Cloud Publications
International Journal of Advanced Remote Sensing and GIS
2020, Volume 9, Issue 1, pp. 3264-3288
ISSN 2320 – 0243, Crossref: 10.23953/cloud.ijarsg.457

Research Article

Environmental-economic Approach to Analysis of Agriculture Land Suitability Using Spatial Modelling

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Publication Date: 20 April 2020

DOI: https://doi.org/10.23953/cloud.ijarsg.457

Abstract Agriculture is a predominant factor economic and Gross Domestic Product (GDP) for any country. However, the agriculture land was changed into urban area and built-up land due to population growth and rapid urbanization. For last two decades, 25% of agriculture lands were converted into other purposes, which lift the economic value for land using and impact the ecosystem economic service value. While comprehensive and continuous valuation of identifying suitable economic and feasible agricultural land are vital for agriculture planning and maintain food security, they typically time consuming and exclusive field studies. We demonstrated using of spatial data to identify the suitable agricultural land integrating economic, physical, biological and chemical parameters. We identified the suitable and economical agriculture land during 2019-2020 in Thanjavur district in Cauvery delta protected agricultural zone. We used spatial analysis to understand the agriculture suitability land into three categories as highly suitable, moderately suitable and low suitable. Our study identifies 1027.2 sq.km areas of Peravurani, Thanjavur, Thiruvaiyaru, Papanasam, Thiruvidaimaruthur are highly suitable for pearl millet cultivation. The 754.12-sq.km areas of Orathanadu, near Thanjavur and near Pattukkottai are suitable for maize. The 1896.28-sq.km areas of Pattukkotai, Peravurani and the small portion of Thanjavur and Papanasam are suitable for sorghum cultivation. The 754.12-sq.km highly suitable areas of Thanjavur and near Orathanadu are suitable for rice cultivation. The 178.42 sq.km areas of Orathanadu are mainly high suitable for cotton. The 745.12-sq.km areas of Thanjavur and near Orathanadu are highly suitable for pulses. The 712.19-sq.km areas of Peravurani and Thanjavur are more suitable for sesame cultivation. Our results provide information to economist, agriculture planning department and urban planners for appropriate methodology to identity the agricultural land.

Keywords *Remote Sensing; GIS; Economic Value; Agriculture; Land suitability; Physical, Chemical and Biological parameters; Ecosystem services*

1. Introduction

Agriculture is a predominant factor economic and Gross Domestic Product (GDP) for any country (Palaniswami, Gopalasundaram and Bhaskaran, 2011). However, the agriculture lands were changes into urban area and built-up land due to population growth and rapid urbanization (Mohammad Shah Nawaz Khan and Mohd. Mazhar Ali Khan, 2014). The quality of agriculture land various depends on the physical, chemical and biological parameters of the soil (Appala Raju, 2015). The economic value of the productive lands associated with the variation of these parameters. However, due to the conversation of land and anthropogenic activities reduces the quality of these parameters influences the economic value of agriculture land (Gizachew Ayalew, 2015).

The investigation of the landuse and landchanges associated with agriculture land changes is momentously increasing significantly, as human activities transform ecosystem in urban and urban near rural land (Jadab Chandra Halder, 2013). Besides, the greatest level of a population has been increasing in the developing countries (Jadab Chandra Halder, 2013). By 2030, world's population is expected to increase by 72%, though landuse of cities of 100,000 could upsurge by 175% (Appala Raju, 2015). The surpassing expansion of city causes urban sprawl that is an extension of settlement decreases the agriculture land, water bodies, and forestland. The study on agriculture land supports different fields of science such as agriculture planning, landscape architecture studies, urban planning, land-use planning, economics and ecosystem services (Jadab Chandra Halder, 2013).

The developing country like India, the people from every part of the villages move towards the cities for better social life, education and income. The increasing population of cities directly consequences of land-cover and land-changes (Jadab Chandra Halder, 2013). High growth of population causes land transformation, land scarcity and deforestation (Jadab Chandra Halder, 2013). The development of city consequences the movement of urban and rural poor onto bordering lands of cities (Appala Raju, 2015). The great movement of urban poor and extension of cities and sudden development of industries and IT sectors cuts of the bordering productive agriculture land, encroachment on water bodies and transformation of wild lands (Jadab Chandra Halder, 2013). There is an essential of greater attention on the urban growth of emerging cities in India (Gizachew Ayalew, 2015). India faces major problems of urbanization and population growth are declining agriculture land, urban sprawl, air pollution, housing, overcrowding, encroachment, slums, disposal of waste, increasing settlements, water scarcity, water pollution and sewage problems (Jadab Chandra Halder, 2013). The urbanization also leads to various environmental impacts, such as higher energy utilization, disturbance of diversity of species, flood risk and ecosystem fragmentation (Gizachew Ayalew, 2015). The predictable growth of urban sprawl, agriculture land suitability and ecosystem services aid to provide better urban planning and eco-friendly cities without major consequence (Gizachew Ayalew, 2015). Meanwhile, the greater dimension of measurement for accessing and monitoring urban sprawl and ecosystem services associated with agriculture land is always needed. The availability of remotely sensed data always gives greater extent to improve the agriculture land, urban modeling, urban landscape pattern analysis (Gizachew Ayalew, 2015), urban growth (Jadab Chandra Halder, 2013) and urban sprawl studies (Jadab Chandra Halder, 2013).

The spatial and physical characteristic of urban and agriculture land features patterns and its form are quantified using spatial metrics. Additional modeling based on the spatial metrics would help in evaluating future variations in urban and agriculture land. These indices measurable can be obtained by computing directly from thematic maps. Recent studies landscape urban model and analysis have employed from spatial metrics and this term called as landscape metrics, which is derived from landscape ecology. These improved studies on landscape feature can facilitate to integrate the physical structure of a landscape, urban and agriculture land situation, and development. However, the precision and validation of these landscape metrics in the urban model can be achieved from spatiotemporal pattern examination and land suitability prediction.

Globally, different studies on urban growth pattern analysis associated with agriculture land suitability and model were achieved but the developing country like India has a limited examination on rapid urbanization. India is one of the fast growing urban in last three decades has resulted in declining agriculture land. Thus, the urban planners need to understand the spatiotemporal changes with addressing these environmental problems and ensure to provide the basic infrastructure and facilities without a disturbing ecosystem.

The present study focused on suitability analysis of economic and parameter based agriculture land for future land-use allocation. Land evaluation can be predominantly based on soil resources inventories commonly called soil survey (Palaniswami, Gopalasundaram and Bhaskaran, 2011). For the purpose of maintaining and developing agricultural land use at a delta region on spatially (Mohammad Shah Nawaz Khan and Mohd. Mazhar Ali Khan, 2014), it is avital to identify the levels and geographic patterns of biophysical constraints for the purpose of land suitability (Appala Raju, 2015). Land suitability analysis is a prerequisite for sustainable agricultural practices (Gizachew Ayalew, 2015). It can be evaluated based on the parameters of physical and chemical characteristic (Appala Raju, 2015). Land suitability is a function of crop requirements and soil/land characteristics (Jadab Chandra Halder, 2013). Thus, the physical and chemical parameters can be measured and tested in the laboratory (Joseph Kihoro, Njoroge J. Bosco and HunjaMurage, 2013). By matching the land characteristics with the crop, requirements that can be analyzed suitability of land (Joshua Jonah Kunda, Anyanwu Nneoma C. and Ahmed Abubakar Jajere, 2013). The main objective of this paper is to create the physiographic map, which is used to identify the soil physical and chemical characteristics to classify the suitable land for different crop agriculture.

2. Study Area

The study area is Thanjavur district, which has a seven taluks such as Kumbakonam, Thiruviyaru, Papanasam, Thiruvidaimaruthur, Orathandu, Pattukkottai and Peravurani (Figure 1). It is bounded by North latitude 10^{0}08' to 11^{0}12' and West longitude 78^{0}48' to 79^{0}38' on the northeast by Nagapattinam district, on the east by Thiruvarur district, on the south by Bay of Bengal on the west by Pudukkottai district and the north by river Kollidam (Khwanruthai Bunruamkaew and Yuji Murayama, 2012). The district lies at the Cauvery delta region, the most fertile region in the state. The Cauvery River and its tributaries irrigate the district (Lefteri DUSHAJ et al., 2009). The climate condition is tropical with average annual rainfall of 938 mm and temperature usually ranges 25-35^{0}C. Thanjavur district had a population of 2,405,890 (Malay Kumar Pramanik, 2016).

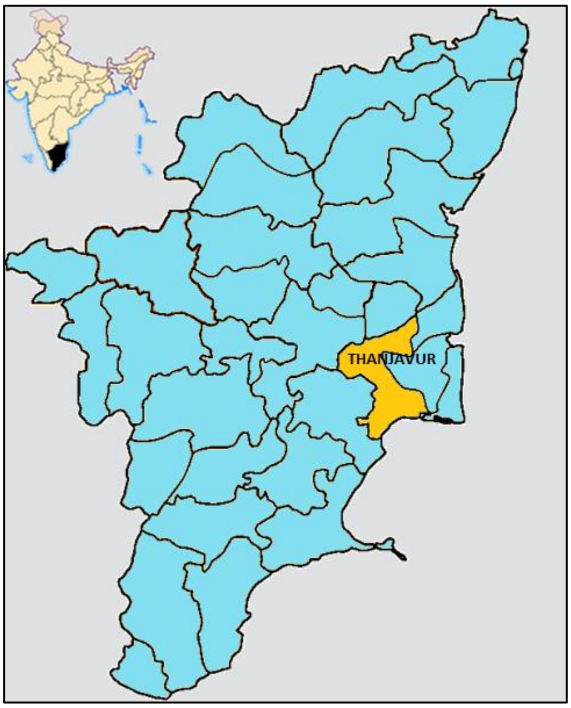

Figure 1: *Map shows the study area, Thanjavur district*

3. Methodology

The Figure 2 depicts the flowchart, which has the methods to generate the socio-economic land suitability for agriculture. There are 20 samples collected from the study area. The soil samples are collected using the GPS instrument.

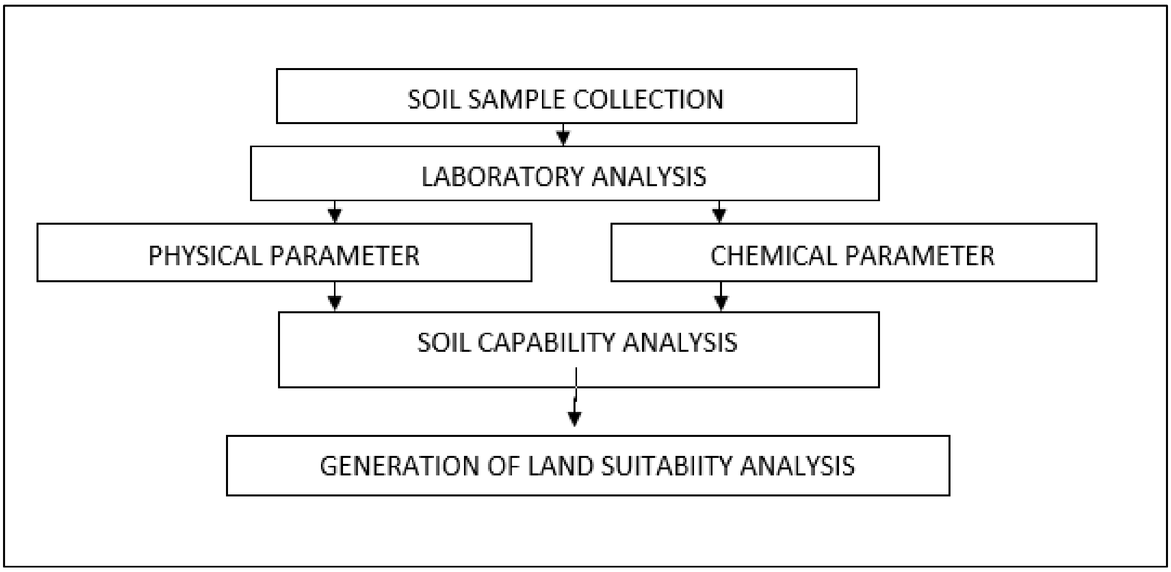

Figure 2: *Flow chart of Land suitability*

3.1. Laboratory Analysis

The collected samples from the specific area are analyzed in the laboratory, which provided the numerical data from the soil parameters as shown in the Table 1. The physical land properties of the study area are evaluated, including the soil texture and water holding capacity. The chemical properties of soil like pH, EC, Potassium, Phosphorus, Organic Carbon and Nitrogen are also taken for soil site suitability analysis.

Table 1: *Numerical data from the Laboratory Analysis*

NAME	TEXTURE	pH	WATER HOLDING CAPACITY	EC	OC	N	P	K
Vallam	SL	7.2	27.396	0.7	0.91	127.4	9	265
Nanjikottai	SL	7.9	53.078	0.74	0.96	144.2	4.51	245
Punnainallur	SL	7.2	56.675	0.66	0.88	130.2	3.85	245
Soorakkottai	L	7.7	43.671	0.88	0.97	134.2	8.5	270
Ullur	L	7.8	18.05	0.7	0.85	128.8	5.75	310
Darasuram	SCL	7.5	23.407	0.72	0.88	130.2	3.85	295
Sathyamangalam	SL	8.1	31.309	0.89	0.97	112	4.5	270
Poondi	SL	6.9	24.201	0.19	0.58	110	5.5	300
Thirupuvanam	SL	6.1	22.51	0.38	0.55	125.2	6.7	288
Madukkur	L	7	25.357	0.25	0.78	140.8	8.55	278
Alathur	L	7	24.01	0.35	0.72	123.5	4.8	340
Pattukkottai	L	7.5	61.851	0.3	0.95	128.5	7.5	325

Peravurani	L	7.4	50.321	0.3	0.85	138.7	9.1	312
Ambalapattu	L	7.3	22.3	0.63	1.27	203	5.25	295
Kanjanur	SCL	8.2	32.654	1.1	0.87	130.2	5.35	265
Ullikadai	SCL	7.5	31.885	0.19	0.85	140.3	5.83	320
Narasingampettai	SCL	8.2	31.885	0.79	0.82	124.6	6	255
Nallavanniyankudikadu	SL	7.1	15.545	0.8	0.95	126	8.5	315
Sendakadu	L	7.8	26.341	0.3	0.85	135.2	7.5	325
Kurungulam	L	6.7	41.11	0.6	0.8	138.7	9.1	312

3.2. Land Suitability Analysis

Land suitability analysis has been performed by the assessment method to assess land suitability for an existing and potential uses. The soil suitability can be mainly analyzed based on the physical and chemical characters of soil (Martine Nyeko, 2012). By using overlay analysis function, the suitability index can be formed for crop requirement (Mohammad Reza Yousefi and Ayat Mohammad Razdari, 2015). Then land characteristics can be evaluated for grouping of specific areas of land in terms of their suitability for agricultural usage as shown in the Table 2. Regarding land suitability, other factors can also be considered in the account such as economics, requirements, farmer access, water and energy access, conflicting and complementary land uses.

Table 2: *Agriculture Land Suitability Criteria*

MAP LAYER	AGRICULTURE LAND SUITABILITY CRITERIA
Soil	Clayey soil Loamy Soil
pH	6.9 to 7.2 - Highly suitable 7.2 to 7.5 - Moderately suitable 7.5 to 8.1 – Low suitable
Electrical conductivity	0.19 to 0.48 – Highly suitable 0.48 to 0.78 – Moderately suitable 0.78 to 1.0 - Low suitable
Organic Carbon	0.55 to 0.75 – Highly suitable 0.75 to 0.85 – Moderately suitable 0.85 to 1.26 – Low suitable
Nitrogen	140 to 171– Highly suitable 110 to 140 – Moderately suitable 171 to 200 – Low suitable
Phosphorus	3.85 to 5.95 – Highly suitable 5.95 to 6.9 – Moderately suitable 6.9 to 9 –Low suitable
Potassium	245 to 271 – Highly suitable 271 to 308 – Moderately suitable 308 to 340 Low suitable
Water Holding Capacity	33 to 48 – Highly suitable 15 to 33 – Moderately suitable 40 to 60 – Low suitable
Texture	Sandy Clay Loamy – Highly suitable Sandy Clay – Moderately suitable Loamy – Low suitable

4. Results and Discussions

The physical and chemical properties of the land are major determinants for crop suitability of agriculture land. The physical land properties of the study area are evaluated, including the soil texture and water holding capacity. The chemical properties of soil are also evaluated such as pH, EC, Potassium (K), Phosphorus (P), Organic Carbon (OC) and Nitrogen (N) that are also taken for soil site suitability analysis. Land suitability index has been calculated by applying the overlay analysis function with crop requirement and land characteristics involving the evaluation. Then the grouping of specific areas of land in terms of their suitability for defined agricultural use. The suitability land categorized into highly suitable, moderately suitable and low suitable.

4.1. Sample Collection

The soil sample collection is the most important step in any nutrient/soil amendment management program. Soil sampling should reflect tillage, past soil alteration placement, cropping pattern, soil type, old field boundaries.

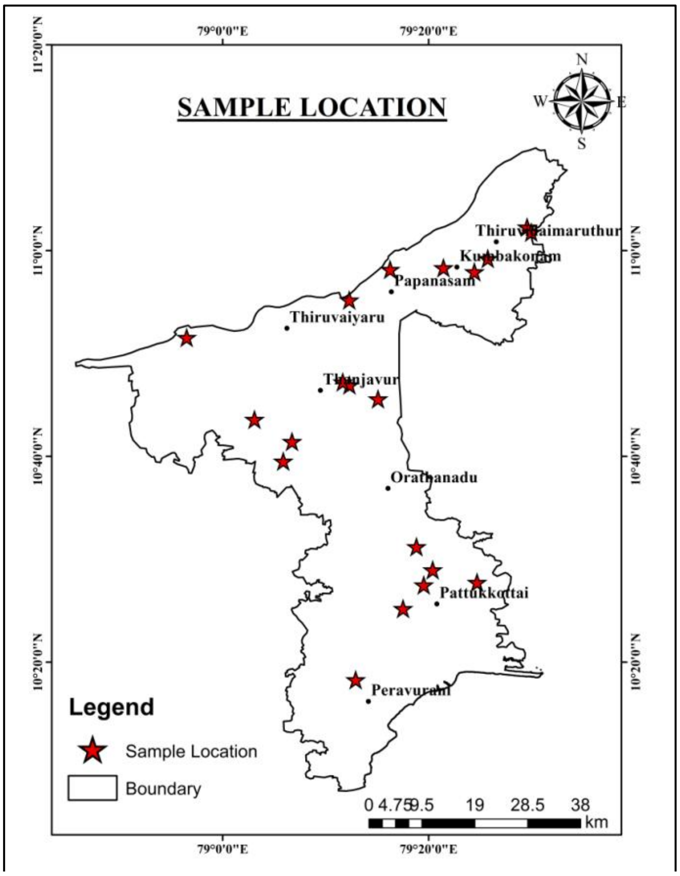

Figure 3: *Sample Location Map*

The soil samples are collected from the various area based on the soil type. The position of sample location is determined using GPS as shown in Figure 3. As of total 20 samples are collected from the study area.

4.2. Generation of Thematic Maps of Soil Parameters

Thematic maps were generated for each of the soil physical and chemical parameter using IDW interpolation provided in Arc GIS 10.2 software. Inverse Distance Weighted (IDW) interpolation determines cell values using a linearly weighted combination of a set of sample points. The weight is a function of inverse distance. IDW lets the user control the significance of known points on the interpolated values, based on their distance from the output point.

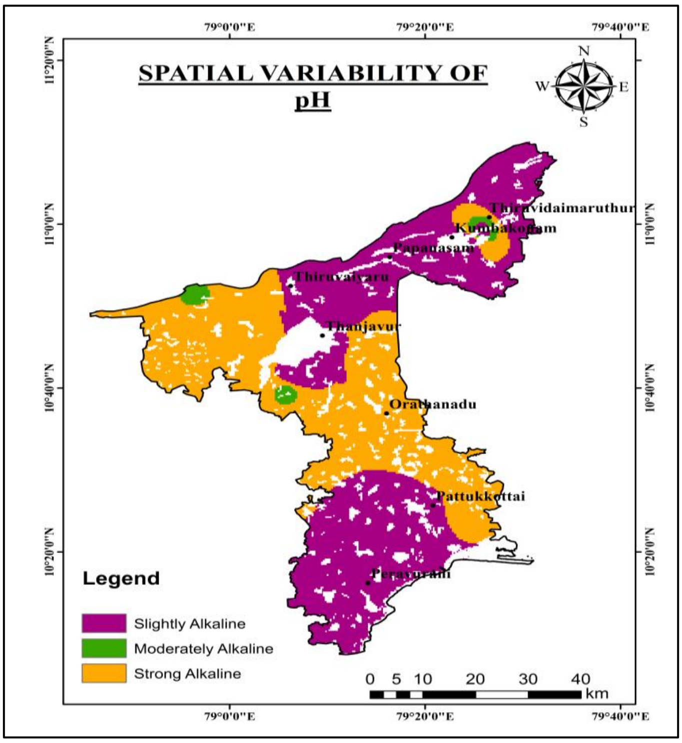

Figure 4: *Spatial variability of pH Map*

The purple color shows the slightly alkaline it is mainly suitable for the agricultural land and its covered area from 1477.7 sq.km as shown in Figure 4.

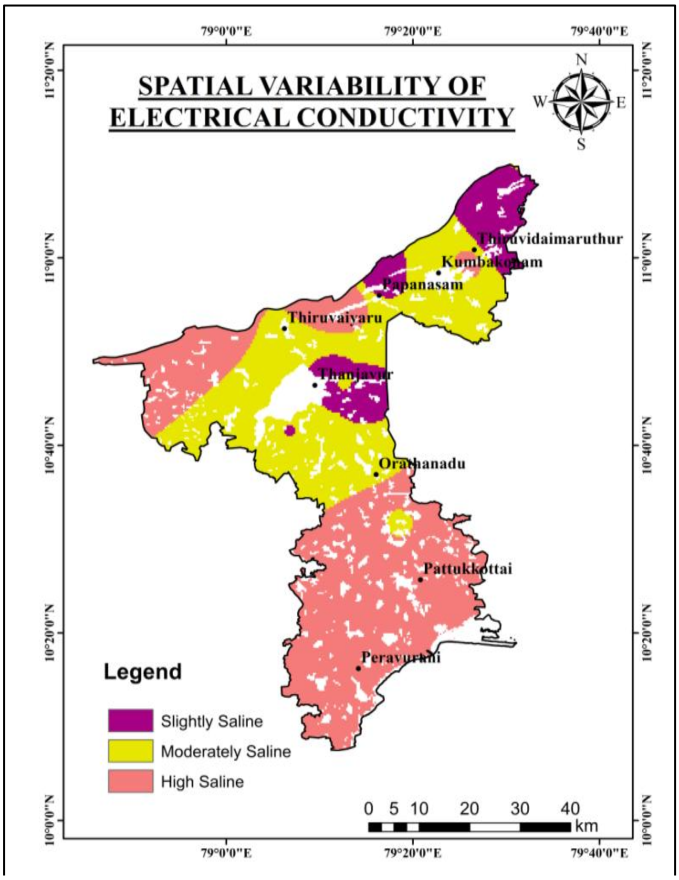

Figure 5: *Spatial variability of Electrical Conductivity Map*

The ranges slightly saline consider from the agricultural land. The slightly saline areas present in the purple color from the map its covered area from 401.18 sq.km as shown in Figure 5. The range of EC is .48 to .78 highly saline and .19 to .48 is slightly saline and .78 to 1.08 is moderately saline.

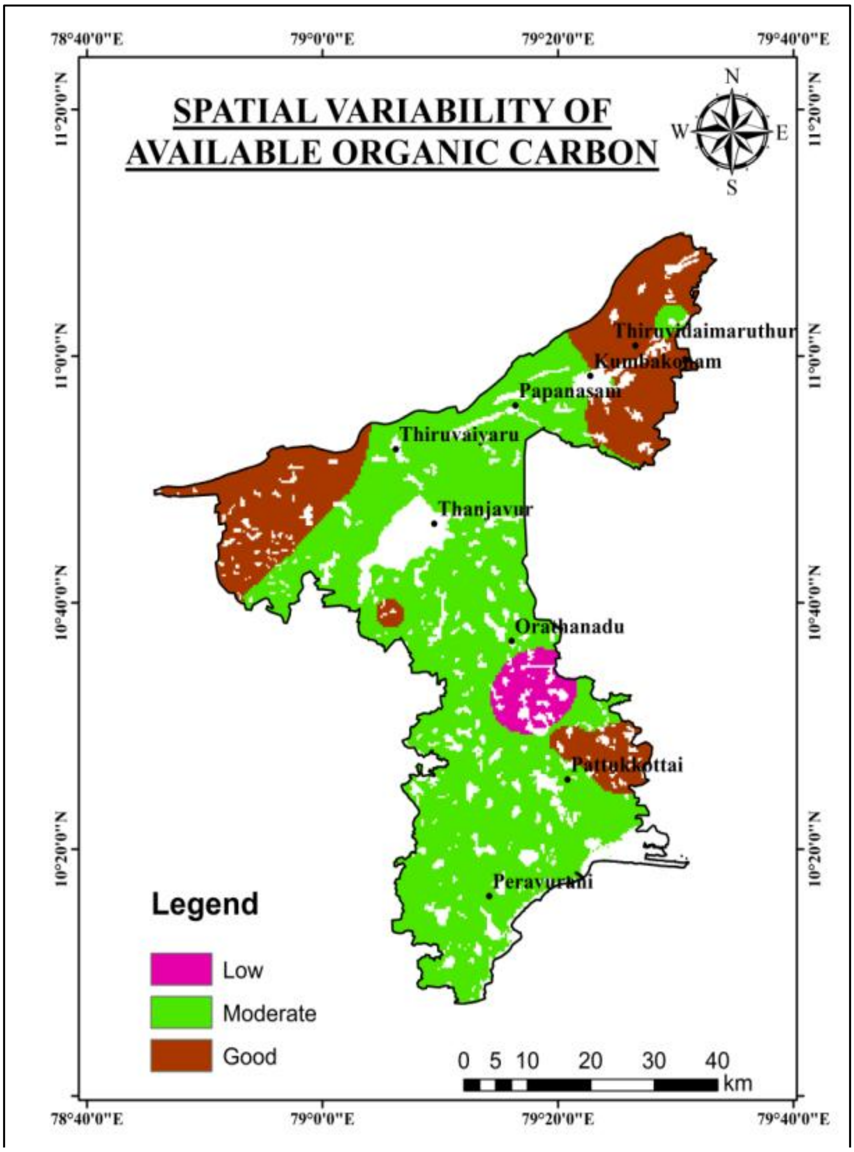

Figure 6: *Spatial variability of Available Organic Carbon map*

The normally the agriculture land ranges from 0.5-0.75 covered area from 825.23 sq.km as shown in Figure 6.

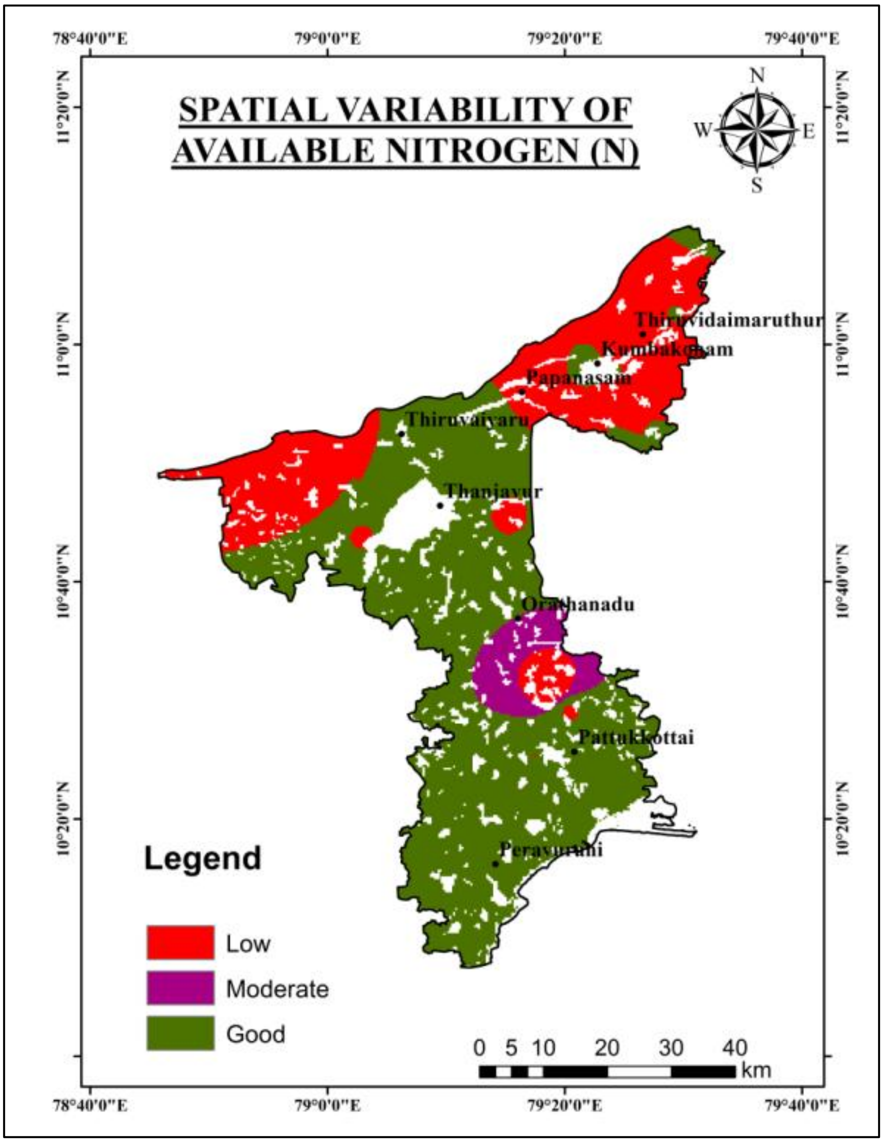

Figure 7: Spatial variability of Nitrogen Map

The range of the nutrients limitation for the agriculture land is 140-171 considered as Good and its covered area about 2256.38 sq.km as shown in Figure 7.

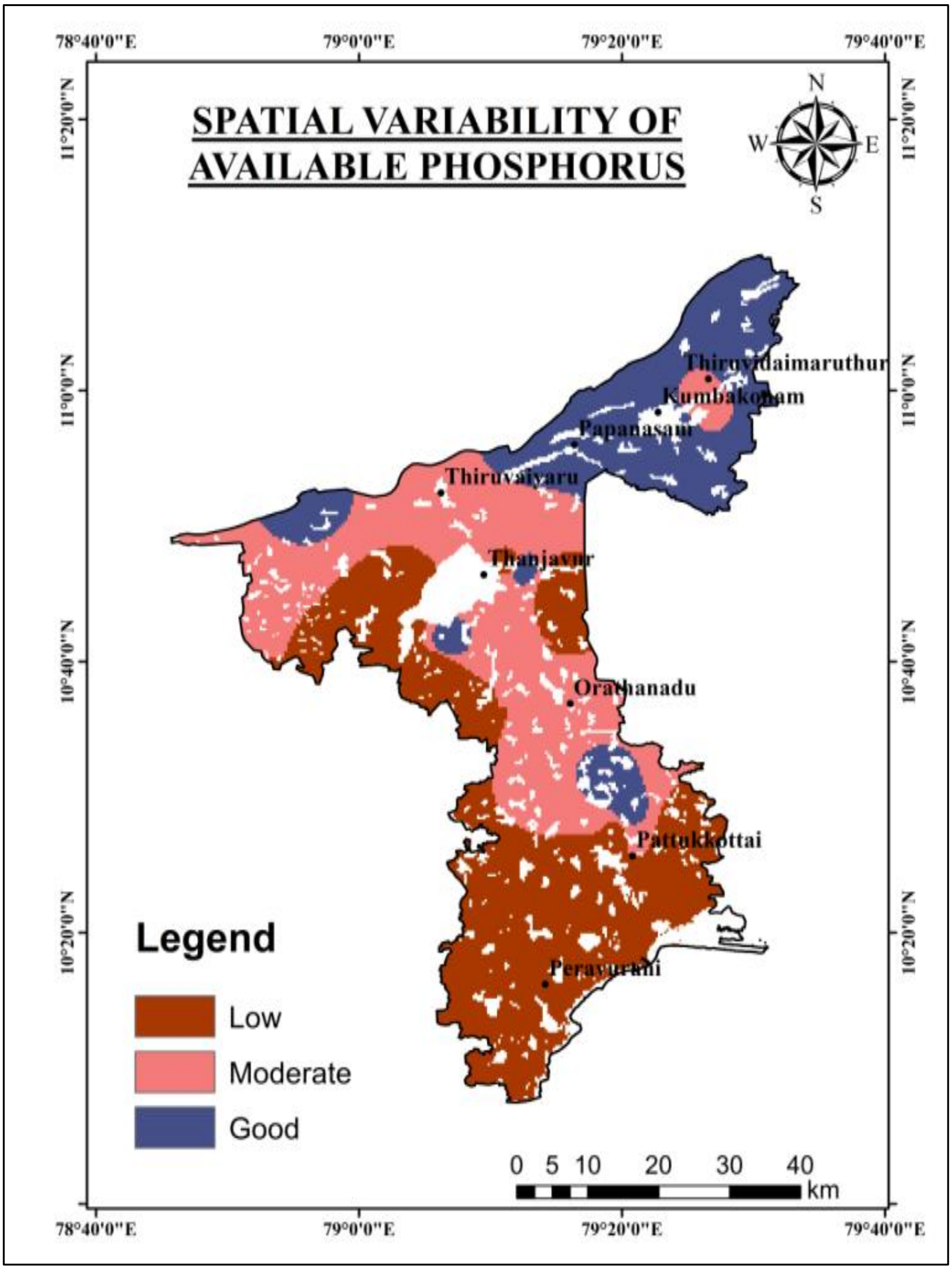

Figure 8: *Spatial variability of phosphorus Map*

The high available P content might possibly be due to the confinement of crop cultivation. The good condition of agricultural land ranges from 3.85-5.95 and its covered area about 787.99 sq.km as shown in Figure 8.

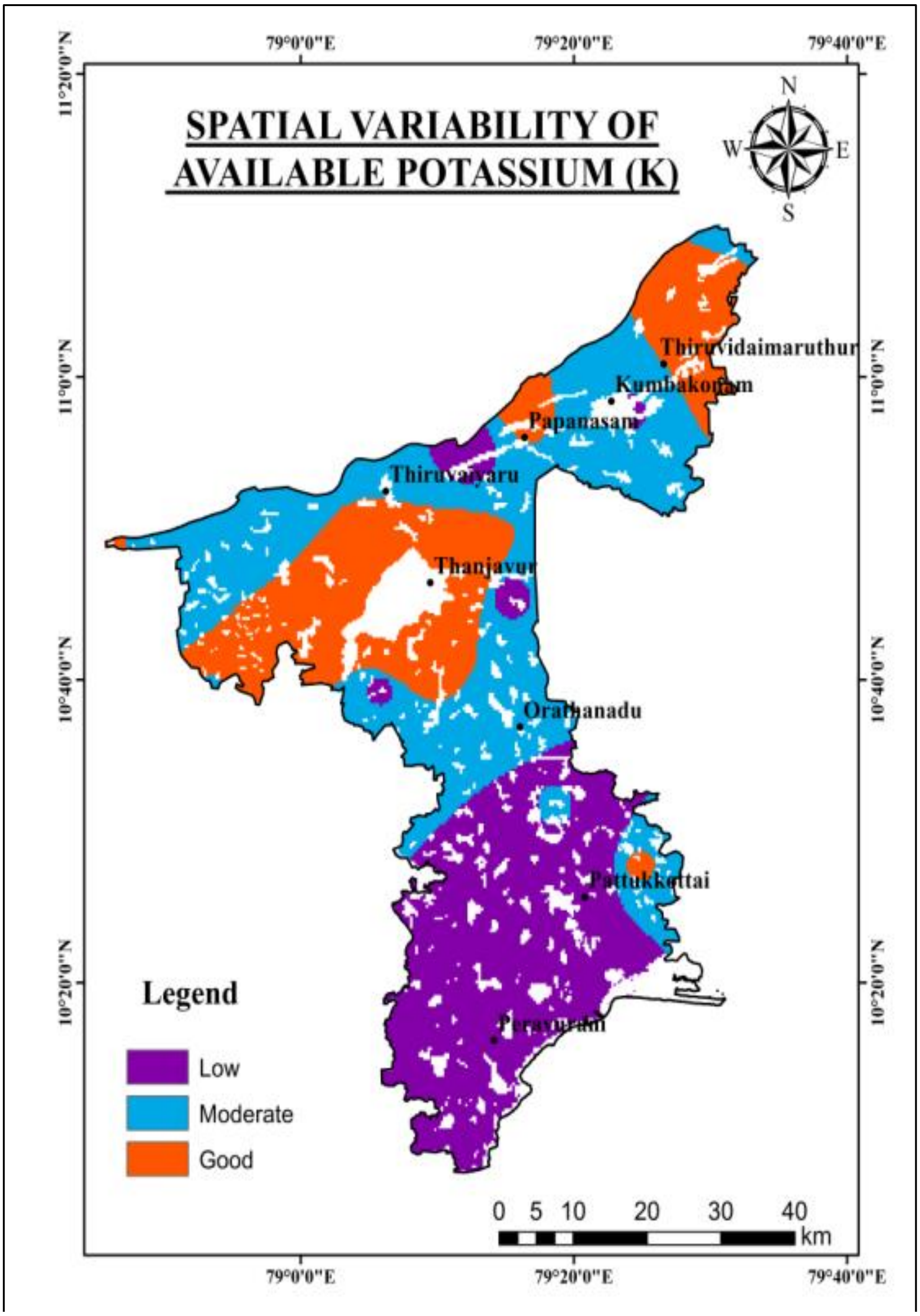

Figure 9: *Spatial variability Potassium Map*

The ranges of K from 245 to 276 which is suitable for agricultural land and its covered area from 1219.82 sq.km as shown in Figure 9.

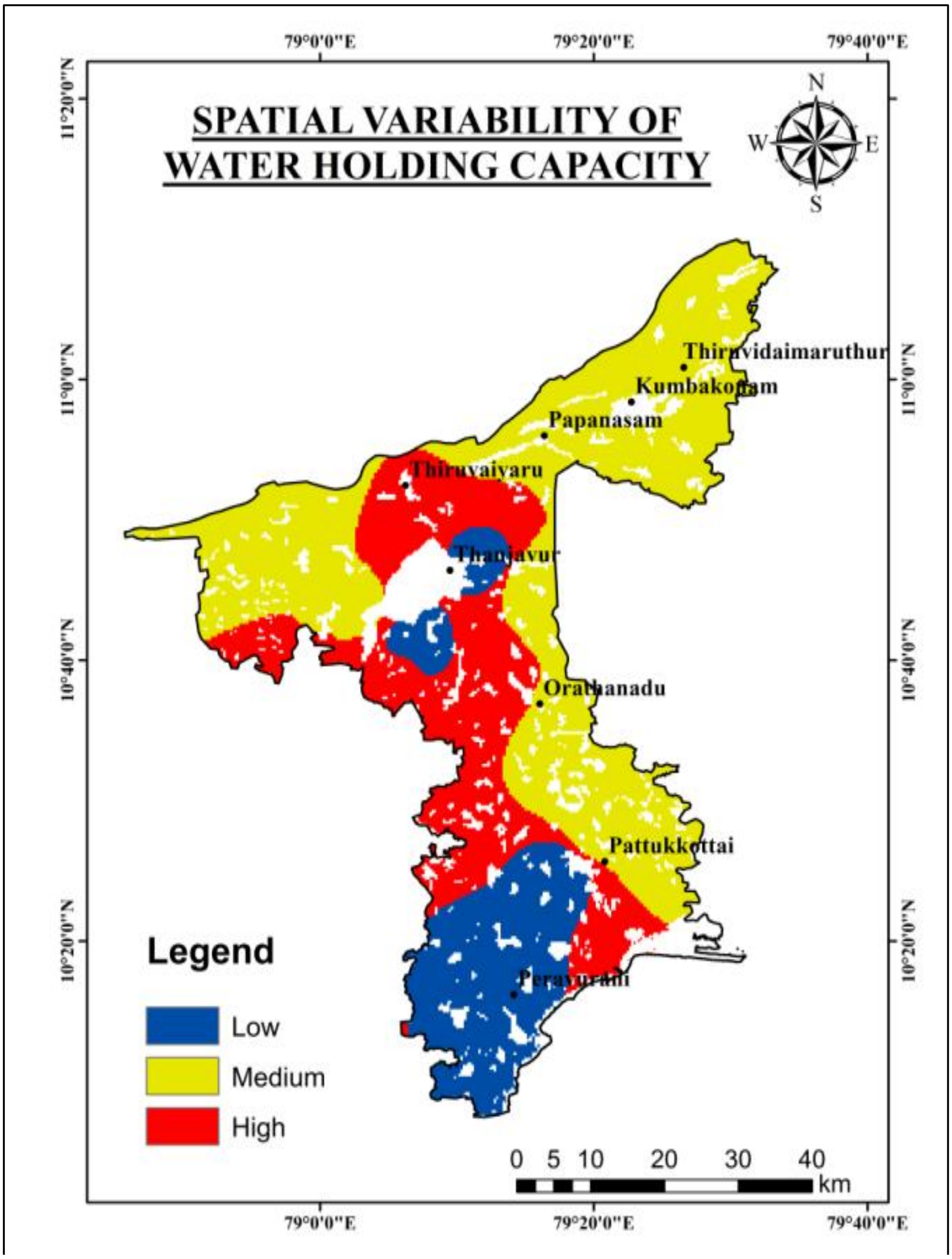

Figure 10: *Spatial variability Water Holding Capacity map*

Soils that hold generous amounts of water are less subject to leaching losses of nutrients or soil. The agriculture land water holding capacity generally ranges from is 33.18-40.2 covered area from 1459.3 sq.km as shown in Figure 10.

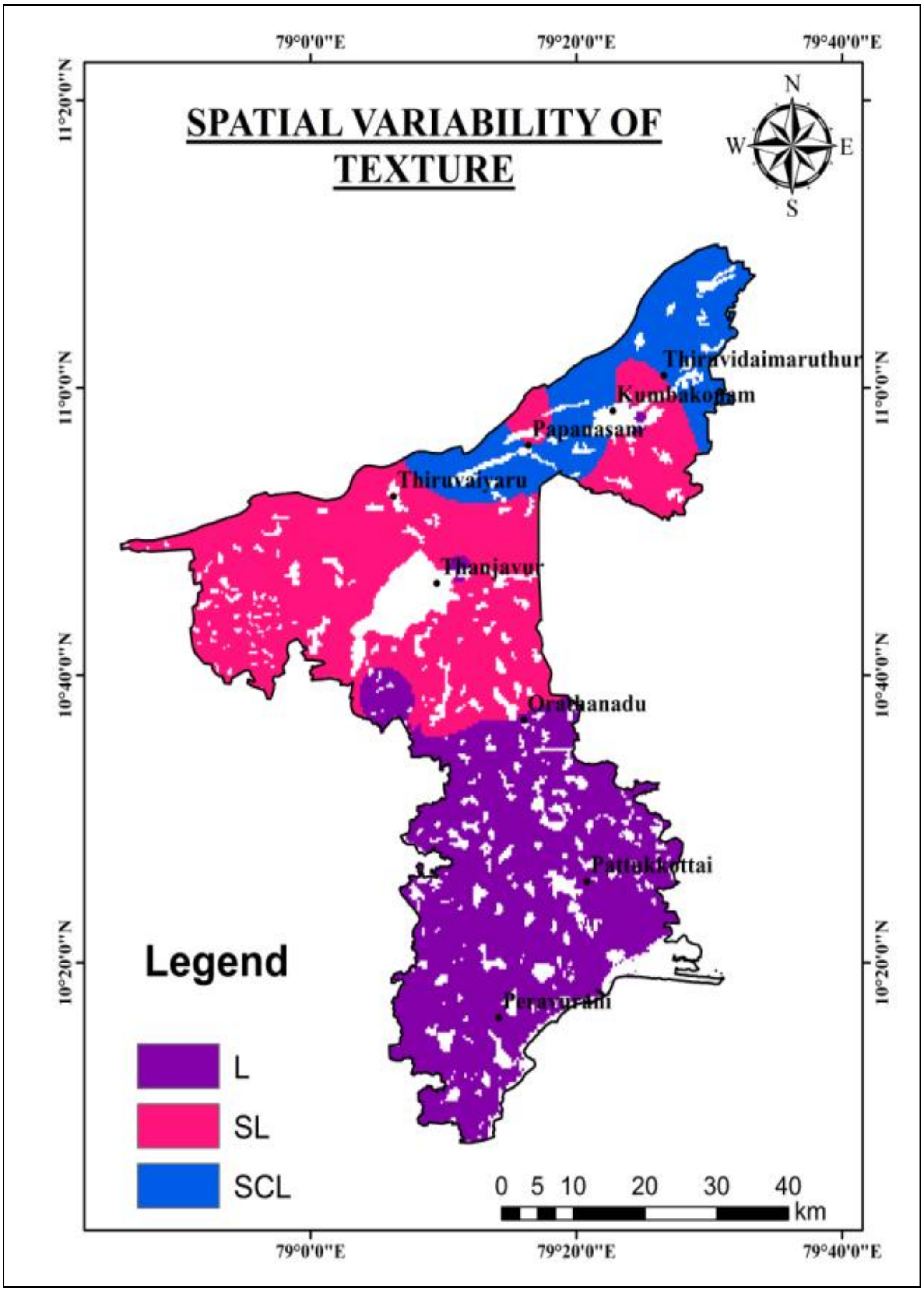

Figure 11: *Spatial variability of Texture Map*

The SCL texture type mainly suitable for agricultural land and its covered area about 481.92 sq.km as shown in Figure 11.

4.3. Overlay Analysis

Land suitability evaluation, on basis of soil conditions requires criterion mostly from the soil attributes. It represents the main soil parameters used for generation of the thematic map layers which used in weighted overlay process for generating the final suitability map for each crop. Once the standardized thematic layers and their weights were assigned for each crop and soil parameter, the weighted sum overlay within Arc GIS was applied to produce the crop suitability map.

4.4. Land Suitability for different crops

A total of 7 crops were evaluated from the for growing in the study area such as pearl millet, maize, cotton, rice and sorghum. With the suitable parameters the *kharif* crops can be identified as shown in Table 3. The quality of each land category was assessed by the ratings highly suitable, moderately suitable and Low suitable that refer to the effects of the individual land qualities on production of the crop. The crop land-use requirements and land qualities were matched for each of the soil series and the final land-suitability maps for each selected crop were made.

Table 3: *Suitable Land Parameter for Each Crops*

CROP	SUITABLE LAND PARAMETER
PEARL MILLET	High pH Electrical Conductivity
MAIZE	Low Organic Carbon Nitrogen Potassium High pH
SORGHUM	Low Potassium Low Organic Carbon Nitrogen High pH
RICE	Organic Carbon Nitrogen Potassium
COTTON	Low Organic Carbon Low Available Nitrogen Low Potassium
PULSES	Organic Carbon Nitrogen Potassium
SESAME	Low Water Holding Capacity Sandy Loamy Soil Texture

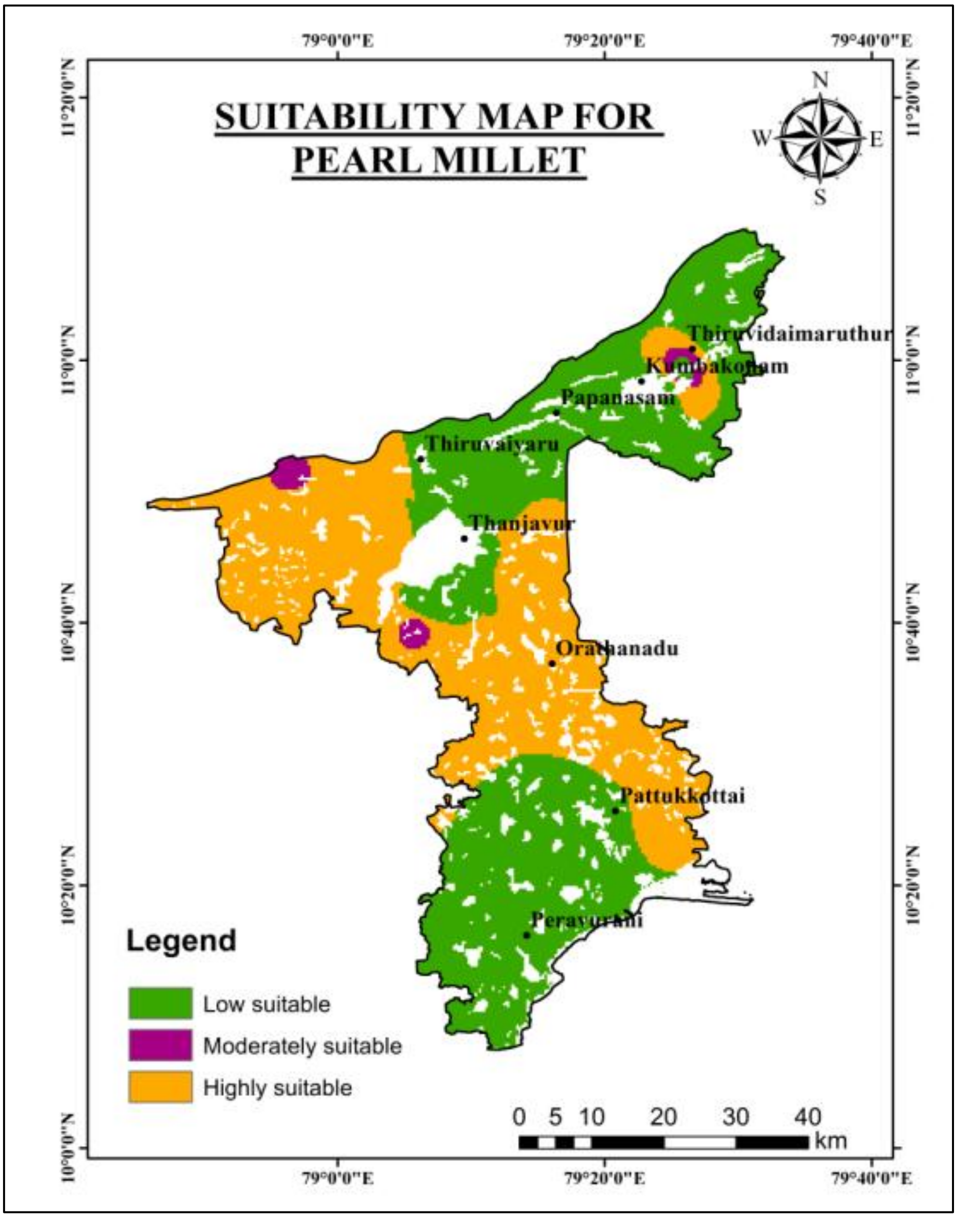

Figure 12: *Suitability Map for Pearl Millet*

Pearl millet is the most widely grown type of millet. High pH and EC are the major limitations. About 43.7 sq.km area of Poondi and near Kumbakonam is moderately suitable whereas1027.2 sq.km and 1859 sq.km of area are highly suitable areas of Peravurani, Thanjavur, Thiruvaiyaru, Papanasam, Thiruvidaimaruthur and nearly Kumbakonam. Marginally suitable areas of Orathandu, Kumbakonam, Vallam and near Pattukkottai as shown in Figure 12.

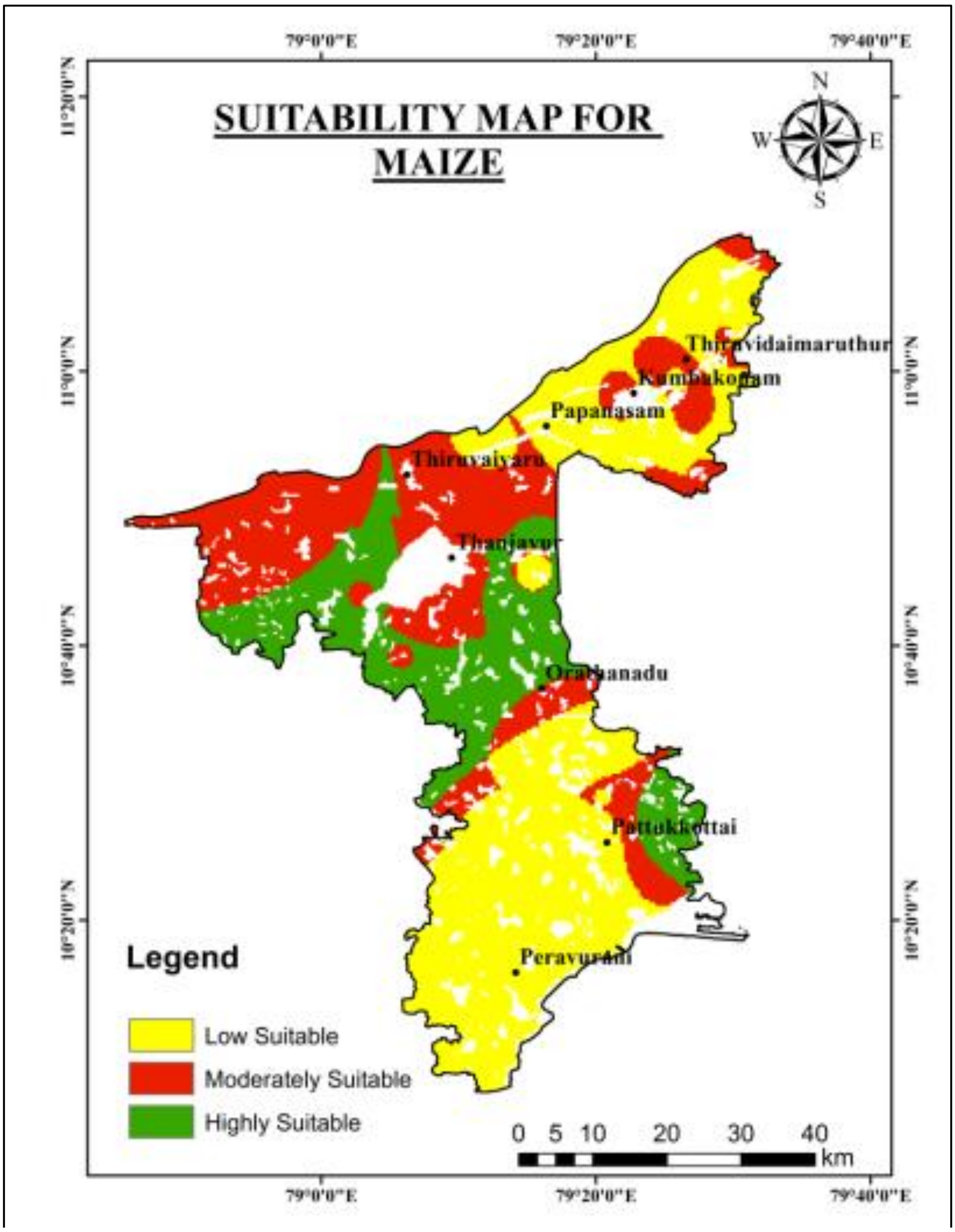

Figure 13: *Suitability Map for Maize*

The major limitations are low organic carbon, nitrogen, potassium and high pH. Around 754.12 sq.km areas of Peravurani, Papanasam and near Pattukkotai are marginally suitable for maize cropping while 652.32 sq.km areas of Orathanau, near Thanjavur and near Pattukkottai and 1000.53 sq.km areas of Thanjavur, near Tiruvidaimaruthur, Papanasam, Kumbakonam are highly and moderately suitable area as shown in Figure 13.

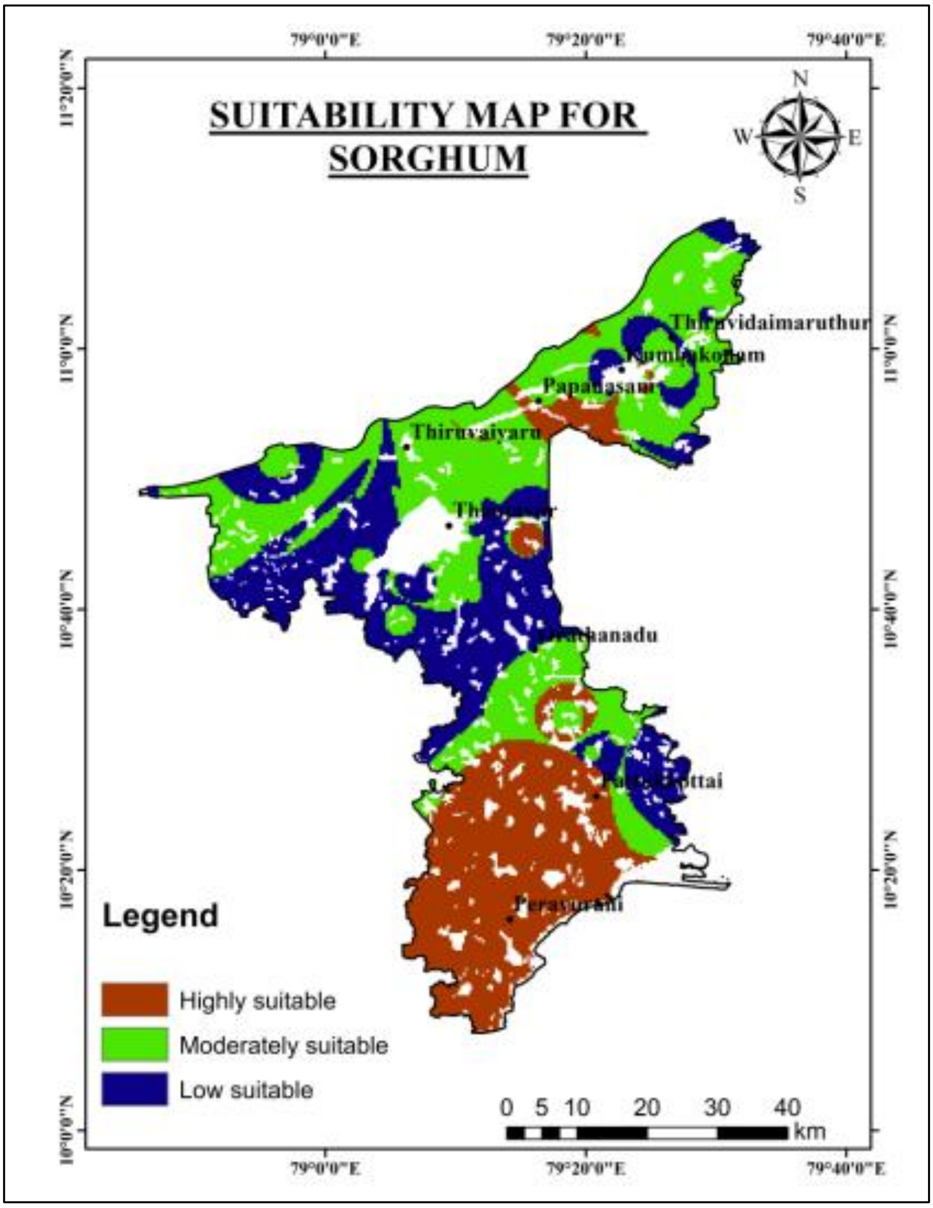

Figure 14: *Suitability Map for Sorghum*

The 1896.28 sq.km areas of Pattukkotai, Peravurani and the small portion of Thanjavur and Papanasam are suitable for sorghum cultivation. The low suitable area of 709 sq.km are present in the Poondi, Thanjavur, Orathandu and near Pattukkotai as shown in Figure 14.

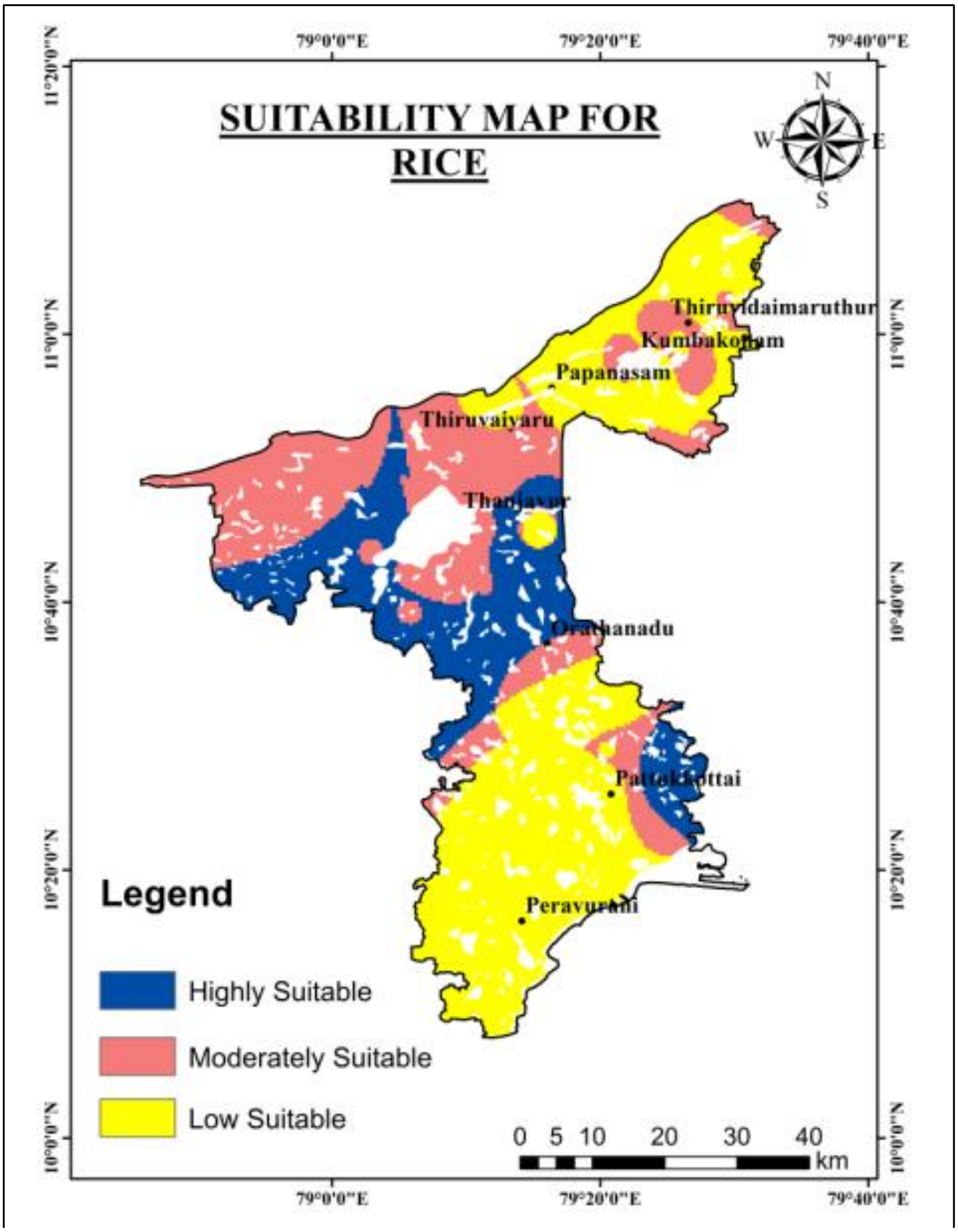

Figure 15: *Suitability Map for Rice*

The area from 754.12 sq.km highly suitable areas of Thanjavur and near Orathandu and 1000.53 sq.km moderately suitable areas of Thiruvaiyaru, Kumbakonam and Nearorathandu as shown in Figure 15.

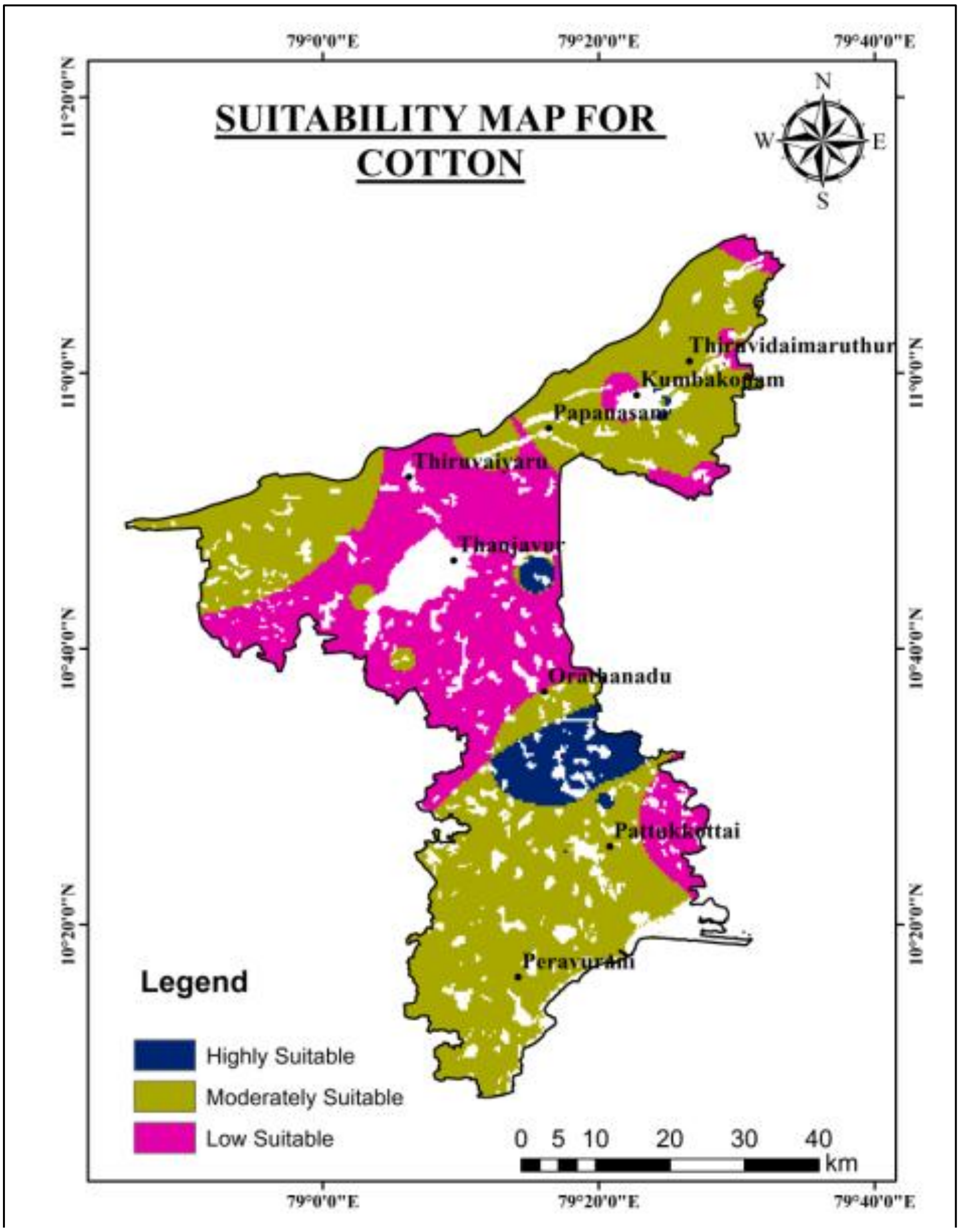

Figure 16: *Suitability Map for Cotton*

The 178.42 sq.km areas of Orathanadu are mainly high suitable, 1804.51 sq.km moderately suitable area from Peravurani, Pattukkottai, Poondi, Papanasam, Kumbakonam and Thiruvidaimaruthur as shown in Figure 16.

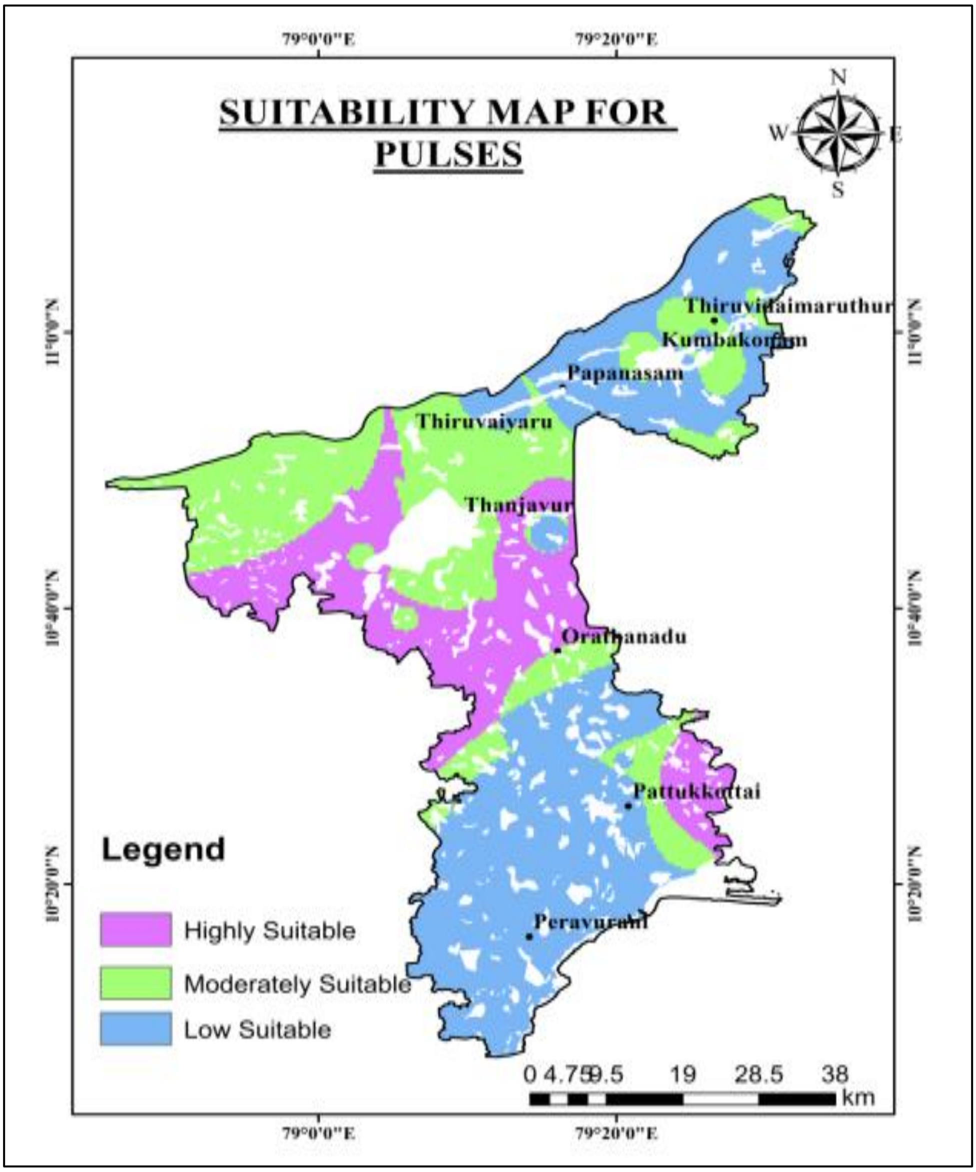

Figure 17: *Suitability Map for Pulses*

The 745.12 sq.km areas of Thanjavur and near Orathandu are highly suitable and 1000.52 sq.km moderately suitable areas of Thiruvaiyaru, Kumbakonam and near Orathandu as shown in Figure 17.

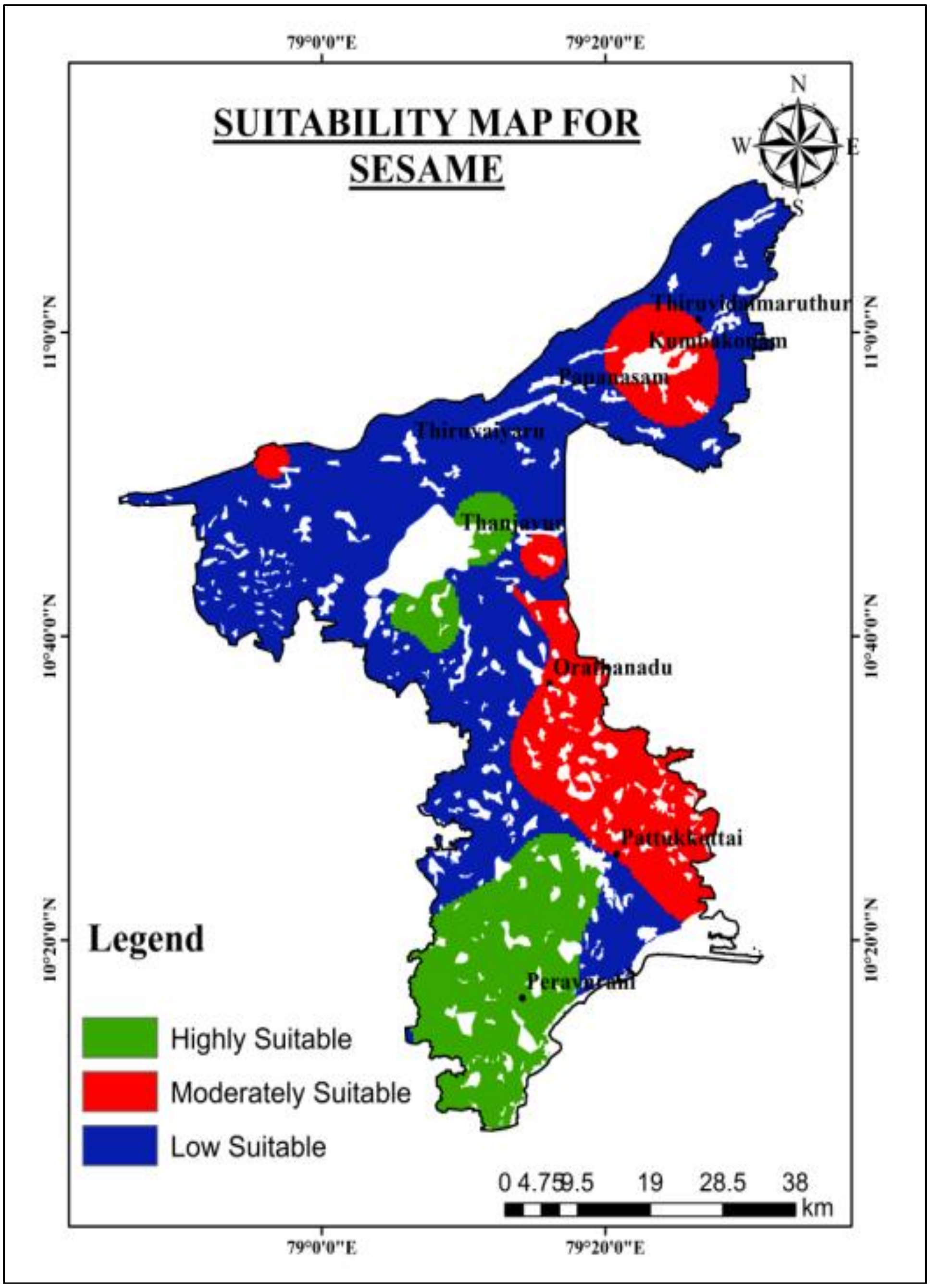

Figure 18: *Suitability Map for Sesame*

The 712.19.37 sq.km areas of Peravurani and Thanjavur are more suitable, 658.76 sq.km areas of Orathanadu, Pattukkottai and Kumbakonam moderately suitable for sesame cultivation as shown in Figure 18.

5. Conclusion

The study indicates the highly suitable economical areas for agriculture production. The moderately and low suitable areas required little investment in fertilizer and agrochemicals for a meaningful production and maintain the economic value. The overlay analysis method commonly used in multi-criteria decision-making exercises was found to be a useful method to determine the weights, in terms of parameters and economic concern. The GIS is found to be a technique that provides greater flexibility and accuracy for handling digital spatial data. The GIS in our experiment proves it is a powerful combination to apply for land-use suitability analysis. The land suitability classes are divided into three categories as highly suitable, moderately suitable and low suitable. The soil-site suitability for kharif crops in Thanjavur district represents that soil suitability class area for pearl millet, maize, sorghum, rice, cotton, pulses and sesame. The 1027.2 sq.km areas of Peravurani, Thanjavur, Thiruvaiyaru, Papanasam, Thiruvidaimaruthur are highly suitable for pearl millet cultivation. The 754.12 sq.km areas of Orathanadu, near Thanjavur and near Pattukkottai are suitable for maize. The 1896.28 sq.km areas of Pattukkotai, Peravurani and the small portion of Thanjavur and Papanasam are suitable for sorghum cultivation. The 754.12 sq.km highly suitable areas of Thanjavur and near Orathanadu are suitable for rice cultivation. The 178.42 sq.km areas of Orathanadu are mainly high suitable for cotton. The 745.12 sq.km areas of Thanjavur and near Orathanadu are highly suitable for pulses. The 712.19 sq.km areas of Peravurani and Thanjavur are more suitable for sesame cultivation. The selected areas are more suitable to left the economic value of the region and maintain the ecosystem services.

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