# IDENTIFYING THE GROUNDWATER POTENTIAL ZONES USING GIS AND RS TECHNIQUES: WITH SPECIAL REFERENCE TO RAMBUKKANA DIVISIONAL SECRETARIAT DIVISION

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**ABSTARCT:** *Groundwater is an important resource that contributes significantly to domestic and industrial purposes. The water demand is increasing due to the depletion of groundwater. Uncontrolled drilling of wells, construction of agricultural wells, and abstraction cause various water-related problems. However, groundwater availability is depleted considerably due to overexploitation, which has led to the collapse of land in some places. The combination of remote sensing (RS) and geographic information systems (GIS) to explore groundwater resources is a breakthrough in the field of groundwater research. It helps in the monitoring, conservation, and assessment of groundwater resources. The main objective of this research is to identify the groundwater potential of the study area through the technique of identifying groundwater potential zones using remote sensing and a Geographic Information System. Satellite data and other secondary data sources were used to obtain the slope, geology, geomorphic units, lineament density, and drainage density, which are considered key parameters that can provide accurate information in identifying groundwater potential zones. Identification and mapping of groundwater potential analysis were done using the weighted overlay method in ArcGIS. The study identified water potential zones of poor (7%), moderate (36%), good (40%), and excellent (17%) groundwater potential zones in the Rambukkanaarea. Additionally, groundwater potential zones based on Village Officer (GN) divisions of the region are analyzed to add strength to the study.*

**Keywords:** Groundwater, Demand, Remote Sensing, Geographic Information Systems

## 1. INTRODUCTION

Groundwater is the fresh achromic creativeness for undeviating and effective matter cater in cityfied and rural areas. Notwithstanding, it is valued for prosperous populations and additional leatherneck and mundane ecosystems (Magesh, Chandrasekar & Soundranayagam, 2012). Groundwater is spirit as one of the most couturier natural resources, the most semiprecious and soul germ of situation distributes for all climates worldwide.

Groundwater is well-defined as the water that fills the entire soil pore space and geologic structure under the water table (Freeze & Cherry, 1979). The researcher has made the context precise in that what happens in groundwater in the formation of the earth and the extent of its exploitation is largely dependent on the formation of porosity. Higher support and higher slopes provide higher flow, while lower degradation increases penetration. The waterlogged area also increases ground flow compared to the groundwater table. Extra water bodies such as rivers, lakes, etc., can serve as regenerative sites (Murugesan, Ramkumar, Venkatramanan, & Gurugnanam, 2012).

Pointed out that the estimated amount of the world's total supply of water is 1.3 × 108 million ha-m. Here salt water and seawater are about 97.2%, and the available amount of fresh water is only 2.8%. Always surface water is available at about 2.2% as clean water and groundwater at 0.6%, of this surface water, 2.15% of fresh water is ice cubes and glaciers that have not been used directly, almost 0.01% is found in lakes and ponds and 0.0001% in streams". 80 million a year is the estimated rate of the growing population of the world and is projected to reach 9.1 billion by 2050 (The United Nations World Water Development Report, 2015). As far as Sri Lanka is concerned, water is distributed under government drinking water schemes through pipes to even larger areas and cities. In the remaining areas, people meet their water needs from open wells, irrigation stations, dams, tanks, lakes, springs, rivers and streams or by harvesting rainwater. Sri Lanka has traditionally been divided into 3 main climates based on regions, i.e. Wetlands, Central and Arid regions depending on the monsoon rainfall. The wet zone receives more than 2500 mm, the central region is between 1750 and 2500 mm, and the dry zone receives less than 1750 mm of annual rainfall (Banabokke & Perera, 2005).

According to the Sri Lanka Water Resources Board, water pollution is considered an increasing problem facing the use and management of groundwater in Sri Lanka (WRB, 2011). Agricultural practices are heavily dependent on chemical fertilizers and pesticides to increase national food production. The risk of groundwater contamination is high through excessive use and abuse of chemicals and heavy irrigation practices. High concentrations of nitrates, chlorides, sulfates, heavy metals and hardwoods have been found in groundwater sources in many areas. In addition, several key factors determine the sustainability of groundwater resources in the country, such as lack of legal and political commitment, poor coordination, lack of proper institutional framework, lack of new knowledge about groundwater resources and use, and general ignorance about access and use of groundwater (Gunawardena & Babasara, 2016) Effective water resource management practices and systematic planning require scientific tools and institutional structures to meet the requirements set forth in them. Rapid advances in understanding the various components of the hydrological cycle have been made since the early 1960s, and the development of digital computers introduced the invention of numerical models. With the discovery and accessibility of these useful tools that have emerged since the late 1960s, integrators can coordinate groundwater use with greater efficiency for the benefit of future generations.

Present-day tools including GIS may be used significantly for water studies and metallurgical purposes, relying on blended facts (vector or raster). isolating potential groundwater assets the use of faraway sensing and GIS is a powerful device (Leblanc, et al., 2006). It allows deception and analysis of each layer of local facts and is used to analyse and model relationships among layers. Remote sensing presents an extensive-range scale of the gap-time distribution of observations and saves time and money (Murthy, 2000). The objective of the observation became to determine the spatial distribution of groundwater capability zones within the Rambukkana DS division.

## 2. METHODOLOGY

### 2.1 Study Area

This study will be carried out at Rambukkana Divisional Secretariat Division (DSD) in the Maha Oya river basin. Maha Oya is one of the major rivers in the Sabragamuwa Province of Sri Lanka. It flows 128 km across four provinces and five districts, which are Kurunagela, Kandy, Gampaha, Puttalam and Kegalle. The Maha Oya River originates from Navalapitti and flows into the Indian Ocean at Kochikadai, north of Negombo in Aranaike region. The Maha Oya Basin has a catchment area of 1,510 $km^2$.

The main river takes 21 tributaries, among which Rambukan Oya, Talagolla Oya and Hingul Oya are the main ones. More than 1.1 million people live along the banks of the river and use the river's myriad benefits for their livelihood and livelihood activities. Rambukkana DSD is located at Kegalle district in Sabaragamuwa province. There are 89 Grama Niladhari Divisions (GNDs) in Rambukkana DSD. According to population census data (2012), the population is 82769.

The average annual rainfall in the study area is about 2281 mm. The average annual temperature is 27°C. (https://en.climate-data.org/) Even though the study area has ample rainfall, most of it flows away as runoff without recharging the groundwater. Many projects have been introduced by the government to make use of the groundwater in that area for better quality drinking water.

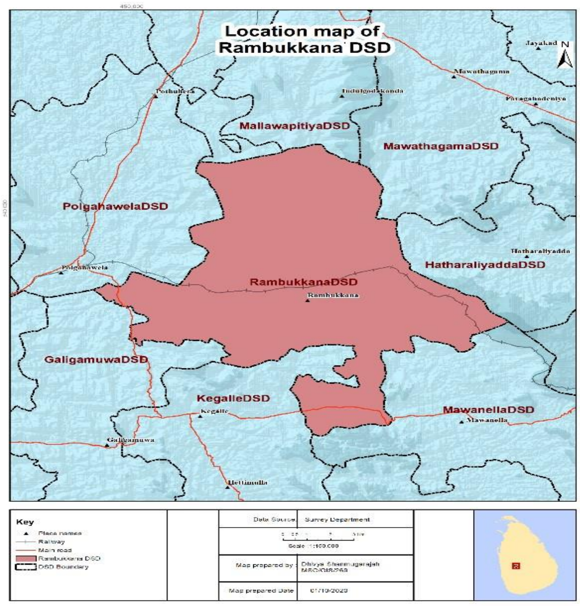



*Figure 1. Research Area Rambukkana DSD*
*Source: Department of Survey*

## 2.2 Data Collection

For this study, the author has used only the secondary data that are obtained from the Survey Department, Irrigations Department, Land use Policy Planning Department SRTM data and Satellite images available on the web. Diverse types of data such as groundwater data, satellite data, meteorological data and topographic maps are collected for the current study intended. The following list of data sources is used.

*Table 1. List of data sources*

| **Criteria** | **Details of Data** | **Data Source** |
|---|---|---|
| DEM Slope | SRTM 30m | Download from USGS earth explorer |
| Land use | | (LUPPD)Land use Police Planning Department |
| Soil | Soil Science Society of Sri Lanka | Soil Science Society of Sri Lanka |
| Geology | Shapefile scanned from 1:100,000 scale published maps | Geological Survey and Mines Bureau of Sri Lanka, (GSMB). |
| Rivers | Delineating from SRTM 30m | Download from USGS earth explorer after delineated checked with Google Earth |

| | | |
|---|---|---|
| Lineament | Shapefile scanned from 1:100,000 scale published maps | Geological Survey and Mines Bureau of Sri Lanka, (GSMB). |

*Source: Created by Author*

### 2.2.1 Usage of Satellite Data

Shuttle Radar Topography Mission (SRTM) is a project from NASA to obtain Digital Elevation Models on a global scale. This is a more advanced mission to complete the high-resolution digital elevation database of the entire globe compared with the prior mission of ASTERGDEM released in 2009. The resolution of 1 - Arc Second and 3 - Arc Seconds images are freely available to cover the study area. SRTM Elevation data can be freely downloaded from http://earthexplorer.usgs.gov/ Spatial reference of the data set is GCS WGS 1 984 and then it is projected to the SLD99 Sri Lanka Grid1 999 system which used a common spatial reference system of this study. Considering accuracy, it used Arc Second resolution images to study. When it is projected to the common spatial reference system, 30m (approx.) the resolution digital elevation data set can be produced.

### 2.2.2 Drainage

The presence of rivers and water courses in the landscape implies interaction with groundwater, either as an expression of groundwater discharge or as a location where groundwater recharge is actively occurring. The characteristics of a groundwater recharge sector can be evaluated using a structural evaluation of the drainage community. Drainage density is characterized by the closeness of the move spacing. it is the sum of all lengths of the move section of all orders consistent with the unit vicinity. Drainage density is an inverse characteristic of permeability. less infiltration of rainfall is seen in less permeable rocks, resulting in floor runoff. ArcGIS software consists of a line density analysis tool that may be used to calculate drainage density inside the take a look at the vicinity. The drainage-length density (Dd) derived from the DEM is the sum of the lengths of every river in the basin divided with the aid of the overall region of the basin as follows:

$$D_d = \frac{\sum_{i=1}^{i=n} S_i}{A} \quad \text{where } \sum_{i=1}^{i=n} S_i \text{ denotes the total length of drainage (L)}$$

$$A \quad \text{denotes the unit area } (L^2)$$

### 2.2.3 Geology

Lithology performs a considerable role in the distribution and prevalence of groundwater. The form of rock present on the surface controls the percolation of water drift. It significantly affects the recharging of groundwater. The degree of weathering and deepness in addition to the forms of water-bearing connections which occur inside the bedrock is controlled in metamorphic and igneous rock types. Borehole yield and success costs are associated with the textural homes and ability of the weathered/fractured zone for the different crystalline basement rock kinds. The lithology layer was generated from the Digitization of scanned 1:100,000 scale published maps which were published by GSMB (Geological Survey and Mines Bureau of Sri Lanka). In terms of Lithology, the study area is dominated by Garnet-sillimanite-biotite gneiss-+graphite, Granlte gnelss, Hornblende-biotite gneiss, undifferentiated chamockitic biotite gneisses, Quartzites, Charnockitic gneisses, etc.

### 2.2.4 Lineaments

Lineaments (fractures, faults) play an important role in groundwater resources particularly in hard rock regions by indicating the presence of high permeability zones for preferential groundwater flow within the crystalline bedrock. These features can extend over several Kilometers and if interconnected, can support high-yielding wells. Determine lineament-length density (Ld) which represents the total length of lineaments in a unit area as:

$$L_{\mathrm{d}} = \frac{\sum_{i=1}^{i=n} L_i}{A}$$

where $\sum_{i=1}^{i=n} L_i$ denotes the total length of lineaments (L)

$A$ denotes the unit area ($L^2$)

## 2.3 Data Analysis

### 2.3.1 GIS Integration and groundwater potential map

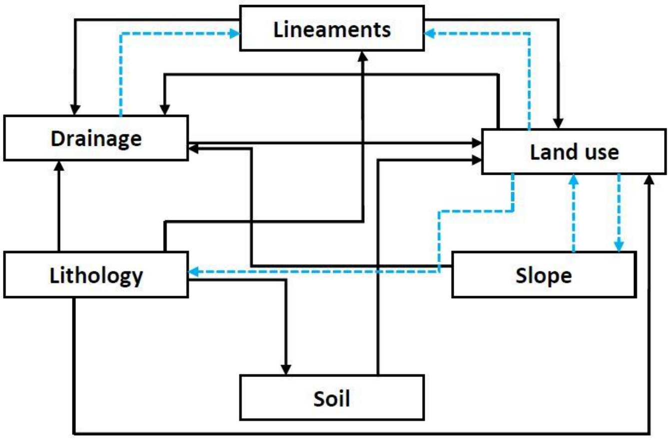
Weighted maps are prepared with the use of the Raster Calculator characteristic in ArcGIS 10.8. A model is created to overlay the thematic maps with the use of version Builder. within the model; instructions within thematic maps were allotted weights via a reclassification tool. subsequently, new, reclassified thematic maps have been protected using a raster calculator. A Groundwater ability Index (GWPI) become calculated for every cellular or pixel.

$GWPI$ **= DDr DDW + LIr LIW +LUr LUW + SOr SOW + SLr SIW + LDr LDW**

wherein DD is the drainage density, LI is the lithology, LU - is the land use, SO - is the soil, SL - is the slope, and LD - is the Lineament density: The subscripts “r” refers to the reclassified fee and “w” refers to the weight. Then the groundwater capability map produced the usage of GWPI, with four relative classes (very low, low, slight and high) the usage of the quantile category technique for higher visible presentation.

*Figure 2. Methodology Framework*
*Source: Created by Author*

The selected factors do not have the same influence on determining good groundwater potential and are not independent of each other. A conceptual plot of




the primary and secondary interrelationships between the factors is shown in (Figure 02). as an instance, Lithology is considered to have a first-rate impact or primary influential dating on the incidence and nature of lineaments, drainage and land use/cover. An issue with a better weight price is considered to have a larger effect on groundwater capability. For the factors under consideration, lithology was deemed to have the largest impact on groundwater potential in the basin. This is consistent with the conceptual understanding of groundwater occurrence and movement in the study area.

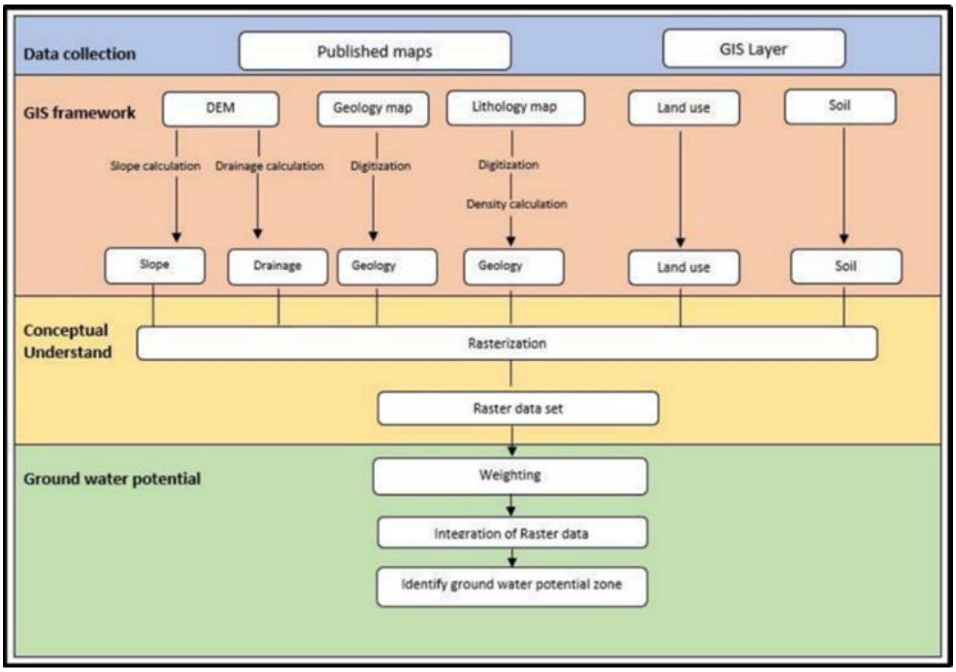



*Figure 3. Concept Frame Work*

*Source: Created by Author*

## 3. DISCUSSION AND RESULTS

Geology, land use, slope, drainage, contour, and soil are the six influencing factors identified to define groundwater potential zones. The relationship is weighted according to its strength and each stratum and class is assigned a weight based on soil and land properties and ranked according to their suitability for groundwater retention using literature available in the past. The sum of all weights from every component is the representative weight of an issue within the viable location. In groundwater capability zones, a higher weighted factor suggests a bigger impact and a decreased weighted aspect shows a smaller impact. A weighted overlay analysis in ArcGIS is used to calculate the potential weights of these combined factors.

### 3.1 Model Builder

Edit, create, and managing models are the main use of the Model Builder application. The sequences of geoprocessing tools are stringed together, and the output of one tool into another tool as input is fed by the models as workflows. The advantage of the usage of model Builder is that it is a smooth-to-use utility, customers can create their tools with version Builder and use them in Python scripting and different fashions. Scripting and model Builder enable users to connect ArcGIS applications.

To identify the Potential groundwater zone, the Continuous Raster used by the researchers are SRTM DEM to drive slope and drainage density. Other categorical rasters are soil, geology, geological structure, and land use that are used to feature to raster in conversion tool in arc GIS after using the reclassify tool, weighted overlay tool is applied.

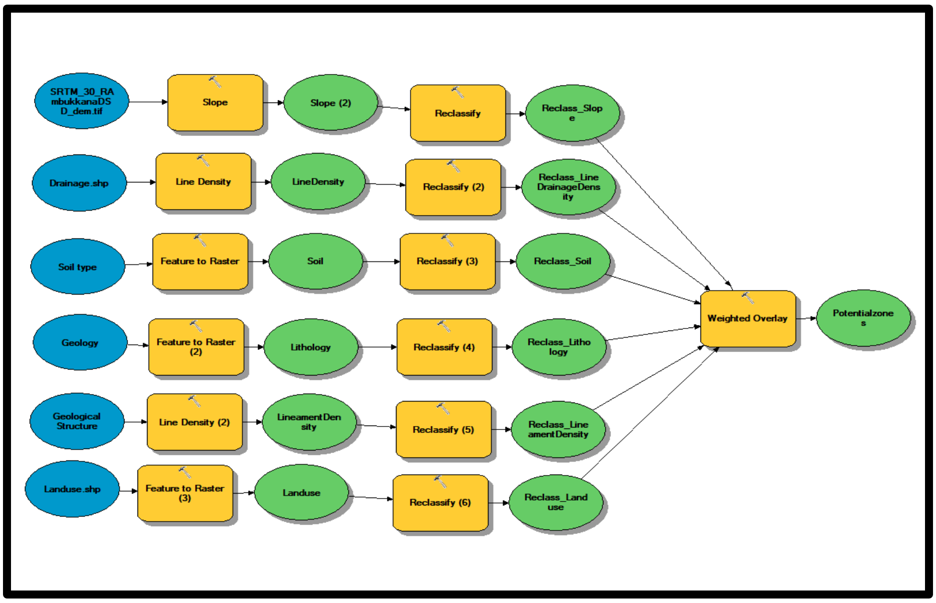



*Figure 4. Groundwater model builder*
*Source: Created by Author*

### 3.2 Weightage calculation

Suitability models and site selection are some multi-criteria problems, that are solved by the most used approaches of the Weighted Overlay tool. Each relationship is weighted according to its strength and each layer and class was assigned a weight based on the available literature in the past ranked depending on their suitability to hold groundwater and based on expected option.

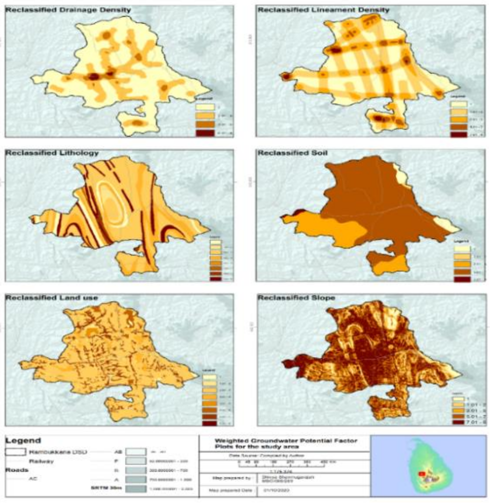


*Figure 5. Weighted groundwater potential factor plots*
*Source: Created by Author*

*Table 2. Groundwater potential zones*

| Factor | Weight (%) |
|---|---|
| Drainage density | 10 |
| Lithology | 30 |
| Land use | 10 |
| Soil | 10 |
| Slope | 20 |
| Lineament density | 20 |
| | **100** |

*Source: Created by Author*

### 3.3. Spatial analysis of groundwater potential zone

The interpreted layers are grouped via a weighted Multi Influencing factor (MIF) and the demarcation of groundwater ability zones is made. Then finally they're assigned as exceptional potential zones. The groundwater potential zone of this takes a look at the area can be divided into four grades, namely excellent, correct, moderate, and poor. approximately 7% of the entire region falls under the 'Poor' area, 36% falls under the 'Moderate' area, forty% falls beneath the 'Good' groundwater capability area, and 17% of the examined area falls under the 'Excellent' area.

*Table 3: Groundwater suitability*

| Groundwater suitable | Area (ha) | Percentage |
|---|---|---|
| Poor | 926.89 | 7 |
| Moderate | 4745.432 | 36 |
| Good | 5345.126 | 40 |
| Excellent | 2306.236 | 17 |
| | 13323.68 | 100 |

*Source: Created by Author*

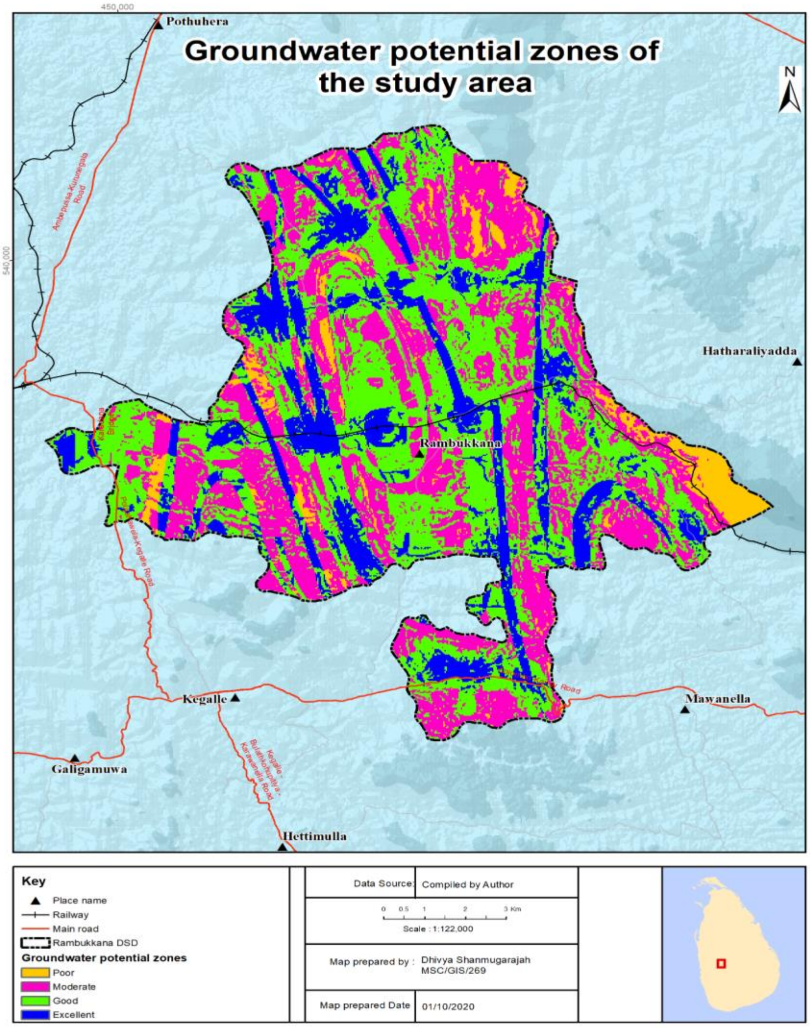



*Figure 6. Groundwater potential zones*
*Source: Created by Author*

The below chat shows the potential of groundwater in the study area based on the GN divisions. The zones are mainly classified into four groups namely. Poor, moderate, good, and excellent. Based on the graphs, the Kumbaldeewela GN division has a more excellent groundwater potential zone, which is approximately 126 ha-m. Henepola has an approximate area of 140 ha-m with a poor groundwater potential zone compared with other GN divisions. Gabbala South has approximately 240 ha-m with moderate groundwater potential and Marukwathura has a good groundwater potential area of 200 ha-m. The overall groundwater potential of the study area is good and certain GN divisions have excellent groundwater potential zones. The poor potential zones of groundwater are comparatively low in the study area which means the study area has enough groundwater potential.

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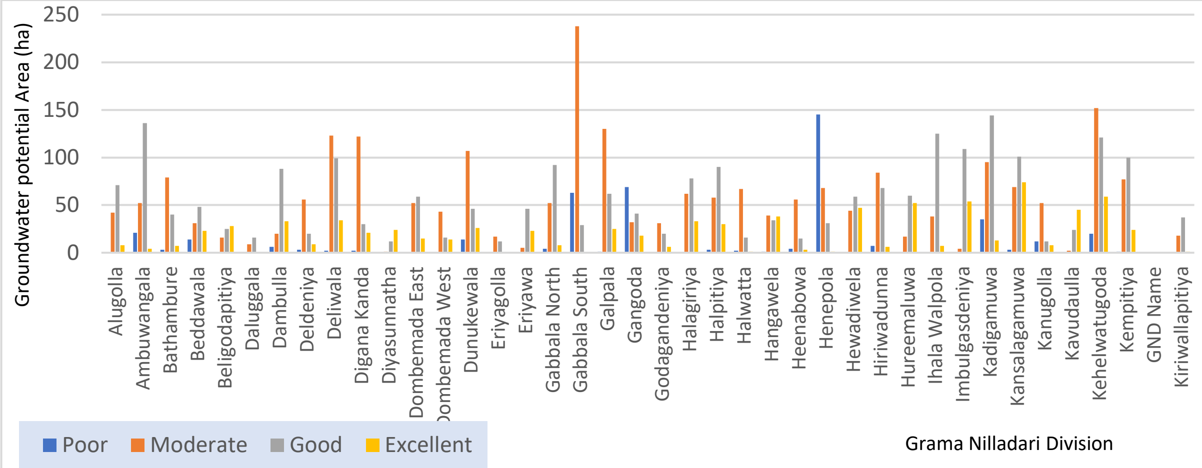


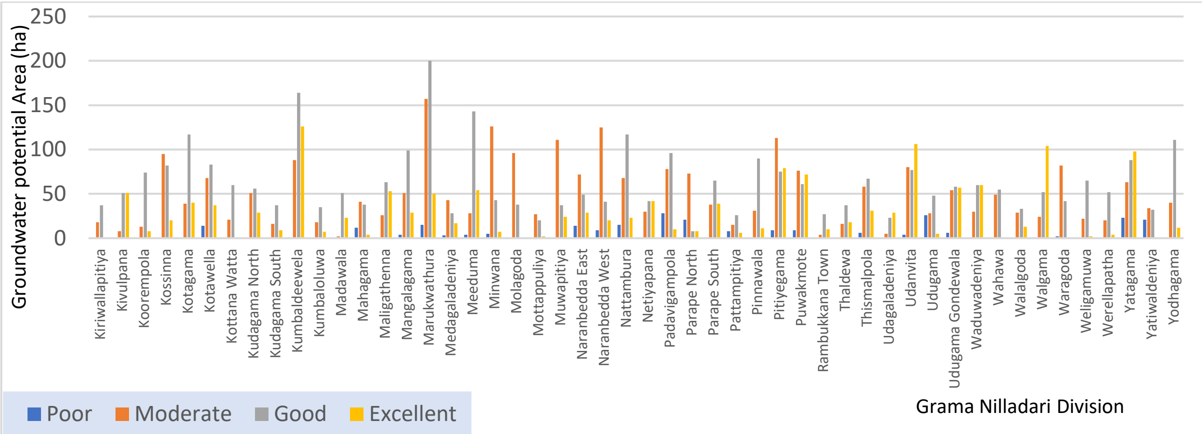


*Figure 7. Groundwater potential zones in GND Wise*
*Source: Created by Author*

## 4. Conclusion

The research aims to identify potential groundwater zones in Rambukkana Divisional Secretariat Division by using GIS and Remote Sensing techniques. Different methodologies are used in mapping the groundwater potential zones. Some of the methods have given accurate results and they were easy to carry on. Each of the techniques has its disadvantages and advantages. The study reveals that the combination of six thematic maps such as slope, drainage density, geology, land use/ land cover, soil and lineament density, which are used in the research study, provides immediate information to the planners and local authorities regarding the appropriate areas for the groundwater exploration. Remote sensing and geographical information system are cost-effective and powerful tools for identifying groundwater potential zones. MIF and GIS are efficient techniques to reduce time, money, and labour. Therefore, we can make quick decisions on sustainable water resource management. Topographic maps, conventional data and satellite imageries are used to develop the thematic layers of lineament density, lithology, slope, drainage density, land use, and soil. MIF is used to assign different weightage to the various thematic layers. Then it's far combined with the GIS environment to provide the groundwater potential zone map of the study region.

consistent with the groundwater potential zone map, Rambukkana DSD is classified into four different zones, particularly 'poor', 'moderate', 'good', and 'Excellent'. The overall groundwater potential of the study area based on the GNDs is good and most of the GN divisions have excellent groundwater potential zones. The poor potential zones of groundwater are comparatively low in the study area which means the study area has enough groundwater potential. Therefore, it can be assumed that the study area, Rambukkana DSD is suitable to make use of the existing groundwater.
In future, the results derived through this research can be utilized and serve as a guideline for artificial recharge projects, in the study area. This may ensure the sustainable utilization of the groundwater. Exploration of groundwater potential zones by using GIS and remote sensing is an empirical method and it is also successful in proposing the potential zones for groundwater. This method can be widely applied to a vast area with rocky topography for the exploration of suitable sites.

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