO) have a dual architecture. The non–spatial attribute information is stored in a relational database management and the spatial information in a separate subsystem, which enables to deal with spatial data and queries. Such architecture however reduces the performance because objectives have to be retrieved and compiled from components stored in the two subsystems. This problem is not easy to solve. Spatial data processing is performed with vector, raster or a combination of the geometric data formats.

The most important and distinguishing feature, which a GIS has over a mere computer mapping systems or CAD, is the ability to manipulate and analyze spatial data. The manipulation and analysis procedures, which are usually integrated in a GIS, are often limited, however to simple spatial operations such as:

- Geometric calculation operators such as distance, length, perimeter, area, closest intersection and union.
- Topological operators such as neighborhood, next link in a polyline network, left and right polygons, start and end nodes of a polyline.
- Spatial comparison operators such as intersects inside, outside neighbour etc.
- Multi layer spatial overlay involving the integration of nodal, linear and polygon layers, and to restricted forms of network analysis.

Product generation is the phase where final products from geographical information system are created. The display and products may take various forms such as statistical reports, maps and graphics of various kinds, depending upon the characteristics of the media chosen. These include video screens for an animated time sequence of displays similar to a movie, laser printers, inkjet and

electrostatic plotters, color film readers, micro film devices and photographic media.

The final module of a geographical information system consists of software capabilities, which simplify and organize the interaction between the user and the GIS software via, for example menu driven common systems.

It is note–worthy that most current GIS is strong in the sophisticated forms of spatial analysis and decision making make them best suitable for natural resource management. As mentioned earlier, the analytical possibilities basically and usually refer to polygon overlay with logical operators, buffering inventor maps, interpolations, and joining and simplified network analysis. GIS capabilities for location – allocation problems, optimal land use allocation and management routing vehicles for delivery of goods and services.

2.7.3 Classification of GIS analysis functions

The development of GIS techniques has provided a constantly growing number of ever more sophisticated analysis functions. A description of even the most common functions would quickly overwhelm the unlimited. The following shows the classification of analysis functions is as follows.

- Maintenance and Analysis of the spatial data transformations – Format, Geometric transformations, transformation between map projections, conflation, edge matching, editing of graphic elements, line coordinate thinning.

- Maintenance and Analysis of the attribute data – Attribute editing functions, attribute query functions.

- Integrated Analysis of Spatial & Attribute data – Retrieval, classification, measurement, overlay operations, search, line in polygon and point polygon, topographic functions, theisen polygon, interpolation, neighborhood operations, contour generation, connective functions, contiguity measures, proximity, network, spread, seek, intervisibility, illumination and perspective view.

- Output Formatting – Map annotation, text labels, and texture patterns.

Graphic Symbols

The first level of classification contains four groups mainly maintenance and analysis of the spatial data, maintenance and analysis of the attribute data, integrated analysis of spatial and non – spatial data and output formatting. Each major group is sub divided into types of function. The distinction among these categories is some what artificial and not clear, but they do provide a useful frame work.

The way that GIS function is implemented depends on such factors as the data modal (e.g. Raster v/s Vector), the hardware and performance criteria (e.g.: how fast it must run, what options must be provided). These details are important and require considerable expertise to properly evaluate.

2.7.4 Application of GIS

Some of the GIS applications include agricultural and land use planning, forestry and wild life management, archeology, geology, municipal applications, civil engineering, Remote Sensing, urban and regional planning, business and commercial applications. The easy acceptability and implementation of GIS are making it very popular for various applications. The three dimensional analysis is

having applications in terrain evaluation, highway route allocation and canal planning etc.

2.7.5 Implementation

The implementation of a GIS is where technology and people meet; one of the reasons for the complexity of the implementation process is that it is necessity to harness the potential that people in an organization that adopt and learn to use the technology.

The implementation of GIS can be seen as a six-phase process.

A). Awareness: People with in the organization become aware of GIS technology and the potential benefits for their organization. Potential uses and users of GIS are postulated.

B). Development of systems requirement: The idea that GIS could benefit the organization is formally acknowledged and a more systematic and formal process is instituted to collect information about technology and to identify the potential users and their needs. A formal need analysis if often done at this stage.

C). System Evaluation: Alternative systems are proposed and evaluated. The evaluation process takes into account the need analysis of the previous phase. At the end of this phase a formal decision must be made where or not to proceed with acquisition of GIS.

D). Development of an implementation plan: having made the decision to proceed with acquisition of a system, a plan is developed to acquire the necessary equipment and staff, make organizational charges and found the

process. This plan may be a formally accepted document or a more or less informal series of actions.

E). System organization and start – up: The system is purchased, installed, staff is trained, creation of database is beginning and operating procedures begin to be established. Creation of the database is usually the most expensive part of the implementation process. Considerable attention is needed to establish appropriate data quality. Controls to ensure that the data entered meet the required standards and those suitable updating procedures are implemented to maintain the concurrency and integrity of the database.

F). Operational phase: By this stage the initial automation of the database is complete and operating procedures have been developed to maintain the database and provide the information services that the organization requires. In this phase procedures are developed to maintain the GIS facility and upgrade services so that the GIS continue to support the changing information needs of the organization. Operational issues concerning the responsibilities of the GIS facility to provide needed services and to guarantee performance standards become more prominent

2.8.Soil Erosion –An Overview

Studies on the effect of erosion on early civilization have shown that a major cause of the downfall of many flourishing empires was soil degradation (Lowdemilk, 1953). Although this is clearly evident through 7000 years of history, an awareness of the problem has developed very slowly.

Soil erosion by water and wind is the major degradation process operating upon the arid and semi arid regions of the world. Globally, an estimated 1.965 billion hectares of land are subject to some kind of degradation. Of these 1.094 billion hectares of land are subject to soil erosion by water. And

an average of 25 billion tons of topsoil from croplands is being washed into oceans. Soil degradation is a process by which the soils population capacity diminishes by one or another means and finally becomes totally denuded and not supported life of flora and fauna etc.

In India alone, out of a 329 million ha geographical area, 150 million ha of land are affected by wind and water erosion is affected by wind and water erosion (Rao ,2003). Soil degradation contributes to an increase in atmospheric carbon dioxide through rapid industrialization and deforestation have led to building up of greenhouse gases in the atmosphere resulting global warming. Besides, another equally important aspect of the sustainability of vegetation is the biodiversity that needs to be preserved. Optimal utilization of natural resources based on their limitations and potential is a pre-requisite for sustained agricultural production.

The process by which soil particles are removed from their original resting places by same external agencies like wind or water is called soil erosion. By this process, the soil loses much of its manorial soil particles, thus becoming useless for productive agriculture in order to keep the land productive, a good conservation program is imperative. Soil and water conservation is the basis of such a program, and also helps improve land impoverished by erosion and overuse – makes it more productive so that it can support more people.

2.8.1.Effective conservation

For effective conservation of soil and water, we must treat and use the various kinds of land according to their capability and need. To do this it is necessary to study the land carefully, so as to be able to fit conservation practices and structures to the various kinds of land. The primary purpose of soil and water conservation is to prevent soil erosion and heal its scars where it has not advanced too far to respond to curative methods. This involves, in many instances, changing the uses to which land is to fit the crop-whether cultivated

crops, trees or grazing plants to the capabilities of the soils and the water available.

2.8.2. Fundamental cause

The fundamental cause of soil erosion is that rain acts upon the soil and the study of erosion can be divided into how it will be affected by different kinds of rain fall events and how it will vary for different conditions of soil .The amount of erosion there fore depends upon the combination of the rain intensity which is Erosivity and the ability of the soil to withstand the rain. In mathematical terms erosion is a function of the Erosivity (of the rain) and the Erodability (of the soil)

2.8.3. Raindrop splash and surface runoff

Soil erosion is a work process in the physical sense that work is the expenditure of energy is used in all the phases of erosion in breaking down soil aggregates, in splashing them in air, in causing turbulence in surface runoff, in carrying away soil particles.

Raindrop impact has other important effects as well as particle detachment. The detached particles lead to sealing of the soil surface and hence to lower infiltration and increased surface run-off. More important the energy causes turbulence in run off, thus greatly increasing its capacity to scour and to transport soil particles.

2.8.4. Causes of soil erosion

The causes for soil erosion are

1) The steep slopes, which accelerate erosion, near the foot of the hills due to rainfall.
2) The way in which land is ploughed and the kind of farming which when not done properly weakens the resistance of the soil, then soil erosion is apt to occur. The faulty methods of cultivation are:

A) Inappropriate land and water management practices

B) Excessive use of fertilizing manures and inappropriate nutrient practices

C) Lack of proper ploughing and land cover with crops.

D) Not adapting the method of rotation of crops and

3) The removal of the cover of grass and forests from the ground to use for cultivation, makes the ground bare and uncovered there by giving rise to soil erosion.

4) Grazing is not controlled in many places.

2.8.5. Factors affecting erosion by water

The major variables affecting soil erosion are climate, soil, vegetation, and topography. Of these the vegetation and to some extent the soil may be managed with ease. The climatic factors and the topographic factors except slope length are difficult to control.

2.8.5.1.Climate

Climatic factors affecting erosion are precipitation, temperature, wind, humidity, and solar radiation. Temperature plays an important role through its effect in the process of weathering which leads to disintegration of rocks. Wind changes raindrop velocities and the angle of impact. Humidity and solar radiation are somewhat less directly involved in that they are associated with temperature.

2.8.5.2.Soil

Physical properties of soil affect the infiltration capacity and the extent to which it can be dispersed and transported. These properties that influence erosion include soil structure, texture, organic content, moisture content and density or compactness, as well as chemical and biological characteristics of the soil.

2.8.5.3.Vegetation

The major effects of vegetation in reducing erosion are:

1) Interception of rainfall by absorbing the energy of the raindrops and thus reducing runoff,

2) Retardation of erosion by decreased surface velocity,

3) Physical restraint of soil movement

4) Improvement of aggregation and porosity of the soil by roots and plant residue,

5) Increased biological activity in the soil

6) Transpiration which decreases soil moisture, resulting in increased storage capacity.

2.8.5.4.Topography

Topography features that influence erosion are degree of slope, length of slope and size and shape of the watershed. On steep slopes high velocities cause serious erosion by scour and sediment transportation. A uniform slope loses more soil than a concave, but less than a convex slope.

2.8.6. Classification of soil erosion.

The erosion from the watershed can be classified as described below.

2.8.6.1.Sheet erosion

Due to heavy rain the crust is uniformly removed like a sheet through out the plain area. The procedure or process is insidious and can not be noticed at all for along time and the fertility of the soil gradually decreases year by year.

2.8.6.2.Rill erosion

In the next stage when sheet erosion is allowed to continue unchecked, the silt laden runoff forms well defined minute finger shaped grooves or rills over the entire field. Rill erosion accounts for majority of erosion from from hillslide.

2.8.6.3.Gully Erosion

In this process, water flows in defined channels and as the eroding power increases, it results in the land being made in the form of trench –like gullies, which become deeper and wider as time passes.

2.8.6.4.Channel Erosion

The channel erosion includes the streambed and stream bank erosion and the flood plain scour. Deposition occurs in channels when the quantity of detected soil coming from the sheet, rill and gully erosion exceeds the transport capacity.

2.9.Sediment yeild

Sediment yield is the " total sediment outflow from a watershed, measurable at a point of reference and a specified period time" (Bennet.,1974) divided the sediment yield process into the upland phase and low land phase. Sediment detachment process predominates in the upland phase, where as in the lowland phase sediment transport and deposition are the main processes.

The study of sediment yield from the watershed is important for various reasons like the deposition of sediment in reservoirs there by reducing its capacity and adversely affecting its function, choking of outlets and damage to structures due to abrasive action of sediment. The eroded sediment from watershed may also be deposited on the riverbeds and banks there by causing the braiding of river reach, submergence of flood plain of river during the floods and reduction of clearance below bridges. On the areas like groundwater it results in lowering of water table at same places and rise at the other giving rise to formation of arid zone and marshes respectively.

The watershed erosion also results in loss of top fertile agricultural soils, resulting in the reduction of agricultural production. Degraded watersheds are also found to give higher flood peaks and changes in groundwater regime.

2.9.1 Modeling sediment load

The estimation of soil erosion potential and its effects on soil productivity are essential for agricultural development and regional environmental planning a number of sediment yield models, both empirical and conceptual, are in use to address wide ranging soil and water management problems. Most conservation planning for erosion control in agricultural lands, construction sites, reclaimed mines and forest management. However use of empirical model to estimate average annual soil loss because of consideration of long time scale, small areas, low cost, short project span and little risk of failure (Singh, 1989). Investigation into such empirical models reveal that most of these models require input parameters in terms of spatial information on land use, vegetation cover, soil, slope, drainage density, besides runoff and rain fall intensity. Acquisition of such spatial information on watershed is time consuming and costly by conventional surveys, whereas satellite data provide convenient tool to derive these information.

The conventional hydrologic models fairly permit defining significant model parameters from remote sensing. The following empirical models can be interfaced with remote sensing data. The following empirical models can be interfaced with remote sensing map-data inputs and are currently in practice.

2.9.1.1.Sediment yield index

The traditional method followed in India for evaluating SYI for prioritization of watersheds is as follows(Dohare et al.,1985).

$$SYI = \frac{A_{ei} \times W_{ei} \times D_r \times 100}{A_w}$$

Where A_{ei} = Area of erosion intensity unit.

W_{ei} = Weightage value assigned to erosion intensity unit.

D_r = Adjusted delivery ratio.

A_w = Area of watershed.

A_{ei} is evaluated basing on detailed land use, solid and drainage maps prepared from satellite images. However, SYI does not provide absolute value of soil loss from watershed nor sediment yield at outlet point, rather it provides relative erodability of the watersheds for taking up conservation management on priority basis.

2.9.1.2.Universal soil loss equation (USLE)

USLE was developed by the Agricultural Research service of the United States Department of Agriculture in 1978 on the basis of nearly 10,000 plot years of runoff plot data (Singh, 1989). The basic equation is

$$A=R.K.L.S.C.P$$

A = Average annual soil loss in tonnes /hectare/yearl

R = Rainfall erosivity factor

K = Soil erodability factor

L = Topographic slope-length factor

S = Topographic slope-steepness factor

C = Land cover and management factor

P = Land conservation practice factor

USLE became very popular and is used extensively as a guide for conservation planning. However, factors in USLE must be properly evaluated under Indian conditions (Singh et al.,1985). Parameter "C" and to lesser extent "P" value can be evaluated based on land use/cover information derived from the

remote sensing data. It may be noted that USLE only estimates average rate of soil erosion and does not take into account delivery ratio or trap efficiency of the watershed system. Therefore, this estimate cannot be taken as sediment yield at the reservoir.

2.9.1.3. Khosla Equation

$Vs = 3.23 \times 10^{-3} A^{0.72}$

Where

Vs = Annual sediment yield (Mm^2)

A = watershed area(Sq.km)

2.9.1.4. Dhruva Narayana Equation

$T1 = 5.5 + 11.1\ Q$

$T2 = 5.3 + 12.7\ Q$

Where Q= T1/A

T1,T2---Annual sedimentation (m^3/yr)

Q = Annual runoff (MHam)

A = Watershed area(Mha)

2.9.1.5.Statistical regresssion model

Statistical regression model developed by Garde is

$Vs = 1.182 \times 10^{-6} \times A^{1.03} \times P^{1.29} \times Q^{0.29} \times S^{0.08} \times Dd^{0.4} \times Fc^{2.42}$ ---------- Eqn(1)

$Vs = 1.067 \times 10^{-6} \times A^{1.29} \times P^{1.38} \times S^{0.13} \times Dd^{0.4} \times Fc^{2.51}$ ---------- Eqn(2)

where Vs = Sediment Yeild,Mm^3/Km/yr

P = Annual precipitation(cm)

Q = Annual rainoff

A = Watershed area,sq.km

S = Slope of the watershed

Dd = Drainage density,km/sq.km

Fc = Vegetative cover factor

In the present project work the statistical regression model given by Garde etal eqn(1) is used for computing the sediment yield of watershed. The strength of this model is that it takes into account dominant watershed characteristics like contributing watershed area, slope, drainage density and vegetative cover factor besides hydrodynamic parameter as precipitation and runoff. These parameters can be easily derived based on remote sensing mapping inputs and topographic units.

2.10.Conservation Planning For Sedimentation In Watershed

The key sectors for conservation planning of sediment is to handle the sediment where it originates and where it creates the problem. There are several approaches based on land deposition, degree of erosion and funds availability.

Agronomic practices coupled with engineering measures answers best many situations requiring control of soil erosion

2.10.1. Agronomic Practices

These include various methods of crop cultivation to ensure protection of the top soil. The various measures include contour farming, mulching, dense growing crops, strip cropping, mixed cropping, organic matter addition and appropriate nutrient management practices.

2.10.2.Contour technique

Ploughing, furrowing, trenching, bunding and vegetative hedging along contours are the important soil conservation measures. They control runoff and

erosion, improve subsurface drainage for favorable aeration status and workability of soil in rock zone, and conserve soil moisture. Contour methods together could conserve more than 60% of the soil erosion and insitu soil moisture. Greenfeild (1987) recommends the interval between the contour activity in relation to slope as 100m for 2% slope, 60m for 5% and 7m for 57% for a vertical interval of 2,3 and 4m respectively.

2.10.3.Ploughing

Ploughing along the slope increases runoff, loses 50-80 per cent of rainfall, decreases soil moisture, and finally erodes soil .The simple measure is to plough along the contour which controls the soil erosion upto 50% at no additional cost. Ploughing deeper for every 2-10 years is another measure of conservation. Depth of tillage is another aspect of importance as it has a subtle influence on the crop yields. It varies with crop, soil and climate. There is much evidence that proper tillage operation are crucial for cropping.

2.10.4.Furrowing

Ploughing leaves minor furrows on the ground and they harvest rainwater flows. A broad bed and furrow (BBF) system, involving graded, wide beds separated by furrows draining into grassed waterways, is experimented by ICRISAT with good results in the Sangameswara, Kothapalli Watersheds(Wani et al.,2002). The BBF system is laid out on grades 0.4-0.85 for optimum performance (Kampen, 1982). The raised portion acts as bund ensuring soil stability while the shallow furrow provides drainage and aeration. The system is flexible with variable spacing for accommodating different crops Continuous furrowing along the contours and ridge development across the furrows is another practice adopted in low rainfall regions for cent per cent harvesting

2.10.5.Trenching

Narrow excavation along the contour is another conservation technique. The economical dimensions are 0.3 m width and o.6m depth in lands with low slopes or good rains. The dimensions can be interchanged in gently sloping fields or where low intensity rains are common. Wherever the degree of erosion is very high due to soft soil, intensive rains, or high runoff and velocity, higher dimensions of the trenching are to be adopted. The soil excavated is to be put as a bund on the downslope side. Trenching proves to be a good conservation technique, especially when plants are grown along the trench for utilizing the high moisture available along the trench.

2.10.6.Bunding

This method consists of making a comparatively narrow based embankment at intervals across the slope of the land on a level that is along the contour. It is an important measure that conserves soil and water in arid and semi-arid areas with high infiltration and permeability, and can be commonly adopted on agricultural land up to a slope of about 6%.

2.10.7.Gradoni

Narrow trenches built along contours for collecting overland flow and increasing soil moisture are known as gradoni. They are either continuous, intermittent or built for individual plants. for dissected slopes with undulating terrain short or individual gradoni are prepared(FAO.,1988) for uniform slopes,continuous gradoni , synonymous to the minor trenching practice can be carried.

2.10.8.Hedging

This method not only solves conservation problems but also produces biomass and stabilizes the ground further by root system. Hedging gives excellent results in catching rainwater and improving soil moisture. Hedging is practiced from gently to moderately sloping lands for increasing crop yields. Hedges are grown either in furrows ,trenches or on bunds. they are grown

across streams for conserving flood load. when practiced in combination with other methods, they conserve almost all the rainwater in drought prone area.

2.10.9.Terracing

Special methodology is required on steep slope of the hills ,where the space between contours of the activity reduces, and velocity of runoff increases with high erosive capacity. the technology for correcting the destructive action is known as terracing. Terracing requires good care in developing as system for avoiding breaching during heavy rains. the effectiveness of the systems depends also on green cover management.

2.10.10.Gully control

Gullies erode headwords of the stream by furrowing into the topsoil, as well as downwards through deepening and widening of the stream course. Gullies are controlled by check dams and vegetative stabilization. The selection type of gully plugging and cover management depends upon hydraulics, sedimentation, soils and vegetation requirement by the people. The check dams check the velocity of water, effect the deposition of flood load, decrease the erosive force of the water, increase the contact time of water with land surface, and thus increase the recharge of rainwater into the ground. The check dams may be classified as pervious and impervious depending on the design of the structure to allow water to pass or pond. The various types of check dams are brushwood, Rock fill, Gabion, Concrete gravity, concrete arch etc. Check dams are constructed with local materials like earth, rock or timber. They are suitable when the watershed is between 40 to 400 hactares.

2.10.11.Bank protection

The earth banks which are steeply sloping are liable to land slides and the key to the control of this form of erosion lies with drainage. the surface erosion of the bank is best controlled by vegetation.

2.10.12.Rainfall Erosion control with geotextiles

On steep ground with little or no covering or vegetation rainfall erosion can be major problem. The geotextile based methods of rainfall erosion can generally be divided into two categories.

1) Surface cover geotextiles
2) Surface reinforcement geotextile

2.10.12.1. Surface cover Geotextiles

These provide a temporary cover over the soil surface which dissipates, the rain drop impact energy in a similar manner to foliage.

Erosion control geotextiles currently available in different forms are:

(i) paper strips held together by a knitted polymer yarn

(ii) Wood wool sandwiched between two layers of polymer knot

Both types of geotextiles are biodegradable. they are placed over the ground surface after seeding and should ideally decompose sufficiently for the for the seedlings to push through shortly after germination .

2.10.12.2.Surface Reinforcement Geotextile

This group of erosion control geotextile in a similar manner to plant roots by reinforcing the soil surface and holding the soil particles together. The four main subdivisions of surface reinforcement geotextiles are:

(i) Thick three dimensional mats

(ii) Cellular geotextiles

(iii) Geotextiles woven from thick, widely spaced yarns

(iv) High profile geotextile nets

Unlike surface cover geotextiles,geotextile mats are seeded after the geotextiles has been laid. On large ,of steep areas, it may prove more efficient to use hydraulic seeding techniques to fill the mat with a mixture of seed, compost and top soil. Cellular geotextile is formed from a mechanically bonded non-

woven product which has been partially impregnated with resin in order to give it slight rigidity, but these are not suitable on slopes steeper than 45^0 to the horizontal. Geotextiles woven from thickly widely spaced yarns are made from thick open woven jute and it helps to protect slopes from erosion in a number of different ways. Jute can absorb almost five times its own weight of water, limiting the surface runoff and maintaining a suitable moist environment for seed germination. Jute which is about 80% natural cellulose is biodegradable and rots in about two years and is flexible enough to follow surface contours and its weight will not permit it to be lifted by wind ,flowing water or growing grass.

2.10.13.Reclamation of Eroded areas

Reclamation measures are justified on the land that has stripped into poor state through mis-use or neglect. Reclamation can be done by Rejuvenation and Restoration.

2.10.13.1.Rejuvenation

The symptoms of the land requiring rejuvenation are easily recognized by sparse vegetation ,high runoff, low filtration, high rates of soil erosion. The corrective technique is to try to identify the limiting factor and improve it.

2.10.13.2.Restoration

When the situation is so bad that major remedial measures are required, an attack on the water balance is frequently made by ripping or sub soiling in an attempt to improve the infiltration. This can be very effective if it is directed towards a particular problem such as breaking up a plough pan or a naturally occurring obstacle to percolation like a layer of laterite. But ripping is an expensive way of achieving what might be done equally well by a cheap surface scarifying operation with a disc harrow or spike-tooth harrow.

Watershed management has its social and economical aspects. Soil conservation measures interfere with traditions and can only be successful if accepted by the local population. If watershed is not large, the effects of soil

conservation methods may be felt in a very short time. In this present study appropriate soil conservation measures are suggested after examining the watershed.

3.Materials Methodology

3.1 Introduction

A detailed database on natural resources, terrain conditions is a pre-requisite to prepare action plan keeping in view the underlying concept of sustainability.

Survey of India (SOI) Toposheet is a representation of the shape, size, position and relation of the physical features of an area, in addition to regional boundaries. The synoptic coverage of satellite imagery permits fairly easy identification and mapping of natural resources like stream network, land use/ land cover, soil characteristics, land irrigability, land capability, hydro geomorphological characteristics and groundwater prospects of the study area in coordination with GIS. IRS-1D PAN (Image NO:3.1) and LISS-III(Image NO:3.2) images acquired from National Remote Sensing Agency (NRSA)were used for the purpose of accurate visual interpretation image to image georeferencing is performed in NRSA.This PAN and LISS-III merged image (Image No: 3.3) is used for the present delineation of resource themes.These maps and information georeferenced with conventionally measured topographic maps through GIS for meaningful synthesis of resource maps of the study area. To reduce the confusion prevailing because of the mingling of all these features for fulfilling the basic objectives of present study.

3.2 Preparation of Thematic Layers

In this chapter the methods of preparation of thematic maps using visual interpretation of satellite imagery and toposheet are discussed as following

Topographic sheets (Scale 1:*50,000*) of NOs 56 L/1 and 56 L/2 are used for the preparation of

1.Base map

2.Drainage and watershed boundary map

3.Slope map

4.Contour map

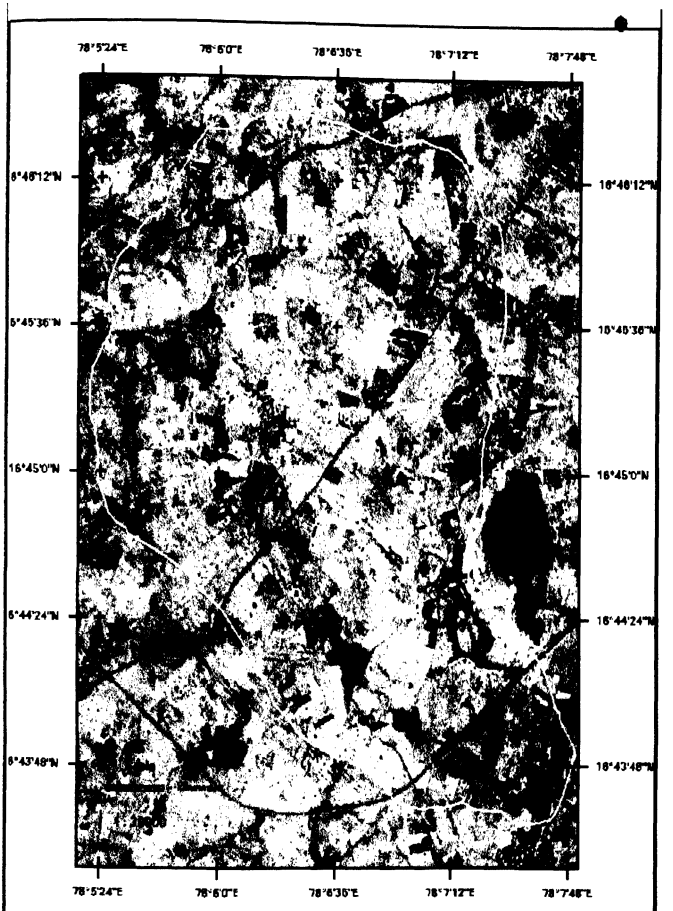


Image 3.1 IRS-1D PAN image of the study area (13-02-2003)

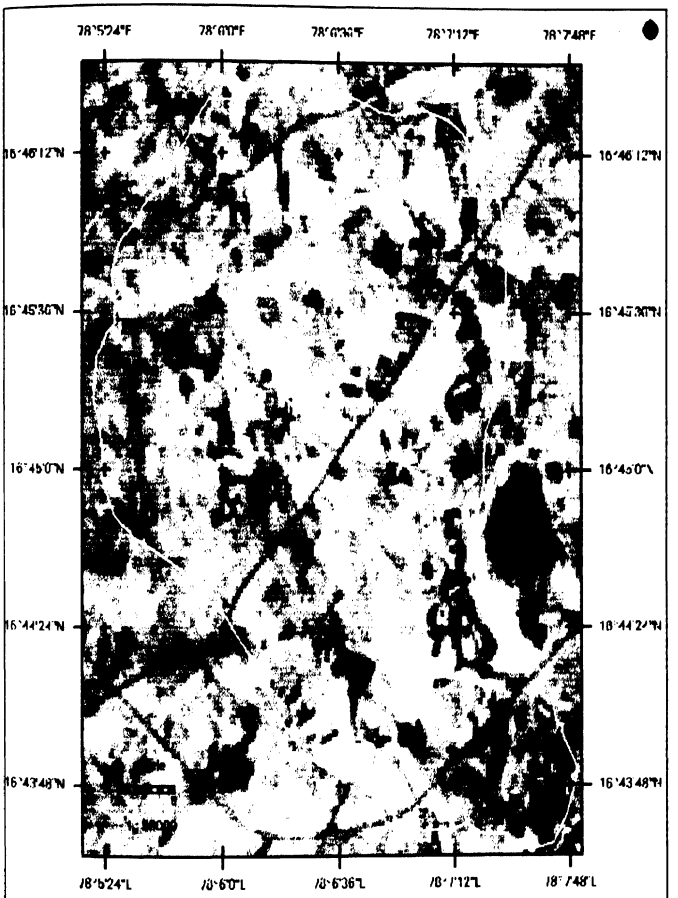


Image 3.2 IRS-1D LISS-III image of the study area (13-02-2003)

Remotely sensed IRS-1D PAN and LISS-III merged data in the form of FCC was used for the preparation of thematic maps as listed below

1.Landuse/landcover

2.Geology

3.Hydrogeomorphology

4.Groundwater Prospects

5.Soil map

6.Land irrigability map

7.Land capability map

3.2.1 Base map preparation

For the preparation of thematic layers, it is necessary to prepare base map to know what are the features in the study area and to get accurate control points. Basemap prepared from toposheet is used for overlaying the satellite imagery over it in order to prepare land use/land cover, drainage map, slope map, hydrogeomorphological map, soil map etc.

To get accurate ground control points certain features like road networks, water bodies, canals, settlements, etc, on the toposheet are used for exact matching with those on the satellite imagery.

This Malleboinapalli watershed falls under Grid no:B3 of 56L/1 and Grid no:B1 of 56L/2.

Base map is shown in the plate No:4.1.1

3.2.2.Drainage and watershed boundary map

Drainage network helps in delineation of watersheds and for suggesting various water harvesting structures and soil conservation measures. Drainage pattern is defined as the plan, which the individual stream courses collectively form. It refers to both spatial relations of individual streams and the overall pattern made by the individual drainage lines. The importance of drainage in soil erosion is naturally well conceived as it drains the watershed not only the water but also the precious soil along with it in the present study.

Data used

SOI toposheet. 56L/1NE and 56L/2SW Map scale: 1:25,000

Methodology:

A tracing film with minimum base details is overlaid on the toposheet .The major streams and streamlets drawn out carefully.The overlay with these details is placed on the post monsoon image and the extent of surface water spread in the tanks, reservoirs and ponds is to be indicated. The extent of water spread during rabi and kharif season demarcated using the respective season satellite image. Watershed boundary is delineated following the drainage devide along the stream course. This map is digitized by using AutoCAD 2000 and edited using ARC/GIS 8.1.2 as shown in plate No:4.1.2.

3.2.3. Contour map

Data source :SOI toposheet 56 L/1, 56L/2 Map Scale 1: 50,000

Methodology

By placing the tracing film with minimum base details is overlaid the toposheet drawn out the major contours which are of 520m, 540m, 560m, 580m, having 20m altitude with each other. Alongwith these spot heights are also noted at the lower reach and upper reach points of the drainage basin.This map is most helpful in the hypsometry analysis.

Contour map is shown in the plate No:4.1.3

3.2.4. Slope map

Slope is very vital one for making land irrigability, land capability assessment and in the estimation of sedimentation yield. Slope map gives an idea of steepness of the land and reflects the quantity of erosion. Flat terrains promote more infiltration and less runoff yielding little sediment while steep terrains generate more runoff that could erode the soil.

Data used

SOI Toposheet Nos : (56L/1 and 56L/2) Map scale 1: 50,000

Methodology

Contours are traced which are having the 20m intervals from topographic sheet in the study area. Vertical drop is estimated from the contour intervals and the horizontal distance in between the contours measured from maps by multiplying the map distance with the scale factor. Closely spaced contours on the map have higher percentage slope as compared to sparse contours in the same space. Thus density of contours on the map is used for preparing the slope map that gives various groups / categories of slopes.

The slope at any point in the watershed computed by measuring the least distance through the point between the two successive contours instantaneously. The slope at any point in the watershed is computed by the following formula,

$$S\ \% = \frac{CI}{D} \times 100$$

Where

S is the slope

CI is the Contour interval

D is the least distance between the successive contours

With the above formula slope map is constructed.

The underlying principle of the slope map is that closely spaced ground contours on the toposheet are indicative of higher percentage slope than fewer contours in the same space. Thus, density of ground contours serves as the tool for preparing the map.

Slope categorization

The classification of ground slope used in the present study is based on the guidelines given by Department of Space, Government of India (NRSA, 1991) that are essentially an adoption of the U.S slope classification (Soil Survey Manual 1962). Categerization is given in the following table.

Table 3.1 **Slope Categories**

S.NO	Slope category	Limits of slope	Limits of contour spacing in map
1	Nearly level sloping	0-1%	>4cm
2	Very gentle sloping	1-3%	1.33-4cm
3	Gentle slope	3-5%	0.8-1.33cm
4	Moderate sloping	5-10%	0.4-0.8 cm
5	Strong sloping	10-15%	0.26-0.4 cm
6	Steep sloping	15-35%	0.11-0.26cm
7	Very steep sloping	>35%	<0.11cm

The slope map is prepared using the principle explained above and this map is digitized, edited and labelled as shown in plate No 4.1.4

3.2.5.Landuse /Landcover Map

The spatial information on land use/land cover and their pattern of change is essential for planning, utilization and management of the country's land resources. Today with the growing population pressure, low man -land ratio and increasing land degradation, the need for optimum utilization of land assumes much greater relevance. Land use/Land cover inventories are extremely important in the various resource sectors like agricultural planning, settlement and cadastral surveys, environmental studies and operational planning. Information on land use/land cover permits a better understanding of the land utilization aspects on cropping pattern, fallow land, forest and grazing land, waste land, surface waterbodies etc, which is very vital for developmental planning. The definition and description of key elements of each one of land use/land cover units are discussed below.

Land use refers to "human activities and the various uses which are

carried on land". Land cover refers to "natural vegetation, water bodies, rock/soil, artificial cover and others resulting due to land transformation". The imagery is interpreted and ground checked by following the General Land use /land cover classification system Level -II (Table No: 3.2) devised by National Remote sensing Agency(NRSA), Government of India with respect to the Indian conditions.(Anji Reddy.M., Text book of Remotesensing and Geographic Information systems)

Table no 3.2 **Land use /land cover classification system**

1. Built up land	1.1 Built up land
2. Agricultural land	2.1 Crop land
	(i) Kharif
	(ii) Rabi
	(iii) Kharif-Rabi
	2.2 Fallow
	2.3 Plantation
3.Forest	3.1Evergreen/semi-ever green forest
	3.2 Deciduous forest
	3.3 Degraded or scrub land
	3.4 Forest blank
	3.5 Forest plantation
	3.6 Mangroove
4.Waste land	4.1 Salt affected land
	4.2 Waterlogged land
	4.3 Marshy/Swampy land
	4.4 Gullied/Ravinous land
	4.5 Land with or without scrub
	4.6 Sandy area
	4.7 Barren rocky/stony waste/ sheet rock area
5.Water bodies	5.1 River/Stream
	5.2 Lake/Reservoir/Tank Canal
6.Others	6.1 Shifting cultivation
	6.2 Grass land
	6.3 Snow covered/Glacial area

The image characteristics of each of the land use/ land cover map of the study area shown in plate No: 4.1.5

3.2.6.Geology map

Source: Geological survey of India(GSI)

The study area comprises lithological structures of Granites, basic intrusives and intermediate lineaments. Granites are peninsular gneissic complex in origin. Granites occurring as linear ridges, hills, inselbergs and sheet like exposure. Granites display distinct intrusive relationship with the metamorphosis.

The geologic structures of the given area are shown in the plate No: 4.1.6

3.2.7.Hydro Geomorphology Map

Information on landforms is an important input for land management, soil mapping and identification of potential zones of groundwater occurrence which are the result of manifold effects of geological and climatalogical changes. The aspects of morphography, morphogenesis, morphochronology and morphometry are vital inputs in preparation of geomorphological maps. Each geomorphologic process develops its own particular assemblage of landforms.

Geomorphologic processes are of two types, namely the exogenetic and endogenetic types. Examples of exogenetic or external processes. Different landforms are identified with the aid of visual interpretation of satellite imagery and the hydrogeomorphological map is prepared . This map makes use of runoff that can be utilized in the areas where groundwater prospects are low by construction of percolation tanks and other groundwater harvesting structures to increase the water table.

Charecteristics of Hydrogeomorphological mapping units are shown in the Table No:3:3. Hydrogeomorphologic mapping units are shown in the Plate No:4.1.7

symbol	Geomorphic unit	Structure	Litho logy	Aspect	prospects
PPS	Pedaling with shallow weathering	May be crisscrossed by lineaments/fractures etc	With shallow overburden of weathered material of varying lithology	Dharwarin schists with highly foliated gently undulating plain with 0.5m weathered thickness	Fracture/faults concentrated zone forms good prospects Generally favourable for shallow aquifers-moderate ground water source.
PPM	Pediplain with moderate weathering	May be crisscrossed by lineaments/fractures	With shallow overburden of weathered material of varying lithology	Dharwarin schists with highly foliated gently undulating plain with 5-20m weathered thickness	Suitable for shallow aquifers in weathered normally having good to moderate ground water prospect. zone.Fracture/fault/ llineaments concentrated zone possess good prospects.
Pediplain	Pediplain	Sometimes controlled by joints, fracture, lineaments etc	Varying lithology	Coalescence of pediment marked by a large area	Moderate to poor varies with under lying lithology and structure
Inselbergs	Inselbergs		Varying lithology	Residual isolated hill stands above the ground level of sorroundinng pediplain ;normally barren and rocky	Poor
Lineaments	Faults/fractures of varying length and breadth				A good source for ground water

Table No: 3.3 **Characteristic features of Hydrogeomorphic units**

3.2.8.GroundWater Potential Map

Source :Hydrogeomorphology map,Lithology map

Methodology

For the identification of groundwater potential zones of the study area , the different thematic maps such as geology, geological structures and land forms have been are integrated using visual interpretation of standard FCC images.The additional details extracted from information collected during limited ground checks are been incorporated into the map. By integrating all the thematic maps, the hydrogeomorphic map showing the spatial distribution of the different landforms developed over different rock types and the associated structures has been prepared. Finally the groundwater condition of the drainage basin is assessed as follows.

Basing on the hydrogeomorphology map groundwater prospect classes identified are

1. Good
2. Modearate.
3. Moderate to poor
4. Poor

Delineated groundwater potential units are shown in the Plate No;4.1.8

3.2.9. Soil Map

Source: NRSA

A good understanding of soils with reference to their nature and distribution is essential to formulate any land based production system. Soil is a diminishing resource whose loss or degradation is slow and not readily noticed. Among agricultural soils, suitability varies for different species. Soils are also known for their unique behavior under irrigated and non-irrigated conditions. Therefore, soil surveys are undertaken to plan optimum management systems that would help in maintaining their health and preservation.

Methodology

Overlays with base map details are superimposed on satellite imagery. With the help of toposheet information, geology, and geomorphology and by using the elements of image interpretation physiographic units are delineated. Understanding the spectral signatures of soils is the key need to map soils. Stratification based on variations in geology, landform parent material, elevation, slope, natural vegetation etc. helps in including maximum possible soil scapes. Sample strips are selected based on the variability of the landform, geology and certain individual land combinations of image interpretation elements then for the ground truth collection. In the next step classification of soils and soil units are demarcated by drawing boundaries with the aid of checking and by use of key developed. Mapping units are partly checked and partly extrapolated by reference. Soil classes are randomly verified in the field for map validation. Soil composition of each geomorphic unit defined by studying soil profile in the field and classifying them upto series -one of the taxonomic units in the hierarchical system of soil classification ,level according to soil taxonomy based on morphological characteristics and chemical analyses data (U.S department of agriculture,1975,1998)

When a high degree of accuracy is achieved legend is finalized. From the satisfaction of legend and unit boundaries final drawing, digitization and final map prepared by using is prepared as shown in plate No:4.1.9

3.2.10.Land Capability Map

Land capability maps are generated based on information on soils and terrain conditions according to criteria given by All India Soil and Land use Survey Organization (All India Soil and Land Use Survey ,1970). Land capability classification is an interpretative grouping of soils mainly based on i)Inherent soil characteristics ii) External land features iii) Environmental factors. The grouping enable one to get a picture (i) of the hazards of the soils to various factors which cause soil damage, deterioration or lowering in fertility and (ii) its potentiality for production. according to those properties that determine the

ability of the land to reproduce on a virtual permanent basis.

Land capability classification serves the following objectives

(i) It indicates the hazards of soil and water erosion and difficulties to be encountered in land use accordingly

(ii) It involves most intensive, profitable and safe use on the application to land use pattern .

(iii) It simplistically provides technical data and indicators for application to land use planning.

(iv) It enables the cultivators to make the use of techniques and inputs available for agriculture as scientific and technical information is available for each class of land.

Land is arranged in various capability classes after considering a number of soil characteristics, associated land capability classes which are soil texture, effective soil depth, permeability, internal drainage, soil salinity, alkalinity and toxicity, coarse soil fragments, slope of land, effect of past erosion, natural soil drainage,frequency of over flow etc.There are two broad groups, namely:

(i) Lands suitable for cultivation.(Class I to IV lands)

(ii) Lands not suitable for cultivation,but suitable for forestry, grassland and wildlife (class V to VII).

In the study area II(1), III(2), IV(3), VI(4), VII(5) classes of land capability are identified. Their land capability rating is shown in the Table 3.4

Land capability map is shown in the plate No:4.1.10

3.2.11.Land Irrigability Map

Land irrigability maps are generated based on information on soils and terrain conditions according to criteria given by All India Soil and Land use Survey Organization (All India Soil and Land Use Survey,1970). The interpretation of soil and land conditions for irrigation is concerned primarily with predicting the behavior of soils under the greatly altered water regime brought about by the introduction of irrigation .For arriving at land irrigability classes, soil characteristics namely effective soil depth, texture of the surface soil, permeability, water holding capacity, course fragments, salinity and

Table No: 3.4:**Land capability rating**

Feature	Class II	Class III	Class IV	Class VI	Class VII
1.Degree of limitations	Moderate	Severe	Very severe	Moderate	Very Severe
2.Soil charecteristics					
(a) Texture	Loams	Clay and loams sands	Clay and sand	No limitations of soil characteristics except that the soils are rocky	These soils only should be conserved for wildlife watershed protection conservation forestry
(b) Soil depth	Deep 45-90	Moderate 22.5-45	Shallow 7.5-22.5	Very shallow	Rocky very shallow
(c)Permeabiality	Moderate slow moderate rapid	Slow rapid	Very slow very rapid		
Associated features					
(a) Slope	Gentle	Moderate	Strong	Steep	Precipitious
(b) Effect of past erosion	Slight sheet erosion	Moderate rill erosion	Severe small gullies	Very severe gullies and sand dunes	
(c) Drainage	Wetness which can be corrected by drainage	Excessive continues after drainage	Excessive wetness	Excessive wetness	Wetness
(d) Damaging runoff	Occassional	Frequent with some damage	Frequent with damage	Excessive runoff	Excessive runoff
3.Climatic limitation on soil use and management	Slight limitations for field crops	Moderate limitations for field crops	Moderately adverse for field crops	Adverse for field crops	Adverse field crops require protection conservation

alkalinity, presence of hard plan in the surface, topography and surface and subsurface drainage are considered`

Land irrigability map is shown in the plate No:4.1.11

3.2.12.Transportation Network, Settlements Location And Village Boundaries map

Communication network plays an important role in the development of a region. Accessibility by roads and rail is essential not only for economic development o f an economic development and social and educational status. Accessibility is an indicator of the level of development and development depends on the quality of transport network. Village boundary helps in identifying the resource potential/ limitation in respect of each village and also the alternate development of action plan recommended for the same.

Mainly two classes of transport network namely roads and railways are demarcated. Further, the roads are classified as metalled and unmetalled road. Metalled roads have black top. Unmetalled roads are normally cart track and footpath.

Data used

SOI toposheet of 1:*50,000* are the main input for mapping transport network. However efforts to update this available information with available details from concerned state departments were made. The digitally enhanced satellite images are also used to extract more information on the newly developed transport network. The settlement boundaries are taken from the revenue maps.

Methodology

The transparent tracing film is placed over the toposheet with the help of light table all the categories of roads are drawn; further settlement locations and block boundaries are drawn from toposheet. Symbols are demarcated. All the railway lines drawn as one category. Block boundaries have to be drawn from toposheet. Symbols and legend represented in the final map. Village boundaries are collected from revenue department and incorporated on this.This transportation map is shown in the Plate No:4.1.12

4. Results Discussions

4.1 Results of Thematic Mapping

4.2 Drainage Morphometry

4.3 Hypsometric Analysis

4.4 Sediment yield computation

4.5 Integration and Generation of Action plan

4.1 Results matic Mapping

All the resource themes generated by the thematic mapping are discussed in this chapter as follows

4.1.1.Base map

Identified ground control points for base map are

1.Settlements: Malleboinapalli, Nakkalavani thanda, Esaikunta thanda,

2.Road network:I.Metalled Roads

A.Hyderabad-Mahaboobnagar

B.Hyderabad -Kurnool

3.Railway track: Broad guage of Secunderabad to Mahaboobnagar.

This base map of the study area as shown in the plate No:4.1.1

4.1.2.Drainage network and watershed boundary map

Drainage network with the water bodies and streams are identified as follows.

The left streamlet of the drainage have the name 'pedda vagu' and right streamlet of drainage with the name 'komanu vagu' are identified and seven waterbodies are identified as follows

1.Naganna kunta
2.Singayya kunta
3.Nallakunta
4.Rekulakunta
5.Komanu kunta
6.Papanna kunta
7.Ura kunta.

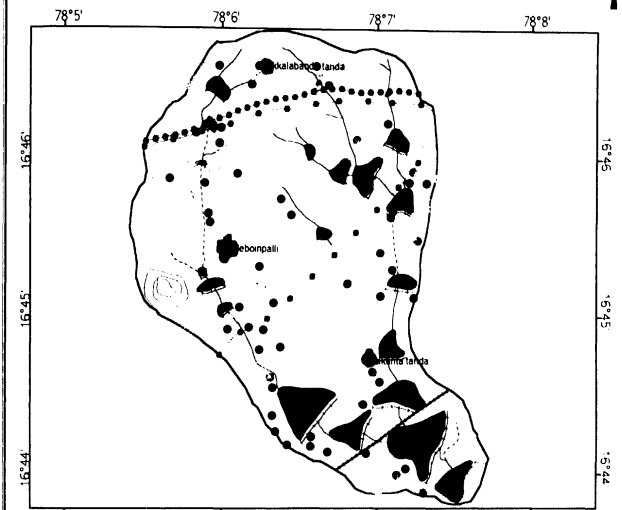
Drainage network and watershed boubndary map is shown in the plate N0:4.1.2

4.1.3.Contour map

In contour map contours with the altitude of 520m, 540m, 560,and 580m are identified.and the the spot heights of of lower reach point(532.9) and upper reach point(589.4) are identified.

Contour map is shown in the plate No:4.1.3

Base map of Malleboinpalli watershed



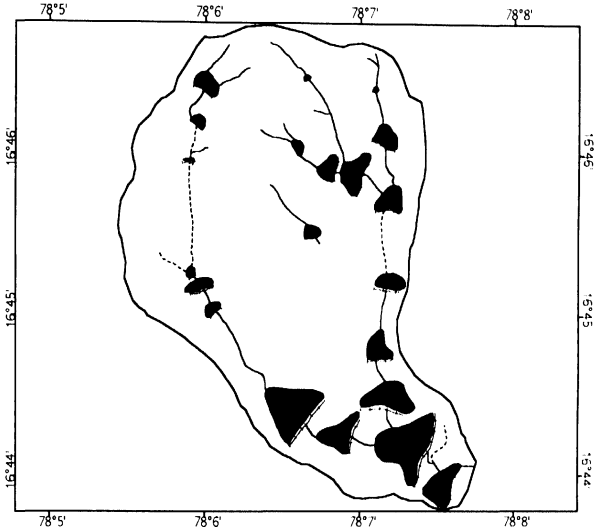
LEGEND

- Settlements
- Open scrub
- Water body
- Bore wells
- Open wells
- Trees
- Boundary
- Railway track
- Metal road
- Unmetal road
- Streams
- Undefined streams
- Bunds
- Telephone line
- Power line

Database : Survey of India Toposheet 56L/1, 56L/2

Plate No: 4.1.1

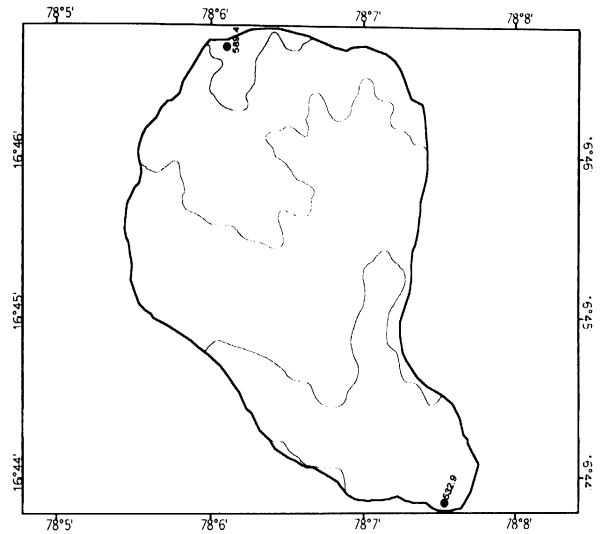
Drainage network map and Watershed boundary map of Malleboinpalli watershed



Database : SOI Topo sheet No 56L/1 NE & 56L/2 SW (1:25,000)

Plate No: 4.1.4

Contour map of Malleboinpalli watershed



1 0 1 2 Kilometers

1:50,000

LEGEND

103 m

540 m

560 m

580 m

Database : Survey of India Toposheet 56L/1 & 56L/2

Plate No: 4.1.2

4.1.4 Slope map

Sloping units identified from the study are as following

1.Nearly level sloping

2.Very gentle sloping

3.Gentle sloping

4.moderately sloping

5.Strongly sloping

6.Moderately steep to steep sloping

Slope map is shown in the plate No: 4.1.4

4.1.5.Land use/ land cover map

Identified land use /land cover units are

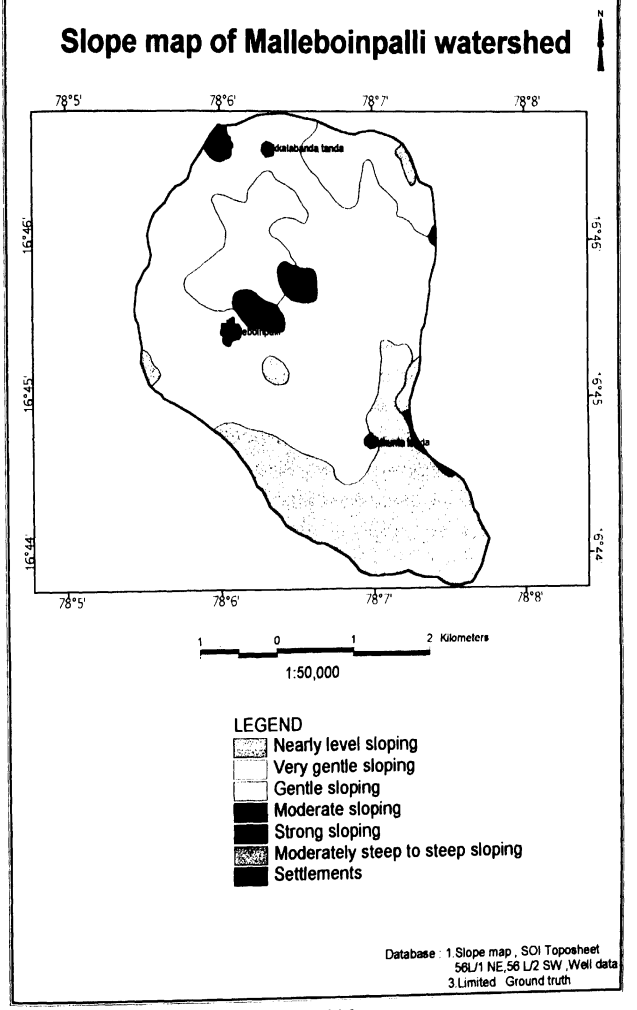
1.Built-upland

It is defined as an area of human habitation developed due to nonagricultural use and that which has cover of buildings, transport, communication, utilities in association with water, vegetation and vacant lands. This feature is identified on the imagery by its dark bluish green to bluish tone, definite size and shape and texture.

2.Cropland

It includes those lands with standing crops as on the date of the satellite imagery. The crops are of kharif, rabi or kharif+rabi seasons.In this category crop land is shown in the form of double crop and kharif unirrigated areas The tonal contrast of crop land varies from bright red to red which may signify greenness of the foliage, different stages of the crop growth, phenological condition besides the nature of soil, type of terrain etc.

Slope map of Malleboinpalli watershed



Database : 1.Slope map , SOI Toposheet 56L/1 NE,56 L/2 SW ,Well data 3.Limited Ground truth

Plate No: 4.1.3

3.Fallow land

It is described as agricultural land, which is taken up for cultivation but is temporarily allowed to rest, uncropped either in kharif or rabi season. It appears light in tone in sandy red soils and in coastal soils, and in dark tone in alluvial black cotton soils. Regular openings amidst cropland also suggest occurrence of fallow lands, the texture is medium to course due to surface irregularities and absence of vegetative core.

4.Wasteland

It is described as degraded land which can be brought under vegetative cover with reasonable effort, and which is currently under-utilized and land which is deteriorating due to lack of appropriate water and soil management or an account of natural causes. Wastelands can result from inherent /imposed constraints such as by location, environment, chemical and physical properties of the soil or financial or management constraints. The wastelands are classified as salt affected land, waterlogged land, Marshy/swampy land, and Gullied/Ravinous land, land with or without scrub, sandy areas (coastal and deserted) and barren rocky/stony waste/ sheet rock area.

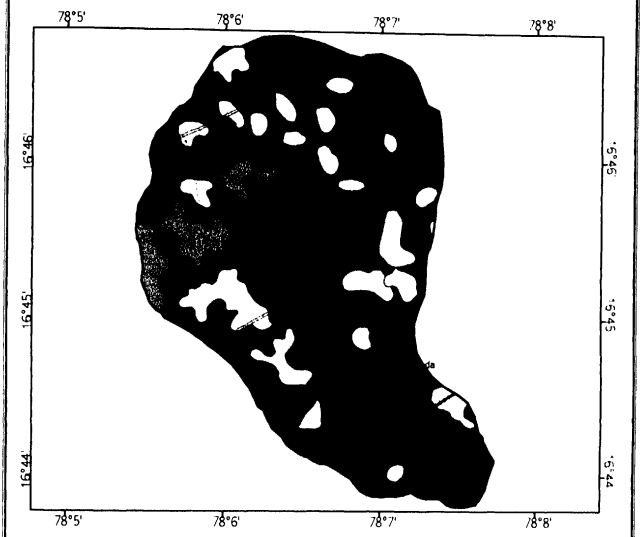
4.1.Land with or without scrub

They occupy higher topography like uplands or high grounds with or without scrub. These lands are generally prone to degradation or erosion. These exclude hilly and mountainous terrain. This category appears in light yellow to brown to greenish blue tone. Wherever the occurrence of scrub on the land is more, reddish tint appears in dots and patches.

4.2.Barren rocky/Stony waste/ Sheet rock area

It is defined as the rock exposures of varying lithology often barren and devoid of soil cover and vegetation. They occur amidst hill forests as openings or scattered as isolated exposures or loose fragments of boulders or as sheet rocks on plateau and plains. This appears in greenish blue to yellow to brownish tone

Land use /Land cover map of Malleboinpalli watershed



LEGEND

- Built-up land
- Kharif Unirrigated
- Double Crop
- Fallow
- Land with Scrub
- Land without Scrub
- Barren Rock/Stony/Sheet rock area
- Water-body
- Boundary
- Railway track
- Metal road
- Unmetal road

Database : 1. Satellite : IRS ID PAN and LISS III Merged FCC
2. Maps : SOI Topo sheet No 56L/1 & 56L/2
3. Others : Limited ground truth

Plate No: 4.1.5

(subject to varying rock types) vary in size with irregular and discontinuous shapes, very coarse to medium texture, linear to continuous and dispersed in pattern.

5.Water bodies

It is an area of impounded water, area extent and often with a regulated flowing water. It includes man-made reservoirs /lakes/tanks/canals, besides natural lakes, rivers, streams and creeks. These waterbodies appear in light blue to dark blue tone. They are small/ medium to large with regular to irregular shapes, smooth to mottled in texture, non contiguous and dispersed in pattern, except canals which show linear pattern.

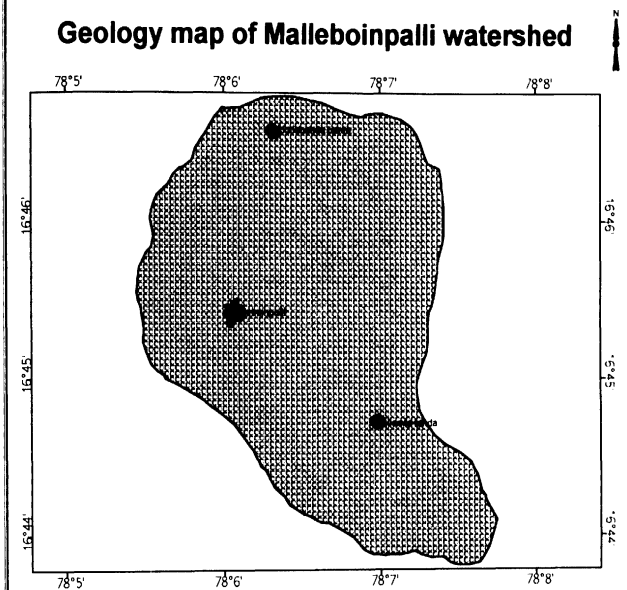
Land use/ land cover map is shown in the plate No:4.1.5

4.1.6.Geology map

In geology map reveals that only granites are present in the study area. These Granites comprise several textural and compositional variants such as granadiorite,hornblende granite and medium grained biotite granite, alkali feldspar granite and medium grained grey granite. However, the medium to coarse grained biotite granite and very coarse grained porphyric granite are widely distributed.The contact relationship between the various types of granites is transitional.These granites are either foliated or non-foliated and compositionally to tonalities, granodiorite and admelite suit. All these structures are hard and massive in nature. Granites have been used as building material since time immemorial in the construction of temples, pillars, tombstone and as road metal. The fine grained granites and porphyric granites are quarried for polishing slabs.

Geology map is shown in the plate No:4.1.6

Geology map of Malleboinpalli watershed



1 0 1 2 Kilometers

1:50,000

LEGEND

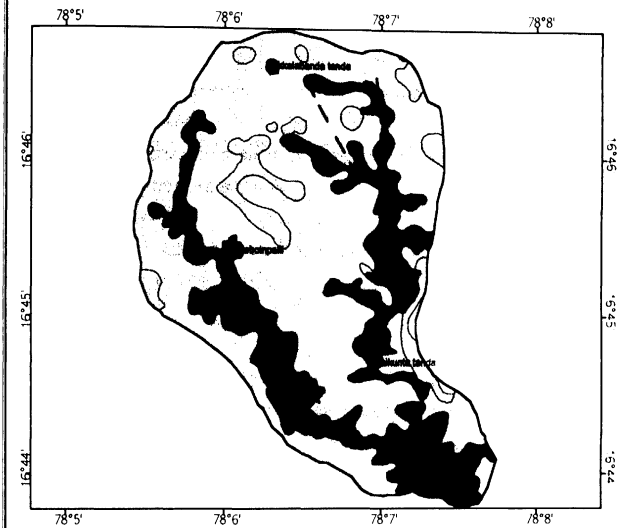
Granites(S.L)

Settlements

Database source Geological survey of India

Plate No: 4.1.6

Hydrogeomorphological map of Malleboinpalli watershed



1 0 1 2 Kilometers

1:50,000

LEGEND

- Pediplain
- Pediplain with shallow weathering
- Pediplain with moderate weathering
- Inselburg
- Dried area of tank
- Water body
- Settlements
- Lineaments

Database : 1. Satellite : IRS ID PAN and LISS III Merged FCC
2. Maps : Topo sheet No 56L/1 & 56L/2
3. Others : Limited ground truth

Plate No: 4.1.5

Table No 4.5.1 Geotechnical characteristics and natural hazards

Engg geological province	Rock type	Permeability	Bearing capacity/Compressive strength	Foundation Charecteristics
Basement crystalline zones	Granites,Gneissesand basic intrusives	Low	Medium(within 500 kg/cm^2)	Good

The location of an epicenter of an earth quake with magnitude less than 5.5 on modified Mercalli (m.m) scale is shown.

Hydrological conditions

The direction of groundwater is towards east.Groundwater restricted to 60 m depth. Permeability is 0.50- 25 m^2/day. Yield prospects in the study area is of 15m^3/hr.

4.1.7.Hydrogeomorphological map

A brief description of each of the units found in study area is given below:

1.Pediplain

The characteristic features of Pediplain are:

-Pediplain is used to describe a series of coalescing pediments.

-Pediplain is the most basic and most wide spread landform stretching from the foot-hill regions of mountain ranges to the nearest stream or river valley.

-These are denudational in origin

- It is the result of cumulative effect of weathering, erosion and mass transport during landscape evolution.

-sometimes controlled by joints, fractures and lineaments.

-Groundwater prospect is moderate to poor.

2.Pediplain with shallow weathering

The characteristics of this shallow weathered pediplain are:

- It is flat and smooth buried pediplain.
- These are denudational in origin

- Thickness of overburden is 0-5m
- It comprises of alluvial/colluvial soils.
- The structure may be crisscrossed by lineaments/fractures.
- Suitable for shallow aquifers in weathered zone .
- Fractures/fault/ lineament concentrated zone posses good groundwater prospect
- Normally groundwater prospect is Moderate to poor.

3.Pediplain with moderate weathering

The characteristics of moderately weathered pediplain are:

- It is flat and smooth pediplain.
- These are denudational in origin
- Thickness of overburden is 5-20m
- It comprises with alluvial/colluvial soils
- The structure may be crisscrossed by lineaments/fractures
- Generally favourable for shallow aquifers
- Groundwater prospect is Moderate

4.Inselberg

The charecteristic features of Inselberg are:

-These are denudational in origin

-Having variable lithology

-Residual isolated hill standing above the ground level of sorrounding pediplain:

-Barren and rocky

-Groundwater is poor

5.Lineaments

-These are structural in origin

-Faults /fractures of varying length and breadth

-A good source of groundwater

Hydrogeomorphology map is shown in the plate No:4.1.7

4.1.8.Groundwater prospect map

Basing on the hydrogeomorphology map groundwater prospect classes identified are

1. Good
2. Modearate.
3. Moderate to poor
4. Poor

Delineated groundwater prospect classes are shown in the Plate No:4.1.8

4.1.9.Soil map

Identified soil map units are of following

1.Coarse loamy typic ustothents, loamy skeletal lithic ustropepts

2.Fine loamy typic Haplostalts, loamy skeletal typic haplostalts.

3.Fine loamy typic ustropepts (sodic), fine typic ustropepts (sodic), fine loamy fluentic ustorthents

4.Fine loamy typic ustropepts,coarse loamy typic ustifluvents

5.Fine typic ustropepts, fine vertic ustropepts

6.Loamy skeletal lithic ustorthents

7.Loamy skeletal lithic ustorthents coarse loamy typic ustorthents

8.Loamy skeletal lithic ustropepts, loamy skeletal typic haplostalts

9.Loamy skeletal typic ustropepts, loamy skeletal typic haplostalts

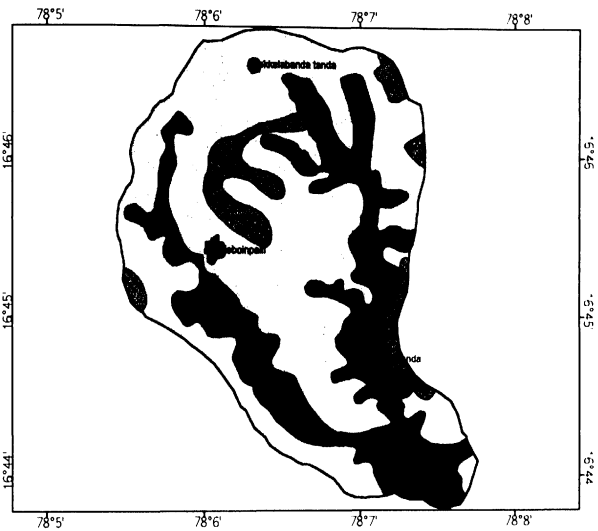
Soil map is shown as plate No:4.1.9

4.1.10.Land capability map

Land capability mapping units of study area are as follows

1. Good cultivable land with minor limitations.
2. Moderately good land with major limitations.
3. Fairly good land suited for occasional or limited cultivation.

Ground water prospect map of Malleboinpalli watershed



1 0 1 2 Kilometers

1:50,000

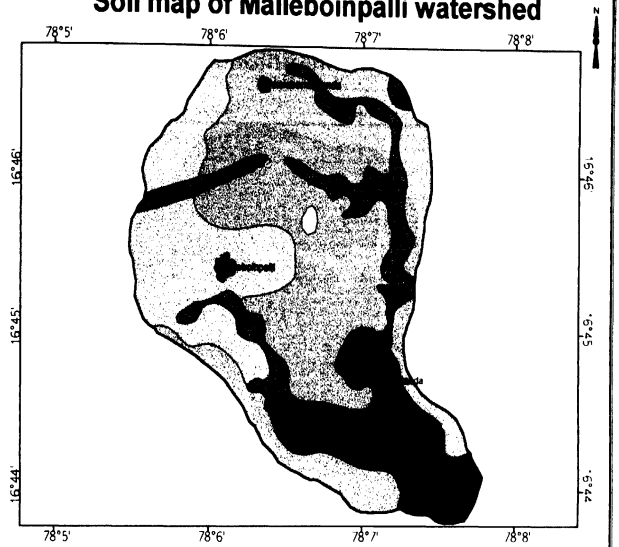
LEGEND

- Good
- Good to moderate
- Moderate
- Moderate to poor
- Poor
- Settlements

Database : Hydro geomophology map
Geology map
Slope map

Plate No: 4.1.8

Soil map of Malleboinpalli watershed



LEGEND

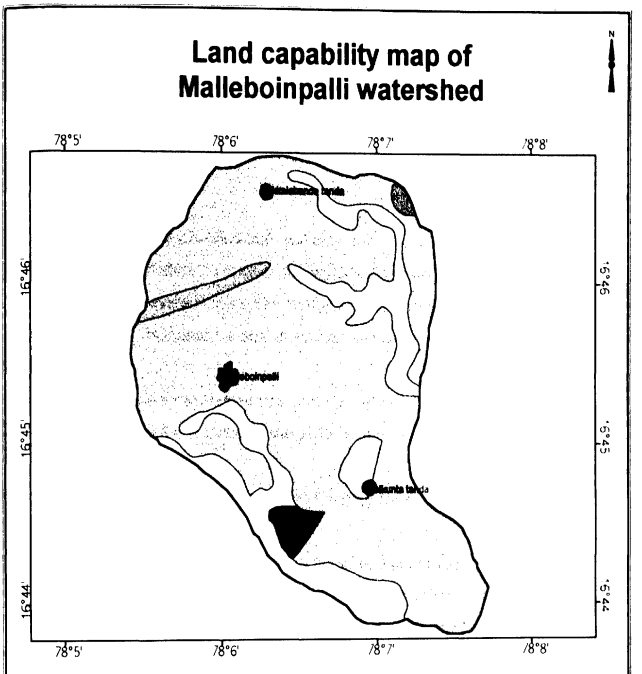
- Coarse loamy typic ustrothents, loamy skeletal lithic ustropepts
- Fine loamy typic Haplostalts, loamy skeletal typic haplostalts
- Fine loamy typic ustropepts (sodic), fine typic ustropepts (sodic), fine loamy fluentic Ustorthents
- Fine loamy typic ustropepts, coarse loamy typic ustifluvents
- Fine typic ustropepts, fine vertic ustropepts
- Loamy skeletal lithic ustorthents
- Loamy skeletal lithic ustorthents coarse loamy typic ustorthents
- Loamy skeletal lithic ustropepts, loamyskeletal typic haplostalts
- Loamy skeletal typic ustropepts, loamy skeletal typic haplostalts
- Settlements
- Water body

Database : 1. Satellite : IRS ID PAN and LISS III Merged FCC
2. Maps : SOITopo sheet No 56L/1 & 56L/2
3. Others : Limited ground truth

Source . National Remote Sensing Agency

Plate No: 4.1.9

Land capability map of Malleboinpalli watershed



LEGEND

- Good cultivable land with minor limitations
- Moderately good cultivable land with major limitations
- Fairly good land suited for occassional or limited cultivation
- Land not suitable for cultivation but well suited for grazing
- Land suitable for pasture & forestry
- Water body
- Settlements

Database: Soil map
Limited ground check
Source: National Remote sensing Agency

Plate No: 4.1.10

4. Land not suitable for cultivation but well suited for grazing or forestry.

5. Land suitable for pasture and forestry.

Land capability map is shown in the Plate No:4.1.10

4.1.11.Land irrigability map

Land irrigability classes identified from soil map are:

1. Lands that have moderate limitation for sustained use under irrigation.

2. Lands that have severe limitation for sustained use under irrigation.

3. Lands that are marginal for sustained use under irrigation because of very severe limitations.

4. Lands not suitable for sustained use under irrigation.

Land irrigability classes are shown in the plate No:4.1.11

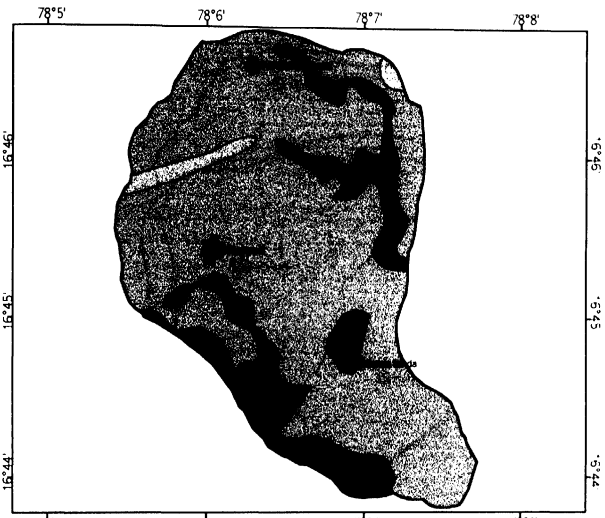
4.1.12.Tansport network, settlements and village boundaries

Identified transport network involves broad gauge of railway line from Secunderabad to Kurnool and state high ways of road network Hyderabad to Mahaboobnagar and Hyderabad to kurnool. Three settlements identified in the watershed area are Malleboinpalli, Nakkalabanda thanda and Esaikunta tanda.village boundaries for these settlements are also drawn.

This transportation map is shown in the Plate No:4.1.12

4.2 Drainage Morphometry

Land irrigability map of Malleboinpalli watershed



1 0 1 2 Kilometers

1:50,000

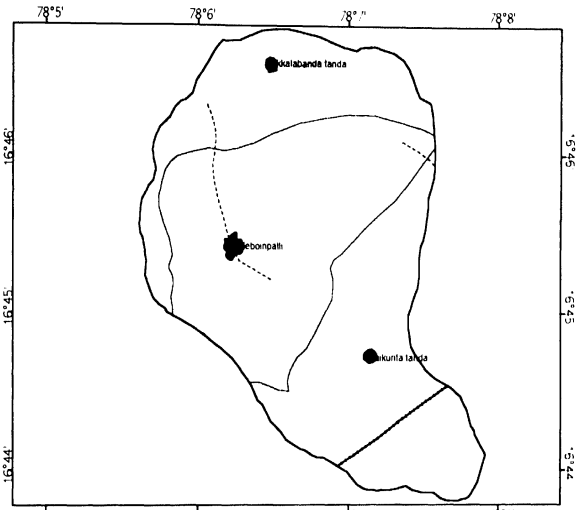
LEGEND

- Lands that have moderate limitation for sustained use under irrigation
- Lands that have severe limitation for sustained used under irrigation
- Lands that are marginal for sustained use under irrigation because of very severe limitations
- Lands those not suitable for sustained use under irrigation
- Water body
- Settlements

Database : Soil map
Land capability map

Plate No: 4.1.11

Transportation network, settlements and Village boundaries of Malleboinpalli watershed



1 0 1 2 Kilometers

1:50,000

LEGEND

- Railway track
- Metal road
- Unmetal road
- Village boundary
- Settlements

Database : Survey of India Toposheet 56L/1, 56L/2

Plate No: 4.1.12

4.3 Hy ometric alysis

4.2.1. Introduction

Morphometry deals with the measurement and mathematical analysis of the configuration of earth's surface and of the slopes and dimensions of its landforms(Clarke 1958).

Morphometry is the quantitative study of surface landform. It is used to determine the geometrics of the watershed especially among their stream networks. Morphometry also gives an idea of erodability of soil. Morphometric characteristics play an important role on the hydrologic performance of watersheds. Hence a number of parameters, which signify the watershed are evaluated as follows.

4.2.2. Elements Of Morphometry.

Various elements of morphometry can be grouped into,

1) Linear elements (stream length, order of the drainage basin, elongation ratio, bifurcation ratio).
2) Areal elements (basin area, basin shape, drainage density, stream frequency, circularity ratio).
3) Relief ratio (basin relief, basin slope).

4.2.2.1. Linear elements

4.2.2.1.1 Stream length

Stream length is defined as the total length of all streams of all orders in the drainage basin.

The stream length of the Malleboinapalli watershed is 18.94 km

Length of the I order streams = 5.215 km.

Length of the II order streams = 9.459 km

Length of the III order streams = 4.265 km

4.2.2.1.2 Order of the drainage basin

Horton introduced the concept of stream order. This is slightly modified by Strahter in 1964 as follows:

The Smallest recognizable channels are designated order 1.

These channels normally flow only during wet conditions.

Two streams of it order "i" meet to result a higher order stream of "i+1".

When two streams of different orders join, the resulting down stream will have an order higher of the two up streams

Malleboinapalli drainage basin is 3rd order basin .

4.2.2.1.3 Elongation ratio

Elongation ratio is defined as the ratio of diameter of circle of the same area as the basin to the length of the basin.

Area, A=15.05 Sq.km

Diameter of an equivalent circle (D) is

$\pi D^2/4 = 15.05$

D = 4.3 km

Re = D/L

Re = 4.3 /7.2 = 0.13

4.2.2.1.4 Bifurcation ratio

Horton found that the number of streams of a given order is fewer than the number of streams of its immediate lower but more than those of next higher order. Thus Horton introduced the morphometric term called bifurcation ratio.

$$Rb = \frac{N_u}{N_{u+1}}$$

Where

N_u — No of streams of $u^{th\ order}$

N_{u+1} — No of streams of u+1 order

The bifurcation ratio of the Malleboinapalli watershed is

$$Rb_1 = \frac{N1}{N2} = \frac{12}{4} = 3.00$$

$$Rb_2 = \frac{N2}{N3} = \frac{4}{2} = 2$$

$$Rb = 5/2 = 2.5$$

4.2.2.2. Areal elements

4.2.2.2.1 Basin Area.

Basin area is the total geographical area under the drainage basin.
The area of the Malleboinapalli watershed is 15.05 Sq.km

4.2.2.2.2.Basin Shape

The shape of the Malleboinapalli basin is dendrite which one of the six common destruct ional drainage patterns which are highly susceptible to soil erosion.

(a) Form factor

$Rf = A/L^2$

Where

Rf= Form factor;

A = Area of the watershed=15.05 km

L = Basin length =7.2 km.

Rf =15.05/7.2 = 2.09

(b) Area-perimeter ratio

Rap = A/P

where

Rap = Area perimeter ratio

A = Area of watershed = 15.05 km

P = Perimeter = 16.32 km

Rap = 15.05/16.32 =0.92

4.2.2.2.3 Drainage density

Drainage density is defined as the ratio of the total length of streams of all orders within the basin (L) to the total area of the basin (A).

$$Dd = \frac{L}{A} \quad (Km^{-1})$$

Dd = 18.94/15.05 = 2.45Km-1

Drainage density of the Malleboinpalli watershed is 2.45Km-1

4.2.2.2.4 Stream frequency

Stream frequency is the ratio of the total number of streams of all orders (N_i) with in a given drainage basin to the area of the Basin (A).

$$F = \frac{N_i}{A}$$

Stream frequency of the Malleboinapalli watershed is

$F = 18/15.05 = 1.19\ km^{-2}$

4.2.2.2.5. Circulatory Ratio

Circulatory ratio is defined as the ratio of basin area to the area of an equivalent circle having the perimeter as the basin.

Perimeter of the Malleboinpalli watershed = 16.32Km.

Diameter of an equivalent circle is,

$\pi D = 16.32$

D = 5.19 km

Area of an equivalent circle (Ac) is,

Arc = A/ Ac

Ac = $\pi D^2/4$ = 21.14 A=15.05

RC = 15.05/21.14 = 0.7

4.2.2.3.Relief elements

4.2.2.3.1 Relief

Relief of the basin is the difference in the elevations of the highest point (Upper reach) and & lowest point (lower reach)

H = 589.4 – 532.9 = 56.5m

4.2.2.3.2 Relief ratio

Relief ratio is the ratio of relief of the basin to the length of the basin.

Relief ratio = 56.5 x 10^{-3}/7.2 = 7.847 x 10^{-3} km

4.2.2.3.3 Relative relief ratio

Relative relief ratio is the ratio of the relief of the basin to the perimeter of the basin

$$R = \frac{H}{P} = 56.5 \times 10^{-3}/16.32 = 3.46 \times 10^{-3} \text{ km}$$

4.2.2.3.3 Basin slope

With the increase in the basin slope sediment yield drastically increases .The effect of slope can be reduced by breaking the continuous length of the stream,It is the ratio of the difference between the levels of end points of main stream to the length of the stream.

Difference between the end points of basin = 56.5m

Length of the main stream = 7.2km

Basin slope = 0.07

The slope of the Malleboinapalli watershed falls into Very gentle to Gentle sloping from the information of slope

4.3.1 Introduction

The basic objective of the Watershed management programme is to maintain an optimal hydrological balance of the region, by constructing water harvesting structures and gully control structures along with other management practices. In watershed that are draining a heavy amount of sediment down the stream courses and reservoirs, which threatens the longivity of the project. One of the accepted methods of controlling soil erosion is to arrest its movement at its source. In order to prepare a comprehensive erosion control programme one should know about the amount of hydraulic load of the watershed is being subjected to and also its behavioral changes with respect to the causes of erosion. This can be arrived by means of hypsometric analysis of a particular drainage basin.(Horton, 1945)

4.3.2. Definition of Hypsometry

It's an analysis that aims at developing the relation between horizontal cross sectional area of the drainage basin and its elevation in a dimensional form. (Leopold, 1963)

The percentage hypsometric curve, which is a plot of continuous function relating relative height to relative area, is useful for comparative study. In hydrologic application, the hypsometry can be of use where some hydrologic factor such as precipitation or evaporation varies with altitude or where the vegetative cover shows altitude stratification (Leopold 1991).

4.3.3. Development of Hypsometric Curve of Erosion Cycle

The percentage hypsometric curve, which is a plot of continuous function relating relative height to relative area, is useful for comparative study. This percentage hypsometric curve can be described by the model hypsometric

function. It is the application in the calculation of sediment load derived from basin in relation to slope.

The value of 'a' i.e., area above a particular contour for all contours of watershed is found out with the help of ARC/GIS and the area of the watershed (A) is also obtained. The relative area (a/A) is then calculated. Similarly taking the watershed area to be bounded by vertical sides and a horizontal base, the relative height is calculated as the ratio of the height of a given contour (h) to the basin height (H). Table 5.1 shows the relative height and its corresponding relative area drawn from the contour map which is shown in plate No:3.3. The hypsometric curve for watershed is plotted between the relative area on the abscissa and relative height on the ordinate. Hypsometric curve of the watershed is shown in the figure No:4.3.1

Table No:4.3.1.**Input data for the hypsometry of watershed**

Elevation	Height of contour elevation above discharge point (h)	Relative height h/H	Area above a given contour(a) in Sq.km	Relative Area a/A
532.9(Lower reach)	0	0	15.052	1
540	8.9	0.15	11.322	0.470
560	28.9	0.51	4.233	0.247
580	48.9	0.86	0.496	0.032
589.4(Upper reach)	56.5	1	0	0

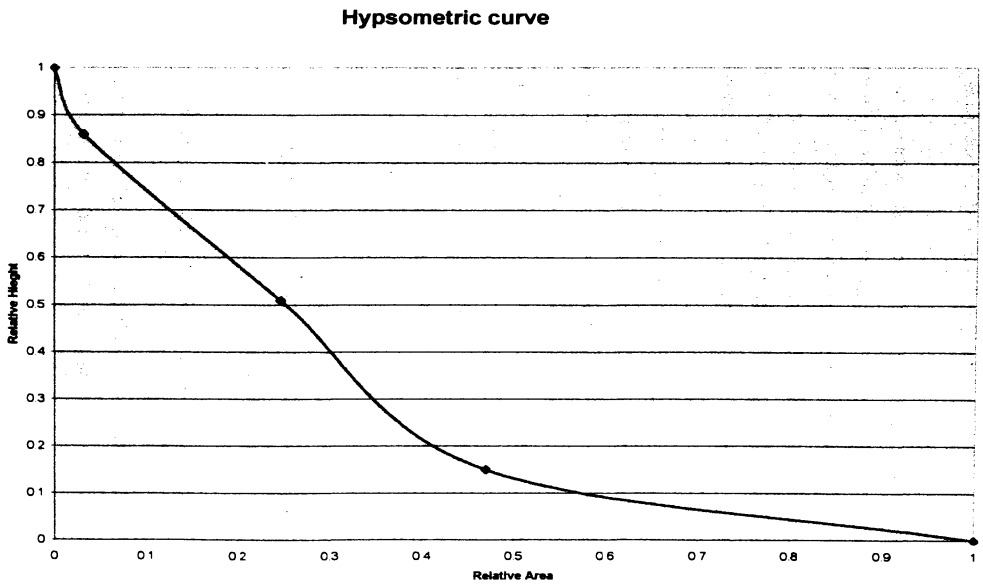

Hypsometric curve
Relative Height
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Relative Area

Fig. 4.3.1

4.3.4. Evaluation of Hypsometric Integral

It is the parameter or more accurately the indicator that decides how much mature is the watershed. Normally a watershed having a 'ç' shaped curve in the hypsometric function x=f (y) is integrated between the limits of x=1.0, a measure of land mass volume remaining with respect to volume of entire reference solid is obtained. This integral is designated here as the "Hypsometric integral" and is equivalent to the ratio of area under the curve to the area of the entire square formed by covering it. It is expressed in percentage units and has been obtained from the percentage hypsometric curves by measuring the area under the curve. Hypsometric curve and the value of hypsometric Integral are important elements in topographic form and show the marked variations in regions differing in stage of development and geologic structure (Pathak .S.K.,1991)

Hypsometric integral values are used to evaluate geological stage of development of the watershed. (R.P.Singh, 1990)

From the hypsometric curve of erosion cycle

Area covered under the curve = 28.6 cm^2

Total area of square = 100 cm^2

$$\text{Hypsometric integral} = \frac{\text{Area under the curve}}{\text{Area of the square}} = 28.62/100$$

Hypsometric integral of the Malleboinpalli watershed = 0.2862

4.3.5 Determination of stage of development of watershed

The stage of development of watershed is obtained by evaluating the hypsometric integral and also by comparing the hypsometric curves with the Model Hypsometric curve. It is inferred that

-If the value of hypsometric integral is above 60%, the watershed is in-equilibrium state. It is easily susceptible to erosion.

-If the value is in between 35% to 60%, the watershed is in equilibrium stage. (It is in mature stage and will be less susceptible to erosion than in equilibrium stage). (Vintechow; 1963)

-If the value of the Hypsometric Integral is less than 35%, the watershed is in monadnock phase i.e., it is the most stable or least susceptible to erosion among the known stages.

Malleboinpalli watershed is in Monadnock stage.

4.4 Sedime[illegible]d computation

4.4.1. Introduction

On the basis of Fourier's estimates, the global sediment yield from all the continents in the world about 14km^3.The rate of erosion is top ranked by Asia and estimated at 166 Tons.km^{-2} (Strakhov., 1994).

Khosla's equation depends on only watershed area which gives same sediment yield under different land use/ land cover conditions.

Dhruvanarayana et al.,(1983) equation is dependant on annual run off and watershed area only.

Garde et al.,(1983) equation is dependant on several parameters like area, runoff, slope, drainage density & vegetative cover factor. It is more appropriate method hence it is used in the present thesis work.

Table No:4.4.1**Sources of input data for estimation of sediment yield**

S.No	Parameter	Source
1	A-Study Area	Thematic map using Arc/GIS
2	Fc-Vegetative cover factor	Land-use/Landcover(Plate No:4.1.5)
3	P-Annual precipitation	Indian Metereological Department Annual rain fall for 30 years from Mahabboob nagar weather station
4	Q-Annual runoff	Computation using Garde's Formula
5	S-slope	Slope map (Plate No:4.1.4)
6	Dd—Drainage density	Drainage map(Plate No:4.1.2)

4.4.2 Vegetative cover factor

Vegetative cover factor is determined from the land use/land cover map. It is one of the parameters used for the computation of sediment yield. Vegetative cover factor is inversely proportional to the sediment yield.

The vegetative cover factor is given by

$$Fc = \frac{0.2F1+0.2F2+0.6F3+0.8F4+F5}{F1+F2+F3+F4+F5}$$

Where F1 = Reserve & protected forest area = 0.624 Sq.Km

F2 = Unclassified forest area = Nil

F3 = Cultivated area = 28.690 Sq.km

F4 = Grass &pasture land = 14.480 Sq Km

F5 = Waste land = 32.182 Sq Km

$$Fc = \frac{0.2(0.624)+0.2(0)+0.6(28.690)+0.8(14.480)+(32.182)}{0.624+0+28.690+14.480+32.182}$$

$$= \frac{75.2664}{75.976} = 0.99$$

4.4.3.Computation of runoff

The Runoff formula developed by Garde et al (1985) is used in the present thesis. Runoff obtained by this formula is accurate and reliable for estimation of sediment yield using remote sensing techniques.

The parameters involved in the computation of runoff are annual rainfall, mean temperature and vegetative cover factor

The Garde formula for runoff is

$$Q = \frac{Fc^{0.49}\,(Pm-0.5\,Tm)^{1.59}}{26.5}$$

where ,

FC => Vegetative cover factor

Pm=> Annual Precipitation in cm

Tm=>Mean temperature(^{0}C)

Q=> Runoff in Mm^3

4.4.3.1 Annual rainfall

Monthly normal rainfall data at Mahaboobnagar weather station for a period of 30 years is collected.The normal annual rainfall from 1971 to 2003 of Malleboinpalli watershed is shown in Table No:4.4.2

Table No:4.4.2 Rain fall data of Malleboinpalli watershed (1971-2002)

Year	Rain fall (cm)
1971	51.0
1972	41.0
1973	76.0
1974	74.0
1975	58.8
1976	76.1
1977	72.3
1978	85.4
1979	81.9
1980	58.4
1981	81.7
1990	58.7
1983	111.1
1984	62.4
1985	42.0
1986	62.2
1987	74.7
1988	80.9
1989	65.2
1990	88.3
1991	69.0
1992	58.1
1993	56.5
1994	40.0
1995	71.2
1996	71.4
1997	35.2
1998	55.6
1999	41.1
2000	59.3
2001	66. 52
2002	58.5
Average	**65.6**

Average annual rainfall of Malleboinpalli watershed is **65.6cm**

4.4.3.2 Mean temperature

The temperature data recorded at Malleboinpalli Weather station The average of mean monthly max/min temperature for 10 years is collected .
The normal mean annual max-min temperature of Malleboinpalli for the last 10 years as shown in the following Table No.6.3

Table No: 4.4.3 Temerature of Malleboinpalli watershed (1989-2002)

Year	Max.temp (^{0}C)	Min.temp (^{0}C)	Mean temperature (^{0}C)
1989	32.28	20.26	26.27
1990	31.10	20.50	25.80
1991	31.83	20.39	26.11
1992	32.11	20.19	26.15
1993	31.58	20.84	26.21
1994	31.33	19.88	25.61
1995	31.76	20.85	26.30
1996	31.38	20.65	26.02
1997	31.87	19.83	25.85
1998	31.98	19.99	25.99
1999	32.32	21.02	26.67
2000	31.90	21.42	26.66
2001	32.41	20.28	26.35
2002	32.98	20.42	26.70

Mean Annual temperature of Malleboinpalli watershed = **26.19(^{0}C)**

$$\text{Run off (Q)} = \frac{Fc^{0.49}\,(Pm-0.5\,Tm)^{1.59}}{26.5}$$

where ,

FC => Vegetative cover factor = 0.99

Pm=> Annual Precipitation =64.9 cm

Tm=>Mean temperature(^{0}C) =26.19^{0}C

Q=> Runoff in Mm^3

$$\text{Annual Runoff(Q)} = \frac{0.99^{0.49}(64.9-0.5\text{x }26.19)^{1.59}}{26.5} = 19.88$$

Table No:4.4.4 **SEDIMENT YIELD EQUATIONS**

Khosla' Equation	$Vs = 3.23 \times 10^{-3} A^{0.72}$	Vs = Annual sediment yield (Mm^2) A= watershed area
DhruvaNarayana	T1 = 5.5 + 11.1 Q T2 = 5.3 + 12.7 q Where Q= T1/A	T1,T2---Annual sedimentation (m^3/yr) Q = Annual runoff(MHam) A = Watershed area(Mha)
Garde	$Vs = 1.182 \times 10^{-6} \times A^{1.03} \times P^{1.29} \times Q^{0.29} \times S^{0.08} \times Dd^{0.4} \times Fc^{2.42}$ $Vs = 1.067 \times 10^{-6} \times A^{1.29} \times P^{1.38} \times S^{0.13} \times Dd^{0.4} \times Fc^{2.51}$	Vs=SedimentYeild(Mm^3/Km/yr) A = Watershed area(Sq.km) P = Annual Rainfal(cm) Q = Annual runoff(km^3) A = Watershed area,sq.km D = Drainage density(km^{-1}) Fc = Vegetative cover factor

4.4.4. Estimation of Sediment Yield

In this study Sediment yield is obtained by using Garde's equation.

The Garde equation for the computation of sediment yield is

$$Vs = 1.182 \times 10^{-6} \times A^{1.03} \times P^{1.29} \times Q^{0.29} \times S^{0.08} \times Dd^{0.4} \times Fc^{2.42} \text{ ------- eqn(1)}$$

$$Vs = 1.067 \times 10^{-6} \times A^{1.29} \times P^{1.38} \times S^{0.13} \times Dd^{0.4} \times Fc^{2.51} \text{ _____ eqn(2)}$$

Where,

A = Watershed area = 35.05 Sq.km

P = Annual Rainfall(cm) = 64.9

Q = Annual runoff(km^3) = 19.88

S = Slope of the watershed = 0.07

Dd = Drainage density(km^{-1}) =2.45

Fc = Vegetative cover factor =0.99

Sediment yield from the Malleboinpalli watershed

$= 1.182 \times 10^{-6} \times 35.05^{1.03} \times 64.9^{1.29} \times 19.88^{0.29} \times 0.07^{0.08} \times 2.45^{0.4} \times 0.99^{2.42}$

$= 0.026958 (Mm^3/yr)$

$= 26958\ m^3/yr$

$$\text{Rate of sediment yield} = \frac{Vs}{A} = \frac{26958}{35.05} = 769.12\ m^3/Sq.Km/yr$$

4.5 Integration [illegible]ration of Action plan

4.5.1 General

The objective of this study is to prepare action plan for the area, which is optimally suitable to the terrain and to the productive potential of the local resources so that the level of production is sustained without decline over time.

The various components of watershed management have to be considered to ensure adequacy of planning to meet multitude of objectives.The components are better appreciated when the problems of different land uses prevalent in the watersheds are considered. Recommendations of this plan considering the contemporary technology, resources including socio-economic database, estimated drainage morphometric characteristics, erosion characteristics, sediment loss, climatic and terrain parameters. Integration of the prepared thematic maps (land use/land cover, slope, geomorphology, groundwater potential, soils, land capability, land irrigability) is achieved systematically through the following steps.

In the present study IRS-ID FCC and Toposheet are used in order to get the landuse/land cover information along with other thematic information required for watershed management like landuse /landcover, hydrogeomorphology, drainage network & watershed boundary, slope, soil, land irrigability, land capability. The Garde et al method with the annual runoff component is used to estimate the sediment yield of each watershed using hypsometric analysis. In order to prepare the action plan map for both land and water resources development of watershed, pressure of population, demand for utilization of land use and the potential of the resources available should be studied and demand for the optimal utilization of land units should also be examined in the light of existing socio-economic conditions. It is in this context that socio-economic data is collected by household survey and analyzed other components of watershed management in view .

4.5.2. Socio economic data collection and analysis

This nucleus watershed consists of only Malleboinpalli panchayat, Nakkalabanda thanda, Esaikunta thanda. ICRISAT and APRLP aiming to focuss on this Malleboinpalli panchayat only .

Malleboinpalli Details

Malleboinapalli *panchayat* covers Malleboinapalli village, Pochamma gadda thanda, Kotta thanda, and Mangalivanikunta thanda.

Mandal : Jedcharla 5 Km apart.

District :Mahaboobnagar 10 km apart.

Latitude :16 45' 56"

Longitude:78 07' 36"

Altitude : 623m

1.Geographical Area	:	524 ha
		406 ha dry land
		27.12 ha Wet land
2.Total cultivable land Area		433 ha
Uncultivable Area		91 ha

3.Rainfall : 670mm

4.Geology : mainly consists of different forms of Granites

5.Distribution of Surface material

5.1 Soil erosion

Slight to Moderate erosion observed

5.2 Soils types

Soil type	Area in (ha)	Depth in cm	Fertility	Moisture retention depth in cm	Moisture retention period
Red clay loam soils	120	45-60	Good	30	15-20 days
Red sandy soils	200	60-105	Mediu m	90	10 days
Saline and alkaline soils	8	90	Poor	90	30 days
Light black soils	20	90-120	Good	90	30 days

6.Type of Housing

No of Households : 450

Category	Huts	Katcha	Pakka	Total
OC	-	36	9	45
BC	8	100	20	128
Harizans	10	47	12	69
ST	-	2	-	2
Pochamma gadda thanda (STs only)	-	47	32	78
Kotta thanda (STs only)	-	62	16	78
Mangalivani kunta thanda(STs only)	8	36	5	49
Total	26	330	94	450

7.Population

Males : 1089

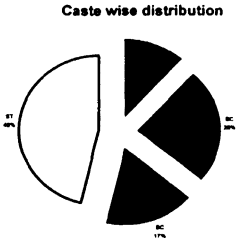
Females:1278

Total : 2267

8.Categorization based on community

Other castes	: 262
Backward castes	: 563
Scheduled castes	: 382
Scheduled tribes	: 1060
Total	: 2267

Fig No:4.5.1Caste wise distribution of Malleboinpalli *Panchayat*.



9.Literacy details

Male : 578(50%)

Female : 311(32%)

Total : 886(45%)

Literacy rate is very low.In village since 15 years only primary school facility for the education. Technically educated people like engineers found in thandas only.

10.Water related details

Drinking water is supplied through bore wells, which are connected to community, and household taps are just adequate in most of the habitats

10.1 Tanks

Water body name	Area in hectares
For the purpose of irrigation	
Naganna kunta	3.36
Singayya kunta	7.37
Nallakunta	3.36
Rekulakunta	3.74
Komanu kunta	3.34
Papanna kunta	4.18
Domestic purpose	
Ura kunta	0.40

10.2.Open wells

No of wells	Functional	Disfunctional	Normal fluctuation
140	---	140	300-350 cm

10.3.Bore wells

No of bore wells	Functional	Disfunctional	Average yield	Min-Max depth	Distribution over the area
78	35	43	2.5'	300 ft	Along the vodka

Note : Icrisat Survey

10.4 Hand bores used for the purpose of drinking

Malleboinapalli	6---2 failed---1 seasonal
Pochammagadda thanda	3---2 not working
Mangalivanikunta thanda	2---1 failed---1not working
Kotta thanda	1

10.5 Crops grown in the watershed under different source of irrigation

Source of irrigation	Area(hectares)	Crops grown
Under Tanks		
Wet	22.24	Paddy
Under bore wells	36.43	Paddy
Wet	24.29	Groundnut
dry	12.14	Vegetables
Total area (rain fed)	283.4	Sorghum , Castor, Cotton, Ragi, Bajra, Pulses, Horse-gram, Vegetables

11.Classification of farmers

Classification	Land holding	No of Farmers
Small farmers	1 ha	382
Medium farmers	1-2 ha	85
Large farmers	Above 2 ha	52
Land less		20

12.Cropping productivity

Major crops	Yield (kg/ha)
Maize	1250
Castor	750
Pigeonpea	500
Sorghum	750
Cotton	1500

13. Livestock details

	Malleboinapalli	K.T	P.G.T	M.K.T
Cows	142	109	100	111
Buffaloes	212	38	5	5
Sheeps	800	---	---	---
Goats	365	150	150	380
Hen	860	460	363	525
Total	2375	757	578	1021

14.Economic status

Most of the Harizans are under the BPL (Below poverty line). All these people are land less. In village small farmers having the annual income of less than Rs 10,000. For the middle size farmers it is Rs 10,000 - Rs 20,000. For the land lords which are very few in number having the income above Rs 20,000. In Thandas there are government employees having Annual Income of 70,000Rs. Depletion of groundwater, failing of bore attempts and drying of surfacewater bodies by hot summer results moving the people towards cities to search for other livelihood options.This shows main effect on the cultivation by that on economy of the people here.

15.Employment and Unemployment

In village most of the Harizans migrate to near by cities for work in summer. Recently established Food corporation of India (FCI) plays an important role in providing employment opportunities to the youth. Depletion of groundwater, failing of bore attempts leading to the migration of labor ,and small farmers. In Mangalivanikunta and Kotta thandas many people are government employees working at somewhere having houses here.

16.Migration details

Most pathetic condition observed that is about the migration. Most of the people move to near by cities Jedcharla, Mahaboobnagar, Boothpoor and Hyderabad. Their wages there for the women 50Rs per day and 70Rs per day.for the works

17.Communication facilities

In village one post office and 10 telephone connections.

18.Health & Sanitation facilities

Here one primary health center and one Veterinary hospital. Only 20 latrines are observed in the village.

19.Assets

20 members having two wheelers and 16 members having Autos (self employment scheme) and 9 Tractors in the village.

20.Transportation facilities

Malleboinpalli is in between the two main state ways one from Hyderabad to Mahaboobnagar and another from Hyderabad to Kurnool. A small foot way of 1.5 Km connects village to the Mahaboobnagar Road another 2km foot way connects second end of the village to kurnool. To the village previously there

was Government bus facility which is withdrawn later because of political differenciations. Now Only auto facility is there for the villagers from Jedcherla, which is mandal head quarters.

21.Government schemes

- 30 ha of land is distributed to the among 35 members (15SC, 8 ST and rest BC with 1.68 ha balance).
- Under Balika sisu samrakshana padhakam 8 members benifitted. Under Deepam padhakam 24 members benifitted. 12 women groups working here who are aware of about savings and earnings.
- Loans are provided to 5 families of weaving under Self-employment scheme
- Houses are constructed for under housing loan scheme for 15 members, Most of the harizans are benifitted under this scheme.

21.1. ICRISAT Programmes

- Research is going on increasing the agricultural productivity of this area by integrated crop management through soil observations, ensuring availability of good varieties of seeds and providing information for balanced fertilization to the farmers
- Integrated Nutrient management

Through Nutrient Budgeting and balanced Fertilization trails, Vermicomposting

- Integrated Pest management

By applying village level HNPV production

- Tropicultor was introduced for the farmers and training was also provided on use and benefits of the tropicultor
- The farmers of the watershed were explained the benefits of *Gliricidia* plants, for which the farmers agreed to plant them, as a result 46,000 saplings were planted on the field bunds of the farmers
- Farmers awareness about the mixed cropping is enhanced.
- Construction of cattle pond for preserving the water and inventory on groundwater

• Weather station and Runoff recorder was setup by the ICRISAT team and manual rain gauges were also installed along with them.

• Farmers awareness about people's participation in the application of watershed programmes is sustainably improved..

22.Impact by the Development programmes

• Exposing farmers to new methods of technologies for managing natural resources through training and field visits. Farmers evaluated improved crop management practices (IPM&INM) along with improved land management practices such as sowing on a BBF land form: flat sowing on contour and inter cultural operations leading to good productivity of the land.

• Vermi compost methodology not only increasing the nutrient supplying capacity of the land but also generating income through Marketing.

4.5.3. Ground truth Analysis

4.5.3.1.General:

Malleboinapalli village is situated in the southern Telangana agro-eco region under the influence of hot, semi arid region with a annual rainfall range of 500-700mm at Latitude :16^0 45' 56"N and Longitude:78^0 07'36"E aiming location of study area.

This watershed lies in between the two major state highways Mahaboob nagar to Hyderabad and other Hyderabad to Kurnool. There is 1.5 km and 3 km cart tracks from the two state high ways respectively. The village is typically varied in topography with a great deal of undulations affording a challenging program on watershed management. It encompasses an area of totally 15.05 Sq.km. Large land holdings are more or less clustered in the south west part of the watershed. Small land holdings are clustered in the eastern and thew south eastern part of the village.

An assessment of hydrogeomorphology of the study area indicates the presence of lineaments 10% of area represents good groundwater resources.

Inselberg occupy 0.34% of area and more than half of the rest(67.03%) under Pediplain with shallow weathering conditions. 24.81% of the study area is under the pediplain with moderate weathering. This moderately weathering pediplain is crisscrossed by lineaments. 7.82% of the area comprises pediplain . Ground water prospects are moderate to poor in half of the area, 20% of area with good expectations and less than 10% of area has negligible exploitable groundwater resources.

4.5.3.2.Survey

First hand information was gathered from the villagers while my socioeconomic survey. As we approach the village a typical rainfed system ecosystem observed where rice and sorghum are major kharif crops. Soils are eroded. *Gliricidia* on the sides of roads died. We observed that the first parcel of the village with backward classes are of small farmers, they cultivate the land only in rainy season. All the remaining time they just leave the land fallow. Next to this block forward caste people occupied the village these are of medium to high land holders. Most of these people having bore wells in their lands. Very few of them cultivate the vegetables through bore well. Most of these people are of literates. Third block of the village consists of Horizans. 95% of Harizans having no single block of land. All of these are daily laborers .These people migrate to near by towns in unseasonal conditions for works. Fourth block of village includes thandas attached to this village are Pochamma gadda thanda, Kotta thanda, Mangalivanikunta thanda, All these people are scheduled tribes. They are having more or less land to cultivate .Lands of these people play main contribution in the Malleboinapalli watershed. Pochammagadda thanda is just attached to the village in the cart track way to wards Mahaboobnagar road. Other two thandas are on the other side of the Mahaboobnagar state way.

4.5.3.3.Cultivation details

Rice is the major crop for food and profit. Sorghum is raised as fodder. Castor cultivation is preferred because of monetary value and less labour

requirements. Farmers know that mixed cropping is a strategy of risk minimization. Farmer replace rice with vegetables when water is scarce. But in this summer all the tanks are dried. Because of the groundwater depletion and lack of rainfall most of the land is left as fallow.

4.5.3.4.Lively hood analysis

An examination of livelyhood analysis reveals that the contribution of agriculture to total income increased with farm size. Dryland farmers derive one third of their total income from sheep rearing. Livestock significantly contribute to the overall income of the small and marginal cultivators. Lively-hood significantly contributes to the overall income of the small and marginal cultivators. The drought conditions rose due to the lack of rainfall and depletion of groundwater. Most of the villagers left the lands on summer of 2003 and going for other works to the near by towns are Jedcharla and Mahaboobnagar. Seventy percent of Harizans went for daily wage works to the near Jedcharla, Mahaboobnagar and Bhoothpur. Recently established FCI plays an important role in providing the employment opportunities for the youth in the watershed area.

4.5.3.5.Trend analysis

Farmers reported a declining trend in the rainfall. The tank, stream and wells in the village also are drying more frequently than earlier. The productivity levels are reported to be falling overtime. They complained about the pest incidence during recent years and declining work of labor due to migration. education facilities are same as from last ten years. Thanda people having well transportation facilities than villagers. They are bothered about the enormous increasing of rates of vegetables mainly in summer. Health and Sanitation facilities are increased from last 5 years. From their perception we found out that the lands also degraded and by that low productivity from lands. Communication facilities have increased from the time but those only used by the land lords of

Rainfall variation for last 30 years for Malleboinpalli Watershed

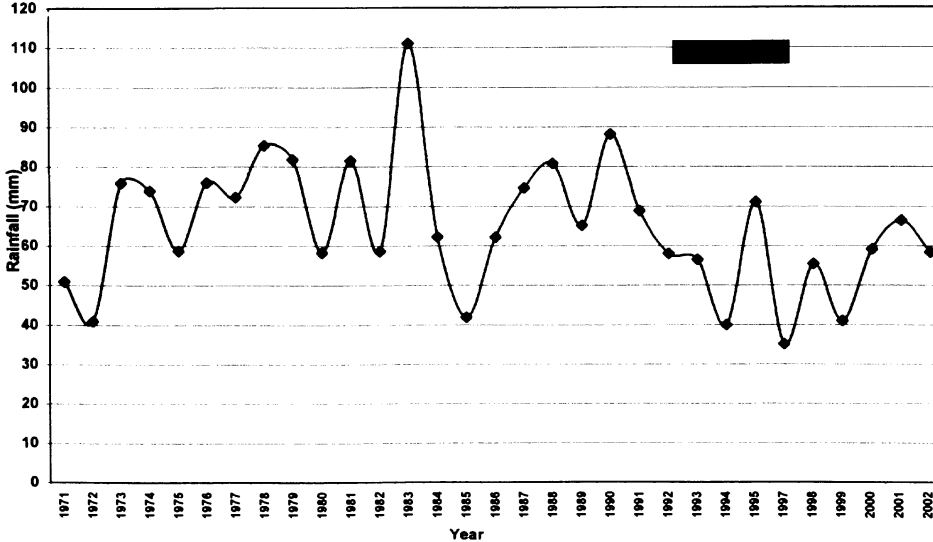


Fig. 4.5.1

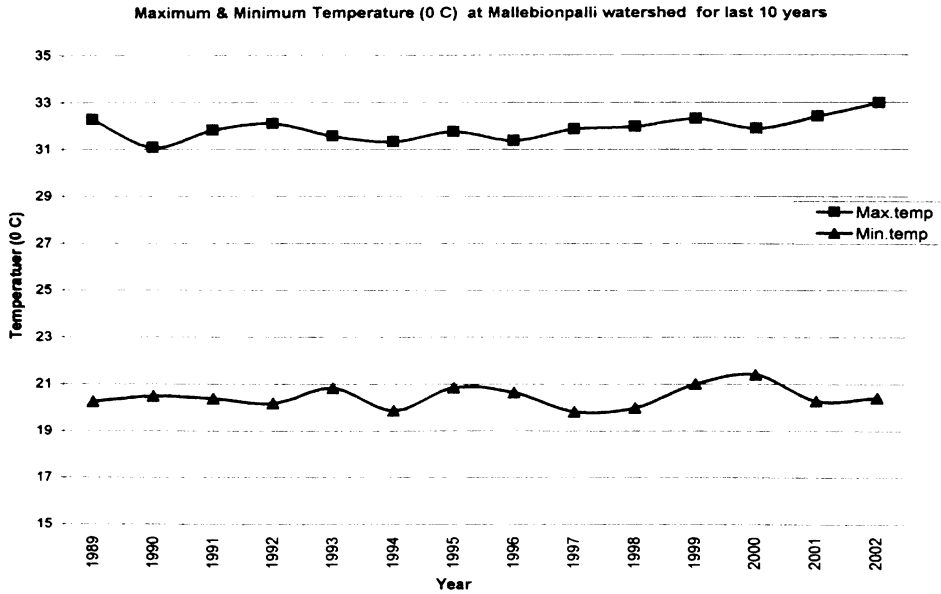

Maximum & Minimum Temperature (0 C) at Mallebionpalli watershed for last 10 years
35
33
31
29
27
25
23
21
19
17
15
Temperatuer (0 C)
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
Year
Max.temp
Min.temp

Fig. 4.5.2

the area. Because of the political menace people are suffering a lot here.Thirty five percent of the people have no legal electricity.

Decreasing trend of rain fall from last 30 years and increasing trend of maximum temperature observed from last 10 years in climatology graphs(Fig No 4.5.2(Rain fall) and Fig No :4.5.3(Temperature)) is the main reason observed in the watershed. Depletion of Ground Water, failing of bore attempts and Drying of surface water bodies by hot summer results moving the people towards cities to search for other livelihood options.This shows main effect on the cultivation by that on economy of the people here. In Mangalivanikunta thanda and kottathanda as many people are of government employees working at somewhere having houses in here.

4.5.3.6.Water management

The Average precipitation in Malleboinapalli watershed is 669 mm. Most of the rainwater is lost in the form of run off due to lack of resources for infiltration into the ground. Thus water management plays a crucial role both for the groundwater recharge and for the control of soil erosion.

The groundwater potential in Malleboinaplli watershed is found as moderate to poor. The total rainfed irrigation area estimated in the Malleboinapalli village 283 ha only . The poor ground water potential has made the Malleboinapalli watershed single cropped area (Khariff) entirely depending upon on rains. The main reason behind this poor ground water resource is the erosion of loose fertile soil which helps in infiltration of rain water to form ground water. 83.5 % of the total land is rainfed.

The groundwater potential must be augmented henceforth, for which detailed studies on hydrogeomorphology and slope of the area is essential. The welldata of Malleboinpalli watershed acquired from limited ground check and ICRISAT observations is presented in the Table No:4.5.1 (% success of wells v/s Hydro geomorphological units) Table No:4.5.2((% success of wells v/s

Table No:4.5.1 **% Success of wells v/s Hydrogeomorphic units**

S.No	Hydrogeo morpholo gical unit	No of successful Bore wells	No of failure Bore wells	% success of Bore wells	No of successful Open wells	No of failure Open wells	% success of Open wells
1	Pediplain	0	3	0	0	1	0
2	PPM	18	11	62.06	5	10	33.33
3	PPS	19	24	44.18	4	23	17.39

Table No:4.5.2 **% Success of wells v/s Sloping units**

S.No	Sloping unit	No of successful Borewells	No of failure Bore Wells	% Success of Bore wells	No of successf ul Open wells	No of failure Open wells	% success of wells
1	Nearly level sloping(0-1%)	5	2	71.4	4	8	33.33
2	Very gentle sloping(1-3%)	25	29	46.29	5	21	18.5
3	Gentle sloping (3-5%)	2	6	20	-	4	0
4	Moderate sloping (5-10%)	-	3	0	-	3	0

Sloping units). Wellls v/s hydrogeomorphic units of the study area is shown plate No:4.5.1 and Wellls v/s Sloping units of study area is shown in plate No:4.5.2 .

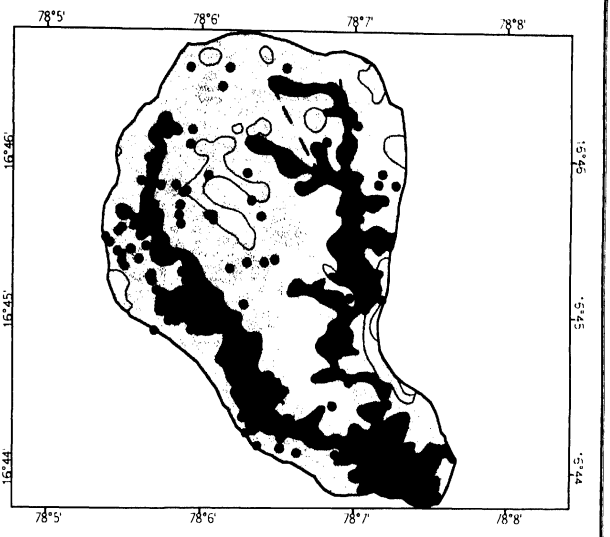
An attempt is made to link the percentage success of wells with the hydrogeomorphic unit and slope unit. In this context two plots % success of wells v/s hydrogeomorphological unit and % success of wells v/s sloping unit are represented in figures (4.5.4 and 4.5.5) respectively.

From the plot % success of wells v/s Hydrogeomorphological unit as shown in the Fig (4.5.4), it is revealed that the percentage success of wells is more in pediplain with moderate weathering(borewells(62.06%) and Open wells (33.33%)). In the study area pediplain with moderate weathering is crisscrossed by lineaments which are of good ground water source. Pediplain with shallow weathering having moderate ground water prospect from ground water prospect map.it is having the percentage of success of borewells as 44.18% and open wells as 17.39%. In case of pediplain ground water is moderate to poor from the remotesensing data . It is proved here from ground truth neither open well nor bore well is not in functioning in this rabi season. In inselberg region no scope for ground water there the ground water prospect is poor.

The generalized concept being that the percentage success should decrease with the increase in the steepness of the slope. This is because slopy terrains can not bear surface detention thus making the percolation of water very poor resulting into poor ground water potential zones.

From the plot % success of wells in slope unit as shown in the Fig No:(4.5.5), nearly level sloping areas have high percentage of success of wells (Borewells(71.4%) and open wells (33.33%)). As per the increasing of slope there the percentage of success of wells is decreasing. In case of very gentle sloping percentage of success of wells is a shown as for borewells(46.29%) and for openwells(18.5%). When we go for gentle sloping it is decreased a lot in case of borewells(20%) but in case of openwells it falls to zero. In case of

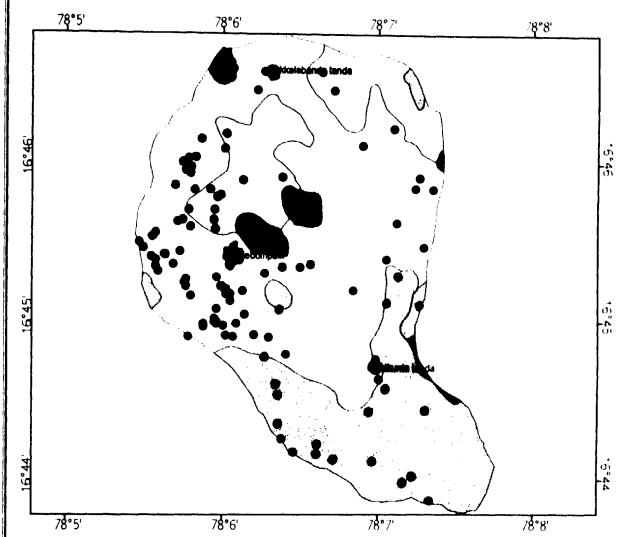
Wells v/s Hydrogeomorphic units of Malleboinpalli watershed



Database 1 Satellite IRS ID PAN and LISS III Merged FCC
2 Maps Topo sheet No 56L/1 & 56L/2
3 Others Limited ground truth
Source GIS Unit - GT3, ICRISAT

Plate No: 4.5.1

Wells v/s Sloping units of Malleboinpalli watershed



LEGEND

- Nearly level sloping
- Very gentle sloping
- Gentle sloping
- Moderate sloping
- Strong sloping
- Moderately steep to steep sloping
- Settlements
- Functional Borewells
- Disfunctional Borewells
- Functional Openwells
- Disfunctional Openwells

Database : 1 Slope map , SOI Toposheet 56L/1 NE,56 L/2 SW ,Well data 3 Limited Ground truth
Source GIS Unit - GT3, ICRISAT

Plate No: 4.6.1

Figure :4.5.4

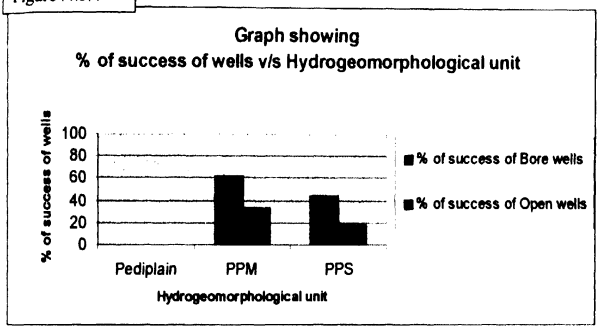
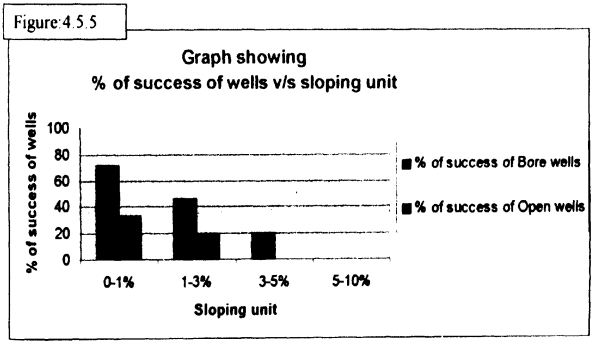


Figure:4.5.5



moderate sloping there is functioning well either borewell or openwell in this rabi season.

Percentage of success of borewells is more higher in all the mapping units of hydrogeomorphological map and slope map than percentage success of open wells

Ground truth and socio economic household survey revealed following facts about Malleboinpalli Nucleus watershed.

The emerging scenario of farming system and constraints to sustainable agriculture were identified some observations are

- Pressure on the land is increasing beyond its carrying capacity.
- Monocropping is predominant. Cropping systems and natural diversity is decreasing.
- Rain fall variability and inadequacy of water availability are main constraints to the intensification of rainfed farming. Farmers are ready to invest in water development programs.
- Cost of inputs are increasing at a rate faster than prices of farm produce.
- Farmers are aware of land degradation but lack of knowledge about erosion control measuring .
- Agriculture extension is poor.

The constraints to the farming systems are

- Climatic variability particularly at crop establishment stage.
- Soil erosion is increasing over the years.
- Weeds and insects are major biotic problems.
- Drought
- Lack of capital and non viability of credit.
- Price fluctuations and lack of support price.

4.5.4.Integrated approach

Watershed approach invites integrated inputs derived from satellite imageries, hypsometric analysis and the quantity of sediment yield for the development of Malleboinapalli watershed in accordance with its socio-

economic data. This approach is the key to protect land, water and other natural resourcesto attain good crop yields and developing the area with limited funds by means of community's participation. The integrated management of watershed elicits broader information that aids in the planning of effective watershed development schemes. In a watershed natural and human resources are inter-dependent. Hence, the land and water resources in conjunction with the socio-economic data serves as a tool for watershed management.

The integrated watershed development must lead to people's self reliance, self support and self esteem. It must enrich the life of the people and improve its quality at gross root level. The introduction of detailed socio-economic aspects generate public interest and augments the understanding of a plan, the objectives of which provide protection, development and management of the land and water resources to maximize the economic returns.

The integrated analysis of the watershed leads to the preparation of erosion intensity map and map showing water and land resources development In this section of the thesis action plan for the land resources development and water resources development are prepared by integrating the information obtained from remote sensing, hypsometry and the concept of sediment yield with the socio-economic data using ARC/GIS 8.1.2

4.5.5.Generation of Action Plan

The generation of an Action plan essentially involves a careful study of thematic maps of land and water resources both individually as well as in combination to identify various land and water resources regions or composite land development unit (CDU) and their spatial distribution, potential and limitations for sustained agriculture and other uses and development of an integration key.

Each CLDU is studied carefully regarding in the light of various natural resources and socio-economic and climatic conditions and a specific land use soil and water conservation practices suggested based on its sustainability.

Subsequently taking landform as a base on integration key in terms of potential /limitations of soil, present land use/land cover, land capability, land irrigability and groundwater potential and suggested alternate land use /action plan has been developed

Preparation of Action plan involves the following steps as follows

4.5.5.1 step-1 Study of individual Thematic maps.

The individual theme maps are studied to make a spatial assessment of the relative variations of resource potential and range of terrain conditions .In order to facilitate this analysis, the range of parameters (resource units) in respect of each theme are listed below

1.Land use land cover Theme

-The landuse classes and their statistics found in the study area are

1.Built-up land
2.Double Crop
3.Fallow land
4.Kharif Unirrigated
5.Land with Scrub

6.Land without Scrub

7.Barren Rock/Stony/Sheet rock area.

8.Water bodies

Table No: 4.5.3 **Area statistics of Landuse/Land cover mapping units**

Landuse/Land Cover Unit	Area(km^2)	Percentage
Built-up land	0.0877	0.58
Double Crop	1.4091	9.36
Fallow	0.1648	1.09
Kharif Unirrigated	11.1437	74.00
Land with Scrub	0.5181	3.44
Land without Scrub	0.6103	4.05
Barren Rock /Stony/Sheet Rock Area	0.1632	1.08
Water bodies	0.9628	6.39

2.Slope theme

-The slope classes and their statistics identified in the study area are as follows

1.Nearly level sloping

2.Very gentle sloping

3.Gentle sloping

4.moderately sloping

5.Strongly sloping

6.Moderately steep to steep sloping

Table No: 4.5.4 **Area statistics of Sloping units**

Sloping Unit	Area(km^2)	Percentage
Nearly level sloping	3.8488	25.56
Very gently sloping	8.2721	54.93
Gentle sloping	2.2438	14.90
Moderate sloping	0.4810	3.19
Strong sloping	0.0661	0.44
to steep sloping	0.1479	0.98

3.Geology Theme

In the study area different forms of Granites only present. These Granites comprise several textural and compositional variants such as

granadiorite,hornblende granite and medium grained biotite granite, alkali feldspar granite and medium grained grey granite. However, the medium to coarse grained biotite granite and very coarse grained porphyric granites are widely distributed.The contact relationship between the various types of granites is transitional.These granites are either foliated or non-foliated and compositionally to tonalities, granodiorite and admelite suit. All these structures are hard and massive in nature.

4.Hydrogeomorphological Theme

In Hydrogeomorphological map various geomorphological structures and their units occurring in the study area are

1.Pediplain with moderate weathering

2.Pediplain with shallow weathering

3.Pediplain

4.Inselberg

Table No:4.5.5**Area statistics of Hydro geomorphology map units**

Hydrogeomorphological unit	Area(km^2)	Percentage
Pediplain	1.1147	7.82
Pediplain with moderate weathering	3.5343	24.81
Pediplain with shallow weathering	9.5507	0.34
Inselberg	0.0484	67.03

5.Ground water prospect Theme

-Various ground water prospect classes and their statistics identified are as follows

1.Good

2.Good to moderate

3.Moderate

3.Moderate to Poor

5.Poor

Table No:4.5.6.**Area statistics of Groundwater prospect zones**

Groundwater Prospect	Area(km^2)	Percentage
Good	2.4151	16.04
Good to moderate	2.4879	17.14
Moderate	8.8687	58.89
Moderate to poor	1.1681	7.76
Poor	0.0262	0.17

6.Soil Theme

Various soil series/associations and their statistics found in the study area are

Table No:4.5.7. **Area statistics of soil map units**

Soil mapping Unit	Area(km^2)	Percentage
Coarse loamy typic ustrothents, loamy skeletal lithic ustropepts	3.1175	21.02
Fine loamy typic Haplostalts, loamy skeletal typic	0.9705	6.54
Fine loamy typic ustropepts (sodic), fine typic ustropepts (sodic), fine loamy fluentic ustorthents	2.1403	14.43
Fine loamy typic ustropepts, coarse loamy typic ustifluvents	1.3678	9.22
Fine typic ustropepts, fine vertic ustropepts	0.2395	1.61
Loamy skeletal lithic ustorthents	0.2746	1.85
Loamy skeletal lithic ustorthents course loamy typic ustorthents	6.6068	44.55
Loamy skeletal lithic ustropepts, loamyskeletal typic	0.0673	0.45
Loamy skeletal typic ustropepts, loamy skeletal typic haplostalts	0.0458	0.31

7.Land capability Theme

Land capability classes and their statistics identified as follows

1.Good cultivable land with minor limitations

These areas are of having good ground water facility. But It varies to moderate condition in the down part o the study area. Geological features of the area is mixed with pediplain with shallow weathering and moderate weathering.

2.Moderately good land with major limitations

These lands are observed with moderate conditions of ground water.

3. Fairly good land suited for occasional or limited cultivation

Table No:4.5.8: **Selection of soil and water conservation farm practices for land suited for cultivation.(Class I to IV)**

Farm practices	Class II(1)	Class III(2)	Class IV(3)
Good farming			
Fertilising	Yes	Yes	Yes
Manuring	Yes	Yes	Yes
Liming, if necessary	Yes	Yes	Yes
Cover cropping	Yes	Yes	Yes
Green manuring	Yes	Yes	Yes
Crop rotation	Yes	Yes	Yes
Conservation crop residues	Yes	Yes	Yes
Simple soil and water conservation practices			
Contour cultivation	Yes	Yes	Yes
Contour strip mapping	Yes	Yes	Yes
Stuble mulching	Yes	Yes	Yes
Contour terracing	Yes	Yes	Yes
Graded terracing	Yes	Yes	Yes
Intense soil and water conservation practices	Yes	Yes	Yes
Bench terracing	No	Yes	Yes
Drainage	Yes	Yes	Yes
Reclamaton of saline and alkali soils	No	Yes	Yes
Ley farming	No	No	Yes

Table No:4.5.9 **Selection of Pature and grazing management practices for land suited for forestry and grazing.(Class V to VI)**

Pasture and forest management practices	**ClassVI**	**Class VII**
Pasture management		
Seeding	Yes	Yes
Fertilising	Yes	Limited return
Liming,if necessary	Yes	Limited return
Controlling water	No	Difficult
Attention to arrying capacity	Yes	Limited grazing
Rotational Grazing	No	Limited grazing
Deferred Grazing	No	Limited grazing
Fencing	Yes	Yes
Location of watering places	Yes	Yes
Forest management		
Plantation	Yes	Yes
Afforestation	Yes	Yes
Prevention of fires	Yes	Yes
Care in exploitation	Yes	Yes

These lands having moderate to poor ground water

4.Land not suitable for cultivation but well suited for grazing or forestry.

Here ground water is very low..

5.Land suitable for pasture and forestry

This land having the capability to give support to the life of plants but here the soil is eroded a lot, these are very steep slope. Selection of soil, water and farm conservation practices for these land capability classes are shown in the tables 4.5.8 and 4.5.9

Table No:4.5.10.**Area statistics of Land Capability units**

	Area(km^2)	Percentage
Good cultivable land with minor limitations	2.3383	15.15
Moderately good cultivable land with major limitations	0.2395	1.55
Fairly good land suited for occassional or limited cultiv	11.9104	77.16
Land not suitable for cultivation but well suited for grazing	0.2746	1.78
Land suitable for pasture & forestry	0.6731	4.36

8.Land irrigabilityTheme

-Land irrigability classes and their statics identified are as follows

1.Lands that have moderate limitation for sustained use under irrigation.

Here irrigation is through ground water and surface water bodies.In the hot summer surface waterbodies will be dried because these are seasonal tanks. But the ground water is good in these areas.

2. Lands that have severe limitation for sustained use under irrigation.

These lands with moderate ground water but at very high

3. Lands that have marginal for sustained use under irrigation because of very severe limitations

Here most of the bore wells failed. Some of them success with no of attempts. Land is not well productive. Erode lands are observed here.

4.Lands that those not suitable for sustained use under irrigation

Both VI and VII classes of land capability falls under this class. This is totally barren rocky area.

This analysis helps in understanding the peculiar nature of the area and its related problems, which need special attention.

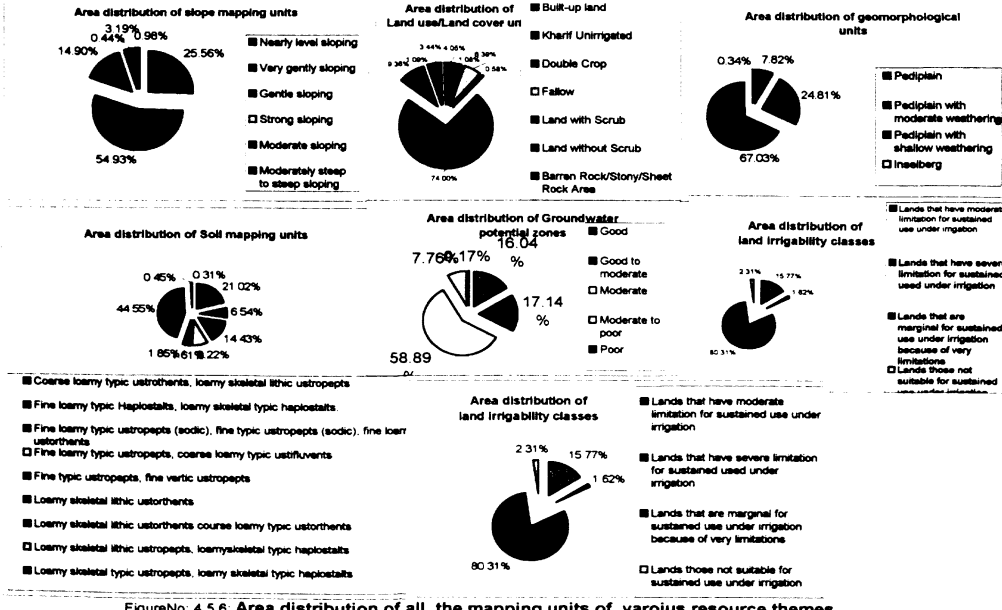
Table No:4.5.11**Area statistics of Land Irrigability units**

Land Irrigability Class	Area(km^2)	Percentage
Lands that have moderate limitation for sustained use under irrigation	2.3383	16.77
Lands that have severe limitation for sustained used under irrigation	0.2395	1.62
Lands that are marginal for sustained use under irrigation because of very limitations	11.9104	80.31
Lands those not suitable for sustained use under irrigation	0.3420	2.31

All the units of the themes are represented in the form of pie charts and as shown in in figure 4.5.6

4.5.5.2 step-2 Study of thematic maps in combination

This step is an extension of the preceding step where in the natural and logical association of parameters of one theme vis-à-vis those of the other are studied with logical explanations, some workable combinations arrived at and odd combinations ruled out. This association analysis helped in better understanding of the cause and effect in respect of not only problems /limitations but also about the potential that exists in the study area. The spatial analysis of the theme maps rules out the possibility of missing any special aspects.It helps in the preparation of Erosion intensity map consequently in the preparation of land and water resource development action plan.



FigureNo: 4.5.6: **Area distribution of all the mapping units of varoius resource themes**

4.5.5.2.A. Preparation of Erosion Intensity zoning map

When the hypsometric analysis shows that a particular watershed is less or moderately or easily susceptible to erosion it has to be compared with its sediment production and has to be checked out for any differences. These differences have to be reexamined by the overlay of landuse/landcover map and slope map. Then the favorable units prone to each class of erosion are demarcated. The final outcome of the above results gives the erosion intensity map which has been categorized as zones of nil to slight erosion, slight, slight to moderate, moderate, moderate to severe and severe erosion.

When the slope is strong and the land use is of degraded scrub land or fallow or sandy area or land with cohesion less material the area is said to be prone to moderate to severe erosion. Whereas for the same land use if the slope is gentles the erosion may be less and can be categorized under slight to moderate erosion. In some cases though the slope is strong , the erosion may be less due to the crop present in the areas with nearly level slope and crop land or silvipasture or forest. Severe erosion may be encountered near the foot of ridges, mountains which are of steep slopes and no vegetative cover at their foot.

Erosion intensity is then prepared using the criteria discussed above. This erosion intensity map is useful for environmental planning for a balanced setup. In table No: 4.5.12 area statistics of various erosion intensity zones of study area are shown. In Fig.(4.5.7) area distribution of these erosion intensity zones are shown in the form of pie chart.This erosion intensity zoning as shown in the Plate No:4.5.3

Erosion intensity zoning map of Malleboinpalli watershed

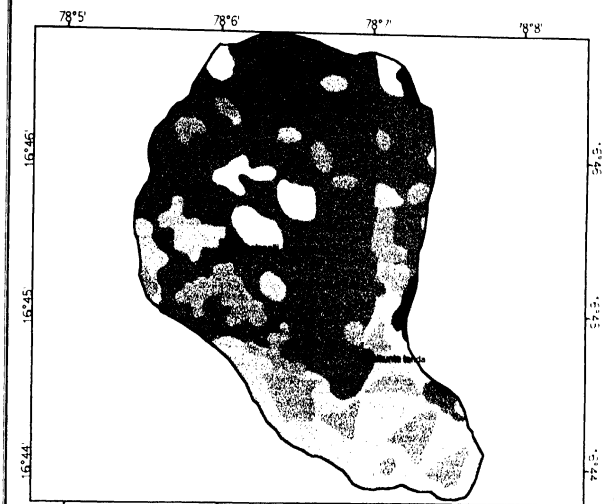


Plate No: 4.5.3

Table No:4.5.12 **Area statistics of Erosion intensity zoning**

Erosion Intensity Zone	Area(km^2)	Percentage
Nil to slight	2.3081	15.33
Slight	3.0904	20.52
Slight to moderate	8.7001	57.77
Moderate	0.7979	5.30
Moderate to severe	0.1087	0.72
Severe	0.0544	0.36

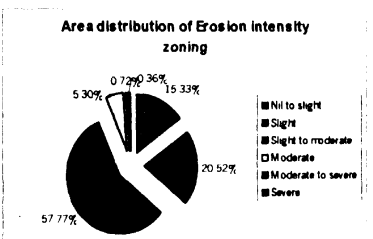


Figure No:4.5.7

4.5.5.3 step-3 Development of decision rules for action plan.

Based on the information available with the consortium of this project on research findings on the suitability of different land use management technologies for given agro climatic conditions, individual combinations of various resource themes have to be recommended for specific activities.

A.Water Resource Development and management

The water resources development and management influence the land resource management to a great deal. Therefore it is necessary to develop, conserve and efficiently utilize the available water in soil profile and

groundwater. Water resource plan is prepared by following the guide lines enumerating suitable site conditions for structures for surface water harvesting, groundwater recharge and exploitation and efficient methods for irrigation.

On finalization of recommendations, the range of resource combinations for each of the alternate recommended practices are identified and then consistently used as guidelines for preparation of site-specific water resources action plan map.

B. Land resources development and Management

During this step ground truth survey plays an important role in this. Spot observations made at Malleboinapalli, Mangalivani kunta thanda, Kotta thanda and Pochammagadda thanda At these spots the land characteristics as mapped in the respective themes maps are recorded along with the present land use. Socio economic data and natural vegetation, which are not reflected in the theme maps, are recorded. The existing crop pattern irrigation practice is also noted. Upon noting all these details a short deliberation made on the optimality of the present landuse especially keeping in view the sustainable production and quality of ecosystem. If the present land use is sub optimal, then a few possible options are suggested for that site to achieve optimality within overall framework of sustainability of production. The threshold limit of a particular parameter vis-à-vis its consideration for a particular recommended land use practice varies from area to area.

Further while making alternate recommendations for land use practice, futuristic considerations such as exploitation of groundwater, if presently not exploited, and possibility of adopting more efficient system of irrigation and water management and other site improvements through soil and water conservation are also kept in view.

Availability of improved varieties of crops, trees, shrubs and grasses and advantages of interdependency of agriculture, livestock and other practices as in case of integrated farming system that have been made available through contemporary research are taken into consideration. Emerged decision rules are shown in the Tables (Table No:4.5.14 to Table No:4.5.18)

Decision rules for land resources action plan for Malleboinpalli watershed

Table No:4.5.13

I. SILVIPASTURE

LANDFORM	SOILFAMILY	GROUND WATER POTENTIAL	SLOPE	LAND USE
Pediplain	Coarse loamy lithic ustorthents ,Loamy skeletal lithic Ustropeptss	Poor to moderate	3-5%	Land with / without scrub Grazing lands
Pediment inselberg Complex	Loamy skeletal lithic ustorthents,Loamy skeletal lithic haplostalts	Poor	3-5%	Land with / without scrub Grazing lands
Residual hills	Loamy skeletal lithic ustorthents coarse loamy typic ustorthents	Poor to nil	>8%	Kharif unirrigated marginally cropped
Pediplain with shallow weathering	Loamy skeletal typic ustropepts,loamy skeletal typic haplostalts	Poor to moderate	3-5%	Land with / without scrub Grazing lands
Pediplain with Moderate weathering	Fine loamy typic ustorthents (sodic),Fine typic ustro pepts(sodic),Fine loamy fluventic ustorthents.	Poor to moderate	3-5 %	Land with / without scrub Grazing lands

Table No:4.5.14

II. FODDER & FUEL PLANTATION

Pediplain	Loamy skeletal lithic Ustorthents	Poor to moderate	3-5%	Land with/without scrub,Mining area
Pediment insel berg Complex	Loamy Skeletal lithic ustorthents Coarse loamy lithic ustochrepts	Poor to nil	5-8%	Land with/without scrub
Residual hills	Loamy skeletal lithic ustorthents	Poor to Nil	8%& above	Barren areas
Pediplain with shallow weathering	Coarse loamy lithic ustorthents, Loamy skeletal lithic ustorthents.	Poor to moderate	Up to 8%	Land with/without scrub Barren areas,Mining areas
Pediplain with Moderate weathering	Loamy skeletal lithic ustorthents,Loamy skeletal lithic haplostalts	Poor to moderate	5-8%	Land with/without scrub Barren areas,Mining areas
Inselberg	Loamy skeletal lithic ustorthents coarse loamy typic ustorthents	Very poor	Above 8%	Barren areas Mining areas

Table No:4.5.15
III. AGROFORESTRY

LANDFORM	SOILFAMILY	GROUND WATER POTENTIAL	SLOPE	LAND USE
Pediplain	Loamy skeletal lithic ustorthents.	Moderate to poor	3-5%	SCA,Fallows
Pediment insel berg Complex	Loamy skeletal typic ustorthents,loamy lithic ustorthents	Good to moderate	Upto 3%	Fallows
Pediplain with Moderate weathering	Fine vertic ustropepts,loamy skeletal typic haplostalts	Good to moderate	3-5%	SCA,Fallows
Pediplain with shallow weathering	Fine loamy typic ustropepts,Fine loamy typic haplostalts	Moderate	3-5%	SCA,Fallows

Note: SCA :Single cropped area

Table No:4.5.16
IV. AGRI-HRTICULTURE

LANDFORM	SOILFAMILY	GROUND WATER POTENTIAL	SLOPE	LAND USE
Pediplain	Fine loamy typic haplostalts,	Moderate	1-3%	SCA
Pediplain with shallow weathering	Fine loamy typic ustorthents (sodic),Fine typic ustro pepts(sodic),Fine loamy fluventic ustorthents	Moderate to good.	1-3%	SCA
Pediplain with Moderate weathering	Fine loamy typic ustorthents,Fine loamy haplostalts	Good	1-3%	SCA
Valley fill Fine loamy typic ustorthents	Fine loamy fluventic ustropepts ,	Excellent to good	1-3%	SCA

Note: SCA :Single cropped area

Table No:4.5.17

V. INTENSIVE AGRICULTURE

LANDFORM	SOILFAMILY	GROUND WATER POTENTIAL	SLOPE	LAND USE
Pediplain	Fine loamy typic haplostalts,Coarse loamy typic haplostalts.	Good to moderate	0-8%	Double crop
Pediplain with moderate weathering	Fine loamy typic ustropepts.Coarse loamy typic ustifluvents.	Good to Moderate	0-8%	Double crop
Pediplain with Shallow weathering	Fine loamy typic ustorthents.Loamy skeletal typic ustorthents.	Good to Moderate	0-8%	Double crop

4.5.5.4 step-4 for Preparation of draft Action plan

The action plan prepared using the decision rules by overlying of thematic maps through GIS / Computer.

Thematic Integration Through GIS

In order to use GIS and computer, the thematic maps are digitized using AutoCAD2000, Coded and stored using ARC/GIS software.Intersection of various theme maps done by overlying one theme over the other progressively and by applying suitable decision criteria as suited to the terrain under study. The final composite units enumerated into various types of homogenous units/ polygons which fit into one or the other combinations of the guidelines arrived at step-3. And assigned to the corresponding recommendation. Accordingly all such homogenous polygons assigned to the same recommendation. In a similar manner all other homogenous polygons assigned to other recommendations as per decision rules.

4.5.5.4.A.Water resources development plan

In semi-arid regions proper harnessing ,exploitation and development are important for their use and to prevent soil erosion are important. An unmanaged watershed posses serious hurdles like tank sedimentation, depletion of groundwater resources, lower agricultural outputs and finally affecting the inhabitants of the watershed.

The streams of this watershed meet only limited water requirement of forming. Major portion of the agriculture land is rainfed. Therefore, management of water resources in the watershed is important for agricultural development. As the rainfall pattern varies within this watershed, the water harvesting structures are required to bring such areas under irrigation. The water harvesting structures such as tanks can be built cheaply using stone-cement-motor lining and thick polythene sheets.

1.Preparation of a map showing sites for soil and water conservation structures.

Water harvesting shall allow an increasing in yield of important crops like paddy and bringing additional area under this crop. Observations on drainage here suggest that the first order streams are still are not disturbed and have good potential. Therefore, ideal conditions exist for water harvesting with suitable planning. Hydrological budgeting is also important

At this juncture, the integrated study is carried out for the conservation of soil and water that led to the preparation of a map showing sites for soil water conservation structures. The thematic maps such as slope map, soil map, drainage map, hydro geomorphology map, erosion intensity map are integrated by overlying one over the other to deduce the information that help in the location of sites for construction of soil and water conservation structure. In the study area activities such as percolation tanks, check dams, raven reclamation structures, rock fill dams, contour and bench terracings and swale are recommended at particular sites are discussed below.

1.Nala Bunds and Percolation tanks

Nala (a natural watercourse) bunds and percolation tanks are structures constructed across nalas for checking velocity of runoff, increasing water percolation and improving soil moisture regime. In fact, both terms are synonyms although used alternately at different places.

Objectives

To facilitate improving of runoff donated by a watershed and to encourage underground percolation of stored water with a view to build up ground water level in the zone of influence of nala bund / percolation tank. To hold the silt flow, which would otherwise reach the multi–purpose reservoirs and reduce their useful life.

Specific site conditions

The feasibility of the site for locating a nala bund depends upon the following technical and economic considerations. The site should be selected in relatively flatter nala reach – the slope net exceeds 2%. As for as possible, the catchment area of the nala bund should be al least 40 hectares. There should be proper site for construction of emergency spillway by the side of the nala bund should be at least 40 hectares. There should be proper site for construction of emergency spillway by the side of the nala bund. For this, the substrata of the nala bund should be hard enough, preferably hard rock, and the nala bed should have soils with adequate permeability. If there are rocky layers at greater depths, they should be designated ones.

Design

The design is based on topographic and storage – height considerations. With these criteria nala bund sections are designed in the light of local norms prescribed for the, structures. In general, the top width of nala bund should not be less then 1.0m. A free board equivalent to one-third of the impounding depth but not less then 1m is provided. The bund section should include provisions on core wall and pebble trench on the line indicated for earthen dams. An emergency spillway of cut outlet type may also be provided depending upon the drainage area.

2. Rokfill Dams

A Rockfill dam – an embankment constructed across a waterway using variable sizes of stones or overburnt bricks – is usually a permeable type of semi – permanent structure, such as a loose / stone checks are generally adopted for gully control.

Objectives

For gully control to slow – down the velocity of runoff and to induce some sedimentation before it leaves for the down stream reach.

1. To facilitate reclamation of board and shallow gullies for agricultural purpose, provides the runoff discharge are with in limits.
2. To stabilize active gullies by encouraging vegetative growth because of favorable moisture situation created by impounding water.

Specific site conditions

Rock fill dams are constructed in places where loose boulders are locally and cheaply available and gullies are not wider than 10m or so. Brick dams usually replace those dams if good quality bricks are cheaply available. In close foundation conditions are highly unstable, gabions are preferred in place of ordinary rockfill dams.

By and large, rockfill dams require better foundation conditions then the earthen dams or earthen gully plugs.

3.Check dams

In general these are constructed on lower order streams up to third order. With medium slopes. They are proposed where water table fluctuation is very high land the stream is influent or intermittently effluent.the watershed area varies widely .

The parameters to be considered are slope , soil cover and thick ness and hydrologically conditions such as rock type, thick ness, of weathered strata, fracture and depth to the bed rock etc. there should be some irrigation wells in the down stream of the proposed structure. This structure serves for dual

purposes, firstly it reduces run off velocity there by minimizing erosion and secondly allows the retained water to percolate and thus resulted in the wells located in the gown stream of the structure.

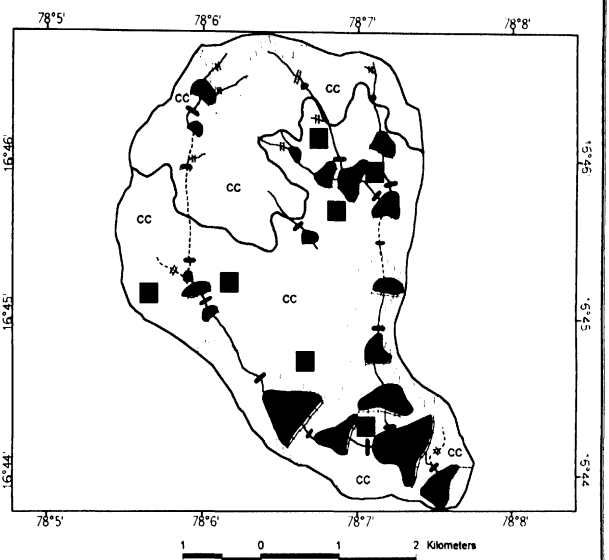
The ideal location for the construction of Raven reclamation structures is first order streams. At the outlets of stream check dam construction serves better in arresting the silt. Check dams are small dams constructed to check the sediment/silt, allowing clear water to the reservoir. These are preferred for steep gradient channels and heavy sediment watershed areas. For economical viability local materials like earth, rock, timber etc can be used for a 10-year life span. A number of water harvesting ponds recharge the ground water and their location will be best suitable immediately upstream to the checkdams.

Construction of swale rejuvenates wastelands especially in hilly regions. Swale is a simple strucure built on raising ridge or small earthen bunds. Swales are infact water absorption beds. In this process run off water flowing on steep slope is intercepted and stagnated for some time to let it infiltrate through the ground. The ideal location for construction of swale is along the 540m,580m contours in the present study area, this is effective in semiarid areas. Contour bunding is made on the land where the slope is not very steep and soil is fairly permeable. Bench terracing consists of a series of platforms having suitable vertical drops along the contour or on suitable graded lines across the general slope of the land. the material excavated from the upper part is used in filling the lower part and small bund is also raised along the outer edge of the terrace. location of sites for construction of alternate contour bunds and bench terraces at suitable intervals across the general gradient of watershed. or along the contour of 560m elevation. Location of sites for soil and water conservation structures is shown in the plate No:4.5.4

2.Efficient irrigation system

In order to avoid water and to increase the extent of irrigation, efficient irrigation systems should be adopted. Popular irrigation systems like Sprinkler

Map showing sites for soil and water conservation structures of Malleboinpalli watershed



LEGEND

- Check dams
- Raven reclamation structures
- Rock fill dams
- Percolation tank
- CC Contour cultivation
- Swale
- 1st order stream
- 2nd order stream
- 3rd order stream
- Bunds
- Alternate contour and bench terracing
- Watershed boundary
- Water body

Database : Drainage map
Slope map
Hydrogeomorphology map
Ground water prospect map

Plate No: 4.5.4

irrigation system and drip irrigation system can be adopted for better water conservation and efficient use of available water.

2.1.Sprinkler irrigation system

Sprinkler irrigation system distributes water spraying it over the fields, stimulating that of natural rain fall. The spray is produced by the flow of water under pressure usually provided by pumping water from wells, tube wells, river, canal and reservoir. It is the best method to use on soils that have steep slopes, undulating or irregular topography and on soils that are to level. It offers adequate distribution of water on rolling or hilly lands nlevelling for surface irrigation is not feasible.

2.2.Drip irrigation.

It is frequent and slow application of water to the base or root zone. It is more useful for horticulture crops more useful in arid and semi-arid regions where water scarcity is higher. This type of irrigation is suitable to plain area, sloping and undulating terrains

3.Recommendations for soil and water conservation

The area recieves 670 mm of of rainfall per year. Soils are of low to medim water holding capacity. This emphasis is to be on harvesting of rainwater and its retention in the watershed. Appropriate measures for conservation and efficient utilization of rain water soil conservation are needed.for this region. Low cost and small structures along with in-situ soil moisture conservation measures are needed. The amount of potential runoff available for harvesting in the watershed is and number of structures across the toposequence are needed. In the watershed openwells are disfunctional and they must be used for rainwater harvesting and recharging to improve the groundwater potential.

By following along with the possible suggested soil and water structure constructions out of these alternate contour and bench terracing, swale, check dam, raven reclamation structures, rock fill dams and percolation tanks construction following suggestions are also made for Malleboinpali watershed.

- Hedging is also suggested for study area. This method not only solves conservation problems but also produces biomass and stabilizes the ground further by root system. Hedging gives excellent results in catching rainwater and improving soil moisture. Hedging is practiced from gently to moderately sloping lands for increasing crop yields. Hedges are grown either in furrows ,trenches or on bunds. They are grown across streams for conserving flood load. when practiced in combination with other methods, they conserve almost all the rainwater in drought prone area.

- Digging of water collection trenches along the contour on the upper part of the toposequence for collection and storage of runoff.
- Dry openwells could be used for recharging.
- Demarcation, stabilization and grassing of Waterways
- Digging of Silt traps in waterways
- Stabilization of bunds
- Plantation of saplings in order to increase strengthens the resistance and stability of bunds
- Grass plantation in the waterways serve both for erosion control and as fodder.
- Human resource development to manage integrated watershed development projects.
  - -Training programmes
  - -Training course on participatory integrated watershed management and in pest management.
  - -A training course on integrated insect and disease management.
  - -Technology extention and public awareness

- To evaluate improved cultivars and cropping systems under farmer conditions.

•Improved cropping systems.

-Trials to evaluate /identify improved cropping systems

•Improved production practices (improved varieties, integrated nutrient, pest, disease management and agronomy)

•Influence of top sequence demonstration of new crops and/ or improved cultivars.

- Observation on Geohydrology of the area through a study of the area on a watershed basis using soil and water runoff recorders

-Treating the entire selected project area as a watershed has been facilitated with the presence of major natural drains in the area.

-Water run off recorders presently help record the amount of water that is being wasted.

-Evaluation of broad bed furrow system of cultivation.

-Continuous monitoring of micro climatic conditions of the region through an automatic weather station.

-Nutrient budgeting

Integrated nutrient management followed in the improved system (sowing on BBF and *Gliricidia* on the bunds) result a balanced budget of nutrients for the cropping system.

-For the application of all the recommendations there is a need of good people's participation.

4.5.5.4.B.Action Plan For Land Resources Development plan

In order to prepare the action plan for land resources development, first the landuse /landcover map is overlaid by slopemap and the favourable units are demarcated and then overlaid by hydro geomorphology map and soil map to derive the composite land development unit for giving the suggestions of action plan to the study area. Each unit has been carefully studied for its resource potential, pressure of potential demand for its utility in the light of its present use. The demand for its optimal utilization is also examined in the light of socio-economic conditions.

By following the Guidelines in accordance with socio-economic conditions following recommendations are suggested for land resources development plan

1. Silvipasture
2. Fodder and fuel wood plantations Silvipasture
3. Agro-forestry
4. Agro- Horticulture
5. Intensive Agriculture
6. Tank foreshore Agriculture
7. Integration of livestock enterprise with alternate landuse system.

Description about the preferred land resource development activities followed is as followed

1.Silvipasture

Silvipasture include combined growing of grasses and tree plants together in a given area to meet the requirements of fodder and its related activities .In olden days silvipasture was limited to forest area. But in the present day context due to increase in population and other several environmental needs, this activity has been recommended.

This system essentially consists of a top feed tree species and grasses or legumes (preferably perennial) as understorey crop. This system is most suited

to marginal dry lands and is preferable where fodder shortages are experienced frequently. Also, to increase fodder supply in rural areas and to improve effective interaction between livestock raising/animal husbandry and crop production, grazing and fodder resources should be created in areas accessible to villages. North side of the village having gentle slope is suitable for the silvipasture mainly.

One effective method will be to introduce silvipastoral land use patterns such as growing of,

- fast growing fodder shrubs and trees in croplands and pasture lands
- pastures in plantations, orchards etc (Horde-pasture)
- pastures in forest tree plantations

2.Fodder and fuel wood plantations

Fodder and fuel plantation is an activity normally recommended in poor soils, any slopes and poor groundwater potential to meet primarily the requirement of fodder for existing livestock and fuel wood for the poor people living in the near by areas. Western, south eastern and south western sides of the Malleboinapalli village small pactches of land are suitable for the *Gliricidia*, *Pongamia*, *Leusena* like plantation for fodder and *Casuarina*, *Acacia* and *Palma rosa* like species for fuel wood. All the suuggested species are drought resistant varieties.

3.Agro- forestry

For imparting stability and providing sustainability to the farming systems in marginal areas, a tree-cum-crop farming system could prove more useful. Intervention of tree/woody crops with annual crops has the following basic features.

- It is often conceived and formulated as improvement of existing land use rather than transformation of landuse. Based on the diagnosis of the present land use

system and the constraints under which farmers are operating, trees and crops are combined

- It can open up new opportunities for raising income levels of small farmers without in any way putting agriculture in jeopardy.
- It puts much emphasis on the sustainability aspects. Trees and shrubs apart from directly providing useful and basic products (wood, fodder, food etc) protect the soil against erosion, provide organic matter to maintain soil fertility, bring up nutrients from deeper soil layers, preventing build-up of pests, weeds and create a more favorable microclimate. Verygentle sloping area above the Malleboinaplli village is more suitable for agro-forestry.

4.Agro-Horticulture

This system plays an important role in that region, where production of annual crops is inefficient. Fruit trees, if suitably integrated, would add significantly to overall agricultural production including food, fuel and fodder, conservation of soil and water and stability to production and income. Dry land fruit trees, being deep rooted and hardy can better tolerate monsoon aberrations than short duration crops, thus can utilize off-season rains and soil moisture from deeper layers.

Varying fruit tree based cropping system–monoculture of a fruit species. Intercropping of fruit tree species with other fruit tree species, fruits with vegetables, fruit species with staple food crops including cereals, legumes, roots and tubers and fruit species with woody forage yielding trees are developed for different agro ecological and socio economic settings in the country.

5.Intensive Agriculture

The double cropped areas with good ground and surface water availability and normally gentle slope areas are recommended for this activity.9.36 % area of total watershed is suggested for intensive agriculture zones. Rainfed crops such as *Millets*, *Sorghum*, *Pigeonpea*, *Green gram* and legume can be successfully grown in these areas. Improved suitble productive

varieties with appropriate Soil water nutrient management (SWNM) options could intensify agriculture. This is suitable for double cropping could be intensified using sequential or inter crops.

6.Tank foreshore Agriculture

Tank irrigation is the major source of production in a semiarid climatic conditions. Since the area is gently undulating tanks are utilizing the appropriate geomorphic configuration of the surface such as ridges which can be used as abutments for creation of tanks or lakes. The foreshore area of tank is recommended for the activity of agriculture and plantation.

7.Integration of Livestock enterprise with alternate landuse systems

Livestock enterprise is the most important in the point of view of income, nutrition and draught power, adequate [production of fodder crops and pastures is fundamental to increased and sustained production of livestock. The alternate landuse systems like silvipasture, agroforestry etc buildup soil fertility, improve soil organic matter, soil structure and water infiltration into the soil. The farm yard manure produced from the livestock enterprise can be ploughed back into the soil to improve the fertility and fodder yields. Livestock based livelihoods provide good income for these people who live poor quality soils and low rain fall conditions. For the land less people like harizans microenterprises such as poultry, goat, sheep and buffalo rearing, vermi composting, nursery raising are suggested

Irrespective of the parameters like landform, soil, slope, etc .the forest blank and degraded forests are recommended for forest gap plantations. Efficient water application systems like drip irrigation system for horticulture and sprinkler irrigation system for crops are recommended. The existing practice of Digging Protection Trenches (DPT) should be popularised on a large scale in highly dissected plateau and denudational hill regions. In the table No:4.5.18 suggested land resource development action statistics are shown

Table NO:4.5.18

Suggested land resources development action	Area(km^2)	Percentage
Silvipasture	1.5478	10.28
Fodder&Fuel plantation	0.2929	1.95
Agro forestry	2.3247	15.44
Agro Horticuluture	7.4463	49.45
Intensive agriculture	1.4091	9.36
Tankforeshore agriculture	0.9867	6.55
Settlements	0.0877	0.58
Water body	0.9642	6.40

In the Fig: (4.5.8) Area distribution of the suggested land resource development action shown in the form of pie chart.

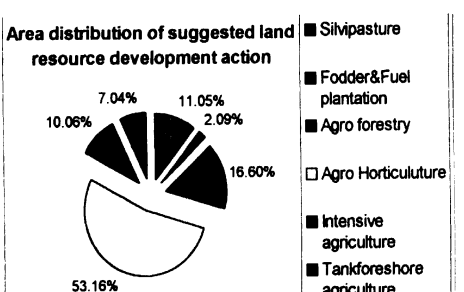
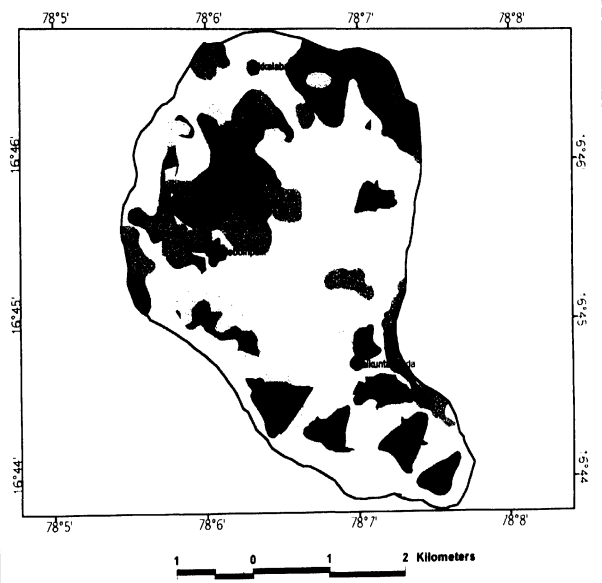


Figure No: 4.5.8

The land resources action plan is shown in the Plate No: 4.5.5

Land resources development action plan map of Malleboinpalli watershed



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LEGEND

- Silvipasture
- Fodder & fuel plantation
- Agro - Forestry
- Agro - Horticulture
- Intensive Agriculture
- Tank foreshore Agriculture
- Water body
- Settlements

Database : Landuse Land cover map
Slope map
Hydrogeomorphology map
Soil map
Land capability map
Land irrigability map
In considering socio-economic database

Plate No: 4.5.5

5. Summary and Conclusions

5.1 Summary

The present study deals with the application of IRS-1D PAN and LISS-III merged data and GIS techniques for the management of Malleboinpalli watershed of Mahaboobnagar district, Andhra Pradesh with an emphasis on the development of action plans for land and water resources for its sustainability. This study is mainly based on the integrated approach, in which the problem of sedimentation because of soil erosion is a focal theme. In order to implement this approach, the input data is derived from IRS-ID satellite imagery, hypsometry, the estimation of runoff potential and sedimentation yield and the analysis of socio-economic data.IRS-1D false color composite, Survey of India Toposheet, Socio-economic survey, recorded data from weather station are the major sources for the data used.

The results are derived from thematic mapping in the form of different layers of Land use/Land cover, hydrogeomorphology, soil, land capability, land irrigability, drainage map and also from hypsometry in terms of erodability charecteristics of the study area are integrated with the estimated sediment yield in accordance with socio-economic data using ARC/GIS 8.1.2 package available at ICRISAT. Erosion intensity zoning map, action plan for land and water resources development and the decision rules for the implementation of developmental activities in the study area are prepared by integrating the results obtained from various stages of this project work.

5.2.Conclusions

Although some achievements have been made in the optimum management of natural resources through watershed approach, the coverage is too small and the overall impact is dismal. The rate at which affected areas are reclaimed and restored for effective production. It is therefore necessary to manage our natural resources both land and water along the soicio-economic resources within the natural boundaries of watershed in holistic manner. Keeping this in view an attempt was made to evolve action plan for the development activities of Malleboinpalli watershed. The Malleboinpalli watershed is

systematically studied for evaluating the natural resources in compatible with the socio-economic factors through which the developmental programmes are outlined.

The study encompasses with

(a) Remote Sensing data acquisition and analysis.
(IRS-ID Pan &LISS-III False color composite)

(b) Drainage morphometry

(c) Hypsometric analysis

(d) Estimation of sediment yield using Garde et al method.

(e) Erosion-Intensity map preparation

(f) Development of Action plan for Land and Water resources on integration of resource data with Socio-economic data base.

Based on the analysis of the results obtained from the above steps (a), (b) and (c) the following conclusions are drawn:

(1) The study on thematic mapping revealed that utilization of remote sensing techniques and Arc/GIS in conjunction with traditional methods have been found a very useful methodology to prepare various thematic maps and tabular information in order to generate sustainable development activities for both land and water resources. GIS through ARC/GIS 8.1.2 package, the latest technology has been demonstrated particularly to bring out the erosion–intensity zoning map and accurate action plan maps.

(2) Malleboinpalli watershed of area 15.05 Sq.km having nearly level to gentle sloping. It is 3rd order drainage basin with stream frequency of 1.19 km^{-2}.Higher the stream frequency the greater is the runoff, consequently more the sediment yield. Shape of the basin is dendritic infers that highly susceptible to soil erosion. Drainage density of the basin is 2.45 km^{-1}.Sediment yield increases with increase of the drainage density of the basin. The bifurcation ratio of the basin is 2.5, which infers that the geologic structures do not disturb the drainage pattern.

The relative relief ratio of basin 3.46 x 10^{-3} km indicates the pressure of potential energy available for the soil erosion process.The relative relief ratio of basin is 0.13 which indicates that the Maleboinpalli watershed is charecterised by a strong relief having wide variety of geologic features. A circularity ratio of 0.7 signifies that the watershed is lower order in Shales and dolomites.

(3) In order to develop action plans for any given watershed and to prepare a map showing erosion intensity zones, the characteristics of erodability must be studied. The hypsometric characteristics developed and compared with the model hypsometric curve finally concluded that the Malleboinpalli watershed is in Monadnock phase i.e., it is the most stable or least susceptible to erosion.

(4) In comparision of the sediment yield of the watershed determine the priority to evolve appropriate conservation management strategy that can be derived out of money-time- effort making scheme. Sediment yield emphasises urgent need of treating the subwatershed to minimise the siltation within the watershed area.

(5) In the combination of land use/land cover and slope map are integrated to derive erosion intensity zoning map with specified decision rules. Inference from this map is study area mainly falls into slight to moderate erosion zoning.

(6) Thematic maps such as land use/land cover, slope, groundwater prospect, soil, land capability, land irrigability drainage network, rainfall data, results of hypsometry, sediment yield of watershed, derived erosion intensity zoning information and socio-economic data pertaining to demography, cultivation and infrastructure facilities like medical, educational, drinking water facilities communication network and other infrastructure facilities have been integrated with one another to form site specific action plan for land and water resources development for each parcel of land in the study area. Decision rules are suggested and graphical representation of action plan are presented in specified chapters of project .

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