REMOTE SENSING AND GIS APPLICATIONS IN WATERSHED MANAGEMENT

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1.0 Introduction

Watershed is defined as the land area from which water drains to a given point. In other word watershed is an area from which runoff, resulting from precipitation flows past to a single point into a stream. It includes all the areas, which collect rain or stream water and discharges it through a common outlet as its minimum elevation (the watershed mouth). The area of the watershed is generally determined from the topography or watershed divide. The divide represents the highest elevation points along the watershed perimeter. The management of watershed in point of view of hydrology is easily possible. Hence, we can arrive to another definition of watershed i.e. "watershed is a Manageable Hydrological Unit". Watershed management is the management of all the natural resources of drainage basin to protect, maintain or improve its water yields. It implies the proper use of all land and water resource of a watershed for optimum production with minimum hazard to natural resources.

A watershed may be of few hectares as in case of small ponds to thousands hectare in case of rivers. All watersheds can be divided into smaller watersheds. An each watershed or sub-watershed is an independent hydrological unit.

2.0 Remote Sensing and GIS in Watershed Management

Survey technique and method to be adopted in integrated survey are critical in making information available to the planners on time. With the introduction of remote sensing, both from aerial platforms and space platforms, a better means of faster, efficient and reliable data acquisition is now available. The remotely sensed data have a unique character. It is the same database, which is utilised by various thematic specialists and hence is of multi-disciplinary utility. For example, in watershed management, information is needed on soil (characteristics, distribution and potentialities), land use, environment and susceptibility of the area to natural disasters, etc. Most of this information can be extracted from the same database. The remotely sensed image constitutes an 'integrated' view of the landscape with all its features manifested together.

Remote sensing derived information will have to be merged or integrated with the conventional database using suitable software. Geographical database can be built from data derived from various sources such as topographical map, thematic maps prepared from remote sensing data or ground surveys, cadastral maps, census reports, etc. These diverse data system can be input into the computer system and converted into consistent map format. Using suitable software, specific integration and analyses of these data can be performed to derive useful outputs in the form of maps or statistical data. Geographic Information System (GIS) serves as an efficient system of compilation, classification, storage, synthesis/analyses or retrieval of relevant information of spatial and non-spatial origin.

Availability of reliable and up to date information, both of spatial and non-spatial origin is crucial to success of any watershed development project. The watershed management information data base consist of;

Remote Sensing Data

It is useful to generate various thematic or resource maps by the digital and/or visual interpretation of remote sensing data obtained from spacecraft or aircraft and using data obtained from collateral sources.

Collateral Data

It consists of topographical maps usually available on 1:50,000 and 1:250,000 scales and available thematic maps/reports of the study area.

Base Maps

Generated by digitising the watershed and sub-watershed boundaries and other cultural features within the watershed using topographical maps.

Meteorological Data

Consist of climatic data, such as rainfall, temperature, wind direction, etc.

can be derived from Digital Elevation Model (DEM). The DEM can be created by using interpolation technique of contour map.

Hydrologic Cover Complexes

A combination of a specific soil and a specific vegetative cover is referred to as a soil cover complex and a measure of this complex can be used as a watershed parameters in estimating runoff.

Hydrologic Soil Groups

The hydrologic properties of a soil or a group of soils are an essential factor in the hydrologic analysis of watershed data. Soils can be classified according to their hydrologic properties if considered independently of watershed slope and cover. Four major soil groups are recognised for the primary classification of watershed soils :

- Group A (Low runoff potential)

  Soils having high infiltration rates even when thoroughly wetted, considered chiefly of sands or gravel that are deep and well to excessively drained. These soils have a high rate of water transmission.

- Group B (Moderately low runoff potential)

  Soils having moderate infiltration rates when thoroughly wetted, chiefly moderately deep to deep, moderately well to well drained, with moderately fine to moderately coarse texture. These soils have a moderate rate of water transmission.

- Group C (Moderately high runoff potential)

  Soils having slow infiltration rates when thoroughly wetted, chiefly with a layer that impedes the downward movement of water, or of moderately fine to fine texture an a slow infiltration rate. These soils have a slow rate of water transmission.

- Group D (High Runoff Potential)

  Soils having very slow infiltration rates when thoroughly wetted, chiefly clay soils with a high soil swelling potential; soils with a high permanent water table; soils with a clay pan layer at or near the surface; and shallow soils over nearly impervious materials. These soils have a very slow rate of water transmission.

Table 1. Hydrologic Soil Groups and Their Characteristics

Group	Minimum Infiltration rate mm/hr	Soil Characteristics
A	8 to 12	Deep sands, deep losses aggregated soils
B	4 to 8	Shallow losses and sandy loams
C	1 to 4	Many clay loams, shallow sandy loams, soils low organic matter, soils high in clay
D	0 to 1	Soils of high swelling percentage, heavy plastic clays and certain saline soils

Hydrologic soil group map can be created by reclassifying soil map. The soil map can be derived by using physiographic association method or by using Remote Sensing in conjunction of ground truth. In physiographic association method, Aspect map, land use Map and elevation map are crossed and then the composite map is reclassified as soil map.

Vegetal Cover

Vegetal cover influence water movement behaviour significantly it affects the infiltration rate, soil erosion evapo-transpiration, sediment production etc.

Remote sensing is a very effective tool to get this information. FCC can be divided into various land use/cover by using supervised classification. NDVI gives the vegetation intensity, which can also be used to assess the vegetal status of land.

Drainage

This is another important factor, which influences the watershed behaviour. A large drainage density (The drainage density is defined as length of drainage channel per unit area) creates situation conducive for quick disposal of runoff down the channels. In watershed, where drainage density is small overland flow is predominant. Length of the channels and area of the watershed can be determined in GIS environment Fig. 1.

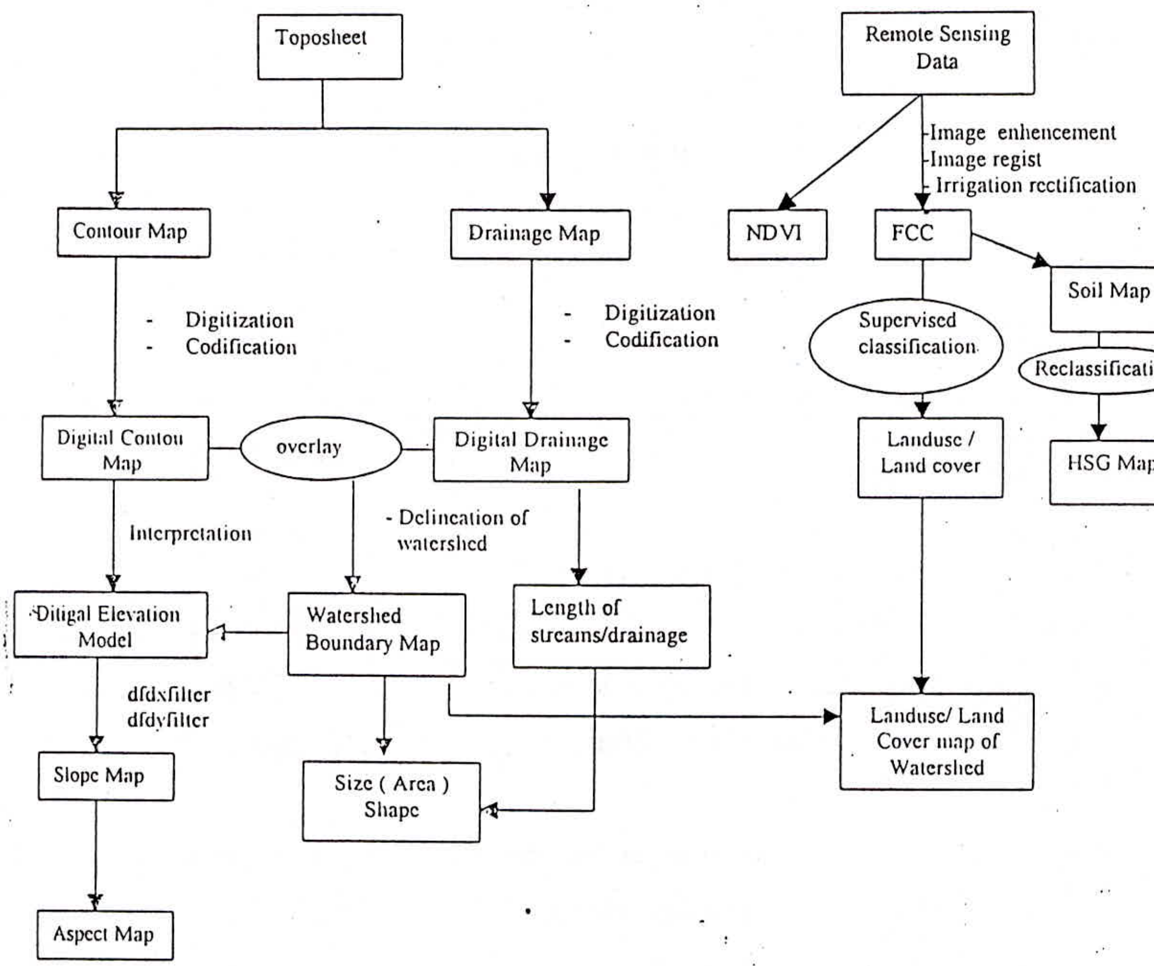

Fig. 1 Steps involved to determine various watershed characteristics by using GIS and Remote Sensing

Climate

Climate parameters like precipitation, humidity, temperature, wind etc. affect the functioning of watershed. Intensity, duration and frequency greatly affect the watershed hydrology. These parameters are the input for hydrological models in GIS environment.

Time of Concentration

This is defined as time which takes for water to travel from the most distant point of a watershed to the watershed outlet.

Following formulae is generally used to determine the time of concentration.

$$Tc = \frac{L^{1.15}}{7700H^{0.38}}$$

Where,

Tc = Time of concentration, hr.

L = Length of the watershed along the mainstream from the watershed outlet to the most distant point. This can be calculated through distance calculation in GIS environment.

H = Difference in elevation between the watershed outlet through the most distance ridge in ft. This can be calculated through DEM.

However, differences in elevation due to overfalls, rapids, or other sudden drops should be subtracted from H. Various watershed characteristics can obtained from Remote Sensing, Toposheets and Base map (Table 2).

Table 2. Important Watershed Characteristics - Data Required for Planning and Management

Sl. No.	Charac-teristics	Required for	Parameters and indices	Source and means to obtain
1.	Size	Average precipitation, runoff and sedimentation (rate & volume); production potential; work; investment	Standard area unit	Topo-maps, aerial photo, satellite image
2.	Shape	Runoff and sedimentation (rate and volume); operational schedule and conveniences	a) Geometric form b) Shape index c) Compactness coefficient d) Form factor	From map by using respective formulae or available regression equation
3.	Relief	Runoff and sedimentation (rate & volume); treatment details; surface storage; operational convenience	a) Mean elevation b) Average slope c) Geometric unit d) Total relief e) Relief ratio	Topographic maps , aerial photo, satellite images and block diagrams (using respective formulae)
4.	Drainage	Runoff and Sedimentation; channel treatment; surface storage; operational convenience	a) Drainage pattern b) Stream order c) Drainage density d) Main stream length	Topographic maps and aerial photos, satellite image (using respective formulae)
5.	Geology	Runoff and sedimentation; ground water; construction material, structure foundation	a) Type of rocks b) Stratigraphy	Geological maps, reports, satellite image interpretation combined with field surveys
6.	Soils	Runoff and sedimentation; treatment details,; production potentials; proper land use; operational convenience	a) Soil series and soil phases b) Morphological, physical and chemical properties c) Hydrological soil groups d) Soil moisture regime	Soil survey reports and maps; field surveys
7.	Climate	Runoff and sedimentation treatment details; proper land use; production potential; operational convenience	a) Precipitation b) Temperature c) Humidity d) Wind velocity e) Sunshine hours	Meteorological resources, reports and other publication
8.	Surface condition and land	Runoff and sedimentation; ground water; soil moisture	a) Present land use condition b) Natural vegetation	Revenue records; forest working plans and reports;

	use/cover	treatment details; operational convenience	c) Canopy percent d) Hydrologic cover condition e) Existing tanks f) Communication	toposheets, aerial photos, satellite images and ground surveys
9.	Ground water	Runoff; production potential; operational conveniences; treatments details	a) Water table concurs or depths b) Quality of ground water	Ground water survey reports; existing wells
10.	Social and legal status	Treatment details; operational convenience; watershed sufficiency/ deficiency in food, fodder & fuel; animal and manpower; acceptance; follow up and maintenance of programmes	a) Human and animal population b) Land holding and tenure laws c) Existing management level d) Land and water development legislation	Census report, revenue records, district legislation

4.0 Action Plan Map Generation

Based on the integration and manipulation of data it would be possible to demarcate Area for action plan in the watershed, such as:

- Locations for integrated soil and water conservation.
- Waste lands for appropriate reclamation measures.
- Locations for land use revision.
- Locations for ground water development/exploration.
- Locations suitable for agricultural or industrial development, etc.

Since our understanding of the integration among the different parameters of the complex social, physical and natural system is limited to suggest a single best course of action; it is necessary to recommended several alternative plans for action. These alternatives are to be developed within the framework of optimal natural resource utilisation in a suitable manner.

The following case studies can be performed by using the integrated approach of remote sensing data as primary input for resource map generation and further integration in GIS environment in the watershed management studies.

- Integrated Natural Resources Survey of Watershed.
- Watershed Analysis for Soil Conservation Planning and Land Productivity Assessment.

- Watershed Categorisation Following Multi-criteria Approach Using Satellite Stereo and Multispectral Data
- Site Suitability Analysis for Water Harvesting Structures on Watershed Basis.
- Monitoring the Impact of Treated Watershed.

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