Site suitability analysis of soil and water conservation structures in watershed using GIS

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Abstract: The planning of conservation measures to conserve water and soil resources taking hydrological planning unit as watershed is considered to be effective. Optimum utilization of natural resources like land, water, soil, vegetation, resources conservation measures and integrated development of the area along with the improvement in quality of lives of people are the main objective of watershed management program. In this study an attempt has been made for selection of the most suitable sites for water and soil conservation structures in GP IV watershed of Aurangabad district in Maharashtra, India using QGIS. Delineation of the catchment area is carried out after georeferencing them. The IRS LISS-III satellite imagery of Sillod study area is used and LULC classes have been derived from it. A soil map is obtained from National Bureau of Soil Survey and Land use planning, Nagpur, India. The slope map and drainage maps are obtained from SRTM Digital Elevation Model. The various thematic maps such as LULC map, soil map, drainage map, slope map are laid over each other and optimal allocation of check dams are proposed for construction according to guidelines for selecting suitable site for water harvesting structures according to Integrated Mission for Sustainable Development (IMSD) Govt. of India. For suggesting soil conservation structures site locations considering slope parameter, slope was divided into eight classes and accordingly structures are suggested for classes. The water balance study was also done for same watershed with monthly average temperature and precipitation data using Thornthwaite Mather model.

Key words: Geographic Information System, watershed management, soil conservation, water conservation

1. INTRODUCTION

Watershed management includes the conservation of natural resources like soil, water and increase the social and economical status of people living in the watershed. Soil and water conservation structures and its position in the watershed is key factor in efficient watershed development program. Constructing water conservation structures at suitable sites will not only conserve the runoff water optimally but also prevent huge investment on the unproductive structures.

Water harvesting structures are extremely important to conserve precious natural resources like soil and water, which is depleting day by day at alarming rate (Singh et al., 2008). There are always strong links between soil conservation and water conservation measures (Subasini et al., 2016). Classification of land according to its capability class is very much important for identification of the area for appropriate soil conservation measure for effective planning and management of watershed (Srivastava et al., 2010). Sillod watershed area in Maharashtra state, India is taken for the study and GIS is used as tool for suggesting water conservation structures and water balance study is carried out for same area using Thornthwaite Mather model. Soil conservation measures are suggested for arable and non arable land.

2. STUDY AREA

The study area of GP IV watershed is located in the Sillod Taluka of Aurangabad district Maharashtra state, India. The study area comes in the region of longitudes of 75°45’ to 75°70’ E and
latitudes of 20°37′ to 20°51′ N with geographical area of 195.052 km².

3. MATERIALS USED

For preparation of thematic maps firstly watershed maps of Aurangabad district is taken to extract study area. SRTM DEM is taken for deriving slope maps. Soil map is taken from NBSS Nagpur and then georeferenced. Weather data is taken for the year 2013. All the data and maps are firstly georeferenced and digitize for further work.

4. METHODOLOGY

4.1 Water balance study

Water balance study for the watershed for each month is done with the use of TM model using data of daily precipitation and monthly mean temperature. The water balance of a small area can be expressed as:

\[ P = I + AET + OF + \delta SM \]  

where:
- \( P \) = Precipitation
- \( I \) = Interception
- \( AET \) = Actual evapotranspiration
- \( OF \) = Overland flow
- \( \delta SM \) = Change in soil moisture

In this study ground water parameter is not considered while doing monthly water balance study. TM model is widely used because it is simple, empirical and convenient and the ET determined by TM model is based on average temperature and length of day (Michel, 1978). Data required for running TM model for monthly water balance and indirectly calculating runoff in watershed are mean monthly temperature, soil textures and their water holding capacities, root zone depth of different soil types which we get from NBSS soil bulletin.

There are three types of soil present in the watershed viz, Clayey soil, Clayey loam and rocky outcrops clayey soil. Soil depth and water holding capacities of these types are get from NBSS soil bulletin data. According to this various components of water balance equation is calculated to get overland flow by using data of rainfall and temperature.

4.1.1 Calculation of PET

For the calculation of PET, firstly monthly heat index for each month is calculated by the equation:

\[ j = \left( t_n / 5 \right)^{1.514} \]  

where, \( t_n \) = mean temperature of nth month, \( j \) = Month heat index

Annual heat index (J) is calculated by the following equation:

\[ J = \sum_{1}^{12} j \]  

PET is calculated with the following equation:
PET = 16 x (10t_n / J)^a

where, PET = Potential Evapotranspiration, t_n = monthly mean temperature, J = Annual heat index, a is cubic function of J and it is calculated as:

\[ a = 0.49 + (1.79 \times 10^{-2} \times J) - (7.711 \times 10^{-5} \times J^2) + (6.751 \times 10^{-7} \times J^3) \]

In this study PET is calculated for the 12 months for the year 2013 then difference of Precipitation and Potential evapotranspiration (P-PET) is computed for each month.

4.1.2 Calculation of Soil moisture

For the calculation of soil moisture:
If P < PET for any month then Soil moisture is considered as full water holding capacity of soil
If P > PET then equation is:

\[ \text{(Soil moisture)}_n = \text{(Soil moisture)}_{n-1} \times e^{(P-PET/ \text{Soil moisture full})} \]

where, \( n = n^{th} \) month

By applying these conditions to all the months of the year and soil moisture is calculated. The change in soil moisture is calculated from the successive months beginning from end of wet season (Table 1).

4.1.3 Calculation of Actual Evapotranspiration (ET)

For the calculation of actual evapotranspiration following two criterias considered:
If P > PET, then ET = PET
If P < PET, then ET = P + change in soil moisture.

The deficit exists only during the months, when precipitation is less than potential evapotranspiration. Excess surplus moisture is termed as runoff and percolation and in the water balance equation is assumed to become stream flow (Q) (Table 1). Similar table is prepared for the other two soil types viz, Clayey Loam and clayey soil and the runoff and runoff volume is computed for the watershed.

<table>
<thead>
<tr>
<th>Month</th>
<th>Precipitation</th>
<th>Average Day Temp</th>
<th>Monthly Heat Index</th>
<th>Annual Heat Index</th>
<th>a</th>
<th>PET</th>
<th>P-PET</th>
<th>Soil Moisture</th>
<th>Change in Soil Moisture</th>
<th>ET</th>
<th>Surplus</th>
<th>Deficit</th>
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<td>56</td>
<td>-27</td>
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</table>

4.2 Water conservation structures

The data of Sillod watershed is obtained from the sources and firstly the maps are extracted for
our region after georeference and then prepared in digital format using Geographic Information System. The flowchart for preparation of thematic maps is as shown in the figure 1 below,

Figure 1. Flow chart of methodology for site suitability of Soil and Water conservation structures

Check dams are suggested according to the following guidelines given by IMSD:
(i) The slope should be less than 15 per cent.
(ii) The land use may be barren, shrub land and riverbed.
(iii) The infiltration rate of the soil should be less.
(iv) The type of soil should be sandy clay loam.

4.3 Soil conservation structures

For suggesting soil conservation structures in the arable and non arable land study area is divided into 8 land capability classes as per land AISLUO(1970) the classification of slope is as per shown in Figure 3.
5. CONCLUSION

5.1 Water balance study

The water balance study is done using the TM model for each month for the Sillod watershed in Aurangabad India. The runoff for the year 2013 was found to be 1249 mm and the total runoff volume for the watershed is 243 Mm$^3$ (Table 1).

5.2 Soil conservation structures

By classifying the study area into 8 land capability classes considering the slope parameter soil conservation structure contour bunding is suggested for class I to IV i.e. for arable lands. The main
aim to provide soil conservation structure in this type of arable land is reducing erosion while keeping desired soil moisture. Contour trenching should provide in the non arable land that is for land capability class V to VIII. The main aim for providing these structures in non arable land region is to reduce the runoff velocity and infiltration of water to increase the groundwater table.

5.3 Sites for check dams

All the thematic maps such as Land use land cover, soil map, slope map and stream network are overlayed and cross operation has been done using GIS and best suitable location for check dams are suggested in the study area and 15 sites for check dams are proposed in the GPIV watershed. The final map of suitable site location is as shown in Figure 4.

![LOCATION MAP OF CHECK DAM](image)

Figure 5. Final map showing suitable location of check dams

REFERENCES

AISLUSA, 1990. Watershed Atlas of India, Department of Agriculture and Cooperation. All India Soil and Land use Survey, IARI campus, New Delhi.


