SPATIAL ANALYSIS OF GROUNDWATER DISTRIBUTION AND QUALITY USING GIS AND REMOTE SENSING TECHNIQUES (CASE STUDY OF BOLGODA RIVER BASIN, SRI LANKA)

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KEY WORDS: Groundwater, water level, water quality

ABSTRACT: Groundwater is an important natural resource for existence of life and environment. It provides higher quality, better protection from possible pollution, less subject to seasonal and perennial fluctuations and much more uniformly spread over large regions than surface water. The demand for groundwater in Sri Lanka is steadily increasing, particularly for urban/rural water supplies, irrigated agriculture and in industrial sector. Ensure the protection of groundwater has been a big challenge due to the industrial and other development activities especially in urban and suburban areas of the country. Lack of database on groundwater resources is the major barrier to reveal the impact of development activities on groundwater resources. This research aims to identify the Ground Water Quality and Distribution in Bolgoda River Basin of Sri Lanka.

Well water was used as the easiest way to access the groundwater and 567 wells were observed. Data collection was done in dry season to identify the minimum water level and maximum water levels were obtained with peoples' experiences. Digital Portable pH Meter was used to test the quality parameters (pH, Total Dissolved Solids(TDS), Electrical conductivity(EC) and temperature). Inverse Distance Weighting (IDW) and Weighted Overlay were main GIS techniques that used for analysis.

Results show a conspicuous difference on spatial distribution of groundwater level and quality. pH level of the area was ranged between 3.6-7.8, EC between 10-900 and TDS between 0-440. Result of Weighted overlay analysis was reclassified into 4 classes as very good, good, moderate and poor. In order to that 6.01Sqkm area was identified as very good in water quality and it represents the 1.3% of total land area. Largest portion of 235.3 was identified as good and 190.7 was in moderate quality. Poor quality land amount was 0.49. Maximum water level was identified as ground level in both seasons and minimum water level was the 14.63meter below from ground level in dry season. Results of this research are very important as based data that can be used to ensure the protection of ground water from industrial and other non point source pollution activities as well as to identify the areas in water scarcity.

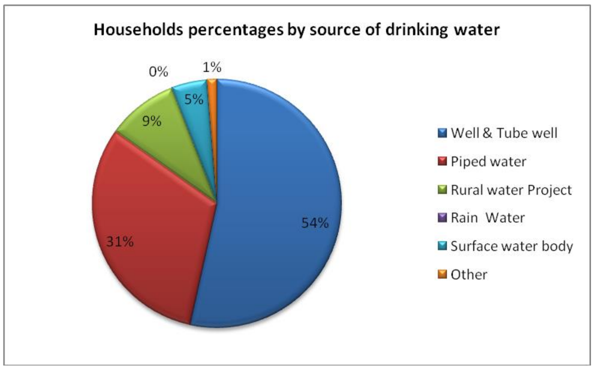
01 INTRODUCTION

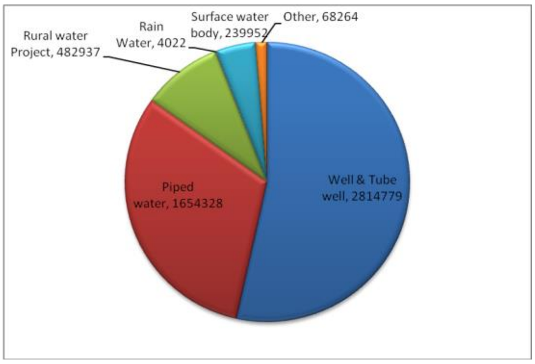
Groundwater is one of the most important natural resource for the existence of life and the environment. Groundwater is also important as it supplies springs, tanks, marshlands, streams, rivers and canals. And its level, distribution, and quality are also very critical for the stability of the surface water system. As a source of water supply, groundwater has a number of essential advantages when compared with surface water, higher quality, better protected from possible pollution including infection, less subject to seasonal and perennial fluctuations, and much more uniformly spread over large regions than surface water.

Groundwater can be defined as "the water lies beneath the ground surface, filling pores in sediments and sedimentary rocks and fractures in other rock types". As an integral part of the global water cycle groundwater is very essential for protecting and maintaining the quality and quantity of the surface water resource. Various human activities can result in significant changes in conditions of groundwater resource formation, causing its depletion and pollution. Groundwater pollution in most cases is a direct result of environment pollution. Groundwater is polluted mainly by sulphates, chlorides, nitrogen compounds (nitrates, ammonia, ammonium), petroleum products, phenols, iron compounds, and heavy metals (copper, zinc, lead, cadmium, mercury).

The demand for water in Sri Lanka is steadily increasing, particularly for urban/rural water supplies, irrigated agriculture and in the industrial sector. This rapid increase in demand is exerting considerable pressure on the available groundwater resources. According to the Source of drinking water report on "Census of Population and Housing - 2012," 54% of Households use underground well-water and only 31% of households were supplied with a piped water and 15% of households use other sources of drinking water as surface water bodies (tanks, streams, rivers, etc..), rain water, bowser, bottle water, etc.. According to above census data, majority of the households use the underground fresh water for drinking purpose while comparing with the other sources.

Households by source of drinking water





(Source - Census of Population and Housing/2012)

Also, in recent times use of groundwater is on an increasing trend because of high piped water tariffs and restricted hours for water supply. These two issues have forced the industrial and commercial users and some individual domestic users around the country who are already supplied with piped water to have a supplementary groundwater supply to reduce costs and to ensure a margin of safety in their supply. Of these, most industries today rely heavily on deep wells because groundwater is free, safe, of good quality, and able to be autonomously managed.

Surface water also is a reflection of groundwater. We try to think of groundwater and surface water as two separate resources. But especially in our country, there are many river systems and many of them are fed by groundwater. Part of the river flow is actually coming from groundwater. So if the groundwater is polluted surface water will be polluted. So there is a very close relationship between groundwater and surface water. Thus finally quality and distribution of all drinking water sources are depended on groundwater quality and distribution. Over-extraction, leaking seawater, subsidence, failure of wells course to drop down of groundwater level and then can see all the sources of pollution. Many of these are present in Sri Lanka. In many cases, contamination problems are catching up with water quantity problems, and for groundwater this is very critical because it is very difficult to remedy it once it is polluted. So we have to see ways of prevention of groundwater pollution. We have to really protect this precious resource from the outset.

Use of groundwater as a potable water source has a limited opportunity due to over extraction, pollution by agriculture, industries. People pay very little attention for this while conducting the developing projects, the industrial distribution and other all human activities. Groundwater distribution and its quality have been threatened by those development activities and this situation is stabilized by the recently reported problems relevant to the groundwater.

It is very important to maintain a country based database for groundwater quality and distribution. Water level measurements from observation wells are the principal source of information about the hydrologic stresses acting on aquifers and how these stresses affect groundwater recharge, storage, and discharge. Long term, systematic measurements of water levels provide essential data needed to evaluate changes in the resource over time, to develop groundwater models and forecast trends, and to design, implement, and monitor the effectiveness of groundwater management and protection programs.

The database will support groundwater quality research and the Central Environmental Authority efforts to educate the public about groundwater quality. The data will be used to generate maps and reports and to answer public concerns about groundwater quality and distribution in Sri Lanka.

1.1 Research Problem

The protector of the environment and as the main responsible organization for issuing Environmental Impact Assessments, Environmental Protection Licenses and Initial Environmental Examinations, it is vital to maintain a database on ground water resources at the Central Environmental Authority. Especially, prior to the establishment of industries and proposed development projects in particular which have high environmental impacts should be paid our attention regarding ground water level and its quality when taking decisions. However their attention is avoided due to lack of common database of ground water distribution and its quality.

Due to the lack of database maintenance, it has become a tedious task to conduct analyses to make decisions at the many issues regarding the quality of ground water around industries and development projects. For an example, CEA had to go through serious issues on deciding if the incidents reported related to ground water crisis in "Rathupaswala" and "Batakeththara" were due to the changes in the physical environment in the areas or the industry itself. When considering the rise of industrial projects day by day, it is essential to maintain a database for the protection of ground water as a hidden natural resource. The Central Environmental Authority has been trying but, failed to obtain data from responsible organizations due to lack of database management in the relevant fields. Therefore, to ensure the protection of ground water sources as the leading national organization that shoulders the national responsibility for keeping the environment clean and safe, CEA hopes to initiate a spatial analysis relevant to groundwater.

1.2 Objectives

1.2.1 Main Objective

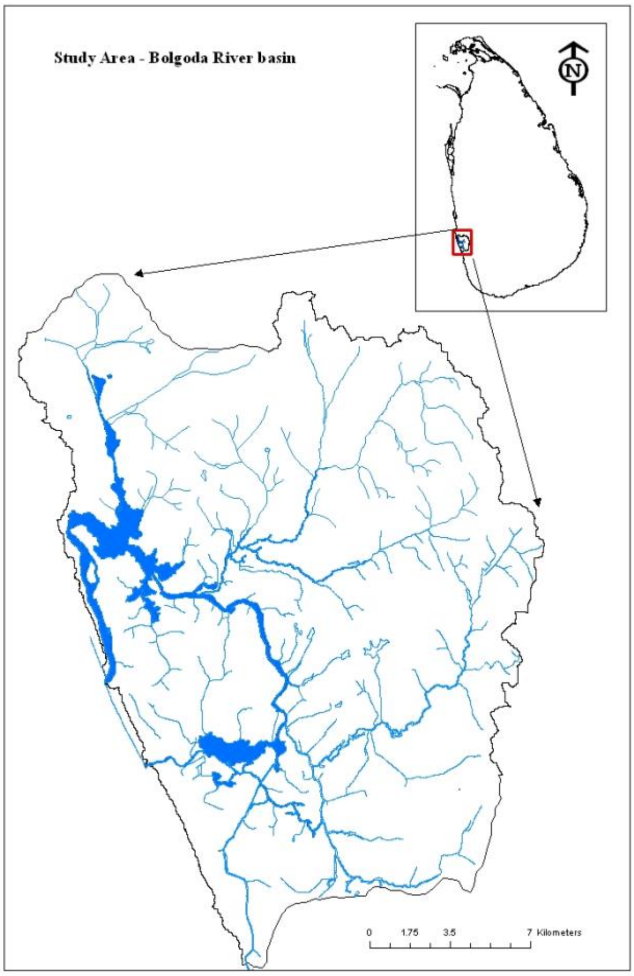
- Do a spatial analysis of Ground Water Quality and Distribution in Sri Lanka using GIS and Remote Sensing

1.2.2 Specific Objectives

- Identification of Ground water distribution
- Spatial and seasonal analysis of the Ground water level
- Develop a Database of Spatial Ground water quality as a primary dataset for future activities

02 STUDY AREA

River basins are very important for the increasing the speed and percentage of absorption of rain water into the ground and is very important for the protection of groundwater quality. Groundwater pollution is occurred due to surface pollution of the river basins and they do a vital role of generating and protecting groundwater. So we have to see ways of prevention of groundwater pollution by managing and controlling pollution activities on basin surface. For this purpose it is very important to have a groundwater data in river basins to consider before issuing approval for such activities. Thus this research is intended to start from Bologoda River Basin as it is mainly fed by groundwater.



This Bolgoda lake system consists of two interconnected lakes (Northern & Southern), and their waterways namely, Weras Ganga, Bolgoda Ganga, Panape Ela, Rambana Ela, Maha Oya, and Thalpitiya Ela. The North Lake discharges to the sea through Panadura Estuary. The total area of the Bolgoda Lake basin is 42728 ha. And it is consisting many water ways, steams and tanks. The annual rain fall is above 2569.3 mm and Annual temperature is 27.1 C

Bolgoda River Basin is located within the 13 Divisional Secretariats in Colombo and Kalutara District of Western Province and 471 GN Divisions. This basin is rich in groundwater, and is under threat due to discharge of industrial effluents, haphazard development activities and encroachments. Thus spatial analysis of the groundwater in the river basin will be very useful for doing future planning while confirming protection of groundwater.

03 METHODOLOGY

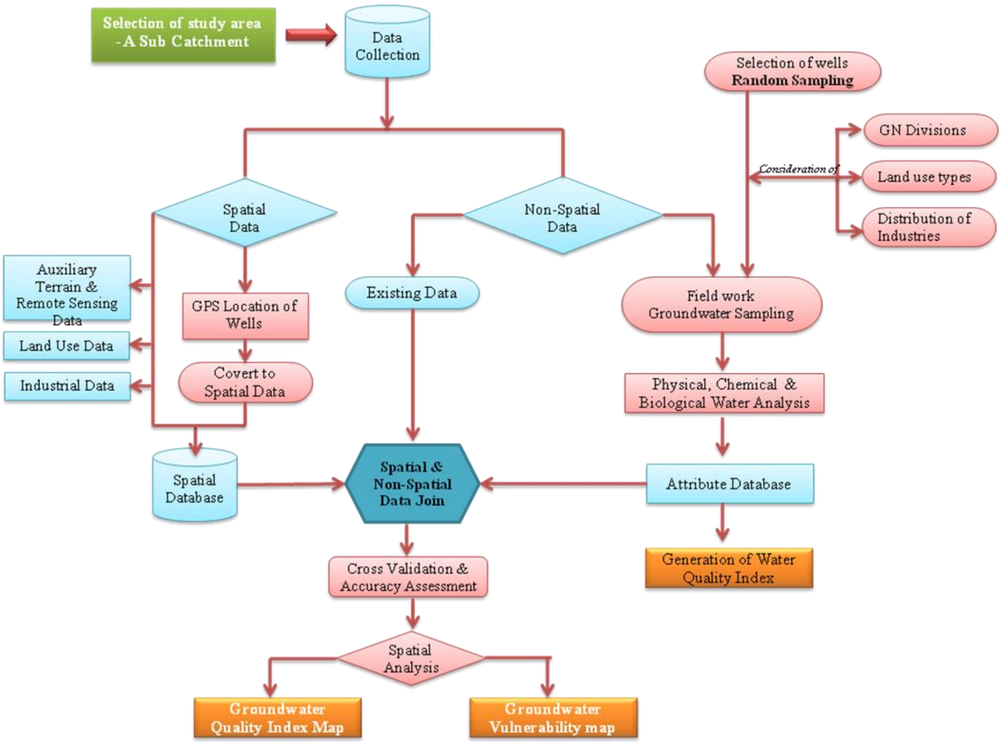


Figure 02 : Methodology used in whole study

3.1 Data Collection

There are several methods to observe the groundwater for research activities. One of the easiest ways to access the groundwater is observation of well water. In this research well water was observed for groundwater sampling and majority of the people in the study area was traditional well water users. As such it could be seen sufficient distribution of wells that helps to observe a representative sample for spatial analysis on groundwater distribution. 5km*5km Grid Index which covers whole study area was used for data collection and randomly selected 5 locations were observed from each grid by field visit. In order to that 567 wells were observed and sampled for the analysis (Figure 03).

Data collection was conducted in dry season and it helped to identify the minimum water levels of wells from the ground level. Data relevant to the maximum water level was obtained by the discussion with the people. Digital Portable pH Meter was used to test **the** quality parameters **(**pH, Total Dissolved Solids (TDS), Electrical conductivity (EC) and temperature**).**

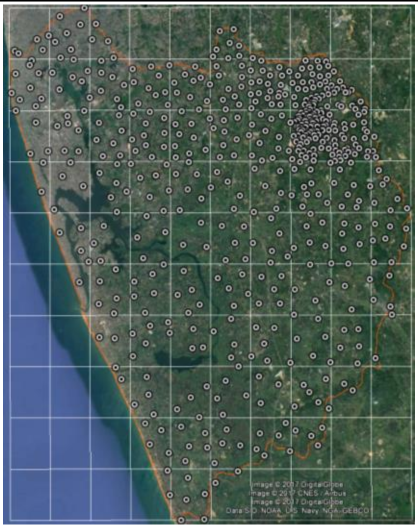


Figure 3 : Locations of observed wells

3.2 Data Analyzing

Inverse Distance **Weighting (**IDW) method was used to analyze the spatial distribution of each water quality parameter and ground water levels in wet and dry seasons. Weighted Overlay method was used to obtain the overall groundwater quality in the study area. In addition to the major analysis, Land use of the study area was updated with Google Earth Satellite images.

04 RESULTS

Results show a conspicuous difference on spatial distribution of groundwater level and quality.

4.1 Spatial distribution of groundwater level

Behavior of the groundwater level of Bolgoda River Basin was analyzed in wet and dry seasons. Majority of the area is rich with groundwater. Highest value of maximum water levels in dry and wet season was the ground level. Shallowest groundwater level ranged was considered from ground level (0) to 1 m level. Area in this range is increased in wet season and 119.81 sqkm area represents a shallowest groundwater level. This area is reduced in dry season and only 5.09 sqkm area was in shallowest range.

Majority of the area in dry season represents moderate water depth ranged from 3.1 to 6 m and that value is 211 sqkm. But 260sqkm of majority represents water depth range from 1.1 to 3 m in Wet season. Highest water depth in Dry season was recorded as 14.53 m and 11.9 m in Wet season. Table 1 shows the classes of groundwater levels and area of each class in dry and wet seasons.

Table 1 – Area (sqkm) in different water levels (Dry & Wet Seasons)

Water level (m) from ground	Class	Area sqkm (Dry season)	Area sqkm (Wet season)
0-1	1	5.07362	119.811
1.1 - 3.0	2	96.105	260.514
3.1 - 6.0	3	211.615	49.3779
6.1 - 9.0	4	109.139	2.1399
9.1>	5	10.3375	0.456141

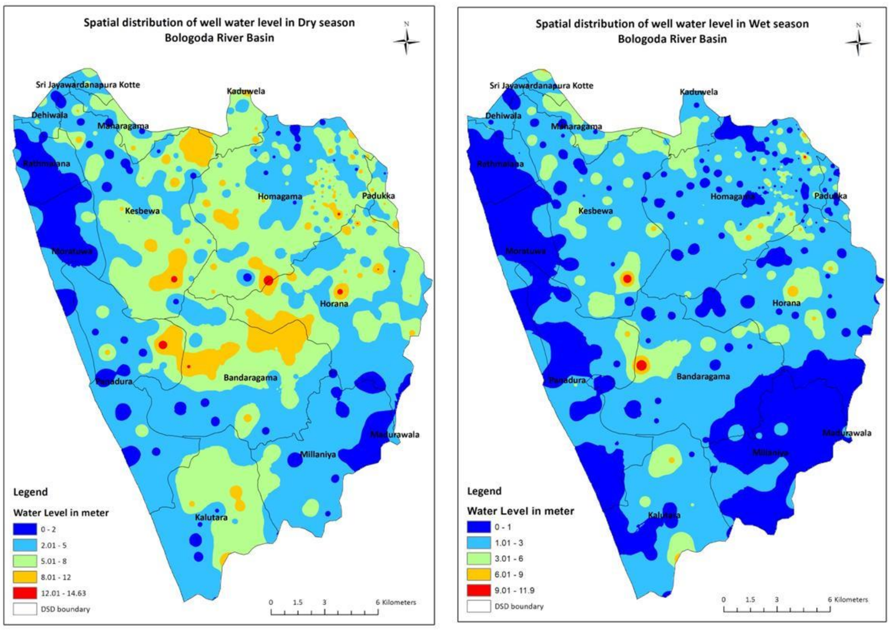


Figure 04: Spatial Distribution of Groundwater level in Dry & Wet seasons

Figure 4 shows the spatial behavior of groundwater levels in wet and dry seasons. In order to that groundwater level had been reduced in the Middle and Sothern parts of the study area in dry season when comparing to the wet season. There are some places could be seen with deepest groundwater level in wet season as well.

4.1 Spatial distribution of Groundwater quality

pH, Total Dissolved Solids (TDS), Electrical conductivity (EC) and temperature were the quality parameters which analyzed at the field survey.

pH

Defined as the negative logarithm of the hydrogen ion concentration. In general, water is weakly acidic, but pure water has a neutral pH (pH 7.00). This is considered one of the most important water quality parameters. In general pH less than 7.00 indicates acidity whereas a pH higher than 7.00 indicates alkalinity. The normal range for pH in groundwater system is 6.0 to 8.5. The safe pH range for domestic use and organisms living is from 6.5-8.5.

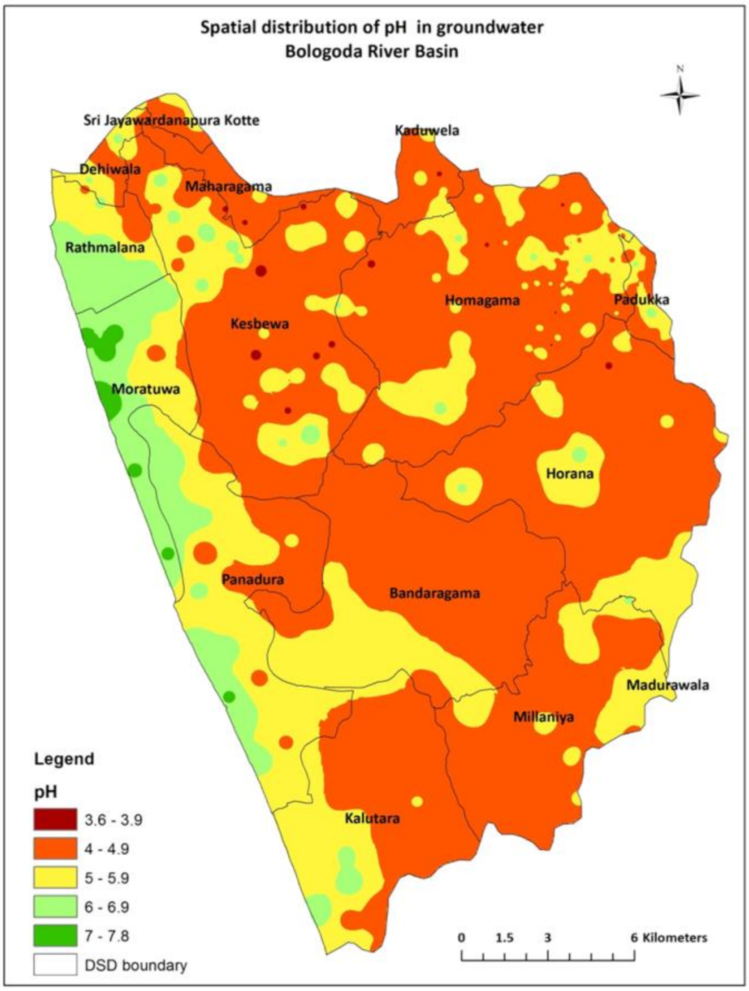


Figure 5 – Spatial distribution of pH

Groundwater quality contours were developed and pH contours in the study area is presented in Figure …pH level of the study area was ranged between 3.6-7.8. It's revealed that pH value in majority of the area that indark brown and orange patches depict low pH values in well water. Whereas in the coastal area light and dark greenpatches depict with range from 6.0 -7.8 pH values in well water. In between pH value range from 5-6 depict in scattered areaswell water. Therefore, this contour map can be used as an initial guide for suitability of future groundwater wells and in addition to providing focus to investigations of the reasons for acidic groundwater.

Topographically Bolgoda basin is in the coastal plains of the western region of the country. The terrain in Bolgoda consists of gently undulating plains with a high density of drainage paths consist mainly of alluvial deposits.A few kilometers upstream in the inland valleys, there is a high-level gravel formation consisting of quartz pebbles embedded in a matrix of laterite separated with pebble-free layers of laterite.

The basin hydrology indicates that there is a fair amount of groundwater potential both in the alluvial aquifers and bedrock. The prominent aquifer bedrock types in the basin are quartzite and a few crystalline limestone (marble) bands. The secondary porosity of these formations provides good conditions for deep aquifers. The alluvial sand/gravel aquifers in the basin are recharged by rainfall and seepage from the rivers. High-potential porous residual laterites also contribute to groundwater supplies. During droughts, river water and springs recharge most alluvial aquifers in the basin.

Factors that affect soil pH include parent material, vegetation, and climate. Some rocks and sediments produce soils that are more acidic than others: quartz-rich sandstone is acidic; in humid areas soils tend to become more acidic over time because rainfall washes away basic cations and replaces them with hydrogen. Addition of certain fertilizers to soil can also produce hydrogen ions.

The main reason for this low pH level in most of the areas of bolgoda basin is soil type and the climate. Major soil type in this area is Red yellow podzolic soils and in the coastal area consist Bog and half bog soils.

Total Dissolved Solids (TDS)

Total dissolved solids is the term used to describe the inorganic salts and small amounts of organic matter present in solution in water. The principal constituents are usually calcium, magnesium, sodium, and potassium cations and carbonate, hydrogen carbonate, chloride, sulfate, and nitrate anions.

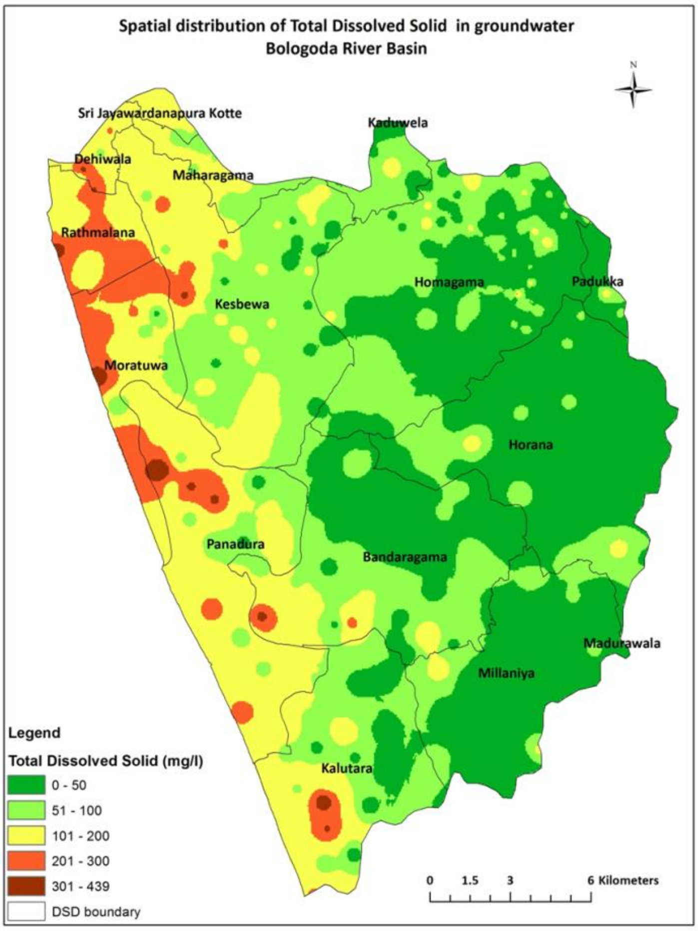


Figure 6 – Spatial distribution of TDS

The presence of dissolved solids in water may affect its taste (1). The palatability of has been rated by panels of tasters in relation to its TDS level as follows: excellent, less than 300 mg/litre; good, between 300 and 600 mg/litre; fair, between 600 and 900 mg/litre; poor, between 900 and 1200 mg/litre; and unacceptable, greater than 1200 mg/litre (1). Water with extremely low concentrations of TDS may also be unacceptable because of its flat, insipid taste.

Water containing TDS concentrations below 1000 mg/litre is usually acceptable to consumers, although acceptability may vary according to circumstances.
However, the presence of high levels of TDS in water may be objectionable to consumers owing to the resulting taste and to excessive scaling in water pipes, heaters, boilers, and household appliances. Water with extremely low concentrations of TDS may also be unacceptable to consumers because of its flat, insipid taste; it is also often corrosive to water-supply systems.

TDS contour in the study area is presented in Figure … and the TDS level of the study area was ranged between 0 - 439 mg/l. It’s revealed that the TDS in the study area is ranges in acceptable level to consume. Also it depicts that in most of the areas of the study area has excellent palatability in the well water according to the WHO standards.

Electrical conductivity (EC)

Electrical conductivity (EC) for groundwater is the ability of 1 cm3 water to conduct an electric current at 25˚C and is measured in micro Siemens per centimeter, so it depends on the total amount of soluble salts (TDS) as charged particles**.** Conductivity increases with the increased concentration of ions. This forms a part of the total dissolved solid content of water. Higher conductivities in water may be due to natural or anthropogenic causes. If the soil and sediments are high in alkaline substances such as calcium and magnesium carbonates, the water will have high EC which is referred to have hardness in water. Addition of soluble chemicals such as fertilizer can also increase EC.

The most desirable limit of EC in drinking water is prescribed as 1,500 µS/cm (WHO 2004). The EC of the groundwater is varying from 64.02 and 2199.57 µS/cm with an average value of 514 µS/cm.

In figure 7 shows the contours of EC in the study area and its ranges from 10 – 899 µS/cm which is in desirable level. The TDS and EC of study area is correlated.

Overall Water Quality

Overall water quality of the area was obtained with weighted overlay analysis. In order to that, Result of Weighted overlay analysis was reclassified into 4 classes as very good, good, moderate and poor. In order to that 6.01Sqkm area was identified as very good in water quality and it represents the 1.3% of total land area. Largest portion of 235.3 was identified as good and 190.7 was in moderate quality. Poor quality land amount was 0.49. Coastal area and its nearest lands show the low water quality comparing to the other areas. Figure 8 represents the spatial distribution of overall water quality in study area by analyzing the mentioned parameters.

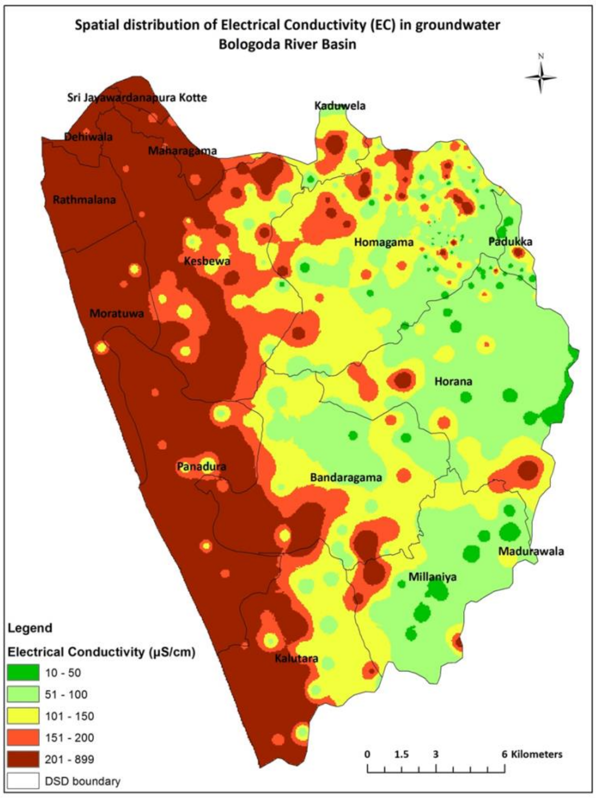


Figure 7- Spatial distribution of EC

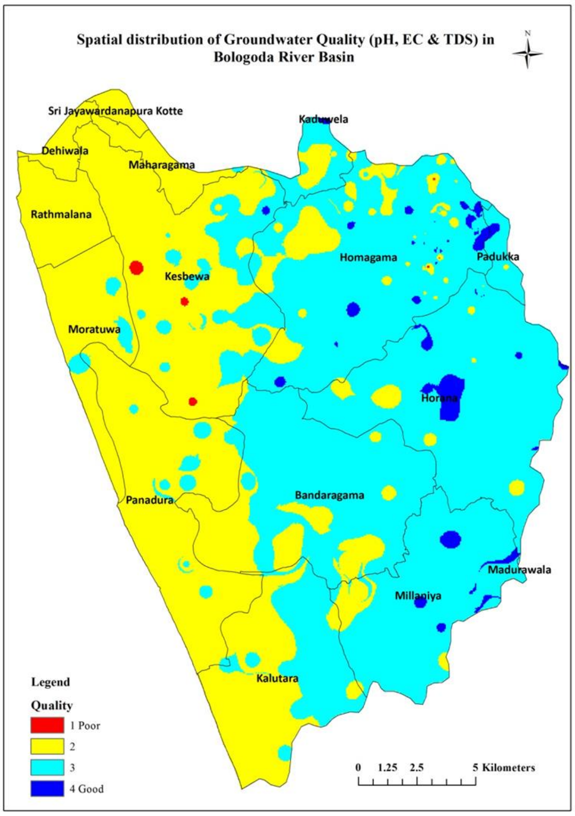


Figure 8 – Spatial distribution of overall water quality

Eastern part of the study area shows good water quality besides some places with low quality.

Conclusions

The demand for water in Sri Lanka is steadily increasing, particularly for urban/rural water supplies, irrigated agriculture and in the industrial sector. This rapid increase in demand is exerting considerable pressure on the available groundwater resources. Lack of database on groundwater resources is the major barrier to reveal the impacts of development activities on groundwater resources. In order to that, It is very important to maintain a country based database for groundwater quality and distribution.

The result of this research has challenged to the traditional awareness of the public regarding the water quality. pH distribution of the area was an unexpected result but it could revealed this is the natural behavior of ground water in whole area.

This database will support groundwater quality researches and the Central Environmental Authority efforts to educate the public about groundwater quality. The data will be used to generate maps and reports and to answer public concerns about groundwater quality and distribution in Sri Lanka.

It is intended to follow this methodology in other river basins and developed a complete database on spatial distribution of groundwater and its quality. In addition to that, Results of this research are very important as based data that can be used to ensure the protection of ground water from industrial and other non point source pollution activities as well as to identify the areas in water scarcity.

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