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INTEGRATED WATERSHED MANAGEMENT OF MANIMUKTHA SUB-WATERSHED IN VELLAR RIVER, TAMILNADU, INDIA

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Abstract

This study deals with prediction of river discharge and quality of a predominantly rural catchments using simple model in an integrated GIS. River discharge is being predicted by using the SCS-CN (Soil Conservation Service) runoff Curve Number model by the export coefficient model. Numbers of attempts have been made by many scientists to demonstrate the usefulness of Remote sensing techniques for rainfall – runoff study. Several new models and approaches for rainfall – runoff have been developed, from Soil Conservation Service to small watersheds by comparing the simulated and actual hydrograph for both gauged and ungauged situations. Ecosystem services are increasingly recognized as important assets for sustainable development, since a close interdependency exists between ecosystem services and groundwater. On the one hand, these services depend directly on the functioning of ecosystems such as wetlands, forests, lakes and coastal areas which derive freshwater for their functioning from sub-surface water, including groundwater. Groundwater recharge is a portion of rainfall that infiltrates into the soil and percolates into the soil mantle and reaches the groundwater only after vegetation interception, evaporation from ground and runoff. In the present study, attempts are made to develop a suitable GIS based model for delineating groundwater potential zones of a watershed by integrating different thematic layers, which have direct control on groundwater occurrence. Land use is the factor on which human beings employ land and its resources including agriculture, urban development, grazing, logging and mining. Remote sensing has proven to be a cost effective tool for studying changes used Satellite data and GIS were integrated with a spatial hydrological model to evaluate the impacts of land.

Keywords: SCS-CN model - Remote sensing and integrated GIS - Groundwater recharge

INTRODUCTION

Water an indispensable constituent of everyday life, is widely distributed in nature so that it may be available quickly and easily. Water systems being life supporting factors, a healthy water system is essential not only for a robust economy but also for a good quality of life. History has demonstrated that almost every action, we undertake take on the land, centres around water systems, for better or for worse. The increasing population, rapid urbanisation and the advent of modern technologies have increased the usage of water tremendously. Hence, there is a need for an early rationale and practical policy for the development of water resources, water usage and conservation for the growth of the country. Watershed is a hydrologic unit and the term is defined as “the total area of land above a given point on a waterway that contributes runoff to the flow at that point” (**Hanson 1954**). The watershed characteristics, such as size, shape, slope, drainage, vegetation, geology, soil, geomorphology, climate and land use pattern, affect the disposal of water from the watershed. A watershed is an area of land that drains into a common water body, such as a river or lake. Watershed can also be also known as a basin or a catchment area and has an ecosystem with complex interacting natural components. Human activities have a direct influence on the quality and quantity of surface water, groundwater and other natural resources in the watershed.

The watershed management aims to protect the proper utilisation of all land, water and natural resources of the watershed. The concept of watershed management is as old as the concepts of crops grown under irrigated conditions and this has led to the development of tanks/reservoirs for increasing the production to meet the demands of the overgrowing population. Remote Sensing and Geographical Information System (GIS) are playing vital roles in the field of hydrology, water resources planning and development. The integration of socio -economic data with Remote Sensing and GIS aids to underline the causes and needs for watershed planning and management. The integrated Remote Sensing and GIS technology is an excellent tool for monitoring. The land degradation, the changes in the use of land as well as soil and water resource changes over a period of time.

SCOPE AND OBJECTIVES OF THE STUDY

For the development of a country, its natural resources must be conserved, utilized and managed properly. This can be achieved efficiently by considering watershed as a basic workable unit and it has been proved by a number of researchers (**David A.Eash 1994, Greene and Cruise 1995**). Watersheds have assumed importance for preserving the ecological balance between natural resource development and conservation, particularly in the fragile and heterogeneous erosion-susceptible hilly ecosystems. The necessary information for resource planning on watershed basis includes the agro-ecological characteristics, resources constraints, and the potential of the watershed for sustainable development. So, watershed management is required for planning, developing, managing and conserving the water and land resources besides efficient irrigation scheduling. Water management may be carried out efficiently by knowing surface and sub-surface runoff from the watershed. Nowadays researchers emphasize the need watershed-based water resource planning and development for successful management practices. The objectives of the present study are:

- To assess the quantity of surface water and groundwater resources of the study area.
- To delineate the areas favorable for groundwater recharge zones in the study area.
- To analyze the nature and extent of Land Use/Land Cover Changes for the past 25 years (1972 – 2007) and to identify the major components that influence the changing trend in land uses in the study area.

STUDY AREA

A sub-watershed of Manimuktha watershed, Vellar Basin, Tamil Nadu, India was considered for this study shown in index map (**Figure 1**). The All India Soil and Land Use Survey Organization in the codification of the micro watersheds as part of the sub catchment 4C1A2 (**AISLUS 1990**). The study area (4C1A2a) extends between North Latitudes 11° 28' and 11° 42' and East Longitudes 79° 14' and 79° 27' with an area of 272.89 km^2. The main water sources are the tanks and dug wells, apart from rainfall. The study area comprises of Virudhachalam, Kammapuram and Ulundurpet blocks. The Virudhachalam rain gauge station provides the data for this study. The maximum rainfall of 1472.7 mm (1996) and the minimum rainfall of 538.1 mm (1982) have been recorded in this area. This watershed experiences tropical monsoon climate without much variation in temperature, humidity and evaporation throughout the year. The monthly maximum and minimum mean temperature ranges between 34º C and 20º C in the month of May and January respectively. The analysis rainfall recorded for 28 years (1980-2009) indicates that the average rainfall of the study area is 1100 mm. The central part of the area gets drained by Manimukthanadhi. The southeastern part of the area gets drained by Vellar Basin. Numerous tanks and streams drain the northern part of the area. The rainfall generally, occurs at the time of low-pressure, depressions of cyclones, during the northeast monsoon period.

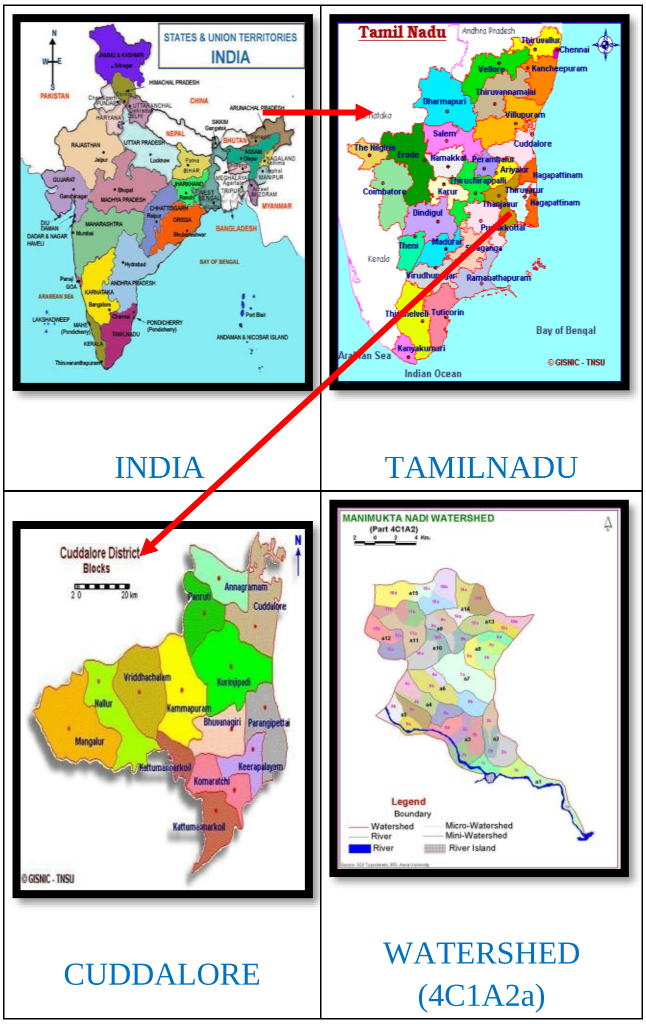

Figure 1 Index map of the Study area

DATA BASE

- Topographical data from Survey of India (SOI) toposheets (1971-72) of scale 1:50,000 58 M/2, M/5, M/7 and 58 M/10.
- Remote sensing data: The IRS IC-LISS III Satellite data (Indian Remote Sensing Satellite of series IC with Linear imaging and Self-scanning sensors) of scale 1:50,000 were collected from Institute of Remote Sensing, Anna University, Chennai. The path 101 and 102, row 65 of IRS IC LISS III and PAN merged for various dated May 1996 and June 2007 to use the Land use/Land cover maps of the study area.
- Daily rainfall data (1980-2009) from the Virudhachalam rain gauge station were used.
- Soil Atlas Report of Cuddalore and Villupuram district, Tamilnadu. (Source: Soil Survey & Land use Organisation, Department of Agriculture, Coimbatore, Tamilnadu).
- Base Map and Drainage Map: The base map was prepared from the SOI Topographic sheets 58 M/2, 6, 7 and 58 M/10 of scale 1:50,000. The base map depicts watershed

boundary, union boundaries and village boundaries, roads and railways and the drainage map was prepared in the same manner.

- Hydrological Soil Map: The soil map was prepared using the satellite imagery.
- Land Use /Land Cover Map: The imagery was interpreted to identify different land uses/land covers to delineate their boundaries. The interpreted map was subsequently updated through ground truth verification using Arc GIS 9.1.

METHODOLOGY

The proposed methodology flow chart for "Integrated Watershed management" of present study is presented in **Figure 2**.

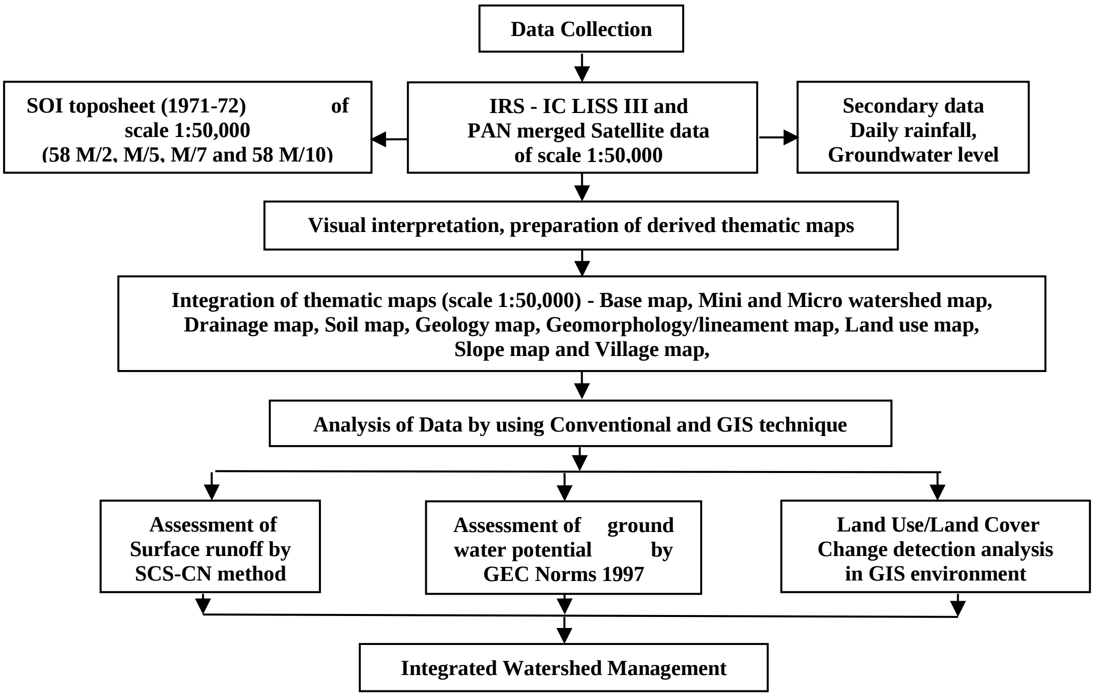

Figure 2 Flow chart of "Integrated Watershed management

i. Surface runoff assessment by GIS based SCS - CN method

The Soil Conservation Service (now called the Natural Resources Conservation Service) Curve Number (SCS-CN) methods (SCS, 1972) are the results of exhaustive field investigations carried out by several early investigators. It is one of the most popular methods for computing the volume of surface runoff for a given rainfall event from small agricultural, forest, and urban watersheds. The method is simple, easy to understand and apply, stable, and useful for ungauged watersheds. The primary reason for its wide applicability and acceptability lies in the fact that it accounts for most runoff producing watershed characteristics: soil type, land use/treatment, surface condition, and antecedent moisture condition. This method takes into account the land use, hydrological soil cover and antecedent moisture conditions for predicting the yield from the basin. The area of Land use/Land cover and hydrological soil types are used in the SCS method and it is used for calculating runoff from the watershed.

ii. Groundwater estimation by GEC Norms - 1997

The Groundwater Estimation Committee (GEC) was constituted by the Government of India in 1997 to recommend methodologies for estimation of the groundwater resource potential in India. It was recommended by the committee that the groundwater recharge should be estimated based on groundwater level fluctuation method. The methodology for groundwater resource estimation by Water level fluctuation method for monsoon season and Rainfall infiltration factor method for non-monsoon season is applied for estimating the gross groundwater potential of the study area.

iii. Land use/land cover change detection

- Survey of India topographical map sheets of scale 1:50,000 and interpreted satellite maps of IRS – IC, LISS III data and LISS III with PAN merged data for the year 2003 and 2007.
- The image elements, correlated with ground truth verification and tonal variation representing the different classes were marked on the hard copy image 1972, 1996, 2003 and 2007. The functionality of GIS namely; overlay analysis was applied to identify the areas of changes taken place.

RESULTS AND DISCUSSION

Surface water assessment and Validation:

The SCS – CN model is widely used to estimate runoff volume from the daily rainfall depths. Land use/Land cover, Hydrological soil cover and AMC factors were considered for computing and predicting the runoff from the sub-watershed. In the GIS based SCS-CN model, the curve number (CN) and daily rainfall values were used as inputs to compute daily runoff. For various curve numbers, the runoff was estimated for different AMC conditions. According to the weighted curve number, the runoff potential for the mini-watersheds were classified as “Moderate”, “High” and “Very high” and mini-watersheds wise surface runoff potential shown in **Figure 3** was prepared. The study area is an ungauged watershed and there is no continuous recorded data on runoff. But in order to validate the proposed rainfall-runoff model using SCS-CN method, the available observed peak extreme event data have been utilized (Source: Public Works Department, WRO, Virudhachalam).

The observed maximum flood discharge values for some selected storm events were collected and regressed with corresponding estimated SCS-CN model values. The runoff depths are computed for each rainfall event. Although there are 17 input values of rainfall events for the year 1982-2007, only 10 peak runoff depths are computed and for the other rainfall events, the runoff volume is computed as 0 due to intensity of rainfall less than 0.3S, where S is the retention parameter. The correlation statistics and test of significance for all the relationships, rainfall Vs runoff (observed and computed) show that the model (**Veernna et al., 2009**) is efficient in runoff prediction. For the validation of the proposed rainfall-runoff model, a statistical analysis using student’s t-test has been carried out for observed and computed runoff.

Groundwater estimation using GEC Norms - 1997

Quantitative assessment of groundwater recharge is an important issue in groundwater development. Estimation of groundwater recharge requires proper understanding of the recharge and discharge process and their interrelationship with geological, geomorphological, soil, land use/land cover and climatic factors. **Figure 4** shows Groundwater potential zones with observation wells of the study area (GEC Norms) and also the identification of groundwater recharge zones of the watershed were delineated as ‘Very high’, ‘High’, ‘Moderate’ and ‘Poor’ as shown in **Figure 5**.

Land use/Land cover change detection

The major common Land use and Land cover categories, such as forestland, wasteland, settlement, water bodies (river and tanks), agriculture land, are identified and mapped from the SOI topographic sheets of the year 1972 and it was compared with those prepared from the satellite imageries (IRS 1C LISS III), and IRS LISS with Pan merged data. The drawn maps for the years 1996, 2003 and 2007 have been digitized and rasterised. The work has been carried out using Arc GIS 9.1 software to create land use coverage and the LU/LC are identified. The LU/LC changes of the study area are shown in **Figure 6** and the Trend in LU/LC change detection of the study area are given in **Figure 7**.

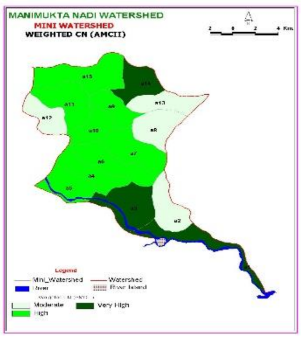

Figure 3 Mini-watersheds wise surface runoff potential

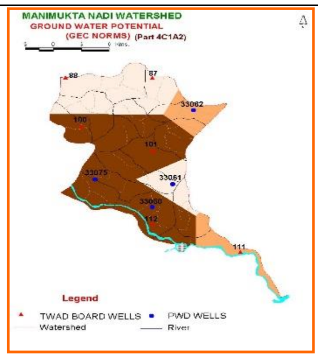

Figure 4 Groundwater Potential zones with Observation wells (GEC Norms)

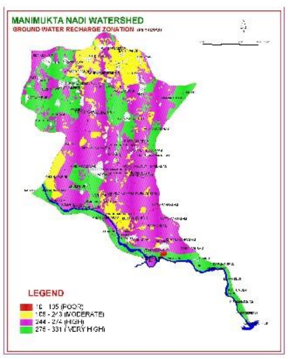

Figure 5 Groundwater recharge zonation

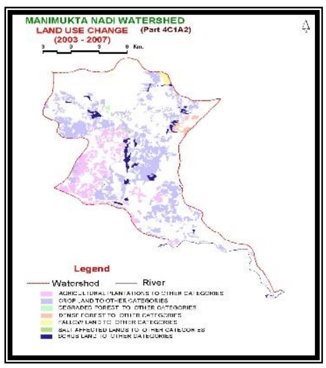

Figure 6 Land use/Land cover change

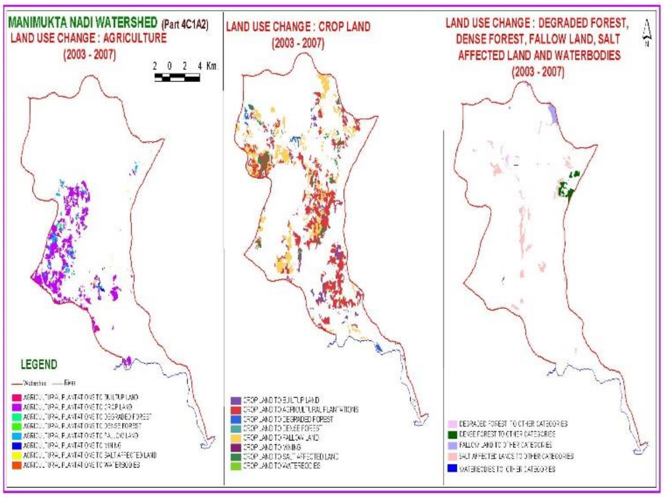

Figure 7 Trend in Land use/ Land cover change detection of the study area (2003-2007)

CONCLUSIONS

The watershed management is a comprehensive interrelated approach to watershed and natural resources management. It examines and recognizes the needs of all resources - soil, water, air, plants, animals, and people - in relation to local social, cultural, and economic factors. The integration of Remote Sensing data and application of GIS provides a powerful tool for efficient watershed management.

The following conclusions are arrived:

- In this study, all the important components of watershed management on multi-dimensional approach were attempted such as Surface water, Groundwater, Soil resources, Change detection of LU/LC, Socio-economic aspects of the study area, which must be considered for efficient watershed management.
- GIS based SCS-CN model can be used effectively to estimate the runoff from the ungauged watersheds and the appropriate soil and water conservation measures can be planned and implemented.
- The three classes of surface water potential zones of the study area categorized as given below:

Very High	- **21.58 %**	- **58.889** Km^2
High	- **50.22 %**	- **137.038** Km^2
Moderate	- **16.83 %**	- **45.934** Km^2
River	- **11.37 %**	- **31.035** Km^2

- Four classes of groundwater recharge potential zones have been identified in the study area as:

Excellent	- **10.03 %**	- **27.362** Km^2
Good	- **57.62 %**	- **157.246** Km^2
Moderate	- **5.31 %**	- **14.503** Km^2
Poor	- **27.04 %**	- **73.786** Km^2

- Majority of the VES curves - combination of Q type curves, and all the 50 VES curves - multilayered geoelectrical sections, and also the groundwater potentials of Cuddalore sand stones are very good.

- Agricultural land area has decreased, considerably, because of human interference. Before implementing any sort of land use practices, in the study area, in future, it is necessary to consider the existing socio-economic scenario.
- Remote sensing is quite useful for land use and land cover mapping and it is found that the main impact, of random growth of settlement, is on the surrounding agriculture land.

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