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RESEARCH ARTICLE

Mapping of rainfed areas in Tamil Nadu using Remote Sensing Technology

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ABSTRACT

A study was conducted to generate the satellite sensor-based map on rainfed cropland areas of Tamil Nadu using remote sensing derived variables and ancillary data. The study primarily utilized three remote sensing variables from different sensors viz., a temperature component using Land Surface Temperature (LST), a vegetation component using one of the vegetation related remote sensing variables and precipitation component using remotely sensed precipitation data for delineating rainfed cropland areas of Tamil Nadu. The study estimated the rainfed cropland areas of Tamil Nadu as 25.67 lakh ha. The rainfed cropland area found to be higher in Ramanathapuram (2.27 lakh ha) district followed by Villupuram (1.90 lakh ha) and Thoothukudi district (1.65 lakh ha). The lesser area, was recorded in Thanjavur, Tiruvarur and Tiruvallur districts of Tamil Nadu. Accuracy of rainfed area classes (rainfed Ground Truth points falling on rainfed area) was found to be 85 per cent with a kappa coefficient of 70 per cent of agreement between the ground control points and predicted map. The rainfed area map generated at lesser resolution with 70 per cent of kappa agreement indicated that the methodology has to be fine-tuned and the rainfed area map has to be generated at higher resolution using high-resolution satellite imageries.

Keywords: *Rainfed, Spectral Matching Techniques, Land surface Temperature, Kappa coefficient*

INTRODUCTION

Tamil Nadu has a gross cropped area of 5.8 million ha of which about 45 per cent is under rainfed/dry farming. Further, about 50 per cent of the area was threatened by soil erosion, salinity, waterlogging, nutrient deficiency, depletion of soil organic matter which leads to decline in productivity. The Spatio-temporal pattern of cultivated crops varies considerably in the state and is strongly determined by varying balances of water supply and demand across regions and seasons. Agricultural productivity in rainfed is exclusively water-centric as rainwater plays a vital role in a crop cycle. The crux of rainfed agriculture lies with soil and moisture conservation supported by soil health and crop diversification. There is a need to selectively grow less water-intensive and highly remunerative crops, which alone will ensure better productivity and profitability in rainfed crops. Rainfed agricultural occupies 67 per cent of the net sown area contributing 44% of good grain production and supporting 40 per cent of the population. In the future, rainfed ecosystem is one of the potential areas where crop production can be intensified and productivity can be increased (Bartholome and Belward, 2005; Freydank and Siebert, 2006; Thenkabail *et al*., 2008). Hence, this project was proposed to generate the satellite sensor-based map of rainfed cropland areas of Tamil Nadu using remote sensing derived variables and secondary data.

MATERIALS AND METHODS

Datasets

Satellite data and ancillary data *(Table 1)*

The satellite sensor and ancillary data used in this research consisted of

(a) MODIS 500 m 8-day composite data for 2010-2018,

(b) MODIS NDVI 250m 16-day composite data for 2010-2018,

(c) SRTM DEM 3 arc second digital elevation data,

(d) Precipitation monthly data for 1971–2018 derived from PWD and TNAU AWS,

(e) Skin temperature data derived from MODIS LST for 2010–2018,

(f) Google Earth very high-resolution imagery ''zoom-in-views'' of 1000 points, and

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(g) Ground truth points of 1938 collected including irrigated (1140) and rainfed (798) cropland areas. (Figure 1)

METHODOLOGY

The basic process involved composing layer stack datasets, segmenting the Tamil Nadu into characteristic regions that were easier to analyze, performing an unsupervised classification on each segment, grouping similar classes through Spectral Matching Techniques (SMTs), setting up a class identification and labeling process, resolving the mixed classes, and calculating the sub-pixel areas (SPAs) (Figure 2).

Segmenting into characteristic regions

The original 394 bands are segmented in different image segments. In order to create segments, firstly masks are created based on the criteria listed below. The five masks are

(1) Precipitation less than 360 mm per year

(2) Precipitation greater than 2400 mm per year

(3) Temperature less than 280°K per year

(4) Forest covers greater than 75% canopy cover

(5) Elevation greater than 1500 m.

Masks are created by taking the secondary datasets such as precipitation, elevation, and temperature and applying simple algorithms in ArcGIS. Segment based classification and class identification is very helpful for rapid identification of classes.

Kappa Coefficient

Another measure of classification accuracy is the kappa coefficient, which is a measure of the proportional (or percentage) improvement by the classifier over a purely random assignment to classes (Richards, 1993). The kappa coefficient can be estimated from the formula given below.

$$\widehat{K} = \frac{\mathrm{NA} - \mathrm{B}}{N^2 - B}$$

For an error matrix with r rows, and hence the same number of columns,

Where,

A = the sum of r diagonal elements, which is the numerator in the computation of overall accuracy

B = sum of the r products (row total x column total)

N = the number of pixels in the error matrix (the sum of all r individual cell values)

RESULTS AND DISCUSSION

The study estimated the rainfed cropland areas of Tamil Nadu as 25.67 lakh ha(Figure 3). The district-wise areas statistics were extracted and given in Table 2.

Table 1. Layer stack data characteristics. All data were resampled to 500 m in the raster stack.

Source	Wavelength range (nm)	Duration (year)	Number of bands	Data format	Range
MODIS TERRA SENSOR 500 M – 8 DAY COMPOSITE					
Band1	620-670 nm	2010-2018	46	16 bit signed integer	-100 to 16000
Band2	841-876 nm	2010-2018	46	16 bit signed integer	-100 to 16000
Band3	459-479 nm	2010-2018	46	16 bit signed integer	-100 to 16000
Band4	545-565 nm	2010-2018	46	16 bit signed integer	-100 to 16000
Band5	1230-1250 nm	2010-2018	46	16 bit signed integer	-100 to 16000
Band6	1628-1652 nm	2010-2018	46	16 bit signed integer	-100 to 16000
Band7	2105-2155 nm	2010-2018	46	16 bit signed integer	-100 to 16000
MOD13A1 – 16 DAY COMPOSITE-250 m	(band 2 band 1)/(band 2+ band 1)	2010-2018	23	Unitless, 8-bit scaled NDVI	-1 to +1
MODIS LST (MOD11A2) 1 KM		2010-2018	46	16 bit signed integer	-100 to 16000
Secondary data					
SRTM DEM3 arc second	DTM	1 time	1	Meters, 16 bit integer	0-65536
Rainfall 500 m	Mean of Monthly 47 years	1971-2018	1	mm, 16 bit	0-65536
Forest and Land use land cover	None	1 time	1	Class names, 8 bit	0-256

The rainfed cropland area found to be higher in Ramanathapuram (2.27 Lakh ha) district followed by Villupuram (1.90 Lakh ha) and Thoothukudi district (1.65 Lakh ha). The lesser area is recorded in Thanjavur, Tiruvarur and Tiruvallur districts of Tamil Nadu. The accuracies and errors were assessed based on pooling two unique and independent datasets that were not used during the class identification and labeling process.

A total of 1938 field plot points were collected during the research period from various parts of

Table 2. District wise rainfed area statistics

Sl.No	District Name	Pixel count	Area (Lakh hectares)
1	Ramanathapuram	40475	2.27
2	Viluppuram	33747	1.90
3	Thoothukkudi	29325	1.65
4	Namakkal	26635	1.50
5	Virudhunagar	25593	1.44
6	Dharmapuri	25403	1.43
7	Tirunelveli	25130	1.41
8	Vellore	24438	1.37
9	Salem	23401	1.31
10	Dindigul	22621	1.27
11	Pudukkottai	17821	1.00
12	Tiruchirappalli	16872	0.95
13	Erode	15440	0.87
14	Madurai	14725	0.83
15	Tiruppur	13748	0.77
16	Krishnagiri	12728	0.71
17	Tiruvannamalai	11295	0.63
18	Kanniyakumari	10714	0.60
19	Sivaganga	9531	0.54
20	The Nilgiris	8835	0.50
21	Coimbatore	8617	0.48
22	Theni	8535	0.48
23	Cuddalore	8212	0.46
24	Perambalur	8112	0.46
25	Karur	5410	0.30
26	Ariyalur	5029	0.28
27	Nagapattinam	1972	0.11
28	Kancheepuram	1387	0.08
29	Thiruvarur	812	0.05
30	Thanjavur	295	0.02
31	Thiruvallur	220	0.01
	Total		25.67

Tamil Nadu. Out of 1938 points, irrigated cropland consists of 1140 points and rainfed cropland

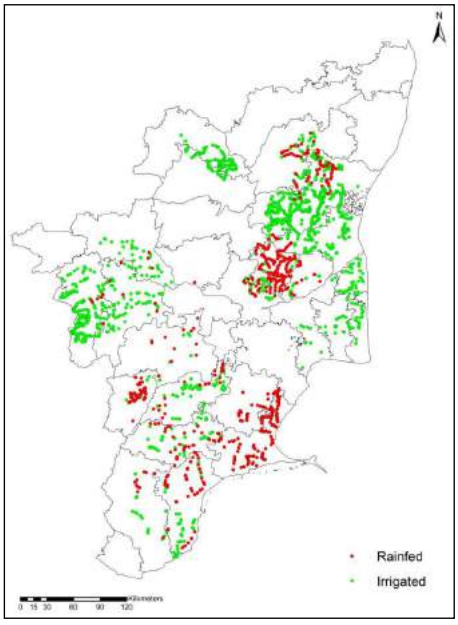

Figure 1. Locations of ground survey

comprises of 798 points. Among the points, 60 per cent of the irrigated and rainfed points were used in spectral matching techniques (training samples) and the remaining 40 per cent of the points were

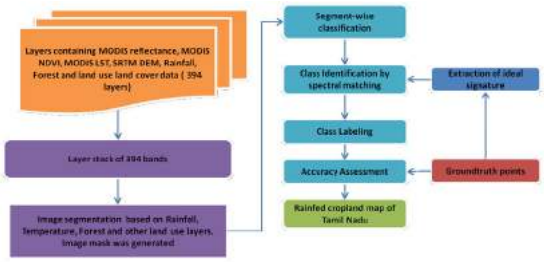

Figure 2. Methodology for rainfed area classification

used for accuracy assessment (456 of irrigated or non rainfed cropland and 318 points of rainfed).

Accuracy of rainfed area classes (rainfed GTR points falling on rainfed area) are found to be 85 per cent with a kappa coefficient of 70 per cent of agreement between the ground control points and predicted map. The rainfed area map generated

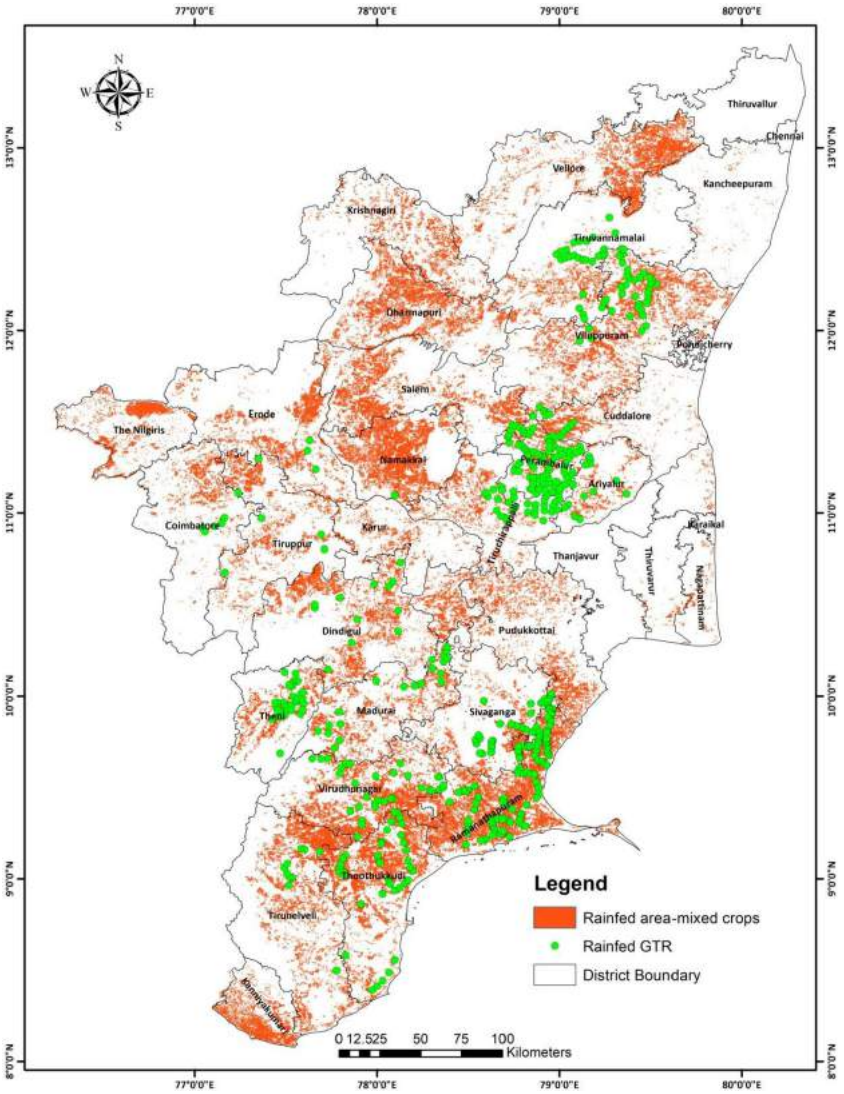

Figure 3. Rainfed area map overlaid with ground truth points

at lesser resolution with 70 per cent of kappa agreement indicates that the methodology has to be fine-tuned and the rainfed area map has to be generated at higher resolution using high-resolution satellite imageries.

CONCLUSIONS

The study estimated the rainfed cropland areas of Tamil Nadu as 25.67 lakh ha. The rainfed cropland area found to be higher in Ramanathapuram (2.27 Lakh ha) district, followed by Villupuram (1.90 Lakh ha) and Thoothukudi district (1.65 Lakh ha). Accuracy of rainfed area classes (rainfed GTR points falling on rainfed area) are found to be 85 per cent with a kappa coefficient of 70 per cent of agreement between the ground control points and predicted map.

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