Chapter 1
GIS Based Management System for Flood Forecast Applications

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Abstract Water resources of a country constitute mainly surface and ground water, with rainfall being the basic source. Due to non-uniform variation of rainfall in India, one region of India receives floods, and the other region is prone to drought. This situation calls for proper management measures to effective utilization of available water. Recent floods in large river systems called for the urgent need to forecast flood conditions and manage the river environment. The author's study on identification of flood prone areas of Cauvery river basin, generated flood inundation maps of several recurrence intervals by using hydrologic (SWAT) and hydraulic (HEC-RAS) models integrated with GIS. Considering this as preliminary study, a flood forecasting system is planned for Krishna river basin by using GIS and Meteorological data. A display map will be prepared using ArcGIS, which includes flood depth, extent of inundation with display maps and this information will be provided in near real time to concerned authorities for taking necessary action. These tools can be used to identify affected parcels to prioritize for remediation. This will help further to manage the water resources in an effective manner, without letting the water into sea or causing submergence to flood plain areas.

Keywords GIS · SWAT · HEC-RAS · Water surface profile · Flood inundation map

1 Introduction

Flood is one of the most common hydrologic extremes frequently experienced by any country. The rainfall received in India is not uniformly distributed both in time and space. According to government of India flood statistics, about 400,000 km^2 [5] of area is getting inundated due to floods every year. Andhra Pradesh has been

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frequently affected by severe floods and has suffered from many flood disasters in terms of the population affected, frequency, extent of inundation and socio-economic costs. The state of Andhra Pradesh has three major river basins; among which Krishna is the second largest perennial river basin. The Krishna River Basin is India's fifth largest river basin covering an area of 258,948 km^2 in Peninsular India, which is nearly 8% of total geographical area of the country [10]. Most of the Krishna catchment area lies in the states of Maharashtra, Karnataka, Telangana and Andhra Pradesh. The river is prone to heavy floods, especially during the South-West monsoon season (June–September) and occasionally due to thunderstorms. Due to rapid land use changes, encroachment and sedimentation, the rivers may not be able to carry the excessive runoff resulting from heavy rains of high intensity. As a result, the river overflows and water enters the flood plain. Flood water surface elevation information is important to know the depth of the flooding. Accurate water surface elevations can be computed using a hydraulic model. Long-term continuous discharge measurements are available only in few locations across the Indian River basins. Since the current study is agricultural watershed, so the flow values at these locations can be simulated using hydrologic model, SWAT [2] based on landuse practices, crop management, irrigation scheduling and reservoir operation.

Flood frequency analysis is carried out for the flow values obtained from SWAT to calculate the flow magnitudes of several recurrence intervals (2, 5, 10, 25, 50 and 100 years) using a statistical technique known as Log-Pearson type-III distribution [9]. In order to map the level of flood inundation at different downstream reaches, water surface profiles are needed at several places along the river reach. But they are available at very limited places along with stream gauges. Hence, to fill this gap, a hydraulic model such as HEC-RAS is often used to compute the flow depth at various locations along the river reach. GIS is used to extract the geometric information from the digital elevation data for input into a hydraulic model, and then used to map the current spatial extent of flood waters using a mapping software. Flood inundation mapping is one of the vital components in developing flood mitigation measures especially nonstructural measures. Flood inundation extent and depth can be found by using a mapping tool called HEC-GeoRAS [8]. Water surface elevations greater than the terrain elevation are included in the inundation depth grid.

2 Study Area

The basin is situated between East longitudes 73° 21′ to 81° 09′ and North latitudes 13° 07′ to 19° 25′ in the Deccan Plateau. There are 13 major tributaries which join the Krishna River along its 1400 km course. About 68% population lives in rural areas and is dependent on agriculture for their livelihoods. There are about 30 major and medium dams and reservoirs constructed in the Krishna River Basin.

The important soil types found in the basin are black soils, red soils, lateritic soils, mixed soils, saline and alkaline soils. Diversified cropping pattern persists in the Krishna River Basin. Principal cultivated crops are: paddy, sorghum, corn, sugarcane, millet, cotton, sunflower, groundnut, turmeric, and a variety of
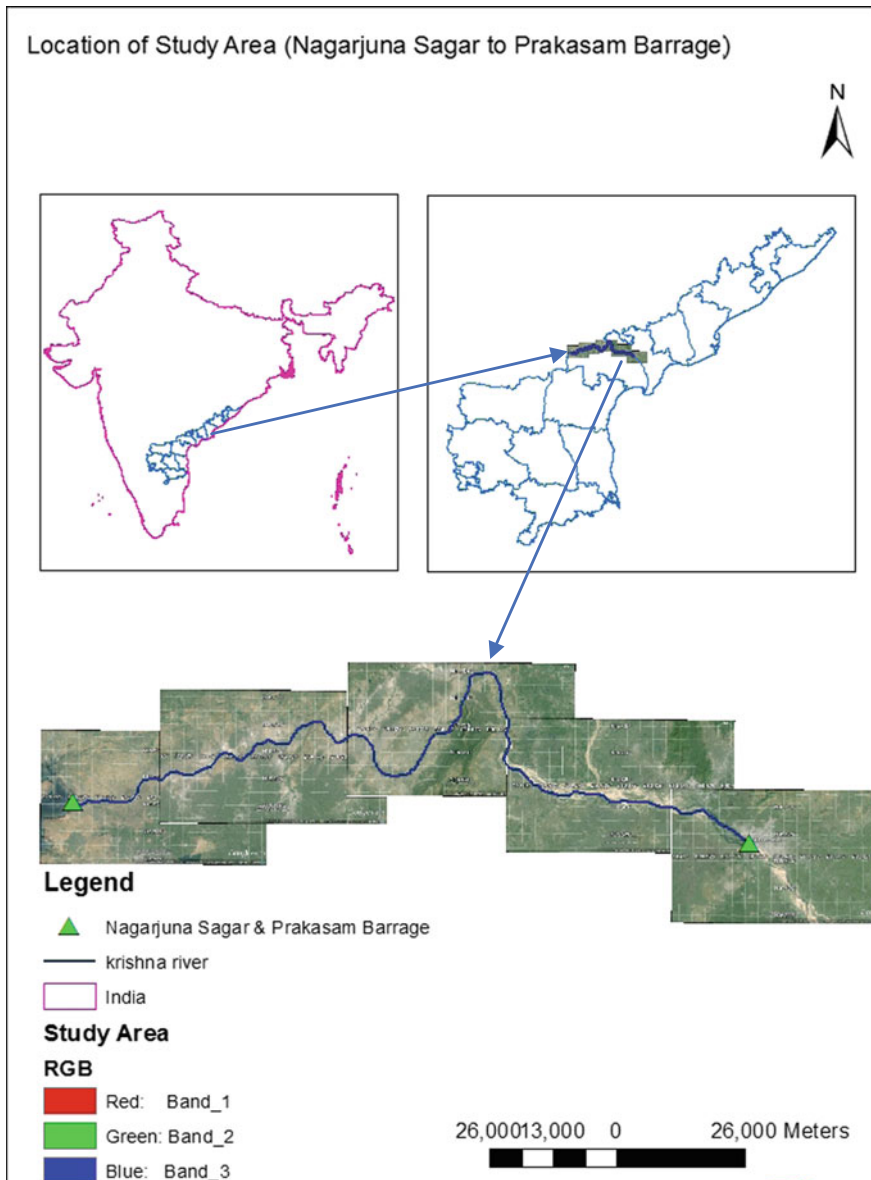

Fig. 1 Location of study area

horticultural crops. The total cultivable area in the basin is about 203,000 km^2, which is equivalent to 78% of the total geographical area of the basin. The current study is identified from Nagarjunasagar to Prakasam Barrage region as shown in Fig. 1. The length of the river reach is 188 km.

3 Methodology

SWAT is a complex physically based distributed parameter hydrologic model developed by the United States Department of Agriculture (USDA), which operates on a daily time step [3]. In SWAT surface runoff is estimated using the SCS curve number procedures [13] from the daily rainfall data. Based on the annual maxima of discharge predicted by SWAT at different reach segments, flood frequency analysis was carried out to predict the flood magnitudes of various recurrence intervals. Log-Pearson Type III distribution is often the preferred statistical technique for flood frequency analysis [12]. The flow values for different recurrence intervals

Fig. 2 Overall methodology
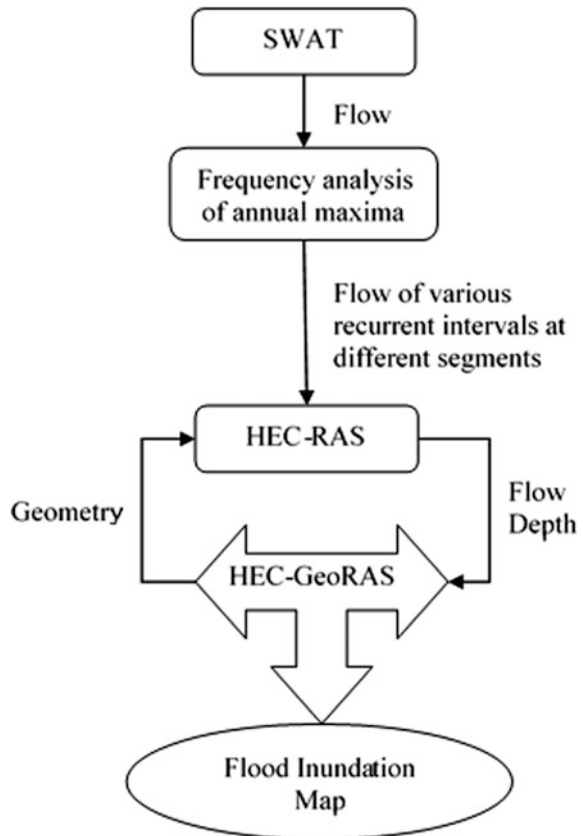
from this technique is given as input into a hydraulic model, HEC-RAS to estimate the water surface profiles. Flood inundation map is generated using HEC GeoRAS by comparing water surface TIN (Triangulated Irregular Network) with DEM, to compute the water surface elevation in the channel and flood plain. The overall methodology process is shown in Fig. 2.

3.1 SWAT Model Set-Up

Hydrologic modeling was carried out by using a distributed hydrological model SWAT. The data required to setup SWAT include topography, land use, soil, weather and land management practices. Accordingly, the ArcGIS SWAT model setup involves five major processes: (1) Watershed delineation (2) Landuse and Soil setup (3) Hydrologic Response Unit (HRU) definition (4) Weather data and
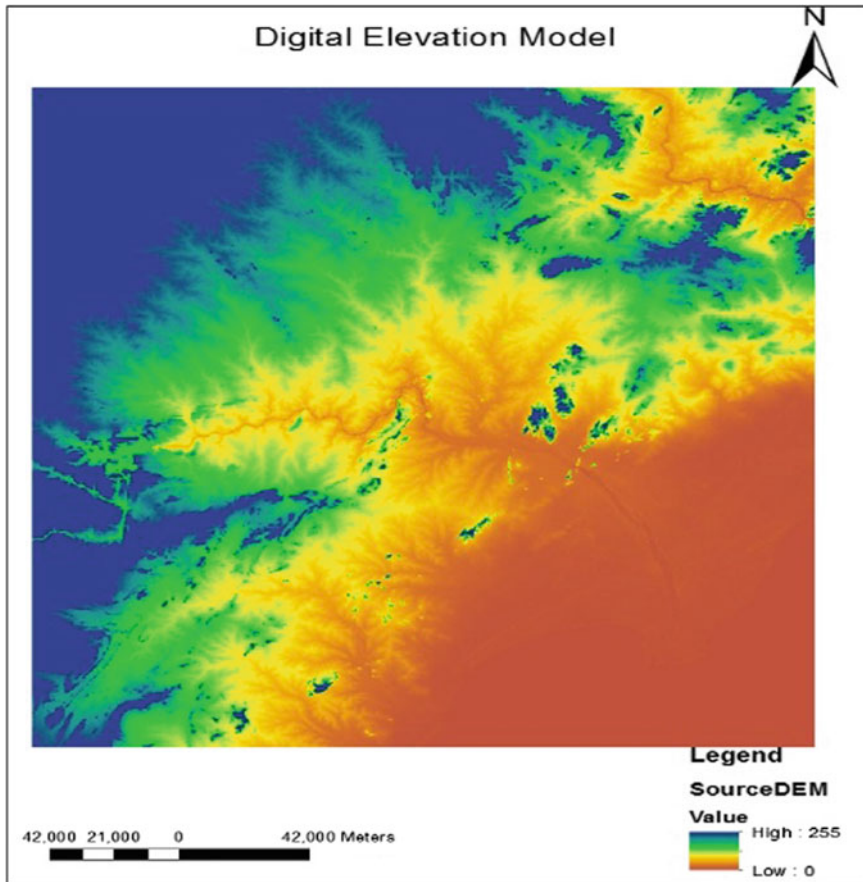

Fig. 3 Digital elevation model

(5) Land management information. ASTER (Advance Space borne Thermal Emission Radiometer) DEM of 30 m resolution was used for watershed delineation as shown in Figs. 3 and 4. Land use/land cover data was obtained from LANDSAT imagery as shown in Fig. 5. Soils data collected from FAO (Food and Agricultural Department), shown in Fig. 6. High resolution (0.5° × 0.5°) daily gridded rainfall data (1971–2005) developed by India Meteorological Department (IMD) [11] and 1° × 1° daily temperature data from IMD (1969–2007) [14] was used as weather data inputs for SWAT modelling. Watershed delineation was performed with a threshold area of 10,000 km^2 and 149 sub basins were obtained as shown in Fig. 4. SWAT performs analysis at HRU level. So, a threshold of 5% is given to land use and soil classifications. 1099 HRUs were obtained after incorporating threshold criteria.
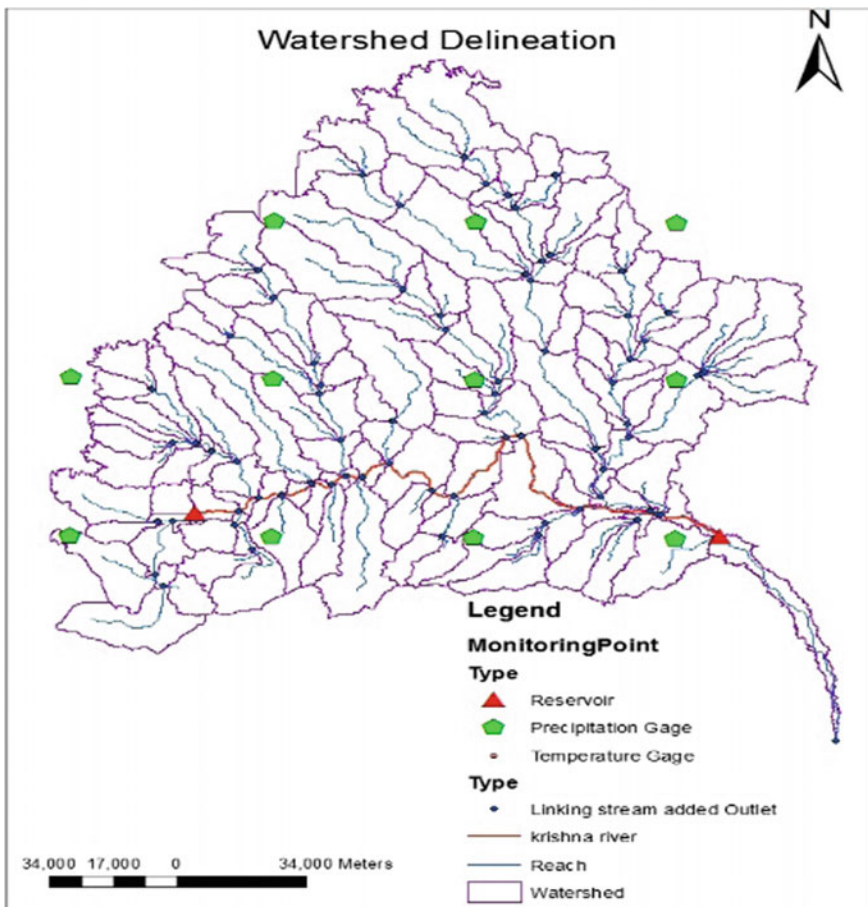

Fig. 4 Watershed delineation

3.2 HEC-RAS Model Set-Up

HEC-RAS is designed to calculate water surface profiles for steady or unsteady Gradually Varied Flow (GVF) in natural and manmade channels. Steady state analysis isperformed in this study to calculate the water surface profiles using the "standard step method". In this method, water surface profiles are computed by solving energy equation using an iterative procedure. HEC-GeoRAS is a geographic river analysis system developed using ArcGIS by U.S Army corps of engineers [7] to function as a pre-processor for preparing the input data for HEC-RAS from GIS and a post-processor to map the extent of flood plain. The data needed to perform these computations are separated into geometric data (elevation, river center-line, hydraulic structures etc.) and steady flow data (flow values of various recurrence intervals). The geometric data required by HEC-RAS were digitized from the Google earth imagery. The network was created on a reach by reach basis, starting from the upstream end and working downstream. Due to the lack of rating curve of flow data, the normal depth condition is assumed as the downstream boundary by assuming the flow below the most downstream section is mostly generally uniform. Many flood plain studies have used normal depth boundary condition at the downstream boundary when the actual water profile or rating curve information is lacking [1, 4]. Water surface profile predicted by HEC-RAS beyond a threshold limit in the river length from the downstream boundary, the effect would be negligible [6].

4 Results and Discussions

The output of the flood modeling is in the form of flood plain map, water surface profiles. The flow values for several return periods at the outlet point of the watershed was obtained by using Log Pearson Type-III distribution was plotted in Fig. 7. It is seen from the results that flood model can simulate the flow profiles for different flow conditions and the flood plain map shows that how much area effected due to flood with different return periods. i.e., 2, 10, 25, 50, 100 years. HEC-RAS provides the user with a large amount of hydraulic information in the form of flood plain maps and water surface profiles for any station or cross section, reach, and profile. sample output of flood plain map and water surface profiles of the region is shown in Fig. 8. The ASTER DEM has a spatial resolution of 30 m, which is a very coarse resolution for flood inundation mapping. So, for many sections along the stream, the active channel portion was not clearly discernable.
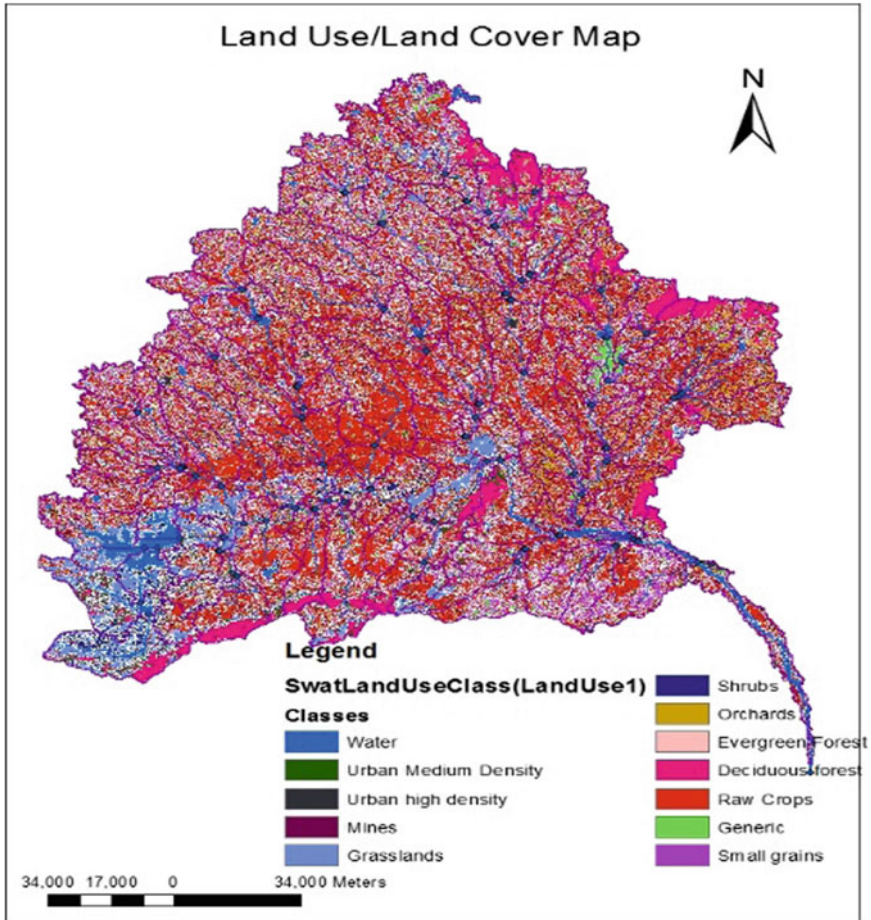
Fig. 5 Land use/land cover

This profile will facilitate to adopt appropriate flood disaster mitigation measures. The flood profiles for different flood intensities with different return periods can be plotted at any given cross section of river. Also, such flood profile can be plotted for entire length of river reach.
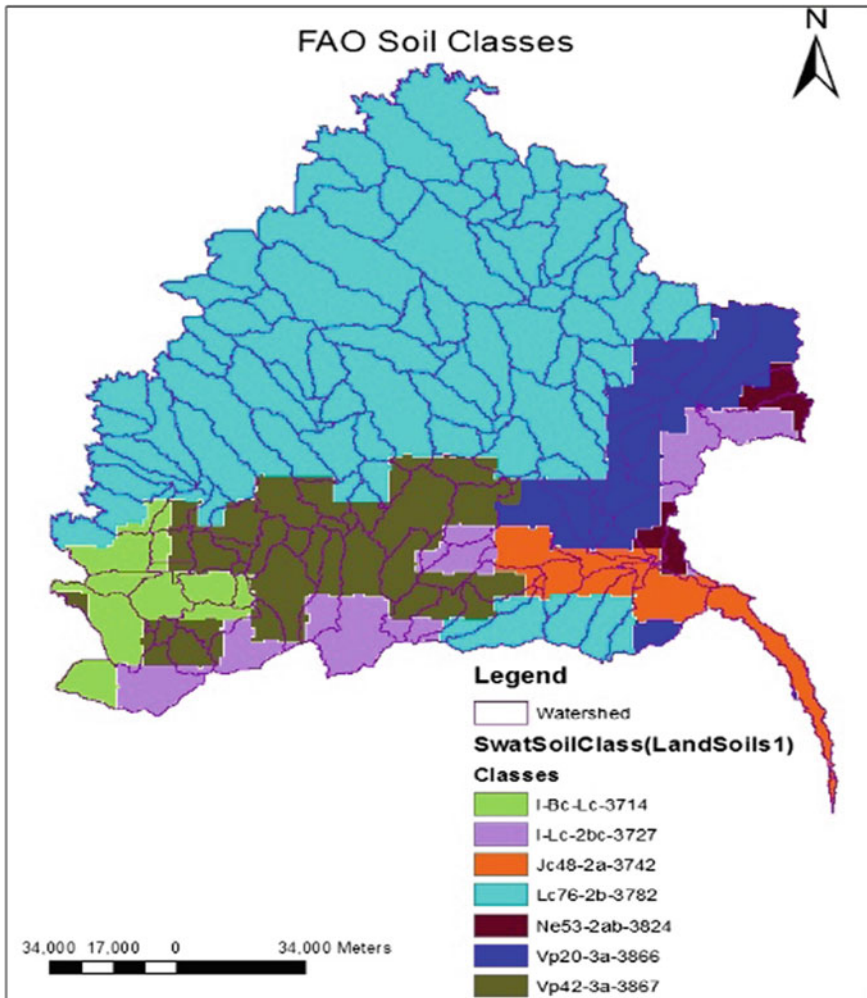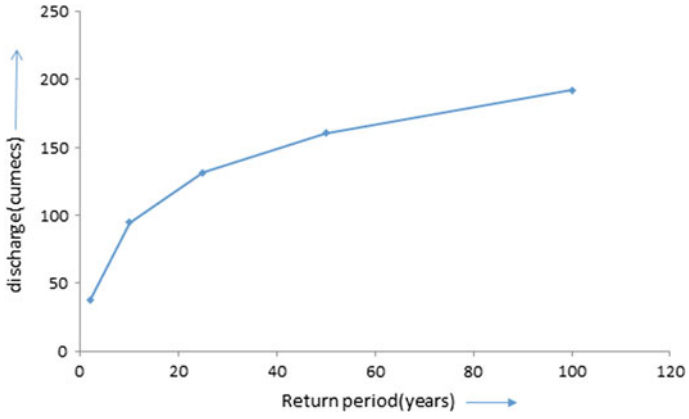
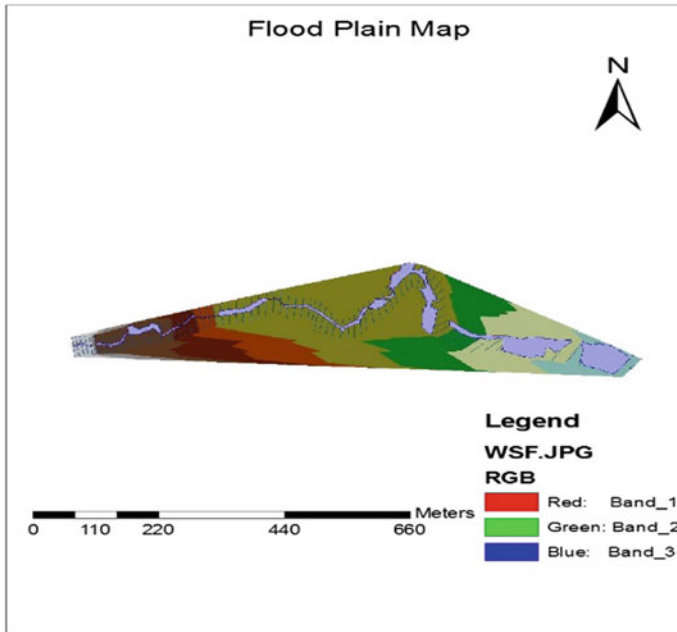**Fig. 6** FAO soils data

Fig. 7 Frequency analysis

Fig. 8 Flood plain map

5   Conclusions

With the increasing availability of GIS data, the combination of SWAT, HEC-RAS and GIS models provides a method for modelling and visualizing the spatial distribution of the catchment response for a given storm event in terms of flood inundation area. The results of the model could be further improved if dense network of weather stations is available along with a good network of stream gauge data. High resolution digital elevation model or detailed channel cross section is not available for this study. In spite of this, the study demonstrates that ASTER DEM of 30 m resolution could be used for exploratory flood plain study of large watersheds. HEC-RAS being a 1-D model, careful attention should be placed to define the active channel section for modelling the flood depth by placing artificial levees on the channel banks. Flood modeling using HEC-RAS is effective tool for hydraulic study, handling of disaster management measures. These results obtained in this study provide essential information for and administrative to analyze and the manage flood hazards.

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