WATERSHED MANAGEMENT - A REMOTE SENSING AND GIS APPROACH

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***Abstract**:* Watershed management decision making is a complex process. Cooperation and communication among federal, state, and local stakeholders is required while balancing biophysical and socioeconomic concerns. The public is taking part in environmental decisions, and the need for technology transfer from public agencies to stakeholders is increasing. Information technology has had a profound influence on watershed management over the past decade. Advances in data acquisition through remote sensing, data utilization through geographic information systems (GIS), and data sharing through the Internet have provided watershed managers access to more information for management decisions. In the future, applications incorporating hydrologic simulation models, GIS, and decision support systems will be deployed through the Internet. In addition to challenges in making complex modeling technology available to diverse audiences, new information technology issues, such as interoperability, Internet access, and security, are introduced when GIS, simulation models, and decision support systems are integrated in an Internet environment.

Index Terms – Watershed Management, Information Technology, Internet, Geography ,Geographical Information Systems (GIS), , Spatial Analysis.

I. INTRODUCTION

Watershed management decision making is inherently complex. It requires cooperation with federal, state, and local bodies while incorporating biophysical and socioeconomic process. Traditionally, transfer of information was unidirectional, typically from state of federal government agencies to landowners. in today's society, bidirectional communication is imperative, expanding the role of land management agencies in the decision making process. However , federal and state budgets are increasingly constrained, and new techniques' for information transfer need to be employed. Watershed management decisions are further complicated by both the complexity of the issues and those processes creating the problems. the difficulties in spatially representing and quantifying biophysical and socioeconomic process require that management decisions be based on imperfect information. Water is life, in all forms and shapes. This basic yet profound truth eluded many of us in the second half of the 20th century. Water professionals and scientists around the world are ringing the alarming bells of an impending water crisis. Yet attempts to address some of the issues or to offer partial solutions met with limited success. The ever-growing population and concomitant expansion of agriculture and industry have placed increasing demand on the limited water resources.

"There is a water crisis today. But the crisis is not having too little water to satisfy our needs. It is a crisis of managing water so badly that billions of people and the environment
– suffer badly" (World Water Council, 2000)

II. OBJECTIVE

The objectives of the study are as follows:-

- To Study the process of watershed management system through Remote Sensing and GIS.

III. SCHEMATIC REPRESENTING PROCESS IN THE GLOBAL HYDROLOGICAL CYCLE

The interdependence and continuous movement of all forms of water on the earth and in the atmosphere is known as hydrologic cycle. The hydrologic cycle can also be defined as the processes and pathways involved in the circulation of water from land and water bodies (sea, rivers, lakes etc.) to the atmosphere and back again.

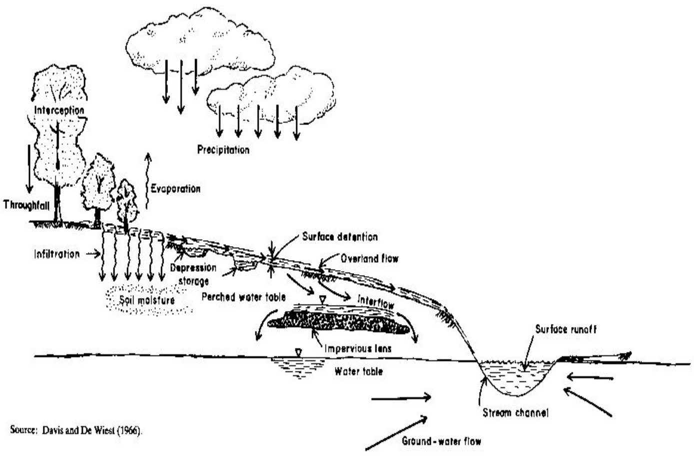

Figure 1

IV. DEFINITION OF WATERSHED

It is defined as the land area from which water drains to a given point. In other words watershed is an area from which runoff, resulting from precipitation, flows past a single point into a stream. Since water is drained off to a given point. 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".

Figure 2 **Delineation of Watershed**

Watershed can be delineated using topographic maps with help of drainage lines which represents the ridge and valleys

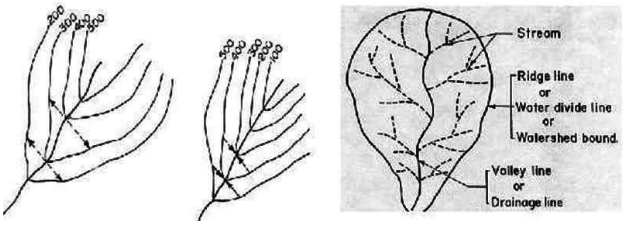

Figure 3 (a) Ridge Line (b) Valley line (C) Ridges and Valleys in a watershed.

Table 1: List of watershed characteristics, how to derive them and why it is required.

S. No.	Characteristic	Required for	Parameters and indicators	Source & means to obtain
1.	Size	Average precipitation ,runoff and sedimentation (rate & volume ,production ,potential, work and investment)	Standard area unit	Topo-maps, aerial photo, satellite image
2	Shape	Runoff and sedimentation (rate & volume),operational schedules and convenience	a) Geometric form b) Shape Index c) Compactness coefficient d) Form Factor	From map by using respective formulae or available regression equations.
3.	Relief	Runoff and sedimentation (rate & volume),treatment details surface storage, operational convenience	a) Mean elevation b) Average slope c) Geomorphic Units 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 details surface storage, operational convenience	a) Drainage pattern b) Stream Order c) Drainage density d) Main Stream length	Topo maps and aerial photos, satellite image using respective formulae
5.	Geology	Sedimentation & runoff, ground water , construction material ,structure foundation	a) Type of rocks b) Stratigraphy	Geological maps, reports , Satellite image interpretation combined with field surveys
6	Soil	Runoff and sedimentation , treatment details , production potentials, proper, landuse, operational convenience	a) Soil series and soil phases b) B) Morphological, physical and chemical, properties c) C) Hydrologic soil groups d) Soil moisture regime	Soil survey reports and maps, field surveys
7.	Climate	Runoff and sedimentation , treatment details , production potentials, proper, landuse , operational convenience	a) Precipitation b) Temperature c) Humidity d) Wind Velocity e) Sunshine hours	Meteorological recourse, report and other publications
8.	Surface condition & landuse	Runoff and sedimentation , treatment details , production potentials, proper, landuse ,operational convenience	a) Present landuse condition b) Natural vegetation c) Canopy percent d) Hydrologic cover condition e) Existing tanks f) Communications	Revenue records, forest working plans and report , toposheets, aerial photo ,satellite image and ground survey
9.	Ground water	Runoff , treatment details , production potentials, operational convenience	a)water table contour or depths b) Quality of ground water	Ground water survey reports, existing wells
10 .	Social & Legal status	Treatment details, operational conveniences, water shed sufficiency deficiency in food ,fodder & fuel ,animal and manpower ,acceptance ,follow –up and maintenance of programmes runoff and sedimentation	a) Human & animal population b) Land holdings and tenure laws c) Existing management level d) Land and water development legislation	Census reports, revenue records, district legislations.

What is Watershed Management?

Watershed management means the rational utilization of land and water resources of watershed for optimal production with minimal hazard to natural resources. Watershed- based management is the most effective way to enhance water quality and natural resources, protect critical terrestrial and aquatic habitat, prevent soil erosion, and sustain resource-based economic activities while concurrently managing the pressures of an increasingly urbanized landscape.

V. IMPORTANCE OF WATERSHED MANAGEMENT IN THE PRESENT SCENARIO

Watershed management or protection implies the proper use of all land and water resources of a watershed for optimum production with minimum hazard to natural resources. The different objectives of a watershed management programme are:

A. To control damaging runoff
B. To manage and utilize runoff for useful purposes
C. To control erosion and effect reduction in the sediment production
D. To moderate floods in the downstream areas
E. To enhance ground water storage wherever applicable
F. Appropriate use of land resources in the watershed and thus developing forest and fodder resources

Adoption of conservation farming practices to improve agriculture, controlled grazing to keep the pastures productive, water management for irrigation and drainage and all other types of erosion control measures could be each watershed are different and program for their management could also be different. Inappropriate land use practices in the upstream catchment leads to accelerated soil erosion and consequent silting up of reservoirs. Watershed management in thus an integral part of any water resources project. The prioritization of watershed i.e. which needs to be paid attention is based on sediment yield potential so that the treatment would result in minimizing sediment load into the reservoir.

VI. ROLE OF REMOTE SENSING AND GIS

Remote sensing and GIS play a very important role in watershed management. Due to synoptic coverage, entire watershed can be mapped for various geo-spatial databases as listed in table 1 earlier, using remote sensing data and GIS data. Using GIS techniques, these database can be converted to information about landuse/ landcover mapping and change detection, runoff estimation, soil erosion study, site suitability analysis for rain water harvesting, watershed prioritization etc. can be effectively carried out using GIS techniques. Further, due to availability of high spatial resolution satellite data like IRS P6 Panchromatic (5.8 m), IKONOS (4 & 1 m), CARTOSAT (2.5 m) can be used to accurately map landuse/landcover classification & location of soil and water conservation structures. Digital elevation model (DEM) can be derived using the interpolation of contour maps derived from topographic maps or analysis of stereo satellite data such as CARTOSAT or TERRA ASTER. Now present time QuickBird data is also availabe(0.6 m). DEM provides the perspective view of watershed. Using DEM, slope, aspect, flow direction, flow accumulation and flow length maps can be derived, which can be integrated to into the other geo-spatial databases to derive suitable sites for various watershed conservation measures etc.

VII. WATERSHED CHARACTERISATION USING REMOTE SENSING AND GIS

Various watershed characteristics required for watershed management can be derived using remote sensing and GIS. A brief description is given here.

A. Size : This characteristic determines the quantity of precipitation received, retained and drained off. Small watershed behaves differently from the large ones in terms of the relative importance of various phases of the runoff phenomenon. This can be delineated using the topographic maps (first instance), by the concept of ridge and valley lines (as explained previously), based on the position of the watershed outlet. The area of the watershed can be digitized using GIS functions. This boundary can be verified with the help of the aspect map, which can be derived using DEM, using any standard GIS function.

B. Shape : Watersheds have many shapes e.g. it could be rectangular, square, palm shape, oval etc. The shape controls the length, width ratio which affects the runoff characteristics. For example, the longer the watershed, the greater is the time of concentration. The longer the time of concentration, the greater the time available for the water to infiltrate, evaporate and get utilized by vegetation. Shape of watershed is the output of watershed boundary delineated in GIS environment.

C. Slope : This is a very important characteristics of a watershed. It affects the time of concentration, infiltration opportunity time, runoff and soil loss. Slope can be derived in GIS environment using DEM. Using the watershed boundary, the weighted average slope of the watershed can be derived in a GIS environment.

D. Drainage : This is another important factor which influences the watershed behavior. A large drainage density (length of drainage channels per unit area) creates situation conducive for quick disposal of runoff down the channels. In watershed where drainage density is less overland flow is predominant. Length of the channels can be derived using the digitized drainage in GIS environment.

E. Geology : Nature of parent rocks, features, faults, extent of outcrops and weathering can be known by interpretation of satellite data and also ground truth collected. It is possible to understand the ground water recharge areas also, using the geomorphology and analysis of other relevant information.

F. Soils: Major soil groups of the watershed and their hydrologic groupings. Physical and chemical properties as required, which can derived using the mapping of physiographic units from the satellite data and combined with the field verification of soil profiles dug in each of the physiographic units.

G. Climate: Precipitation, its annual, seasonal and monthly distribution, forms of precipitation, storm pattern, rainfall intensity and duration are to be collected from metrological stations. Their spatial distribution can be understood in a GIS environment. Other climatic factors include air temperature (min. and max.), soil temperature, evaporation, relative humidity, wind velocity, wind direction, and solar radiation are also required for understanding the hydrology of the area. If necessary, these data can be converted into spatial data using GIS functions.

H. Surface condition and Landuse : Existing land use and cover conditions including forest lands, range lands, cultivated lands, waste lands, habitations and miscellaneous uses can be derived using interpretation of satellite images and also ground truth. Forest type and area under each classification (like stock forest, degraded forest, scrub etc. hydrologic conditions, legal status (reserved, demarcated, protected, un demarcated, protected, unclassified, private, community etc.) can be obtained from remote sensing images. Extent of agricultural lands, land capability classification, area under each class and subclass, area under irrigation, major crops, rain fed area along with crops grown, orchards and their extent etc. can be obtained by interpretation of remote sensing data and collection of ground truth.

I. Ground Water : Source of ground water and ground water levels during pre-monsoon and post-monsoon conditions are necessary to understand extent of ground water-recharge and possible quantity available for utilization.

J. Economic Data : General economic conditions of the people, important professions and their dependence on watershed resources, markets and marketing practices, return from forests including fire wood, and minor forest products, return from range land, grazing value, returns from cultivated land including irrigated and rain fed etc.

K. Texture: Textures provide important characteristics for the analysis of many types of images including natural scenes, remote sensing data and biomedical modalities. The perception of texture is believed to play an important role in human visual system for reorganization and interpretation. Pervious method of analysis for accomplishing texture classification may be roughly divided into three categories : statistical, structural and spectral.

VIII. WATERSHED MANAGEMENT

Concept of Watershed Management: The concept of Watershed Management is shown pictorially with various aspects which need to be considered, as the sentiments of the people living within the watershed area have to be given utmost priority in implementing various watershed management schemes.

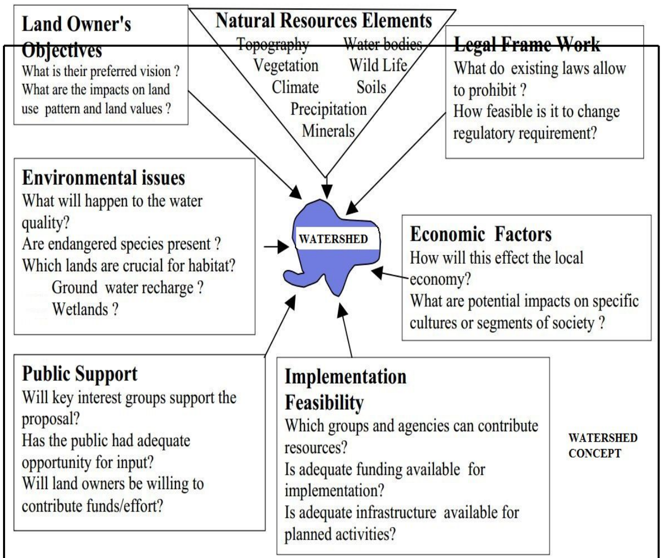

Figure 4

IX. AIMS OF WATERSHED MANAGEMENT

A. To control damaging runoff.
B. To control erosion & sediment yield.
C. To moderate flood.
D. To enhance ground water storage.
E. To use land resources optimally.
F. To protect, conserve, & improve lands.
G. To develop & mange water resources.

X. PROBLEMS IN WATERSHED MANAGEMENT PROGRAMME

A. Professional problems

- Identifying existing problems

- Convincing concerned authority
- Defining local requirements
- Selecting proper management practice
- Designing & implementation

B. Social problems

- Low awareness
- Reluctance to change existing practices
- Poor participation of locals
- Feudal social structure

C. Financial problems

D. Psychological problems

XI. ROLE OF GEOINFORMATION TECHNOLOGY

Satellite data have been extensively used in many watershed All India Soil and Landuse Survey, Ministry of Agriculture, Government of India. Space borne multispectral data have been used to generate baseline information on various natural resources, namely soils, forest cover, surface water, ground water and land use/ land cover and subsequent integration of such information with slope and socio- economic data in a Geographic Information System (GIS) to generate locale-specific prescription for sustainable development of land and water resources development on a watershed basis.

XII. CONCLUSION

Watershed Management has assumed urgency for planned development of land and water resources and to arrest land degradation process to preserve environment and ecological balance. Decision support to such management planning requires scientific knowledge of resources information, expected runoff and sediment yield, priority classification of watersheds for conservation planning, monitoring of watershed for environmental impact assessment and technologies of GIS for data base creation, scenario development and appropriate decision making. Remote sensing technique is ideally suited to evolve such a management strategy. Scientific basis of this approach is explained.

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