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GEOSPATIAL MAPPING OF GROUNDWATER POTENTIALITY IN SOORIYAWEWA DIVISIONAL SECRETARIAT DIVISION BY UTILIZING GIS

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ABSTRACT

The dry zone of Sri Lanka is affected by drought conditions owing to a lack of rainfall. Hence, mapping the distribution of groundwater potential zones is vital for water management. The Hambantota district, which is in the dry zone is a severely afflicted area due to lack of rainfall, and Sooriyawewa divisional secretariat area faces water scarcity. Therefore, this study aims to map groundwater potentiality in the Sooriyawewa divisional secretariat division using a geographical information system. For this study, spatial interpolation techniques, weighted overlay analysis, georeferencing, and digitizing methods were used. In this study, the annual average rainfall, geology, geomorphology, drainage density, lineament density, land use land cover, slope, and soil maps were prepared, and integrating those maps, the final groundwater potential zones map was prepared by using ArcMap 10.5 software. The study found that there were no high-potential groundwater zones in the Sooriyawewa divisional secretariat division and it already consists of low and moderate ranges. Therefore, the final groundwater potential zone map was categorized as very low, low, and moderate. The Percentages of area Coverage according to classes as, very low 2%, low 91%, and moderate 7%. This study can be highly helpful in identifying the groundwater potential zones in the Sooriyawewa divisional secretariat division and in preventing water scarcity because identified groundwater potential zones can be used for effective water management and provide essential information to responsible authorities for decision-making. Furthermore, the identified potential zones can be used for rainwater harvesting and can be used properly for future consumption.

KEYWORDS: *Georeferencing, Geographical Information System, Spatial Interpolation, Weighted Overlay, Groundwater Potential*

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1. INTRODUCTION

"Water in a zone of saturation, fills the open pores of mineral grains or fissures and cracked rocks in a rock mass," is one of the definitions of groundwater. Groundwater is a crucial natural resource in the consistent and expensive supply of drinking water in both rural and urban regions. The quantity of groundwater accessible in each location is referred to as groundwater potential, and it is determined by a few hydrologic and hydrogeological parameters. A dimensionless quantity that serves in the prediction of available groundwater regions in a given area is subsurface potential (Pathmanandakumar, Thasarathan and Ranagalage, 2021).

The slope, weathering depth, the presence of cracks, canals, surface water bodies, and irrigated fields all influence groundwater conditions. Geological, geomorphological, and hydrological data are the most common types of data accessible for groundwater research (Ganapuram et al., 2009). For years, governments and research organizations all across the world have attempted to analyze groundwater potential and anticipate its spatial distribution (Oh et al., 2011).

The value of groundwater is increasing globally as an effect of a variety of causes including population expansion, enhanced irrigation practices, industrial uses, etc. Groundwater consumption and demand have grown as a result of population expansion, grown irrigated agriculture techniques, and economic development, with little regard for the significance of groundwater's environmental balance. In Sri Lanka, groundwater is often used for drinking as well as other household needs. The potential for groundwater in Sri Lanka is less than the nation's surface water. Therefore, Groundwater potential is projected to be 7.8 billion Cubic meters per year. In Sri Lanka's dry zone, the primary source of water for rural inhabitants is groundwater. One of the greatest choices for helping dry-zone residents improve their lives by improving agricultural production without depleting groundwater supplies is to develop sustainable groundwater resources. Sri Lanka's annual freshwater withdrawals were projected to be 13 billion cubic meters by the World Bank in 2014. In the dry zone of the country, water scarcity is the most pressing concern. The Hambanthota district's need for freshwater is increased during the dry season due to a lack of surface water resources (Pathmanandakumar, Thasarathan and Ranagalage, 2021).

Due to the unequal distribution of annual rainfall, the dry regions of Sri Lanka cope with drought regularly. With the district's ongoing major construction developments, water consumption will rise in the next few years (Senanayake et al., 2013). Hence, for effective water management, it is essential to identify the distribution of groundwater potential zones. Sooriyawewa Divisional Secretariat Division (DSD) consists of many natural resources but most of the people living in that area are not economically sound. Drinkable water, as well as all other water resources, are critical in this region for many reasons, involving household activities, farming uses, and ongoing initiatives. Due to the lack of a well-defined water management system in the Sooriyawewa DSD, there is a probability of future water scarcity. People in this region of Sooriyawewa DSD are also in despair as a result of this issue. Due to the low-income level of most people, they cannot afford the water from the National Water Supply and Drainage Board (NWSDB). But if there is a correct solution for this issue much money can be saved to be used for other purposes. Hence, it is necessary to prepare groundwater potential zone maps to provide essential data to responsible authorities. As a result, the study's most important purpose is to detect the groundwater potential zones in the Sooriyawewa DSD.

2. METHODOLOGY

Study Area

Sooriyawewa Divisional Secretariat is a Divisional Secretariat located in the Hambantota District, of Southern Province, Sri Lanka (Figure 1). Sooriyawewa DSD consists of 21 Grama Niladhari Divisions (GND). It has an extent of 185.6312 km2. It has a population of 43680 people and occupied an area of 192 square kilometres in 2006 (Department of Census and Statistics – Sri Lanka). Topographically the landscape varies from category Argo ecologically and the division belongs to the agroecological zone.

27.6° C is the average temperature. The warmest month is July, and the coolest month is January. 1137.1 mm is the average annual rainfall. (Hambantota Center).

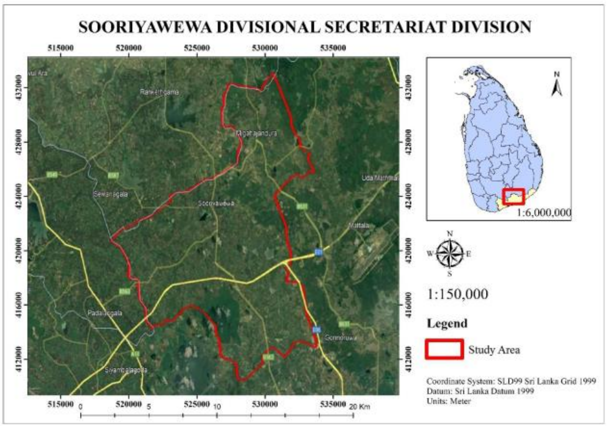

Figure 1: Study area under investigation, Sooriyawewa DSD Sri Lanka

Data used

In this investigation was used secondary data for the analysis. Rainfall data, Land Use Land Cover (LULC) data, soil map, contour data, geology and geomorphology map of Sri Lanka, and stream network data were used for the analysis. And also well coordinates and water depths of the wells in the Sooriyawewa DSD were used for the validation.

15-year period rainfall data were obtained from the Meteorology Department from 2005 to 2019. LULC data, contour data, and stream network data were obtained from the Survey Department of Sri Lanka. Data of wells were obtained from NWSDB for validation.

Data analysis

The analysis aims to discover potential groundwater zones. The type of this study was quantitative and the design of this research was descriptive. ArcMap 10.5 software was used for the data analysis. For this study, eight parameters were considered, i.e. LULC, soil, slope, rainfall data, lineament density, drainage density, geology, and geomorphology. Rainfall data were one of the main focuses of this analysis. Using the kriging interpolation technique, the rainfall distribution of Sri Lanka from 2005-2019 was obtained (Sandamali et al., 2021). Therefore kriging interpolation technique was used for this study to obtain the rainfall distribution of the Sooriyawewa DSD. Using the above past 15 years of rainfall data average annual rainfall map of the Sooriyawewa DSD was prepared.

By using LULC data obtained from the Survey Department LULC map was prepared. To prepare the soil map of the Sooriyawewa DSD, World soil maps were downloaded by using the Food and Agriculture Organization of the United Nations website and separated the soil layer of the Sooriyawewa DSD. By using Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) contour data Digital Elevation Model (DEM) was prepared and a slope map was obtained utilizing that DEM data set of the Sooriyawewa DSD. Using an image of a map of geomorphology and geology map of Sri Lanka, geomorphology and geology maps of the Sooriyawewa DSD were generated through georeferencing and digitizing.

A lineament Density map was generated by utilizing ASTER DEM. Before preparing the lineament density map obtained the hillshade and lineament polylines were digitized. A drainage density map was generated by utilizing stream network data. By using weighted overlay analysis all those maps were integrated and the final map of the groundwater potential map of the Sooriyawewa DSD was generated. The ranks and weights were assigned by modifying previous literature (Modified after Senanayake et al., 2016; Pathmanandakumar, Thasarathan and Ranagalage, 2021). Table 1 and 2 shows the rank assigned to the parameter influencing and Weights assigned to classes of each theme based on their influence on groundwater potentiality.

Finally, utilizing coordinates of wells and water depths validation was done. Before doing the validation, first, the most suitable interpolation method was identified for the groundwater data mapping. Therefore, Root Mean Square Error (RMSE) calculations were done for Inverse Distance Weighted (IDW), Ordinary kriging, and Spline interpolation techniques.

Table 1: Ranks assigned to the parameters influencing groundwater potentiality (Modified after Senanayake et al., 2016 and Pathmanandakumar, Thasarathan and Ranagalage, 2021)

Parameter	Rank Assigned
Rainfall	15
Land Use Land Cover	10
Slope	11
Soil	14
Geology	15
Geomorphology	12
Lineament Density	13
Drainage Density	10

Table 2: Weights assigned to classes of each theme based on their influence on groundwater potentiality (Modified after Senanayake et al., 2016 and Pathmanandakumar, Thasarathan and Ranagalage, 2021)

Themes and Classes	Weight Assigned
Rainfall	
1497-1500	2
1501-1550	3
1551-1650	4
1601-1650	6
1651-1700	9
Land use Land cover	
Built up Area	1
Barren land	2
coconut	6
Open Forest	3
Forest plantation	3
Marsh	7
Other Cultivation	4
Paddy	7
Playground	1
Rock	2
Scrub Land	5
Sparsely Used Cropland	4
Home Graden	2
Water Bodies	8
Soil	
Alluvial soils of variable texture and drainage; flat terrain	4
Erosional remnants of steep rock land and various lithosols	1
Redish brown earth and low humic gley soils	6
Slope	
0-1	9
2-3	8
4-5	6
6-7	4
8-12	3
13-32	1
Drainage Density	
0-1	1
2-3	2
4-5	3
6-7	5
8-10	6
11-16	8
Lineament Density	
0-0.5	1
0.5-1	4
1-1.5	6
Geomorphology	
Wet zone Chrnockitic	7
River Differentiated	7
Lower Intermediate plantation Chrnockitic	3
Dry zone Chrnockitic	4
Geology	
River	7
Rock	3
Charnockitic biotite geniss	2

3. RESULTS AND DISCUSSION

The potential of groundwater in the Sooriyawewa DSD was examined in this study. LULC map, soil map, rainfall map, lineament density map, drainage density map, slope map, geology and geomorphology maps were prepared. All the maps were prepared in SLD 99 Sri Lanka grid 1999.

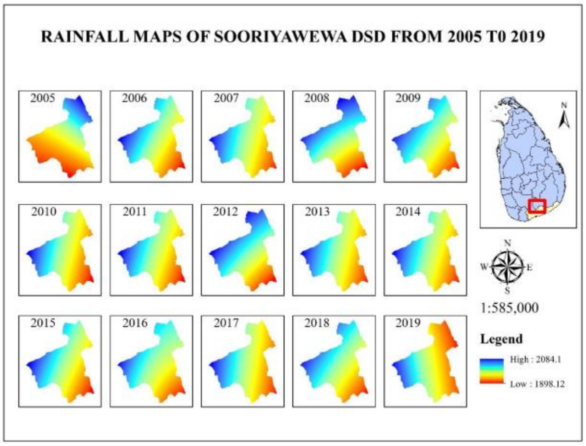

Figure 2: Rainfall Maps of 15 years in Sri Lanka

The 15 years of rainfall data (2005-2019) were considered for the prepared average annual rainfall map (Figure 2). Using the above past 15 years of rainfall data, the average annual rainfall map of the Sooriyawewa DSD was prepared. The average annual rainfall ranges between 1497-1700 mm and it was classified as five classes given the weights of each class (Figure 3).

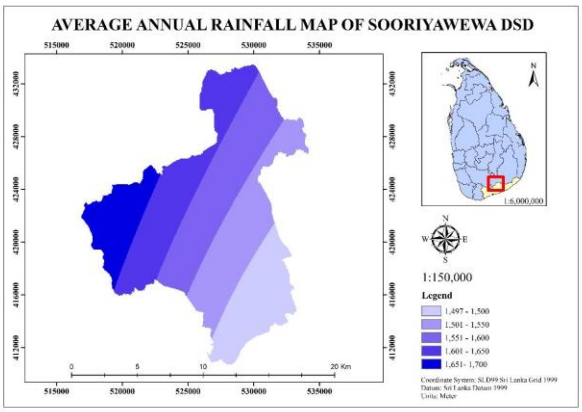

Figure 3: Average Annual Rainfall Map of Sooriyawewa DSD, Sri Lanka

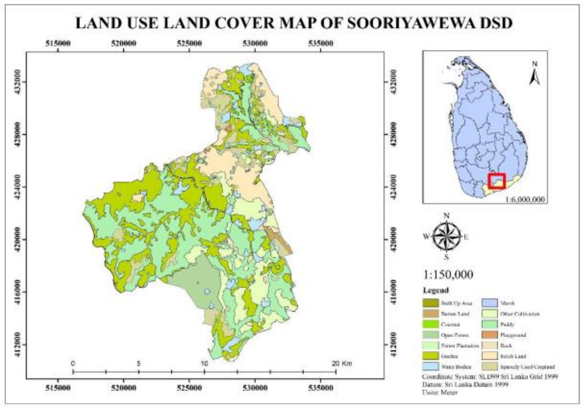

Figure 4: Land Use Land Cover Map of Sooriyawewa DSD, Sri Lanka

The LULC map of the Sooriyawewa DSD, Sri Lanka was classified as built-up area, barren land, coconut, open forest, a forest plantation, marsh, other cultivation, paddy, playground, rock, scrubland, sparsely used cropland, home garden, and water bodies for giving the weights to each class (Figure 4).

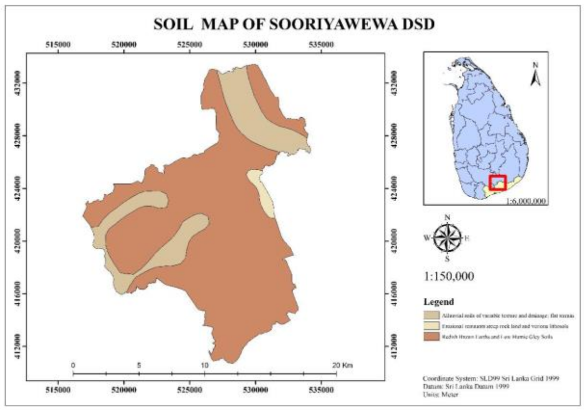

Figure 5: Soil Map of Sooriyawewa DSD, Sri Lanka

The Soil Map of the Sooriyawewa DSD, Sri Lanka was generated according to the soil type and classified into three classes, i.e. Alluvial soils of variable texture and drainage, Erosional remnants of steep rock land and various lithosols, and Redish brown earth and low humic gley soils (Figure 5).

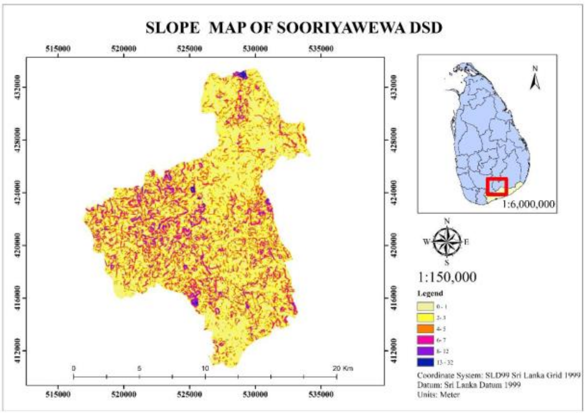

Figure 6: Slope Map of Sooriyawewa DSD, Sri Lanka

The range of the slope in the Sooriyawewa DSD between 0-32 and it was classified into six classes according to natural breaks (Figure 6).

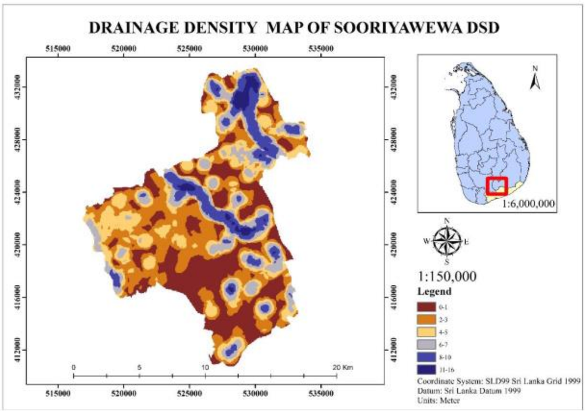

Figure 7: Drainage Density Map of Sooriyawewa DSD, Sri Lanka

The range of the drainage density in the Sooriyawewa DSD was between 0-16, and it was classified into six classes according to natural breaks (Figure 7).

By using ASTER DEM, lineament density map was prepared. The range of the lineament density in the Sooriyawewa DSD was between 0-1.5, and it was classified into three classes (Figure 8).

The Geomorphology map was generated according to the type and was classified into four classes, i.e. Wet zone Chrnockitic, River Differentiated, Lower Intermediate plantation Chrnockitic, and Dry zone Chrnockitic (Figure 9).

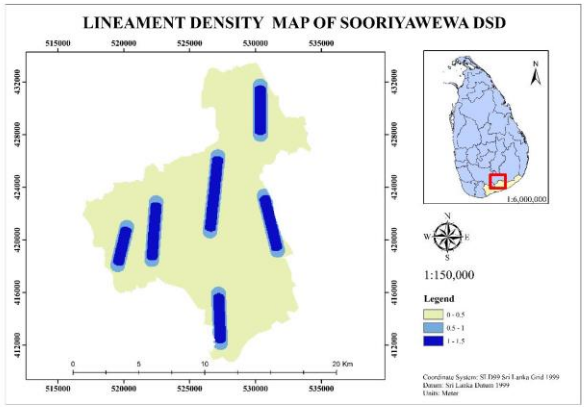

Figure 8: Lineament Density Map of Sooriyawewa DSD, Sri Lanka

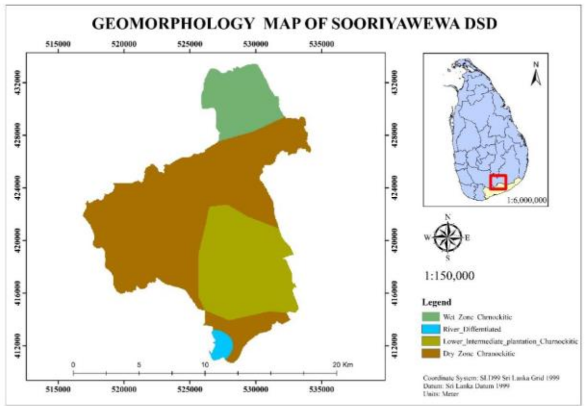

Figure 9: Geomorphology Map of Sooriyawewa DSD, Sri Lanka. Source: Open access data from the European Soil Data Centre (ESDAC)

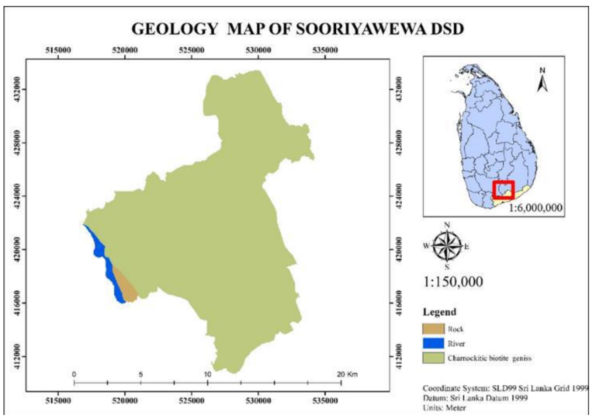

Figure 10: Geology Map of Sooriyawewa DSD, Sri Lanka. Source: Open access data from the European Soil Data Centre (ESDAC)

The Geology map was generated according to the types and was classified into three classes, i.e. Charnockitic biotite gneiss, Rock, and River (Figure 10).

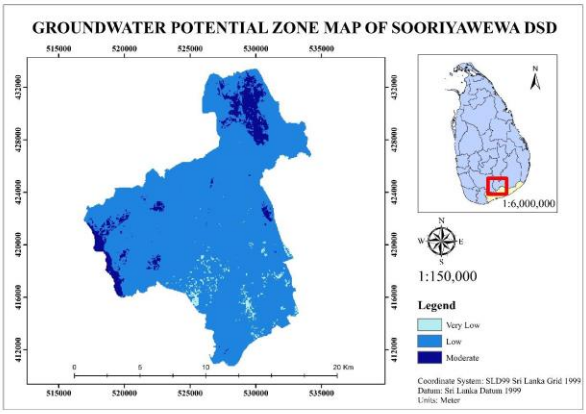

Figure 11: Groundwater Potential Zone Map of Sooriyawewa DSD

According to the result, the Sooriyawewa DSD does not consist of high potentiality, and it already consists of low and moderate ranges. Therefore, the final map was classified into 3 classes such as very low, low, and moderate (Figure 11). According to the results, the 34075km^2 area coverage is very low class, 174.73km^2 area is low class, and 14.1875km^2 area is moderate class. As a percentage very low - 2%, low - 91%, and moderate - 7%.

Table 3: Percentages of area Coverage according to classes

Groundwater level	Area (km^2)	Percentage
Very Low	3.4075	2%
Low	174.73	91%
Moderate	14.1875	7%

By using well data, validation was done. For the validation, RMSE calculations were done to find the suitable interpolation technique. The result of the RMSE calculations indicates the minimum error in the spline interpolation technique. The spline interpolation technique was the most suitable method for mapping the groundwater data according to RMSE calculation. Therefore, spline interpolation was used for the validation of the study.

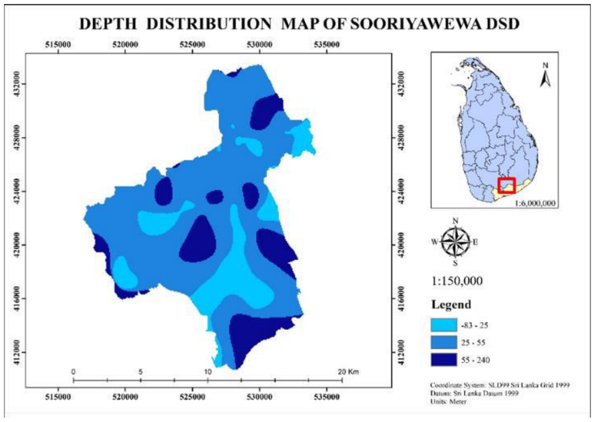

Figure 12: Depth Distribution Map of Sooriyawewa DSD

The interpolated map of groundwater data, classified according to the depths of groundwater. In Sooriyawewa DSD depths of groundwater succeed in the -83 to 240 range (Figure 12). Therefore, it was classified into 3 classes according to (Siddi Raju, Sudarsana Raju and Rajasekhar, 2019). In this study, the -83-25 range was considered very low, the 25-55 range was considered low, and the 55-240 range was considered moderate. For the validation, 30 points were collected from the final groundwater potential zone map variated with very low, low, and moderate as shown in Figure 11. Those points were extracted with real data obtained from the NWSDB. The overall accuracy of the result was 82% according to the RMSE calculation.

This study can also be applied to other areas in Sri Lanka that suffer from groundwater scarcity. Mapping the distribution of potential zones of groundwater is vital for water management to launch public water distribution projects more effectively. This analysis can provide essential information to responsible authorities for decision-making. Cost controlling through proper analysis of projects like minimum water line to feed maximum clients, wastage due to improper plantation in unsuitable areas like those without sufficient groundwater storage and established tube wells in places with less water level, etc. Moreover, with the help of the NWSDB and the survey department of Sri Lanka the annual groundwater potential zone maps can be produced and updated for certain areas that are mainly faced with droughts. Focusing on the above-mentioned, future development can give huge job opportunities to the people in this area by introducing new commercial crops and establishing new croplands.

As a recommendation, this analysis can be used to prevent water scarcity and to identify the groundwater potential zones. Hence, this analysis can be used for decision-making about groundwater potentiality. Groundwater can be used for day-to-day work and the potential zones should be used effectively. This study can direct farmers to effective crop cultivation by analyzing the crops and their productivity with the water level, and hybrid crops that match the water level and the client's requirements can also be introduced for the zone.

4. CONCLUSION

In the world, there are many natural resources. Among them, groundwater is one of the most important and valuable water resources. For residential, agricultural, and industrial uses, groundwater resources are significant natural resources. Due to the rising population, more sophisticated irrigation techniques, and industrial use, groundwater demands have significantly increased.

Sri Lanka's dry zone frequently experiences serious drought conditions, and the situation gets worse over time. The Hambantota district, which is in the dry zone, appears to be a severely afflicted area based on groundwater availability. To solve this issue, it is essential to have an effective water management system, to preserve the current surface and groundwater resources, and to recycle the groundwater and surface water waste.

The area under this analysis is the Sooriyawewa DSD because it is located in the Hambantota district and is facing the same issues. Many natural resources can be found in Sooriyawewa DSD, but most of the people there are not well off economically. Drinkable water, as well as all other water resources are critical in this region for a variety of reasons, including household activities, agricultural uses, and ongoing initiatives. As a result, Sooriyawewa DSD is suffering from the same problems. Due to the polluted water, people are also facing several health issues such as the unidentified kidney disease, urinal infections, and considerable effects on their oral health (depositing of calcium on the tooth surface). The presence of heavy metal ions and salts in groundwater can be stated as the main reason for the above health issues. The outcome of this study identifies the groundwater potential zones in Sooriyawewa DSD. The Sooriyawewa DSD's groundwater potential mapping can have a tremendous impact on both the island and the related area.

The scarcity of drinkable groundwater across the most parts of Sri Lanka will cause heavy trouble in the future and groundwater is a vital resource sustaining the home supply of water, irrigated agriculture, and industries. Matters about the potential degradation of the resources, deteriorating water quality, and other risks have been raised due to the massive use of groundwater in the past few decades. Given the public's misunderstanding that groundwater is a limitless water supply and limits in hydrogeologic characterization and understanding of its reaction, groundwater systems are used inefficiently and even wastefully. Consequently, the provision of drinking water is greatly influenced by groundwater supplies.

In this analysis, the main objective was to map the groundwater potential zones in the Sooriyawewa DSD by utilizing GIS and the ability was critical for successful analysis, prediction, and validation. LULC maps, soil maps, rainfall maps, lineament density maps, drainage density maps, slope maps, drainage density, geology, and geomorphology maps were prepared by using ArcGIS and thematic maps were generated. Thematic maps were overlayed and the potential zones of groundwater were obtained. Finally, distribution levels of groundwater potential zones and mapped groundwater potential zones in the Sooriyawewa DSD were identified.

This analysis is highly helpful in preventing water scarcity by identifying the groundwater potential zones in the Sooriyawewa DSD and directing public water distribution projects like tube wells. Furthermore, this investigation can be used for decision-making about groundwater potentiality in Sooriyawewa DSD and further analysis. In

Sooriyawewa DSD identified groundwater potential zones as very low, low, and moderate. According to the results, the 34075Km^2 area coverage is very low class, 174.73Km^2 area is low class, and 14.1875Km^{2}is moderate. As a percentage very low -2%, low -91%, and moderate -7%. Although there are no high-potential zones, there is a significant amount of medium potential. Therefore, groundwater can be used for the day-to-day work and the potential zones should be used effectively. And also, if properly used the identified potential zones can be used for scarcity prevention in the Sooriyawewa DSD. As there is minimal rainfall in Sooriyawewa DSD, the identified potential zones can be used for rainwater harvesting, which can be used properly for future consumption.

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