CRITERIA MAPS FOR RAINWATER HARVESTING IN POTOHAR REGION

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ABSTRACT: *Agriculture of Potohar region, Pakistan is mostly rainfall dependent. Most of rainwater runs off the Plateau unutilized. The population is affected the most in the absence of rains. Rainfall pattern in the study area is unpredictable. Delayed monsoons or dry spells result in poor soil water availability during growing season and affect crop yield and increase risk of drought. Owing to un-predictable rainfall patterns due to Climate change, the likelihood of flood would increase unless measures are undertaken to control the run-off at the source. Therefore, in such circumstances, the importance of rain water harvesting for agriculture, domestic, livestock use and controlling flash floods in an economically and environmentally sustainable manner is getting attention all over the world as well as in Pakistan. In this paper spatial variations in landscape characteristics such as land cover, rainfall, slope information and drainage characteristics are defined as important criteria for identifying rainwater harvesting sites. The primary objective of the study is to present a number of criteria maps to Support feasibility studies for the planning and design of rainwater harvesting sites in Potohar region. Different Remote Sensing and GIS techniques were utilized in the preparation of the criteria maps. At present, the criteria maps for suitable site selection have been used and explained in this study. Advancement in technology and Geographic Information System (GIS) integrated with remote sensing is a useful tool to identify different criteria. Satellite products for Land Use and Land Cover (LULC), Digital Elevation Model (DEM) for slope, stream order, drainage density and hydrological analysis, and above all the most important factor in this study of railfall data are explained. Output of this study, based on geospatial and hydrological modelling, is presented. Different criteria based maps have been developed as basic unit for Rainwater Harvesting (RWH) site identification and criterion is discussed in each section.*

Key Words: Rainwater harvesting, Drainage Density, Slope, Land-use, Land-cover.

INTRODUCTION

Pakistan being a water stressed country is directly affected economically, since agriculture sector contributes up to 21% of the national GDP. Increasing population demands more food to be produced requiring more water for farming. It is estimated that, by 2025, 70 million tons of food shortage will occur due to the 32 % shortfall of water [1]. Recent figures show that climate change siltation of major reservoirs will decrease the capacity of surface water storage up-to 30% by 2025. Water storage capacity in Pakistan is only 150 m3 per capita, which is very low as compared with the capacity of other developed countries like China, Australia and United States [1].

Water is a indispensable for humans as well as plants and animals. Life without water cannot be imagined. This resource is being wasted without any realization and if preserved can sufficl our future requirements. Potohar region is one of country's most drought affected region. The present situation necessitates better water management to mitigate and avert droughts. One of the popular methodology for management of water resources and supply is rain water harvesting [2]. Rainwater harvesting is the process of collection and storage of rain water and its utilization for many purposes, indoor use, livestock, agriculture, industry and to recharge ground water wells [3, 4] as well as for commercial needs, and flood control purposes[5]. RWH is a common practice in semi-arid and arid areas where water scarcity exists. Due to uneven nature of precipitation, the chances of crop failure is very high. Rainwater harvesting can support agriculture in drought prone areas where rainfall is un-predictable in nature [4].

In many arid regions, rainwater harvesting runoff control systems increase the life standards of the rural community by increasing the crop production and grassland for livestock [6-9]. Developments in geospatial techniques such as remote sensing and GIS are widely used for identification of RWH potential sites/zones and selecting sites for RWH structures, and in the management of water resources [7-14].

The rainwater harvesting site selection criteria are mainly based on land-use land cover, rainfall, slope, drainage density, stream order, topographic information and socio-economic factors. There are some important parameters that are pivotal in the selection of rainwater harvesting sites, Meteorological data (rainfall), hydrology (Drainage density and stream order), topography (land slope and geology), socio economic (distance from historical sites), soil (texture, structure and depth) [9, 11-13, 15].

OVERVIEW OF THE STUDY AREA

Potohar region is mostly rain-fed with supplementary canal irrigation in some parts. In such areas the crop yield is totally dependent upon the amount and intensity of rainfall. Potohar Region of the Pakistan has four districts namely Rawalpindi, Attock, Jhelum and Chakwal. Total area covered by four districts of Potohar region is 22305 Km^2. The extent of the Potohar Region is between 32.5°N to 34.0°N latitudes and from 72°E to 74°E longitude. On the East of Potohar Region the River Jhelum flows, on the west the River Indus, on the north there are Margalla hills and Kala Chitta Range, and it is bounded by Salt Range in South. The mean annual l rainfall of the region lies between 900 to 1900 mm and maximum rainfall falls on Murree Hills [16]. More than 70% of annual rainfall falls in the monsoon season [17]. The soils of the area are classified as loam, clay (light), and loamy sand and have medium texture.

METHODOLOGY

Landsat images, SRTM DEM data and rainfall data were used to extract the thematic layers for the study area. All these layers are reclassified and used as criteria maps for rainwater harvesting after GIS and Remote sensing analysis. Details of these respective layers and criteria are discussed in next sections.

Land Use and Land Cover (LULC)

Up to date data of LULC is required to make quick and effective decisions for any developmental activity. Prior information on land use and land cover is essential for national planning in various spheres of life and hazard assessment. The existence of physical material on earth surface is called Land cover while the human activity is Land use [9]. Land use and Land cover mapping is the main parameter for RWH site selection studies. Curve number calculations are also performed using LULC map. Then Curve Numbers are used for rainfall runoff modelling.

Three Landsat 8 images with a spatial resolution of 30m, were downloaded [18] for October 2013. To acquire whole study area three images were mosaicked using mosaic tool and region of interest was extracted from this mosaic. For LULC classification spectral signatures were collected from the image. Signature means was used in unsupervised classification tool to extract the desired classes. The total Potohar Region is divided into seven major classes as shown in Figure 1. The basic purpose of this this study is to identify the criteria for RWH site/zones. Agriculture land is highly suitable for micro catchment RWH systems [19]. LULC was used to map in-situ and pond sites closer to agriculture activities [19].

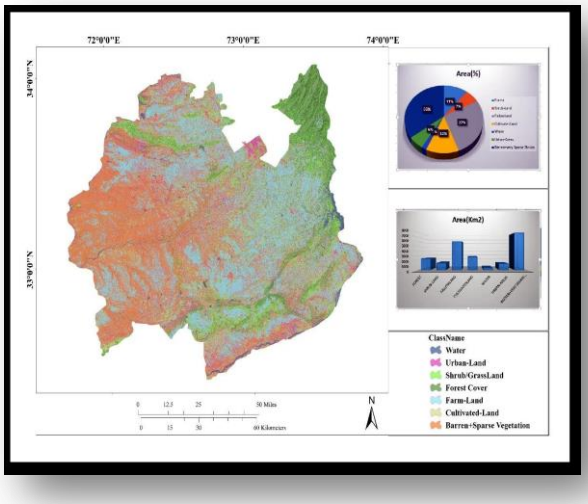

Figure 1: Land-use and Land-cover Map of the Study Area

RESULTS AND DISCUSSION

Rainfall Interpolation

RWH systems totally rely on the amount of rain that can be stored. The magnitude of rainfall have very significant role in RWH site selection criteria [12].

The six rain gauges that lye in Potohar are not located in any uniform sequence. For interpolation very dense network of rain gauges is required to map the rainfall. This rain gauge data is used to interpolate rainfall for surrounding areas to generate a complete rainfall map. Annual average data of five years are used for interpolation. Six rain gauges data, two from Islamabad, one at Dhamyal Pindi, Murree, Jhelum and Chakwal were acquired from Pakistan Meteorological Department.

There are different geostatistical interpolation algorithms; Like the Thiessen polygon; inverse distance weighted; and ordinary kriging. Larger prediction errors are observed when Ordinary Kriging was compared with other interpolation methods. Ordinary kriging predicts values more accurately and gives more accurate estimations of rainfall [20]. Hence Ordinary Kriging technique was used to interpolate the annual average rainfall data. Figure 2 shows annual average rainfall map of Potohar Region. Rainfall is the key factor role in any water harvesting system [21]. More rainfall in any particular region means higher chances of harvesting part of it. Most of the area in the region is suitable for rainwater harvesting systems.

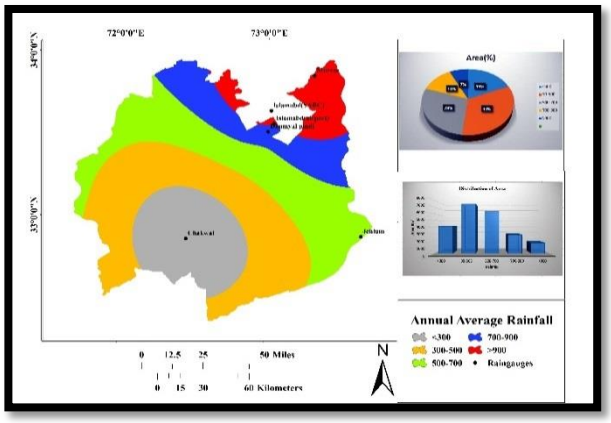

Figure 2: Rainfall Map of the Study Area

Digital Elevation Model (DEM) and Hydro Processing

For extraction of hydrological parameters, SRTM DEM with 90 m cell size was downloaded [18]. Murree hills has maximum elevation of 2261 m from mean sea level and minimum elevations are observed in North-West and South-East regions of Potohar.

Before hydrological analysis DEM was pre-processed to remove the sinks. Fill method of removing pits from a DEM was used to remove sinks from DEM before the final hydrological analysis.

DEM was processed using hydrological tools in GIS environment to extract the drainage network. Fifth order drainage network was observed in the study area. STRAHLER Stream order was used to classify the streams into stream order. Drainage order map for Potohar Region is shown in Figure 3. Percolation tanks and check dams are mostly located on 2nd and 3rd order streams [11]. The lengths of 2nd and 3rd order streams are 3448 Km and hence these lengths are favorable for percolation tanks and check dams along the stream [11]. The total lengths of all streams from 1st to 5th order has length of 8887.3 Km. Hence stream order is also one of the parameter for rainwater harvesting site selection.

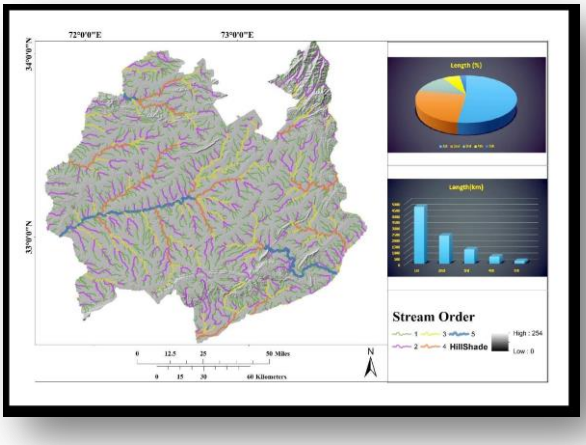

Figure 3: Drainage Order Map of the Study Area

Drainage Density

Drainage density defines that how landscape is analyzed by stream, thus it shows both the erodibility of the surface material and attitude of the drainage basin to generate surface runoff [22]. Drainage density is defined by the following Equation:

Drainage Density (Dd) = Length of Stream / Area of Basin Km/Km^2

High drainage densities areas will observe limited infiltration rates and they result in considerable runoff amount. Drainage Density map of Potohar Region is shown in Figure 4. High Drainage densities are less favorable for RWH purposes, and low surface drainage densities are highly favorable for RWH sites/zones [11]. Very small area of Potohar lies in the category of low drainage density values. Most of the area falls in between low and moderate drainage density values. Drainage Density and drainage order are important parameters in the site selection procedure of RWH systems.

Land Slope

Slope is the key factor in all RWH systems after the rainfall. The slope of a given area have greater impacts on recharge and infiltration rates, hence finally the runoff amount which is generated from this area. The slope of land have important role in site selection and implementation of all ground based RWH systems, especially pans, ponds, weirs, *in-situ and all other micro catchment* RWH systems [19].

Slope was calculated using the SRTM DEM 90 m resolution. Slope Map is, expressed as percentage slope according to FAO guidelines for RWH systems. The slope map was divided into five slope classes [23]. Each slope class is suitable for different kind of ground based RWH structures.

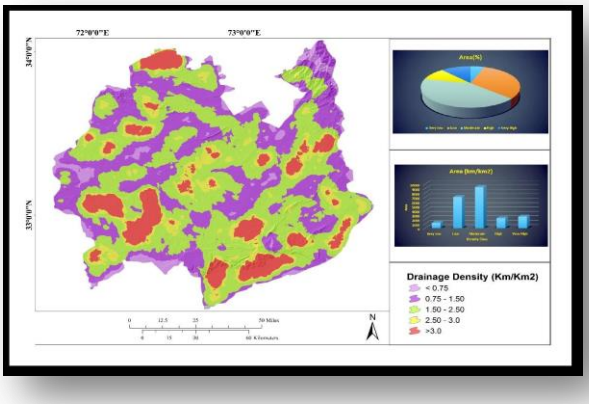

Figure 4: Drainage Density Map of the Study Area

The higher runoff potential is present in the South-East and North-East part of the study area because this area has hilly slopes and soils with low infiltration rates. About 75% of the area lies between slope ranges of flat (<2%) and undulating (2-8%) which are favorable for the, farm ponds, percolation tanks on the ground, percolation tanks along the streams and rolling slope class is also suitable for check dams [11]. Micro catchment rainwater RWH systems is not suggested in areas having slope greater than 5% due to uneven distribution of runoff and very costly earthworks are needed which is not cost effective solution while low slopes are not favorable for macro catchment RWH [15, 24]. Slopes (<3 %) are also favorable for semi-circular bunds RWH systems (Figure 5). All types of slopes exist in the Potohar region which are favorable for all kind of zones/sites for RWH systems and structures. Hence slope is the key parameter for the RWH site suitability analysis.

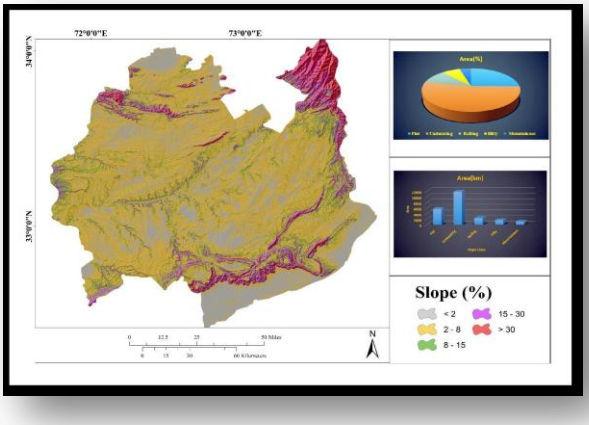

Figure 5: Slope Map of the Study Area

COCLUSION

To meet the increasing demand of food and agriculture activities, there is a need to explore the best RWH sites using sound methodology. By refining the criteria for RWH site identification we can have better site suitability analysis. The main purpose of this research work is to identify and refine the criteria which can later be used for RWH site selection and management. It has been demonstrated that best RWH site selection can be done on the basis of defined criteria of LULC, drainage network, drainage density, slope and rainfall data. Some other socio economic parameters like, distance from archeological sites, distance from recreational sites and distance from roads can also be considered to refine the site selection criteria. Distance from seismic faults as criterion for site selection of macro dams may also be considered. The Potohar region has full scope for percolation tanks, farm ponds and check dams. It was further established that GIS and remote sensing tools could be used to define the criteria for optimum RWH site selection. Water demand in Potohar Region could be met through intelligent selection of RWH sites and such cost effective techniques can help decision makers and water resource planners to meet water challenge in the region.

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