

# Comparative and Suitability Analysis of Different Sand Dune Terrain by using DEM data in Marakkanam Taluk of Villupuram District, Tamil Nadu

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**Abstract:** Digital Elevation Model (DEM) plays an important role in characterizing the surface topography. Over a decade, DEM from satellite imageries like SRTM, CARTOSAT etc. are becoming popular as well as gaining wide applications. However the accuracy of DEM generated from satellite images are of major concern for remote sensing applications. The objective of this study is to analyze the suitability of DEM derived from different satellite images for the assessment of certain geomorphic features with better accuracy. This paper attempts to compare the DEM derived for three different morphological features like palaeo coastal sand dunes, younger coastal sand dunes and interdunal depression of Marakkanam coast of TamilNadu. Comparative study of elevation data profile analysis of the features using different interpolation methods such as IDW, Spline, ANUDEM and Kriging were attempted. The profile analysis indicated that for highly elevated regions, data from Cartosat and GPS show morphologically closer resemblance to the real field condition whereas in plain areas SRTM and Google Earth data show closer resemblance to the real field condition.

**Keywords:** SRTM-DEM, Cartosat-DEM, Field Accuracy, Interpolation, Comparison

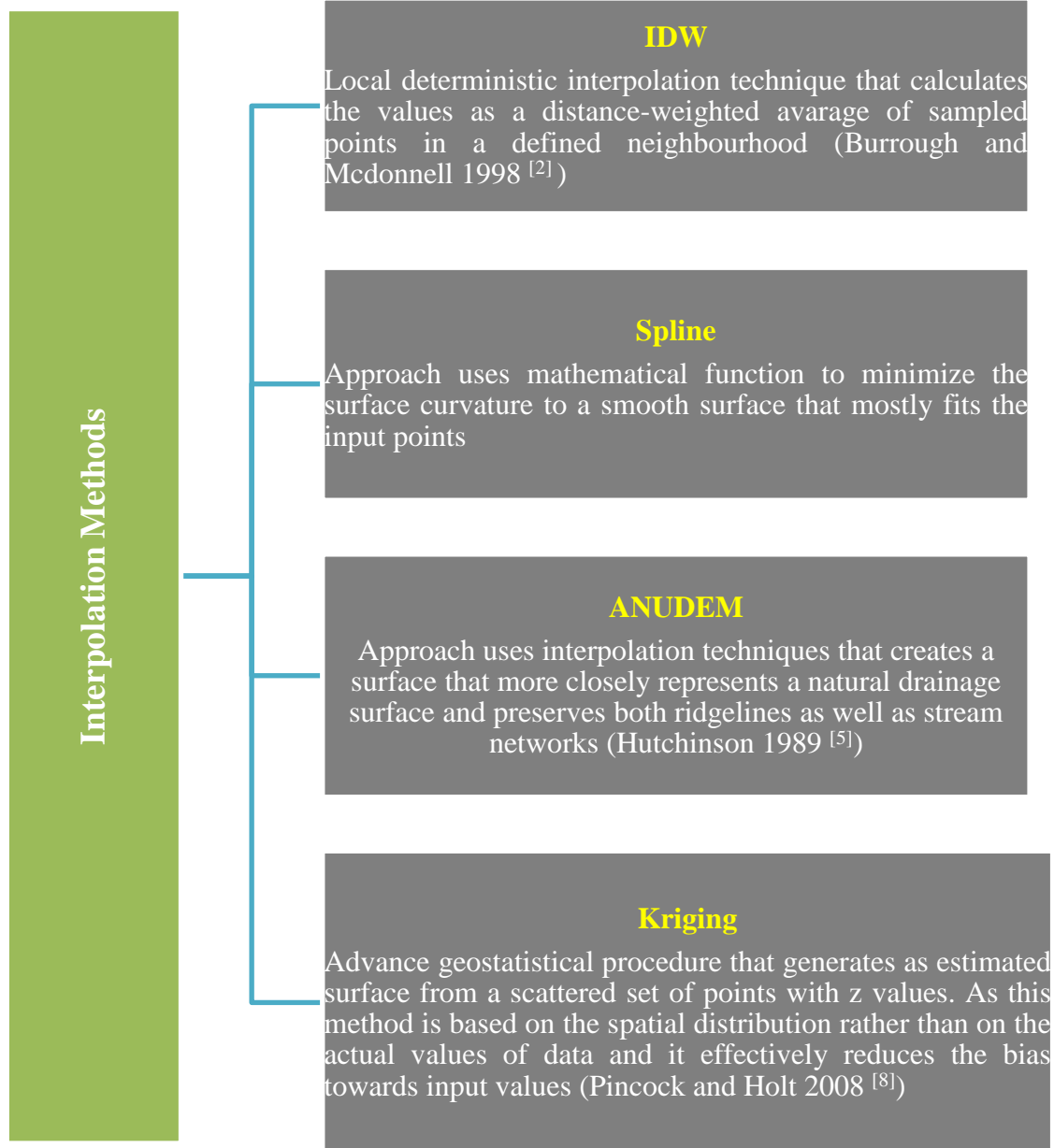
## 1. Introduction

The term Digital Elevation Model (DEM) refers to the digital representation of earth's surface topographic data. DEM is the generally adopted data structure for storing topographic information which can be interpolated to establish the values of the entire terrain surface. DEM is an

array representation of squared cells called pixels in which each cells associate an elevation value (Manuel 2004 [6]). In recent years, many satellite systems are available to render DEM data.

Cartosat I is an Indian satellite launched in May 2005, that acquires panchromatic stereoscopic data of 2.5 m resolution that are particularly useful for producing Digital Elevation Model of the earth's land surface (Gayla Evansa et al. 2008 [4]). The availability of this high resolution satellite images has opened new possibilities for terrain surface studies. Shuttle Radar Topography Mission (SRTM) was a space shuttle mission launched in February 2000 objected to obtain RADAR data of the earth surface to produce high resolution topographic maps (Nikolakopoulos et al. 2006 [7]).

DEM generated from satellite images need to be validated by using Ground Control Points (GCP's) for further analysis (Suganthi S and Srinivasan K 2010[9]). Interpolation predicts values for unknown pixels in a raster format from the limited number of known pixel values. Thus interpolation techniques are generally based on the principle of spatial autocorrelation which assumes that closer points are more similar to the real world information (GCP) compared to farther ones (Arun P.V 2013 [1]). The interpolation methods that are widely used include Inverse Distance Weightage (IDW), Spline, ANUDEM, Nearest Neighbor and Kriging.



### 1.1 Geomorphologic features considered for the study

Most of the earlier studies were attempted to compare the DEM of any two satellite products for any one geomorphologic feature like hill or plain or coastal landform of different geographic locations. The present study validates the elevation of three geomorphological features such as palaeo coastal sand dunes, younger coastal sand dunes and interdunal depression using two different DEM data. Sand dunes along the coast renders several vital services such as acting as natural barrier against

hazards, provide habitats for variety of flora and fauna species etc.

### 2. STUDY AREA

Marakkanam was an ancient seaport on the coast of Bay of Bengal. The study area is located between north of Marakkanam Yedayantittu lake mouth and south of Kunimedu with geographical coordinates from 80°00'25.745"E, 12°15'15.152"N to 79°54'13.965"E, 12°05'37.128"N. The coastal length considered for the study is about 20 km.

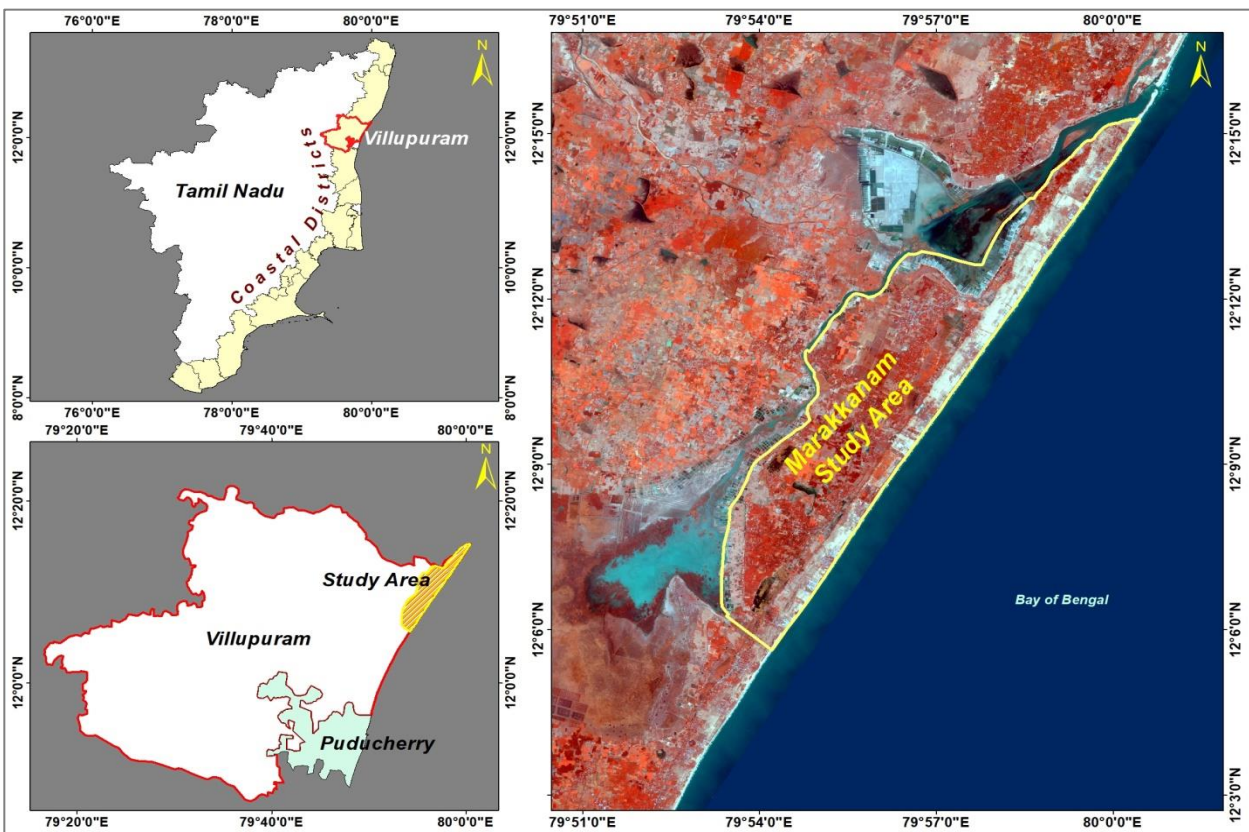


Fig-1: Study Area

### 3. DATA USED

The data source used for the study is given below.

Table-1: Data Source

S.No.	Satellite	Images	Resolution (m)
1	IRS - P5 (Cartosat I)	Cartosat DEM	1 Arc

2	Shuttle Radar	SRTM DEM	1 Arc
3	IRS - P6	LISS IV (2019)	5.8

### 4. METHODS

Digital Elevation Model from SRTM and Cartosat has been used to assess the elevation of different sand dunes. Tin model has been prepared for perpendicular profile to identify the terrain undulation and comparative analysis of Cartosat and SRTM DEM for different sand dune study. For the assessment of elevation accuracy, E-value calculation

has been used. E-value descriptive statistics (in terms of Mean, Median, Standard Deviation, Skewness, Kurtosis and Jarque-Bera J-B statistics) of variables used for empirical analysis in the present study. J-B statistics shows that all

variables are more than 5% level, having normal distribution as data do not support to reject the null hypothesis that variables under consideration follows normal distribution.

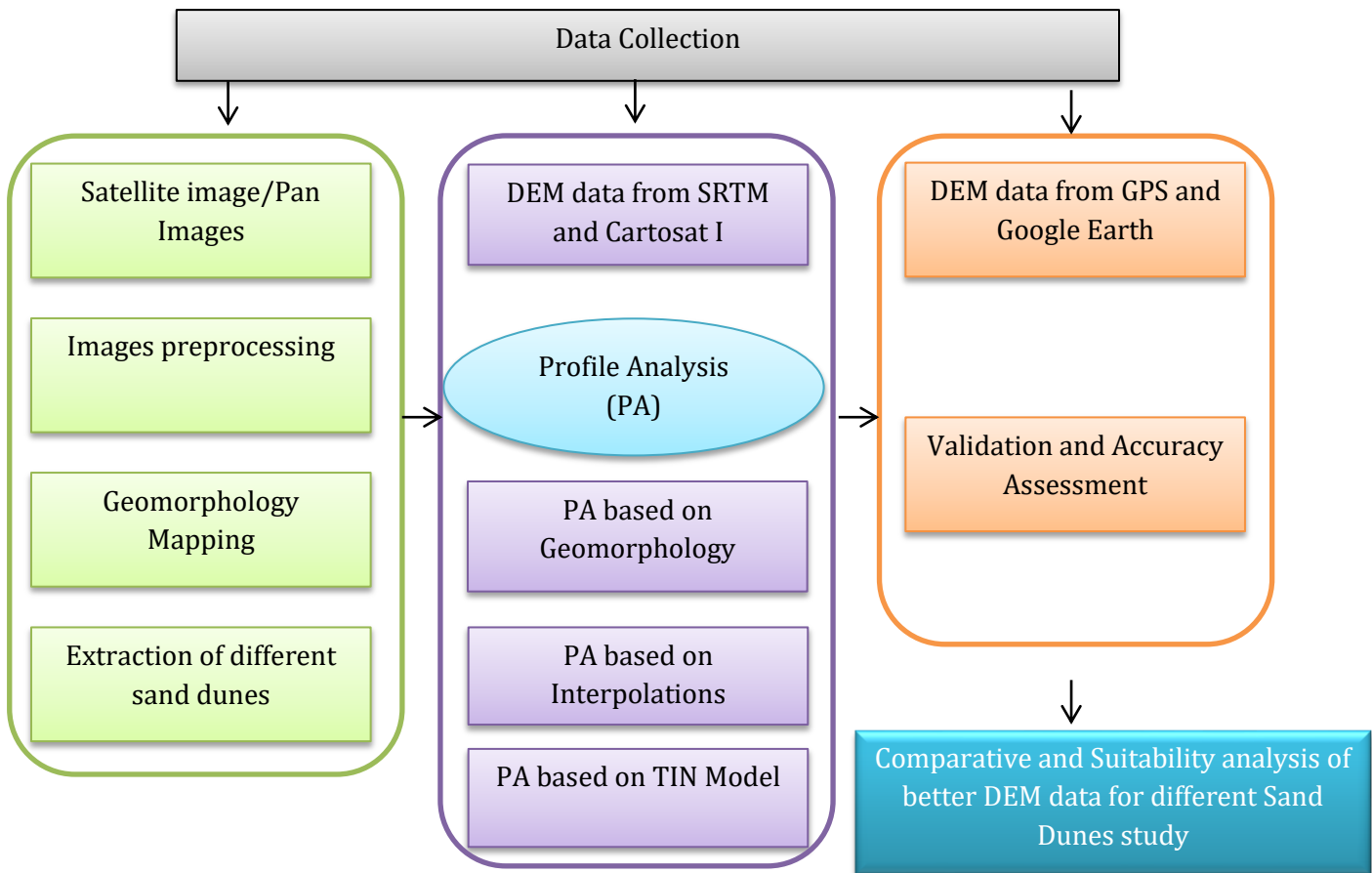


Fig-2: Methodology

#### 4.1 Reference Elevation Data (Ground Truth Data)

The accuracy assessment of the height of different sand dunes derived from Cartosat DEM and SRTM DEM was carried out by two means of reference data i.e. Google Earth and field derived elevation data. Intensive field

survey (Figures 3 & 4) using Juno handheld GPS was carried out to collect the elevation details of respective features considered in the study. In Fig.3, pictures A-D represent Ridges (Young), E- represents sandy beach area, F-represents undulating terrain (Young), G and K-represents Swale/Interdunal depression whereas H-J represent Ridges (Palaeo).

### 4.2 Accuracy assessment methods

Elevation data from field has been collected for assessing the accuracy of Cartosat-DEM and SRTM-DEM. The elevation error of the vertical accuracy of the Cartosat -DEM and SRTM-DEM were assessed by computing the difference between the DEM pixel value and the corresponding reference (field) elevation points using the equation given below:

$$Z_{error} = Z_{DEM} - Z_{reference}$$

Whereas  $Z_{error}$  is the elevation error

$Z_{DEM}$  is the elevation value of the DEM being explored and

$Z_{reference}$  is the corresponding reference elevation of point being considered

Positive difference indicates that the location where the DEM elevation exceeded the reference elevation points and whereas negative error occurs at locations, where the DEM elevation was below the reference elevation points. Common statistical measure such as Mean error, Maximum error, Minimum error, Standard Deviation (STD) error and Root Mean Square (RMS) error have been used to quantify the error of vertical accuracy of both DEM data. In this study the following statistics have been applied.

$$\text{Mean}_{error} = \sum \frac{Z_{error}}{n}$$

$$\text{STD} = \pm \sqrt{\frac{\sum (Z_{DEM} - \text{Mean}_{error})^2}{n-1}}$$

$$\text{RMSE} = \sqrt{\frac{\sum (z_{error})^2}{n}}$$



Fig-3: Geomorphic features visited during field survey

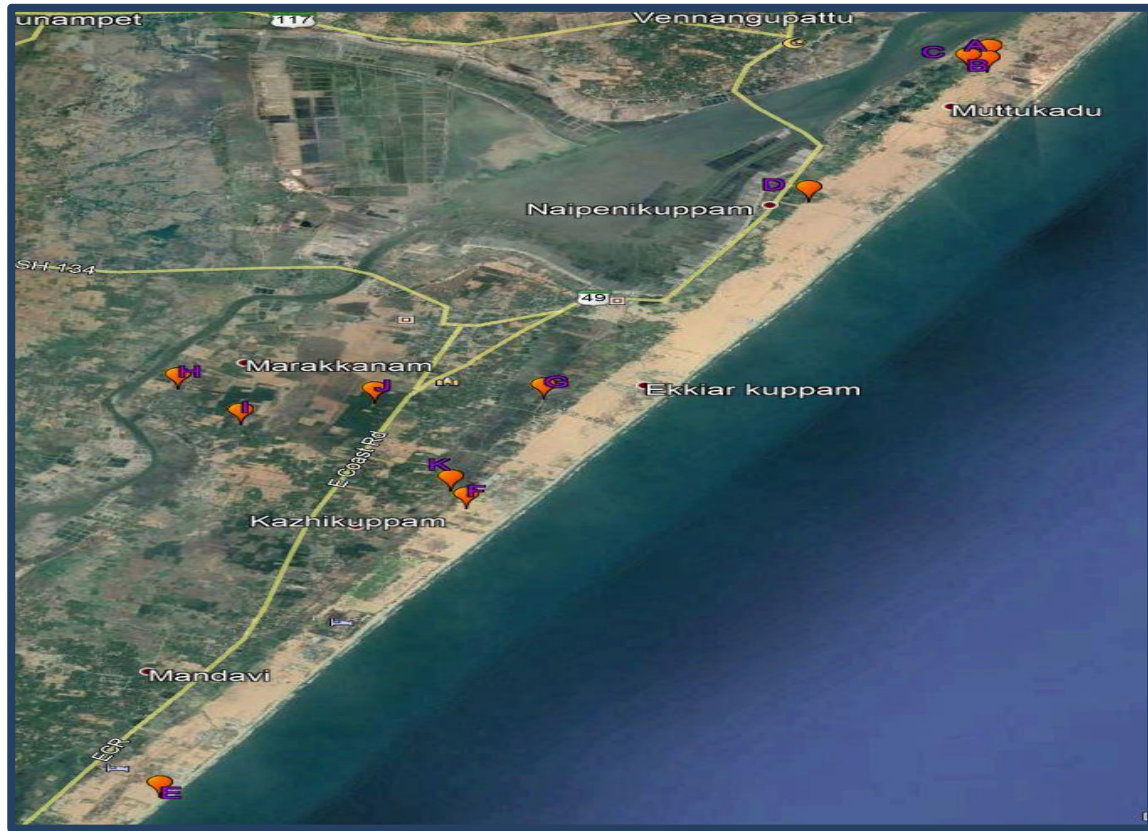


Fig-4: Field visited locations within the study area

## 5. RESULT AND DISCUSSION

The present study concentrates on the analysis of geomorphological features in the Marakkanam coastal area using different DEM data.

### 5.1 Geomorphology mapping

Geomorphology map of Marakkanam has been prepared on 1:25000 scales based on visual interpretation of pan sharpened image (SRTM and LISS IV- 2019) satellite images. Different coastal landforms such as ridges (young and palaeo), young sandy foredunes, saltpans, sandy beach and interdunal depression were identified in the coastal stretch of the study area (Fig.3). However the geomorphic features considered for the study were ridges (palaeo, young), sandy foredunes (young) and interdunal depression.

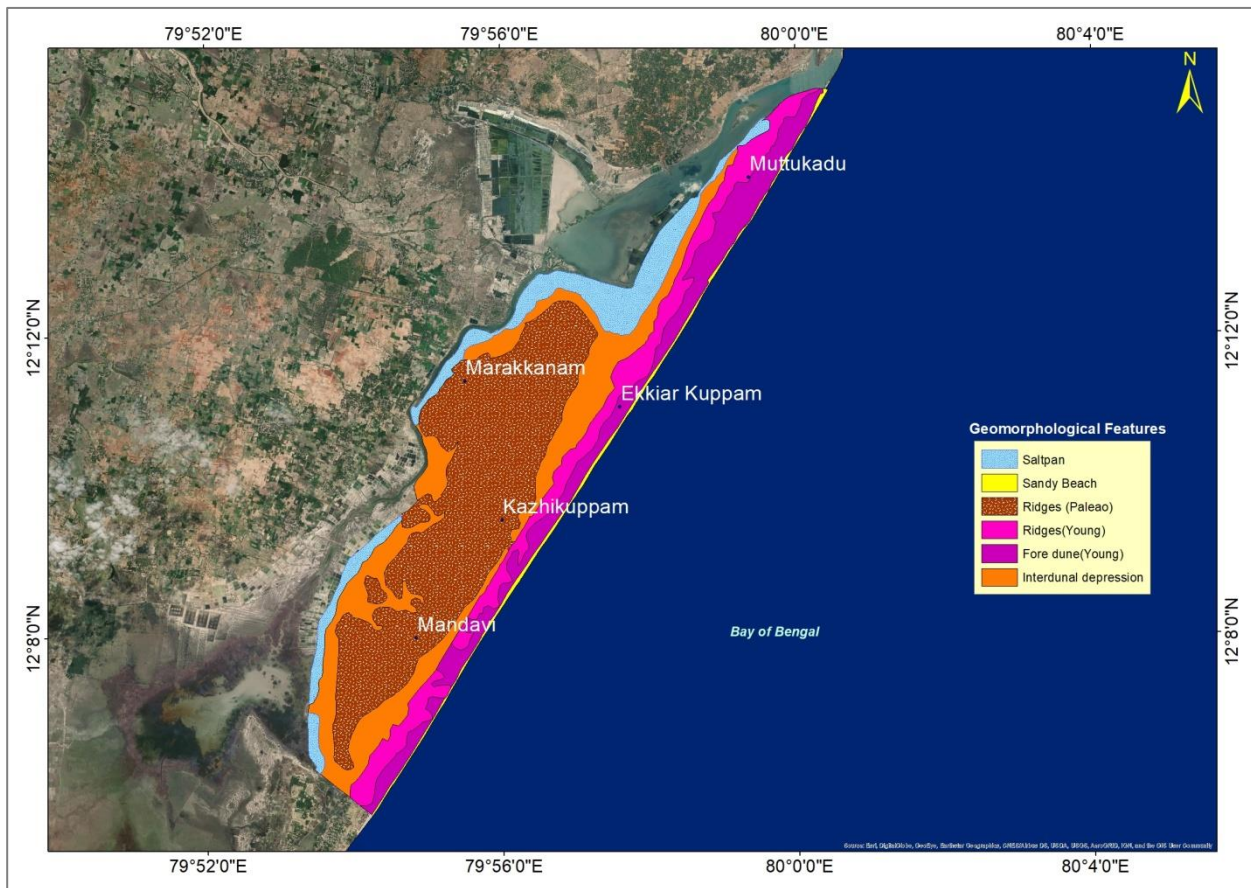
In Marakkanam area, uniformly well undulated terrain has been distributed from landward side to coastal sand beach. Paleo ridges (Fig.3- H, I) are found in landward side of the coast while interdunal depression/Swale (Fig.3- G and K) is found seaward between the palaeo ridges and young ridges. Undulating sand dunes are distributed along

seaward side of the coast (Fig.3- F) saltpans are surrounded on the landward side.

### 5.2 Profile Analysis

#### i) Features Profile Analysis based on geomorphology

Figure 5 show the location of field collected GCP along different geomorphic features of the coast. Table 2 depicts the elevation of field points with reference to different source. The average elevation of ridges (palaeo) in Cartosat DEM and GPS is about 7-14 m, whereas in SRTM DEM and Google earth it was about 7-17 m. The average elevation of ridges (young) in Cartosat DEM and GPS were found to be 4-10 m, whereas in SRTM DEM and Google earth it was about 5-15 m. In few places, maximum elevation of ridges (young) with respect to Cartosat DEM and GPS data was 14-18 m. Average elevation of fore dune (young) with respect to Cartosat DEM and GPS was 5-7 m and it was found to be 7-9 m with respect to SRTM DEM and Google earth. Elevation of rest of the morphological features such as interdunal depression areas and some part of foredune areas were found to be below 5 m in the DEM data and other source data.



**Fig-5: Geomorphology of the Marakkanam Coastal area**

***(ii) Features Profile Analysis based on different interpolation methods***

Comparative performance of different techniques of interpolation for undulated terrain of the present study has been attempted for Cartosat and SRTM DEM by visual comparison. Nearest neighbor method indicated smooth curves rather than spikes for undulations so the output of the interpolation was considered for the study. Figure 6 and 7 shows the DEM interpolation using different techniques for Cartosat and SRTM. Red dots indicate field collected data locations. Comparison of interpolated data with field observed points revealed that the IDW approach performed accurately in average cases when compared to others.

Interpolated heights at different test points (points having coordinates from GPS survey) have also been compared for the four different methods and results are summarized

in Figures 6 and 7. It is revealed that different interpolation approach produced varied results over the same points. Interpolated height values for different methods at each point have been plotted. Deviations of interpolated height points give a better result and points well distributed, understanding about the performance of each method and reveal a better performance of the IDW approach in SRTM and Cartosat DEM, in this methods take into consideration autocorrelation structures of elevations in order to define optimal weights. Interpolation techniques like IDW and ANUDEM have been found to adjust themselves to the terrain variations in both DEM when compared to other methods. Kriging method is spatially distributed in both DEM especially in SRTM actual elevation points not visualized, due to less points cannot make Kriging interpolation. Spline method is well interpolated in Cartosat when compare to SRTM.

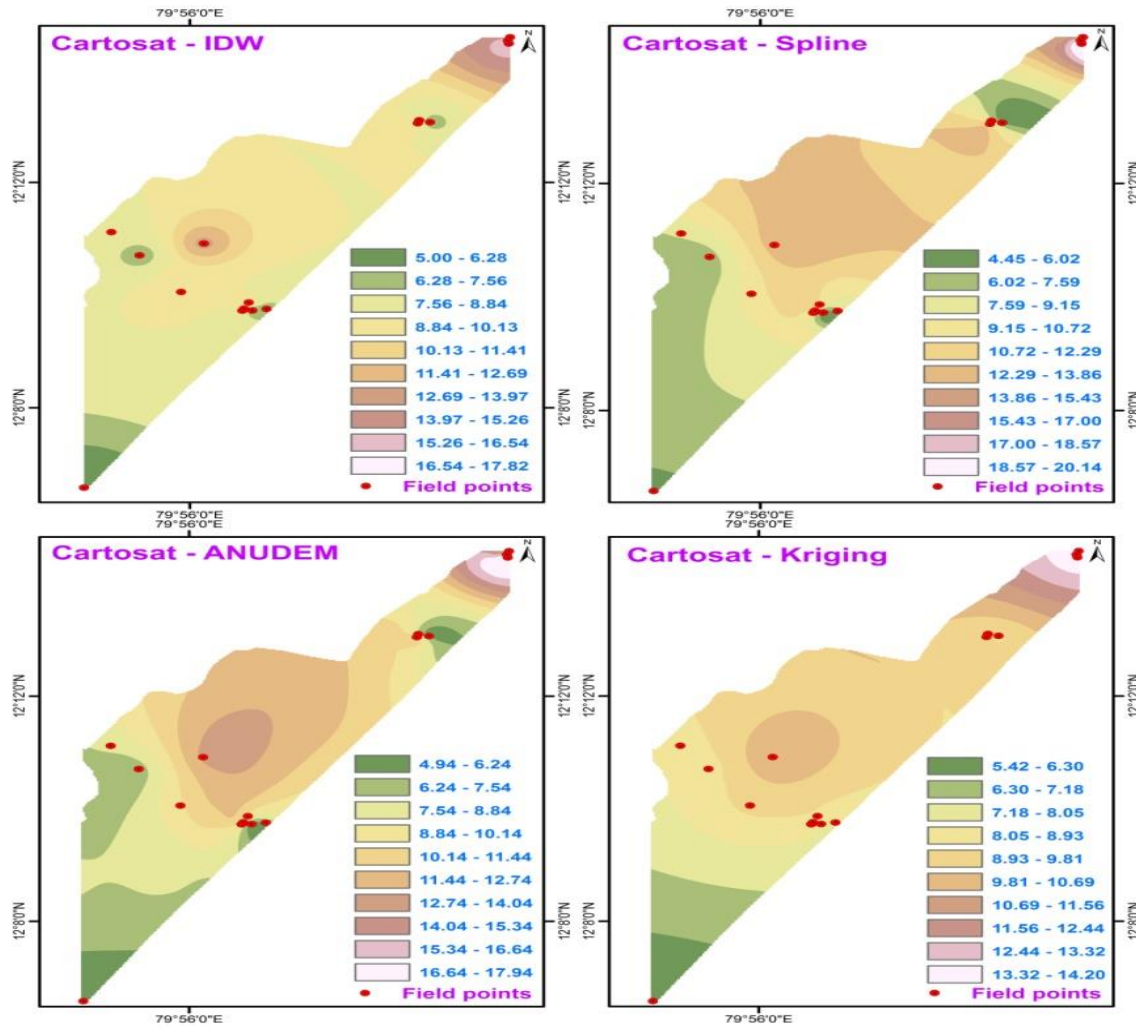


Fig-6: Different interpolations for Cartosat DEM



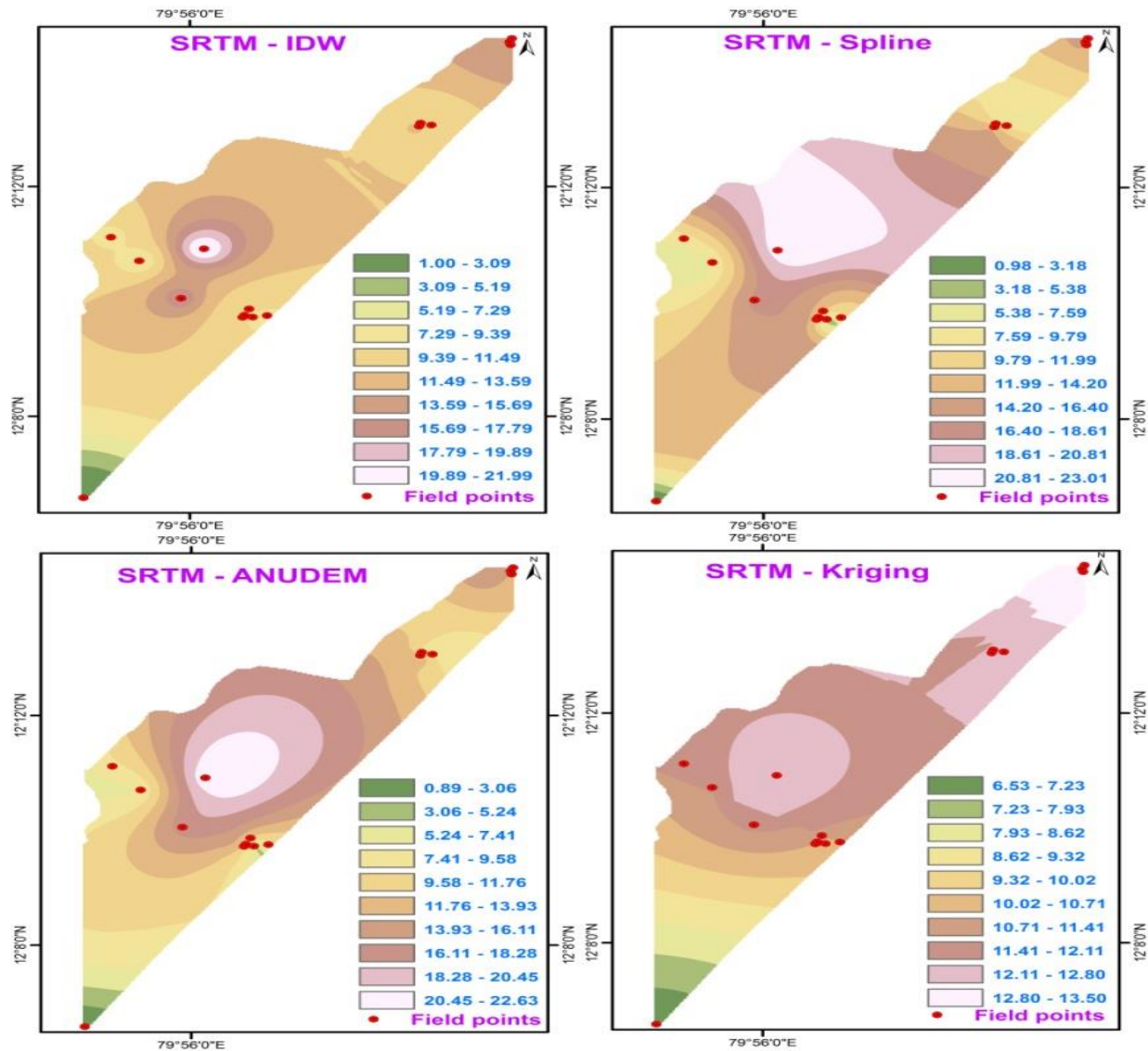


Fig-7: Different interpolations for SRTM

Table-2: Elevation value of selected points depicted from various source

Site. No	Field Locations	Cartosat-(in m)	SRTM-(in m)	Google earth Elevation-(in m)	Juno-B3-(in m)
1	79°59'34.13"E 12°14'27.827"N	17	14	14	18
2	79°59'33.423"E 12°14'30.821"N	18	16	15	13
3	79°59'34.991"E 12°14'34.56"N	9	15	14	9
4	79°56'9.483"E 12°10'54.936"N	13	22	22	9
5	79°55'26.268"E 12°10'42.3"N	7	8	7	7.2
6	79°55'7.358"E	8	9	9	4

	12°11'7.054"N				
7	79°55'54.189"E 12°10'3.303"N	10	17	17	14
8	79°54'48.985"E 12°6'34.934"N	5	1	1	4.4
9	79°56'35.278"E 12°9'43.332"N	9	12	10	9
10	79°56'36.491"E 12°9'45.511"N	10	11	10	14
11	79°56'41.933"E 12°9'43.585"N	5	5	7	4
12	79°56'51.559"E 12°9'45.182"N	7	9	7	7
13	79°56'39.545"E 12°9'52.019"N	10	12	11	9
14	79°58'41.16"E 12°13'4.112"N	6	9	8	7
15	79°58'34.045"E 12°13'6.162"N	8	10	11	7
16	79°58'33.003"E 12°13'2.965"N	11	13	11	10

**(iii) Features Profile Analysis based on Tin model**

Perpendicular profiles are closer based on SRTM and Cartosat TIN model elevation profile in Marakkanam Study area. In the profile X axis indicates distance in meters and Y axis indicates vertical elevations. Figures 8 and 9 depict the perpendicular profile with directions from east to west of the randomly selected points. Comparing the Figures 8 & 9, the following inferences were made.

Profile 1: SRTM (approximately- 15 m) elevation is lower than that Cartosat DEM (approximately - 20 m)

Profile 2: Cartosat- DEM and SRTM- DEM close to each other (approximately - 10 m)

Profile 3: SRTM elevation (approximately - 20 m) is higher than that Cartosat DEM (approximately - 15 m)

Profile 4: Cartosat- DEM and SRTM- DEM close to each other (approximately - 20 m)

Profile 5: SRTM elevation (approximately - 15 m) is higher than that Cartosat DEM (approximately - 13 m)

Profile 6: SRTM elevation (approximately - 20 m) is gradually higher than that Cartosat DEM (approximately - 15 m).

Qualitative assessment of Cartosat and SRTM DEM were executed by comparing the elevation profile. DEM depicts the elevation curves according to their directions of East-West for the study area. The profiles have been chosen based on the area covering both low gradient and high gradient terrain.

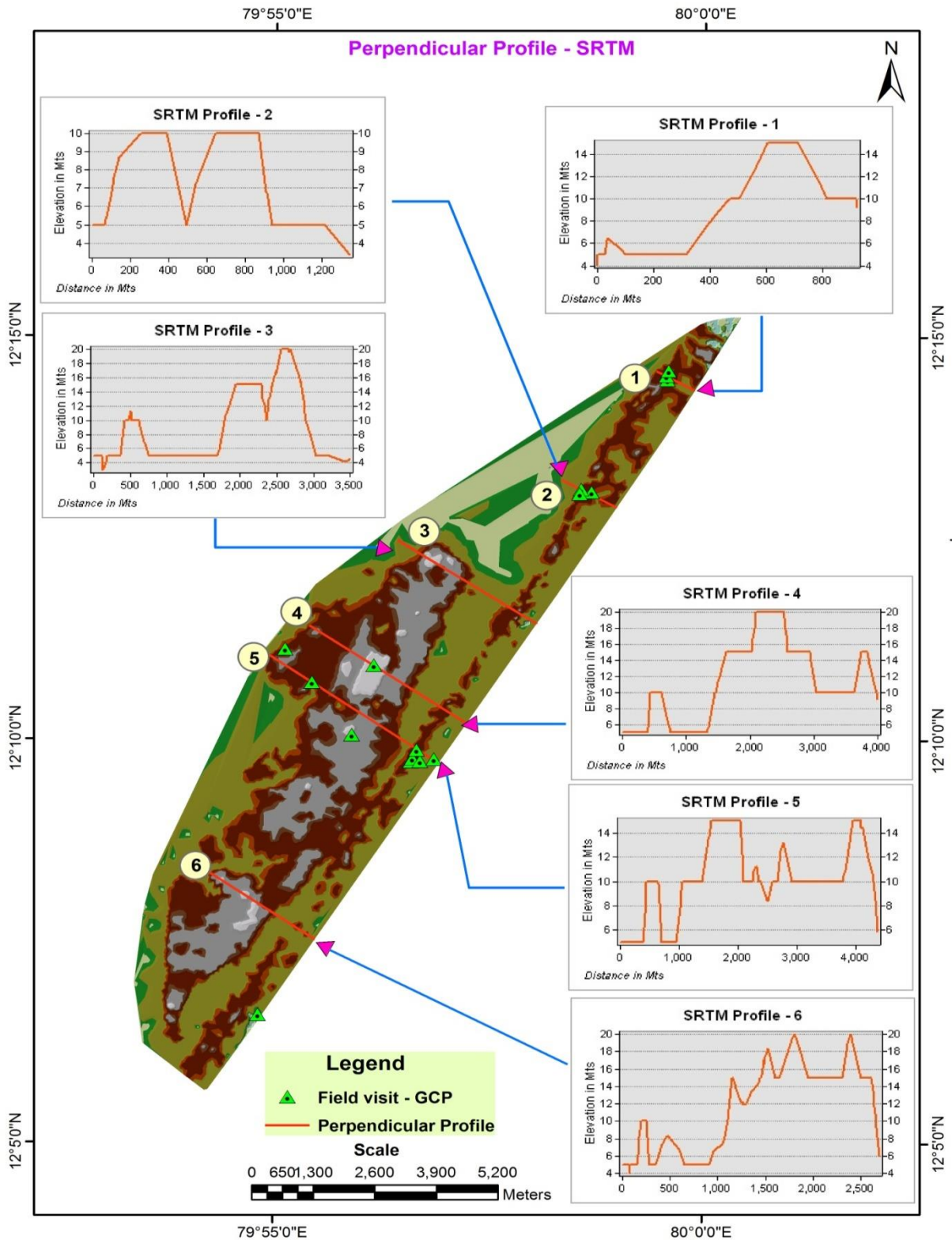


Fig-8: Profile Analysis for SRTM DEM - TIN model

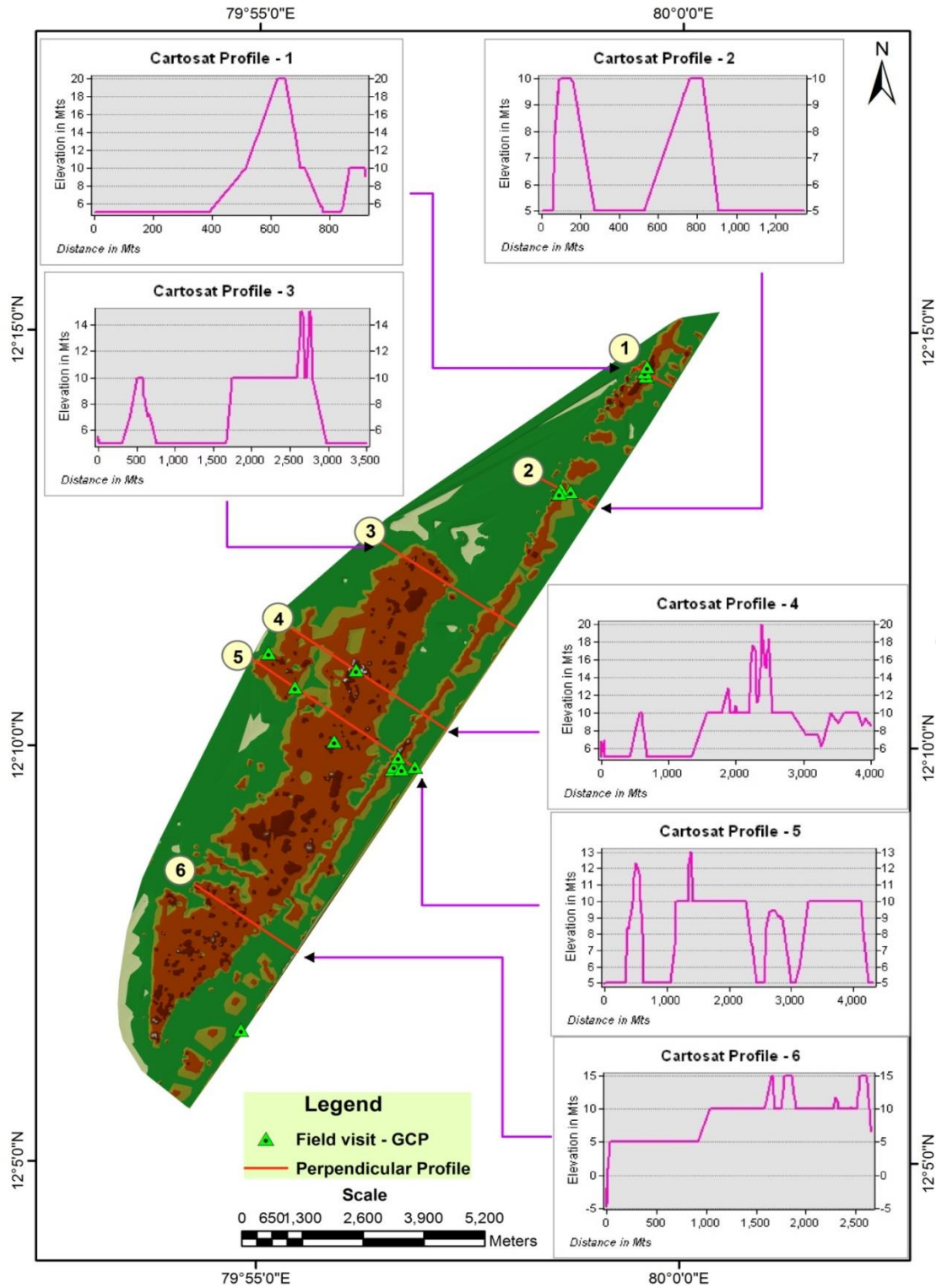


Fig-9: Profile Analysis for Cartosat- TIN model

### 5.3 Accuracy Assessment

The spatial accuracy of Cartosat - DEM and SRTM - DEM with reference to the field data has been determined using 16 randomly selected points from the study area. Table 3 lists out the statistical errors of mean and standard deviation, skewness of Cartosat-DEM and SRTM-DEM. The difference in the minimum elevation value for the Cartosat-DEM, SRTM-DEM, Google earth elevations and Juno GPS were found to be 5 m, 1 m, 1 m and 4 m respectively. The difference in the maximum value for the Cartosat-DEM, SRTM -DEM, Google earth elevations and

Juno GPS were 18 m, 22 m, 22m and 18 m respectively. The vertical accuracy of DEM can be measured by the overall RMSE (absolute vertical accuracy). In this research, the RMSE of Cartosat-DEM and SRTM-DEM in relation to ground truth data has been calculated. The RMSE of vertical accuracy for Cartosat DEM and SRTM -DEM were 2.52 m and 4.5 m respectively (Table-5). SRTM-DEM is almost closer to the values derived from Google earth. It is clear that elevations estimated from Cartosat- DEM (Table-4) are more close to GPS as compared to SRTM-DEM and Google earth elevation.

**Table 3:** E-value calculation

Descriptive statistics	Cartosat	SRTM	Google Earth	JUNO_B3
Mean	9.56	11.43	10.87	10.00
Median	9.00	11.50	10.50	9.00
Maximum	18.00	22.00	22.00	18.00
Minimum	5.00	1.00	1.00	4.00
Std. Dev.	3.77	4.95	4.85	3.85
Skewness	0.99	0.01	0.34	0.43
Kurtosis	3.28	3.29	3.51	2.10
Jarque-Bera	2.69	0.05	0.48	0.52
Probability	0.25	0.97	0.78	0.77
Sum	153.00	183.00	174.00	80.00
Sum Sq. Dev.	213.93	367.93	353.75	152.48
Observations	16	16	16	16

**Table 4:** Standard deviation for DEM and other indicators

STANDARD DEVIATION			
Cartosat	SRTM	GoogleEarth Elevation	Juno-B3
3.77	4.95	4.85	3.85

**Table 5:** Correlation with RMSE Error for DEM and other indicators

Correlation	RMSE (in m)
Juno GPS with SRTM	4.50
Juno GPS with Cartosat	2.52
Juno GPS with GoogleEarth Elevation	4.36

## CONCLUSION

Present study described the comparative analysis of different types of DEM such as SRTM, Cartosat and GPS with the help of elevation profile analysis of the morphological features like paleo sand dune, younger sand dune, interdunal depression (Plain) of the coastal region. The profiles generated from Cartosat and Juno-B3 for highly elevated areas show morphologically closer resemblance to the real field condition whereas in plain areas, SRTM and Google earth data show closer resemblance to the real field condition. In visual interpolation IDW has been found to yield a better performance for ridges as well as slope terrain areas in both DEM. Overall, based on this analysis Cartosat DEM can be effectively used for analysis. The accuracy of the study can be improved by using DGPS for validation of the elevation data.

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