TRAINING COURSE
ON

# HYDROLOGICAL MODELING AND GIS

## (MAY 26 TO JUNE 06, 2014)

FOR

UNFAO & Ministry of Energy and Water, Afghanistan

LECTURE NOTE
ON

# WATERSHED MANAGEMENT USING REMOTE SENSING AND GIS

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# WATERSHED MANAGEMENT USING REMOTE SENSING AND GIS

## INTRODUCTION

Watershed is the smallest hydrological unit used for planning and management of natural resources. It exhibits spatial heterogeneity of the various physical and chemical processes occurring in the hydrologic system. Land and Water are vital watershed resources and are the basis of the existence of mankind. Management of these resource including its conservation and utilization is of crucial importance. The watershed management refers to the process of guiding & organizing, land and other resource usage in a watershed ensuring the sustenance of the resources. In many countries across the globe, land and water are subjected to varying degrees and forms of degradation due to the pressure of the growing population, increased demand for food, fodder and fuel wood and intensive industrial activity. Watershed management requires these resources to be properly utilized and developed.

The main principles of watershed management are as under:

a. Utilizing the land according to its capability.
b. Maintaining adequate vegetative cover on the soil for controlling soil erosion, mainly during rainy season.
c. Conserving maximum possible rainwater at the place where it falls, on arable land by contour farming.
d. Draining out excess water with a safe velocity to avoid soil erosion and storing it in ponds for future use.
e. Preventing erosion in gullies and increasing ground water recharge by putting *nullah* bunds and gully plugs at suitable intervals.

## OBJECTIVES OF WATERSHED MANAGEMENT

Watershed management implies the wise use of soil, water and vegetation of a watershed to obtain optimum production with minimum hazard to the natural resources. The basic objective of watershed management is to solve the problems of soil and water not in terms of anyone resource but on the basis that all the resources are interdependent and must therefore, be considered together. Watershed management aims to improve the standard of living of common man by increasing his earning capacity through offering all facilities required for optimum production. The overall objectives of watershed management programmes may be outlined as under:

a. Recognition of watershed as a proper unit for judicious utilization and development of all lands. The land should be treated according to the requirement and by adopting suitable methods that will control soil erosion, conserve water, improve farm income, encourage wildlife and prevent flood damage to the lands.

b. Prevention and retardation of floods through construction of reservoirs and other impounding structures.
c. Provision of adequate water supply for agricultural, Industrial and domestic purposes.
d. Abatement of soil, water and air pollution.
e. Creation of recreational facilities with more lakes and streams suitable for picnic, camping, swimming, boating and fishing.
f. Utilization of natural resources for improving agriculture and allied occupation or industries in order to improve socio-economic conditions of local people.

The objectives of managing a watershed should be clearly and precisely defined. Different objectives call for different techniques, manpower, inputs and approaches for proper planning and execution. The monitoring and evaluation criteria vary according to the objectives. It is therefore essential that the main objective should be identified so that a correct approach can be developed.

**Role of Remote Sensing and GIS Technology**

The Remote Sensing of natural resources and Geographical Information can be utilized to evolve a system for monitoring, assessment and management of natural resources. Remote Sensing (RS) data and Geographical Information System (GIS) play a rapidly increasing role in the field of hydrology and water resources development. Although very few remotely sensed data can be directly applied in hydrology, such information is of great value since many hydrologically relevant data can be derived from remote sensing information. One of the greatest advantage of using RS data for hydrological modeling and monitoring is its ability to generate information in spatial and temporal domain, which is very crucial for successful model analysis, prediction and validation. However, the use of RS technology involves large amount of spatial data management and requires an efficient system to handle such data. The GIS technology provides suitable alternatives for efficient management of large and complex databases.

Image data have been used as a primary source of natural resources information in thematic mapping which in turn is utilised in various hydrological studies. The remote sensing data provides synoptic view of a fairly large area in the narrow and discrete bands of the electromagnetic spectrum at regular intervals. The space borne multispectral data enable generating timely, reliable and cost effective information on various natural resources, namely surface water, ground water, land use/cover, soil, forest cover and environmental hazards, namely waterlogging, salinity and alkalinity, soil erosion by water etc. For many hydrological purposes, remote sensing data alone are not sufficient and need to be merged with data from other sources. Hence a multitude of spatially related (i.e. geographic) data concerning topography, rainfall, evaporation, vegetation, geomorphology, and soils have to be considered. Also of interest are social and economic data related to where the demand is for water for urban and industrial supplies, irrigation, etc. In addition, technical data are required, such as locations and types of tubewells, rain

and river gauges, etc. GIS provides an extremely useful technology for considering the interaction between spatially distributed resources.

Geographic Information System (GIS) a technology to store, manipulate and display spatial and non-spatial data, has gained much attention in many areas that requires spatial description and manipulation of information. The GIS technology provides suitable alternatives for efficient management of large and complex data base. Spatial statistics and grid design capabilities of GIS can improve the modelling effort and aid in reliability assessment. The GIS data base for watershed modelling will include details on landuse, water use, soils, hydrological characteristics, drainage network and digital elevation model. These type of data related to catchment characteristics can be accurately and more easily handled in GIS. Further these type of data being in digital form can be easily updated and modified. In the early days GIS were mainly used as hydrological mapping tools.

Remote Sensing data and Geographical Information System play a rapidly increasing role in the field of land and water resources development and management. Remote Sensing technology has demonstrated its capabilities to provide information on natural resources such as crop, land use, soils, forest etc on regular basis. One of the greatest advantages of using RS data for hydrological modeling and monitoring is its ability to generate information in spatial and temporal domain, which is very crucial for management of natural resources. Satellite remote sensing technology coupled with conventional methods can be used to generate information on the current status and utilization potential of land and water resources. The process of management and development of natural resources coupled with this information is done by looking at different watershed characteristics. The success of planning for developmental activities depends on the quality and quantity of information available on both natural and socio-economic resources.

**Application of Remote Sensing Technology**

Remote sensing data obtained from the satellites in the form of an image can be used as a primary source of natural resources information in thematic mapping which in turn is utilized in various hydrological studies. The remote sensing data provides synoptic view of a fairly large area in the narrow and discrete bands of the electromagnetic spectrum at regular intervals. The space borne multispectral data enable generating timely, reliable and cost effective information on various natural resources, namely surface water, ground water, land use/cover, soil, forest cover and environmental hazards, namely water logging, salinity and alkalinity, soil erosion by water etc. For many hydrological purposes, remote sensing data alone are not sufficient and need to be merged with data from other sources. Airborne laser-based terrain mapping (ALTM), in conjunction with detailed mapping through digital camera, and traditional photographic survey provide valuable information on terrain characteristics in terms of topography, detailed land use/ cover, geological features, etc. for implementation of water resources infrastructure projects. Hence a multitude of spatially related (i.e. geographic) data

concerning topography, rainfall, evaporation, vegetation, geomorphology, and soils also need to be considered. Social and economic data related to demand of water for urban and industrial supplies, irrigation, etc is also need to be merged with the spatial and temporal information thus obtained from the remote sensing data. For this purpose, technical data, such as locations and types of tubewells, rain and river gauges, etc are required. GIS provides an extremely useful technology for considering the interaction between spatially distributed resources.

**Major Field of Remote Sensing Application in Watershed Management**

Space-borne spectral measurements can be used for (i) rainfall estimation, (ii) snow and glacier studies leading to snow melt runoff forecasting, (iii) irrigation water management and identification of potential irrigable lands, (iv) watershed management (v) disaster management (vi) Precision farming (vii) water quality assessment, and (viii) ground water assessment and prospecting, planning and implementation of developmental activities, infrastructure development, disaster management and environmental monitoring.

**Rainfall Estimation**

Rainfall is one of the most important processes in the hydrological cycle and is also one of the most difficult to monitor. Since late 1960s, many researchers have attempted to derive techniques for the estimation of rainfall from the visible and infrared imagery provided by meteorological satellites. Manual, interactive and automatic methods have been developed for the estimation of rainfall at a number of temporal and spatial scales, and these have been applied in many different areas and situations with varying degree of success.

**Snow and Glacier Studies**

Snow and glacier investigations and snow melt runoff forecasting are yet another area where satellite remote sensing imagery can provide information on retreading glaciers as well as possible potential snow melt run-off. Seasonal and short term (weekly) forecasts of snowmelt runoff are being provided for some of the Indian river basins and elsewhere in the world.

**Irrigation Water Management**

Irrigation projects can be evaluated using multispectral measurements at regular intervals. The anticipated increase in irrigated area, equitable distribution and crop productivity have been studied in some of the major irrigation command projects in India such as centrally sponsored Command Area Development (CAD) scheme and National Water Management Project.

**Watershed Management**

Inappropriate land use practices in the upstream catchment leads to accelerated soil erosion and consequent silting up of reservoirs. Watershed management is thus an integral part of any water resources project. Space borne multispectral data can be 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 socioeconomic 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.

**Disaster Management**

In the event of natural calamities like drought, flood and cyclones, that adversely affect the water security, space technology has made substantial contributions in different phases such as preparedness, prevention and relief. The Earth Observation satellites, which include both geostationary and polar orbiting satellites, can provide comprehensive, synoptic and multi-temporal coverage of large areas in real time and at frequent intervals, which can prove to be valuable tools for continuous monitoring of atmosphere as well as surface parameters related to droughts and floods. While Geo-stationary satellites provide continuous and synoptic observations over large areas on weather including cyclone tracking. Polar orbiting satellites have the advantage of providing much higher spatial resolution images that could be used for detailed monitoring, damage assessment and relief management at the watershed scale.

**Precision Farming**

Remote Sensing can play a vital role in precision farming. Data on spatial variation of both soil and crop parameters collected through aerial and satellite observation platforms can be used to map cropping area, to establish understanding of plant vigor and fertility status, to determine land levelling, and to monitor pest and disease outbreak. GIS based management system can be effectively utilized in all aspect in precision farming, i.e., i) to develop a data base of the soil properties and yield in paddy field, ii) to update database using global positioning system (GPS) and data collected from the field, iii) to evaluate the relationship and correlation between crop yield and soil properties, and iv) to create user Friendly Graphic User Interface (GUI) for farm Applications.

**Watershed Management Using RS and GIS**

The three main components in watershed management are land management, water management and biomass management. Land Management like terrain, slope, formation, depth, texture, moisture, infiltration rate and soil capability are the major determinants of land management activities in a watershed. Water characteristics like *inflows* (precipitation, surface water inflow, ground water inflow) *water use* (evaporation, evapotrasnpiration, irrigation, drinking water) *outflows* (surface water outflow, ground

water out flow) *storage* (surface storage, ground water storage, root zone storage) are the principal factors to be taken care of in sustainable water management. Major intervention areas for biomass management are Eco-preservation, Biomass Regeneration, Forest Management & Conservation, Plant Protection & Social Forestry, Increased Productivity of Animals, Income & Employment Generation, Activities, Coordination of Health & Sanitation. The management of these components requires the careful representation of watershed boundary and identification of the priority areas for optimal utilization of watershed resources. RS and GIS can help in elucidating the available resources.

**Watershed Delineation**

Digital elevation model (DEM) prepared from the digitized contours can be used for delineation of watershed boundary. While considering the watershed conservation work, it is not feasible to take whole area at once. This calls to divide the watershed in small units that is sub-watershed, by considering its drainage system. The sub-watershed at smaller scales are more feasible to mange because of the spatial homogeneity.

**Drainage Network Delineation**

The automatic generation of stream network based on the DEM is possible using the GIS techniques. The identification of river network can help in building the management plan for water resource development. Also the areas vulnerable to water quality deterioration can be identified by superimposing the point and not-point sources of pollution.

**Land Capability Classification**

Land capability is the basis of watershed management programs. The basic principle of soil and water conservation is to use the land according to its capability and treat the land according to its needs. Land capability classification indicates the hazards of soil and water erosion, waterlogging etc. and these hazards limit the use of land for particular purposes only. For studying land capability classification beside the climatic factors, parameters related with watershed characteristics are required. For such parameters GIS is one of the best available tool. The spatial information based on the watershed characteristics such as slope and soil type, the land can be classified under different land use capabilities.

**Problems Associated with watershed management**

The major problems associated with management of watershed are listed below:

- Flooding
- Unstable Slopes / Land Slides
- Erosion from Denuded Land
- Deficient Water Supplies/Drought
- Sedimentation of Navigation Tracks
- Watershed Prioritization

The solutions to these problems require large spatial as well as temporal information, which can be better addressed using the modern GIS and RS technology.

**Flooding**

The objective of most watershed plans is to prevent flooding, whether at a local drainage level or on a regional stream level. Estimation of design flood for hydrological design of various water resources structures, particularly for medium and major water resources schemes, has been one of the most active areas of research for the hydrologists and water resources engineers. The important geomorphological parameters which represent the linear, areal and slope aspects of the catchement are required to be evaluated. Application of GIS package provides an efficient and accurate means for the evaluation of these characteristics. The use of RS and GIS technology has already been reported in several flood studies. Which require a careful possible interaction of:

- Flood Control Reservoirs,
- Construction of Levees
- Flood Plain Management
- Re-vegetation(Denuded Areas)

The RS can help in assessment of flood affected areas and GIS technology can help in locating the possible locations for construction of flood control reservoirs. Also flood plain management activities can be implemented in an efficient way using RS and GIS technology. The Peak Rate of Runoff using watershed characteristics can be computed by overlaying the various layers.

**Unstable Slopes / Land Slides**

The unstable slopes especially in hilly terrain poses a major threat in mountainous watersheds, also the fragile soil always creates a danger of land slide and erosion. Such studies require a regular health check up of the watershed. In absence of proper technology this task not only requires lot of money to gather information for management of such watersheds, but it is very difficult to collect information on high altitude. The result of such problems lies in the use of satellite images, the temporal information generated from two different time images can be analyzed to know the possible loss of soil during landslides.

**Erosion from Denuded Lands**

The process of soil erosion is complex. Several studies have been reported for the estimation of soil erosion based on the geomorphological characteristics using RS and GIS technique. Information obtained using remote sensing techniques can help decision makers to detect the change on land surface and prepare resources maps accurately in less time and cost. GIS, in other hand, helps model, analyze and solve complex problems. Further management options of erosion control structures can be implied and effect of these structures can be studies using the GIS based modeling techniques.

**Deficient Water Supplies/Drought**

Water is a major input in agriculture and its relative availability in different agro climatic zones calls for efficient water resource development plans. There is, close relationship between water scarcity and reduced food productivity, mainly applicable to rain fed areas of the country. The water resource development on watershed basis has shown encouraging results in mitigating the water need in water stressed agriculture. Major institutional, policy and technological initiatives are therefore, required to ensure efficient, socially equitable and environmentally sustainable management of water resources towards achieving the water security along with food security for the country. Water scarcity areas can be easily identified with the help of GIS and storage reservoirs and water harvesting structures can be planned in water deficit areas. The drought management plan can be prepared by overlaying the spatial information related with water availability and soil moisture information.

**Watershed Prioritization**

As the condition of sub-watersheds may not similar, they can be prioritized for conservation work. The task can be achieved by overlaying of spatial information over the watershed boundary for prioritizing the critical areas vulnerable to soil erosion and other forms of land degradation. GIS can help in analyzing the priority areas in a cost effective manner. Also the treatments are repetitive in nature without actually implementing them on the actual area for analyzing the effect of particular land management practices.

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