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Identification of Suitable Sites for Water Harvesting Structures in Kecheri River Basin

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Abstract

Water is the most precious resource on the earth which is essential for the existence of life. Though Kerala is blessed with two prominent monsoons with an average rainfall of around 3000mm, it experiences water scarcity in off monsoon seasons. Peculiarities such as steep slope and undulating terrain accelerate surface flow and hence most of the water received as rainfall goes as unutilized. Water Harvesting is the best technique which can be used effectively to trap the unutilized surface runoff and thereby increase the groundwater recharge. But these structures have to be located at places where water is available in excess and conditions are favourable for enhanced infiltration. The objective of this study is to identify suitable sites for water harvesting structures. For ideally locating the sites, the guidelines put forward by NRSA, Hyderabad for Integrated Mission for Sustainable Development (IMSD), is being followed. ArcGIS is used for the spatial analysis and the sites are located by overlaying thematic maps of land use, soil, slope, runoff potential, soil permeability and stream order. It is found that 37 percentage of the total area is ideal for constructing check dam, 7 percentage for farm pond, 4 percentage for percolation pond and about 2 percentage for subsurface dyke. Check dams are the most suited one and location for subsurface dykes is sparse. Locations of water harvesting structures are suggested by conducting meteorological and topographical analysis. However, for the practical implementation of these structures, viability of other considerations such as economy, social implications, practical feasibility etc. need to be considered.

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Keywords: Water harvesting; Site identification; ArcGIS; Thematic maps

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1. Introduction

The amount of water present in earth is always constant. It is transformed from one form to another in a specified manner. Though two by third of earth is filled with water, the usable water for irrigation and drinking purpose is only two percentage of total available. So proper management of the available water is very important for the sustainable utilization of it. The major share of usable water is present in the inner part of earth known as ground water. Increase in the ground water storage of a region is the direct measure of water richness. Water harvesting technique plays a vital role in increasing the ground water recharge.

Kerala, the southernmost state of India is blessed with two important monsoons, South-West and North-East. Plenty of water is available from these two monsoons. According to the Kerala Hydrologic Department, the average rainfall of Kerala is more than 3000 mm, still most part of it experiences water scarcity. The worst thing is the fact that though the rainfall is high, it doesn't effectively increase the groundwater storage as the major share of water is not infiltrated through the soil but flows off as overland flow. Kerala have its own peculiarities and pattern in terms of surface terrain, topography and climatic conditions which promotes runoff. Thus the plenty of water available from the two rich monsoons can't be effectively utilized for domestic and other purposes in off monsoon season. So to meet the requirement of water round the year, it is essential to effectively trap the surface runoff in monsoon season and retain it so long as to get infiltrated which can be done by proper management of excess rainwater available in monsoon season.

Harvesting is the technique which is used to effectively trap the surface runoff. In technical terms, water harvesting is a system that collects rainwater from where it falls around its periphery rather than allowing it to go as runoff. By constructing water harvesting structures in appropriate sites it is possible to increase the ground water recharge and level of water table, so that we can effectively use this water for irrigation and drinking purpose in the off monsoon season [1]. Also these structures act as a barrier to soil erosion and prevent flooding. Percolation Ponds, Subsurface Dykes, Farm Ponds, Check Dams, Bunds etc. are some of the type of water harvesting structures that are widely in use [2].

In this study the suitable sites for constructing water harvesting structures in Kecheri watershed is identified using ArcGIS. For the selection of suitable sites many guidelines put forwarded by various agencies are available such as IMSD, INCOH, FAO etc. In this study, selection of water harvesting structure is done on the basis of IMSD (Integrated Mission for Sustainable Development) guidelines put forwarded by NRSA (National Remote Sensing Agency, Hyderabad). Integrated Mission for Sustainable Development is one of the projects put forwarded by the department of Space for providing practical solutions to various problems through the technology of satellite remote sensing [3].

2. Study area and Data collection

2.1. Study Area

Kecheri River basin lies between $10^0 25^{'} 44.41''$ to $10^0 43^{'} 17.77''$ North latitude & $76^0 02^{'} 05''$ to $76^0 21^{'} 26.25''$ East longitude. It covers an area of 772.09 km^2. The Kecheri river consists of two main Rivers, namely, Kecheri River and Puzhakkal River. Kecheri River is also known as "Wadakkancheri Puzha". The Kecheri river originates from Machadmalai and the elevation is 365m. Puzhakkal river also originates from Machadmalai with an elevation of 525m. Length of Kecheri river is 51km and that of PuzhakKal river is 29km. The main tributary of Kecheri river is Chundalthodu and that of Puzhakkal river are Parathodu, Pomaalthodu, Naduthodu and Kattachirathodu and that of Puzhakkal river are Parathodu, Pomalathodu, Naduthodu and Kattachirathodu. Vazhani is the existing irrigation project in the study area. Vazhani dam is one of the biggest clay dams in Kerala having a length of 792.48 km. This water is mainly used for irrigation and drinking purposes. The project was completed during the year 1962 and it envisages construction of an earth dam built across the Vadakkancheri puzha.

Kecheri Mainly has mixed plantation and forest. Gravelly clay, Clay, Sand, Loam and Gravelly loam etc. are the normally seen soil textures in this region. Kecheri River basin has its presence in 10 blocks in Thrissur District and one in Palakkad District. There are 48 Panchayats and 39 villages in this basin.

Upper region of the basin mainly comprises of agricultural land and forest land. Agricultural land consists of a mixture of agriculture and horticulture plantation. Middle region of the basin is mainly under agricultural land, waste land and forest land. Lower region comes under agricultural land and water bodies. Agricultural land is around 40% of the area and it is double cropped paddy lands. Rest is water body.

2.2. Data Collection

Digital Elevation Model (DEM), Rainfall data, Different thematic maps are needed for this study. Aster DEM is downloaded from http://earthexplorer.usgs.gov. (Site of United States of Geographical Survey). Daily rainfall data of all rain guage stations situated in and near Kecheri river basin is obtained from Hydrology Department, Thiruvananthapuram. The rainguage stations chosen are Amala Nagar, Kunnamkulam, Vazhani, Vaniampara, Enamakkal and Ollukkara. The thematic maps used in this study are Landuse map,Classified slope map, Stream order map, Runoff potential map and Soil permeability map [4].

Land use map gives the pictorial representation of the purpose for which each portion of the study area has been used. It is collected from the Kerala Forest Research Institute, Peechi. The study area comprises of Agricultural crop land**,** Agricultural fallow land, Built up land (Village-Residential)**,** Built up land (Town-Commercial), Forest, Waste land**,** Water bodies and Wetland. The figure 1 shows the land use map.

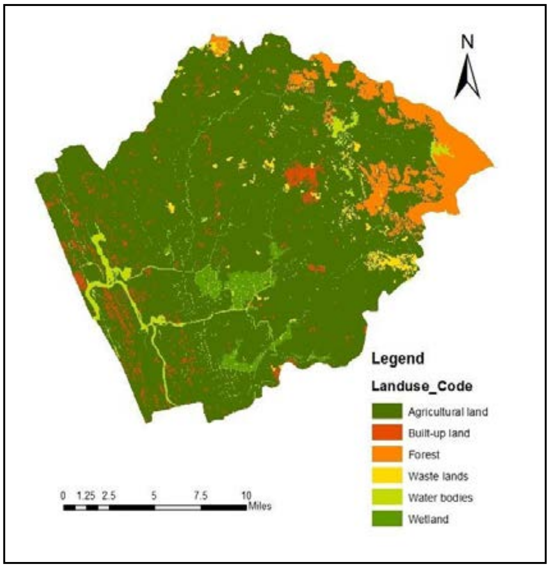

Fig. 1. Land use map of Kecheri River Basin.

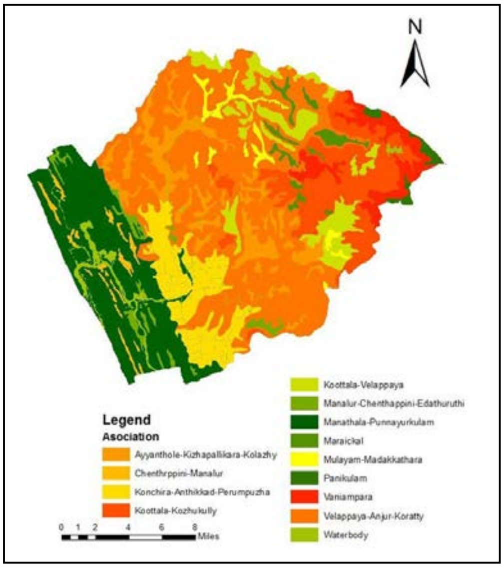

Fig. 2. Classified soil map

There are mainly four types of soil in the district. They are sandy loam, laterite soil, clayey soil and alluvial soil. Sandy loam type soil seen in part of Mukundapuram, Thrissur and Chavakkad taluks. Laterite type soil seen in eastern part of Thrissur and Western part of Talapally taluks. Clayey soil seen in back-water area of Chavakkad and Mukundapuram taluks, Alluvial soil seen in portions of Chavakkad taluk. Soil map is obtained from Kerala Forest Research Institute, Peechi. Kecheri river basin consist of soil texture such as Sandy clay loam, Silty clay loam, Clay loam, Sandy clay, Clay, Loam and Loamy sand. The figure 2 shows the classified soil map.

3. Methodology

3.1. Identification of Suitable Sites for Water Harvesting Structures

Land use map, Soil map, Runoff potential map, Stream order map, Permeability map and Slope maps are used for identifying the suitable sites for water harvesting structures by overlaying [4]. Overlaying of these map are done by using “Intersect” from “Overlay” option of “Analysis Tools” in ArcGIS. Land use map and Soil maps are obtained from Kerala Forest Research Institute, Peechi.

- Classified Slope Map

Slope is an important parameter for site selection of water harvesting structures. The runoff, recharge, and movement of surface water depend on the slope of the area. Slope map can be generated from DEM. It is done by Surface option from Spatial Analyst Tools. The derived slope map is classified base on slope in degree into 7 categories as per IMSD Guidelines as Nearly level (0-1), Very Gentle (1-3), Gentle (3-5), Moderate (5-10),Strong (10-15), Moderately steep (15-35) and Very steep (greater than 35) [5]. The classified slope map is shown in figure 3.

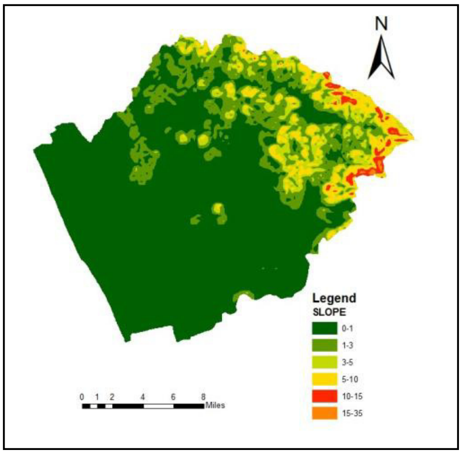

Fig. 3. Classified slope map.

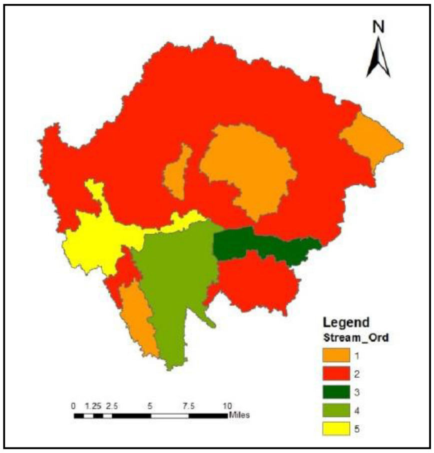

Fig. 4. Stream order map.

- Stream Order Map

Stream order map can be generated from DEM data. It is done by choosing “Hydrology” option from “Spatial Analyst Tools”. To start with, the DEM should be geo-referenced and transferred to projected coordinate system. Then Flow direction map of the area is determined. Then Flow accumulation of the area is then prepared by eliminating the values which are below five hundred in flow accumulation map. This Flow accumulation and flow direction maps are used to generate stream network. After generating the stream network, identify the stream order of each sub basin. It can be done by allocating the order of the stream to the sub-basin it drains from. Figure 4 shows the stream order map.

- Runoff Potential Map

Runoff potential map is prepared by calculating the runoff contribution of unit area of each sub basin to the total runoff from the basin. It is prepared after hydrologically modeling the Kecheri river basin in SWAT [6]. The daily runoff data of each sub-basin is obtained from SWAT output file. To find out the runoff potential of each sub basin, the runoff from each sub-basin is computed for a period of one week in which maximum rainfall is available. The runoff contribution of unit area of each sub basin to the total runoff is calculated. Based on this runoff potential, sub basins were divided into three categories namely Low, Medium and High. The runoff potential map is shown in figure 5.

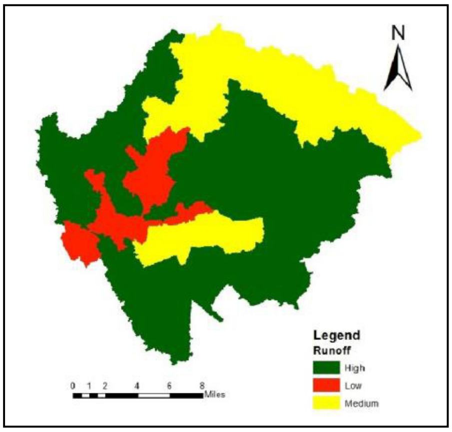

Fig. 5. Runoff potential map

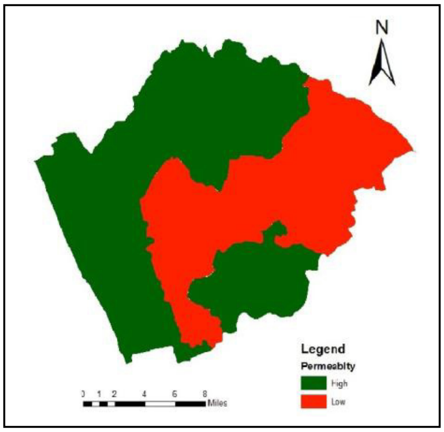

Fig. 6. Soil permeability map

- Soil Permeability Map

Permeability of soil is an important parameter which determines the rate of infiltration. The entire river basin is classified into two permeability groups, namely Low and High based on the type, texture and nature of the soil [5]. The classification of permeability is done based on 'Soil textural classes and related saturated hydraulic conductivity' table by United State Department of Agriculture, USDA shown in Table II. The permeability map is shown in figure 6.

Table 1 Soil Textural Classes and Related Hydraulic Conductivity Classes (Source: USDA)

Texture	Textural Class	General	K_{sat} Class	K_{sat} Rate ()
Coarse sand	Coarse	Sandy	V. rapid	> 141.14
Sands Loamy sands	Coarse	Sandy	Rapid	42.34- 141.14
Sandy loam Fi. san. loam	Mod. Coarse	Loamy	Mod. Rapid	14.11 – 42.34
v. fi. sa. loam Loam Silt loam Silt	Medium	Loamy	Moderate	4.23 – 14.11
Clay loam Sa. cl. loam Si. cl. loam	Mod. Fine	Loamy	Mod. Slow	1.41 – 4.23
Sandy clay Silty clay Clay	Fine and very fine	Clayey	Slow	0.42 – 1.41
Cd horizon Natric horizon, fragipan, ortstein			V. slow or impermeable	0.00 – 0.42

3.2. Selection of Type of Water Harvesting Structures

Every water harvesting structure has its own peculiarities. So proposing the sites and type of water harvesting structure in the basin has to be done judiciously. As per IMSD guidelines, percolation pond is normally suggested for recharging aquifer and used where surface storage is available for restricted period. It may be used for limited irrigation, live stock and domestic demand. The required site conditions are high permeability and well defined broad stream channel. Check dams are used for surface storage and its application is restricted for irrigation and domestic needs. The site conditions for check dam are well defined straight stream channel with level banks. Farm ponds are normally used for live stock storage and restricted irrigation. Narrow elongated depression, gentle slope and small catchment area are the required site condition for the farm ponds. Subsurface dyke are used to check the base flow in river and reduce evaporation losses. It is mainly used for domestic needs. Straight and Wide River with 2 to 3 m thick sandy-gravely bed material are the required condition for constructing Subsurface dykes. The IMSD site selection criteria for water harvesting structures are given in Table II [5].

Table II IMSD Guidelines

Structure	Slope (Degree)	Permeability	Runoff	Stream Order
Farm Pond	0-5	Low	Medium/High	1
Check Dam	< 15	Low	Medium/High	1-4
Subsurface Dyke	0-3	High	Medium/Low	>4
Percolation Pond	<10	High	Low	1-4

4. Results and Discussions

Identification and selection of type of water harvesting structures is done by overlaying Land use, Soil, Slope, Runoff potential, Soil permeability and Stream order map. The criteria assigned are based on the IMSD guidelines. Proposed sites for percolation ponds, Farm ponds, Subsurface dykes and Check dams are shown in figure 7. Proposed sites for Check dam is shown in figure 8.

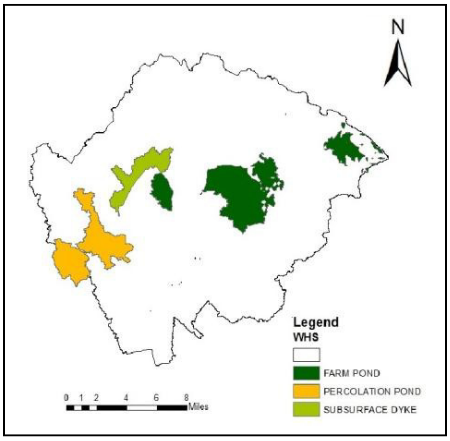

Fig. 7. Proposed sites for Percolation pond, Farm pond and Subsurface dyke.

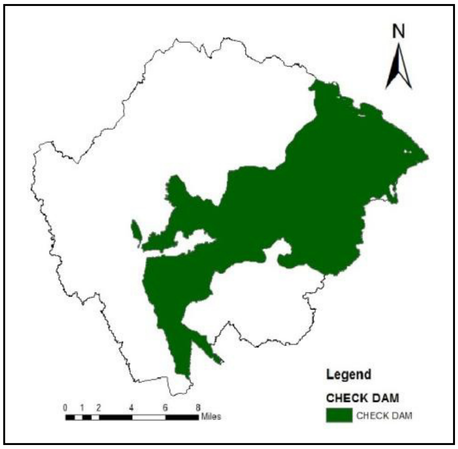

Fig. 8. Proposed sites for Check dam

As per the study, farm ponds are suitable in 7.07 % of total area. The ideal sites for farm ponds are mainly located in middle and eastern region of the Kecheri river basin. Also suitable areas are seen scattered all over the lower part of the Kecheri river basin. Percolation Ponds are suitable in 4.27 % of total area and are located in the western region of the Kecheri river basin. Suitable site for subsurface dykes is very limited and is only 1.91 % of total area. Check dams are suitable in streams contained in 37 % of total area which forms the major portion of the basin.

5. Conclusion

The identification of water harvesting structures is done by overlaying various thematic maps. Selection of suitable type of water harvesting structures in this selected area is done as per IMSD guidelines.

- Suitable locations for constructing water harvesting structures such as farm ponds, check dams, subsurface dyke and percolation pond are available in Kecheri watershed.
- Check dams are the most suited one for major portion of the area.

6. Limitation

- Though the sites for water harvesting structures are suggested by conducting hydrological modeling, meteorological and topographical analysis; for the practical implementation of these structures viability of other considerations such as economy, social implications etc. need to be considered.

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