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Scopus Compendex and Geobase Elsevier, Chemical Abstract Services-USA, Geo-Ref Information Services-USA, List B of Scientific Journals, Poland, Directory of Research Journals

ISSN 0974-5904, Volume 08, No. 02

International Journal of Earth Sciences and Engineering

April 2015, P.P.391-396

Delineation of Groundwater Potential Zones in selected Urban and Peri-Urban Clusters of Kozhikode District, Kerala, India

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Abstract: An integrated approach has been made in the study to identify groundwater potential zones in the urban and Peri-Urban Clusters of Kozhikode district, Kerala. Although, the region receives very high rainfall on an annual basis, its uneven distribution within a year and indiscriminate exploitation of water resources often results in floods during the monsoon season and significant water deficit during the non-monsoon season . Appropriate and efficient techniques are necessary to locate potential sites for drilling of wells and for putting up artificial recharge structures in order to ensure sustainability of well yields and counter the problem of water table depletion. In the current work, Interpretation of remotely sensed data is carried in conjunction with the existing information and groundwater level data from the fieldwork to map the controlling and indicative parameters, and integrated these parameter layers in the GIS environment using Weighted Index Overlay Analysis (WIOA) method. It has been concluded that 99.5km2 area has very good groundwater potential which is only18.9% of the total study area. However the area having good, moderate and poor groundwater potential is about 24.3%, 43.9% and 12.9% respectively.

Keywords: *Groundwater prospective zones, Remote sensing, GIS, Urban cluster, Kozhikode*

1. Introduction

The situation is likely to worsen further as demands for freshwater will increase with the tremendous growth in population with time. As ground water forms an important component of the total water supply (e.g. about 90% in rural areas and 30% in urban areas of India), the aquifers are often under stress, resulting in lowering of the water table and drying up of springs and wells at many places. Groundwater in any region shows large spatial and temporal variations in its occurrence and distribution. Although, this is primarily influenced by the uneven distribution of precipitation, other factors like topography, geomorphology, land use and hydrogeology also play a critical role. Even though the groundwater problems (qualitatively and quantitatively)are generally found to be more pronounced in urban environment, scientific studies on urban groundwater resources and management have not gained the required importance in India.

This is mainly due to the lack of reliable data/ information on the spatial parameters like geology, geomorphology, topography, recharge, discharge, and aquifer characteristics in both space and time domain. The occurrence and movement of groundwater in an area is governed by several factors such as topography, lithology, geological structure, depth of weathering, slope, land use/land cover (LULC), and interrelationship between these factors [1].To delineate groundwater prospects of an area, integration of conventional surveys along with satellite image data interpretation techniques, and geographical information systems (GIS) technology, are useful, not only to increase the accuracy of results, but also to reduce the bias on any single theme [2, 3, 4, 5].Spatial information system based on an efficient groundwater database can serve as a Decision Support tool for evolving plans for the sustainable development and management of groundwater resources in the region of interest. Rapid advances in the development of the GIS, provides spatial data integration and tools for natural resource management has been proved to be an efficient and successful tool for groundwater studies [1, 6, 7].

Kozhikode coast, one among the major higher order urban zones of the state has been selected for such a comprehensive study. The high density of population in this coastal zone has necessitated a large scale housing development and near the urban centre, the density of housing has reached such alarming proportions. The unusual shortage of surface water and a great demand for groundwater resources, salt water intrusion, quality problems in drinking water, and coastal erosion are some of the problems faced by the coastal zones. According to [9] report Kozhikode block comes under over–exploited category and Balusseri and Tooneri are in critical zone for groundwater status. Spatial information system based on an efficient groundwater database can serve as a Decision Support tool for evolving plans for the sustainable development and management of groundwater resources in the region of interest.

1.1. Study Area

The study area has an area extent of 525.2 km^2 and is lies between North latitudes 11º 12' and 11º 48' and East longitudes 75 º 7' and 75 º 96' (Figure.1).

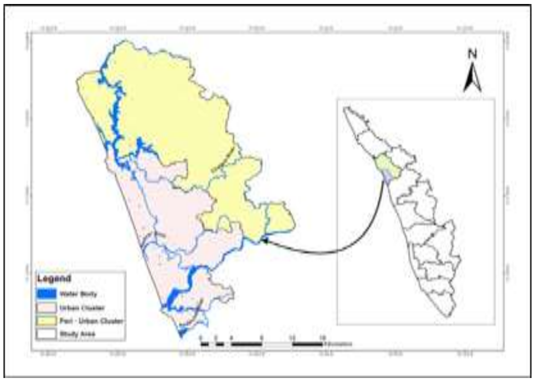

***Figure 1** Location map of the study area*

It is the nodal point for all districts in the northern region of the state and shows highest pace of urbanization [10]. Study area constitutes Urban and Peri-Urban Clusters of Kozhikode. Urban cluster of the study area have an aerial extent of 196 km^2, concentrated along the coastal zone. The district is drained by six rivers of which one is of medium nature (Chaliyar River) and all others are minor ones namely Kuttiyadi, Mahe, Kadalundi, Kallayi and Korapuzha. Connolly Canal running across the heart of the city has a length of 11km. The study site has long seashore of 36 km. The Soil conditions are very good for cultivation of spices and coconut especially and normal for other crops. The population density of the District i.e., 1318 persons per km^2 is greater than the State average (860 persons per km^2.).

2. Methodology and Data used

Survey of India (SOI) topographic sheet (1:50 000) was used to prepare base, drainage maps. Remotely sensed image data from IRS ID (LISS III) used to generate the geomorphology & landuse/landcover map of the study area. The SOI topographic maps and satellite images have been geometrically corrected using ERDAS v9.1and ArcGIS v10.0software. Geology map of the basin was prepared using Geological Survey of India (GSI) in the scale of 1:2,50,000 whereas the soil map was prepared using the data from National Bureau of Soil Survey (NBSS) at1:2,50,000 scale. To validate the Groundwater potential zone, groundwater level data inventoried from the existing well for pre-monsoon period of the year 2014 is utilized. The sampled wells represent different depth of aquifer, different land-use pattern and varied geological formations. SRTM DEM was used to extract slope percentage. Finally all data (geomorphology, slope, geology, landuse/ landcover, soil and their corresponding categories) were assigned with a knowledge based ranking according to their degree of prospect depending on the suitability to hold groundwater, integrated multi-thematic information and delineation of groundwater prospect map generated in ArcGIS environment [11]. Thematic maps were prepared for geology; geomorphology, soil, slope, land use/land cover and groundwater level are discussed as follows.

2.1. Geology

Geology plays an important role in the distribution and occurrence of groundwater. The storage capacity of the rock formations depends on the porosity of the rock. In the rock formation the water moves from areas of recharge to areas of discharge under the influence of hydraulic gradients depending on the hydraulic conductivity or permeability (Figure.2). Charnockite is the dominant geological structure in the area, occupies an area of 327.6km^2 (62.4%).Fluvial coastal sediments considered as the sources of groundwater [12], covers an extent of 117.4 km^2 (22.4%).

2.2. Geomorphology

In general, geomorphology reflects various landforms and structural features [13]. The geomorphology of the study area (Figure.3) is dominated by unit lateritic forms which covers 304.09Km^2 (58%), Valley fills covers an area 79.85 km^2 (15.2%), Coastal Plain 77.6km^2 (14.78%), floodplain 30.91km^2 (5.88%), Water body 22.41 km^2 (4.27%) and Residual Hills covers 10.33 km^2 (1.97%).

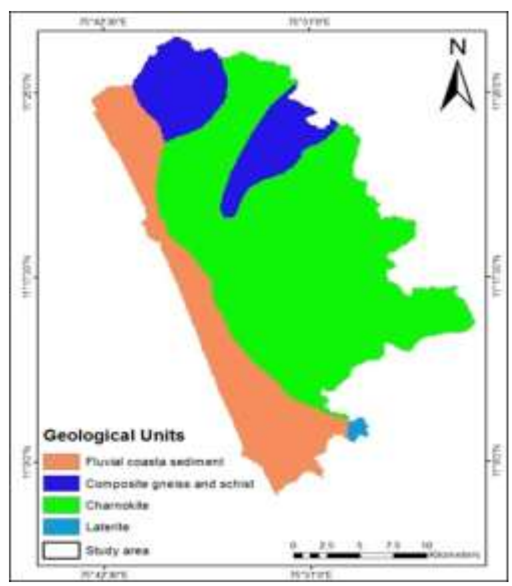

***Figure 2** Geology map of the study area*

More promising groundwater is in flood plains, coastal plain and valley fills that are associated with thick alluvial and weathered materials to give high porosity and permeability.

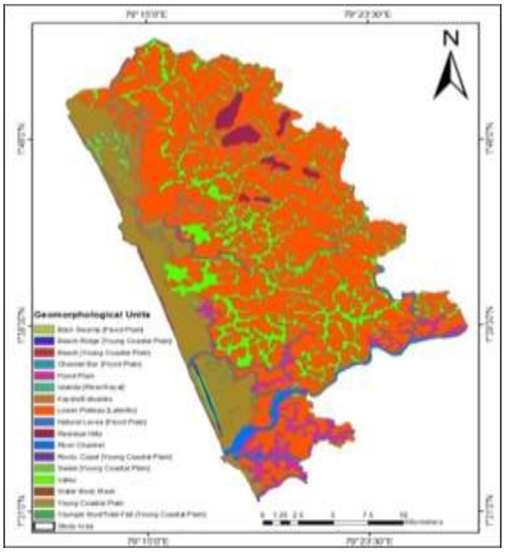

***Figure 3** Geomorphology of the study area*

Groundwater prospects in valley fills are good to excellent because of the topographical location at the bottom of the hill and geological composition consisting of highly porous materials. Subsurface water potential is also good to excellent in the valley fills [14].

2.3. Slope Analysis

Slope is the principal factor of the superficial water flow since it determines the gravity effect on the water movement [15, 16]. It influences surface and subsurface flow of rain water and its recharge to the groundwater reservoir. Based on the percentage of slope the entire Study area is classified into four-categories (figure. 4).

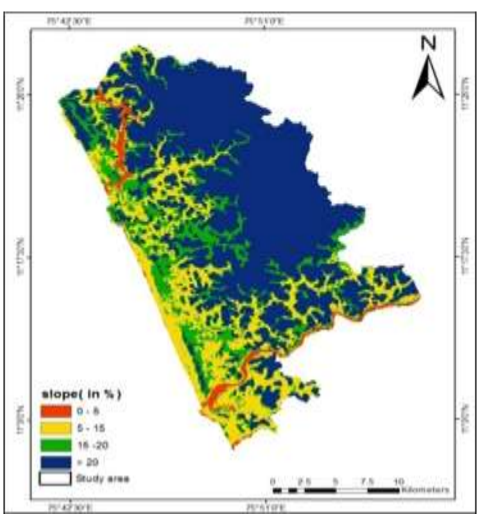

***Figure 4** Slope of the study area*

The area with 0 to 5 % slope falls in the 'very good' category for groundwater storage due to the nearly flat to gentle terrain, slow of surface runoff allowing more time for rainwater to percolate and relatively high infiltration rate. These flat terrains have 14.19144 sq km (2.7%) of the total study area. The area with 5-20% slope is considered as 'moderate' for groundwater storage due to slightly undulating topography with some run-off. It covers an area of 39% of the total area. According to [11], a break in the slope (i.e., a steep slope is followed by a gentle slope) promote an appreciable groundwater infiltration. The fourth (> 20) categorized are considered as 'poor' due to higher slope and run-off.

2.4. Landuse Classification

Landuse describes how a parcel of land is used for agriculture, settlements or industry, whereas landcover refers to the material such as vegetation, rocks or water bodies, which are present on the surface [17]. Classification of land use/cover for analysis was done based on their character to infiltrate water in to the ground and to hold water on the ground [18].

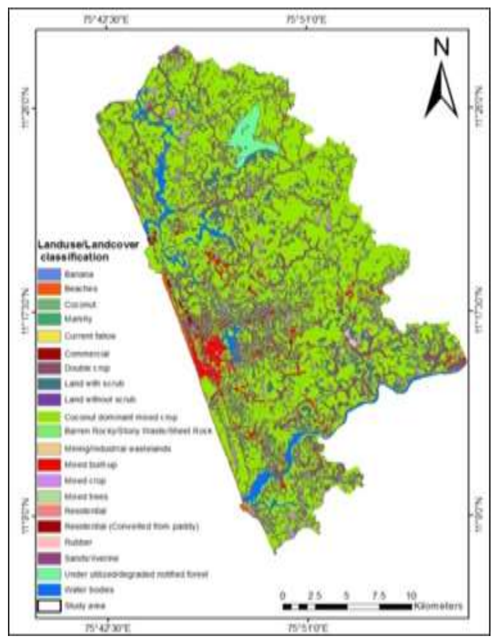

***Figure 5** Landuse/Landcover classes of the study area*

Land cover and land use also affect evapotranspiration, volume, and timing and recharge of the groundwater system. From the land use point of view (Figure.5), crop lands (coconut, rubber, and other crop) as well as forest is an excellent site for groundwater exploration. Since Cropland and mixed trees together constitute an area of 432.05 km^2 (82%), ground having the capability to hold water. Meanwhile urban area or built up land which occupies an area of 39.03 km^2 (7.43%) is given low score due to adversely affected recharge of the groundwater regime i.e. least suitable for infiltration. The study area occupies the region with highest rate of urbanization in the state (census 2011) (means addition of more urban population in a specific time period) will enhance the groundwater depletion in the region.

2.5. Soil

The area occupies 5 different types of soil: imperfectly drained-clay, moderately well drained-clay, moderately well drained-sandy, well drained- clay, well drained-gravelly clay. The majority of the area dominated by the well-drained-gravelly clay and is about 92.83%of the total study area. Soil ranking is related to the infiltration capability. Infiltration rate in turn depends on soil thickness and grain size (permeability). Fine-grained soil s has low permeability as compared to coarse - grained material. Sandy soils and coarse sandy clay are good according to the influence on ground water occurrence due to light textured and excellent rate of infiltration [19]. Meanwhile clay is classified as poor due to poorly drained, slowly perm able, severely eroded, and low hydraulic conductivity [2].

2.6. Depth to Water Level

As depth of occurrence of water observed in wells reduces, corresponding groundwater prospects increases [20].

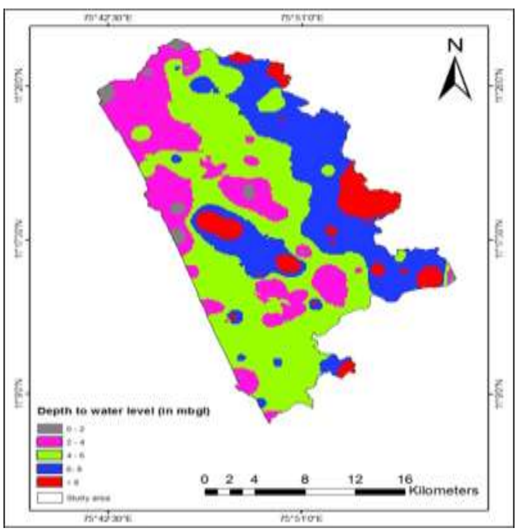

Figure 6 *Groundwater level during Pre-Monsoon period*

The water levels for pre-monsoon (april) season were collected from 90 dug wells with depth range of 0-13 meters below ground level (m bgl) in the year of 2014. The groundwater level data (attributes) were imported into spatial theme for GIS analysis. The spatial distribution of available water column from different well locations during pre- monsoon season in the study area is shown in Figure. 6.

During pre-monsoon season, about 1.5 of the wells have water column of less than 2 m depth, 22 % of the wells have water column of 2-4m, 43% of the wells have water column of 4-6 m, 26.3% of the wells have water column of 6-8m and the remaining 7.4% wells have water column ranging from > 8 m. Based on the groundwater occurrence least weightage was given to the area with depth to water level less than > 6 m were as higest weightage is given to < 2m and Depth to water level in the range 2-6 m comes under the category of moderate groundwater potential.

3. Result and Discussion

3.1. Delineation of groundwater potential zones

To demarcate the different groundwater potential zones, all the thematic layers such as (a) geomorphology (b) slope (c) geology (d) landuse (e) Soil (f) groundwater level are integrated with one another according to their importance through overlay analysis in ArcGIS.

The database thus generated identifies suitable site for groundwater potential & groundwater recharge areas. On the basis of the result, the groundwater potential zones are classified into (i) very good 99.51km^2 (18.9% of the area) (ii) good, 127.4 km^2 (24.3% of the area) (iii) moderate, 230.4 km^2 (43.8% of the area) and (iv) poor 67.89 km^2 (12.9% of the area) as shown in figure .7.The aerial extent of groundwater prospects zone of the study area illustrated in Figure.8.

The maximum area is characterized by moderate to good potential zone that occupies 68.1% of total area. The map indicates that the coastal plain with fluvial coastal sediments and flat terrain is identified as very good prospective zone and the area with valley fill, floodplains, lateritic plateau, steep terrain together constitute moderate to good groundwater potential zone. While, the steep terrain underlain by lateritic plateau, residual hills are classified as poor prospective areas.

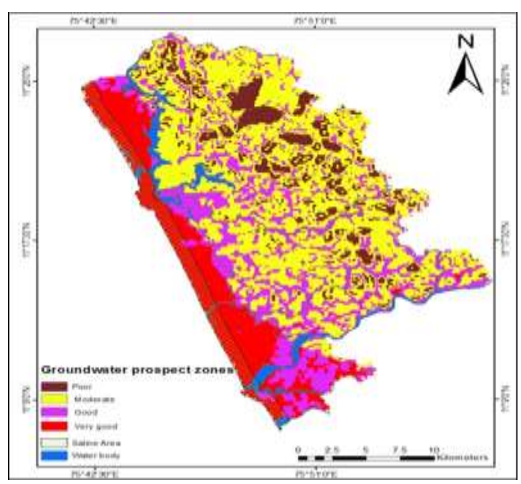

Figure 7.*Groundwater prospects Zone of the study area*

Saline intrusion in the of Kozhikode coast is limited to about 1km [20],and the entire region susceptible to saline intrusion (almost 37.5 km^2 along the coast) situated in the very good groundwater potential zone. Therefore, even the above region having very good ground water potential, it is recommended that groundwater in this region is not useful for the drinking water purposes.

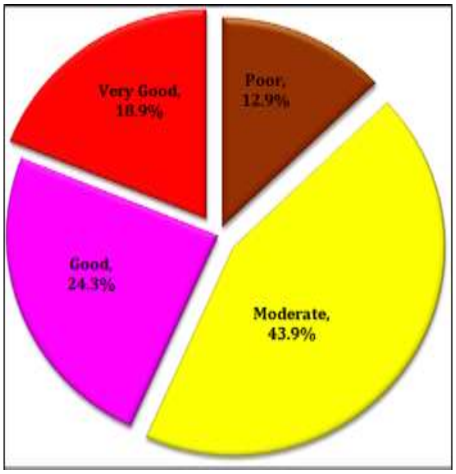

Figure.8. *Aerial extent of the Groundwater prospect zones of study area*

While urban cluster situated in the region with very good to moderate groundwater potential region, the region is at risk to quantitative and qualitative problems. The rising urban trend ensures the same. Therefore special attention is needed. The integrated groundwater potential map thus could be useful for development of sustainable scheme for groundwater development in the area.

4. Conclusion

Groundwater resources potential has been evaluated in selected urban and Peri-urban clusters of the Kozhikode district, Kerala, India using remote sensing and geographical information system techniques. Various thematic maps like base map, geomorphology map, slope map, soil map, geology map , land use/land cover map and groundwater level map of the study area have been prepared and integrated using overlay analysis in the ArcGIS platform. The results show that there are four categories of groundwater prospect zones ranging from very good to poor, in which the moderate to good prospective zone (68%) dominated the entire study area. Even though the region having 43.2% of good to very good groundwater potential, proper attention is needed for the sustainability of resources. Further, the integrated remote sensing and geographical information system based approach is a powerful tool for assessing groundwater potential based on which suitable locations for groundwater withdrawals could be identified.

5. Acknowledgement

The authors express their sincere thanks to the Executive Director, CWRDM (Centre for Water Resources Development and Management) and acknowledge gratefully the funding received under the scheme of KSCSTE (Kerala State Council for Science Technology and Environment).

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