THE INTERNATIONAL JOURNAL OF
SCIENCE & TECHNOLEDGE

Runoff Map Preparation for Khadakwasla using Arc-CN Runoff Tool

Yamini Suryaji Jedhe
Department of Environemntal Sciences, University of Pune, India

Abstract:
Khadakwasla watershed was investigated to generate the runoff maps using the Arc CN runoff tool which is an extension of the ArcGIS with the help of remote sensing and geographical information system. Attempt was made to understand the basaltic terrain in spatial context to find out runoff from Landsat Thematic Mapper imagery and other collateral data. Subsequently, these layers were processed to derive runoff from Soil Conservation Service Curve Number (SCS-CN) method using Arc-CN runoff tool. In conclusion, the method used in present study deciphers the more precise, accurate and ability to process large catchment area to generate the runoff maps.

Keywords*: Runoff, Khadakwasla Watershed, Rainwater harvesting, Remote sensing, Geographical information system*

1. Introduction

The runoff maps using the Arc CN runoff tool is the precise and the easiest menthod to create a runoff maps for the larger watersheds. Identification of the runoof of total watershed is important to plan for the rainwaterharvesting structures and the sources of the siltation to the reservoir because of the slope of the watershed.

To assess the rainwater harvesting potential, Khadakwasla watershed has been selected.Water budget is balance between incoming rainfall and water loss by evapotranspiration, groundwater recharge and runoff of an entire watershed (Jasrotia et al. 2009). Out of which, runoff is one of the important parameter to predict potential rainwater harvesting sites. Furthermore, runoff is primarily dependent on soil type, landuse/landcover and antecedent moisture conditions of the area (Winnaar et al. 2007). Thus, a detailed understanding and analysis of various interrelated parameters mentioned above are functions of slope, rainfall and lithology (Kim et al. 2003). Various methods such as water balance approach (Jasrotia et al. 2009); agricultural non point source (Mohammed et al. 2004), Thiessel polygon (Kim et al. 2003) and Soil Conservation Service Curve Number (SCS-CN) method have been used to study the rainfall runoff of watershed. However, SCS-CN method is used to calculate runoff parameter and having its advantages over other above said methods, if integrated with advance tools such as remote sensing and geographical information system. This enhances the accuracy and precision of runoff prediction, eventually helps for better identification of potential rainwater harvesting structures for cost effective water resource management. This method accounts for many of the factors affecting runoff generation including soil type, land covers and land use practice, surface condition, and antecedent moisture condition (early moisture condition of the watershed prior to the storm event of interest), incorporating them in a single curve number parameter (Winnaar et al. 2007; Mishra et al. 2008; Bo et al. 2011).

2. Materials and Methodology

Spatial data such as landuse/landcover map of 1:50,000 scale was derived from digital satellite data of Landsat Thematic Mapper of 16th October 2006 using supervised classification. Soil classification map (scale 1:500,000) was upgraded to 1:50,000 scales by Landsat data image ratios and principal component analysis. Further, soil classification of study area is reclassified on the basis of USDA soil classification system.

Geological map of Geological Survey of India (scale 1:250,000) was also used. Survey of India toposheets of 1:50,000 scales were used to derive base, contour and drainage map. Digital elevation model was derived from contour layer and validated with differential global positioning system surveyed points and survey of India toposheet. The drainage map was generated from the toposheets and updated using satellite data and digital elevation model using Arc soil water assessment tool (Arc SWAT).Climatic data was acquired from India Meteorological Department, Pune. Rainfall data of the watershed (Pune City rain gauge station) for the period from 1995 to 2007 was analyzed for recurrence of storm/flood event. Since the precipitation data has been collected from single available station, the variations in antecedent moisture conditions could not be accounted. Hence, antecedent moisture conditions II is considered for the entire watershed for the given storm event **Table** 1. The runoff estimates for different combinations of soil group, land use classes and antecedent moisture conditions classes are estimated by following the procedure of SCS-CN method.

SCS-CN method is very sensitive to curve number values, necessitating accurate determination of this parameter. Curve number is again as a function of hydrological soil group, land use and antecedent moisture conditions. The antecedent moisture conditions are determined by total rainfall in the 5-day spell preceding a storm. As the soil moisture increases due to rainfall in early spell, runoff during storm event increases. Since, rainfall data used in this work derived from a single meteorological station, curve numbers were evaluated for antecedent moisture conditions II condition only (Geetha et al. 2007). Knowing the value of curve number, runoff from study area was computed from Eqs. 1 and 2.

AMC Class	**5 day total antecedent rainfall (mm)**		**Condition**
	Dormant season	Growing season	
I	<12.5	<35	Dry
II	12.5 to 27.5	35 to 52.5	Normal
III	>27.5	>52.5	Wet

Table 1: Classification of antecedent moisture conditions (Geetha et al. 2007)

This simplified assumption (Ponce and Hawkins 1996) resulted in the following runoff equation, where, CN ($0 \le CN \le 100$) (USDA 1972) represents a convenient representation of potential maximum soil retention (S):

$$\text{Runoff} = \frac{(\text{Rainfall}-0.2S)2}{\text{Rainfall}+0.8S} \quad \text{If Rainfall} > 0.2S$$
$$\text{If Rainfall} < 0.2S \quad \text{.........Eq 1}$$

For Indian Conditions
S=(1000/CN)-10 Inch and S =(25400/CN)-254 in mm, SI units (Ramakrishnan et al. 2009).
In this study, curve numbers were weighed with respect to the watershed area (generally <15 km2) using following Eq. 3:

$$CNw = \frac{\sum (CNi \ X \ Ai)}{A} \quad \text{....................Eq 2}$$

Where

- CNw is weighted curve number
- CNi is curve number from 1 to any number N
- Ai is area with curve number CNi; and
- A is total area of watershed.

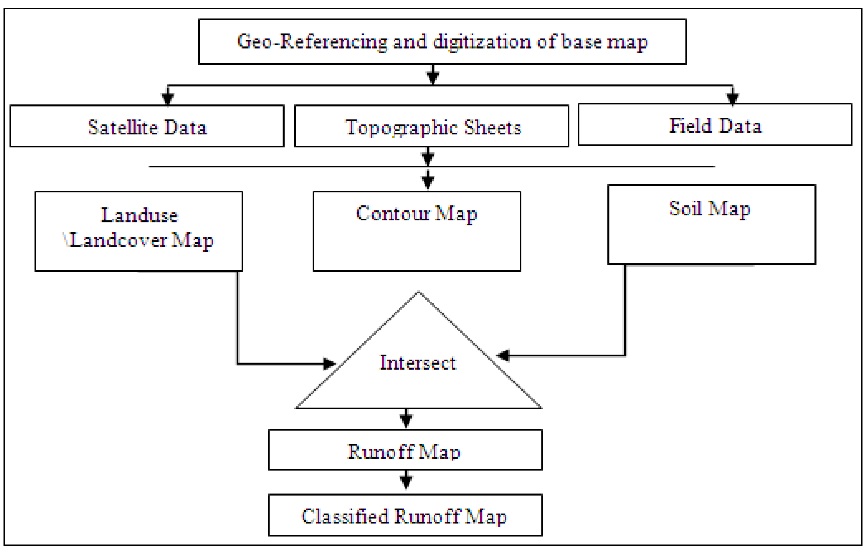

Figure 1: Methodology of Research

3. Analysis

Usually, an area weighted average curve number for the entire watershed is used to study the runoff of a watershed. The details of the spatial variation in the watershed are often lost. However, ArcCN-Runoff extension of ArcGIS 9.3 is used for accurate and precise determination of runoff.

Soil and landuse/landcover data were processed for preparation of runoff potential map. Soil and landuse/landcover data were clipped to watershed boundary layer (study area). the soil data was reclassify according to USDA soil classification system from six different classes to four classes (A, B, C and D).

Landuse/landcover and soil data was intersected based on the attributes of ‘soil type’ in soil data and ‘class name’ in landuse/landcover data. Soil and landuse/landcover data were intersected to generate new and smaller polygons associated with soil type and landuse class name.

Figure 1 depicts a detailed illustration of the methodology. Accuracy assessment was carried out by overlaying the existing structures identified at ground truth survey on derived potential rainwater harvesting map for their matching percentage

S.N.	LULC	% Area	Significance	Recommended Rain water Harvesting Structures
1	Water	4.37	Unsuitable	-
2	Vegetation	2.87	Suitable	Farm Pond
3	Scrub Land	45.45	Suitable	Percolation tank, Check dam, Farm pond
4	Barren Land	22.06	Suitable	Percolation tank, Check dam, Farm pond
5	Agriculture	7.17	Unsuitable	-
6	Fallow Land	12.19	Suitable	Gully plug, Check dam

Table 2: Land use classes and their applicability for rain water harvesting

Soil infiltration rate and its texture determine the structure to be located for its runoff potential (Jasrotia et al. 2009). Soil physical and chemical characteristics are the manifestation of disintegration of parent lithology, however, soil from study area is derived from basaltic rocks, shows alkaline nature due to presence of alkaline earths (Kale et al. 2010).

S.N.	ID	Name	Hydrogroup	Area%	Type of Soil	Runoff Potential	Infiltration Rate	Significance
1	77	Loamy soil	B	65.91	soils have moderate infiltration rates when thoroughly wetted and consist chiefly of moderately deep to deep, moderately well to well drained soils with moderately fine to moderately coarse textures. These soils have a moderate rate of water transmission (0.15-0.30 in/hr).	Moderate	Moderate	Moderate rate of water transmission
2	118	Sandy soil	A	7.71	Soils have low runoff potential and high infiltration rates even when thoroughly wetted. They consist chiefly of deep, well to excessively drained sands or gravels and have a high rate of water transmission (greater than 0.30 in/hr).	Low	High	High rate of water transmission
3	266	Clay soil	C	26.38	Soils have low infiltration rates when thoroughly wetted and consist chiefly of soils with a layer that impedes downward movement of water and soils with moderately fine to fine texture. These soils have a low rate of water transmission (0.05-0.15 in/hr).	Low	Low	High rate of water transmission

Table 3: Hydrological Soil Group

4. Results

The computed runoff values are shown in Table 4. The hill shows reserved forest with soil group B revealing least runoff potential (8.76 mm). On the basis of histogram distribution, the runoff potential map was classified into four classes.However, 68.59 % of the area is dominated by moderate runoff potential zones, where as high runoff potential zone covered an area of 35.26 %. High to Moderate runoff potential zones were suitable for selecting rainwater harvesting structure.

Hydro Group	Class Name	AREA (M)	CN	RUNOFF (MM)
B	Barren Land	71348305.858	55	16.37
B	Scrub Land	175840000.000	61	17.73
B	Agriculture	20638306.819	77	20.75
B	Vegetation	40089394.510	58	17.07
B	Fallow Land	27911142.054	66	18.76
B	Water	2815963.523	100	24.00

Hydro Group	Class Name	AREA (M)	CN	RUNOFF (MM)
A	Barren Land	5356363.243	30	8.76
A	Scrub Land	18741838.631	39	11.93
A	Agriculture	1868798.587	67	18.96
A	Vegetation	247066.122	30	8.76
A	Fallow Land	15171539.710	48	14.59
A	Water	126998.616	100	24.00
B	Barren Land	3036253.183	55	16.37
B	Scrub Land	8942344.456	61	17.73
B	Agriculture	1120164.006	77	20.75
B	Vegetation	2348103.041	58	17.07

Table 4: Runoff estimated for different soil group and land use classes

5. Accuracy of the Results

The landuse/landcover classification accuracy evaluated by error matrix, showed 82 % and 94 % accuracy for the producer and the user estimates respectively. Higher accuracy is maintained by using Landsat thematic mapper imagery of 30 m resolution to identify possible rainwater harvesting sites. Accuracy assessment was carried out by overlaying the existing structures identified at ground truth survey on potential rainwater harvesting map.Such a higher accuracy of the study (75–100 %) offers a good guidance for field implementation.

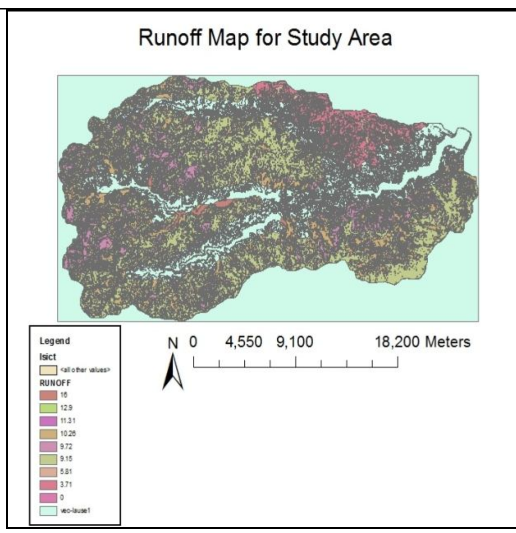

Figure 2: Runoff Potential Map of Khadakwasla

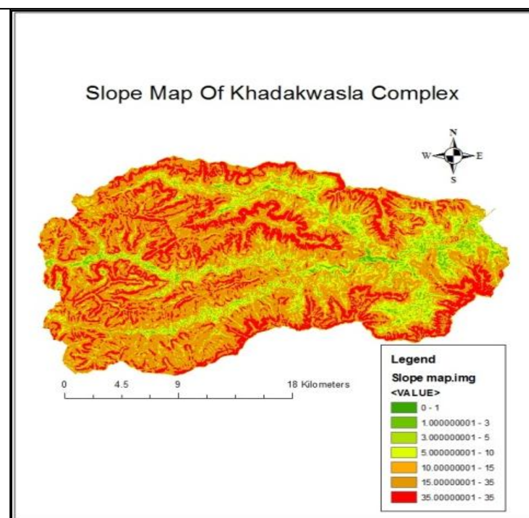

Figure 3: Slope map of Khadakwasla

6. References

1. Abdulla FA, Al-Shareef AW (2009) Roof rainwater harvesting systems for household water supply in Jordan.Desalination 243:195–207
2. Zhan X, Huang ML (2004) ArcCN-Runoff: an ArcGIS tool for generating curve number and runoff maps.Environ Model Softw 19:875–879
3. Jasrotia AS, Abinash M, Singh S (2009) Water balance approach for rainwater harvesting using remote sensing and GIS techniques, Jammu Himalaya, India. Water Res Manage 233:35–55
4. Kale SS, KadamAK, Kumar S, Pawar NJ (2010) Evaluating pollution potential of leachate from landfill site, from Pune Metropolitan City and its impact on shallow basaltic aquifers. Environ Monit Assess 162:327–346
5. Kale SS, KadamAK, Kumar S, Pawar NJ (2012) Identifying Potential Rainwater Harvesting Sites of a Semi-arid, Basaltic Region of Western India,Using SCS-CN Method Water Resour Manage DOI 10.1007/s11269-012-0031-3
6. Horton RE (1945) Erosional development of streams and their drainage basins: hydrophysical approach to quantitative morphology. Geol Soc Am Bull 56:275–370
7. Kim SJ, Kwon HJ, Jung IK, Park GA (2003) A comparative study on grid-based storm runoff prediction using Thiessen and spatially distributed rainfall. Paddy Water Environ 1:149–155

8. Geetha K, Mishra SK, Eldho TI, Rastogi AK, Pandey RP (2007)Modifications to SCS-CNmethod for long- term hydrologic simulation. J Irrig Drain Eng 133(5):475–486
9. Mohammed H, Yohannes F, Zeleke G (2004) Validation of agricultural non-point source (AGNPS) pollution model in Kori watershed, South Wollo, Ethiopia'. Int J Appl Earth Observ Geoinform 6:97–109
10. Ramakrishnan D, Durga Rao KHV, Tiwari KC (2008) Delineation of potential sites for water harvesting structures through remote sensing and GIS techniques: a case study of Kali watershed, Gujarat, India.Geocarto International 23(2):95–108
11. Ramakrishnan D, Bandyopadhyay A, Kusuma KN (2009) SCS-CN and GIS-based approach for identifying potential water harvesting sites in the Kali Watershed, Mahi River Basin. India J Earth Syst Sci 118 (4):355–368
12. Sazakli E, Alexopoulosb A, Leotsinidis M (2007) Rainwater harvesting, quality assessment and utilization in Kefalonia Island, Greece. Water Res 41:2039–2047