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Validation of Derived Groundwater Potential Zones Using Well Yield Data through Agreement Scheme Approach with Geoinformatics in Ken River Basin

Deepak Patle, Manoj Kumar Awasthi and Sourabh Nema[1]

Department of Soil and Water Engineering, College of Agricultural Engineering
Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur-482 004, India
[1]National Institute of Hydrology, North West Regional Centre, Jodhpur-342 003, India
E-mail: deepak.patle12@gmail.com

Abstract: This study focused on validation of derived groundwater potential zones (GPZ) map from well yield data using the Agreement Scheme approach in Ken River Basin with the help of geoinformatics. Total 100 random points were generated over the classified GPZ map of the study area. Information regarding different groundwater potential zones were extracted for each random point. Then, theses points were imported in to Bhujal-Bhuvan Portal of ISRO. In this portal, the "Ground Water Prospects" map represents different well depth and well yield ranges, which is developed by Rajiv Gandhi National Drinking Water Mission Project with collaboration of CGWB and NRSC, Hyderabad. In order to validate the groundwater potential zones map, the well yield data was classified into five classes namely, Very Poor (< 50 LPM), Poor (50-100 LPM), Moderate (100-200 LPM), Good (200-400 LPM), and Very Good (> 400 LPM). After that, 100 random points were superimposed over the Ground Water Prospects map and extracted well yield data. The accuracy of the GPZ was cross-validated with the well yield data using agreement scheme. The overall validation accuracy was about 84%, which shows a very good correlation between groundwater potential zones and the well yield. It proves that the applied approach provided significant reliable outcomes for the present study, allowing decision makers to create an effective plan.

Keywords: Groundwater, Well yield, Validation, Ken River Basin, Geoinformatics

In present scenario of water crisis in the country and changing climate conditions, the groundwater resource management is essential for food, water security, and economic growth. Groundwater, a precious yet hidden resource, remains elusive to direct detection, making its mapping a daunting task. However, with increasing demand for water and depleting surface water resources, it is imperative to explore this underground natural resource. The Ken Basin's geological conditions are known to be highly variable, and as such, mapping the potential of its groundwater resources has posed a complex and challenging task that remains largely unexplored. An advanced remote sensing technique combined with GIS is proving to be a powerful tool for identifying and mapping groundwater potential zones in time and cost-effective manner (Chouhan et al 2014, Patle et al 2022).

Validation of the resulted data is one of the most important works after making any model to check the proficiency of the predicted results. Various methods are extensively used to validate groundwater potential zones maps such as receiver operating characteristics (ROC) approach, groundwater well yield data, net availability of groundwater and groundwater level fluctuation data etc. (Basavarajappa et al 2016, Arulbalaji et al 2019, Elubid et al 2020, Sajil et al 2022, Mahato et al 2022). Several studies have been conducted to validate the groundwater potential areas by implementing different statistical approaches in a GIS environment (Sharma et al 2012, Gajbhiye et al 2015, Patil et al 2017). Pradeep and Gopal (2022) studied in Mewat district of Haryana, to validate the groundwater potential zones using water level of test wells during pre-monsoon of 2019, and documented the satisfactory results. Validation of the result/ product shows the significance of the study and its practicability. To validate any model/ predicated result, the availability of field data is a challenging task. Hence, an attempt has been made in this study to validate the derived groundwater potential zones map through geoinformatics techniques in Ken Basin by using Agreement Scheme approach.

MATERIAL AND METHODS

Study area: The Ken River is one of the major rivers of the Bundelkhand region of central India. It originates from the Ahirgawan village in Katni district (MP) and confluence with the Yamuna River at Chilla village, Banda district (UP). Ken River travels a total distance of 427 km. Ken River Basin lies between 23°07'-25°51' N latitudes and 78°30'-80°38' E longitudes. Total geographical area of the Ken River basin is about 28,671 km^2, out of which 86.73% of this area lies in MP and 13.27% in UP. The basin covers a total of eleven districts, out of which eight districts from Madhya Pradesh (Katni, Sagar, Damoh, Chhatarpur, Panna, Satna, Narsinghpur, Raisen) of Madhya Pradesh and three districts of Uttar Pradesh (Hamirpur, Mahoba, and Banda). The location map of the study area was given in Figure 1.

The Ken Basin is a part of the Yamuna Basin (Lower Ganga Basin), is varied in its geological setting. The following types of hydro-geological formations are found in the Ken Basin: Alluvium supergroup (newer/ younger and older alluvium), Bundelkhand Granite-Gneiss supergroup (Bundelkhand granite and gneiss), Dharwar supergroup (Bijawar), Deccan supergroup (Malwa, Lameta and Laterite), and Vindhyan supergroup (Bhander, Kaimur, Rewa, and Semri). The northern portion of the basin was covered by the alluvium geologic group, southern eastern portion covered by bhander group, and, the southern western part covered by malwa group. In Ken River Basin, Alluvium group depicted in Banda, Hamirpur and Mahoba districts of Uttar Pradesh, having more than 2000 lpm aquifer yield. The Bhander and Laterite group consists 900-1250 lpm, Bijawar and Rewa groups refers 700-900 lpm, Malwa and Semri group states 400-600 and, Bundelkhand Granitoid Complex and Lameta group ranges less than 200 lpm aquifer yield. The hydraulic conductivity varies from 5-15 m/d. Similarly, specific yield is generally in the range of 5 to 15%. The wells are recorded to be generally up to 25 to 30 m in depth with water levels in the lean part of the year exceeding 10 m bgl.

Methodology: The Groundwater Potential Zones (GPZ) map of Ken River Basin was developed by integration of different nine thematic layers like geology, geomorphology, lineament density, land use/ land cover, soil texture, slope, drainage density, and rainfall through AHP (Analytical Hierarchical Process) which is widely used as a multi-criterion decision making approach. In this study, validation of the groundwater potential zones map of Ken River Basin was done through the "Ground Water Prospect Study" map available on Bhujal-Bhuvan portal (https://bhuvan-app1.nrsc.gov.in/gwis/gwis.php) which provides the spatial information on well yield. This geospatial platform was developed by the CGWB and NRSC under the Rajiv Gandhi National Drinking Water Mission Project. In the Agreement Scheme Approach (Patle 2022), random points (at least 100) generated over the Groundwater Potential Zones map of the Ken River Basin using ArcGIS 10.8 software (Fig. 2).

The information of different zones from the GPZ was extracted for each random point. Then, all the points (vector format file) were converted into km layer file so that it can be open in Bhujal-Bhuvan portal appropriately. All the random points were imported in Bhujal-Bhuvan portal (Fig. 3).

In Bhujal-Bhuvan portal, Madhya Pradesh selected in state option and checked the 'Ground Water Prospect' option.

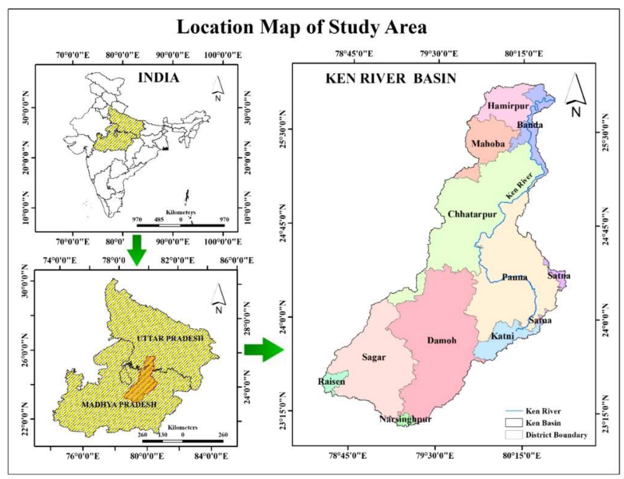

Fig. 1. Location of Ken River Basin

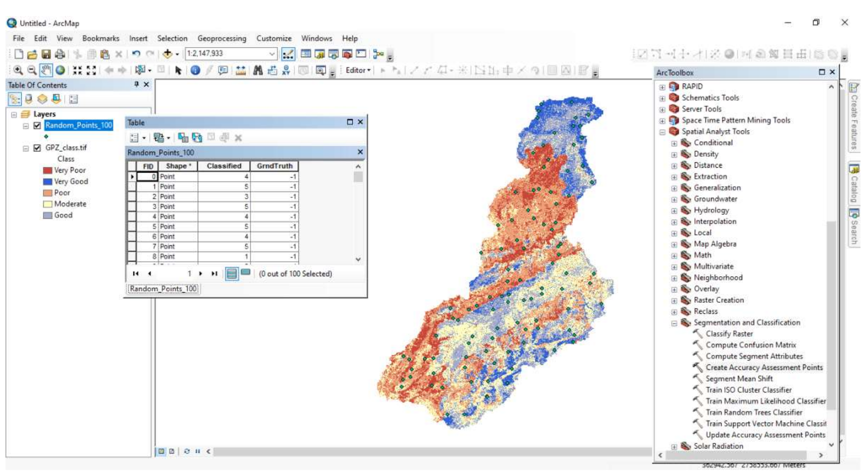

Fig. 2. Random point generation

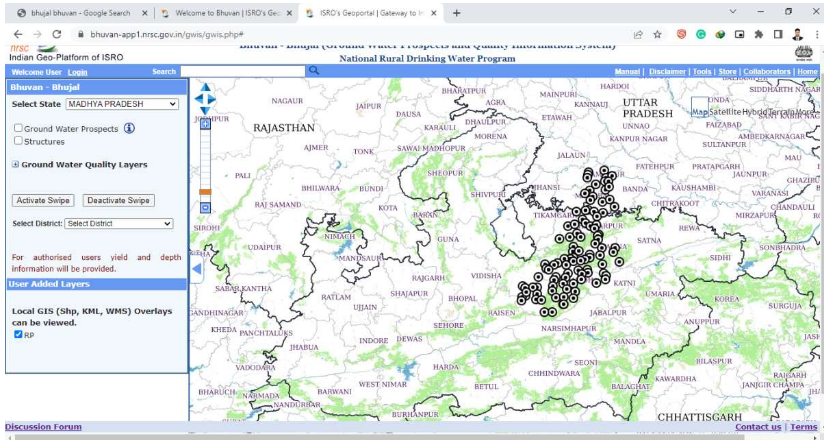

Fig. 3. Imported random points in Bhujal-Bhuvan Portal

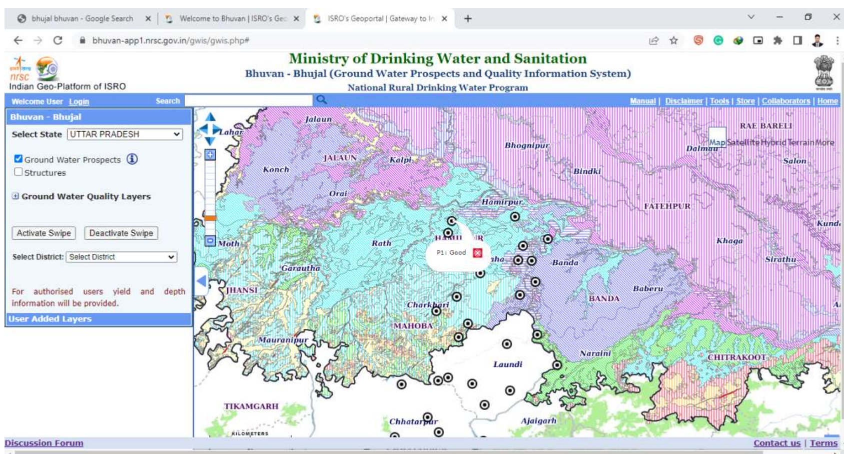

Fig. 4. Information extraction from the map

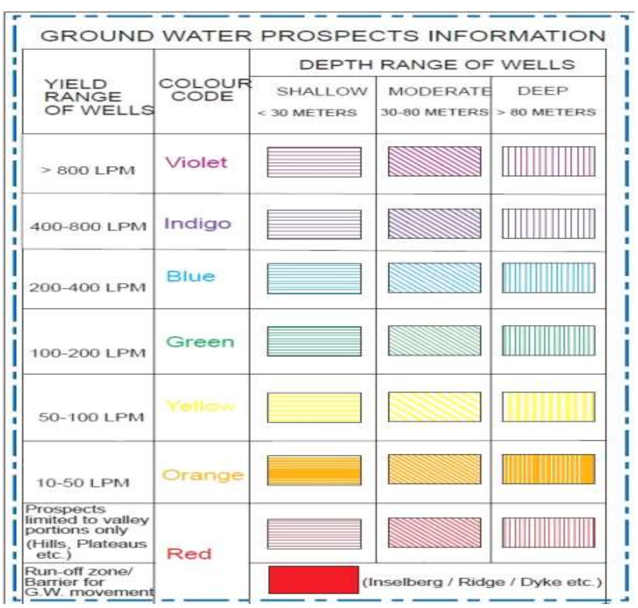

Fig. 5. Colour coding given in user manual of groundwater prospect

Afterward, clicked on each point and zoom-in it. Then, identified the *colour* code and *lining* pattern of existing polygon (Fig. 4). Classification of well yield ranges was given in the User manual of "Groundwater Prospect Mapping" (NRSA, 2011) (Fig. 5). The available yield ranges of well are classified into six classes from 10-50 LPM to > 800 LPM. These ranges of well yield are regrouped into five categories from < 50 LPM to > 400 LPM. The well yield ranges extracted for all the random points, by clicking on each point manually using zoom-in & zoom-out option in Bhujal-Bhuvan portal. This information was obtained based on colour code and lining pattern of existing polygon below the particular point. Both the data, well yield classes and GPZ classes were categorized into five categories like very good to very poor (Table 1).

The Random Points containing info of GPZ class was compared with the Well Yield ranges and prepared a table having point no., longitude, latitude, GPZ, yield, and agreements. Overall accuracy was estimated based on "agree condition (agree, agree-less, and agree-excess)" and

Table 1. Classification of well yield

Yield range of wells	Class
> 400 LPM	Very good
200 - 400 LPM	Good
100 - 200 LPM	Moderate
50 - 100 LPM	Poor
< 50 LPM	Very poor

"disagree" statement between well yield class and GPZ classes.

Accuracy (%) = No. of points in agree condition / total no. of points x 100

The validation accuracy can be classified into the following categories: 0.5 - 0.6 (poor) 0.6 - 0.7 (average); 0.7 - 0.8 (good); 0.8 - 0.9 (very good); and 0.9 – 1.0 (excellent) (Hosmer and Lemeshow 2000).

RESULTS AND DISCUSSION

The Groundwater Potential Zones (GPZ) map of Ken River Basin was derived through the Analytical Hierarchical Process (AHP) by integration of nine thematic parameters in GIS environment. The major portion (55%) of the study area is covered with gentle slope to moderate slope which reflects good to moderate groundwater potential. The Bhander geology group (45%) is dominated and represents poor potential because of sandstone and shale rocks with low aquifer yield. The pediment pediplain complex (58%) geomorphological unit is dominated in the study area which indicates moderate potential for groundwater. The loamy soil (48%) and clayey soil (47%) were majorly found in Ken Basin which depicts moderate to poor groundwater prospective due to infiltration and percolation properties. A major part of the basin was found about 24.85% in good groundwater potential zones (Fig. 6). The moderate and poor zones also contribute almost an equal share of the basin which is 23.32 and 23.03% respectively. The very poor zones also contribute 18.30% area of the basin. Least area found in the very good potential zones which is about 10.50%. However, this study seeks to break new ground by utilizing advanced remote sensing and GIS techniques to identify and demarcate varying groundwater potential areas within the Ken River Basin in India. It is providing valuable insights into the region's water resources and paving the way for more informed management and conservation efforts.

The main purpose of the study was to provide a scientific systematic manner to validate the groundwater potential zones map. The appropriate dataset for validation of groundwater potential zones map is well yield of an area. The Bhujal-Bhuvan portal provides easy access to get spatial information on well yield. In Agreement Scheme approach, cross validation between GPZ classes and well yield ranges were done based on statements given in Table 2. Groundwater potential zones was verified with well yield data which shown in below given Table 3. In this method of validation, results also revealed that numbers and percentage of points (with concerning yield ranges) are correctly classified in all the zones of groundwater potential over the entire area. Numbers of random points were identified in different zones of groundwater potential map with different agreements represented in Table 4.

The 45% of points were classifed under the agreement condition and only 16% of points found in disagreement category (Fig. 7). Rest of the points found under the

Table 2. Agreement for cross validation between GPZ classes and well yield ranges

Well yield class	GPZ Class	Agreement	Well yield class	GPZ Class	Agreement
Very good	Very good	Agree	Moderate	Poor	Agree - Less
Very good	Good	Agree - Less	Moderate	Very poor	Disagree
Very good	Moderate	Disagree	Poor	Very good	Disagree
Very good	Poor	Disagree	Poor	Good	Disagree
Very good	Very poor	Disagree	Poor	Moderate	Agree - Excess
Good	Very good	Agree - Excess	Poor	Poor	Agree
Good	Good	Agree	Poor	Very poor	Agree - Less
Good	Moderate	Agree - Less	Very poor	Very good	Disagree
Good	Poor	Disagree	Very poor	Good	Disagree
Good	Very poor	Disagree	Very poor	Moderate	Disagree
Moderate	Very good	Disagree	Very poor	Poor	Agree - Excess
Moderate	Good	Agree - Excess	Very poor	Very poor	Agree
Moderate	Moderate	Agree			

Table 3. Comparison analysis of derived GPZ map and actual well yield data

Random point/ validation point	Longitude	Latitude	Well yield (LPM)	Well yield class	GPZ class	Agreement
1	80.297	25.838	100 - 200	Moderate	Good	Agree - Excess
2	79.954	25.822	100 - 200	Moderate	Very Good	Disagree
3	80.151	25.815	50 - 100	Poor	Moderate	Agree - Excess
4	80.208	25.807	200 - 400	Good	Moderate	Agree - Excess
5	79.903	25.798	50 - 100	Poor	Moderate	Agree - Excess
6	80.300	25.787	< 50	Very Poor	Poor	Agree - Less
7	80.286	25.766	< 50	Very Poor	Moderate	Disagree
8	80.089	25.755	50 - 100	Poor	Moderate	Agree - Excess
9	80.335	25.744	100 - 200	Moderate	Moderate	Agree
10	79.923	25.724	> 400	Very Good	Good	Agree - Less
11	79.972	25.713	100 - 200	Moderate	Poor	Agree - Less
12	80.380	25.703	50 - 100	Poor	Poor	Agree
13	80.460	25.701	> 400	Very Good	Good	Agree - Less
14	79.865	25.675	200 - 400	Good	Moderate	Agree - Excess
15	80.111	25.674	> 400	Very Good	Very Good	Agree
16	80.253	25.669	200 - 400	Good	Poor	Disagree
17	79.965	25.665	50 - 100	Poor	Moderate	Agree - Excess
18	80.332	25.645	> 400	Very Good	Moderate	Disagree
19	80.165	25.639	50 - 100	Poor	Moderate	Agree - Excess
20	79.836	25.631	100 - 200	Moderate	Good	Agree - Excess
21	79.934	25.594	200 - 400	Good	Moderate	Agree - Less
22	79.764	25.587	50 - 100	Poor	Good	Disagree
23	79.751	25.579	50 - 100	Poor	Moderate	Agree - Excess
24	79.917	25.542	200 - 400	Good	Good	Agree
25	80.301	25.532	200 - 400	Good	Moderate	Agree - Less
26	79.880	25.525	200 - 400	Good	Moderate	Agree - Less
27	79.755	25.491	> 400	Very Good	Good	Agree - Less
28	79.951	25.464	< 50	Very Poor	Very Poor	Agree
29	79.762	25.456	100 - 200	Moderate	Moderate	Agree
30	80.212	25.454	< 50	Very Poor	Moderate	Disagree
31	80.208	25.387	50 - 100	Poor	Moderate	Agree - Excess
32	79.946	25.362	50 - 100	Poor	Poor	Agree
33	80.108	25.361	< 50	Very Poor	Very Poor	Agree
34	79.762	25.355	< 50	Very Poor	Very Poor	Agree
35	79.907	25.350	50 - 100	Poor	Very Poor	Agree - Less
36	80.375	25.344	200 - 400	Good	Good	Agree
37	79.927	25.327	< 50	Very Poor	Very Poor	Agree
38	80.390	25.311	100 - 200	Moderate	Moderate	Agree
39	79.807	25.305	100 - 200	Moderate	Poor	Agree - Less
40	79.807	25.305	100 - 200	Moderate	Poor	Agree - Less
41	80.408	25.285	> 400	Very Good	Very Good	Agree
42	80.431	25.259	> 400	Very good	Very good	Agree
43	80.439	25.251	> 400	Very good	Very good	Agree
44	79.964	25.244	< 50	Very poor	Very poor	Agree

Cont...

Table 3. Comparison analysis of derived GPZ map and actual well yield data

Random point/ validation point	Longitude	Latitude	Well yield (LPM)	Well yield class	GPZ class	Agreement
45	79.905	25.233	< 50	Very poor	Very poor	Agree
46	80.293	25.233	< 50	Very poor	Moderate	Disagree
47	80.426	25.231	200 - 400	Good	Good	Agree
48	80.047	25.226	< 50	Very poor	Very poor	Agree
49	80.454	25.209	100 - 200	Moderate	Moderate	Agree
50	80.054	25.194	< 50	Very poor	Very poor	Agree
51	79.879	25.133	< 50	Very poor	Ver poor	Agree
52	79.942	25.104	100 - 200	Moderate	Poor	Agree
53	80.188	25.074	50 - 100	Poor	Poor	Agree
54	79.697	25.051	< 50	Very poor	Poor	Agree - Less
55	80.297	25.048	> 400	Very good	Good	Agree - Less
56	79.721	24.994	50 - 100	Poor	Poor	Agree
57	79.909	24.973	200 - 400	Good	Poor	Disagree
58	80.276	24.976	100 - 200	Moderate	Very poor	Disagree
59	79.597	24.909	< 50	Very poor	Poor	Agree - Excess
60	79.520	24.908	100 - 200	Moderate	Moderate	Agree
61	80.245	24.900	100 - 200	Moderate	Poor	Agree - Less
62	79.942	24.847	100 - 200	Moderate	Poor	Agree - Less
63	79.604	24.834	100 - 200	Moderate	Poor	Agree - Less
64	79.833	24.813	50 - 100	Poor	Moderate	Agree - Excess
65	79.881	24.781	50 - 100	Poor	Very poor	Agree - Excess
66	79.963	24.779	50 - 100	Poor	Very poor	Agree - Excess
67	79.826	24.772	50 - 100	Poor	Very poor	Agree - Excess
68	79.910	24.773	200 - 400	Good	Poor	Disagree
69	79.494	24.621	50 - 100	Poor	Poor	Agree
70	80.135	24.621	< 50	Very poor	Very poor	Agree
71	79.611	24.604	200 - 400	Good	Moderate	Agree - Less
72	79.656	24.582	200 - 400	Good	Good	Agree
73	80.264	24.561	200 - 400	Good	Moderate	Agree - Less
74	80.175	24.548	100 - 200	Moderate	Moderate	Agree
75	80.084	24.513	200 - 400	Good	Moderate	Agree - Less
76	80.028	24.506	200 - 400	Good	Good	Agree
77	80.028	24.506	200 - 400	Good	Good	Agree
78	79.709	24.479	> 400	Very good	Good	Agree - Less
79	80.282	24.406	200 - 400	Good	Poor	Disagree
80	79.853	24.394	< 50	Very poor	Very poor	Agree
81	80.472	24.384	< 50	Very poor	Very poor	Agree
82	79.774	24.362	< 50	Very poor	Very poor	Agree
83	80.050	24.351	200 - 400	Good	Good	Agree
84	80.296	24.333	> 400	Very good	Very good	Agree
85	79.693	24.307	50 - 100	Poor	Very good	Disagree
86	79.648	24.287	< 50	Very poor	Poor	Agree - Less
87	80.047	24.262	100 - 200	Moderate	Poor	Agree - Less
88	79.825	24.241	200 - 400	Good	Good	Agree
89	79.660	24.224	100 - 200	Moderate	Moderate	Agree
90	79.964	24.179	100 - 200	Moderate	Moderate	Agree
91	80.304	24.174	200 - 400	Good	Good	Agree
92	79.454	24.104	50 - 100	Poor	Good	Disagree
93	79.511	24.070	< 50	Very Poor	Very Poor	Agree
94	79.640	24.062	100 - 200	Moderate	Very Good	Disagree
95	79.259	24.047	50 - 100	Poor	Poor	Agree
96	79.148	24.034	100 - 200	Moderate	Moderate	Agree
97	78.929	24.010	100 - 200	Moderate	Very Poor	Disagree
98	79.042	24.012	100 - 200	Moderate	Very Poor	Disagree
99	80.166	24.020	> 400	Very Good	Very Good	Agree
100	79.180	23.976	50 - 100	Poor	Moderate	Agree - Excess

Table 4. Validation of derived GPZ with well yield

Groundwater prospect zones / Well yield points	Very good	Good	Moderate	Poor	Very poor	Total
Number of points under agreement	6	9	9	7	14	45
Number of points under agreement with less yield	0	5	6	10	1	22
Number of points under agreement with excess yield	0	2	11	1	3	17
Number of points under disagreement	3	2	4	4	3	16
No. of points under different zones	9	18	30	22	21	100

agreement with less and excess yields about 22%, 17% respectively. Figure 7 illustrated that the well yields points with the agreement are mostly observed in entire zones of the groundwater potential zones. The overall accuracy of groundwater potential zones was found 84% which is denotes very good accuracy. One of the most important criteria for evaluating a system/ model/ approach is its validation. The validation of Groundwater Potential Zones

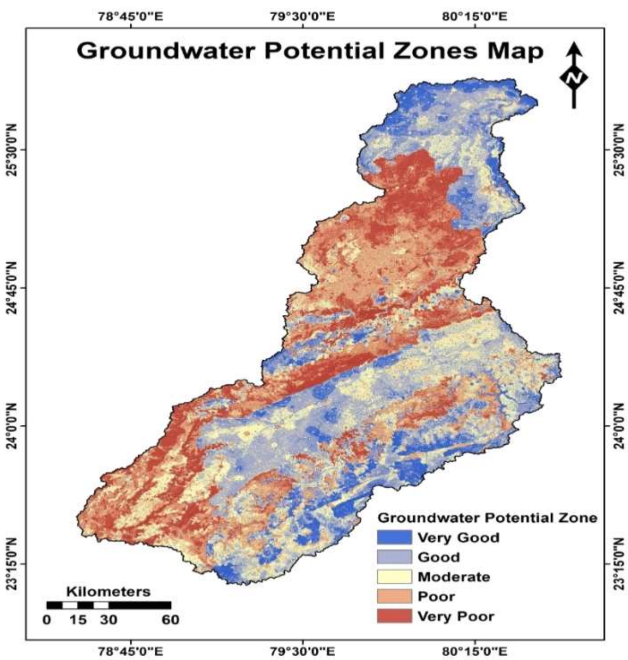

Fig. 6. Groundwater Potential Zones (GPZ) map of Ken River Basin derived by AHP

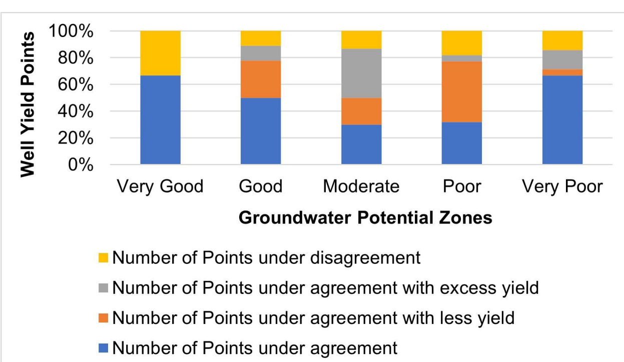

Fig. 7, GPZ with well yield

map is an essential step in defining its authenticity. An important aspect of validating GPZ maps is the availability of data. Collection of validation data such as water level (pre & post monsoon), well yield, groundwater availability, groundwater recharge, etc. on random locations is a typical task. Similarly, a few or limited samples of data using for the validation of GPZ may be causing inappropriate results. It may affect the accuracy of the groundwater potential zones map. Keeping this in mind, the validation of groundwater potential zons map was done using well yield data collected from the Bhujal-Bhuvan portal through the agreement scheme approach.

CONCLUSIONS

The main purpose of study was to provide an easy and scientific way to validate the groundwater potential zones map. Generally, the data collection for validation of GPZ is a hectic task. Many Researchers are used well yield data and groundwater level fluctuation data. These data are not freely available on village, block, and district level. These data must also be acquired from different government agencies, which is time consuming. So, the Bhujal-Bhuvan portal may be used for the validation purpose which is open access portal developed by NRSC and CGWB. In some studies, ROC (relative operating characteristics) curve method was used to validate the GPZ map using different datasets. The ROC curve plots between the true positive rates (sensitivity) and false positive rates (1-specificity). This statistical method is difficult to recognize and execute. Accuracy Scheme approach was used in this study. The data availability and the validation approach are simple, accurate, and easy to implement. This approach will be helpful to validate the different water resource management and prediction models.

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