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CONTENTS

Mapping of ground water potential zone in complex hydrological system of Suyal basin in the Mid-Himalayan Region using Analytic Hierarchical Process

RITESH JOSHI, H.J SHIVA PRASAD, JYOTHI PRASAD, P. S. MAHAR, DEEPAK KUMAR[1] and PANKAJ KUMAR[1]

Department of Civil Engineering, [1]Department of Soil and Water Conservation, College of Technology, G. B. Pant University of Agriculture and Technology, Pantnagar- 263145 (U.S. Nagar, Uttarakhand)

ABSTRACT: With the increase in water consumption and climatic variation, hundreds of spring fed watersheds is at a great threat. Due to decline of discharge in conventional water resources crop land has also shrunken which has affected the economy of the region to a great extent. Underground water is present in the form of porous aquifer and springs in hilly and mountainous regions. Due to lack of maintenance and over exploitation many conventional water sources are at the verge of extinction. In this study, GIS- based weighted sum analysis approach was used to identify sites of water potential zones which can be used for both water extraction and rejuvenation of these conventional water sources. GIS based tools can be used for studying of relief and structural aspects of basin. Different factors were quantified and the influence of each factor over is judged. Results show that 21% of area lies under good recharge potential while 79% of the area lies under poor groundwater potential region. Areas with good to excellent recharge potential may be considered for augmentation measures to sustain its specific yield in the future.

Key words: Analytical hierarchical process, ground water rejuvenation, spring fed, weighted sum analysis approach

It is said that the Himalayas contain numerous rivers, springs, and glaciers. Springs and other underground water systems play a pivotal role in meeting the water demand of a large human and animal population in the Kumaun region of the Middle Himalayas through spring-fed rivers and streams. Climate change has made the Kumaun Himalaya one of the most vulnerable regions in terms of water stress (Mishra, 2014). There are several reasons for this which includes rainfall variability and complex hydrogeological behavior of springs (Negi and Joshi, 2004). Conventional water resources groundwater such as naulas, Dharas play a very important role in providing water to people residing there. Depletion of groundwater has been reported in many parts of Kumaun Himalaya. Gagas, Gaula, Ramganga, Saryu and Kosi watershed are the major water shed of the region which feeds maximum population (Al-Hadithi *et al*., 2003). But a large population of state is dependent on ground water and one such water shed is Suyal River watershed. Suyal river is a tributary of kosi river and its water shed lies in Almora and Nainital district of Uttarakhand state, India. It is also tried to map such ground water recharge points in Suyal River watershed which covers an area of 400km^2 lying in two districts of Almora and Nainital. The objective of the current study is to identify sites of water potential zones which can be used for both water extraction and rejuvenation of these groundwater sources.

MATERIALS AND METHODS

Study Area

The Suyal river watershed (Figure 1) stretches between 79 °37^1 to 79 ° 51 ^{1} East longitudes and 29 ° 32 ^{1} to 29 ° 42 ^{1} North Latitude in Lesser Himalayan Ranges. This basin is about 400 km^2 and basically situated in Nainital and Almora districts of Uttarakhand State. Location map of the Suyal Watershed is shown in Figure 1. The geomorphology of region suggests highly dissected hills and valley of structural origin along with the presence of structural lineaments namely faults, joints/factures, and the axial trace of folds (Bhuvan, NRSC, ISRO). Climate of this region is basically temperate. There are three seasons namely winter, summer and monsoon. Temperature of region varies from -1°C (December) to 32°C (June). Total precipitation in watershed is 1132.5 mm annually as per Indian Meteorological Department. Highest precipitation occurs in July and August months due to monsoon effect. Elevation of region varies from 1024 to 2384 m. Pine and oak trees are the main vegetation. Three cropping seasons exists every year, which are Rabi, Kharif and Jaid.

Mapping of sources where probability of ground water is maximum using Analytic Hierarchical process. In the present study GIS based data and processed, it using arc GIS software. Weighted sum analysis and assigned different weightage for different factors which influence potential ground water potential points. GIS based approach is relatively simple and precise approach and need of time for mountainous region. Here we have used seven factors of rainfall, slope, lineament density, drainage density, land use land cover, soil and geology of area. Weightage assigned them according to their contribution. Map of each factor is prepared using Arc GIS software. Finally, a ground water potential map is prepared after overlying these factors into different layers. Map which is obtained shows regions of high, very high, medium, low and very low ground water potential.

Data Collection and Processing

Water shed boundary of the region was obtained from Survey of India (SOI) topographical map. SOI map was first converted into digital format and then Geo referenced (projection- UTM, spheroid and datum-WGS, Zone 44 North). Rainfall data is obtained from IMD. Geomorphology of region is obtained from DEM, obtained from NRSC-Bhuvan. Slope and elevation of area was derived from DEM. Soil data is obtained from NBSS & LUP, Nagpur. Land use land cover data was obtained from Sentinel-2 (Available from Copernicus Senitel -2 ONDA- DIAS onda-dias.eu).

The information about lineaments and lithology was collected using a high resolution LISS-IV sensor (5m). All these maps were processed using ERDAS Imagine 2013 and further processed using ArcGIS-10.4 software.

Weightage Assignment

In order to find ground water potential zones seven factors were identified which are rainfall, elevation, lineament density, drainage density, LULC, soil and geology. These factors were selected because they are the major contributors and most important in influencing ground water potential of study area. Weightage is assigned to them based on their influence. Higher weightage is given to those factors which contribute the most and least to the factor which has lowest contribution (Saaty, 1980). Parameters and their weightages are presented in Table 2.

RESULTS AND DISCUSSION

Land Use Land Cover and Ground water potentiality

Land use and Land cover (Figure 2) represent all the physical substance that covers the earth's surface. This includes all the biotic and abiotic components lying in the area such as grass lands, forest, built up area, barren land, and agricultural land. Land Use Land Cover can be obtained from two basic approaches which are Field survey and remote sensed images. Here we have obtained Land Use land cover map from Land Sat Thermic Mapper alongside with top sheets of Survey of India. The

Table 1: Parameter and their sources

Rainfall	IMD (Indian Meteorological Department)
Geomorphology	SRTM 30m
Soil	From NBSS and LUP, Nagpur
Land use and land Cover	Sentinel-2 (Available from Copernicus Senitel -2 ONDA- DIAS onda-dias.eu)
Geology	GSI India

Table 2: Parameters and their weightage calculation

Factors	Rainfall	Elevation	Drainage density	Lineament density	LULC	Soil	Geology	Weight
Rainfall	0.3861	0.3854	0.3856	0.3857	0.3858	0.3856	0.3857	0.3857
Elevation	0.1931	0.1927	0.1928	0.1929	0.1929	0.1928	0.1928	0.1928
Drainage density	0.1287	0.1285	0.1285	0.1286	0.1286	0.1285	0.1286	0.1286
Lineament density	0.0965	0.0963	0.0964	0.0964	0.0965	0.0964	0.0964	0.0964
LULC	0.0772	0.0771	0.0771	0.0771	0.0772	0.0771	0.0771	0.0771
Soil	0.0644	0.0642	0.0643	0.0643	0.0643	0.0643	0.0643	0.0643
Geology	0.0552	0.0551	0.0551	0.0551	0.0551	0.0551	0.0551	0.0551
Total	1	1	1	1	1	1	1	1

GW patternable = (38.57×Rainfall) +(19.28× Elevation) +(12.86×Draiangedensity) +(9.64×Lineament density) +(7.71×LULC) + (6.43× Geology) +(5.51× Soil). According to Griot (2007), If total Parameters obtained is one then result are satisfied. Based on above decision matrix, the analysis along with the priority is summarized in Table 3.

Table 3: Parameters and their weightage analysis along with priority

S. No.	Parameters	values	Priority	Weightage
1	Rainfall	540-917 mm	Very Low	1
		917-1224 mm	Low	2
		1224-1516 mm	Medium	3
		1516-1811 mm	High	4
		1811-2214 mm	Very High	5
2	Elevation	1024-1296m	Very High	5
		1296-1568m	High	4
		1568-1840m	Medium	3
		1840-2112m	Low	2
		>2112m	Very Low	1
3	Drainage Density	2.22-26.94 m/m^2	Very Low	1
		26.94-39.12 m/m^2	Low	2
		39.12-50.55 m/m^2	Medium	3
		50.55-63.10 m/m^2	High	4
		63.10-96.03 m/m^2	Very High	5
4	Lineament density		Very High	1
			High	2
			Medium	3
			Low	4
			Very Low	5
5	LULC	Forest Evergreen	Very high	5
		Shrubs	High	4
		Agricultural land	Medium	3
		Grass land	Low	2
		Built up	Very Low	1
6	Soil	Clay Loam	Medium	3
7	Geology	Mesozoic Igneous Rocks	High	3
		Precambrian rocks (pC)	medium	2
		Tertiary igneous rocks. Low	1	

land use land cover of region is also available from onda-dias.eu using Seintel – 2. The land is divided into five classes land which contributes most towards water recharge is given highest priority and weightage. Different classes of land are shown with the help of different colors and number. Lowest weightage of 1 is given to build up area because most of built-up area is made of concrete and concrete has high surface runoff. It covers 244.632 km^2 area of total catchment area. Grassland is represented by dark blue color and is given weightage of 2 having total area of 1.276 km^2. Agricultural land is given weightage of 3 because it percolates large amount of water provided for

Table 4: Parameters and Percentage area of Lineament density with their weightage analysis along with priority

Category	Rainfall in mm	Area in km^2	Percentage of area of Lineament density	Weightage
Very low	540-917 mm	296.68	74.17	1
Low	917-1224 mm	46.92	11.73	2
Medium	1224-1516 mm	33.84	8.46	3
High	1516-1811 mm	16.28	4.07	4
Very High	1811-2214 mm	6.12	1.53	5

Table 5: Rock type and distribution

Sl No.	Rock type	Water holding ability	Area in km^2	Percentage	Weightage
1	(Mi)Mesozoic Igneous Rocks	Low	296.68	74.17	1
2	(pC) Precambrian rocks	Medium	46.92	11.73	2
3	(Ti) Tertiary igneous rocks	High	33.84	8.46	3

Table 6: Elevation and distribution

Sl. No.	Elevation	category	Area in km^2	Percentage	Weightage
1	1024-1296m	Very Low	75.37	18.84	5
2	1296-1568m	Low	95.56	23.89	4
3	1568-1840m	Medium	Lineament density	Lineament density	Lineament density
4	1840-2112m	High	95.51	23.88	2
5	>2112m	Very High	37.28	9.32	1

Table 7: Ground water potential in sub classes in terms of their percentage area

Sl. No.	Type of ground water recharge potentiality	Area (sq.km)	Percentage Area
1	Very Low	54.36	13.59
2	Low	199.61	49.90
3	Medium	102.52	25.63
4	High	30.29	7.57

irrigation to ground. Shrubs are given weightage of 4 as around 90 per cent surface water is seeped to ground from this land. Area under shrubs is represented by light green color. Forest area is given highest weightage of 5 as it percolates above 95 per cent surface water to ground and only small amount is lost in form of interception loss and evapotranspiration losses.

Lineament density and ground water potentiality

Lineament is a linear feature in a landscape which is an expression of an underlying geological structure such as a fault. However, there is small difference between fault and lineament that fault tells the geological history of a small area but lineament is used for much larger area. Lineaments represent larger area of weakness in earth's crust. It is clear from geological investigation of area (Figure 3) that most of the regions with lineaments density higher are more frequent regions of underground water sources. 74.17 per cent of the watershed area has very low lineament density, 11.73 per cent area has low lineament density, 8.46 per cent area has medium, and 4.07 per cent area has high while only 1.53 per cent area has very high lineament density. Lineament density of study area suggests that northern region of water shed has good lineament density compared to southern part of watershed.

Rainfall Map and Ground water potentiality

Rainfall is the most significant and important factor in any water conservation work. Rainfall represents the form of precipitation in the form of liquid drops of size 5 mm to 6 mm. Higher rainfall area have more water available for both surface overflow and ground recharge. Therefore, rainfall is given highest weightage in our analysis. Area receives most of rainfall from south west monsoon during summer and from western disturbances in winters. The entire basin can be divided into five classes depending upon amount of rainfall received.

As clear from diagram and table that the area with high to very high rainfall is very less but overall rainfall received by the watershed is sufficient enough to make it a good watershed for water potential.

Slope and Ground water potentiality

Slope of the area represents steepness or gentleness of a basin. Higher slope will have lesser water holding ability because water flows away easily so will have lower probability of water recharging zones. The slope map of the study area (Figure 4) has been prepared using ASTER-DEM of resolution 30m. Slope of the area has been divided to five classes *viz.,* very low, low medium, high and very high. Dem was first imported to Arc GIS software and clipped for study area and final a map is prepared. Higher slope areas are hills or mountains while lower slope areas are valley plain region.

Geology Map and Ground water potentiality

Historical record of area suggests us that most of area of Suyal basin is under three rock types which are Mesozoic Igneous Rocks (Mi), Precambrian rocks (pC) and Tertiary igneous rocks (Ti). Northern and middle portion of region is under Ti rock which has excellent porosity and water retaining ability. Precambrian rocks (pC) also have good water conductivity. (Mi) Mesozoic Igneous Rocks are almost similar to procambium rock but have slightly lower water retentively. The Geological map of the study area has been prepared from World Geologic Maps (USGS) of India and clipped for the study are presented in Table 5.

Elevation and Ground water potentiality

Elevation of the study area was obtained from Digital elevation model (DEM). DEM of area posturizes the elevation of area ranges from1024 to 2112 m. Southern region of study area signifies high elevation because it is surrounded by Shivalik ranges of Nainital on southern side. Northern region of study area has relatively lower elevation. DEM of the region has been reclassified into 5 categories a) very low (5056-7795 m), b) low (4018-5056 m), c) medium (2865-4018 m), d) high (1827-2865 m) and, e) very high (444-1827 m).

Final ground water potential map

Final ground water potential map (Figure 7) shows us the locations where probability of finding water is most. The map suggests us that around 132 km^2 area has high to very high ground water recharge potentiality. About 102.52 km^2 area is medium and 253 km^2 areas have low to very low ground water recharge potentiality.

Final ground water potential map suggests us that Suyal River watershed has immense scope of rejuvenation of conventional water resources because it contains sufficient points of potential water recharge. Proper afforestation should be done on these locations especially of broad leaf plants. Proper ditches and trenches must be dug at desired locations. Regions with extremely high-water potential must be conserved the most.

Water conservation measures to be adopted

Final ground water potential map suggests that Suyal River basin has great ground water recharge ability. The water conservation augmentation measures adopted for different regions will be different. The region where potential is low should be planted and grass seeded. Check dams should be built for moderate water potential zones. The regions with high water potential can be recharged with help of contour trenches and recharge pits.

Scope of further studies

AHP technique can be used for various other fields such as food analysis of region. It can be used to rejuvenate different natural resources of water, finding plantation area for afforestation, finding appropriate measures of land conservation, river conservation etc. Maps can be used for rainfall pattern analysis, geological study, river conservation,

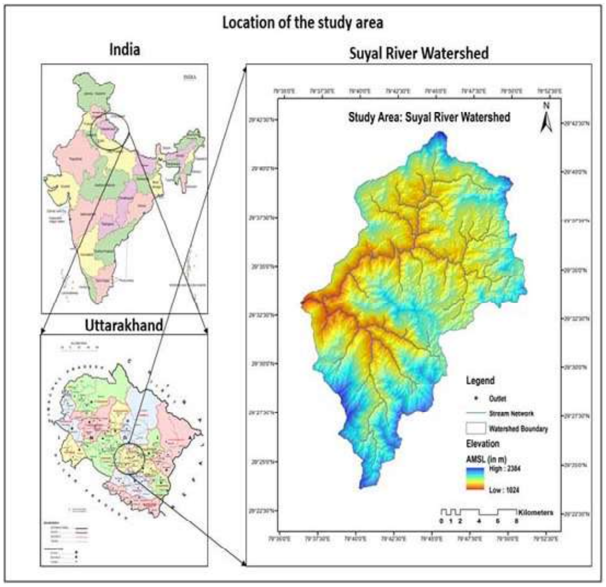

Fig.1: Location map of the Suyal watershed

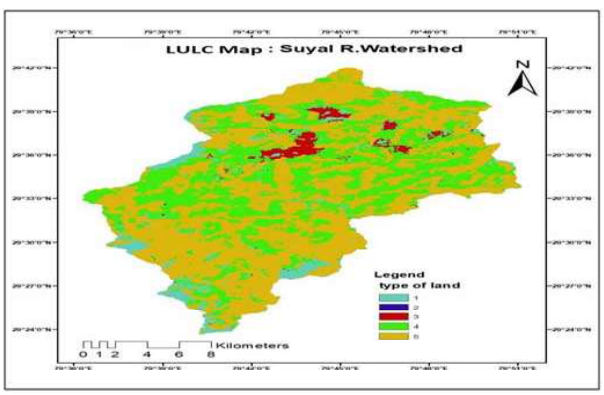

Fig. 2: Land Use land cover map of Suyal watershed

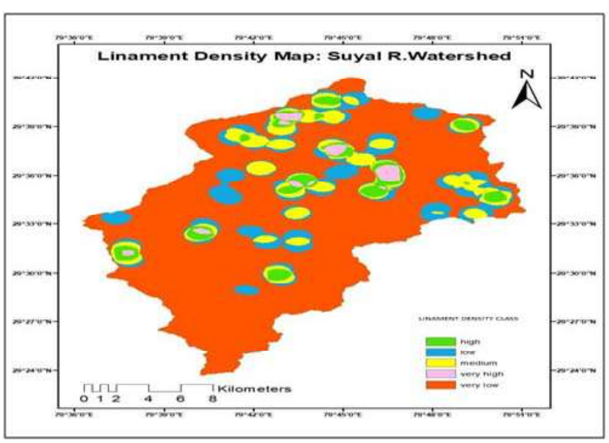

Fig. 3: Lineament density map of the Suyal watershed

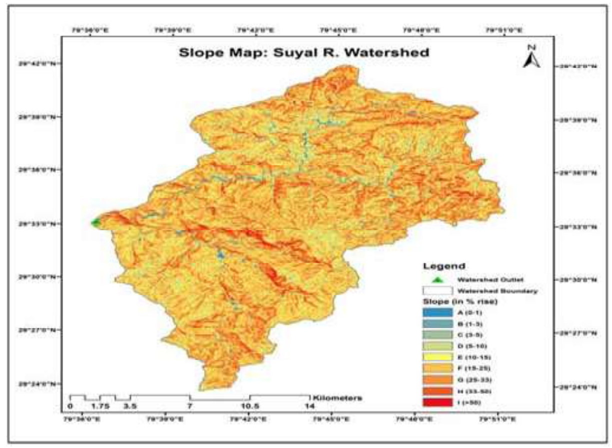

Fig. 4: Slope Classification of the Suyal Watershed

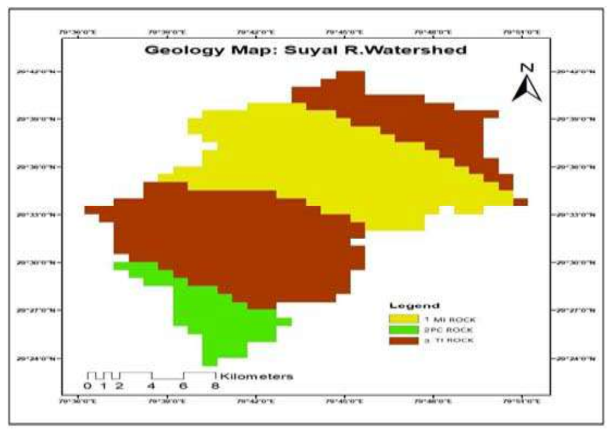

Fig. 5: Geological Features of the Suyal watershed

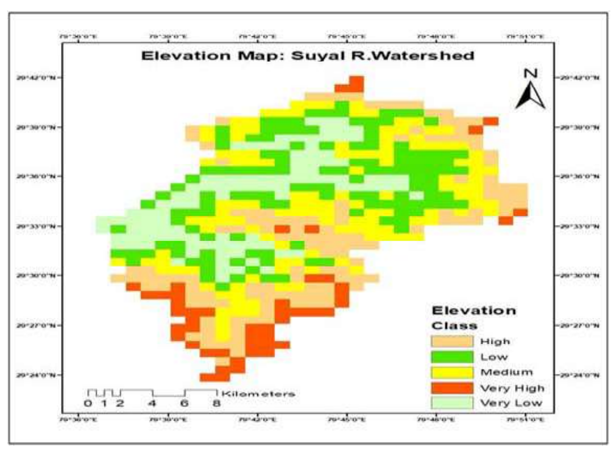

Fig. 6: Elevation Profile of the Suyal watershed

agricultural improvement, afforestation projects, irrigation projects etc. can also be widely used in Government River conservation program and water conservation programs.

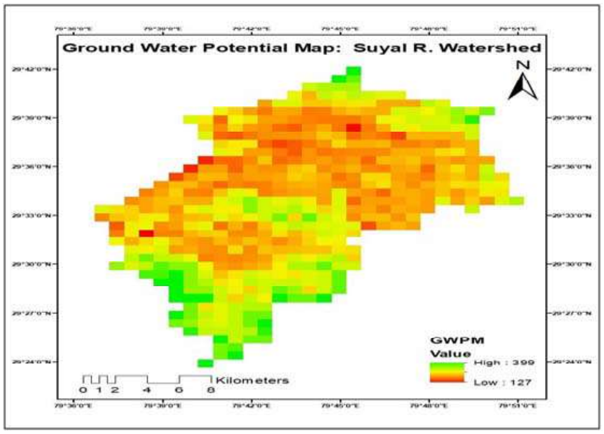

Fig. 7: Groundwater Potential map of the Suyal watershed

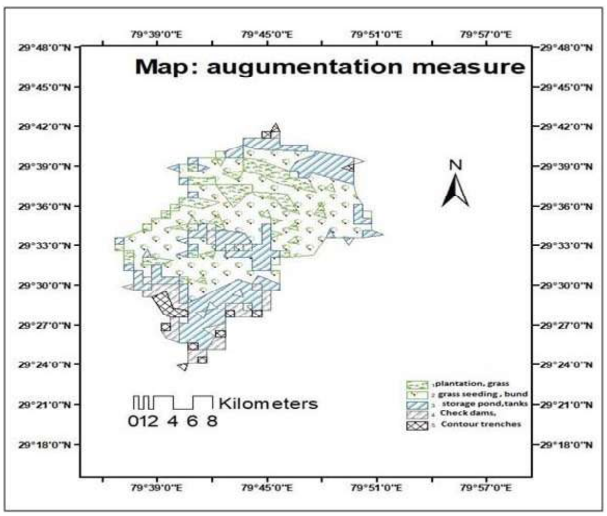

Fig. 8: Areas of Water conservation measures to be adopted in the Suyal watershed

CONCLUSION

Water is one of the basic necessities of living organisms. People living in hilly region of Kumaon are highly dependent on underground water resources for their survival. Ground water present there is in the form of springs and falls. Here attempts have been done to study and find all such points and locations in Suyal River basin which are potential points of water using GIS data and techniques. The basin has good ground water potential zones which have immense potential of retaining as well as recharging ground. In this study seven basic parameters such as rainfall, elevation. LULC, lineament density, Drainage density, Geology and soil are used to evaluate and find these points which are based on final ground water potential map. Finally suggested a model of proper augmentation measures that can be adopted for each region so that water can be preserved and conventional water resources can be rejuvenated.

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