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Generation of Detailed Soil Information for the Virudhunagar Aspirational district of Tamil Nadu using Remote Sensing & GIS Techniques for Developmental Planning

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Abstract: Detailed Soil Survey and Land use Planning for entire Virudhunagar aspirational district of Tamil Nadu consist of 11 Blocks such as Rajapalayam, Sirivilliputhur, Sivakasi, Sattur, Aruppukkottai, Virudhunagar, Thiruchuli, Kariyapatti, Watrap, Vembakkottai and Narikudi were completed on 1:10,000 scale using Remote Sensing and GIS techniques. The total area of the district is 4.24 Lakh ha. There are 44 soil series have been identified in the district. Out of which Virudhunagar series occupied 11.08% of the total geographical area. Granite Gneiss Geology and Pediplain (Upper and Lower) Physiography covered 65.54% and 71.37% respectively. Most of the soils are Very deep (41.91%) and Very gently sloping (61.34%) in nature affected by Moderate Erosion (66.43%). Soils series of the district are classified under soil orders Entisols, Inceptisols, Alfiisols and Vertisols. Among them Inceptisols and Vertisols dominated the area. Every Block village wise soil map, problematic area details and Land Capability Classes are generated. Majority of the soil series interpreted in Land Capability Classes II (33.66%) and III (39.64%). Cultivated Lands occupied 59.76% followed by culturable wastelands 16.1% (68,098 ha). These culturable waste lands area are occupied by vegetation i.e. Acacia species and scrublands leads to ground water depletion, soil erosion and land degradation. There is a tremendous scope to convert these lands for agriculture, horticulture and forestry activities.

Keywords: *Remote sensing and GIS techniques, soil series*

Introduction

Soil and water are the most vital natural resources essential for sustenance of mankind on the earth. Soil and land resource information is essential for developmental planning on watershed basis to mitigate the challenges posed by climate change and GHG emissions etc. Survey involves systematic examination of soils in the field and in laboratory characterization and classifying the soils followed by mapping. Detailed soil survey aims in generating scientific database on soil and land resources to develop a comprehensive Soil information system for planning, designing and implementation of agricultural development and integrated watershed management program.

Aspirational Districts Programme (ADP)

Launched by the Hon'ble PM in January 2018, the Aspirational Districts Programme (ADP) aims to quickly and effectively transform 112 most under-developed districts across the country . The Government is committed to raising the living standards of its citizens and ensuring inclusive growth for all – "Sabka Saath Sabka Vikas aur Sabka Vishwas". To enable utilization of their potential, this program closely focuses on

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improving people's ability to participate fully in the burgeoning economy. NITI Aayog works closely with the respective line Ministries and various development partners to fast-track progress at the district level. The districts are also encouraged to develop and replicate best practices that drive improvement across the socio-economic themes .The Aspirational Districts Programme essentially is aimed at localizing Sustainable Development Goals, leading to the progress of the nation. To boost the agriculture sector "Krishi Kalyan Abhiyan" (KKA) was launched by Ministry of Agriculture and Farmers' Welfare" in the Aspirational districts. Virudhunagar and Ramanathapuram Districts are allotted under Aspirational districts for Generation of Detailed Soil Information and for Developmental Planning.

The present work of Detailed Soil Survey and Land Use data base have been generated in Virudhunagar District from Kanyakumari to Caurvey River Basin 4A (Vaippar and Gundar), Catchment-4A1 and 4A2 and Sub-Catchment 4A1C, D & 4A2A using GIS and Remote Sensing Techniques (Watershed Atlas of India 2012). The database generated out of the survey, help evaluate the productive potentials and limitations of the land resource for optional land use planning and watershed management.

Location of the District

Study area

The Virudhunagar District lies between 77° 20' 11" to 78° 25' 15" East Longitudes and 9° 11' 39" to 9° 46' 41" North Latitudes. Virudhunagar District consist of 11 Blocks such as Srivilliputhur, Rajapalayam, Watrap, Vembakottai, Sivakasi, Virudhunagar, Sattur, Kariapatti, Aruppukottai, Narikudi and Tiruchuli. The location map of the study area is shown as Fig.-1. The district lies under Agro-climatic zone- X- Southern Plateau and Hilly region. The area lies between the Western Ghats Region in the west to Eastern plain in the South East of India and occupying an area of 4.24 Lakh hectare. The Geology includes Granite Gneiss, Charnokite, Sandstone, Laterite and Alluvium. The Physiographic unit identified are Hills side slopes, Pediments, Upper pedi-plains, Lower pedi-plains, Alluvial plains and Stream banks.

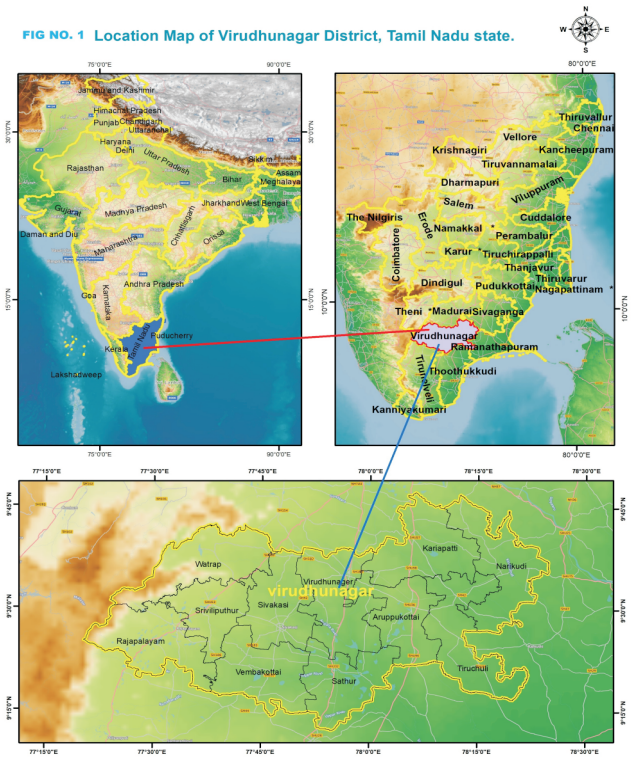


Fig.1. Location map of Virudhnagar District, Tamil Nadu.

The major land use/ land cover categories identified in the study area are: Agriculture, plantations, forest, culturable waste lands, open scrub land, water bodies, habitation and other miscellaneous lands.

Materials and methods

Detailed soil survey was carried out by using "on screen interpretation Technique" on high resolution (5.8 mt) LISS-IV sensor of Resourcesat-1 and /or 2 satellite data at 1:10,000 Scale. The digital layers such as village boundaries, contour, drainage, and hydrologic data acquired from Survey of India, verified village boundary data sets, Carto DEM downloaded from BHUVAN, and Micro-watershed Atlas of India dataset respectively. On screen satellite data interpretation carried out to separate probable soil units based on image elements namely colour, tone, texture, size, shape, site and association to develop satellite data interpretation key through recording of reflectance and probable soil units code have been prepared. Soil mapping was carried in field ground truthing by traversing and studying soil profiles, augur bores and shallow pits as required depending upon the physiographic heterogeneity of the area.

Soils profiles up to d5 depth (>100 cm) or up to depth of parent material whichever comes earlier were exposed and examined in details to record the morphology of the soils. The shallow pits and soil auger bore were examined for confirming extent of soil unit boundary. On the basis of these studies, the soils of the area were classified into 44 soil series. The relationship between terrain condition and distribution of various types of soils were also noted during traversing.

The morphological description of these profiles was recorded in field according to the guidelines of Soil Survey Manual developed by Soil and Land Use Survey of India organisation (AIS & LUS 1970). The collected soil samples from the selected profiles were analysed for their basic physico-chemical properties.

The data obtained as raster was converted into vector using GIS software and the spatial data was generated using ArcMap to create different theme maps. The spatial data was analysed for different land use particularly for Culturable waste land and their characteristics and limitations to evaluate their present and future potentialities. This will be vital input to prepare a strategic planning for effective and efficient decision making and soil water conservation programme.

The following steps have been followed in generation of soil information.

1. Selection of map scale according to area of interest.
2. Selection and acquisition of remote sensing data
3. Organise the collected/arranged the satellite, DEM, permanent, administrative, hydrological data/ layers in digital format
4. Generation of False Colour Composite (FCC)
5. Computation of contour from DEM
6. Pre-field satellite data interpretation based on geology, physiography, LU/LC and slope.
7. Ground truth verification and field work
8. Digitization of non-spatial data collected in ground truthing work.
9. Post-field Interpretation & modification based on ground truth data & finalization of map
10. Area calculation of various mapping unit
11. Soil sample analysis for pH, EC, Org.C, CaCo3, Mech.analysis, Ex. Ca, Mg, Na & K, CEC Base saturation and establishment of Soil series (SLUSI: Soil Analysis, Working manual (2006))
12. Drafting of report and creation of thematic maps on various themes
13. Generation of Soil Survey Report

Results and Discussion

Based on the Satellite data, Survey of India Toposheets and field survey, the Geology and physiography of the district was identified and delineated. Based on different morphological characteristics of the soil 44 soil series are identified. Major Geology in the study area is Granite Gneiss and major physiographic units in the study area are Upper Pediplains followed by Lower Pediplains. Very deep soil occupied 41.91% followed by deep soil 19.05%. Most of the area having very gently sloping of 61.34% and

majority area affected by moderate erosion. The Comprehensive System of Soil Classification (Soil Taxonomy, 2014) was followed to classify the different soils to correlate the physiographic and taxonomic units. Soils of the district were classified under orders Alfisol, Entisols, Inceptisols, and Vertisol. Among them Inceptisols (39.49%) and Vertisols (28.79%) dominated in the Virudhunagar District. Majority of the soil series interpreted in Land Capability Classes II (33.66%) and III (39.64%). Present Soil information under different subheads as indicated below.

Table 1. Major Soils of Virudhunagar District

Out of 44 soil series, 23 major soil series and its description given below (Fig.2)

Sr No.	Soil Series	Description
1	Achchankulam	Achchankulam series comprises deep, clay loam to clay texture, very gently sloping to gently (1-5%), slight to moderate water erosion, imperfectly drained soils with LCC II to III and Soil Taxonomic Classification: Fine, Montmorillonitic, isohyperthermic Leptic Haplusterts
2	Ayyanar Kovil	Ayyanar Kovil series comprises shallow, gravelly sandy clay loam skeletal texture, steep to very steep sloping (25 -50%), severe water erosion, excessively drained soils with LCC VI and Soil Taxonomic Classification: Loamy skeletal, Shallow, Mixed, isohyperthermic Typic Ustorthents
3	Ammapatti	Ammapatti series comprises moderately deep, sandy clay loam to sandy clay texture, very gently to gently sloping (1 - 5%), moderate water erosion, well drained soils with LCC III and Soil Taxonomic Classification: Loamy, Shallow Mixed, isohyperthermic Typic Calciustepts
4	Chikklampatti	Chikklampatti series comprises deep, sandy clay loam to sandy clay texture, gently sloping (3 - 5%), moderate water erosion, moderately well drained soils with LCC III and Soil Taxonomic Classification: Fine loamy, Mixed, isohyperthermic Typic Haplustepts
5	Chinnakamanpatti	Chinnakamanpatti series comprises shallow, sandy loam to sandy clay loam texture, very gently to gently sloping (1 - 5%), moderate water erosion, well drained soils with LCC IV and Soil Taxonomic Classification: Loamy, Shallow, Mixed, isohyperthermic Typic Ustorthents
6	Eluipaiyur	Eluipaiyur series comprises very deep, sandy clay loam to clay texture, very gently to gently sloping (1 - 5%), moderate water erosion, moderately well drained soils with LCC II to III and Soil Taxonomic Classification: Fine, Mixed, isohyperthermic Oxyaquic Haplustepts

7	Esali	Esali series comprises very deep, sandy loam to sandy clay texture, nearly level to very gently sloping (0 - 3%), none to slight water erosion, moderately well drained soils with LCC II to III and Soil Taxonomic Classification: Fine, Mixed, isohyperthermic Typic Haplustepts
8	Kilavikulam	Kilavikulam series comprises deep, sandy clay loam to clay texture, very gently sloping (1 - 3%), moderate water erosion, well drained soils with LCC III and Soil Taxonomic Classification: Fine, Mixed, isohyperthermic Typic Haplustalfs
9	Kunnalukulam	Kunnalukulam series comprises deep, sandy clay loam to sandy clay texture, very gently to gently sloping (1 -5%), moderate water erosion, moderately well drained soils with LCC II to III and Soil Taxonomic Classification: Fine loamy, Mixed, isohyperthermic Typic Haplustalfs
10	Mettamalai	Mettamalai series comprises shallow, sandy loam to clay loam texture, very gently to gently sloping (1 - 5%), moderate water erosion, well drained soils with LCC IV and Soil Taxonomic Classification: Loamy, Shallow, Mixed, isohyperthermic Typic Ustorthents
11	Muthulingapuram	Muthulingapuram series comprises moderately deep, sandy loam to sandy clay loam texture, very gently to gently sloping (1 - 5%), moderate water erosion, well drained soils with LCC III and Soil Taxonomic Classification: Loamy, Shallow, Mixed, isohyperthermic Typic Haplustepts
12	Narikkudi	Narikkudi series comprises very deep, sandy loam to clay loam texture, very gently to gently sloping (1 - 5%), moderate water erosion, well drained soils with LCC III and Soil Taxonomic Classification: Loamy, Mixed, isohyperthermic Typic Haplustepts
13	Nathampatti	Nathampatti series comprises very deep, clay loam to clay texture, very gently to gently sloping (1 - 5%), moderate water erosion, moderately well drained soils with LCC II to III and Soil Taxonomic Classification: Fine, Mixed, isohyperthermic Typic Haplustepts
14	Parampalli	Parampalli series comprises shallow, gravelly sandy loam to gravelly sandy clay loam loamy skeletal texture, very gently to gently sloping (1 - 5%), moderate water erosion to severe water erosion., well drained soils with LCC IV and Soil Taxonomic Classification: Loamy skeletal, Shallow, Mixed, isohyperthermic Typic Ustorthents

15	Rajapalayam	Rajapalayam series comprises very deep, sandy loam to sandy clay texture, very gently to gently sloping (1 - 5%), moderate water erosion, well drained soils with LCC II to III and Soil Taxonomic Classification: Fine, Mixed, isohyperthermic Typic Haplustalfs
16	Ramachandarapuram	Ramachandarapuram series comprises very deep, sandy clay loam to clay texture, very gently to gently sloping (1 - 5%), none to slight water erosion to moderate water erosion, poorly drained soils developed with LCC II to III and Soil Taxonomic Classification: Fine, Mixed, isohyperthermic Vertic Haplustepts
17	Sivakasi	Sivakasi series comprises very deep, sandy clay loam to clay fine texture, very gently to gently sloping (1 - 5%), none to slight water erosion to moderate water erosion, imperfectly drained soils with LCC II to III and Soil Taxonomic Classification: Fine, Montmorillonitic, isohyperthermic Typic Haplusterts
18	Shenbagathopu	Shenbagathopu series comprises shallow, gravelly sandy clay loam loamy skeletal texture, moderately sloping (5 - 10%), severe water erosion, excessively drained soils with LCC VI and Soil Taxonomic Classification: Loamy skeletal, Shallow, Mixed, isohyperthermic Typic Ustorthents
19	Tayilpatti	Tayilpatti series comprises shallow, gravelly sandy loam loamy skeletal texture, very gently to gently sloping (1 -5%), moderate water erosion to severe water erosion, moderately well drained soils with LCC IV and Soil Taxonomic Classification: Loamy skeletal, Shallow, Mixed, isohyperthermic Typic Ustorthents
20	Viracholan	Viracholan series comprises very deep, Sandy loam to sandy clay texture, nearly level to very gently sloping (0 - 3%), none to slight water erosion to moderate water erosion, well drained soils with LCC II to III and Soil Taxonomic Classification: Fine, Mixed, isohyperthermic Fluventic Haplustepts
21	Virudhunagar	Virudhunagar series comprises very deep, clay loam to clay fine texture, very gently sloping (1-3%), slight water erosion to severe water erosion, imperfectly drained soils with LCC II to IV and Soil Taxonomic Classification: Fine, Montmorillonitic, isohyperthermic Typic Haplusterts
22	Vembakottai	Vembakottai series comprises deep, clay loam to clay texture very gently to gently sloping (1 - 5%), moderate water erosion, imperfectly drained soils with LCC II to III and Soil Taxonomic Classification: Fine, Montmorillonitic, isohyperthermic Leptic Haplusterts

23	Valaikulam	Valaikulam series comprises very deep, sandy loam to sandy clay loam texture, very gently to gently sloping (1 - 5%), moderate water erosion to severe water erosion, well drained soils with LCC II to III and Soil Taxonomic Classification; Fine, Mixed, isohyperthermic Typic Rhodustalfs

Source: Compendium of Soil and Land Resources Database (2014), Soil and Land Use Survey of India, NewDelhi-110012.

Climate

The climate of the district is tropical savanna climate (Köppen climate classification Aw) with distinct wet and dry seasons. It is observed from rainfall data that the average annual precipitation for 10 years period (2009 to 2018) is about 648.4 mm. Most of rainfall season occur during North East Monsoon (Table 2).

Table 2. Climatic Condition Prevailing over the District (2010 to 2019)

Months	Temperature (°C)			Average Rainfall (mm)
	Maximum	Minimum	Mean	
January	31.95	20.04	25.99	23.54
February	34.06	20.84	27.45	11.35
March	36.91	22.79	29.85	43.93
April	38.61	24.68	31.64	64.74
May	37.06	25.03	31.05	66.48
June	37.85	25.06	31.46	6.23
July	37.53	25.04	31.29	7.04
August	36.64	25.50	31.07	21.71
September	35.95	23.88	29.91	45.53
October	33.95	23.65	28.80	163.54
November	31.61	22.55	27.08	145.17
December	30.93	22.33	26.63	49.15
Total Average	**35.25**	**23.45**	**29.35**	**648.4**

Source: Tamil Nadu Agricultural University Regional Research Station, Aruppukottai – 626107.

Prevailing climatic condition i.e. Average maximum Temperature is 35.25°C and Average minimum Temperature is 23.45°C. Mean annual summer temperature (MAST) is 34.27°C whereas Mean annual winter temperature (MAWT) is 26.69°C. Difference between mean summer and mean winter temperature is 4.58°C. Hence the Temperature regime comes under Isohyperthermic and Ustic moisture regime (USDA 2014: Key to Soil Taxonomy).

The length of growing period (LGP) analysis for Kariapatti, Narikudi and Tiruchuli blocks of Virudhunagar district revealed that there had been around 100 to 120 days available for cropping in Kariappatti, Narikudi and Tiruchuli blocks. Therefore Short to

medium duration crops like pulses and millets are fine with this growing period and especially the complete rainfed cultivation of the district is essential (Kowshika M *et al.* 2023).

The district having a subtropical climate and the chief irrigation sources in the area are the tanks, wells and tube/bore wells. Reservoirs and Tank irrigation is highest in Srivalliputtur, Thiruchuli and Kariyapatti blocks followed by Aruppukottai, Rajapalayam, Sivakasi, Sattur, and Virudhunagar blocks (A. Balachandran, Central Ground Water Board 2009).

Land Use

Major crops grown and fertilizer recommendation are given below (Table 3)

Table 3. Season wise crops and fertilizer recommendation (Kg /ha) for Virudhunagar district

Season	Crops	Seed rate (Kg /ha)	Spacing (cm)	Fertilizer recommendation (Kg /ha)			
				N	P	K	Micronutrients mixture
Kharif	Paddy	50	12.5 x 10	120	38	38	12.5
Rabi	Sorghum	10	45 x 15	16	8	0	12.5
Rabi	Pearl millet	5	45 x 15	16	8	0	12.5
Rabi	Maize	20	60 x 20	135	62.5	50	12.5
Rabi	Foxtail	5	25 x 10	44	22	0	12.5
Rabi	Black gram	20	30 x 10	12.5	25	0	5
Rabi	Green gram	20	30 x 10	12.5	25	0	5
Rabi	Cowpea	20	30 x 15	12.5	25	0	5
Rabi	Groundnut	140	30 x 10	10	10	45	60 (s)
Rabi	Sunflower	10	60 x 30	30	15	15	0
Rabi	Gingelly	5	15 x 15	23	13	13	0
Rabi	Cotton	2	120 x 60	120	60	60	12.5

Source: Additional Director of Agriculture, Sivakasi Taluk, Virudhunagar District ,Tamil Nadu

The following cropping patterns are followed in the survey area of Virudhunagar district:

Sole Crops

Paddy, Jowar, Pearl millet, Maize, Foxtail, Ragi, Black gram, Green gram, Red gram, Bengal gram, Horse gram, cotton etc .

Inter cropping system

Maize + Cowpea, Groundnut + Gingelly, Cotton + Green gram etc.

Cereals, pulses, and millets, which do not require much irrigation, are the main crops grown. Paddy is grown where tank or bore well irrigation is available.

Soil / Land resource potential and constraints for agriculture

The soils of the District are of poor productivity and are mainly coarse loamy to clay soil (locally known as Karisal mannu). Black soil in the major parts of the district, the recharge potentials are very low and it has also resulted in water quality problems. In order to increase the recharge, tanks, percolation ponds may be provided with the recharge wells/recharge shafts penetrating this impervious layer to make it more effective in recharging the aquifer (A. Balachandran, Central Ground Water Board, 2009). Major area is under very deep soils with low hydraulic conductivity. It is difficult to plough and high power tillage implements are required. These soils are used for mostly dryland cultivation and partially Occupied as Culturable waste lands.

Culturable Waste Lands of the Virudhunagar District

Out of 44 soil series identified in this district, 38 soil series are having a culturable waste lands of 68,098 ha (16.10%). Vembakottai, Sivakasi, Sattur, Narikudi and Tiruchuli blocks are highly affected. Most of the culturable waste lands area is dominated with Acacia species and scrub land. It leads to Increasing biotic pressure, absence of adequate investments and appropriate management practices. Virudhunagar (2.21%), Achchankulam (1.68%), Chikklampatti (1.11%) Vembakottai (1.12%) and Sivakasi (1.06%) series are dominated with culturable waste land and most of them are vertisol in nature.

Alternate land use option for culturable wasteland

Removal of Acacia species and scrub land and grow suitable dry land crops such as Jowar, Pearl millet, Maize, Ragi, Black gram, Green gram, Red gram etc. Practice of cultivating crops along with horticulture component such as Mango, Sapota, Guava, Ber, Tamarind, Custard apple, Wood apple, Jamun, Bael, Jackfruit and Cashew plantation in red soil also suggested here. Vegetables such as Drumstick, Curry leaf, Tomato, Chilli and Cluster bean and aromatic crops i.e. lemon grass, citronella and khus grass are also suitable (G. M. Sujith, Alternate Land Use Systems, UAS, Bangalore).

Central/State sponsored agricultural developmental schemes

Kalaignar's All Village Integrated Agriculture Development Project (KAVIADP) was initiated in 2021-22 by Govt. of Tamil Nadu. The programme aims at overall development of villages and transforming them to be self-sufficient. Particularly for selection of wasteland clusters to be converted into agriculture lands, constructing a borewell/tube well and the electricity connection or solar power pump and providing seeds of toor dal, black gram, green gram etc.,

Integrated Wasteland Development Programme (IWDP) was started in the year 1992 by Government of India, mainly for development of wastelands in non forest areas in totality by involving local people at every stage of development. Major programme implemented for improving the productivity of waste & degraded lands keeping in view the poverty, backwardness, gender & equity is Integrated Wasteland Development Programme.

Soil mapping units and its legends

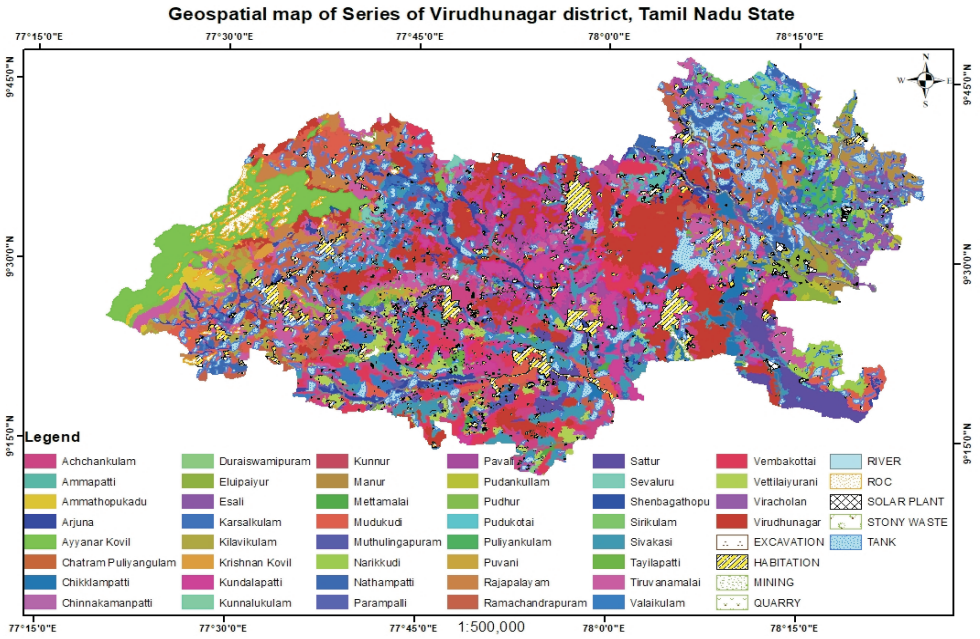
Virudhunagar district consist of 560 mapping units. soil mapping unit is demarcated as RM5kB2 where 'RM' for Rajapalayam Soil Series, '5' for Very deep soil depth, 'k' for sandy clay loam surface texture, 'B' for Very gentle slope and '2' for moderate erosion.

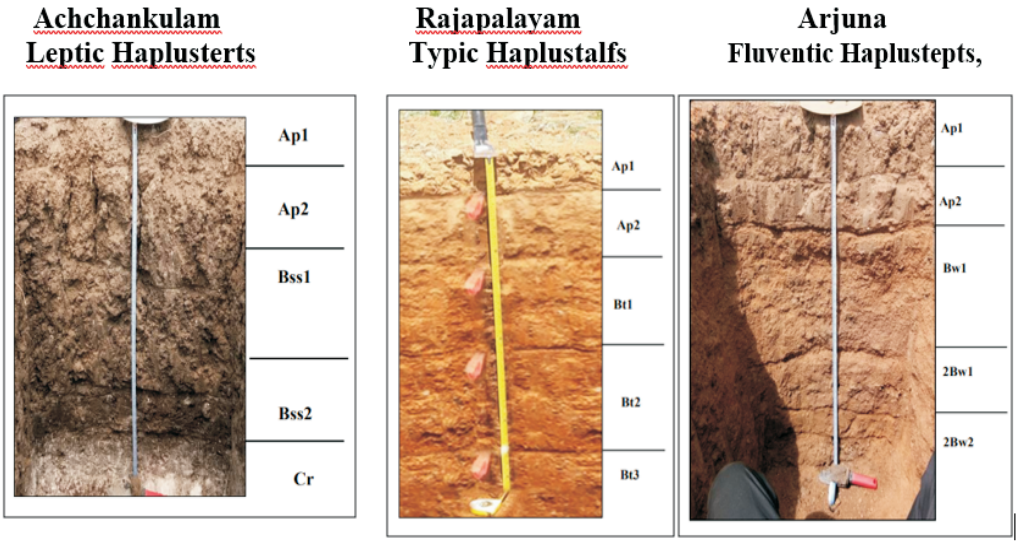
S.N	Soil Depth	Symbol
1.	Very Shallow soil (<10 cm)	1
2.	Shallow soil (10-25 cm)	2
3.	Moderately deep (25-50 cm)	3
4.	Deep (50-100 cm)	4
5.	Very deep (> 100 cm)	5

Sl. No.	Erosion classes	Symbol
1.	None to slight	e1
2.	Moderate	e2
3.	Severe	e3

Sl. No.	Slope Classes	Symbol
1.	Nearly level (0-1%)	A
2.	Very gentle slope (1-3%)	B
3.	Gentle slope (3-5%)	C
4.	Moderate slope (5-10%)	D
5.	Strong slope (10-15%)	E
6.	Moderate steep slope (15-25%)	F
7.	Steep slope (25-33%)	G
8.	Very steep slope (33-50%)	H

Source: SLUSI (2014): Compendium of Soil and Land Resources Database





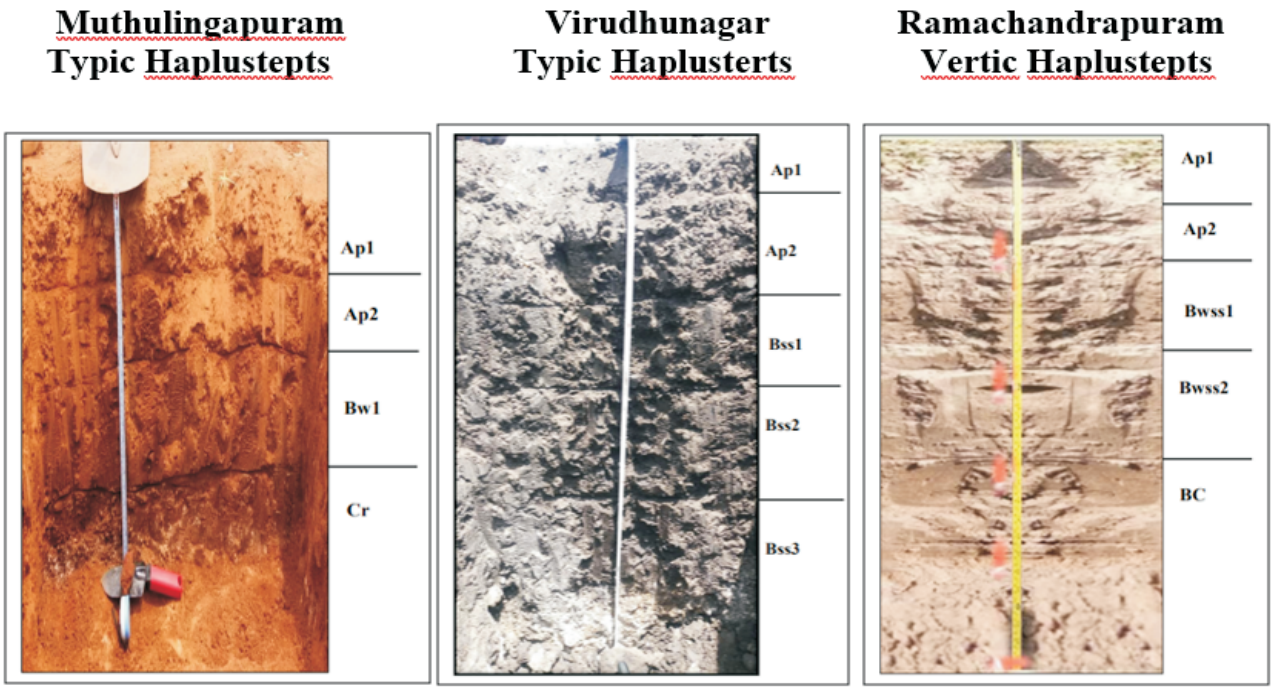


Fig.2. Soil Series Geo-spatial map and glimpses of Profiles and its classification.

Conclusions

The study helps in evaluating the land use and land cover in the district of Virudhunagar includes its Blocks and Villages. The study revealed that Sustainable Agriculture Development in the district possible through via. Integrated Nutrient Management, Integrated Wastelands Development Programme, Agroforestry, Social forestry etc in dryland areas. In-situ soil and moisture conservation measures like terracing, bunding, trenching, vegetative barriers and drainage line treatment by vegetative and engineering structures are very essential. Remove Acacia species and scrub lands cultivate them with suitable dry land and Horticulture crops. Dry land field crops such as Jowar, Pearl millet, Maize, Ragi, Black gram, Green gram, Red gram etc. and horticultural crops such as Mango, Sapota, Guava, Ber, Tamarind, Custard apple, Wood apple, Jamun, Bael, Jackfruit etc are suitable here. Planting and sowing of multi-purpose trees, shrubs, grasses, legumes which encourage natural vegetative regeneration. Wood species substitution and fuel wood conservation measures also essential. Awareness programmes, training & extension activities essential for sustainable development of the Virudhunagar District. Encouraging people's participation through community organization and capacity building. Development of small water Harvesting Structures and afforestation of degraded forest and non-forest wastelands are also very essential.

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