Outline

- Geographic Information System (GIS)
- Digital Elevation Model (DEM)
- Integration of RS, GIS, DEM and Hydrological Models
- Remote Sensing in Watershed & Water Quality Models
- Case Study: AV SWAT for Malaprabha
- Conclusions

Integration of RS, GIS, DEM and Hydrological Models

- Hydrological model is a good tool for understanding and managing phenomena related to hydrological processes
- RS provides essential inputs for hydrologic processes
- GIS provides a Platform for Simulation of Hydrological Model.
- RS, GIS & DEM combined with mathematical models provide a convenient platform for handling, compiling, and presenting large amounts of spatial data essential to river basin management and the use of GIS makes the models accessible to a broad range of users.
- GIS technology is often linked to information and knowledge management systems and is readily available to most governmental entities, a high degree of transparency in decision making for stakeholders can be achieved.

Introduction

- Models vary in many ways
  - Time step, scale, whether the model simulates single event or on a continuous basis, and how different components are computed.
  - For example, for NPS (Non Point Source) modeling, the only feasible option is to incorporate a continuous approach. Loadings from a watershed area need to be represented over time, not just for a single event or single point.
Components

- Rainfall Estimation
- Rainfall-runoff modeling
  - SCS CN Method
- Routing of the runoff
  - St. Venant’s equation
- Sediment yield
  - USLE
- Chemical transport
  - Nitrogen and Phosphorus

Rainfall Estimation

- Delineating the boundaries of areas likely to get rain
- Assessing basin rainfall totals over time
- Assessing extreme events of rainfall
- Assessing the climatology of rainfall distributions
- Forecasting of rainfall especially in regions with sparse data

Rainfall Estimation

- Most commonly used Wavelengths for rainfall studies are
  - Visible (VIS) : 0.5 – 0.7 μm
  - Infrared (IR) : 3.5 – 4.2 μm and 10.5 – 12.5 μm
  - Microwave (MW) : 0.81 to 1.55 cm
  - NOAA, GOES, GMS, Meteosat, INSAT

Rainfall-Runoff Studies

- RS data is used either as a hydrologic model input or for the determination of model parameters
- Need to develop structures of hydrological models, which are amenable to the spatial and temporal resolution provided by RS data
- SCS CN depends on the hydrological soil group and land use description
  - RS provides these inputs

Watershed Planning and Management

- Physiographic measurements from RS
  - Watershed area, size and shape, topography, drainage pattern and landforms
  - Wavelengths: 0.6-0.7 μm & 0.8-1.1 μm
- Stereoscopic attributes for basin topography
- Information on drainage network/ pattern
  - Lithology and structure of the basin
  - Stream orders, stream length, stream frequency, bifurcation ratio, stream sinuosity, drainage density and linear aspects of channel systems

Watershed Planning and Management

- Watershed degradation of soil and land resources
- SRS for mapping of soil degradation involving salinity/alkalinity, water logging, erosion, desertification, shifting cultivation, excessive permeability, wet lands etc
- Growth of desertification, flood damage area and encroachment of ravines on agricultural lands
Erosion Features from RS

- Erosion potential associated with changes in vegetation and litter
- Changes in soil type and soil color
- Occurrence of dendritic soil patterns
- Occurrence of sand dunes
- Definition between bare soil or rock and vegetal cover

Soil Salinity

- Causes for soil salinity problems
  - Rising water tables due to recharge from irrigation canals and watered fields
  - Naturally poor groundwater quality
  - Rock weathering
  - Salinity effects in irrigated areas
    - Stunted crop growth, poor and patchy germination, crop stress, death of crop, encroachment of halophytic species, bare soils with efflorescence and salt crust development

Watershed/ Water Quality Models

- STORM
  - Storage, Treatment, Overflow Runoff Model
- SWMM
  - Storm Water Management Model
- DR3M-QUAL
  - Distributed Routing, Rainfall, Runoff Model – Quality
- CREAMS/GLEAMS
  - Chemical, Runoff, and Erosion from Agricultural Management Systems/ Groundwater Loading Effects of Agricultural Management Systems model
- EPIC
  - Erosion/Productivity Impact Calculator

Watershed/ Water Quality Models

- SWRRB
  - Simulator for Water Resources in Rural Basins
- PRZM
  - Pesticide Root Zone Management model
- AGNPS
  - Agricultural Non-Point Source pollution model
- SWAT
  - Soil and Water Assessment Tool

Primary inputs for all these models can be obtained from
- Remote Sensing
- Digital Elevation Model (DEM) and Geographic Information System (GIS)

Soil and Water Assessment Tool (SWAT)

- SWAT is a river basin, or watershed scale model (Neitsch et al., 2002)
- Physically based & Continuous time model
- To predict the impact of land management practices on water, sediment and agricultural chemical yields in large complex watersheds with varying soils, land use and management conditions over long periods of time.
- Due to its easy adaptability to situations with limited data availability, it has become very popular even to study the climate change impact on a river basin scale
SWAT - Advantages

- Watersheds with little monitoring data (e.g. no stream gauge data) can be modeled
- Relative impact of alternative input data (e.g. changes in management practices, climate, vegetation, etc.) on water quality or other variables of interest can be quantified
- Computationally efficient. Simulation of very large basins for a variety of management strategies can be performed without excessive investment of time or money.
- Enables users to study long-term impacts. Many of the problems currently addressed by users
  - Involve the gradual buildup of pollutants
  - Impact on downstream water bodies

SWAT - Inputs

- **Weather Related Parameters**
  - Mean monthly weather data for weather generator
  - Max temperature
  - Min temperature
  - Daily Solar radiation reaching the earth surface
  - Daily rainfall
  - Relative humidity
  - Wind velocity
  - Latitude of the sub basin
  - PET values
  - Daily or hourly precipitation

- **Soil Properties**
  - Detailed spatial soil map
  - Bulk density
  - Percentage sand, silt & clay
  - Available water holding capacity
  - Depth of individual soil layer in the horizons
  - Plant uptake compensation factor
  - Soil cover index

- **Topography**
  - DEM
  - Drainage network

- **Vegetation**
  - Detailed landuse-landcover map
  - Plant uptake compensation factor
  - Water stress that triggers irrigation
  - Land management practices

- **Irrigation**
  - Timing of irrigation (month/day)
  - Irrigation amount (depth of irrigation in each HRU)

- **Channel Characteristics**
  - Top width of channel at full bank
  - Depth of channel at full bank
  - Slope of the channel
  - Length of channel
  - Manning n for the channel
  - Muskingum X
  - Weighing coefficient – 1. Fraction of storage time constant for full bank
  - Weighing coefficient – 2. Fraction of storage time constant for full bank
  - Effective hydraulic conductivity of channel
  - Revap coefficient
  - Bank flow recession constant
  - Fraction of overland flow

SWAT - Inputs – contd...

- Topography
  - DEM
  - Drainage network

- Vegetation
  - Detailed landuse-landcover map
  - Land area index
  - Plant uptake compensation factor
  - Water stress that triggers irrigation
  - Land management practices

- Irrigation
  - Timing of irrigation (month/day)
  - Irrigation amount (depth of irrigation in each HRU)

- Channel Characteristics
  - Top width of channel at full bank
  - Depth of channel at full bank
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  - Weighing coefficient – 1. Fraction of storage time constant for full bank
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  - Revap coefficient
  - Bank flow recession constant
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Description of the Study Region

- The study region is the catchment of Malaprabha River, upstream of Malaprabha reservoir.
- It has an area of 2093.46 km² situated between latitude 15°30' N to 15°56' N and longitude 74°12' E to 75°8' E.
- It lies in the extreme western part of the Krishna river basin and includes parts of Belgaum, Bagalkot and Dharwad districts of North Karnataka.
- The Malaprabha irrigation project has a masonry dam of height 145.53 m and length 40.23 m.
- The reservoir has a gross storage capacity of 37.73 TMC (∼1070 Mm³) and live storage capacity of 29.82 TMC (∼ 830 Mm³).
- Area envisaged to be irrigated by RBC is 2,02,708 ha and that by LBC is 41,364 ha (PIR, 1986).
- The sub-basin has a wide variety of soils such as medium black soil, deep black soil, mixed red and black soils, red sandy soil and red loamy soil (NIH, 1989), which can be broadly classified into three textures, namely clay, skeletal clay and loam. Further, among all the soils in the sub-basin, black soil is predominant.
Data used for the Study

Daily rainfall records at 16 gauging stations in the catchment of Malaprabha dam are considered. Rainfall data, from May 1979 to November 2003, is procured from the Directorate of Economics and Statistics (DES), Bangalore.

Meteorological parameters such as daily maximum, minimum, and mean temperatures, wind velocity and relative humidity, for the period June 1991 to December 2003, observed at Santebastwadi station are obtained from WRDO, Bangalore.

Runoff data (inflows into Malaprabha reservoir) is collected from WRDO.

Rain gauge & CWC Stream gauge Locations in Malaprabha basin

Thiessen polygons for the catchment of Malaprabha reservoir to compute representative rainfall

SRTM DEM data pre-processed using ArcView interface of SWAT model, to obtain stream network in the catchment of the Malaprabha reservoir

Temporal distribution of average rainfall over the catchment of Malaprabha reservoir and resulting streamflows at the reservoir site

Stream network was reviewed and drainage basin outlets are specified through screen interactive option of the SWAT model to form 26 drainage sub-basins.
Land use/land cover theme of the Malaprabha reservoir catchment

Major soil groups in the Malaprabha reservoir catchment

Area (in ha) under different land use/land cover and soil textures in the Malaprabha catchment within the 26 drainage sub-basins

Area (in ha) under different land use/land cover and soil textures in the Malaprabha catchment within the 26 drainage sub-basins – Contd.

Curve numbers used in the SWAT model for different land use/land cover types

Observed and simulated monthly streamflows at Malaprabha reservoir (Jun 1989-Dec 1994)
Average rainfall received by the catchment and average observed and simulated streamflows at the reservoir site for the period Jun 1989 - Nov 1998

<table>
<thead>
<tr>
<th>Month</th>
<th>Rainfall (mm)</th>
<th>Streamflow in depth units</th>
<th>Simulated (mm)</th>
<th>SWAT generated (mm)</th>
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<tbody>
<tr>
<td>January</td>
<td>5.38</td>
<td>2.30</td>
<td>2.36</td>
<td>2.30</td>
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<tr>
<td>February</td>
<td>8.00</td>
<td>3.48</td>
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<td>March</td>
<td>9.82</td>
<td>3.84</td>
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<td>April</td>
<td>4.73</td>
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<td>20.47</td>
<td>5.46</td>
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<td>June</td>
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<td>July</td>
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<tr>
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<td>November</td>
<td>144.19</td>
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<tr>
<td>December</td>
<td>3.18</td>
<td>8.40</td>
<td>8.40</td>
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<tr>
<td>Annual</td>
<td>1243.54</td>
<td>395.69</td>
<td>395.69</td>
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</table>

Typical Output from AVSWAT model for the catchment of Malaprabha reservoir

<table>
<thead>
<tr>
<th>Year</th>
<th>Month</th>
<th>Rainfall (mm)</th>
<th>SURQ</th>
<th>LATQ</th>
<th>GWQ</th>
<th>PERC</th>
<th>ET</th>
<th>WYLD</th>
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<td>155.8</td>
<td>-95.0</td>
<td>-20.4</td>
<td>-129.5</td>
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<td>155.8</td>
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<td>204.7</td>
<td>25.49</td>
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<tr>
<td>1980</td>
<td>3</td>
<td>473.0</td>
<td>155.8</td>
<td>-95.0</td>
<td>-20.4</td>
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<td>1981</td>
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<td>-95.0</td>
<td>-20.4</td>
<td>-129.5</td>
<td>204.7</td>
<td>25.49</td>
</tr>
</tbody>
</table>

Concluding Remarks

- Strong potential for use of remote sensing, GIS & DEM for water resources planning and management
- Proper image processing of remotely sensed data, DEM and spatio-temporal analyses with GIS would be very effective for better understanding and management of water resources.