27 th International Conference on Hydraulics, Water Resources, Environmental and Coastal Engineering (HYDRO 2022 INTERNATIONAL) at Punjab Engineering College Chandigarh, India during December 22 -24, 2022

Dam Site Suitability using Remote sensing and GIS techniques

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Abstract

Increasing the amount of surface water is the efficient way to tackle the water crisis which directly and indirectly supports the water requirement for humans and increasing the groundwater table in the surrounding area respectively. Rainfall is one of the major source of surface water in most of the areas on land. Huge amount of rainwater is carried by rivers which mixes into ocean at the end which is of no use for human society. Dams are the suitable structures to store this runoff water and make it available for public demand during water scarcity. Development of Remote sensing and GIS paves a way for determining the location of reservoir where trillions of cubic metre of water can be stored at a lesser cross sectional area. Many environmental and socio- economic factors were studied in previous studies such as geology, lineament, soil type, slope and population. In addition to these factors, ground water potential (GWP) areas, an indirect parameter is also considered to divert the stored surface water from the dam to those GWP zones in the view of directly replenishing the groundwater levels. Implementing these factors in decision making techniques like traditional AHP will provide the information of dam site suitability across a river.

Keywords: Surface water storage, Remote sensing, AHP, Groundwater recharge

1. Introduction

Change of climate especially increase of temperature is emerging as a major issue since the everyday activities and processes on the earth is dependent on it. The water exists in three phases and for which the temperature is the major dependent parameter for each phase. As a generalised view all over the world, the demand for water has been increased to balance both environmental and socio-economic factors. A mass storage of water can be done on surface with the use of a dam, and a dam requires its own criteria such as location volume of water to be stored and the purpose. So, for selecting a suitable or proper site for the placement of dam which will be more efficiently used to store and utilise the water flowing through the river of that particular basin eight factors were considered in this study. One of the MCDM techniques called AHP is used in the GIS environment to predict certain position for placement of Dam. Since as there were many studies have been carried out using the multi criteria decision making techniques and the accuracy of the method were also presented in previous studies and accuracies were good.

ArcGIS 10.8 is the software which was used to process and create the maps for all the factors affecting site suitability and the MCDM technique was used from the catalog tools in the same environment. GIS has the capability of analyzing the special variations of a parameter in detail

with high level of accuracy. With the integration of MCDM (Multi Criteria Decision Making) and GIS, analysis will be much more accurate and time saving. This has been proven in previous studies in many other areas of interest. AHP was first developed by saaty where the weight age of the parameters is given using a scale in which numbering is from 1 to 9 where the 1 represents equal importance three represents moderate importance five represents strong importance seven represents very strong importance nine represents extreme importance and all other intermediate even numbers represent the intermediate importance. In this study, saaty scale has been selected for the site suitability of dam. The comparison of the input parameters was completely acquired from the knowledge kind from the previous studies done in the same research.

In Palar basin, the North Western and the Western parts of the basin reviews lower rainfall compared to the eastern and south-eastern parts. In the year 2021 after a long period a huge amount of rainfall has been recorded all over Tamil Nadu and especially in this part of the area the discharge of River was overflowing and it flooded the nearby villages which took human life to a risk. And the entire water which was the surface runoff was majorly wasted into the Bay of Bengal. Hence it is an overall demand from the villages of the basin so that the water can be saved and used in future for both drinking and agriculture purposes.

2. Materials and Methods

2.1 MCDM Techniques

2.1.1 AHP

Analytical hierarchical process is an MCDM technique which is employed to determine the extent of importance of a factor among other parameters. Since AHP is a decision-making technique, this can be used for the selection of a suitable site for the Dam placement. In the study for a Dam to be sustained for longer period the geology is the major parameter of consideration. Suppose if we consider in Geology and distance from roads geology will be given higher weightage. Similarly, all other parameters will have different weightages and finally we determine the percentage of weightage given to each parameter and this percentage distribution is fed into the GIS environment so that a proper site for a dam can be done. The weightage is calculated in an excel spreadsheet.

$$\mu(x) = \frac{1}{1 + \left(\frac{x}{f2}\right)^{-f1}}$$

The inputs to the equation are f1, the spread, and f2, the midpoint.

2.2 Study Area and Data Source

2.2.1 Palar River basin

Palar Basin is one of major river basins which touches Karnataka, AP and most of the area in TN. The river starts at Nandhi Durg in Kolar, 800m MSL, in the eastern part of Karnatak. Then it stretches through Kolar and Bangarupet Taluks, forming the Bethamangal tank, which serves as the primary water supply for Kolar Gold Field. It enters Andhra Pradesh and runs for a short distance in Kuppam Tk of Chitoor dist. Then the river enters Vellore Dist, Tamil Nadu and mixes into the Bay of Bengal, east of Maduranthagam and south of Mahabalipuram. The Palar River Basin covers a total of 17,633 km^2, including 3,123 km^2 in Karnataka, 4,267 km^2 in AP, and 10273 km^2 in Tamil Nadu.

In Tamil Nadu, the basin includes the districts of Vellore, Thiruvannamalai, Kancheepuram, Thiruvallur, Villupuram, and Krishnagiri. Poineyar, Kaudinya Nadhi, Malattar, Cheyyar, Agamar, Killiyar, Kamandalar, Naganadhiar and Vegavathiar are the significant tributaries. The Eastern Ghats ranges, plateau and the plains of coastal area make up the three main topographical divisions of this basin. An undulating topography is traced after declining from higher hill ranges. The undulating topography ranges from 305 to 91 m. It is constrained by numerous low relief zones that can range in height from 76 to 91 metres. There were several spring channels in the river's bed when the water table was close to the river's bed level. These spring channels dry out for a significant portion of the year, so, the sandy river bed becomes the primary source of groundwater for crop fields and drinking water. The remaining 1383 km^2 is mostly comprises of sedimentary rock formations such fluvial, upper Gondwana and deposits of coasts. The area of 10273 km^2 of the total area is observed to be crystalline formations like Charnockites (a type of granite), proterozoic epidote and peninsular Gneissic complex.

2.2.2 Data collection

The Basin shapefile for palar was obtained from the HydroSHEDS website (https://www.hydrosheds.org/). The daily rainfall data from 2011 to 2021 were collected from India Meteorological Department (IMD), Pune. The geology (1:2M scale) and lineament data were downloaded from Geological Survey of India (https://bhuvan-app3.nrsc.gov.in/data/download/index.php). The world soil type data was extracted from FAO and it was processed to extract for the study area. The land use land cover data was extracted from Sentinel-2 10-Meter Resolution Land Use/Land Cover from ESRI website as tiles (https://livingatlas.arcgis.com/landcover/). The tiles were merged and extracted for the area of interest. Digital elevation model (DEM) SRTM was extracted from USGS earth Explorer (https://earthexplorer.usgs.gov/).

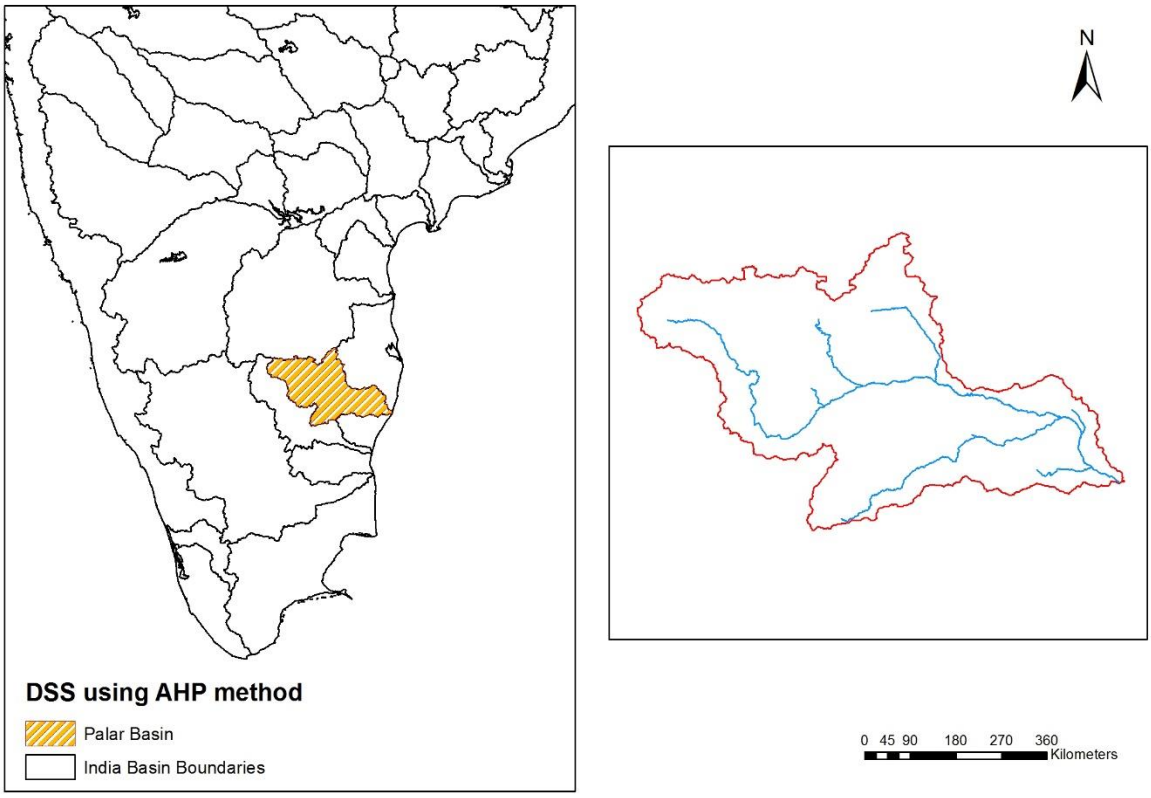

Figure 1 Index map of study area

2.3 Selection of Input Parameters

As we know that dam is a heavy structure which holds a huge volume of water, the factors affecting the suitability study should be properly selected. The input parameters were selected based on the previous studies conducted on site suitability. From fig 2 to fig 9, the thematic maps are presented which was created using tools of ArcGIS. The mean annual rainfall intensity varies from 522 to 1661mm in-between the years 2011 to 2021.

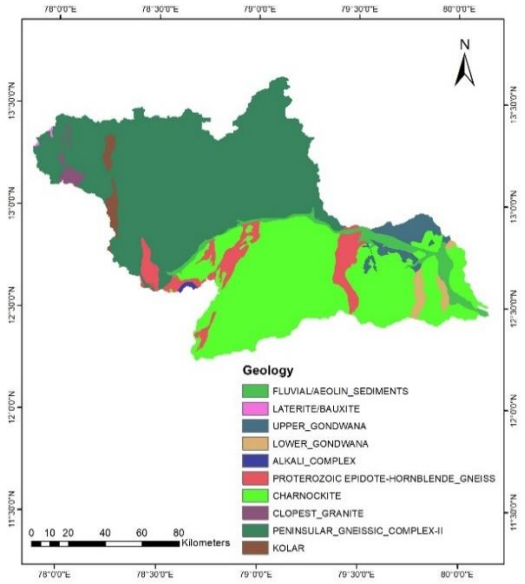

Figure 2 Geology of study area

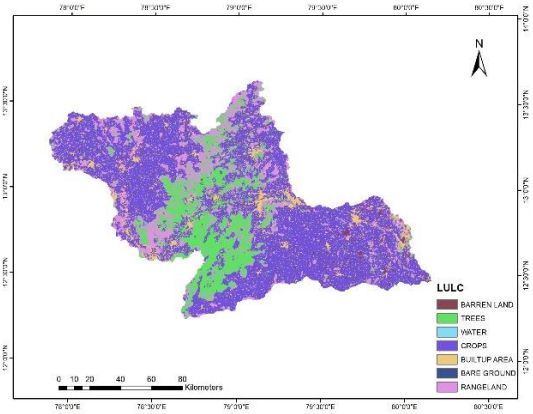

Figure 3 LULC of study area

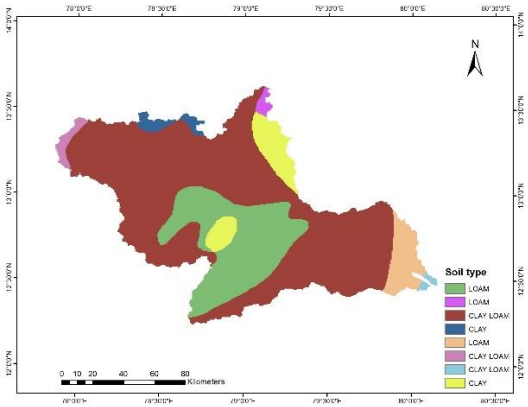

Figure 4 Soil map of study area

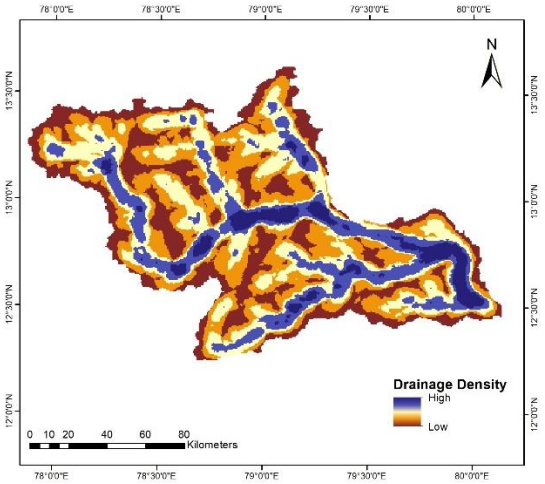

Figure 5 Drainage Density map of study area

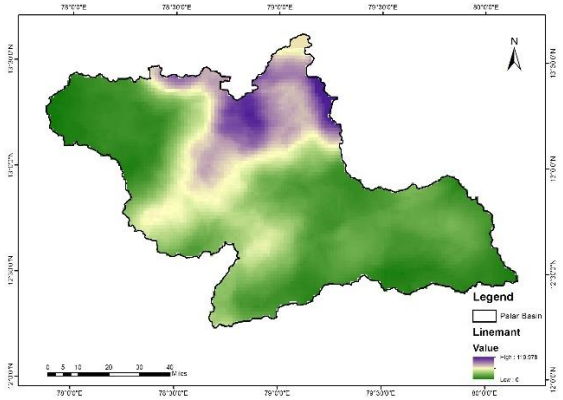

Figure 6 Lineament density map of study area

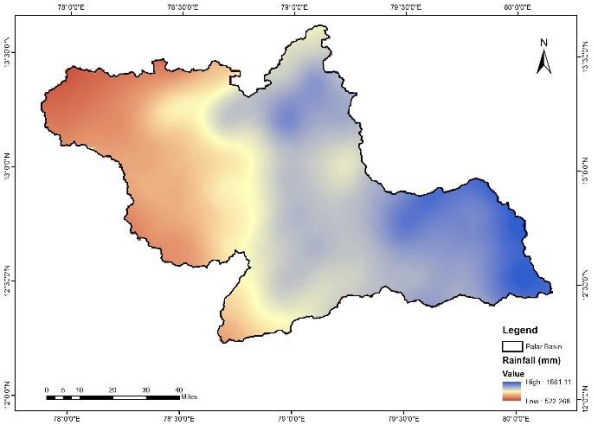

Figure 7 Rainfall map of study area

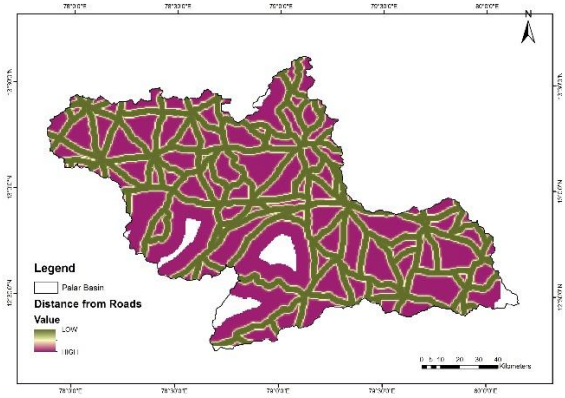

Figure 8 Distance from Roads map

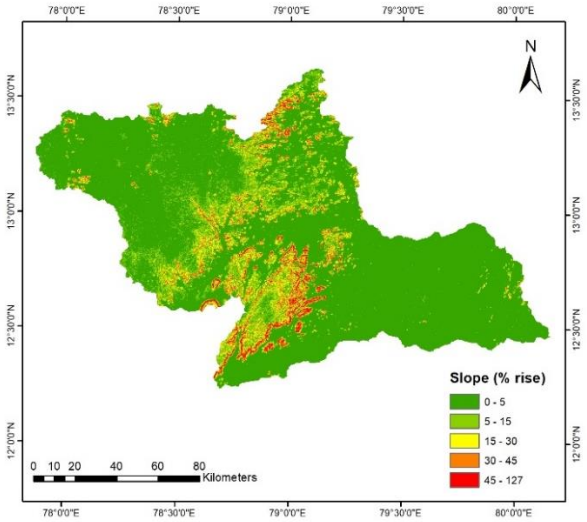

Figure 9 Slope map of study area

Variables	***Weightage***
Geology	*31.5*
Rainfall	*14.1*
Slope	*11.5*
Drainage Density	*13.2*
LULC	*6.2*
Lineament	*8.3*
Soil	*12.7*
Distance from roads	*2.6*

Table 1 Weightage of dam site suitability factors using AHP method

3. Results and Discussions

The AHP technique gives three suitabilities along the stretch of the river which is low, medium and high. Most of the northwestern part of the basin comes under low to medium suitability. The central portion of the river reach shows medium suitability for dam construction. The suitable locations are divided into three parts which shows that the location of dam is suitable in that stretch. Since the AHP is not showing the results at specific locations additional factors are required or on site survey is required to increase the accuracy and get better results.

The results shown in the AHP method are observed to be a higher range of medium suitability areas. If we consider a branch of the river in the southernmost part of the basin, there is less proportion of higher suitability and remaining is medium suitability. This is because the slope, soil and geology are the parameters remaining constant over the stretch of that branch. There are no low suitability areas in this branch because the lineament density is low to very low, drainage density is high to very high. And rainfall is the second highly weighted parameter which makes this stretch as medium suitable for dam site.

Coming to the central part of the basin, the map shows low to medium suitability. Low suitable areas are shown because, the variation of slope is higher which shows its peak slope of greater than 30%. Medium suitability is shown due to loamy soil present in those locations. Even though the slope parameter supports the suitable locations, lower range of rainfall from 750mm to 900mm (which is lesser comparing with the eastern part of the basin) makes the stretch of the river as medium suitable. If the rainfall gives the sufficient amount of water, then this stretch could be chosen for dam site since the proportion of built-up area is higher. The higher suitable sites are shown since all the parameters supports the location of dam construction.

The majority of the Palar River basin region was made up of zones with moderate and poor ground water potential. Along the course of the river, zones having good ground water potential are located. The northwestern region of the basin, comprising Ambur, Vaniyambadi, Gudiyatham, Vellore, and the neighbouring territories, has poor ground water potential zones. The areas around Arani, Arcot, Gudiyatham, Polur, and Kancheepuram are among those with zones of moderate ground water potential in the centre of the basin along with the northeastern regions. Alluvial flood plains along the river, as well as the lands near Cheyyar, Uthiramerur, Maduranthagam, and Chengam, are regarded as good prospective zones (The Groundwater potential was referred from Palar report from Govt of Tamilnadu). The Dam location can be considered nearby these areas in the upstream side so that the stored water in the dam can be recharged into ground to increase the level of groundwater and can be used during the summer or in extreme drought seasons. The reason of constructing the dams nearby the groundwater potential zones is to reduce the cost of construction of canals from Dam to the recharge zones and also to reduce the conveyance charges.

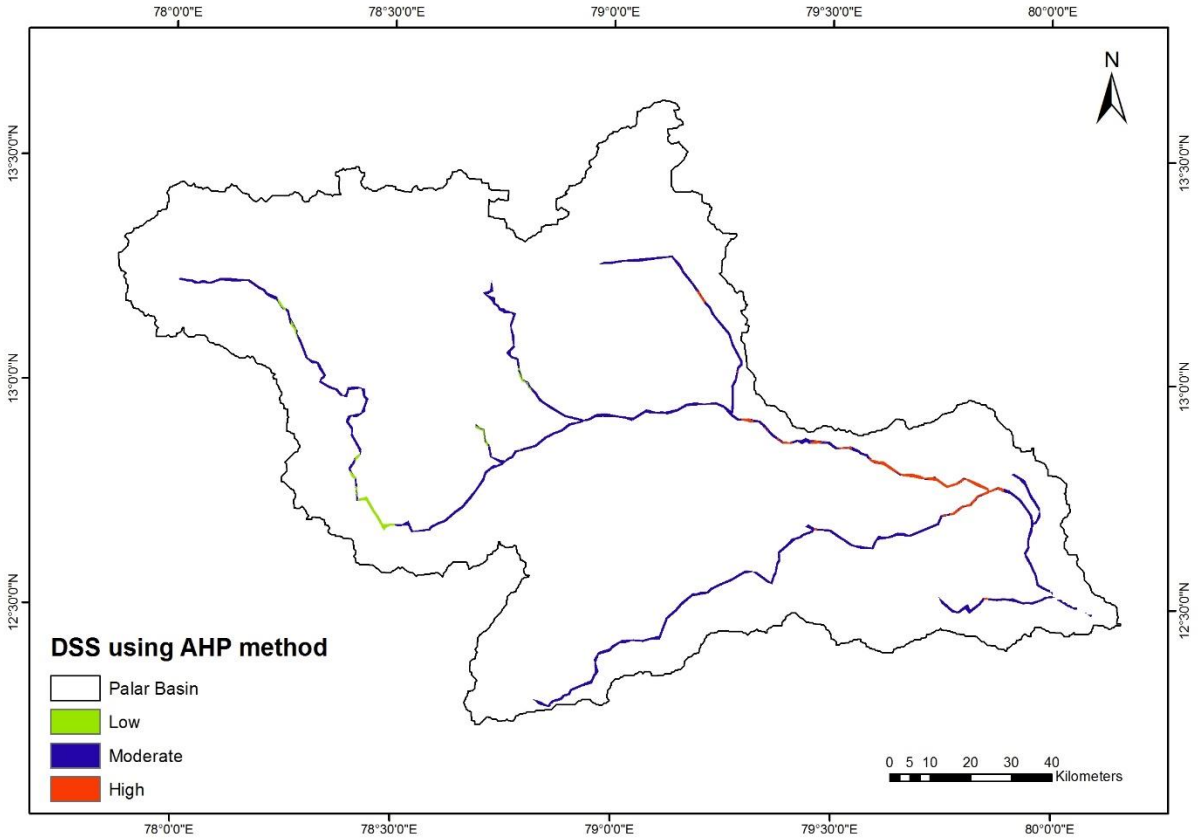

Figure 9 Suitable Dam sites using AHP Method

4. Conclusions

Palar basin is the study area in south India was considered which lacks water storage structures. Eight factors were considered to determine the locations of dam site. AHP, an MCDM technique was chosen. As we can observe from the fig.9 that AHP technique gives result as Low, medium and high suitability over the stretch of the river. Specific point or location is not being shown. Central part and south eastern parts of the basin show higher proportion of medium to high suitability. Slope map also confirms the same. Further onsite surveying is also required to get the detailed overview of the present situation of the sites before finalizing the dam location.

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