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Estimation of Runoff Potential and Planning of Water Harvesting Structures using Geospatial Techniques for Halia Basin

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ABSTRACT: Runoff is one of most important hydrological component that is used in planning for rainwater harvesting structures, groundwater recharge structures, optimal use of reservoirs and warning of flood hazards. Adoption of *in-situ* soil and water conservation techniques and construction of rainwater harvesting structures are very essential for moisture conservation and rainwater harvesting for supplemental irrigation especially in cases of unpredictable nature of monsoon rainfall. Planning and implementation of rainwater harvesting structures like farm ponds, check dams, percolation tanks etc. needs data of runoff potential for its long-term sustainability. The present study was taken up in Halia river basin located in Nalgonda district of Telangana where the runoff data availability is very limited. Hence, SCS-CN and GIS was used for estimating the runoff potential availability over the years. The Halia basin was delineated using ARC Hydro tool and 416 sub-catchments were generated. The main soil types found in the basin are clay skeletal, clayey, loamy, and loamy skeletal. Different thematic layers were intercepted in ArcGIS and SCS-CN method was applied to estimate the runoff spatially. Most of the study area has rainfall less than 790 mm. Most of the catchment has runoff ranged from 10.5% to 17.5% of average annual rainfall. The potential sites for water harvesting structures like ponds, check dams and percolation tanks were identified using geospatial techniques. This layer was converted into. kml file format and exported to Google earth and locations of existing structures were validated in Google earth and by visual interpretations. The ground truth related to location of existing structures was collected during the survey and was exported to ArcGIS and identified new potential sites for planning of additional structures.

Key words: Arc GIS, Google earth, runoff, water harvesting structures

Introduction

Runoff is one of the most important hydrologic component used in water resources applications especially in the planning of water harvesting and recharge structures. The quantity of runoff depends on soil, topography and rainfall characteristics like intensity, duration and distribution. Understanding surface runoff is important because when it occurs, it affects the distribution of plant and wildlife communities, and impacts the water resources. The direct runoff is the cause of numerous troubles and without proper technique to estimate it; no preventive measures can be applied. Soil Conservation Services Curve Number (SCS–CN) technique is one of the primogenital and simplest method for runoff modeling. Hydrologic soil group, land use and vegetation cover are the basic catchment characteristics used for curve number calculations. The soil Conservation Service Curve Number method is usually followed by researchers and it can be easily integrated with advanced tools like GIS and remote sensing (Nandgude *et al.,* 2014; Rejani *et al.,* 2015a). Many researchers have directly used, modified and evaluated the SCS-CN model (Mishra *et al.,* 2004; Amutha and Porchelvan, 2009; Malekani *et al.,* 2014) and estimated runoff. This estimated runoff could be utilized for planning of water harvesting and groundwater recharge structures (Prasad *et al.,* 2014; Ahmad and Verma, 2016; Rejani *et al.,* 2017; Satheeshkumar *et al.,* 2017). The present study was taken up in Halia river basin located in Nalgonda district of Telangana where the runoff data availability is very limited. The overall goal of this study is to plan the SWC interventions based on the runoff potential under current scenario using geospatial techniques.

Materials and Methods

Study area

The selected study area is Halia river basin, a tributary of Krishna river, situated in Nalgonda district of Telangana state. Geographically, it lies between 16º 37’ 19” to 17º 17’ 21” N latitudes and 78º 34’ 23” to 79º 29’ 20” E longitudes with an elevation ranging from 54 to 701 m above mean sea level. The average annual rainfall of the basin ranges from 700 to 800 mm (Figure 1). The catchment receives 90% of the rainfall during south-west monsoon, sets by middle of June and withdraws by middle of October. More than 70% of rainfall occurs during the months of July, August and September. The length of the river is 112 km and it drains from an area of 3918.41 km^2.

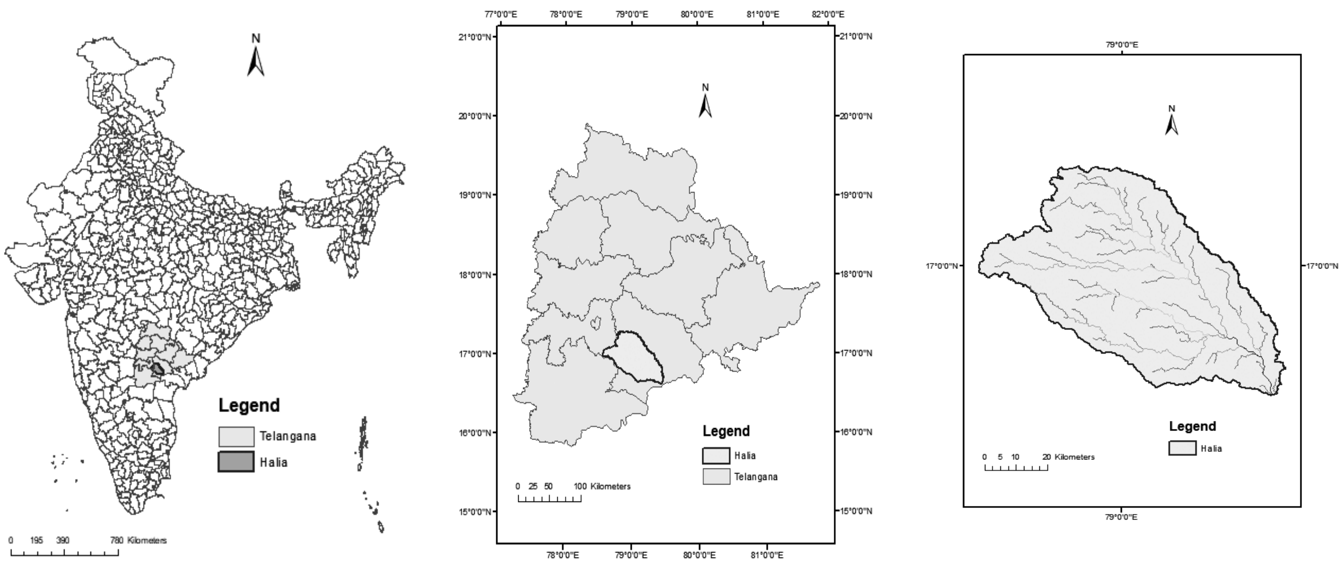


Fig. 1: Location map of the study area

Estimation of runoff potential and planning of water harvesting structures

Water resource managers use geographic information system (GIS) technology to visualize and analyze hydrologic data for tasks such as estimating water availability, understanding the natural environment and managing water resources. Arc Hydro was used to delineate watersheds, generate catchments, drainage lines, slope maps etc. It helps to develop data inputs for external hydrologic and hydraulic models. Various soil and water conservation measures (SWC) are needed to reduce surface runoff in degraded and drought-prone watersheds. This includes *in-situ* moisture conservation interventions and water harvesting structures, which are very essential for the sustainable management of agricultural lands. Planning of these interventions depends on runoff potential which was estimated spatially using SCS-CN and GIS. This method is widely used because of its flexibility, simplicity, as well as it considers major watershed characteristics that governs runoff generation. Water is the most critical input for agriculture and sixty percent of agriculture area is rainfed. Resource interventions undertaken as part of soil survey activities throws light on the status of the natural resources, their limitations and ameliorative measures. Different thematic layers like soil, LULC, slope, rainfall and stream orders were intercepted in GIS and are planned using the selection criteria given in Table 1. The major soil and water conservation interventions generally recommended in semi-arid areas includes farm ponds, check dams, percolation tanks and gabion structures.

Table 1: Site selection criteria for the planning of various soil and water conservation structures

Structure	Slope (%)	Runoff coefficient	Stream order	Rainfall (mm)
Farm ponds/percolation tanks (crop land)	0-5	Medium/high	1-2	>500
Check dams (scrubs/ trees/ river bed)	<15	Medium/high	3-4	>700
Check dams (crop land)	<=3	Medium/high	3 (c)	>700
Percolation tanks (scrub land)	<10	Low	1-4	>700

(Source : Rejani *et al.,* 2017)

Estimation of surplus runoff potential and determination of potential sites for structures

In semi-arid regions, runoff potential availability and its temporal variability were considered as alarming factors. Hence, the final locations and number of structures were optimized based on the spatial availability of surplus runoff after *in-situ* soil moisture conservation and storage in the existing structures.

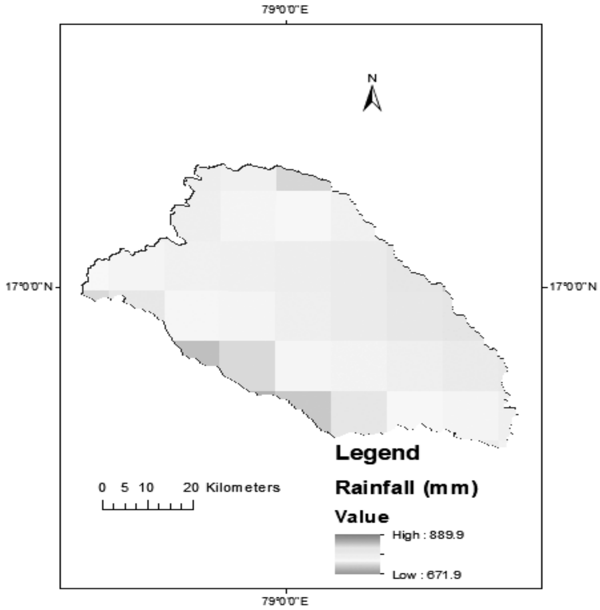
Validation of potential sites

The map of potential locations identified was converted to. kml file, exported to Google Earth and validated with the locations of existing structures by visual interpretation. The ground truth pertaining to location of existing structures (latitudes and longitudes) was collected during the survey was exported to GIS for further validation and planning for additional structures. The additional structures needed were planned after deducting the storage of runoff in the existing structures.

Results and Discussion

Spatial variation of rainfall and runoff

The runoff was estimated using the rainfall data for 1951 to 2020. The rainfall varied spatially from 672 to 890 mm and average annual rainfall is 790 mm (Figure 2a). The percent runoff varied from 10.5% to 20.00% over the Halia catchment. Most of the catchment has runoff ranged from 10.5% to 17.5% of average annual rainfall (Figure 2b).



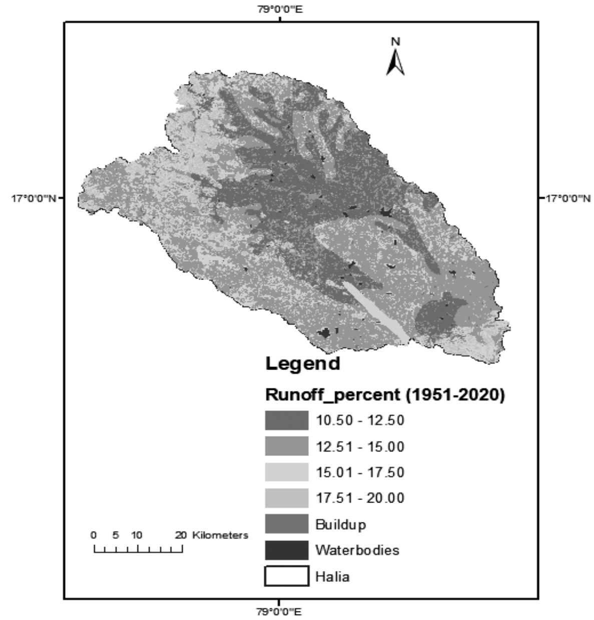


Fig. 2a & b: Spatial variation of rainfall and runoff at Halia catchment

Stream order

The stream order map was generated using Arc hydro tool and the DEM data. When two first order streams join, the resulting stream is second order. When two streams with the same order join, the resulting stream has the next highest order than the joining streams (Figure 3). In addition, for mapping rainwater conservation streams, the order analysis is significant due to higher stream orders having lower infiltration and permeability.

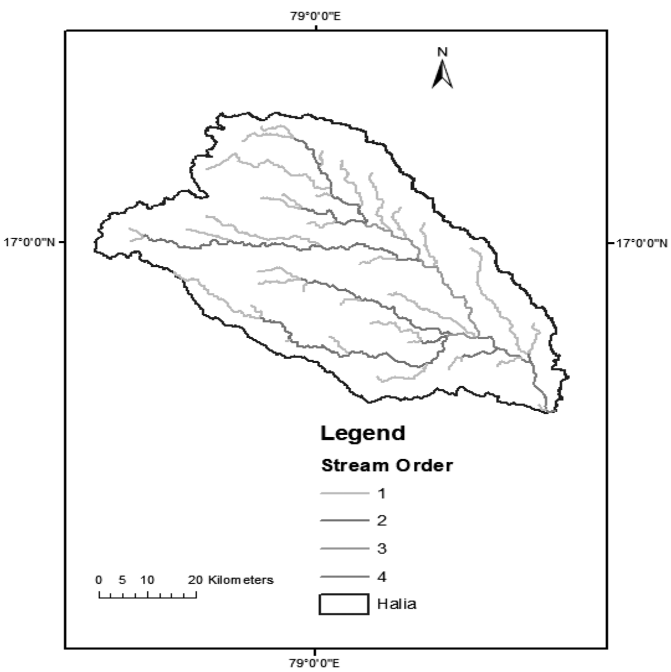


Fig. 3: Stream orders in Halia catchment

Identification of potential sites for water harvesting structures

Understanding the spatial pattern of runoff is very essential for planning of soil and water conservation interventions. The suitability of water harvesting structures depends on slope, rainfall (amount and distribution), soil type and soil depth, water holding capacity, location of impervious layer, agricultural practices, land use land cover and stream order. The Soil and Water Conservation Department has been implementing various soil and water conservation measures in watersheds like gabion structures, farm ponds, check dams, percolation tanks etc., to intercept rainfall where it falls and to obviate the chances of the runoff water from acquiring erosive velocities in watershed. Spatial information on runoff coefficient, slope, stream order, soil type, rainfall distribution plays a critical role in site selection for runoff harvesting/recharging structures. First stream order occupied major portion with gabion structures in Halia catchment area. The farm pond/percolation tank is constructed at junction of two first-order channels forms a second-order channel. The check dams is constructed at third-order channel is formed by the junction of two second-order channels in Halia river basin. After intercepting the required thematic layers in GIS, the suitability criteria for each structure was applied and potential site for each structure was identified using geospatial techniques (Figure 3). Similar methodology was used by Rejani *et al.,* 2017 for finding potential locations for constructing different water-harvesting structures in a semi-arid watershed located at Goparajpalli watershed in Warangal district using geospatial techniques.

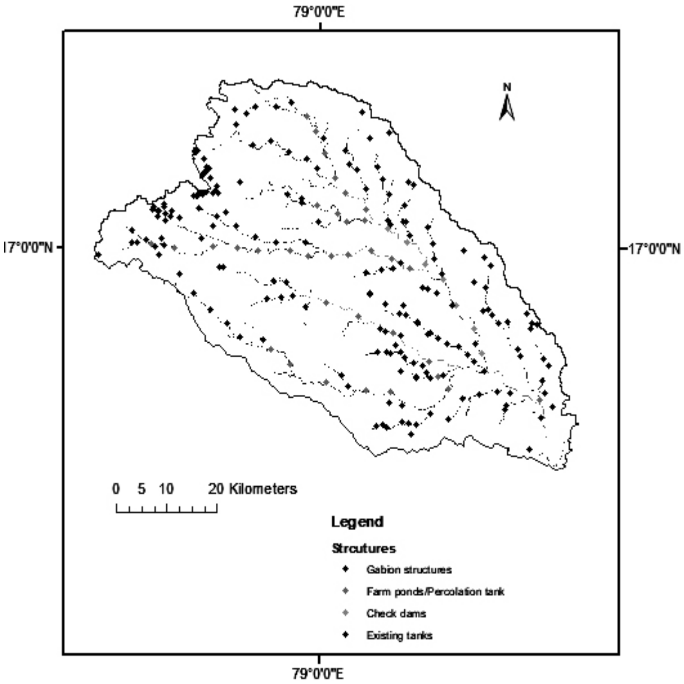


Fig. 3: Location of existing structures and potential sites for additional water harvesting structures for Halia river basin

Validation of potential sites for water harvesting structures

The potential locations for water harvesting structures was converted into. kml file format and exported to Google earth (Figure 4). The ground truth related to location of existing structures was collected during the survey and was exported to ArcGIS and identified new potential sites for planning of additional structures. The derived sites were field investigated for suitability and implementation.

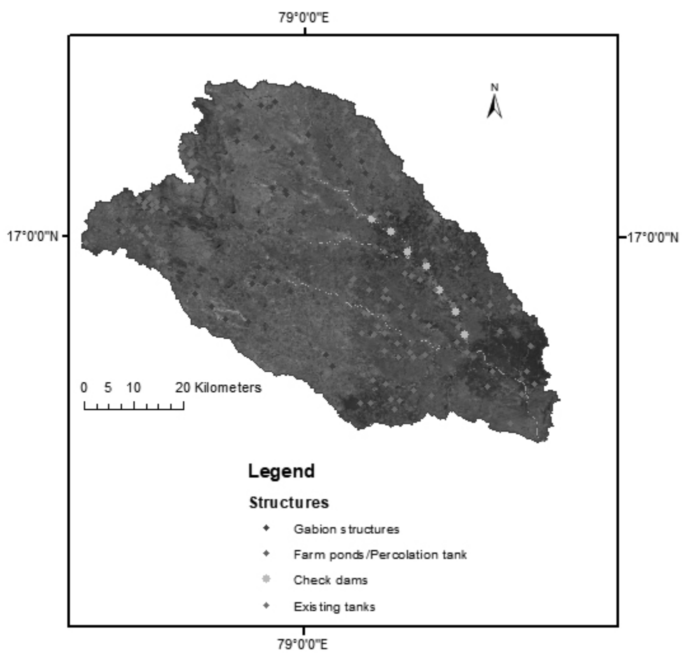


Fig. 4: Validation of water harvesting structures for Halia catchment using Google Earth

The additional structures needed for controlling of runoff and water storage are gabion structure, farm pond/ percolation tanks and check dams. Ramakrishnan *et al.,* 2009 also used geospatial techniques for planning water harvesting structures for Kali sub-watershed situated in the semi-arid region of Gujarat and proposed potential sites for runoff harvesting structures like check dam, percolation pond, farm pond, well and subsurface dyke.

Conclusions

Adoption of *in-situ* soil and water conservation techniques and construction of rainwater harvesting structures are very essential for moisture conservation and rainwater harvesting for supplemental irrigation especially in cases of unpredictable nature of monsoon rainfall. Planning and implementation of rainwater harvesting structures like farm ponds, check dams, percolation tanks etc. needs data of runoff potential. In this scenario, various soil and water conservation measures (SWC) have been required to harvest the surface runoff for supplemental irrigation in Halia catchment. Water harvesting structures such as farm ponds, percolation tanks and check dams located at potential sites are recommended for desiltation and renovation by increasing their size along with lining so that they can be utilized for rainwater harvesting and supplementary irrigation resulting in sustainable management of the Halia basin. The implementation of these soil and water management practices will result in increased water availability, net cultivated area, area under supplementary irrigation and productivity of crops and groundwater levels.

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