Jr. of Industrial Pollution Control 33(S3)(2017) pp 1496-1499
www.icontrolpollution.com
Research Article

GEOSTATISTICAL ANALYSIS OF GROUNDWATER PARAMETERS IN KERALA STATE, INDIA

DEEPTHA THATTAI*, SATHYANATHAN RANGARAJAN, ABHISHEK SENTHIL, KISHORE KUMAR AND GUJJA VAMSHIDHAR REDDY[2]

Department of Civil Engineering, SRM University, Chennai, TN 603203, India

(Received 17 June, 2017; accepted 24 November, 2017)

Key words: Groundwater extraction, Pollution, Geostatistical software

ABSTRACT

India has the fastest rate of groundwater extraction in the world, and the extraction rate is more than the replenishing rate. The effects of such extraction will manifest as not only depletion of groundwater but also pollution of the existing source. In this study, an attempt is made to study the spatial variation of groundwater parameters using data collected from CPCB. A geostatistical software, SpaceStat, is used for the study.

INTRODUCTION

It is reported that India has the fastest rate of groundwater extraction in the world, and the extraction rate is more than the replenishing rate (WWAP, 2012). The effects of such extraction will manifest as not only depletion of groundwater but also pollution of the existing sources. As we depend on groundwater to a large extent for all uses, care has to be taken not to use more than needed and to keep the water pollution-free. Pollution of groundwater can occur from discharges of industries, increased use of fertilizers and pesticides in agriculture and intrusion of seawater along the coasts due to unlimited extraction of freshwater.

Geostatistical analysis is a spatiotemporal procedure to analyse available information in the space–time domain. Geostatistics finds applications in various fields of natural resources such as hydrology, mining, geophysics, soil science, remote sensing and environmental sciences (Goovaerts, 1997). In this study, the geostatistical method kriging has been applied to groundwater point data in Kerala state and the spatial variations are mapped on regional scale. This will give a broad idea about the variations of the parameters over the entire region of study.

GEOSTATISTICAL ANALYSIS

Geostatistics is basically the theory of regionalized variables. It is a set of tools for analysing the available information in space–time domain. The basic assumption of geostatistical analysis is that all variables in a given field are related, but nearer values are more related to each other. A variability model is fit to all the data in the field. This model, called the semivariogram, is a measure of the dissimilarity among the observations and depends on the distance between the observations and the direction. The semivariogram is given by the equation

$$\gamma(h) = \frac{1}{2N(h)} \sum_{\alpha=1}^{N(h)} [z(\mathrm{u}_\alpha) - z(\mathrm{u}_\alpha + h)]^2 \qquad (1)$$

where γ(h) is the semivariogram, h is the vector of lag distance, N is the number of observations, h is the distance between two observation points, u is the vector of observed values, and z is a stationary random function with known mean and variance. The semivariogram is then used in kriging, which is a generalized least-squares interpolation method that can predict the variables at every point within the region. The interpolation function is given by:

$$z^*(u) = \sum_{\alpha=1}^{n(\mathrm{u})} \lambda_\alpha(\mathrm{u}) z(\mathrm{u}_\alpha) \qquad (2)$$

where λ is the weighting function. Kriging is a geostatistical interpolation technique that attempts to incorporate the spatial autocorrelation among

***Corresponding authors email: sangeetha@avit.ac.in**

the measured values of a spatial random variable to estimate a value for an unsampled location (Ashrafzadeh, *et al.*, 2016). With kriging, we can obtain not only the estimates but also the predicted variances of each estimate, which helps in better management of the problem.

(Nikroo *et al.*, 2010; Moukana, *et al.*, 2013) used kriging to map groundwater levels. Studies of groundwater pollution using geostatistics have also been made (Goovaerts, *et al.*, 2005; Lee, *et al.*, 2007).

STUDY AREA

The state of Kerala is in the southwest corner of India, a narrow strip bordered by the Arabian Sea on the west, Western Ghats and Tamil Nadu State on the east. Kerala is bounded by the latitudes 8° 18′ N and 12° 48′ N and the longitudes 74° 52′ E and 77° 22′ E (Fig. 1). The groundwater in Kerala is not uniformly distributed and is recently undergoing heavy exploitation (Shaji, 2011).

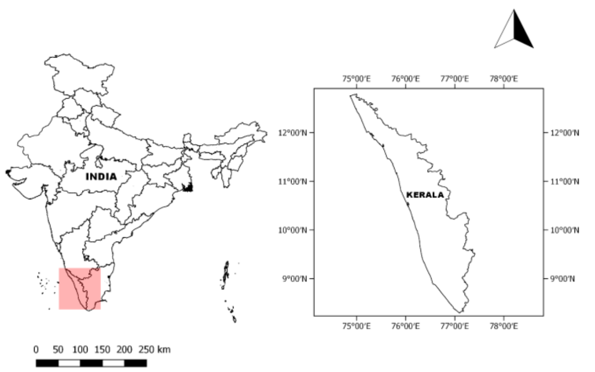

Fig. 1 Location map of Kerala state, India.

METHODOLOGY

Groundwater quality data for the year 2014 pertaining to 27 sites in Kerala were obtained from the CPCB ENVIS site (http://www.cpcbenvis.nic.in/). The parameters available were temperature, pH, BOD, conductivity, and nitrate+nitrite. A kmz file of the stations was created in Google Earth and it was converted into a shapefile in QGIS (Fig. 2).

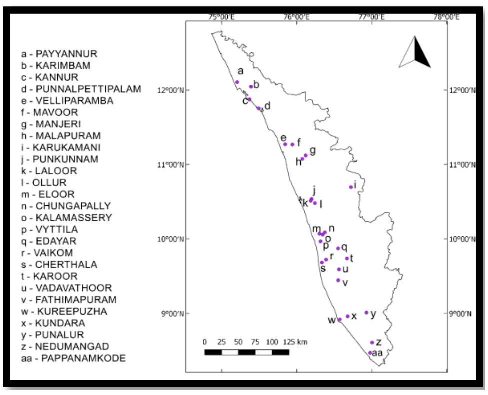

Fig. 2 State map of Kerala with the 27 data location.

The parameters were then entered into a text file with the appropriate lat/long coordinates. The shape file and data file were imported into SpaceStat, a geostatistical software for the exploration and analysis of spatiotemporal data. After creating a map of the parameter (say BOD), a grid was created with the shapefile as the mask. The observed variogram for BOD was generated. The experimental variogram was then created and checked for consistency with the observed variogram. For BOD, the best variogram was a cubic model with the sill at 0.139 and MSS error 0.042. The lag was 0.203. Kriging (with a trend for some parameters) was then performed on the data to generate the estimates and variances.

RESULTS AND DISCUSSION

The results of kriging for all the five parameters in Kerala are shown in (Figs. 3–7).

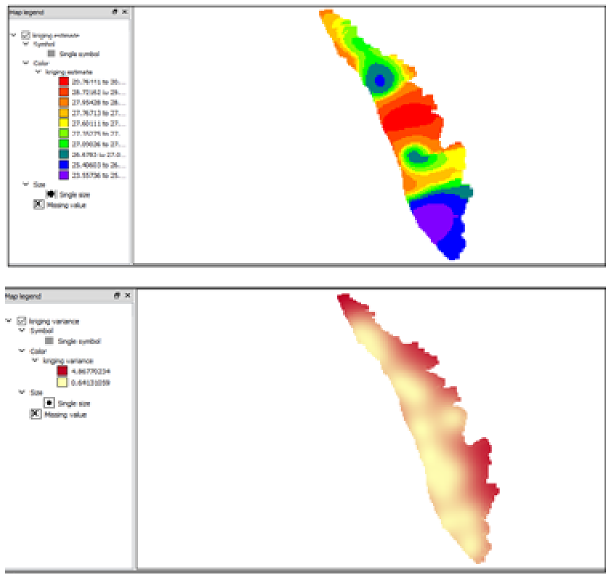

Fig. 3 Estimate (top) and variance (bottom) of temperature for Kerala.

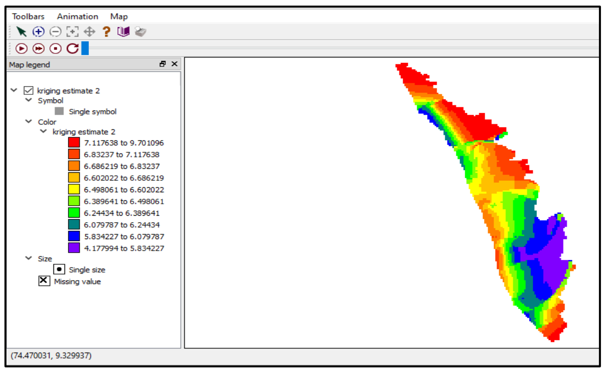

Fig. 4 Estimate of pH for Kerala.

The temperature is low at Velliparamba, Mavoor, Kureepuzha, Kundara, Punalur, Nedumangad and Pappanamkode. The latter five stations are in south

Kerala. High temperature is noticed in central Kerala – Karumakani, Punkunnam, Laloor and Ollur. As the available data are spread north–south over the state, kriging has captured the variation well in this direction and is able to provide decent estimates. The data, however, do not cover the Ghats region along the eastern border; hence, the variability along the east border is higher (Fig.3).

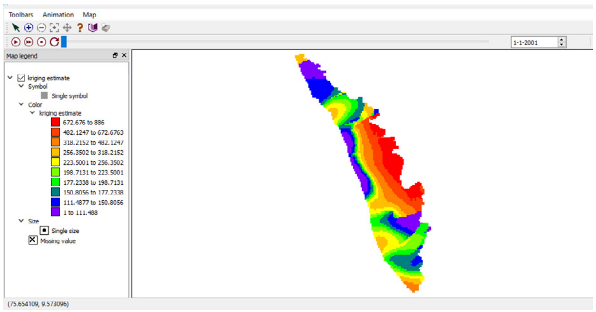

Fig. 5 Estimate of conductivity for Kerala.

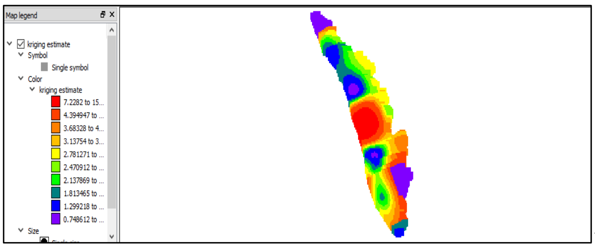

Fig. 6 Estimate of BOD for Kerala.

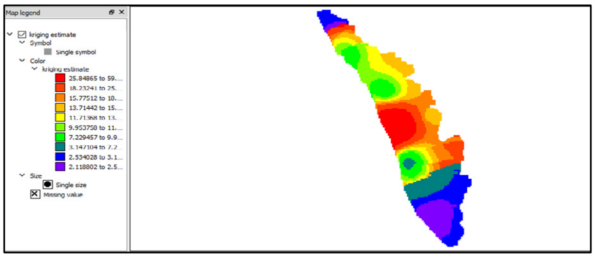

Fig. 7 Estimate of nitrate + nitrite for Kerala.

The pH values in the 27 stations vary from 4.7 to 7.7 and are mostly acidic. Central Kerala and the southernmost tip have neutral–slightly alkaline pH whereas the pH of southern region and northwest coast is acidic in nature (Fig. 4). (Boominathan, *et al.*, 2012) opine that the low pH can be due to sulphide oxidation or acidic soils or aquifer origin. The results on the eastern border cannot be considered as we have only one data point and the estimates will not be valid. Still, we can see that the majority of the state has acidic water that needs to be treated before use.

The conductivity varies from 1 to 885 – a wide range. Karukamani, the lone station in the Ghats, has the highest conductivity. Kriging with a Y-Y trend was used to capture the variation (Fig. 5).

Conductivity is a proxy for salinity. Higher conductivity along the coast (Kureepuzha, Pappanamkode and Cherthala) could be due to seawater intrusion, which an investigation can confirm.

Whereas the high conductivity was in the east, a single station in central Kerala had high BOD of 53.2 (Kalamassery) while all other stations had very low BOD. This makes estimation a bit trickier since coupled with the lack of uniform data, the kriging procedure was not able to capture the range fully. The best estimate we could obtain is shown in (Fig. 6); central Kerala has a zone of higher BOD values while the other regions are below standard limits.

A similar problem occurred for nitrate+nitrite, again with a single station Laloor having high value (Fig. 7). All the other stations are below standard limits.

CONCLUSION

An attempt to estimate the spatial variation of groundwater parameters in Kerala was made using the geostatistical software SpaceStat. The data were obtained from CPCB. The problem with the available data is they are not distributed throughout the state, and this makes it difficult for spatial investigation.

ACKNOWLEDGEMENTS

The authors acknowledge CPCB ENVIS for the data. They thank Dr. Pierre Goovaerts for providing an evaluation version of the software program Spacestat. The authors also thank the management of SRM University and the HOD, Civil for their constant encouragement and support.

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