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# Geographic Information System for evaluation of groundwater and its suitability for agriculture in Marudaiyar basin, Tamil Nadu, India

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## Abstract

In this paper an attempt has been made to understand the groundwater chemistry and its suitability for agriculture through Geographical Information System (GIS) in Marudaiyar basin, Tamil Nadu, South India. Water quality data were collected from the Water Resources Organization, Government of Tamil Nadu. The groundwater quality data consisting of Sodium Adsorption Ratio (SAR), Residual Sodium Carbonate (RSC) and Electrical Conductivity (EC) were drawn for water quality parameters in order to understand their spatial distribution in the basin. Following the water quality evaluation, thematic maps were generated and digitized; spatial analysis and integration were carried out to assess groundwater suitability for agriculture in the basin.

**Keywords :** geographical information system, groundwater, agriculture, marudaiyar basin, water quality.

## INTRODUCTION

Water quality evaluation and preparation of hydrogeochemcial thematic maps are emerging issues in groundwater studies. The hydrogeochemical maps reveal the zones and quality of water that are suitable for drinking, agricultural and industrial purposes. The quality of the water, normally evaluated through water samples, depends upon the factors like geology, soil and other environmental conditions in which the water happens to stay or move and interact with the surface and underground and consequently the presence of different physical, chemical and biological characteristics, will change the water quality. Understanding the chemical composition of groundwater is very important before applying it for agriculture and suitable amendments and measures of groundwater care leads to good results in agriculture. Doneen (1966) had pointed out that no water is unfit for irrigation if it is properly utilized, which is the basic issue for water resources management for irrigated agriculture. Hydro-geochemistry and its relationship to agriculture were described by Kelly (1940), Eaton (1950) and Wilcox (1955). Sivagnanam and Kumaraswamy (1988) had applied the USDA based water classification methodology designed for agricultural purpose in Vaippar river basin, Tamil Nadu, India. In this paper an attempt has been made to understand the groundwater chemistry and its suitability for agriculture purposes through Geographic Information System (GIS) in Marudaiyar basin, Tamil Nadu, India.

## STUDY AREA

Marudaiyar basin, the study area is located in the central part of Tamil Nadu State, India concerning an areal extent of 623 sq. km. It is geographically located between the latitudes 11°02′ - 11°15′ N and the longitudes 78°48' - 79°15′E (Fig.1). Water samples were collected and analysed in 32 observation wells in the study area during 2006 - 2007 (Table 1) and (Fig. 2)).

**Table 1.** Location of observation wells in the study area

| Sl.No | Location of Observation Wells |
|---|---|
| 1 | Pudunaduvalur |
| 2 | Aranarai |
| 3 | Alambadi |
| 4 | Thuraimangalam |
| 5 | Kavulpalayam |
| 6 | Perali |
| 7 | Chittali |
| 8 | Kunnam |
| 9 | Aiylur |
| 10 | Kalpadi |
| 11 | Sirukanpur |
| 12 | Kottari |
| 13 | Kuttur |
| 14 | Killamathur |
| 15 | Ottakovil |
| 16 | Kadugur |
| 17 | Irur |
| 18 | Naranamangalam |
| 19 | Garudamangalam |
| 20 | Kulattur |
| 21 | Nochechikulam |
| 22 | Pappancheri |
| 23 | Valajanagaram |
| 24 | V. Krishanpuram |
| 25 | Pudupalayam |
| 26 | Hasthinapuram |
| 27 | Reddipalayam |
| 28 | Periathirukkonam |
| 29 | Vilangudi |
| 30 | Sundakkudi |
| 31 | Ambapur |
| 32 | Ulliyakkudi |

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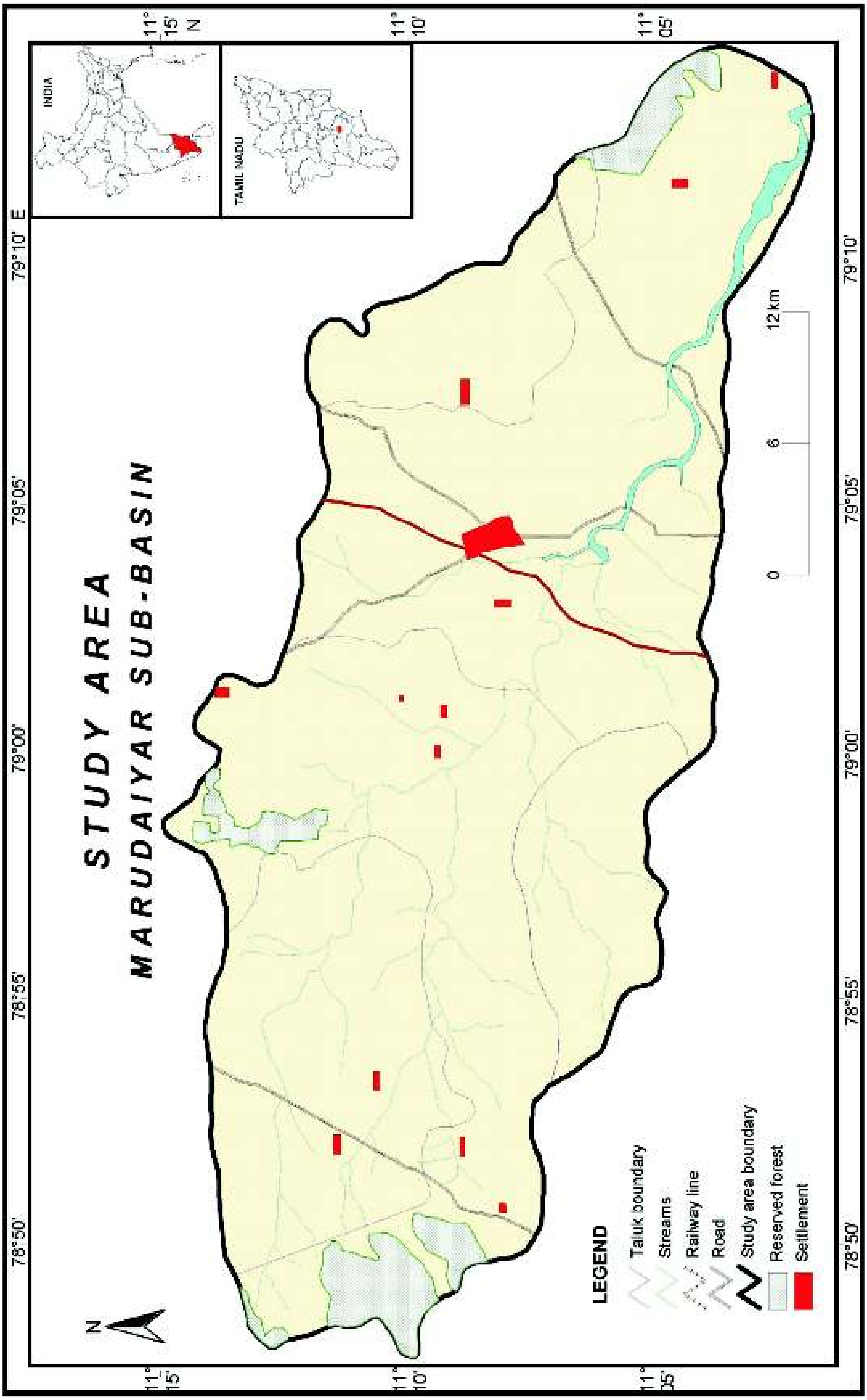


Figure 1. Map of Study Area : Marudaiyar Sub-basin

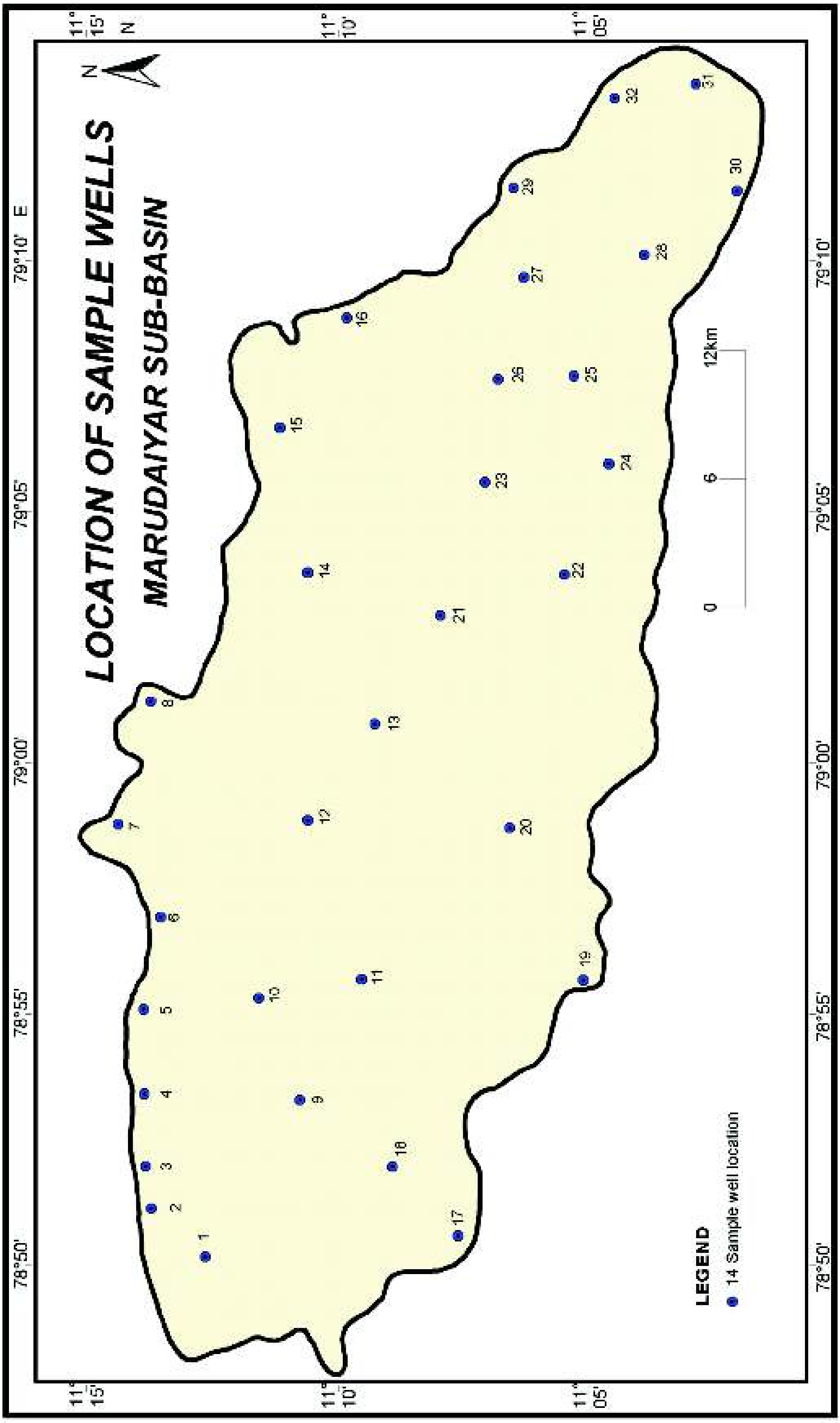


Figure 2. Location of sample wells in the Marudaiyar Sub-basin

The study area is composed of series of plains, valley bottoms, undulating uplands and broken chains of eastern - ghats *viz.*, Pachamalai. The average height of Pachamalai hill is 100 metres. But few of its peaks are above 1020 metres from MSL. The elevation of the basin ranges from 250 to 400 metres. The Marudaiyar basin has its origin from the Pachamalai hills, and it flows in the southeastern direction, passing through the Perambalur, Kunnam, Ariyalur, Udaiyarpalayam and Lalgudi taluks of Perambalur and Tiruchirappalli Districts before joining the Coleroon River. On the northern side, the study area is bounded by Chinnar basin and on the eastern side by Udaiyarpalayam basin. On the southern and western side it is bounded by Nambiyar and Swedhanadhi minor basin, respectively. In the study area, the average annual rainfall ranges from 750 to 1000mm. The area comes under the influence of both the southeast monsoon (June – September) and northeast monsoon (October-December) due to orographic effect. Most of the people in the study area are engaged in agricultural activities and the important crops cultivated in the area include paddy, sugarcane, cotton, groundnut, sorghum, pearl millet, finger millet, red gram and banana.

Geologically, the river basin is mainly occupied by Archaean group of rocks composed of gneisses and charnockites. The Marudaiyar river basin, especially in its eastern part is composed almost entirely of sedimentary rocks especially calcareous rocks (limestone, sandstone, calcareous sandstone etc.,). Alluvium, deposited by the Marudaiyar river is found to occur in the downstream area especially in areas were the river joins the Coleroon River.

## DATABASE AND METHODOLOGY

The study is carried out with the help of three major components: *viz.*, topographic sheets, satellite data and water quality data. They have been considered for the analysis of groundwater suitability for agriculture in the river basin. The maps of drainage density, lineament density and slope maps were prepared from 1: 50,000 scale topographic sheets of the Survey of India (SOI) and different thematic maps of geology, geomorphology and lineament were prepared from remotely sensed data at 1:50,000 scale. Water quality data for the years 1997, 1998 and 1999 were collected from the Water Resources Organization, Government of Tamil Nadu. The groundwater quality data consisting of Sodium Adsorption Ratio (SAR), Residual Sodium Carbonate (RSC) and Electrical Conductivity (EC) were drawn for water quality parameters in order to understand their spatial distribution in the basin. Following the water quality evaluation, thematic maps (TM) were generated and digitized; spatial analysis and integration were carried out to assess water quality suitability for agriculture in the basin.

Different polygons in the aforesaid thematic maps were labeled separately. Unique attributes were assigned for all the features in different thematic maps. The polygons in thematic maps were i). excellent ii). good, iii). moderate and iv). poor, in terms of their importance with respect to groundwater quality. Suitable weights were assigned to each thematic feature after considering their importance. All the thematic layers have been integrated and analysed using a model developed with logical conditions in the GIS. The methodology adopted in the present study is shown below in the form of a flow chart (Fig. 3).

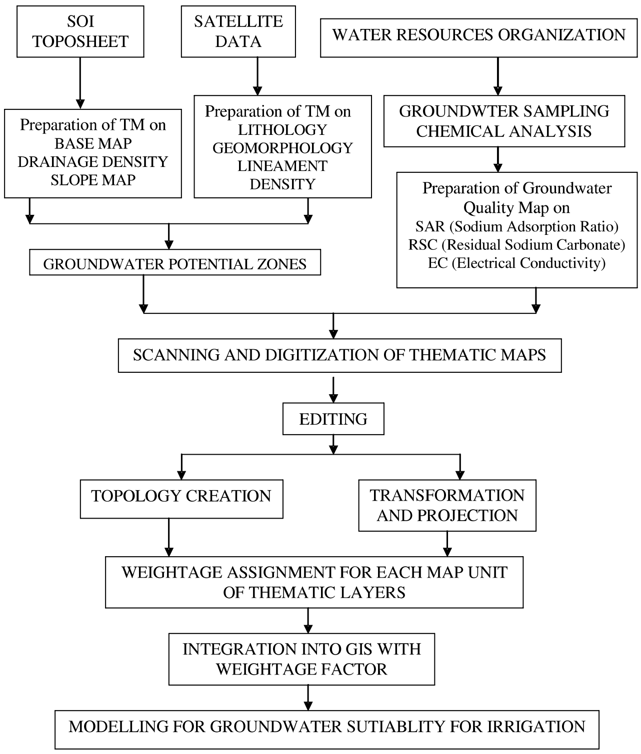


**Figure 3.** Flow Chart Depicting the Methodology for assessing Groundwater Suitability for Irrigated Agriculture.

## RESULTS AND DISCUSSION

After understanding the significance of groundwater quality for irrigated agriculture, the different classes were initially categorized. The feature-based categorizations of different thematic maps and the exact weight assigned to each of the thematic features based on the relative merits and demerits with respect to groundwater quality is given in Table 2. The logical reasoning adopted for categorization and weight assignment for each of the thematic features are as given below.

**Table 2.** Rank and Weightage Assigned for Various Thematic Layers with Respect to Groundwater Quality

| Parameters | Weightage | Class | Rank |
|---|---|---|---|
| Electrical Conductivity (EC in mmhos /cm) | | | |
| <250 | 50 | Excellent | 1 |
| 250 - 750 | 40 | Good | 2 |
| 750 - 2250 | 20 | Moderate | 3 |
| >2250 | 10 | Poor | 4 |
| Sodium Adsorption Ratio (SAR in epm) | | | |
| < 10 | 50 | Excellent | 1 |
| 10 - 18 | 40 | Good | 2 |
| 18 - 26 | 20 | Moderate | 3 |
| > 26 | 10 | Poor | 4 |
| Residual Sodium Carbonate (RSC in epm) | | | |
| < 1.25 | 40 | Good | 1 |
| 1.25 – 2.5 | 20 | Moderate | 2 |
| > 2.5 | 10 | Poor | 3 |
| Groundwater Potential Zones (Weightage values) | | | |
| 240 - 180 | 50 | Excellent | 1 |
| 180 - 120 | 40 | Good | 2 |
| 120 - 60 | 20 | Moderate | 3 |
| < 60 | 10 | Poor | 4 |

**a) Electrical Conductivity (EC)**

Conductivity is the measure of capacity of a substance to conduct the electric current. It is otherwise defined as reciprocal of resistance. As most of the salts in water are present in their ionic forms and capable of conducting current, conductivity is an indirect indicator of dissolved solids and a good indicator in assessing groundwater quality. The criteria for evaluation of the study area based on EC and the number of wells that fell under different water quality classes based on EC are give Table 3.

From the EC values collected for 32-observation samples in the study area, it was observed that the EC ranged between 373 micro mhos/cm (in Naranamangalam) and 2412 micro mhos/cm (in Irur) during the pre-monsoon period. During the post-monsoon period the EC was in the range between 131 micro mmhos/cm (in Kadagur ) and 2623 micro mmhos/cm (Kuttur).

Both the seasons had good, moderate and poor water classes based on the electrical conductivity. The excellent water classes are observed in the post monsoon season which is at Kadagur and Kulathur area.

**b) Sodium Adsorption Ratio (SAR)**

The sodium hazard in irrigation water is expressed by the Sodium Adsorption Ratio (SAR) which was estimated based on Karanth's (1987) formula. Based on the values, isolines were drawn to understand the spatial pattern of SAR ratio in the study area. The classification of irrigation waters with respect to SAR is based primarily on the effect of exchangeable sodium on the physical condition of the soil. Sodium sensitive plants, may however, suffer injury as a result of sodium accumulation in the plant tissue, when exchangeable sodium values are lower than those cause deterioration of the physical condition of the soil. The Sodium water classification based on SAR proposed by Richards (1954) and the number of wells that fell under different water quality classes based on SAR are given Table 4.

**Table 4.** Irrigation Water Classification based on Sodium Adsorption Ratio

| Sodium Adsorption Ratio (SAR in epm) | Water class | No. of Water Samples (Wells) | |
|---|---|---|---|
| | | Pre-monsoon | Post-monsoon |
| Less than 10 | Excellent | 32 | 30 |
| 10 to 18 | Good | - | 2 |
| 18 to 26 | Permissible | - | - |
| More than 26 | Unsuitable | - | - |

In the study area during the pre-monsoon season, the SAR was found to range from 0.030 epm (in Kalpadi) to 4.585 epm (in Aranarai). Further more, during the pre-monsoon period, the concentration of SAR was in the "excellent" water class (<10 epm) in all the sample wells. The central part of the study area the values were

**Table 3.** Irrigation Water Classification Based on Electrical Conductivity

| Classes of Water | E C (micro mhos/cm) | No. of Water Samples (wells) | | Relationship to Salinity |
|---|---|---|---|---|
| | | Pre-monsoon | Post-monsoon | |
| Excellent | <250 | 0 | 2 | Water of low salinity and is generally composed of higher proportions of calcium, magnesium and bi-carbonate ions |
| Good | 250-750 | 11 | 11 | Moderately saline water, having varying ionic concentrations |
| Moderate | 750-2250 | 18 | 17 | High saline waters consisting mostly of sodium and chloride ions |
| Poor | >2250 | 3 | 2 | Waters containing high concentrations of sodium bi-carbonate and carbonate ions and have high pH |

from 1.0 to 2.0 epm. In the remaining parts of the study area had values of above 2.0 epm.

In the post-monsoon period, the concentration of SAR was ranging from 0.248 epm (in Kadagur) to 13.598 epm (in Kuttur) of the study area. Thirty out of thirty two samples fell under in "excellent" water type (<10) during this season. The "good" water class (10-18) was recorded in Chittali and Kuttur during the post-monsoon period.

**c) Residual Sodium Carbonate (RSC)**

Karanth (1987) has suggested that waters having carbonate and bicarbonate ions in excess of calcium and magnesium will lead to much greater alkaline formation than is indicated by its SAR and thereby decreasing the soil permeability. The carbonate and bicarbonate hazards in water samples can be estimated based on RSC formula. Kelly (1940), Eaton (1950), Wilcox (1955) and Handa (1979) have proposed certain indices to find out the alkali hazards and Residual Sodium Carbonate (RSC) which could be used as criteria for finding out the suitability of irrigation waters (Table 5).

**Table 5.** Irrigation Water Classification based on Residual Sodium Carbonate

| Residual Sodium Carbonate (RSC) in meq/L | Water class | No. of Water Samples (Wells) | |
|---|---|---|---|
| | | Pre monsoon | Post monsoon |
| <1.25 | Good | 27 | 26 |
| 1.25 – 2.5 | Doubtful | 3 | 5 |
| >2.5 | Unsuitable | 2 | 1 |

In evaluating the RSC, if carbonate and bicarbonate are less than calcium and magnesium, then the results would be negative which is generally good for agriculture and if the value exceeds 2.5 meq/L, it certainly affects the soil and as a consequence, the crop yield would be poor (Nordstrom, 1982). In the study area, RSC ranged between -14.50 meq/L (in Kunnam) and 8.30 meq/L (in Pudupalayam) during pre-monsoon and -27.60 meq/L (in Chittali) and 4.60 meq/L (Pudupalayam) during the post-monsoon period (Table 5). The "good" quality water was found in about 87.5 per cent of the sampling locations in pre-monsoon and 81.25 per cent sampling locations in post-monsoon period of the study area. Eight samples were found to be "doubtful" water class for irrigation, which included Naranamangalam, Nochechikulam and Pappancheri locations during pre-monson and Aranarai, Kavulpalayam, Pappancheri, Valajanagaram, and V.Krishnapuram locations during post-monsoon. The samples from Pudupalayam were of "unsuitable" water class during both seasons and the sample from Irur was unsuitable only during the pre-monsoon season.

**d) Groundwater Potential Zones**

GIS based groundwater prospects for drinking and irrigation purposes were investigated by many authors (Hong-IL Ahn and Hyo-Taek Chon, 1999; Kumar *et al.*, 2000; Murthy, 2000; Gogu *et al.*, 2001; Arora and Goyal, 2002; Zhen and Jayant, 2002; Erhan *et al.*, 2004; Satti and Jacobs, 2004). To demarcate different groundwater potential zones, all the thematic layers were integrated with one another according to their importance with respect to groundwater prospects through GIS union concept. The sequence adopted in the present exercise are as follows: i) geology, ii) geomorphology, iii) drainage density, iv) lineament density, v) slope and vi) iso-apparent resistivity with respect to depths in metres.

In the present study, the delineation of groundwater potential zones were made by grouping the polygons of the integrated layer, into different potential zones, such as excellent, good, moderate and poor. Instead of just dividing the maximum and minimum values into different categories, which does not have any logical reasoning, a model has been developed using relevant logical conditions through Geographical Information System. Table 6 gives the integrated groundwater categories after adding weightages to the parameters. The upper and lower limits of the weightages derived for demarcation of the groundwater prospecting areas are also given.

**Table 6.** Groundwater Categories after Integration

| Categories | Weightage values |
|---|---|
| Excellent | 240 – 180 |
| Good | 180 – 120 |
| Moderate | 120 – 60 |
| Poor | Less than 60 |

Accordingly "excellent" prospect areas are delineated by grouping the polygons with the weightage ranging between 240 and 180. The other categories were "good "(180 to 120), "moderate" (120 to 60) and "poor" prospective zones (polygons), which have the weightage factor of less than 60. By utilizing the above discussed model a map showing different groundwater potential zones of the study area was prepared (Fig. 4).

**Integrated Mapping**

The spatial integration method for water quality mapping was carried out using overlay analysis in Arc GIS software. Groundwater quality for irrigation is normally evaluated by using the traditional classification methods using EC, RSC, SAR with groundwater potential zones. The three thematic layers with "good", "moderate" and "poor" classes were integrated using the overlay and spatial analysis modules of the software.

**Groundwater suitability for agriculture: GIS Approach**

Anbazhagan and Nair (2004) have developed GIS based groundwater quality mapping and geochemical analysis to indicate the level of quality for drinking and irrigation purposes. We applied the same procedures for assessing groundwater suitability for agriculture. The groundwater suitability for irrigated agriculture was made by grouping the polygons of integrated layers, into different potential zones, such as "good", "moderate" and "poor" . Instead of just dividing the maximum and minimum values into different categories, which has limited logical reasoning, a model has been developed using relevant logical conditions through Geographical Information System. Table 7 gives the integrated groundwater categories for the pre and post-monsoon seasons of the study area after adding the weightage in different thematic layers derived for demarcation of the groundwater prospecting areas.

**Table 7.** Groundwater Suitability Categories After Integration, at the Study area during pre and post-monsoon seasons

| Categories | Weightage values for Pre- monsoon | Weightage values for Post-monsoon |
|---|---|---|
| Good | 80 – 40 | 45 – 15 |
| Moderate | 40 – 20 | < 15 |
| Poor | Less than 20 | - |

After adding all the scores the maximum weightage got was 80. "Good" prospect was delineated by grouping the polygon which have weightage values of 80 to 40, "moderate" for weightage values of 40 to 20 and "poor" prospective zone as polygons which are having the weightage factors less than 20 in pre-monsoon. During the post-monsoon groundwater suitability fell in "good" (with weightage values of 45-15) and "moderate" (with weightage values of Less than 15) categories only. By utilizing the above-discussed model groundwater suitability for irrigated agriculture of the study area for pre and post-monsoon seasons were prepared and shown in Figs. 5 and 6.

## CONCLUSION

The integration and analysis of thematic layers depicting various zones of groundwater potential and groundwater quality using Arc GIS software has helped to demarcate the study area into various zones (as "good", "moderate" and "poor") based on their ground-water suitability for irrigated agriculture (for both pre-monsoon and post-monsoon seasons).

The resulting map from the GIS analysis for pre-monsoon season is shown in Fig. 5. From the figure it is evident that during the pre-monsoon season, areas which are highly suitable are found in patches that are well scattered in various parts of the study area. However the concentration of such patches are found more in the central parts of the study area covering the villages of Kottari, Kuttur, Kulattur and Nochechikulam. A large patch of the same category is found in the eastern most part of the study area in and around the villages of Hasthinapuram, Reddipalayam, Periathirukkonam, Vilangudi, Sundakkudi, Ambapur and Ulliyakkudi, while a few relatively large patches are found on the western part of the study area. During this season, the areas where groundwater is poorly suitable for irrigated agriculture are found restricted to a few small patches on the western part of the study area in and around the villages of Pudunaduvalur, Alambadi, Irur and Naranamangalam. In the rest of the parts the groundwater is moderately suitable. The areal extent of the areas, which are highly, moderately and poorly suitable for irrigated agriculture during the pre-monsoon season, occupy about 182, 432 and 11 sq.kms respectively. In terms of percentage these categories occupy about 29.12, 69.12 and 1.76 per cent of the study area, respectively.

During the post-monsoon season most of the parts of the study area are found highly suitable for irrigated agriculture (Fig.6), which includes Ambapur, Sundakkudi, Villangudi, Ulliyakkudi, Hasthinapuram, Valajanagaram, Pappancheri, Kulattur, Kottarai, Aiylur, Perali and Thuraimangalam. During this season, the areas where groundwater is moderately suitable for irrigated agriculture are found restricted to a few small patches on the western part of the study area in and around the villages of Pudunaduvalur, Alambadi, Irur and Naranamangalam. During the post-monsoon season the areal extent of the highly suitable and moderately suitable zones for carrying out irrigated agriculture occupy about 569 sq.km and 56 sq.km, respectively, of the study area. In terms of percentage these categories occupy about 91.04 and 8.96 per cent of the study area, respectively.

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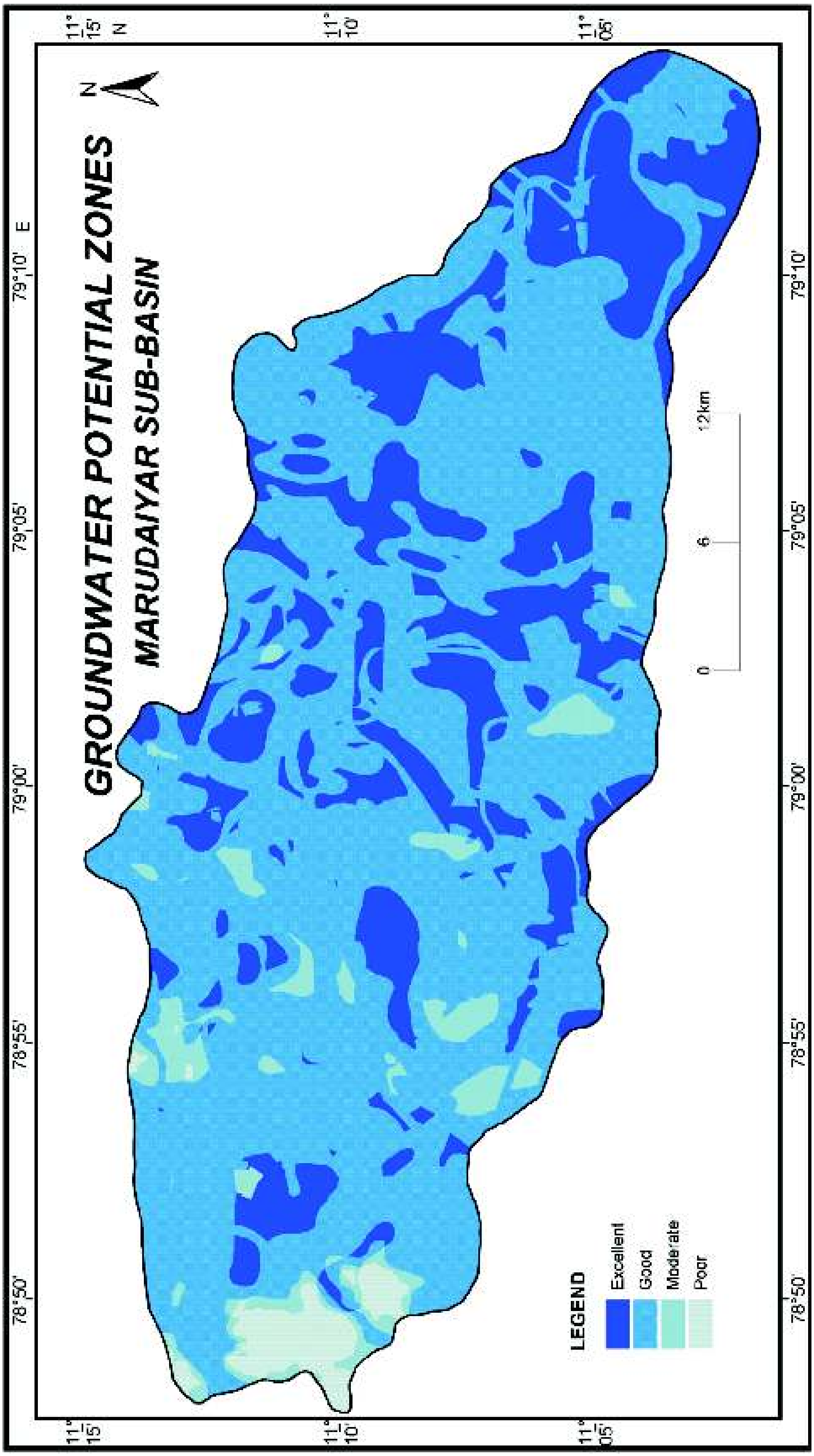


**Figure 4.** Groundwater potential Zones of Marudaiyaar Sub-basin

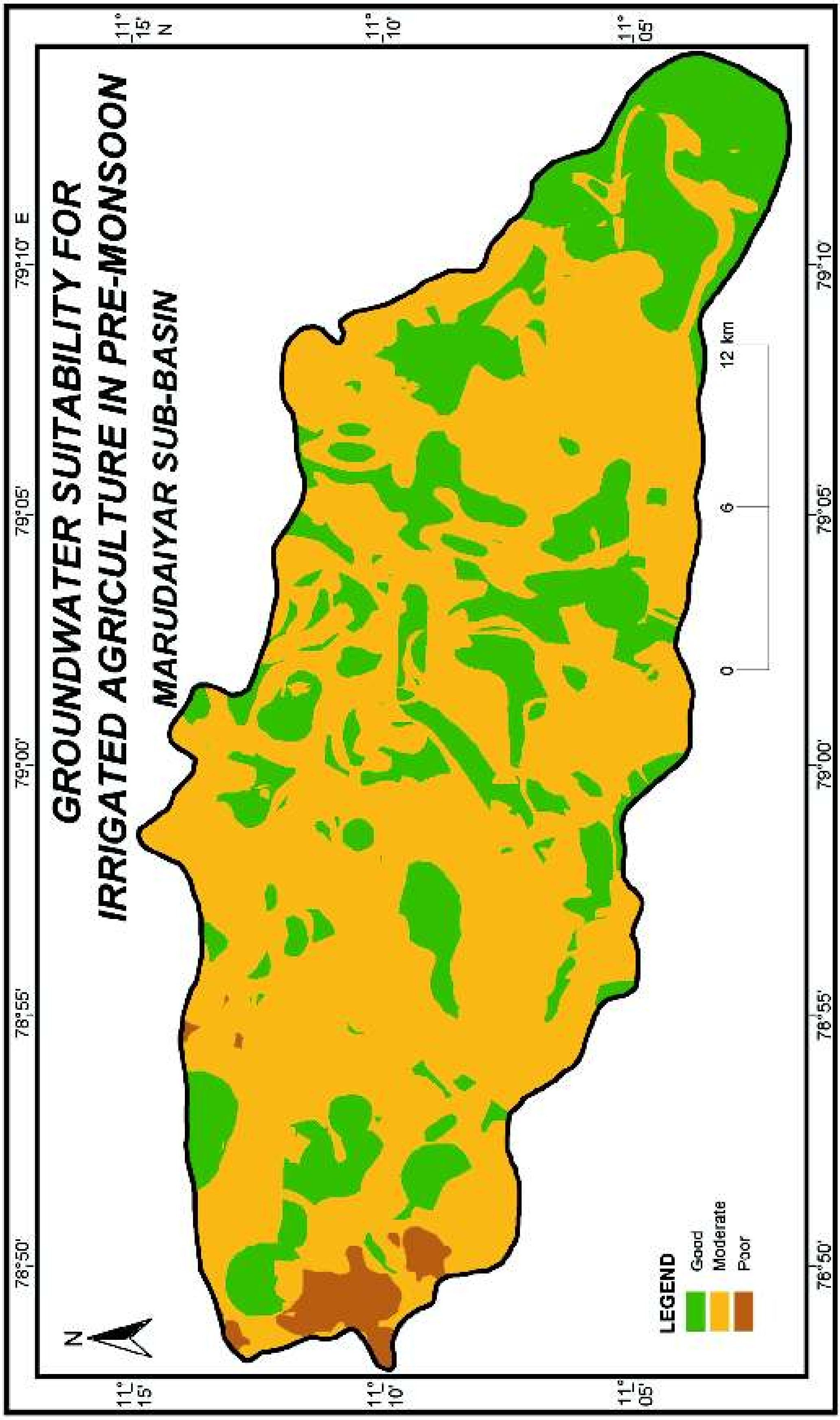


**Figure 5.** Groundwater suitability for irrigated Agriculture in Pre-monsoon in Marudaiyaar Sub-basin

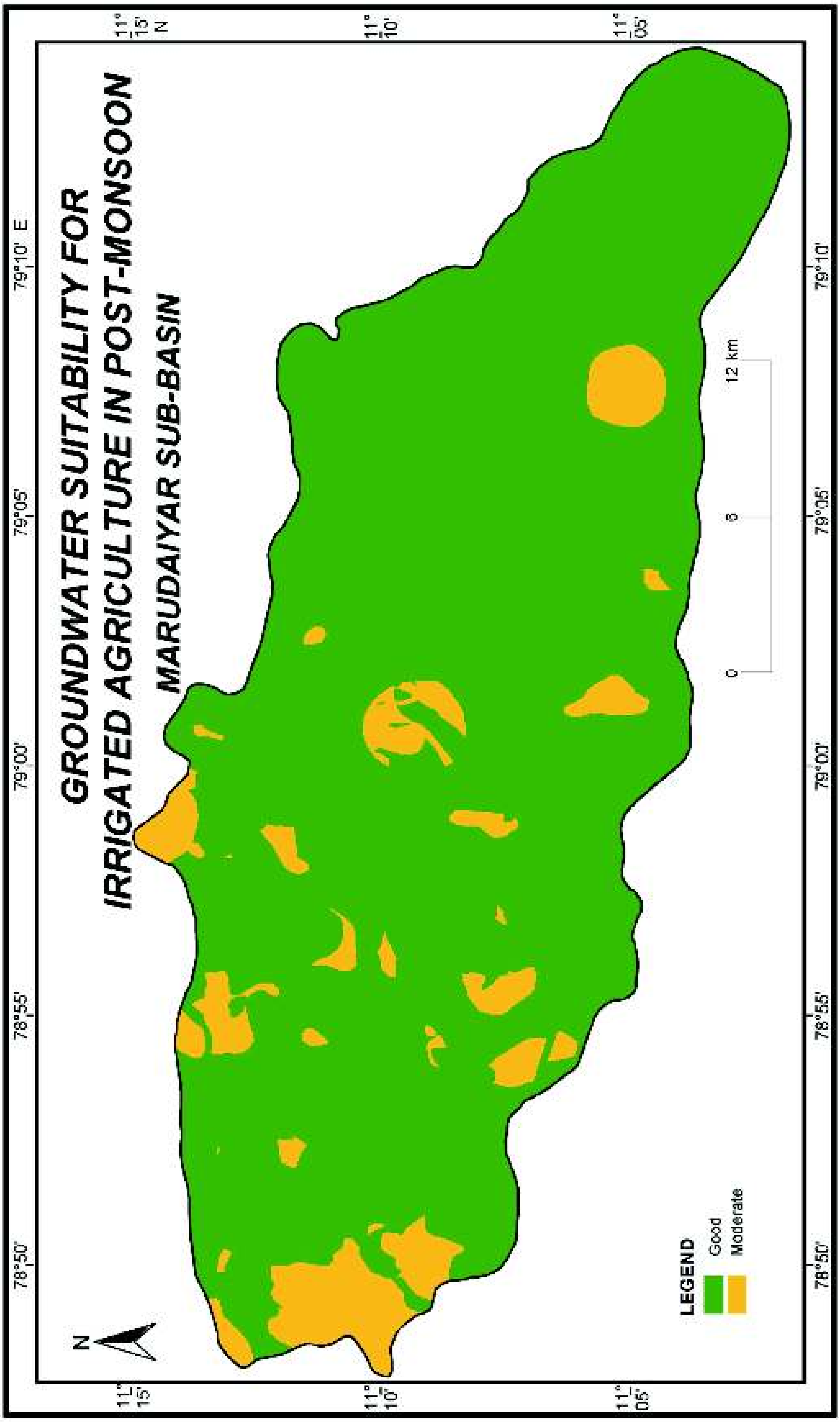


**Figure 5. Groundwater suitability for irrigated Agriculture in Post-monsoon in Marudaiyaar Sub-basin**

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