Exploring Geospatial Technology in Kadiri Basin of Ananthapuramu District, A.P. for Demarcation of GWPZ and Identification of Recharge Structures

P. P. Chowdary, S. Kumar, S. Kumar, V. G. K. Villuri, and P. Srinivas

Abstract Geospatial technology (GT) has played a crucial role in identification of groundwater potential zones (GWPZ). Weighted overlay analysis (WOA) is a multicriterion study for the GWPZ under the umbrella of GT wherein investigation was carried out with multifaceted things for determining certain themes with the aid of assigning rank to the respective features class and then assign weightage to the respective parameters depending upon the weightage of the theme on the objective. For this purpose, criteria for the analysis were defined, and each parameter was assigned weightage based on its importance. In the present study, weighted overlay model in GIS environment (ArcGIS software) has been utilized to identify and demarcate the suitability for groundwater recharge zones in Kadiri basin of Ananthapuramu district, Andhra Pradesh, which was explored further for suitable recharge structures. Integration of various thematic layers was done for developing groundwater potential zones map of the study area which has four categories, i.e. poor, average, good and excellent GWPZ, respectively. Multiple thematic layers of influencing parameters were prepared and assigned features class rank as per the importance in the selection of recharge sites. Using this suitability modelling, suitable areas were identified wherein the classes with higher values indicate the most favourable zones for natural recharge in GIS platform and generated a composite map

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showing proposed locations for suitable groundwater recharge structures like check dams, percolation tanks, subsurface dykes and gabion structures.

Keywords Remote sensing · GIS · Weighted overlay analysis · Kadiri basin · GWPZ map

1 Introduction

Indiscriminate exploitation of surface and subsurface water has led to severe water scarcity and environmental degradation. The spatial-temporal variation in rainfall has further aggravated the problem. To meet the challenges of the scarcity, increasing demand and depletion of groundwater levels, water resources should be developed and managed in an effective manner. Kadiri basin in Ananthapuramu region, Andhra Pradesh, India, is drought-prone because the entire Ananthapuramu district falls under rain-shadow region of A.P. The area receives scanty rainfall and has no major irrigation projects. In addition, a major part of agricultural sector in this region fully depends on groundwater irrigation. As a result of overexploitation of groundwater, water scarcity prevails in the area. Proper groundwater management in a scientific manner is very much essential for the study area. Hence, delineation of groundwater potential zones has been carried out for this area using remote sensing and GIS technologies for better and optimal utilization of this precious resource for sustainable development.

2 Materials and Methods

2.1 Study Area

Kadiri basin is in the south-eastern part of Ananthapuramu district, A.P., India is geographically located between 78° 00′–78° 20′ E longitudes and 13° 55′–14° 10′ N latitudes with a total area of 517.28 km^2 (Fig. 1). The area comprises four mandals, namely Kadiri, Gandlapenta, Nalla Cheruvu and Obuladevara Cheruvu. Agricultural land occupies the major part of basin followed by forest area.

2.2 Data Collected

Satellite imageries, toposheets, geological maps and soil maps were procured from National Remote Sensing Center, Hyderabad, Survey of India, Hyderabad, Geological Survey of India, Hyderabad and National Bureau of Soil Survey and Land

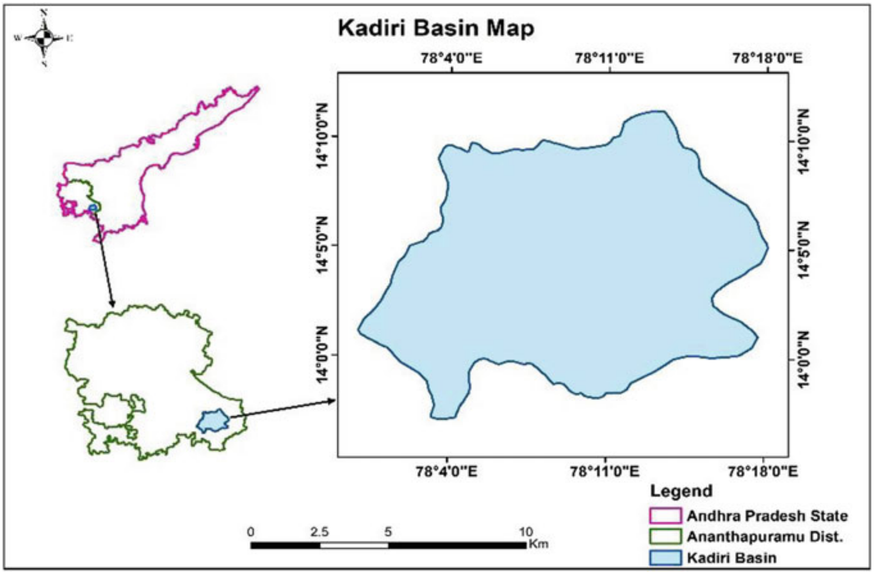

Fig. 1 Study area map

use Planning, Bangalore, respectively for the study area. Other important and required data related to study area were collected from various Andhra Pradesh State Government departments of Ananthapuramu district like Groundwater Department, District Water Management Agency, Panchayati Raj Engineering Department, Water Resources Department, Rural Water Supply and Sanitation Department, and Chief Planning Office which were utilized for various analysis in the present study.

2.3 Methodology

Different types of data have been used to generate the various layers of GWPZ map in Kadiri basin, Ananthapuramu district of Andhra Pradesh, India. Several steps involved to develop the six different thematic layers for GWPZ map were performed using spatial analyst tools and WOA technique in ArcGIS software. All the georeferenced maps were assigned weights. In order to identify the groundwater potential zones, several factors are needed based on their relative importance and it is achieved by rating scheme. The ratings are assigned based on the associated causative factors for prediction of ground water potential surveyed in the field and based on the knowledge by expertise on GWP causes as published in literature [9, 13]. The ranking is provided for each parameter separately for every thematic layer. In this study, ranks are given based on the rating scale of 1–20 scale and weight of each parameter assigned between 1 and 100% [7], where geology has more weight as 28 %. Higher ratings are of greater influence on GWPZ. The rating and weightage assigned for each parameter are provided in Table 1. Thus, basin-wise groundwater potential zones with four classes such as excellent, good, average and poor zones are obtained.

The weighted overlay is a method of modelling suitability considered as a simple and widely used method in different areas such as for evaluating the potential land slide area [2, 12], area for fisheries agroindustry [14], landfill site selection [3] and groundwater potential areas [8, 11, 13]. In this method, each raster layer is assigned

Table 1 Details of thematic layers created by GIS software with their subunit, weight and rating

Layer	Sub Unit	Weight	Rating
Geology	Grey granite/Pink granite	28	12
	Hornblende-biotite gneiss		28
	Meladacite		6
	Melandacite		6
	Rhyolite/Quartz		18
Soil type	Rock lands	20	6
	Fine loamy		12
	Loamy skeletal		20
Slope (°)	< 7	17	17
	7–14		14
	15–22		11
	> 22		7
Geomorphology	Denudation hills	14	8
	Granite-Gneiss		7
	Pediment-Pediplain		14
	Dyke ridge		8
Land use land cover	Agricultural land	12	12
	Barren rocky land		2
	Built up area		4
	Fallow land		5
	Forest area		8
	Scrub land		5
	Water body		10
Drainage density (Km/Km^2)	0.00–0.87	9	9
	0.88–1.74		7
	1.75–2.61		4
	2.62–3.48		2
	3.49–4.35		1

a weight and reclassified in the suitability analysis. Raster layers are overlaid, multiplying each raster cell's suitability value by its layer weight and by totaling the values to derive a suitability value. These values are written to new cells in an output layer, which are labelled in the symbology.

2.3.1 Maps Generated

Six thematic layers were generated using geospatial techniques, i.e. geology, soil type, slope, geomorphology, land use land cover and drainage density of the study area. The computed revised weights obtained for the layers were 28, 20, 17, 14, 12 and 9, respectively. A parameter assigned a higher weight value shows a major influence and similarly a lower weight value shows a minor influence on groundwater potential [1, 5, 15]. Integration of all thematic layers was done through weighted overlay technique (WOT) for developing GWPZ map of the study area using GIS software.

To ensure sustainable development of the basin, groundwater recharge structures were proposed. WOA is a multicriterion study wherein investigation was carried out with multifaceted things for determining certain themes with the aid of assigning rank to the respective features class and then assign weightage to the respective parameters depending upon the weightage of the theme on the objective. The effectiveness of this method is that the individual thematic layers and their classes are assigned weightages based on their relative contribution towards the output [4, 6]. There is no standard scale for a simple weighted overlay method. For this purpose, criteria for the analysis were defined, and each parameter was assigned weightage based on its importance [10]. Determination of weightage of each class is the most crucial in integrated analysis, as the output is largely dependent on the assignment of appropriate weightage. Consideration of relative importance leads to a better representation of the actual ground situation. In the present study, weighted overlay model in GIS environment (ArcGIS software) has been used to identify and demarcate the suitability zones for groundwater recharge which can also be utilized as sites for artificial recharge. Thus, multiple thematic layers of influencing parameters like geology, soil, slope, drainage density, lineament density and land use land cover which were prepared are assigned features class rank as per the importance in the selection of recharge sites. In this model, six parameters were converted into raster from vector base according to the weights. Each raster was assigned percentage influence based on its importance, and its features class were ranked between 1 and 6 scales (Table 2). Each input raster was weighted, and the total influence for all raster equals 100%. Moreover, individual thematic layers and their classes were assigned weightage based on their relative contribution towards the output. Using this suitability modelling, ideal areas were identified wherein the classes with higher values indicate the most favourable zones for groundwater recharge and also for location of artificial recharge structures.

Table 2 Rank and weight of different parameters for groundwater recharge zonation

Parameters	Features class	Weight	Rank
Land use land cover	Built-up area	35	1
	Barren rocky land		2
	Fallow land		3
	Forest land		4
	Scrub land		5
	Agricultural land		6
Soil	Rock lands	25	1
	Fine loamy		2
	Loamy skeletal		3
Slope	0–5%	15	5
	5–10%		4
	10–15%		3
	15–30%		2
	30–100%		1
Drainage density	Very low	15	5
	Low		4
	Medium		3
	High		2
	Very high		1
Geology	Hornblende_biotite gneiss	5	5
	Rhyolite/Quartz		4
	Grey granite/Pink granite		3
	Meladacite		2
	Melandacite		1
Lineament density	Very low	5	1
	Low		2
	Medium		3
	High		4
	Very high		5

3 Results and Discussions

3.1 Demarcation of Groundwater Potential Zones

The objective of the study was to analyse and to identify the groundwater prospect zones (GWPZ) by developing groundwater potential zone map for Kadiri basin of Ananthapuramu district in Andhra Pradesh, India. Revised weights as well as ratings to the respective subclasses (Table 1), raster layers were overlaid through WOT in GIS environment to develop GWPZ map which was further reclassified into four categories, i.e. poor, average, good and excellent groundwater potential zones, respectively. GWPZ map of the study area is shown in Fig. 2. Major portions of excellent and good groundwater potentiality occur in the eastern and central region of the study area. From GIS overlay analysis, it was inferred that groundwater potentiality of the basin is majorly good and average, except in few areas of central, eastern and south-western portion. The areal distribution of the groundwater potential zones is shown in Table 3.

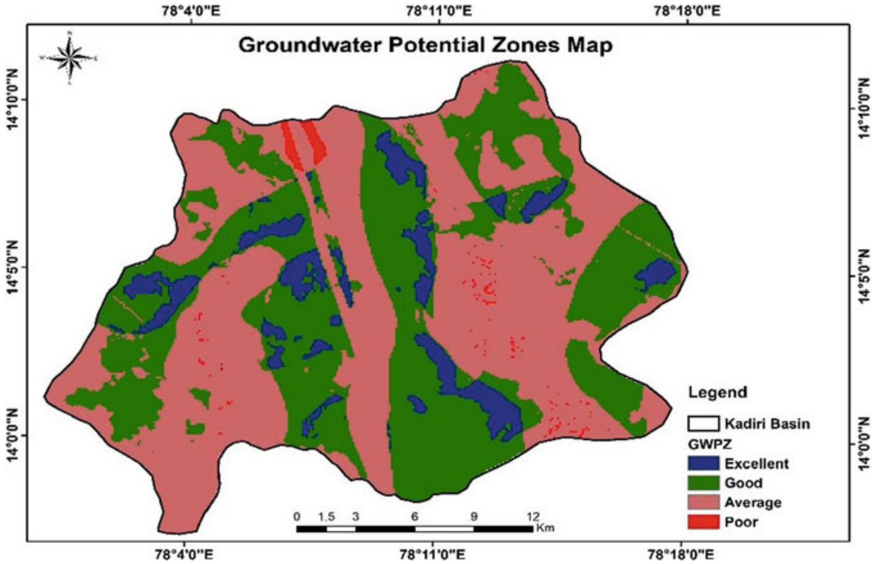

Fig. 2 GWPZ map

Table 3 Statistics of GWPZ

Groundwater potential zones	Area (Km^2)	Percentage of total area (%)
Excellent	40.29	7.79
Good	206.11	39.84
Average	266.66	51.55
Poor	4.22	0.82

3.2 Locating Suitable Sites for Groundwater Recharge Structures

The overall perspective of this study is to have a detailed study on the availability of groundwater resources in Kadiri basin and suggest suitable measures for efficient utilization of existing resources and for further improving the quantity and quality of groundwater resources in a more sustainable way. Based on the data collected and with the thematic information derived from the remote sensing data, groundwater recharge structures like check dams, percolation tanks, gabion structures and subsurface dykes were identified at various locations to improve the groundwater quantity and quality in the study area. The proposed groundwater augmenting structures in the study area are shown in Fig. 3.

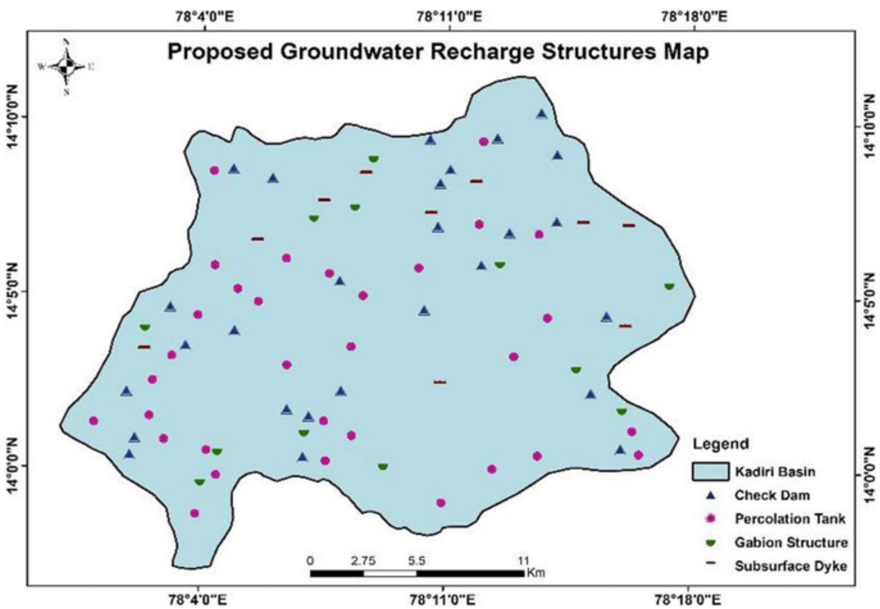

Fig. 3 Proposed groundwater recharge structures map

After assigning the weightages, each theme was overlaid by using ArcGIS, and favourable zones for artificial recharge area were delineated. Later drainage network map was superimposed over the artificial recharge zones map and considering the concern terrain conditions, groundwater augmenting structures such as percolation tanks, check dams, gabion structures and subsurface dykes were suggested accordingly. Areas suggested for the construction of 27 number of check dams were on area having 1st to 3rd order streams and for 32 numbers of percolation tanks on area having 2nd to 3rd order streams. Also, the area suggested has flat terrain for maximum storage of runoff in the proposed sites of check dam and percolation tank. Subsurface dykes (10 numbers) were proposed on the areas having shallow impervious layer with wide valley and narrow outlet. Gabion structures (12 numbers) were proposed along the small streams to conserve stream flows with practically no submergence beyond stream course.

4 Conclusions

Indiscriminate exploitation of surface and subsurface water has led to severe water scarcity and environmental degradation. With the gradual dwindling of surface sources, the role of subsurface sources is gaining momentum in the drought prone area of Kadiri basin. It is therefore, very necessary to have a quantitative and qualitative analysis of groundwater in the study area, for its planned and sustained development.

The conclusions arrived at from this research study are as follows:

- Excellent groundwater potential zones identified were mainly in pediment-pediplain with flat slope, agricultural land of loamy skeletal soil.
- Major portions of excellent and good groundwater potentiality occur in the eastern and central region of the study area.
- Areas suggested for the construction of check dams were on area having first- to third-order streams and for percolation tanks on area having second- to third-order streams. Also, the area suggested has flat terrain for maximum storage of runoff in the proposed sites of check dams and percolation tanks.
- Groundwater recharge structures of 81 no. of which 27 no. of check dams, 32 no. of percolation tanks, 10 no. of subsurface dykes and 12 no. of gabion structures were proposed at various locations for improving the quantity and quality of groundwater resources in a more sustainable way.

The following points need consideration for sustainable management of groundwater resources:

- Groundwater basins used to provide drinking water supplies should be protected from depletion by other uses as well as from contamination.
- In drought-prone areas like Kadiri basin, certain groundwater basins should be earmarked for drinking purposes only.

- Implement the proposed groundwater recharge structures like check dams, percolation tanks, gabion structures, subsurface dykes to improve the groundwater resources and retain soil fertility for sustainable development of the study area.
- Severe unemployment problem in the study area and migration of farmers for works due to scarcity of water and prevailing drought conditions can be averted by improving the groundwater levels by implementing proposed groundwater recharge structures which increases crop yield there by living standards of people will be raised.
- The groundwater potential zones map generated could be useful for optimal utilization of the groundwater resources and for identification of suitable locations for extraction of water, preparation of better management plans that will help in improving the socio-economic conditions and for sustainable development in the Kadiri basin.

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