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Site suitability for potential soil and water conservation structures in Gundlakamma Subbasin using Geoinformatics

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Abstract
The present study was conducted to investigate the site suitability of soil and water conservation in Gundlakamma Subbasin. The Gundlakamma subbasin is predominantly agricultural based and Gundlakamma is a seasonal river. Hence, 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 Gundlakamma Subbasin of Prakasam district in Andhra Pradesh, India using Arc GIS. Delineation of the catchment area is carried out after georeferencing them. The IRS LISS-III satellite imagery used for 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 four classes and accordingly structures are suggested for classes.

Keywords: LULC, Soil map, Slope Map, check dam, percolation tank

Introduction
Water is a finite resource and its availability is declining with each passing day. Agriculture sector, the largest consumer of water i.e, 82.8% (World Water Assessment Programme (UNESCO WWAP), is facing competition from other sectors due to the ever increasing demands of the burgeoning population and accelerated pace of urbanization and industrialization in the country. It is expected that reduction in the average size of land holding, declining per capita water availability, deterioration of water quality, etc. will seriously affect the sustainable use of water resources and will make it difficult to accomplish the target of producing 345 Mt in 2030 and 494 Mt in 2050 AD (Rattan, 2004). With growing scarcity and increasing inter-sectoral competition for water, the need for efficient and sustainable management of water has also become more important. Finding ways to meet the competing demands, while also achieving positive economic and environmental outcomes, requires the aid of modelling tools to analyze the impact of landuse land cover change scenarios.

Therefore, hydrological modelling studies in basins with spatial and temporal variability are important because they help to understand processes that control water movement and the likely impacts on water quantity and quality. Impact assessments on water resources is one of the most relevant factors of hydrological models, which are fundamental tools for a basin planning and management (Viola *et al.*, 2009). Several hydrological models have been developed and applied in several basins for varied purposes. Among the hydrological models, the conceptual distributed one, which simulate various processes that make up hydrological cycle based on empirical functions and input parameters in spatial form, which is possible through model and Geographic Information System (GIS) integration. With the advent of GIS, it has become easier to handle a large amount of data that conceptual distributed hydrological models demand, thus, enabling process simulations with greater physical foundation.

Gundlakamma is one such basin which is predominantly agricultural based. Gundlakamma is a seasonal river that flows through the east central part of the state of Andhra Pradesh, India. It covers an area of 45% in Prakasham District. The catchment area of the Gundlakamma River is 7910 Km^2. The capacity of the reservoir is 29.29 TMC and the Utilization is 12.845 TMC and it supplies drinking water for 2.56 lakh population and the command area of the project is 32,400 ha. At present the major portion in the command area is under cultivation of rain fed dry crops only as flows into the reservoir have been reduced due to no rains in the catchment and no regenerated water from Nagarjunasagar project right canal. Hence, presently the project is not able to meet the total demand of water for Agriculture, Domestic and Industrial needs.

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) [12]. 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, Singh *et al*. 2017a; Singh *et al*. 2017b; Singh *et al*. 2017c; Singh *et al*. 2018; Tiwari *et al*. 2018; Tiwari *et al*. 2019a; Tiwari *et al*. 2019b; Kour *et al*. 2019; Singh *et al*. 2019) [2, 3, 4, 5, 6, 7, 8, 9, 10, 11]. In these study area, GIS is used as tool for suggesting water conservation structures is carried out soil conservation measures are suggested for arable and non arable land.

Materials and Methods

Description of Study Area

The study area was a part of Gundlakamma river basin and is predominantly agricultural based. The Gundlakamma river is a seasonal river and its rises in the Nallamalla Range of the Eastern Ghats. After passing the mountains, it enters the plains of Andhra Pradesh, India. It is located between the latitudes of 15° 50' 59.166" -15° 29' 27.166" N and 79° 38' 7.794" -80° 11' 24.858" E (Fig.1). The Gundlakamma subbasin comprises of Thurupu vagu, Pasapugalla vagu, Nalla vagu, Kalla vagu, Dornapu vagu and Chillakaleru tributaries (Fig.2) which are contributes to Gundlakamma river.

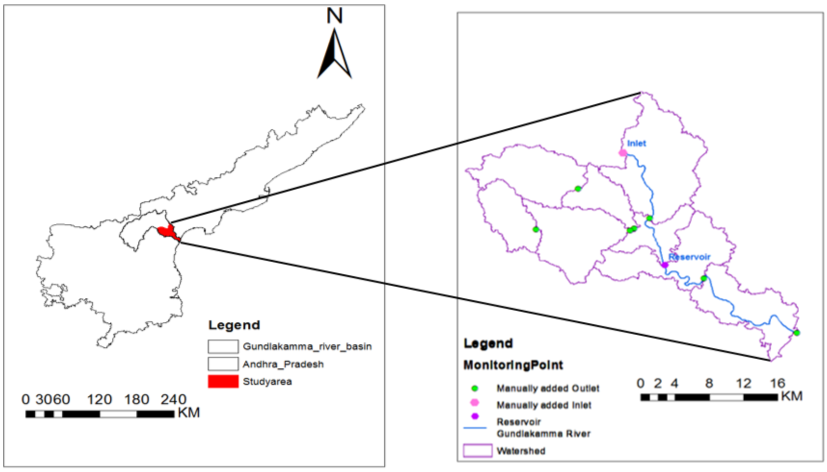

Fig. 1: Location map of Gundlakamma subbasin

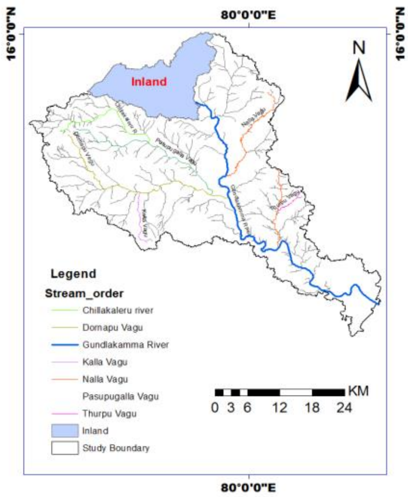

Fig. 2: Location map of tributaries of Gundlakamma subbasin

Preparation of Thematic Maps of Study Area
The basic maps required for the Arc-SWAT 2012.10_3.19 is compatible with Arc-GIS 10.3.1, build 4959 include digital elevation model, soil, landuse landcover and drainage network (stream lines). In addition, the SWAT interface requires the designation of land use, soil, weather as well as the simulation period to ensure a successful simulation. Universal Transverse Mercator (UTM) projections corresponding to zone 44 N was used as the co-ordinate system for all the thematic maps. To create a SWAT dataset, the interface needs access to ArcGIS compatible raster and vector datasets (shape files and feature classes) and database files which provide certain types of information about the watershed.

Delineation of Watershed
The Advanced Space borne Thermal Emission and Reflection Radiometer (ASTER) Digital Elevation Model (DEM) with a resolution of 30 m x 30 m was downloaded from USGS (United States of Geological Survey) https://earthexplorer.usgs.gov/. Two tiles were downloaded and mosaicing and rectification was done. The DEM of the study area was loaded through ArcGIS environment and mask area which is the area of interest was also created to generate stream network. The ArcSWAT interface automatically generated stream and drainage network by taking into consideration elevation values of DEM, mask and pre-defined stream network generated from toposheets. The outlet point needs to be identified as the entire watershed contributes flow to the specified outlet. The delineation of watershed was completed based on outlet point of each subbasin and there are 8 subbasin in the study area in Fig.1. The delineated watershed and stream network is depicted in Fig 2. The area of the subbasin was 1330.791 km^2.

Land Use / Land Cover Map

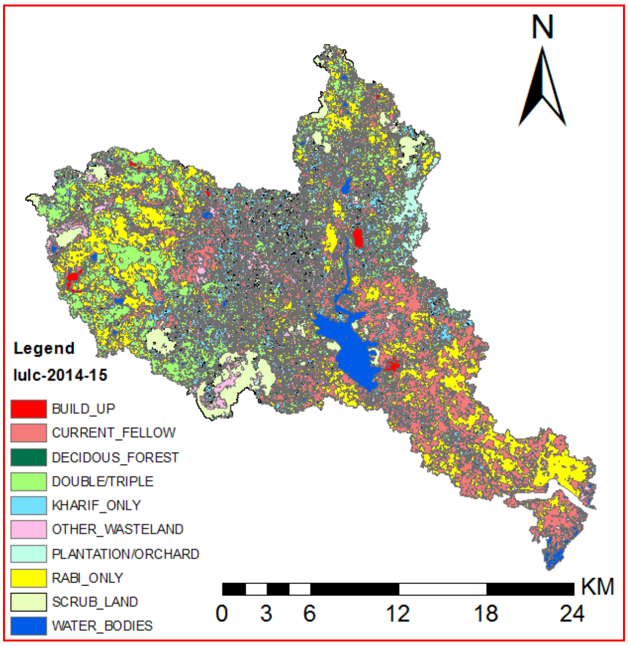

Fig. 3: Land use land cover map of Gundlakamma subbasin during 2014-15

The LULC map was prepared for the study area using IRS P6, LISS III images downloaded from https://bhuvan-app3.nrsc.gov.in/data/download/index.php of December, 2011 and September, 2012 and December, 2014 and September, 2015. The information from LISS III image and toposheets were utilized for classification of land cover generation of training sets. Ground truth survey was carried out by walking around the field boundaries for two times during 2011 to 2012 (*rabi* 2011 and *kharif* 2012) using GPS.

Major portion (55 %) of the study area was covered with agricultural crops viz., paddy during *rabi* and *kharif. Kharif* contains chillies, cotton and redgram. *Rabi* contains tobacco and bengalgram. Plantation trees were also present in some parts of the study area. The study area has more current fallow land (24.79 %) and scrubland (9.54 %) followed by less forest area (0.34 %). The different land uses of the study area were shown in Fig. 3.

Soil Texture Map
The soil map (1: 250,000) developed by NBSS & LUP https://www.nbsslup.in/ has been taken as reference map and clipped to the catchment area. The soil textural classes were identified. In addition to that the soil map prepared by SWAT group for India was also considered to ascertain the types of soils. The different types of the soils in study area (Fig.4) were clay, clay loam and sandy soils with 51.11 %, 46.26 % and 2.63 % area representation respectively.

The soil poperties such as soil texture, available water content, hydraulic conductivity and bulk density for different layers were obtained from literature for the study area (Chandrasekhar *et al.*, 2017).

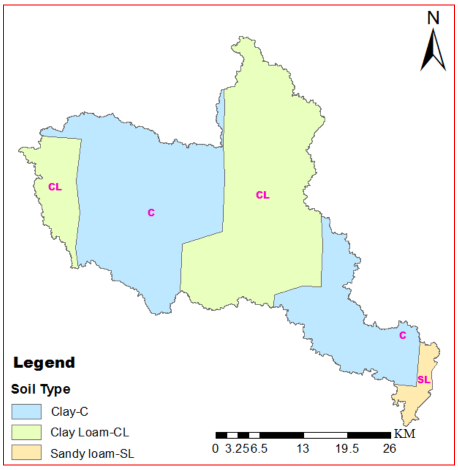

Fig. 4: Soil map of Gundlakamma subbasin

Custom weather database which includes all the climatic parameters of the study area was needed as input to obtain accurate estimate of the water yield of the catchment. The inputs like precipitation (mm), temperature (^{0}C), solar radiation (MJm^{-2}d^{-1}), relative humidity (%) and wind speed (m sec^{-1}) were prepared using DBase IV spread sheet.

Results and Discussion
Slope map
From the DEM slope map was generated and four classes were specified (Table. 1) for the study area. The area under more than 8 % was 31.12 %. The area between 6-8 % slopes was 17.25 %.

Table 1: Percentage area under different slope classes of study area

Land slopes (%)	Area (ha)	Area (%)
0-4	38106.15	28.63
4-6	30606.17	23.00
6-8	22952.15	17.25
>8	41414.63	31.12

Water saving techniques are key elements to improve water use efficiency (WUE) and consequently yield and cropping intensity. Aerobic rice cultivation or direct seeding (dry or wet -soaked seed) rice cultivation is suggested to save the water. Adoption of micro irrigation increases the water use efficiency and brings additional area under cultivation.

Suitable structures in the subbasin will definitely augment the ground water resources. Soil and water conservation measures were planned for catchment area treatment based on estimated morphological features of basin. Site selection for soil and water conservation measures is carried out by overlaying the slope, soil, land use/land cover and stream order maps. The multi-layer integration of land use/ land cover, soil, slope, flow direction, drainage and settlement gave the suitability units for identifying sites for percolation tanks and check dams (Pandey *et al.*, 2011, Prasad *et al*., 2014). Factor layers (maps) were incorporated in ArcMap multi criteria evaluation analysis, using the weighted overlay function in the ArcGIS analyst. Finally, a suitability map was developed that show the potential sites for different conservation structures in study area.

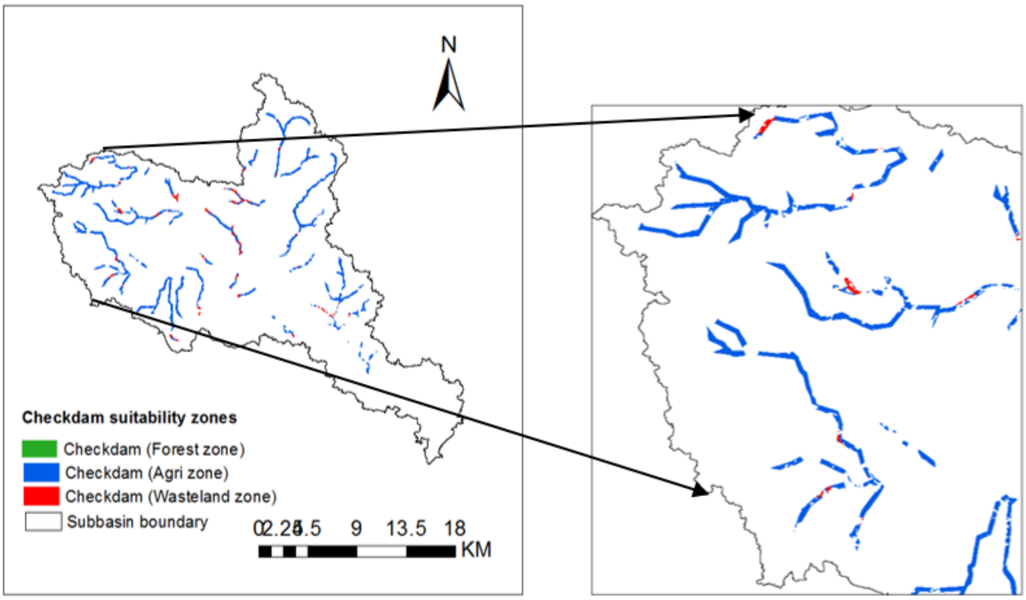

Fig 4.42: Suitable site for check dam in Gundlakamma subbasin

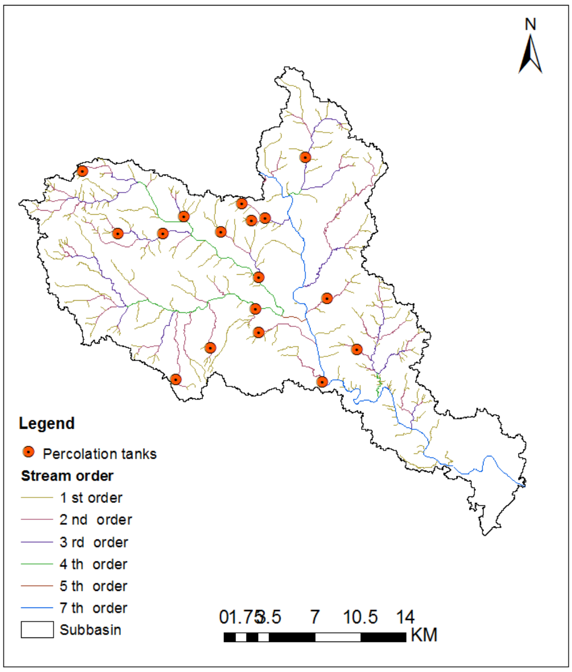

Fig 4.43: Suitable site for percolation tanks in Gundlakamma subbasin

The sites for check dams were identified in agriculture, forest and waste land zone. The sites for percolation tanks were identified in waste lands. The proposed structures will definitely aid in improving the availability of ground water resources.

Based on the above results, the following inferences can be drawn.

Average annual precipitation and temperature is expected to increase in the Gundlakamma subbasin. The climatic change has a significant impact upon fresh water resources availability. The demand for water also increased tremendously due to an increasing population, expanding agriculture and rapid industrialization in different sectors of water use. There is a need to allocate water judiciously among different sectors of water use to maximise the profit per unit of water consumed. Keeping in view of the above facts, it is necessary to adopt water saving technologies to improve water use efficiency. The soil and water conservation structures will augment the ground water resources. Improved water use efficiency of surface water in addition to increased availability of ground water will lead to hydrological sustainability in the subbasin.

Conclusion

1. Check dams and percolation tanks were proposed for augmenting the ground water resources to achieve hydrological sustainability of the basin.
2. Suitable sites were identified for conservation structures in agricultural, forest and wasteland zones.

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