Identifying Potential water harvesting sites using GIS

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Abstract:

Water crisis has been rapidly increasing these days in many parts of the world which emphasize the importance of a refinement in water management systems. Harvesting of rain water, which involves collection and storage of rain water for future use, is an area of increasing interest. Drought-like situations prevail in many parts of India and has to be immediately studied for employing proper rain water harvesting (RWH) techniques. Here, remote sensing and GIS can be successfully used as a tool to identify the location since the effectiveness of RWH depends on site selection. Various features like run-off potential, slope, storage loss and drainage have to be considered in this context. ArcCN–Runoff, a tool based on ArcGIS , can be used for mapping runoff. SCS-CN method, being the most common method for calculating the runoff value, has been employed in this tool .It relies on runoff curve number(CN) which predicts the direct runoff occurring after a rainfall. The process involved in suggesting locations for RWH schemes using GIS is discussed in this paper. The study area chosen here is Malappuram district in Kerala, considering Nilambur , Perinthalmanna and Kuttipuram blocks.

Key words : runoff, curve number, rain water harvesting, GIS, site selection

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Introduction

As the world is facing an alarming situation of water scarcity, its conservation requires immediate action. The amount of available water resources has decreased over the years due to its inefficient usage and environmental degradation. The sustenance of life in future largely depends on how we protect these resources. Increasing population has resulted in over-exploitation of resources and the situation has become worse with increasing droughts in many areas.

This paper focuses on 3 blocks of Malappuram district in Kerala, namely Nilambur, Perinthalmanna and Kuttipuram. A study of various water resources in Kerala state and its usage has been carried out by Centre of Excellence in Environmental Economics (CEEE) of the Kerala Agricultural University (KAU) which brings out a gap of about 1268 billion litres between the demand of water and its supply for 2021. This gap has been estimated based on current rainfall level , its storage and ground water available. The study also points out that the ground water status of Kerala state has been alarming. Malappuram district is reported to have the third largest relative vulnerability index in Kerala with a value of 108.52. Rain water harvesting (RWH) is an optimal solution which involves collection and storage of rainwater. This can be done using methods like underground check dams or even at houses in a small scale, say using tanks or pots. Proper sites should be identified immediately for rain water harvesting based on the demand and supply of water in that particular area. Water being not only important to sustain life but also for domestic, agricultural and industrial uses, thus demands an adequate planning to preserve the resources for future. This motivates the generation to adapt various techniques like rain water harvesting. In this paper, the procedure for finding critical areas using GIS is discussed. Three blocks of Malappuram district, which requires action for employing rain water harvesting system, is chosen as the study area. For this area, soil map, land use map, drainage map and slope map have been developed which can be used in the identification of RWH sites. Tools like ArcGIS and Image processing software have been used in this context. ArcCN – Runoff is used to generate runoff and curve number maps.

Study Area

The study area chosen is Malappuram district of Kerala state in India. Slope map, soil map, landuse map, study area map and drainage map have been developed focusing 3 blocks of the district, using ArcGIS , which are useful while identifying optimal locations for rain water harvesting. The district covers an area of about 33.61 km2 . Kuttipuram, Nilambur and Perinthalmanna are the 3 blocks chosen. The study area map is shown in figure 1.

Fig 1: Study area

Slope Map

A slope map indicates the slope of a given area. It is generally a representation of slope using different colours. Here, the slope map of the study area in Malappuram has been shown in figure 2 . It has been divided into 5 classes where the 1st class (0-1) indicates nearly flat areas. The slope of any terrain can be expressed in terms of slope degrees which varies from 0-90 degrees or as percent functions which extends from 0-1000 %. A slope of 0-5 degrees represents flat surfaces whereas 31-90 degrees indicate steep slopes. The significance of slope map in identifying proper rain water harvesting sites relies on the fact that slope of a given area affects the amount of runoff and movement of surface water.
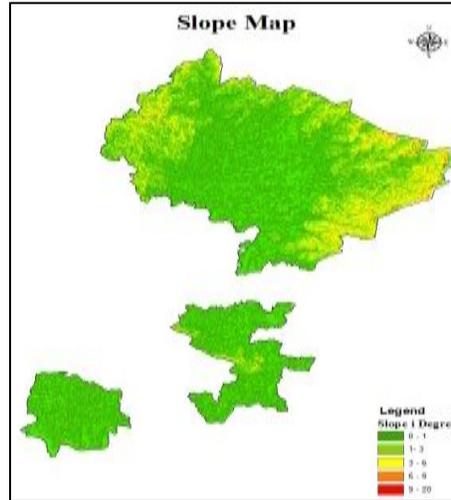
Fig 2: Slope Map

Land use and soil maps

In this study, Indian Remote Sensing (IRS-LISS-III) satellite data has been used to obtain land use classes. Unsupervised classification has been done on satellite data using Image processing software dividing the study area into 5 classes, namely water-body, housing area, hill, cloud and forest. The land use map is shown in figure 3. Further, field visit study can be done to improve the classification of land use. This can be made use of while selecting appropriate sites for rain water harvesting. Land use pattern holds a significant part while selecting the parameter called runoff curve number (CN). This can be used to predict the direct runoff occuring in an area after a rainfall. A low infiltration and high runoff is indicated by a high value of curve number. The soil map of study area is shown in figure 4. Runoff occurring after rainfall largely depends on the type of soil in that particular area which highlights the relevance of a soil map.
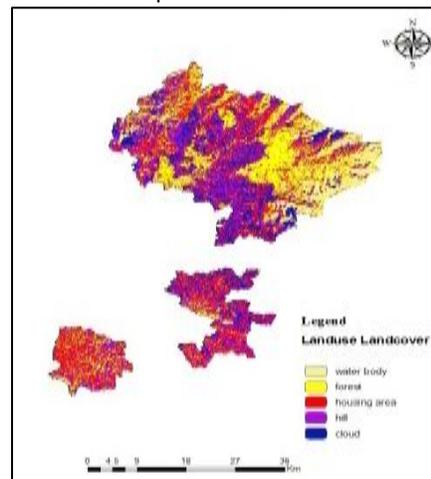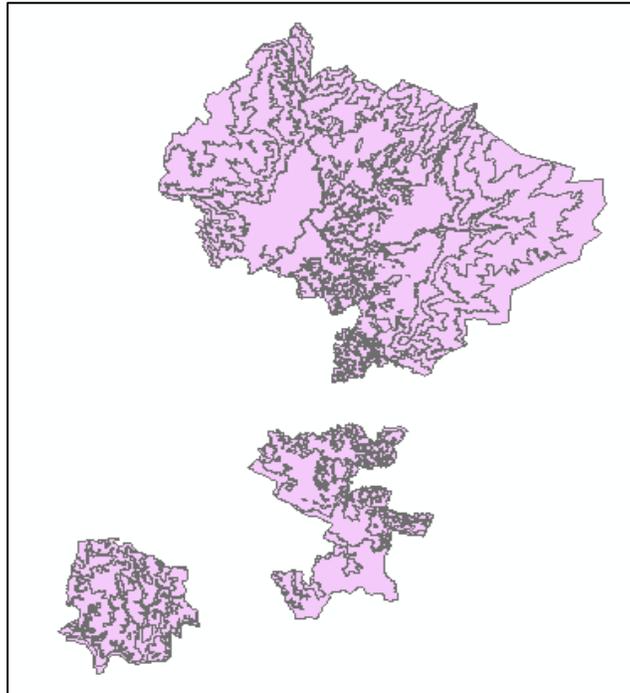

Fig 3: Landuse Map

Fig 4: Soil Map

Drainage pattern

The drainage network for the study area is shown in figure 5. The distribution of ponds, lakes and reservoirs which contribute to water storage in that particular area is mapped in a drainage map. Based on their distribution, selection of critical areas should be made for building check dams and appropriate structures for rain water harvesting.
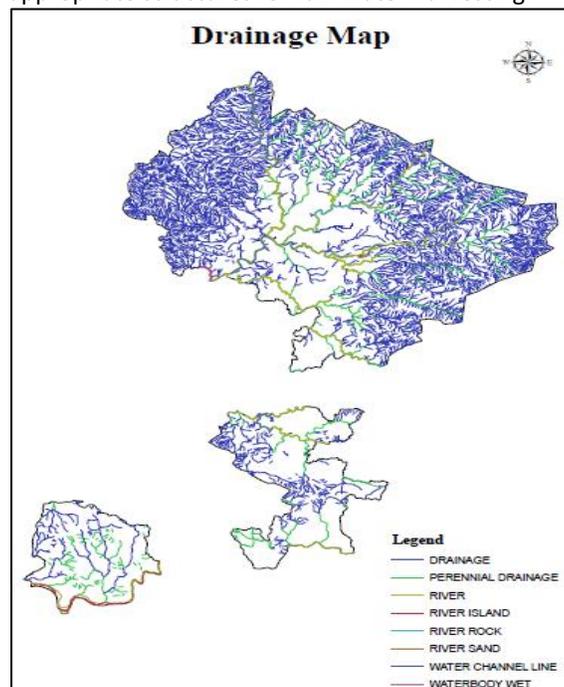

Fig 5 : Drainage Map

Determining runoff in a particular area

In general, factors affecting runoff include precipitation and watershed. The size, shape, topography, soil and land use thus affects runoff. NRCS curve number method divides soil data into 4 hydrologic soil groups (HSG) namely A, B, C and D. The curve number (CN) for a particular antecedent moisture condition (AMC) is available which can be effectively used provided the HSG of that area has been properly identified. Once CN has been calculated, we can use the equations:

$S = (1000/CN) - 10$

$$Q = \begin{cases} 0 & for\ P \le Ia \\ \dfrac{(P-Ia)^2}{(P-Ia+S)^2} & for\ P > Ia \end{cases}$$

Where P is the rainfall depth (inches) and Q is the excess runoff (inches). Ia is the amount of water in the area before runoff and is usually assumed to be as a factor of S, say 0.2S. Works related to calculating runoff, water poverty index and identifying feasible locations for rain water harvesting have been done in India in areas like selected regions of Gujarat and Palakkad . They can be used as a reference for proper guidance while identifying the best possible sites for employing rain water harvesting techniques.

ArcCN – Runoff

Curve number and runoff maps of an area can be easily generated using an ArcGIS tool called ArcCN–Runoff. The tool is an excellent visualization method for analyzing the runoff occurring in a specific area. This helps in easy interpretation of areas with different runoff values. It aids in identifying proper rain water harvesting sites based on runoff potential. In this tool, only 2 inputs are needed – soil and land use data. The hydrologic soil group (HSG) of area under consideration should be added as a table in the attribute table of soil data. Land use data includes various land use classes as an attribute table. The 2 datas , namely land use and soil, are then intersected. An example of the attribute table of the intersected shape file in ArcGIS is shown in figure 6. The curve number database can be added by the user in .dbf format based on field data. Precipitation value of the desired area is also given. Detailed explanation of the tool is available which can be referred. The tool makes use of the popularly used SCS-CN method for calculating runoff. The steps involved in ArcCN–Runoff tool is shown in figure 7.

| FID	Shape	HYDGRP	COVERNAME	AREA	CN *	RUNOFF *	RUNOFFV_M
0	Polygon		Bur Oak Floodplain Woodland	22465.065	0	0	0
1	Polygon		Cattail Marsh	195.364	0	0	0
2	Polygon		Cottonwood Floodplain Forest	69069.026	0	0	0
3	Polygon		Cultivated Land	21446.573	0	0	0
4	Polygon		Low or Wet Prairie	0.002	0	0	0
5	Polygon		Mixed Oak Ravine Woodland	45467.742	0	0	0
6	Polygon		Non-Native Grassland	64611.463	0	0	0
7	Polygon		Oak - Hickory Forest	198769.443	0	0	0
8	Polygon		Tallgrass Prairie	11082.878	0	0	0
9	Polygon		Water	520211.52	0	0	0
10	Polygon	B	Ash - Elm - Hackberry Floodplain Forest	55659.02	60	0.42	589.44
11	Polygon	B	Bur Oak Floodplain Woodland	150469.435	55	0.26	983.8
12	Polygon	B	CRP (Conservation Reserve Program)	244803.176	69	0.79	4924.64
13	Polygon	B	Cattail Marsh	205631.936	58	0.35	1824.52
14	Polygon	B	Cottonwood Floodplain Forest	1564258.783	60	0.42	16565.94
15	Polygon	B	Cottonwood Floodplain Woodland	92417.255	55	0.26	604.24
16	Polygon	B	Cultivated Land	5570678.456	86	1.85	262367.85
17	Polygon	B	Low or Wet Prairie	98041.487	58	0.35	869.05
18	Polygon	B	Mixed Oak Floodplain Forest	183920.456	60	0.42	1947.77
19	Polygon	B	Mixed Oak Ravine Woodland	624452.794	55	0.26	4062.81
20	Polygon	B	Non-Native Grassland	3227621.312	69	0.79	64929.22
21	Polygon	B	Oak - Hickory Forest	2863656.277	60	0.42	28208.86
22	Polygon	B	Pecan Floodplain Forest	11550.771	60	0.42	122.33
23	Polygon	B	Tallgrass Prairie	8239366.889	69	0.79	165749.2
24	Polygon	B	Water	82334.269	0	0	0
25	Polygon	C	Ash - Elm - Hackberry Floodplain Forest	13685.8	73	1	351.6
26	Polygon	C	Bur Oak Floodplain Woodland	190718.977	70	0.84	4073.6
27	Polygon	C	CRP (Conservation Reserve Program)	154723.184	79	1.35	5318.26
28	Polygon	C	Cattail Marsh	150777.342	71	0.89	3413.64

Fig 6 : Attribute table
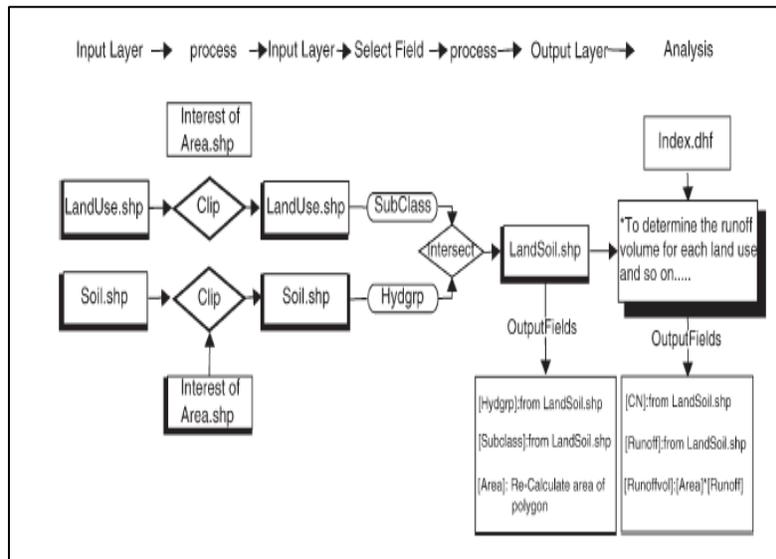
Fig 7 : Flow chart

Conclusion

The steps involved in identifying proper rain water harvesting (RWH) sites using ArcGIS have been discussed in the paper. Field visit to the proposed site location can be done to improve the accuracy of appropriate site selection. The role of ArcGIS and ArcCN–Runoff tools for proper identification of water harvesting structures is huge. The paper gives an overall idea of how the procedure of site selection can be carried out. Different maps have been developed in ArcGIS for the study area concerned. In this manner, ArcGIS can be effectively used as a tool for proper identification of RWH sites so that water scarcity situations in many parts of the world can be easily tackled.

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