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IDENTIFICATION OF SUITABLE SITES FOR RAINWATER HARVESTING IN NANGAL CHAUDHARY USING GEOGRAPHIC INFORMATION SYSTEM

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Abstract

The world's water supply is rapidly diminishing at the present time. To alleviate this water scarcity, long-term strategies must be developed. Harvesting rainwater is one potential answer to this issue. This study presents a methodology based on geographic information systems (GIS) for identifying the ideal spots for rainwater harvesting installations using publicly available imagery and remote sensing data, as well as data from other sources. The present study conducted in the Nagal Chaudhary block, which is located in the southern region of Haryana's Mahendragarh district. Except during the monsoon, the climate is characterized by dry air, a scorching summer, and a cold winter. From March to June, temperatures begin to rise, with June being the hottest month. Landsat OLI and ASTER DEM data were used to create thematic layers. The procedure for site selection included six parameters: soil texture, slope, land use/land cover (LULC), distance from irrigated farmland, distance from residential areas, and distance from road. With this low-cost and low-data-intensity technology, RWH can be used in arid locations as a practical response to worsening water scarcity.

Keywords: Rainwater Harvesting, Geospatial Techniques, Nangal Chaudhary.

Introduction

In the driest and semi-driest parts of the world, when precipitation is scarce, water is a precious commodity. Many regions suffer severely from water shortages, making water shortage a significant worldwide issue (Jasrotia et al. 2009). High intensities of precipitation over a short period of time are typically associated with water availability in this type of location. Semi-arid regions are characterised by a paucity of ground- water resources and surface water, as well as an uneven distribution of rainfall in terms of place and time, high temperature, and evaporation (Khosravi et al. 2019; Malik et al. 2020). To raise the groundwater level for the purpose of sustainable water management, it is important to acquire expertise on the identification of suitable areas for groundwater recharge and surface water conservation. The practice of gathering and retaining rainfall for subsequent utilization or replenishment of underground water sources is generally referred to as rainwater harvesting (RWH). An ever-increasing daily need for water across a wide range of uses, including agriculture, industry, and households, has made RWH crucial for ensuring reliable access to clean water in modern times (Tiwari et al. 2015).

The term "rainfall harvesting" (RWH) refers to the practise of collecting, storing, and then using rainwater as a primary or secondary water source. It can be used for drinking and other purposes (Fewkes, 2006). Various systems have been established to facilitate the provision of water for a wide range of purposes, including irrigation, livestock watering, groundwater replenishment, flood mitigation, industrial water usage, and emergency fighting fires, among numerous other applications (Gould & Nissen-Peterson, 1999; Konig, 2001; Datar, 2006). Systems can range from the really simple, a water butt attached to a downspout, to the extremely complex, the collection of water from many hectares and the distribution of that water to enormous populations (Leggett et al, 2001a). Historically, rainwater harvesting (RWH) systems were commonly utilized in regions characterized by restricted availability of other water sources. These sites included coral islands (Krishna, 1989) as well as remote arid locations without sufficient surface or groundwater resources (Perrens, 1975).

The issue of water and fragile land is severe and urgent, necessitating novel approaches to regulation and administration. The rapid consumption of water from several sources is a major contributor to an impending water crisis caused by rising population and

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agricultural expansion. Furthermore, in the absence of any scientific management of watershed, problems such as water logging, alkalinity and salinity of the soil, numerous water-born diseases, and social difficulties have emerged in regions where irrigation water is made available. This study was designed to address these issues and provide potential solutions, including the use of rainwater collection and improved groundwater management.

Rainwater harvesting and its possible occurrence can be studied in a number of different ways, using either direct or indirect methods of data collection. Characterizing the RWH framework has been facilitated in part by geospatial technologies. The use of geospatial technology to locate, protect, and monitor a rainwater collection site has shown great promise (El-Awar et al. 2000; De Winnaar et al. 2007; Jasrotia et al. 2009; Weersinghe et al. 2010; Kadam et al. 2012; Napoli et al. 2014; Adamowski 2015; Mah- moud and Alazba 2016). Various topographical features, including slope, soil composition, drainage patterns, land use/land cover, and lineament characteristics, significantly influence the suitability of a water harvesting location. Remote sensing and Geographic Information Systems (GIS) have shown to be valuable techniques for creating these spatial layers. The current study employs GIS and buffer analysis techniques to evaluate RWH potential and locate diverse RWH structures in the Nagal Chaudhary block of Mahendragarh District.

There is a need for in-depth research at such locations with the purpose of establishing a clear relationship between the relevant components because some RWH approaches are site-specific and sometimes indigenous knowledge exists in those settings. In the area under study, the undulating topography causes a significant portion of the runoff to flow via a stream, and the hard rocky geohydrological conditions limit the amount of groundwater that can be recharged and stored below the surface. As a result, determining the areas in the study region that have the capacity to collect rainwater is crucial if one wants to address the problem of a lack of available water. In the area under consideration,

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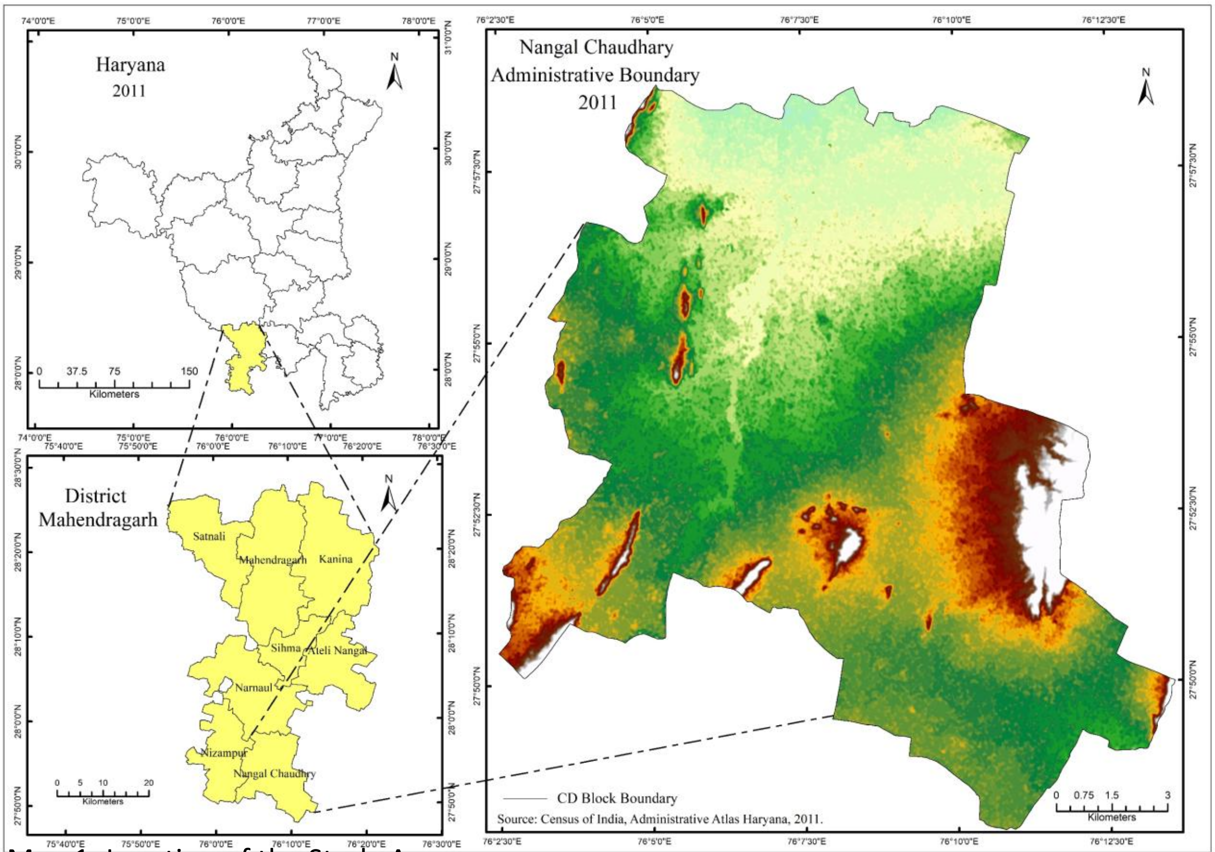
there is a dearth of research and data pertaining to areas and places that would be appropriate for RWH harvesting as well as effective management of watersheds.

Study Area-The study area, which is the Nangal Chaudhary CD block of Mahendragarh District, is located between the 27˚ 47’ 50.34" to 27˚ 58’ 45.64" N latitude and 76˚2’ 28.44" to 76˚13’ 35.31" E longitude. The elevation of the study area is varied between 263 to 570 m above mean sea level. It constitutes an area of 200 sq. km. The study area has a physiographic composition that encompasses a fluvio-aeolian plain, aeolian plain, flood plain, sand dunes, pediment zone, and the Aravalli hills. The climate, with the exception of the monsoon season, is characterized by arid air, a warm summer, and a frigid winter. Approximately 75% of the total annual precipitation is typically obtained between the months of July to September, which correspond to the southwest monsoon season.



Map 1: Location of the Study Area.

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Methodology

Fig. 1 is a flowchart detailing the improved methodology. To determine the depth of the depression, the study area's digital elevation model (DEM) was first subtracted from the area's filled DEM. Using an advanced GIS method, the area's drainage system was mapped directly from the DEM. A big, continuous depression on a drainage network was identified as a potential RWH location. It was determined that the 500 m buffer worked best for Nagal Chaudhary out of the several sizes tested. Buffer sizes smaller than 500 metres increase the region of continuous depression while bigger buffer sizes have no discernible effect. Depressions inside the buffer zone are retrieved using various GIS techniques, and adjacent depressions are grouped together. The numerous depression cells in the buffer zone are depicted in (Map 5). Next, the depressions with the greatest combined volume are chosen among the contiguous depressions. Using the DEM and drainage map, we calculated the catchment area of each depression.

Criteria

1. Locations of depressions with an area that is greater than one hectare are chosen. (IMSD 1995).
2. For the remaining sites, 35 have been chosen for further investigation because they have the biggest volume depression.
3. In order to lessen the amount of water lost to evaporation, depression sites with a larger volume to area ratio of more than 2 are chosen.
4. Depression sites that are located in or near a built-up region are eliminated from further consideration and are not taken into account. This is due to the fact that locations that are near to an already built-up area typically have higher land acquisition costs.
5. The ideal location for a RWH structure is a depression site that will collect a substantial amount of runoff volume.

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Data Base

1. Open series SOI topographical maps (https://onlinemaps.surveyofindia.gov.in/FreeMapSpecification.aspx).
2. Advanced Land Observing Satellite (ALOS) PALSAR DEM (https://search.asf.alaska.edu/#/).
3. Google Earth Images.

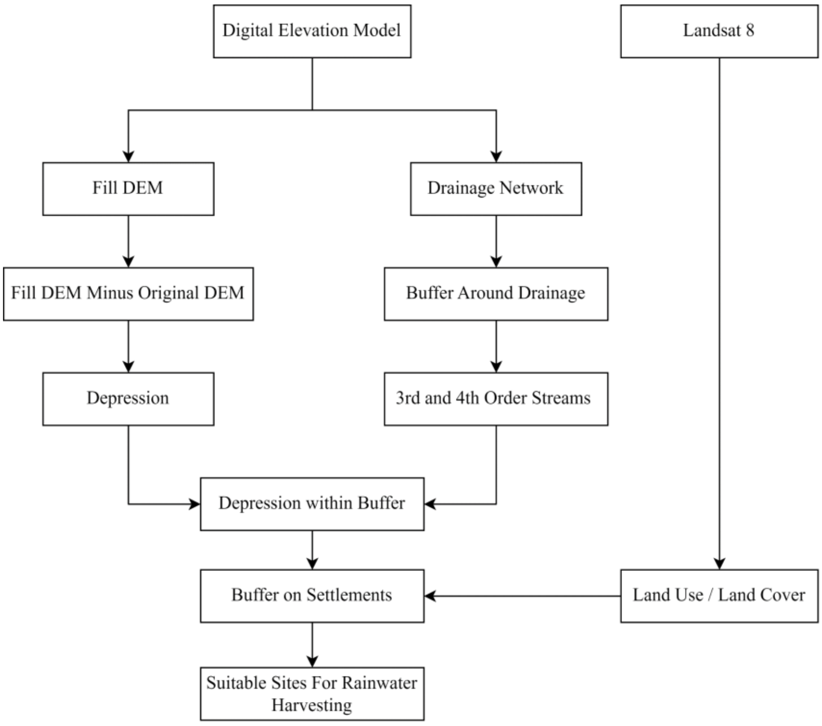

Fig 1: Flow chart of Methodology to Identify Suitable Sites for Rainwater Harvesting.

Results and Discussion

Landuse/ Landcover

The utilization of remote sensing and GIS techniques provide valuable preliminary data on a wide scale for the purpose of land use and land cover mapping. This process plays a crucial role in the identification and analysis of land use patterns through visual interpretation, as highlighted by previous studies (Tiwari and Khanduri, 2011; Rawat et al., 2013). The impact of land use and land cover on runoff and rainwater harvesting has been widely recognized in the literature (Kadam et al., 2012; Jasrotia et al., 2009). The land use and land cover patterns of the study area were derived using Landsat OLI 9 satellite data and subsequently validated through ground truth survey. The present study considers nine distinct categories of land use, which include rural built-up areas, urban built-up areas, waste land, thick forest, hilly areas, open scrubland, open forest, agricultural land, and water bodies. Table 1 displays the distribution of landuse classifications in the given area.

Rural builtup indicates the area covered by buildings and other man-made structures in rural areas. In this region, it covers 7.70 square km or 3.85% of the total land area. Open Forest indicates the area covered by forests that have relatively low tree density and are often used for grazing and other purposes. In this region, it covers 37.60 square km or 18.79% of the total land area. Agriculture land shows the area covered by agricultural land used for crop cultivation, livestock rearing, and other related activities. In this region, it covers 114.64 square km or 57.29% of the total land area.

Table 1: Area under LULC Categories.

Sr. No.	Category	Square km	In Percent
1	Urban Builtup	0.00	0.00
2	Rural Builtup	7.70	3.85
3	Transport Network	0.57	0.29
4	Cannal Network	0.28	0.14
5	Sandune	0.82	0.41
6	Other Land	12.86	6.42
7	Open Forest	37.60	18.79
8	Bare Land	1.22	0.61
9	Dense Forest	0.00	0.00
10	Hilly Area	7.34	3.67
11	Water Body	2.61	1.31
12	Agriculture Land	114.64	57.29
13	Pedements	14.44	7.22
	Total	200.09	100.00

Slope

In ArcGIS ALOS PALSAR DEM (10 m spatial resolution) was used to create the slope map. The angle between the slope and the horizontal is measured in degrees, from 0 to 90. It's a major factor in how much rain falls and how fast water flows (Kadam et al. 2012; Khanduri et al. 2012; Adham et al. 2016). The effectiveness of the water storage at a harvesting location is increased by a steep slope. Slope variation in the research area is shown in Fig. 5. The majority of KBNIR has mild to very mild inclines. According to IMSD's recommended standards, we've divided the slopes map for Nangal Chaudhary into seven distinct groups (NRSA 1995).

Stream Order

Strahler's stream order method is a commonly used method for classifying streams based on their relative size and complexity. It was first proposed by Arthur Strahler in 1952 and has since been widely adopted in hydrology and geomorphology studies (Strahler, 1952). Streams are classified based on their Strahler order, which can range from first-order to higher-order streams. Higher-order streams are typically larger and more complex, and they tend to have a greater impact on the surrounding landscape and ecosystems (Montgomery and Buffington, 1997). In addition to being a useful tool for stream classification, Strahler's stream order method can also be used to analyze stream network patterns and to identify areas of potential flooding or erosion (Marrero and Flores, 2016). larger streams and rivers have a much larger catchment area, which means that rainwater harvesting requires can be effective in these areas because of high volume of runoff

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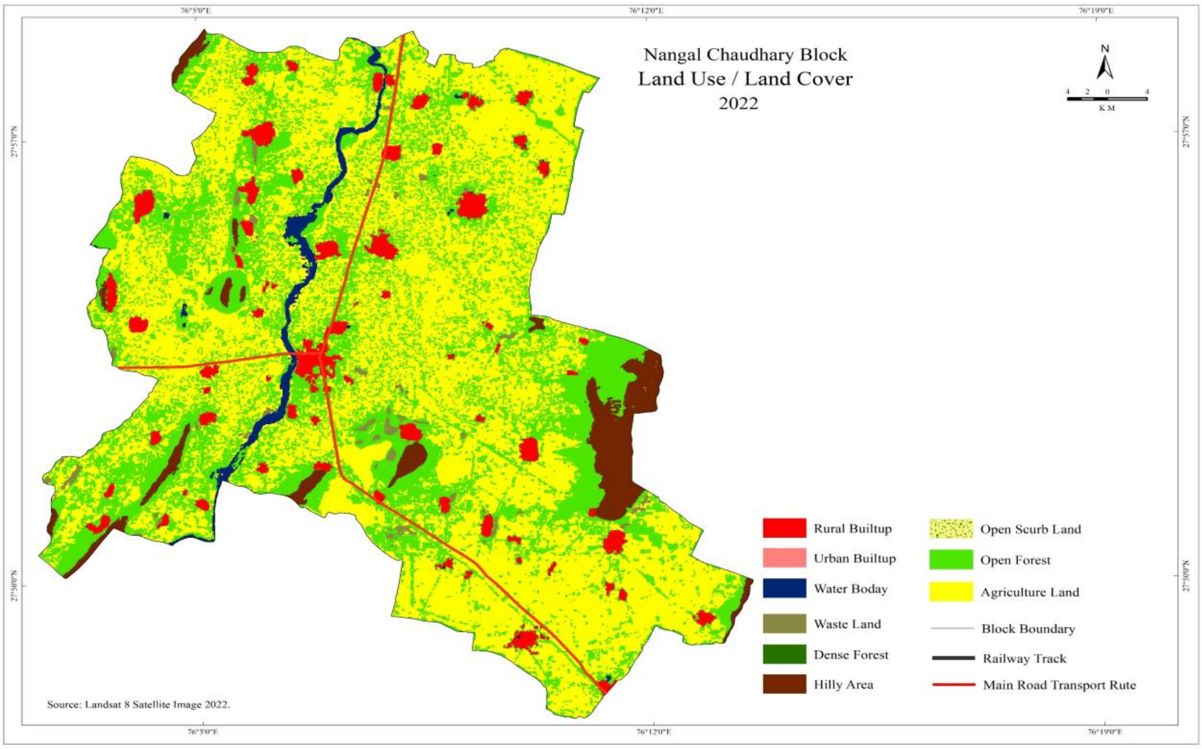
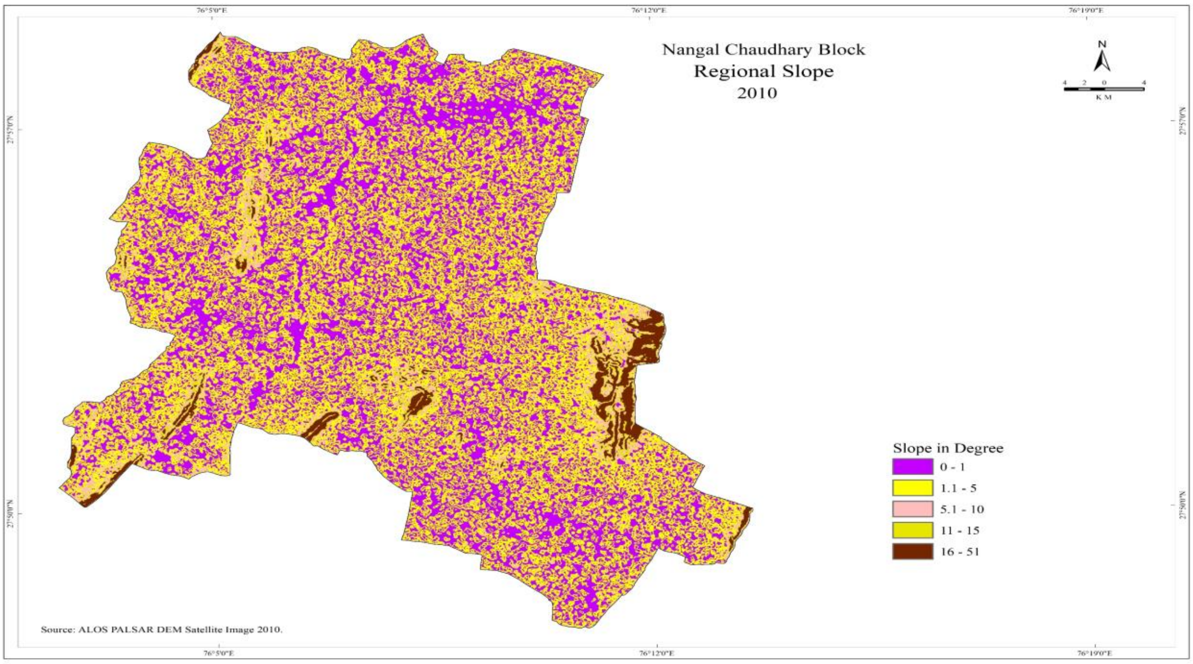


Map 2: Land Use / Land Cover map of Nangal Chaudhary, 2022.



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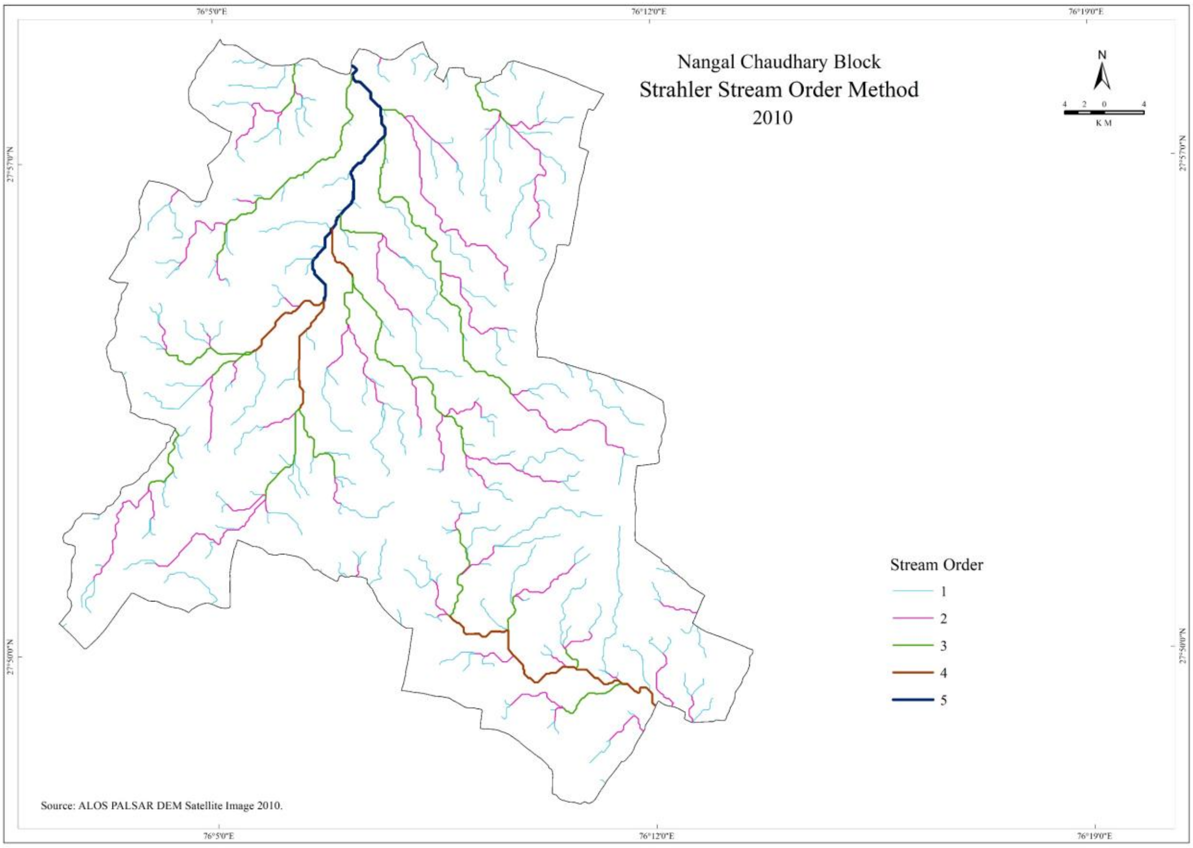
Map 3: Regional slope map of Nangal Chaudhary, 2010.



Map 4: Stream Order map of Nangal Chaudhary, 2010.

Identification of Suitable Sites

A number of methods have been documented in scholarly literature with the purpose of integrating several criteria in the selection process of appropriate Rainwater Harvesting (RWH) locations. This study used the buffer analysis method to figure out how much runoff was available, and chose the RWH site based on the reliability of water flow, water quality, and cost-benefit analysis. The site selection techniques for rainwater harvesting (RWH) also took into account several elements, including slope, land use/land cover, soil attributes, drainage order, runoff, watershed area, and socio-economic factors. These parameters were evaluated using multiple criteria (Weerasinghe et al. (2011), Kadam et al. (2012), and Rejani

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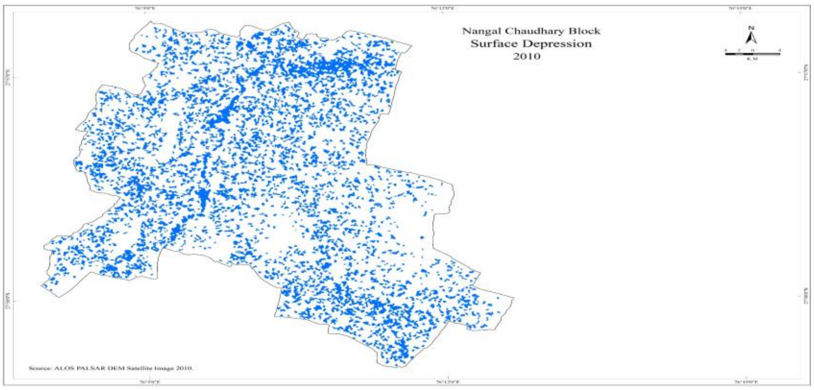
et al. (2017). The output presented a straightforward process that relies on readily accessible data and basic Geographic Information System (GIS) tools to find suitable areas for Rainwater Harvesting (RWH). This methodology has the potential to effectively reduce both time and economic costs, while also facilitating the identification of the most suitable area for rainwater harvesting (RWH). Adham et al. (2016) also highlighted the importance of engaging all relevant stakeholders and utilizing cost-effective data and analysis to inform the design of rainwater harvesting (RWH) buildings, with particular attention to understanding the indirect economic impacts.

One of the most significant features of RWH constructions is the careful selection of a suitable location. With the assistance of the raster calculator tool found within the ArcTool box, the fill DEM file is subtracted from the original DEM file in order to locate the depressions that are present in the area under study. The end result of this method offers us a total of 1651 depressions, ranging in size from small to large. Using this procedure, depressions along the 4th and 5th order streams are chosen for further investigation, bringing the total number of depressions down from 1651 to 35. The reasoning for this procedure is based on the presumption that streams with higher order transport a greater volume of water than those with lower order. In accordance with the criteria that have been presented, the depressions that are to be chosen for the rainwater collection must be located some

Map 5: Surface depression map of Nangal Chaudhary, 2010.



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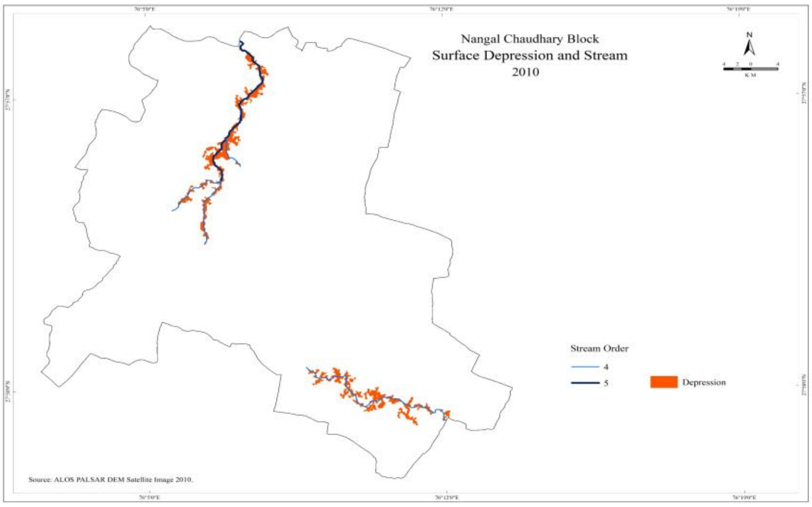
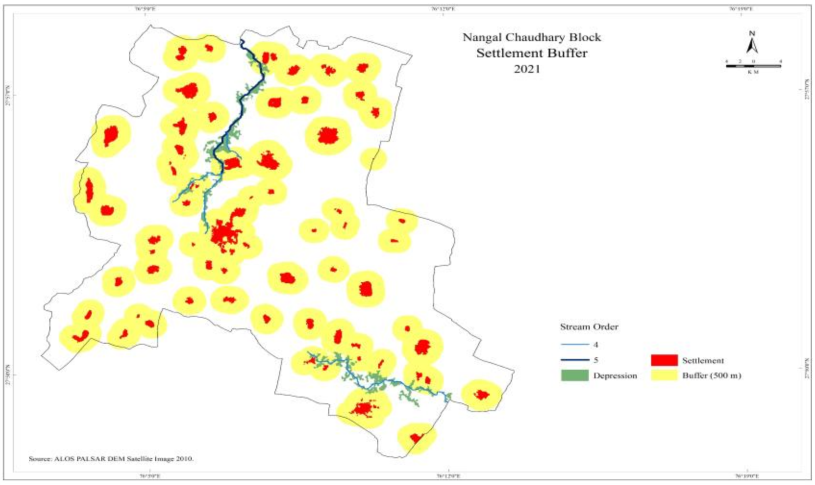
Map 6: Surface depression with stream order map of Nangal Chaudhary, 2010.



Map 7: 500-meter settlement buffer map of Nangal Chaudhary, 2010.



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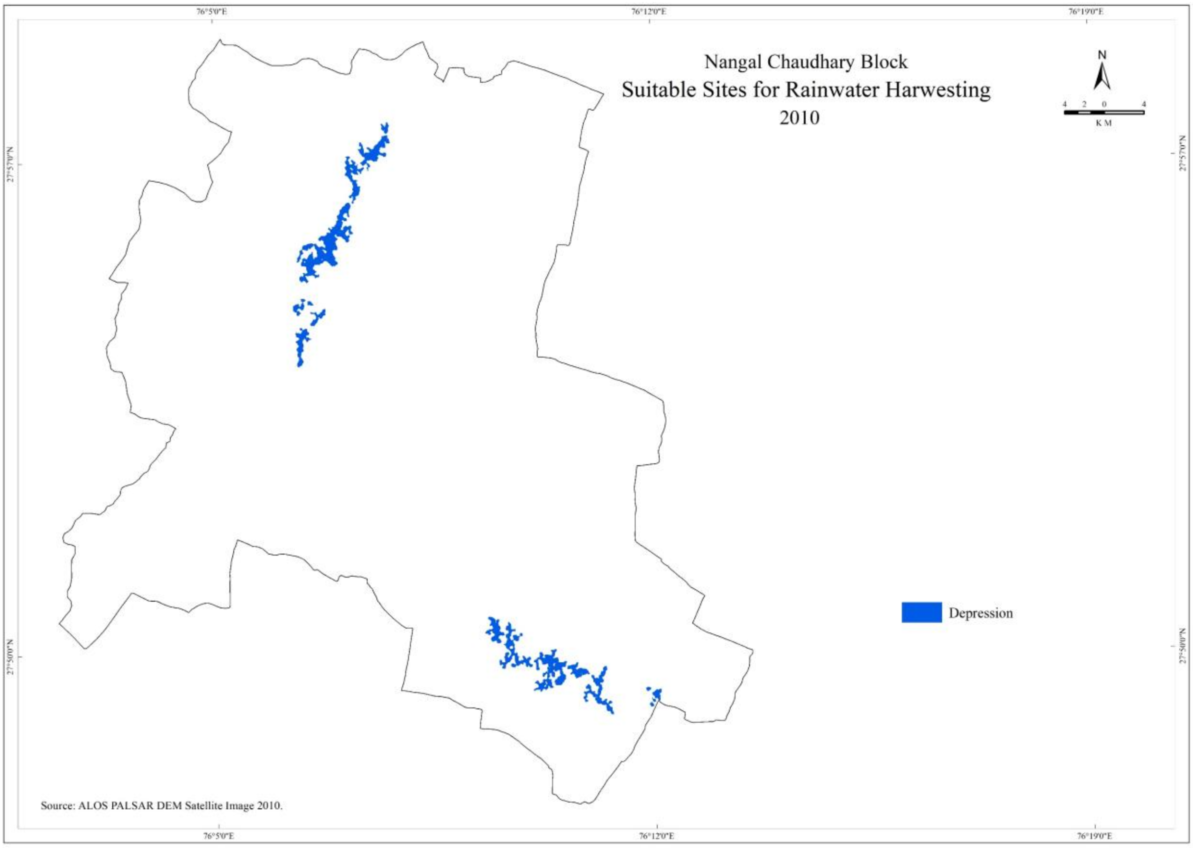

Map 8: Suitable sites for rainwater harvesting in Nangal Chaudhary.

distance from the settlements. For this reason, a buffer of 500 metres is placed around the settlements in the study region, and any depressions that fall within the buffer zone are removed from consideration in the study. The final result of this methodology gives us the 17 depressions which can be used for the rainwater harvesting. The area of depressions varied from 0.01 km^2 to 0.84 km^2. These rainwater harvesting sites must be developed for the well being of farmers and ecology of the area.

Table 2:

Number of Depressions	Area in Square Kilometers
1	0.01
2	0.01
3	0.01
4	0.01
5	0.01
6	0.04

7	0.04
8	0.06
9	0.06
10	0.11
11	0.15
12	0.16
13	0.22
14	0.26
15	0.29
16	0.42
17	0.84

Conclusion

Literature describes several techniques for integrating RWH site selection criteria. This study used buffer analysis to calculate runoff volume and selected RWH sites based on water supply reliability, water quality, and cost-benefit analysis. Outcome showed how free data and basic GIS tools may discover appropriate RWH locations. This strategy could save time and money while selecting the best RWH location. Adham et al. (2016) stressed stakeholder interaction, low-cost data, and indirect economic consequences when designing RWH frameworks. RWH structures require careful site selection. The ArcTool box's raster calculator tool subtracts the fill DEM file from the original DEM file to find the area's depressions. This approach yields 1651 small-to-large depressions. This reduces the number of depressions from 1651 to 35 by selecting 4th and 5th order stream depressions for further research. This approach assumes that higher-order streams carry more water. According to the criterion, rainwater-collecting depressions must be far from settlements. The study excludes depressions within a 500-metre buffer around communities in the study region. This method yields 17 rainwater-harvesting depressions. Depressions covered 0.01–0.84 km2. Farmers and the environment need these rainwater gathering sites.

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