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## Generation of Soil Site Suitability Maps for Major Crops Grown in Nethakuppam Watershed of Ramachandrapuram Mandal in Chittoor District Using RS and GIS

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### Abstract

Composite surface soil samples (0-15 cm) were collected from 250 sites across Nethakuppam watershed of Ramachandrapuram mandal in Chittoor district of Andhra Pradesh using Arc Map software with the grid size of 10 ha. The GPS data at each sample location was collected. A study was undertaken to evaluate their soil site suitability for Rice, Sugarcane and Ground nut. The soil site suitability maps for rice, sugarcane and groundnut delineate the areas in to suitable and not suitable which could be utilized for selecting the proper cropping pattern at local level. Suitability analysis of rice crop in study area indicated 92 ha is highly suitable (S1), 648 ha is moderately suitable (S2) and 1508 ha is marginally suitable (S3). The remaining area of 23 ha is having severe limitations that preclude the growing of rice making it not suitable (N). Soil site suitability maps for sugarcane crop in study area indicated that about 880 ha is highly suitable (S1), 1386 ha is moderately suitable (S2) and soil site suitability analysis of groundnut crop in Nethakuppam indicated that about 1713 ha is highly suitable (S1), 526 ha is moderately suitable (S2) and the remaining area of 23 ha is marginally suitable (S3). It can be summarized that new technologies of remote sensing, GIS and GPS have opened a new era in generating natural resource database to integrate and assess their potential on spatial basis. Integration of GIS with various models in the present study was highly useful in generating the soil suitability assessment.

**Keywords:** Andhra Pradesh, Arc map software, GPS, suitability maps, watershed

### 1. Introduction

Crop management in India has been driven by increasing use of external inputs during the past four decades. Nutrients through fertilizers have played major role in improving the crop productivity and the food grain demand is estimated to increase from 212 Million tons in 2001-02 to 300 Million tons per year by 2025 for which the country requires 45 Million tons of nutrients. To sustain production demand, the productivity of major crops has to increase annually by 3 to 7.5% (NAAS, 2006), much of this to be met by increasing genetic potential and improved production efficiency of the resources and inputs like water and nutrients. Watershed is a practical unit for transfer of rain fed agricultural technology from lab to land and for formulating the various developmental programmes to improve the crop production and minimize land degradation resulting in optimum land use Planning (Reddy et al., 2015). Remote Sensing is the most efficient tool in the bag of geoscientists for geological, geomorphological and soil resource mapping with respect to their nature, extent, spatial distribution, potential and limitations for

optimal utilization of natural resources on sustainable basis. (Govardhan, 1991; Roy, et al., 1991; Ahuja et al., 1992). Geographical Information System (GIS) analyses and displays multiple data layers derived from various sources and provides valuable support to handle voluminous data being generated through conventional and remote sensing technology both in spatial and non-spatial format particularly in soil surveys. It is a computerized database management system for capturing, storing, validating, maintaining, analysing, displaying and managing spatially referenced data with primary function to integrate data from variety of sources. (Zhang et al., 2010).

The main aim of evaluating the soil suitability for crops is to identify which parcels of land supports best for different crops. This helps to recommend the farmer the land use and management techniques to be adapted to that particular parcel of land. Land management practices that can control the process of land degradation, and their efficiency in this respect, will largely govern sustainability of a given land use (Smyth unit match the requirements of a particular form of land use (FAO, 1976). GIS is a powerful and sophisticated



tool which helps in analyzing the spatial relationships between geographic phenomenon in the form of vectors and images. These spatial variability maps generated for the soil parameters utilizing Arc View GIS 3.2 software are overlaid to prepare soil suitability maps. The suitability classes are derived based on the structure of suitability classification given by FAO. (Table 1). Soils with very shallow depth, having very high clay content, poor drainage or excessive slopes are appeared to be unsuitable (Giri et al., 1994). Assessing the land capability to adopt suitable soil conservation measures and suggest appropriate land use through RS and GIS approaches. Thematic information on soils, slope and land use was generated from remotely sensed data, Soil quality index top sheet and field survey. This spatial information was integrated using GIS techniques for generating basic resource maps such as composite land use and land capability (Patel et al., 2001). These soils were grouped into IIs, IIIs, IVs, IVes and VIes land capability sub-classes and good with poor to extremely poor soil productivity. The soil suitability analysis indicated that very shallow soils were marginally to not suitable and very deep soils of valley plain were moderately suitable for growing cotton, sorghum and soybean. Suitable conservation measures and interventions have been suggested to improve the productivity of these soils (Nagaraju et al., 2010), the yield contributing soil parameters such as ground water table, coarse fragments, soil depth, available nitrogen and phosphorus contents were the most important factors for crop suitability (Shivaramu, 2012).

The soils of Karanjwera highly suitable (S1) for cotton, pigeon pea, sorghum. Soils of Sonuri, Dharna, Sakhara and Kongara were moderately suitable (S2) for cotton, sorghum, pigeon pea and wheat. Soils of Wathoda was marginally suitable (S3) for cotton, soybean, wheat, gram. Soils of Via, Singledeep-2 and Sakhi potentially suitable (N1) for soybean, gram, wheat, cotton (Nasre et al., 2013).

Evaluated soils of Zaheerabadmandal of Medak district, Andhra Pradesh for soil suitability of three major crops (paddy, sugarcane, and potato) grown in that area and reported that Typic Rhodustalf, Rhodic Kandustalf and Typic Haplustalf (P5) were moderately suitable (S2) for paddy and sugarcane and not suitable for growing potato crop, while Lithic Rhodustalf and Typic Rhodustalf were marginally suitable (S3) for paddy and sugarcane while Typic Haplustalf (P4) moderately suitable for sugarcane and marginally suitable for paddy, and not suitable for potato crop (Singh et al., 2013).

The soils of Nalgonda district are suitable for growing soybean, moderately suitable (S2) for paddy, sorghum, red gram and cotton, and marginally suitable (S3) for groundnut (Kiran et al., 2014).

Crop suitability evaluation studies in Patapura micro-watershed in Raichur district revealed that higher elevated areas are marginally suitable (S3), while lowland area is unsuitable (N1) for cultivation of crops like cotton,

pigeonpea and sorghum crops (Kantharaj et al., 2015) land characterization and soil-site suitability for major crops of Pratapgarh district, Rajasthan, results showed that the soils were moderately suitable (S2) class for rice, maize, green gram, soybean, wheat, mustard, gram, isabgol and garlic as well as horticulture crops in both transects can be upgraded to highly suitable (S1) class with adequate lifesaving irrigation, organic matter in the form of FYM and green manuring and soil conservation, and the soils that were found not suitable for any type of crops can be developed as a grassland or utilized for silviculture and also for plantation of economically important crops like mango, guava and anola (Singh and Rathore, 2017).

Alternate land use plan for a Peri-urban watershed in sub-tropical humid region of Meghalaya, India. The results showed that out of 265.91 ha watershed area, only 10.97% area was suitable for paddy cultivation, maize was suggested in few low land areas where rice cultivation have some limitations. The upland hill soils with less than 15% slope are suggested for maize and pineapple cultivation besides agro-forestry. In the higher hill slope with slope of 15-45% are suggested for pineapple or agro-forestry (Zothansiami et al., 2017).

Soil site suitability assessment reveals that low land and mid land were moderately suitable (S2) for cultivation of field crops like sorghum, red gram, green gram, Bengal gram, black gram and soybean with moderate limitations of drainage and fertility while upland area is marginally suitable (S3) for cultivation of these crops. The uplands were not suitable (N) for horticulture crops like mango, guava, custard apple, sapota and jamun, because of severe limitation of depth. Whereas, low land and mid land, with moderate limitations of rooting depth and texture are moderately suitable (S2) for these crops in Dotikal micro-watershed in Kalaburagi district in North- Eastern Transition Zone of Karnataka (NaveenKumar et al., 2018).

The major crops cultivated in Nethakuppam watershed are rice, sugar cane and groundnut. In this study, the land suitability analysis is made for major crops such as rice, sugar cane and groundnut. The soil variables like soil texture, soil depth, soil drainage, soil slope and erosion status were considered as the parameters influencing the crop yield. Potentials and limitations of soils in the division were assessed for these variables. The spatial variability of these soil properties was layered and matched with soil suitability criteria for these crops.

## 2. Materials and Methods

The study was under taken in 2018 year in Nethakuppam watershed located in Ramachandrapuram Mandal of Chittoor district of Andhra Pradesh. The geographical area of watershed is 2266 hectares comprises of three villages, viz., Nethakuppam, Anupalli and Chittathur Kalepalli. Its geographic limits range from 13°46' to 13° 54' North Latitude



and 79° 26' to 79° 38' East Longitude and is covered by Survey of India Topographic Map No. D44N11. It has an average elevation of 413 meters (1355 feet amsl). Climate of watershed experiences tropical climatic conditions.

The common natural vegetations are short grasses which consist of *Cynodon dactylon*, *Cyperus rotundus* found in light textured soils, *Argemone maxicana*, *Lamea pinnatifida*, *Blumealacera* associated with silty soils, *Chenopodium alba*, associated with loam soils and *Acacia nilotica*, *Borassus flabellifer*, *Tamarindus indica*, *Tephrosia purpurea*, *Parthenium hysterophorus*, *Azadirachta indica*, *Abutilon indica*, *Sygium cumini*, *Cassia auriculata* and *Calotropis gigantean* etc.

After traversing 250 soil samples (0-15 cm) collected and analysed for physio-chemical properties and also prepared thematic maps (Figure 1). The land suitability is mainly based on the inherent soil characteristics, external land features and environmental factors. In this study, five variables namely, soil type, soil depth, soil drainage, soil erosion and soil slope have been considered as specific crop requirement factors to identify the land suitability according to the FAO guidelines

(1976) as given in (Table 1) All the paper maps have been scanned and digitized. Feature layers were digitized and attribute data were added for all these variables using Arc GIS 9.3.1. These layers were converted into grid format and reclassification was adopted to determine the soil site suitability categories of rice (Table 2), sugarcane (Table 3) and ground nut (Table 4).

Table 1: Structure of the suitability classification

Order	Class	Description
S	S1	Land having no significant limitations to sustained application of a given use, or only minor limitations that will not significantly reduce productivity and benefits and will not raise inputs above an acceptable level
	S2	Land having limitations which in aggregate are moderately severe for sustained application of a given use, the limitations will reduce productivity or benefits and increase required inputs to the extent that the overall advantage to be gained from the use.
	S3	Land having limitations which in aggregate are severe for sustained application of a given use and will so reduce productivity and benefits, or increase required inputs, that this expenditure will be only marginally justified.
N	N1	Land having limitations which may be surmountable in time but which cannot be corrected with existing knowledge at currently acceptable cost, the limitations are so severe as to preclude successful sustained use of the land in the given manner.
	N2	Land having limitations which appear as severe as to preclude any possibilities of successful sustained use of the land in the given manner.

Source: FAO (1976)

Initially, the digital data were processed to transform it for improving the image contrast and to generate photo-products for subsequent analysis/interpretation. The standard monoscopic visual interpretation was employed to realize the objectives. The LISS-III and PAN merged digital data were down loaded on to Silicon Graphics work station with ERDAS/IMAGINE image analysis software. Initially, the study area was identified and extracted in both the data sets. Using map to image transformation algorithm, ground control points (GCPs) were identified both on the PAN image as well as the topographic map and the former was geo-referenced with a sub-pixel accuracy using first order

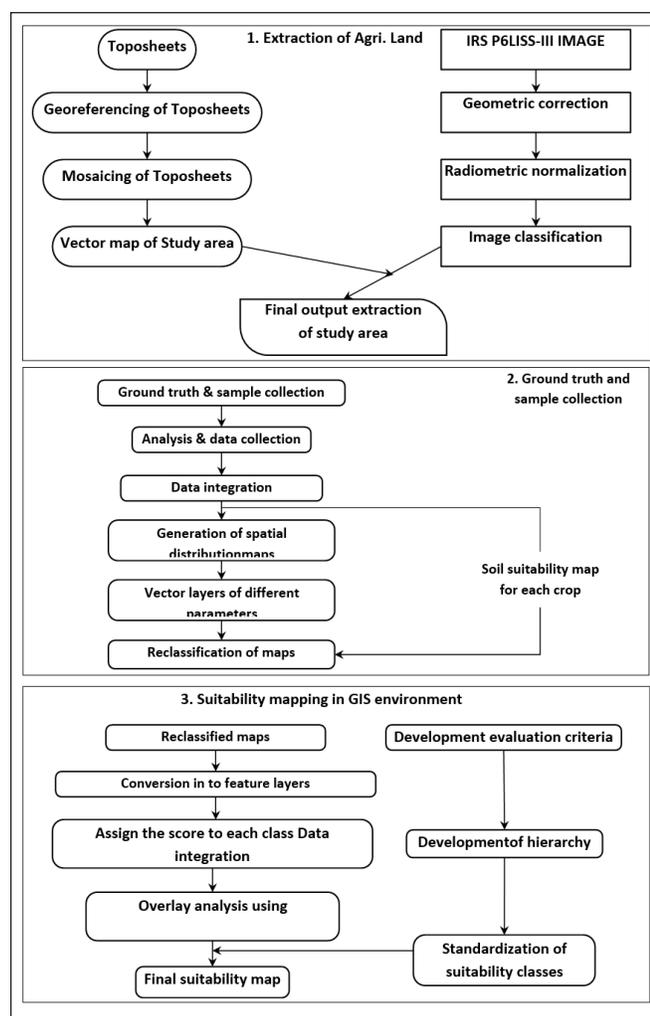


Figure 1: The conceptual flow of research approach

Table 2: Soil site suitability criteria (Crop requirements) for Rice

Soil-site Characteristic		Rating			
		Highly suitable S1	Moderately suitable S2	Marginally suitable S3	Not suitable N
Soil drainage	Class	Imperfect	Moderate	Well	Excessive
Soil texture	Class	C, sic, cl, sicl, sc	Scl, sil, l	Sl, ls	S
Effective soil depth	Cm	>75	51-75	25-50	<25
Erosion	Class	Nil	Slight	Moderate	Severe
Slope	%	0-1	1-3	3-5	>5

s: sand, ls: loamy sand, sl: sandy loam, scl: sandy clay loam, cl: clay loam, sil: silt loam, l: loam, sic: silty clay, sc: sandy clay, c: clay

Table 3: Soil site suitability criteria (Crop requirements) for Sugarcane

Soil-site Characteristic		Rating			
		Highly suitable S1	Moderately suitable S2	Marginally suitable S3	Not suitable N
Soil drainage	Class	Imperfect	Moderate	Poor	Poor but drainable
Soil texture	Class	SiC, SiL, CL, Si	LS, SL	LS, LcS	S, cS
Effective soil depth	Cm	>125	80-50	50-25	<25
Erosion	Class	Nil	Slight	Moderate	Severe
Slope	%	0-1	2-4	4-6	>6

s: sand, ls: loamy sand, sl: sandy loam, scl: sandy clay loam, cl: clay loam, sil: silt loam, l: loam, sic: silty clay, sc: sandy clay, c: clay

Table 4: Soil site suitability criteria (Crop requirements) for Ground nut

Soil-site Characteristic		Rating			
		Highly suitable S1	Moderately suitable S2	Marginally suitable S3	Not suitable N
Soil drainage	Class	Well drained	Moderately well drained	Imperfectly drained	Poor drainable
Soil texture	Class	ls, sl	cl, sicl, scl	c, sic	
Effective soil depth	Cm	>75	51-75	25-50	>25
Erosion	Class	Nil	Slight	Moderate	Severe
Slope	%	<3	3-5	5-10	>10

s: sand, ls: loamy sand, sl: sandy loam, scl: sandy clay loam, cl: clay loam, sil: silt loam, l: loam, sic: silty clay, sc: sandy clay, c: clay

polynomial transformation. Later on, LISS-III and PAN data were registered to each other with sub-pixel accuracy and LISS-III was resampled using cubic convolution algorithm. Thus, both the data sets were brought to a common projection. Study area was delineated with the help of mandal boundaries and the geo referenced toposheet. The data pertaining to the study area was extracted as a subset for further processing and using ERDAS IMAGINE software and merging of Toposheets. The study area boundary vector shape file has been generated and similarly vector layer showing the Nethakuppam watershed was created. Preliminary survey of the study area was conducted by moving through all the three villages. Representative areas of soils are arrived by following grid method in the study area. GPS readings were recorded at each and every sampling

location. Information regarding crops and cropping systems followed in the study area was also collected by interviews with farmers. Survey of India topographic map D44N9 at 1:50,000 scale covering the study area was used. Satellite data provided by National Remote Sensing Centre (NRSC), Hyderabad was utilized for this study.

### 3. Results and Discussion

The resulting soil suitability maps are depicted in Figure 2 Figure 3 and Figure 4 (Table 5.) for rice, sugarcane and ground nut respectively.

#### 3.1. Soil-site suitability for rice crop

Soil suitability criteria of rice crop shows that clay, silty clay, clay loam, silty clay and sandy clay textured soils with a depth



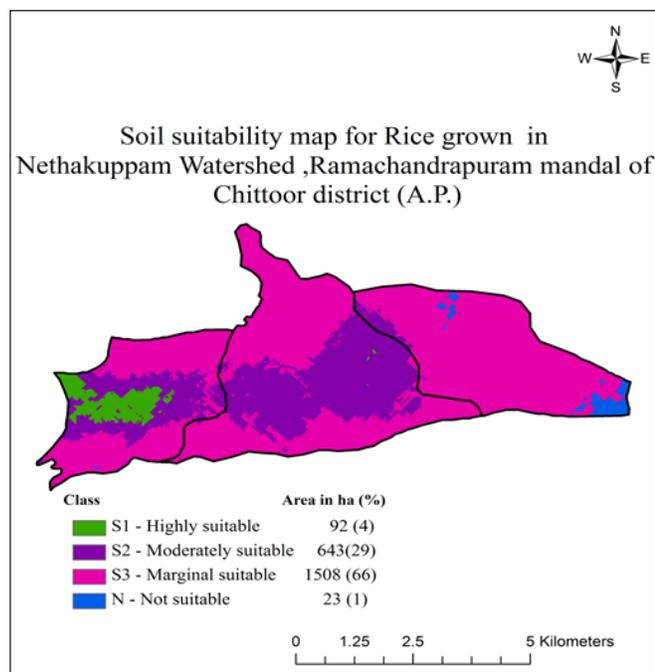


Figure 2: Soil suitability map for rice cultivation in Nethakuppam watershed

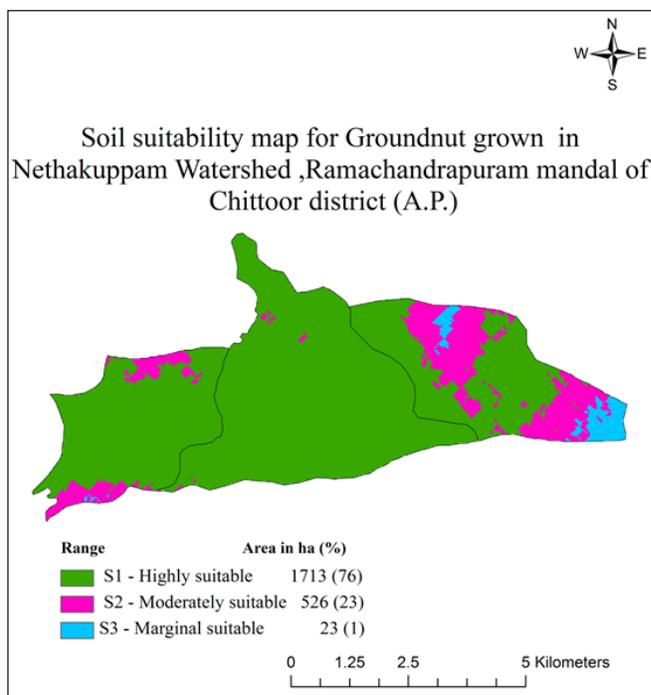


Figure 4: Soil suitability map for ground nut cultivation in Nethakuppam watershed

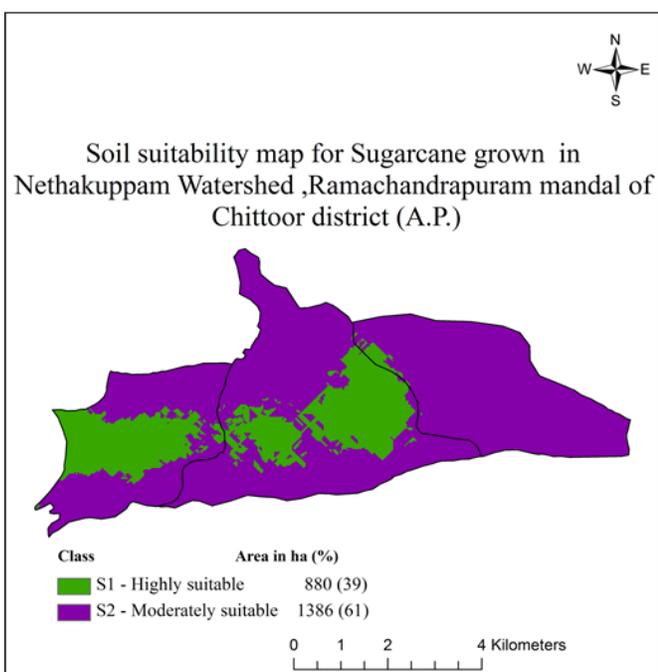


Figure 3: Soil suitability map for sugarcane cultivation in Nethakuppam watershed

of >75 cm, imperfectly drained, 0 to 1 % slope and no erosion hazard are highly suitable (S1) for rice cultivation. Sandy clay loam, silty loam and loamy soils with 51 to 75 cm depth, moderately well drained, 1 to 3 % slope and no erosion hazard are moderately suitable (S2). Sandy loam and loamy sand soils with 25 to 50 cm depth, well drained, 3 to 5 % slope and no erosion hazard are marginally suitable (S3). While Sandy soils

with less than 25 cm depth, excessively drained, > 5% slope and with erosion hazard are not suitable (N) for rice cultivation (Table 2). Suitability analysis of rice crop in Nethakuppam watershed indicated 92 ha (4%) is highly suitable (S1), 643 ha (29%) is moderately suitable (S2) and 1508 ha (66%) is marginally suitable (S3). The remaining area 23 ha (1%) is having severe limitations that preclude the growing of rice making it not suitable (N) (Figure 2 and Table 5).

Table 5: Area under different categories of suitability classes for major crops under cultivation in Nethakuppam watershed

Class	Rice		Sugarcane		Groundnut	
	Area (ha)	Area (%)	Area (ha)	Area (%)	Area (ha)	Area (%)
S1	92	4	880	39	1713	76
S2	648	29	1386	61	526	23
S3	1508	66	-	-	23	1
N	23	1	-	-	-	-

### 3.2. Soil-site suitability for sugarcane crop

Soil suitability criteria of sorghum crop shows that clay, clay loam, silty clay and sandy clay loam textured soils with a depth of 125 to 100 cm, well to moderately drained, 1 to 2% slope and erosion hazard are highly suitable (S1) for sugarcane cultivation. Silty clay, sandy loamy soils with 80 to 50 cm depth, imperfect drainage, 2 to 4% slope and erosion hazard are moderately suitable (S2). Sandy loam and loamy sand

soils with 50 to 25 cm depth, poor and excessively drained, 4 to 6% slope and erosion hazard are marginally suitable (S3). While Sandy soils with less than 25 cm depth, very poorly drained, >6% slope and erosion hazard are not suitable (N) for sugarcane cultivation (Table 3). Suitability analysis of sugarcane crop in Nethakuppam watershed indicated that about 1386 ha (61%) is highly suitable (S1), 880 ha (39%) is moderately suitable (S2) (Figure 3 and Table 5).

### 3.3. Soil site suitability for ground nut crop

Soil suitability criteria of ground nut crop shows that loamysand, sandyloam textured soils with a depth of >75 cm, well drained, <3% slope and no erosion hazard are highly suitable (S1) for groundnut cultivation. Clay loam, silty clay loam and sandy clay loam soils with 51 to 75 cm depth, moderately well drained, 3 to 5% slope and no erosion hazard are moderately suitable (S2). Clay and silty clay soils with 25 to 50 cm depth, imperfectly drained, 5 to 10 % slope and no erosion hazard are marginally suitable (S3). less than 25 cm depth, poorly drained, >10% slope and with erosion hazard are not suitable (N) for ground nut cultivation (Table 4). Suitability analysis of ground nut crop in Nethakuppam watershed indicated that about 1713 ha (76%) is highly suitable (S1), 526 ha (23%) is moderately suitable (S2) and 23 ha (1%) is marginally suitable (S3) (Figure 4 and Table 5).

## 4. Conclusion

The soil site suitability maps show that an area 4, 76 and 39 % is highly suitable (S1), 29, 23 and 61% is moderately suitable (S2), 66 and 1% is marginally suitable (S3) for rice, ground nut and sugarcane cultivation, respectively, in Nethakuppam watershed. This information could be utilized for selecting the proper cropping pattern at local level.

## 5. Future Research

The future research must be on land suitability assessment based on physical, physio- chemical and chemical parameters using most advanced RS and GIS techniques.

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