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Validation of Satellite Based Datasets for the South-West Coast of Kerala, India

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ABSTRACT

As our country is vulnerable to several kinds of ocean / water body related disasters, several methods should be adopted for predicting and assessing these kind of disasters and thereby predicting their future arrivals. Numerical modelling, vulnerability index mapping, hazard assessment etc. should carried out at regular intervals for accelerating mitigation activities. For all the above, the height of terrain with respect to Mean Sea Level (MSL)is the most pertinent factor. The topography of terrain can be estimated using field surveys like DGPS surveys, Dumpy level, Total station etc. But these field investigations are all time consuming, expensive, laborious and tedious. So alternative sources should be sought, which includes different satellite derived topographic datasets. This investigation is the validation of several different topographic datasets pertaining to Kollam-Alappuzha coastal stretch of Southern Kerala, South-West coast of India. The datasets identified are ASTER, GMTED, and SRTM. Several different transects perpendicular and parallel to shoreline were selected and each were validated individually with field data, which was taken as base.The results reveal that each dataset shows drastic variation in comparison with field data. This will lead to a harbinger, because the vulnerability and extend of inundation show major varying changes on using different datasets.This will directly affect advisories and mitigation in the event of a natural disaster. Soeach and every dataset should be *field investigated, calibrated and should be validated before being fed into such kinds of predicting investigations, hazard assessments and numerical modelling.*

Keywords Satellite datasets, Validation, GMTED,ASTER,SRTM

1.0 INTRODUCTION

In India Natural disastersaremainly caused by flooding, earthquakes, landslides, volcanic eruption, cyclones, tsunami etc. Many of them are associated with the climatic conditions that cause tremendous loss of life and assets.As per the United Nations Office for Disaster Risk Reduction (UNISDR), India ranked third among the top five most disaster hit nations in the world in 2015. This may due to the geographic and variations in climate of India. The Odisha cyclone (1999), earthquake in Gujarat (2001) are scenarios of this. The people living on the Indian Peninsula, particularly the state of Keralawas under the assumption that Kerala is not vulnerable to these kind of disasters. These preconceived notions were changed by the arrival of Tsunami in 2004, Ockhi in 2017 and the recent floods of 2018. Several other disasters such as storm surge, cyclones, sea erosion and Kallakadalalso had affected our coast at regular intervals. Kallakadal is a term used by the fishermen community which is now adopted by UNESCO too. The term Kallakadal means the unexpected intrusion of water towards the land during good weather conditions. These kind of natural disasters are devastating and difficult to access at times. Due to these kind of natural disasters, several methods such as hazard assessment, vulnerability index mapping etc. should be adopted for predicting and assessing natural disasters and thereby their future arrivals.One such method is numerical modelling. These methods are essential for the safety of coastal population and also for the rescue workers.The main component of numerical modelling is the prediction of inundation/run-up for these kind of disasters which can only be accomplished through the process of numerical modelling. Numerical modellingrequire fine quality high resolution data. The best data for these is the data collected from field measurments. But however collecting field data is laborious, tedious and time consuming. So alternate sources of data such as the satellite derived datasets should be

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used. This investigation is an attempt to find the variation in satellite data with reference to field data using different techniques.

2.0 NUMERICAL MODELLING

The state of Kerala in the South West Coast of India lacks a 24*7*365 Disaster Warning Center (DWC). Besides each disaster should be grouped and a peer team comprising of researchers, scientists and various other stake holders, should be formulated. The primary objective of this disaster warning center is the prediction of natural disasters and its impact. Numerical modelling is a method for predicting the natural calamities and their future arrivals by describing the physical state of a system using mathematical equations and computer programming languages. Using numerical modelling, we can represent the real time scenarios in terms of numbers, mathematical equations and computer simulations. Mathematical calculations and simulation are essential for predicting thefuture outcomes and possibilities of a given real time scenario. The various steps involved in the numerical modelling processare shown in the Figure 1.

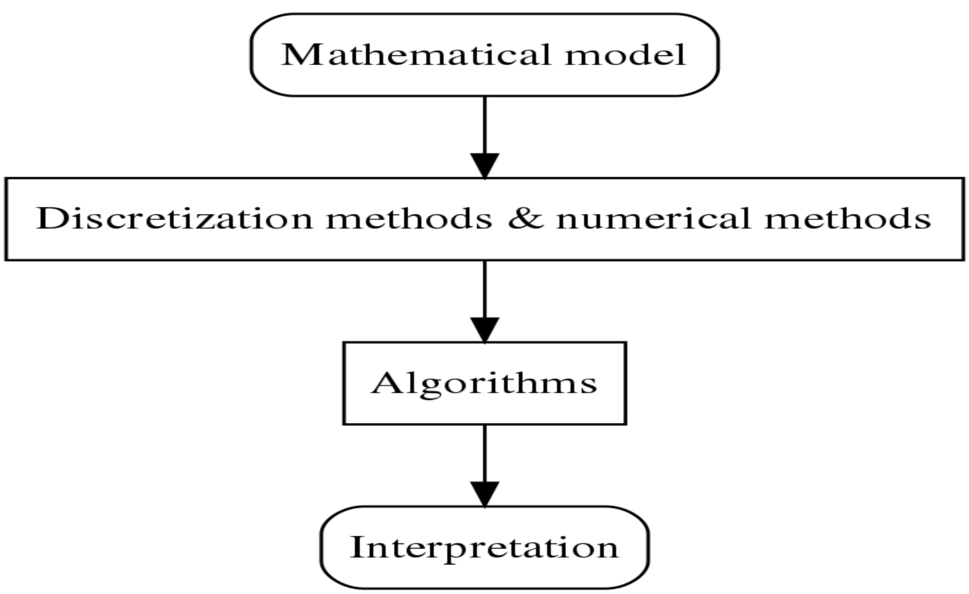

Fig.1 Different steps in numerical modelling

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(Source:https://commons.wikimedia.org/wiki/File:Flowchart_of_Numerical_modelling.svg#/media/File:Flowchart_of_Numerical_modelling.svg)

For numerical modelling to be successful two sets of data are very much important.Bathymetric data, representing the underwater depth of oceans/lakes and topographic data, representing theelevation of the surface. The intrusion of water level towards the land, the process we call inundation should also be noted. To make fine resolution data grids without errors, the only option is measuring data directly i.e. Field survey.

3.0 FIELD SURVEY

Field survey is referred as the collection and gathering of information at local level by conducting primary surveys. These primary surveys are called field surveys. These components are necessary for acquiring geographical information through the observations, interviews, sketching, measurements etc. Such surveys are important for understanding the patterns of spatial distributions, their associations and relation through micro and macro levels. Field survey can be trusted since it is the data that we measured directly from the required areas.

There are certain limitations for this field survey. These all are time consuming, since our coastal area is around 560 km, also expensive, laborious and tedious. In order to overcome this we have to depend on satellite data, as an alternative to field data and to avoid the above mentioned practical difficulties.

4.0 REMOTE SENSINGAND ITS NEED

“Remote sensing refers as a science of acquiring information about objects or areas by using electromagnetic radiation without being in direct contact with the object or area. This is done by sensing and recording reflected or emitted energy and processing, analysing and applying the information that we made” (Reference:Fundamentals of remote sensing-A Canada Center for

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Remote Sensing Tutorial, Prentice hall, New Jersey). For instance, reading newspaper, watching TV etc. are all remote sensing activities of human eye. The human eye receives the light reflected by these objects, after that our brain interprets these lights, intensity variations and the data get transformed to information. Remote sensing is now applicable in environmental characteristics such as geography, geology, forestry, agriculture, meteorology, oceanography, botany, zoology and civil engineering.

Remote sensing is playing a key role in our efforts to understand the ecological system of the earth; to measure size of ozone hole in atmosphere to understand its dynamics of ozone concentration. For the maintenance of forests, and to monitor nature reserves, the information obtained by remote sensing is necessary. Remote sensing can be classified as active remote sensing and passive remote sensing. When the signal emitted by a satellite or aircraft and its reflection by object is detected by sensor, it is referred as active remote sensing. While passive remote sensing, refers when the reflection of sunlight is detected by a sensor. For instance, sunlight is the most common source of radiation measured by passive sensors. Radiometers, infrared, photography etc. are examples of passive remote sensing. RADAR and LIDAR constitutes active remote sensing. Figure 2 shows the methodology of passive and active remote sensing.

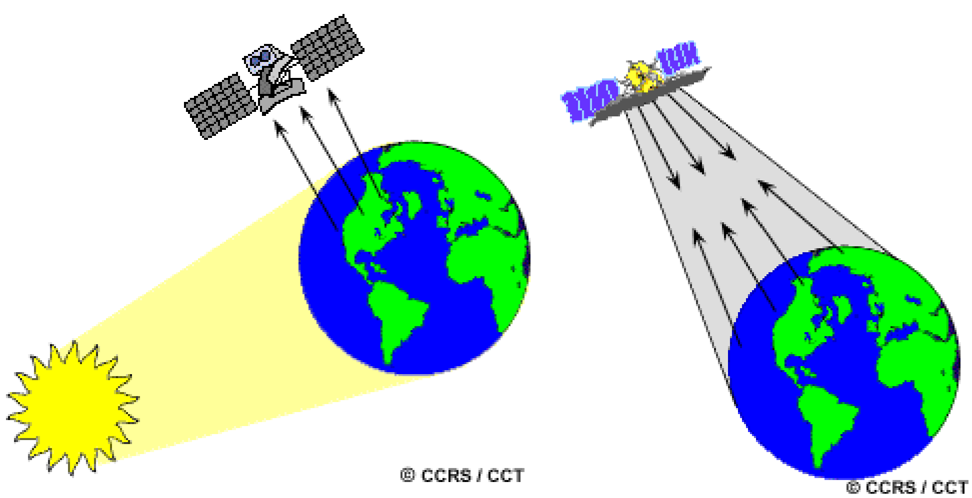

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Fig 2.Passive Remote sensing and Active Remote sensing

(Source: https://owlcation.com/stem/-Introduction-and-Scope-of-Remote-Sensing)

Abdul Rahman (2010) describes that remote sensing makes it possible to collect data on dangerous or inaccessible areas. He also reported that the applications include monitoring deforestation in areas such as Amazon Basin, the effects of climate change on glaciers in Arctic and Antarctic regions and depth sounding of coastal and ocean depths. In the case of ocean spills, through multi-temporal imaging, the obtained data can provide information on the rate and direction of oil movement, and input to drift prediction modelling and can facilitate in targeting clean up and control efforts. Remote sensing devices that used includes the use of infrared video and photography from airborne platforms, thermal infrared imaging, airborne laser flurosensors, airborne and spaceborne optical sensors, as well as airborne and spaceborne SAR (Fundamentals of Remote Sensing, Canada Center for Remote Sensing). The major advantage of SAR sensors is that with the use of optical sensors, they can obtain data under poor weather conditions and also during the absence of light. Remote sensing finds application in multifaceted terrains. For the atmospheric and ocean science related studies satellite sensor data have been more useful. Geographers use the remote sensing techniques to find the changes on earth's surfaces. The forester uses the technique to evaluate the growth of trees and if they have been affected by diseases, fire or pollution. The geologist is interested in obtaining valuable minerals. For the identification of pollutants such as oil slicks on ocean, environmentalist needs remote sensing techniques.

5.0 DIFFERENT SATELLITE DATASET USED IN THIS INVESTIGATION

The different satellite datasets used in the investigation are as follows.

5.1SRTM (Shuttle Radar Topographic Mission)

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SRTM is an international research effort to obtainDigital Elevation Models (DEM) on a near- global scale from 56˚S to 60˚N to generate the most complete high resolution digital topographic database of Earth. SRTM is normally available in 30 m and 90 m resolution. Here we use 30 m. A data resolution of 30 m was used for this investigation.

5.2ASTER (Advanced Spaceborne Thermal Emission and Reflection Radiometer)

ASTER is a Japanese sensor which is one of the five remote sensory devices on board the Terra satellite launched into Earth orbit by NASA in 1999. The resolution range of ASTER varies between 15 m and 90 m. Aster data of 90 m resolution is used in this investigation.

5.3GMTED (Global Multi-Resolution Terrain Elevation Data)

The USGS has global DEM data at several resolution levels- 30- arc -seconds (1 km), 15-arc -second (450 m) and 7.5-arc-second (225 m). Here a data resolution of 225 m was taken for validation.

6.0STUDY AREA

The study area stretch taken in this investigation is Kollam-Alappuzha coastal stretch of southern Kerala, South West Coast of India (Fig. 3). This study area was selected as it is one of

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the worstly affected sectors with reference to various natural disasters which affected the Kerala Coast.

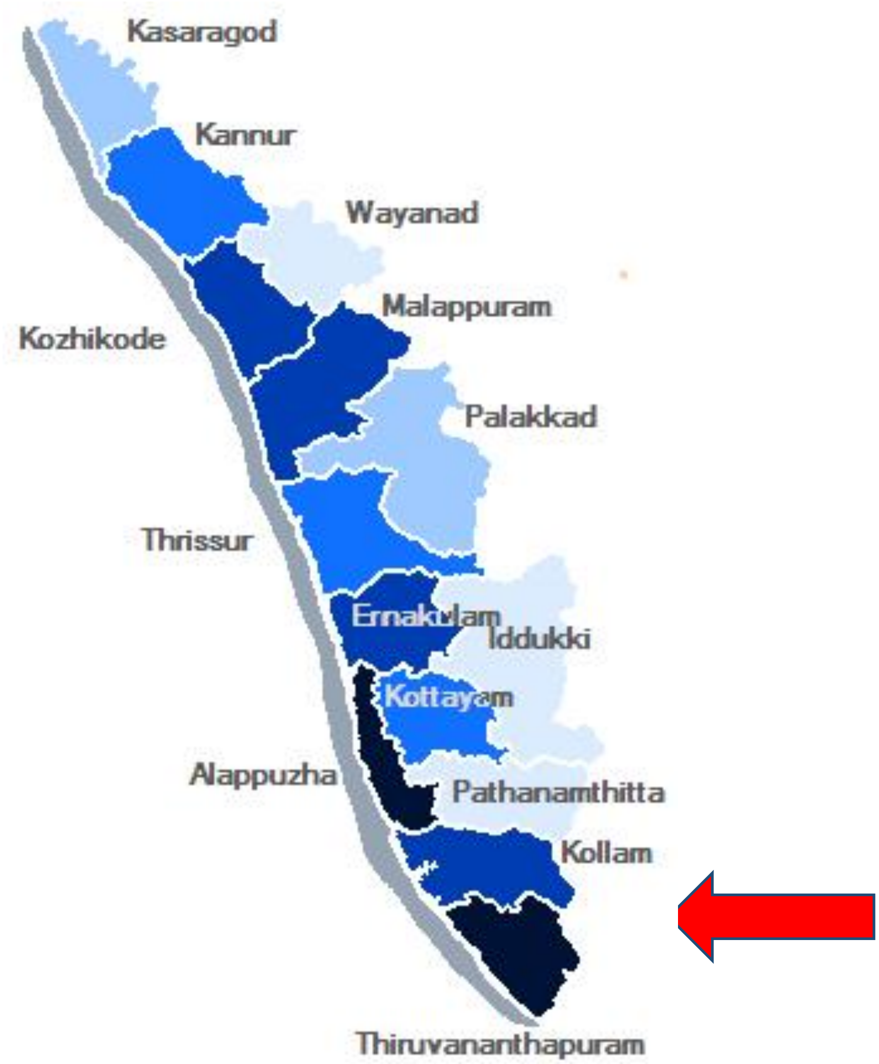

Fig.3. Study area chosen for the investigation

Besides these were the areas which were mostly affected during Sumatra Tsunami 2004. Coastal areas are always notorious for seasonal flooding, sea erosion and several other natural calamities. Topography or elevation of a particular point is also important. During the recent floods in Kerala, the rescue operation was done by this fishermen community

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and they were thereafter referred as the 'Army of Kerala'. So their safety isof utmost importance. The coastal population is also very high and theydependsmainly on sea for their daily food.

7.0 METHODOLOGY OF THIS INVESTIGATION

The methodology used in this investigation is mentioned below.

7.1 Collection of Satellite Data

Our Indian Remote Sensing (IRS) provides various satellites for the data collection. The satellite datasets for the coastal area were collected from the websites of United States Geological Survey (USGS). The text form of data can be converted into shapefile using a software called Geographic Information System (GIS). Using shapefile, the data is represented in a digital terrain form. i.e. the features of earth surface can be represented in the form of grid where each pixel with its attributed unique elevation value.

7.2 Derivation of Satellite Data

The data is derived from the website of USGS and was subjected to three different process called georeferencing, datum and projection. Georeferencing and datum pertains to "location" and projections are the means by which features from the surface of the earth are transferred onto a sheet of paper to make a map. Georeferencing refers to providing a reference frame such as name, feature or coordinate for a geographic location. On the other hand, datum can be used to generate coordinates i.e. latitude and longitude. Projection helps to transform the features of earth surface onto a sheet of paper to make a data map.

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7.3Validation of Satellite Data

The satellite data should be validated with reference to the field data. For that perpendicular and parallel data transects were selected . The data points were extracted from each transect and was compared with field data points.

Before utilising these datasets for hazard assessment or modelling, it is mandatory to field investigate each and every datasets and field calibration should be conducted.Based on this, appropriate correction should be incorporatedinto satellite data.

After these procedures, these data can be used for numerical modelling investigations.

7.4 Statistical analysis

Finally, statistical analysis of the extracted points and the field data points were carried out. The statistical analysis are primarily intended for identifying, estimating and analysing the deviation and the pattern of errors associated with satellite data. The field data was selected as the reference data. The variation of each data with reference to field data should be estimated. The different methods used for this are T-test, and ANOVA test .

8.0 RESULTS AND DISCUSSIONS

The results of this investigation are mentioned below in three different segments. The segments are perpendicular transects, parallel transects and statistical analysis

8.1 Perpendicular Analysis of Transects

The perpendicular analysis of transects are shown in Fig. 4.

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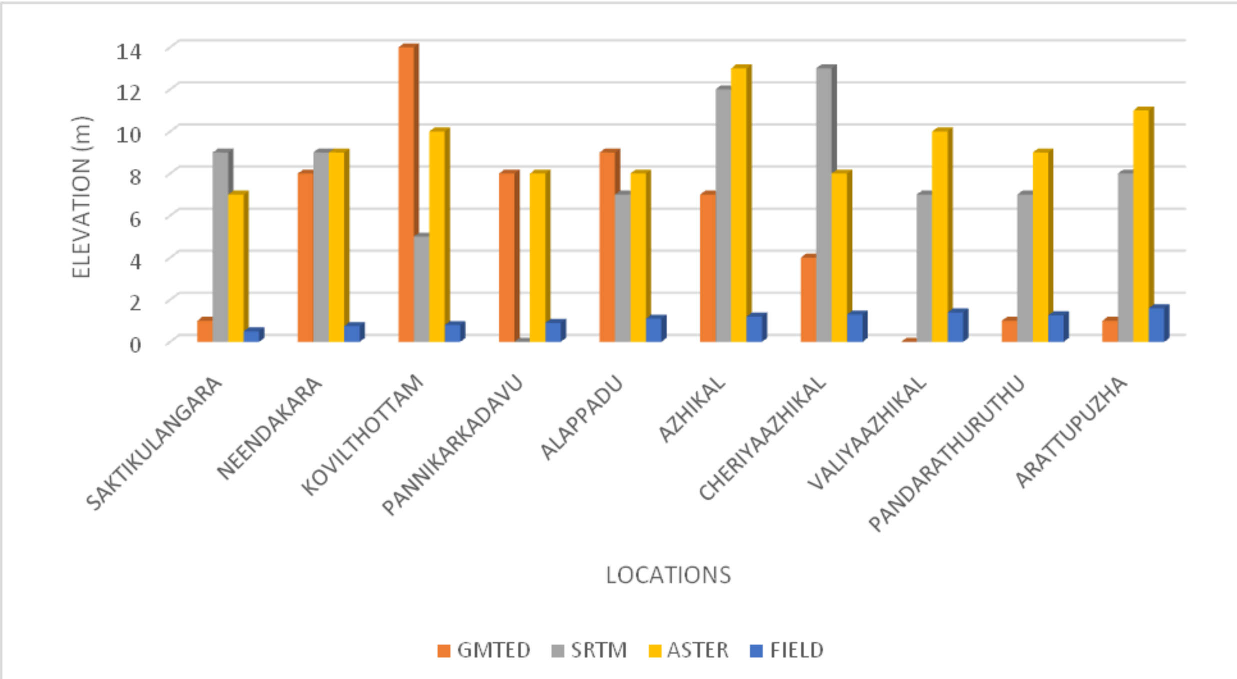

Fig.4 Schematic diagram showing horizontal transect analysis of different locations perpendicular to the shoreline.

The figure gives different transects perpendicular to the shoreline, which were validated individually with reference to the field data. The maximum elevation is given by GMTED at Kovilthottam which is about 14 m. But the GMTED shows zero elevation in Valiazhikal. Also SRTM at Panikarkadavu shows zero elevation. While comparing all these dataset, the field data shows minimum elevation which lies between 0 and 2 m. By observing the field data, the maximum elevation is at Arattupuzha and minimum at Sakthikulangara. In Neendakara, SRTM and ASTER shows similar elevation where in Panikarkadavu GMTED and ASTER displays similar elevation. GMTED shows drastic variations in different locations and ASTER shows variation between 6 m and 13 m. SRTM shows variations between 0 and 13 m elevation. In Kovilthottam, the elevation of field data is about 1 m and at the same location GMTED shows maximum elevation. In Kovilthottam, all the datasets shows comparatively large variations.

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8.2 Parallel Analysis of Transects

The analysis of transects taken parallel to shoreline are shown in Fig.5.

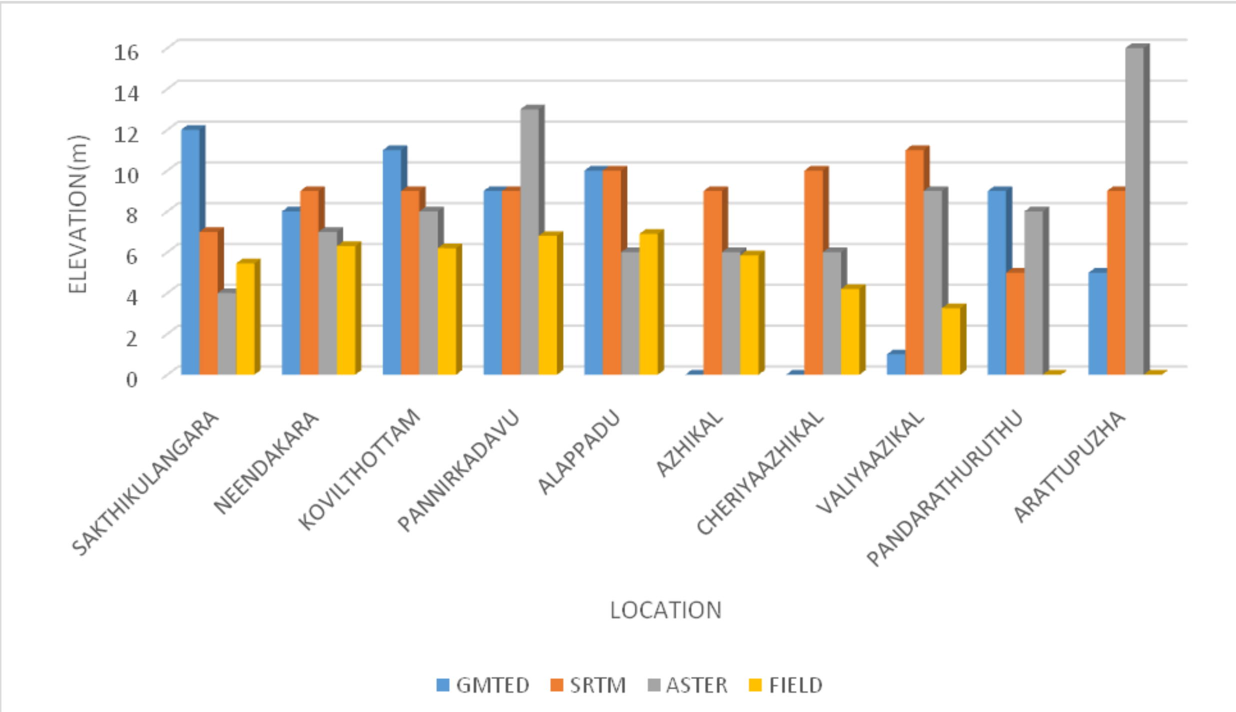

Fig.5 Schematic diagram showing vertical transect analysis of different locations perpendicular to the shoreline.

The figure describes different transects parallel to the shoreline, each were validated individually with reference to the field data. In this graph, there are only zero and positive elevations. The zero elevation is in Azhikal, Cheriyaazhikal, Pandarathuruthu and Arattupuzha. The GMTED shows zero elevation inAzhikal and,Cheriyaazhikal, and the Field data shows zero elevation in Pandarathuruthu and Arattupuzha. In Arattupuzha, the peak elevation is exhibited by ASTER datasets. The elevation of field data is maximum at Alappadu. Besides GMTED and SRTM exhibit same elevation values which is about 10 m. Similarly the SRTM and GMTED have the same value in Panikarkadavu. The GMTED shows comparable variations in different location as we seen in the graph. The SRTM lies in the range between 4 m and 11 m.

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8.3 STATISTICAL ANALYSIS

The variations in the datasets require calibration. Calibration is done by using statistical analysis. In statistics, the checking of normality test between satellite data and field data has been carried out. Through this, the analysis of transformation was carried out and the result was interpreted using Anova and T- test.

Table1: Descriptive analysis showing transformation properties of different satellite datasets

Reading	View	No of obs	Mean	S.d	Maximum	Minimum
GMTED (Satellite 1)	Perpendicular	70	8.414	3.936	15	-1
	Horizontal	70	7.729	3.671	15	-3
SRTM (Satellite 2)	Perpendicular	70	8.829	4.357	19	-3
	Horizontal	70	8.129	3.795	15	-4
ASTER (Satellite 3)	Perpendicular	70	11.043	3.329	21	0
	Horizontal	70	9.414	2.651	16	-4
Field (Satellite 0)	Perpendicular	70	2.130	1.222	5.25	0
	Horizontal	70	3.015	2.067	7.7	0

The p value of the normality test for the readings of satellites (GMTED SRTM, ASTER) and field values are less than 0.10. So, these variables are not satisfying normality.

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The failure in selection indicates the absence of transformation which is a major limitation. Table 1 shows the transformation properties of datasets. Figure 6 shows the boxplot of satellite datasets and field dataset indicating the mean value of data attributes.

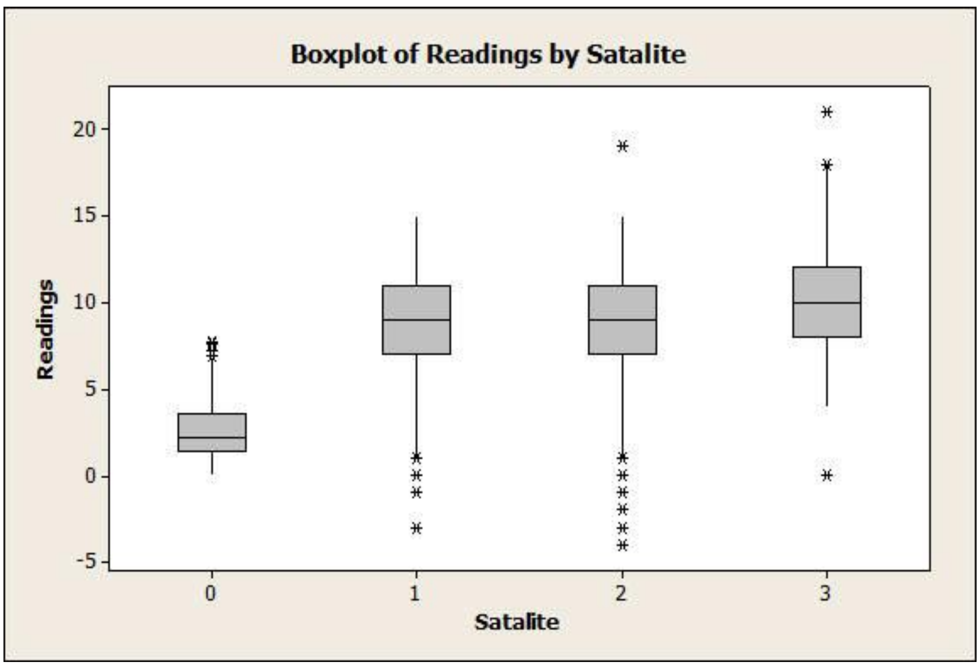

Fig 6.Boxplot of readings by satellite

There is a significant difference in the average values of readings from satellites and the field value. From the descriptive statistics,it is clear that all the satellite readings are over estimates of the field values. Figures 7-9 shows the scatterplot of different satellite data sets.

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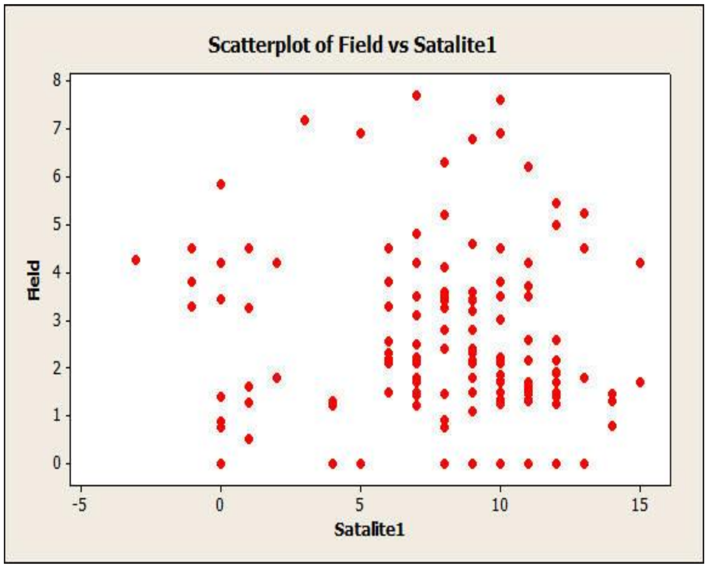

Fig. 7 Scatterplot of Satellite dataset 1-GMTED

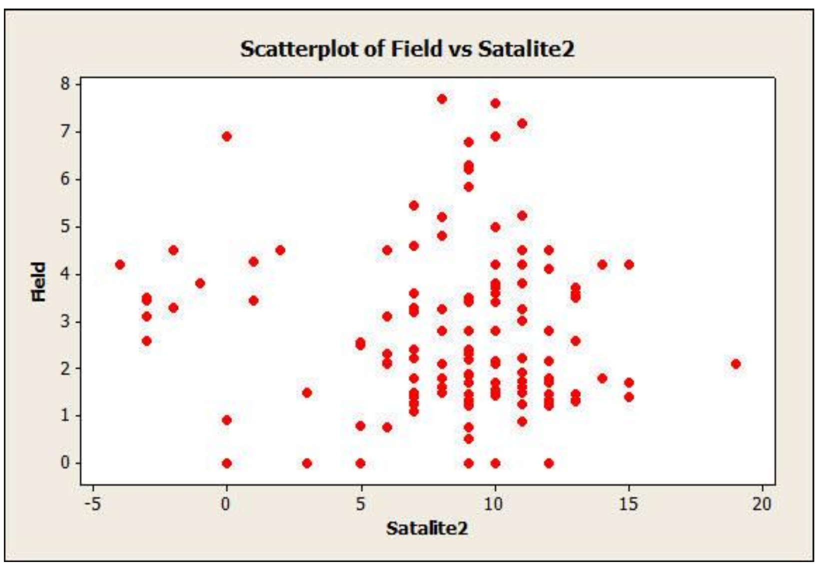

Fig. 8 Scatterplot of Satellite dataset 2- SRTM

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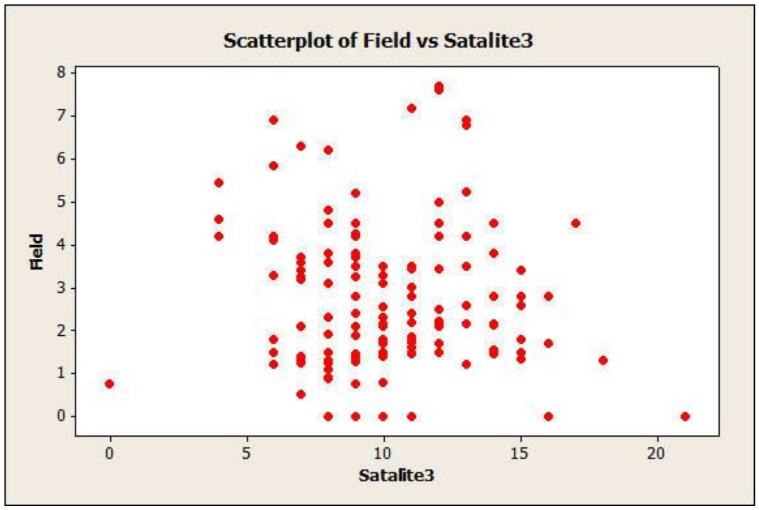

Fig. 9 Scatterplot of Satellite dataset 3- ASTER

The scatterplot shows the variations of datasets for each satellite. Figures 7-9 show the variation of elevation values with reference to each satellite data**,** which clearly underscores the need for calibration and validation of the datasets with reference to field data.

From the results of transect analysis and statistical analysis it is clear that there is no similarity or attribute uniqueness for satellite datasets and field data. Satellite datasets are mostly overestimates while comparing with that of field data. In certain locations where field data is overestimate, the satellite data shows underestimate values. The statistical analysis shows that there is no regular pattern, shift or trajectory for satellite datasets. It is almost scattered. As the methodology behind the collection of satellite data using remote sensing is not prevailing in the scope of this investigation, the investigation trust the field data as it was directly collected from field. The investigation urges the need for the fine tuning of satellite data. The fine tuning should be done by applying appropriate corrections. The appropriate corrections should be incorporated by properly understanding the trends, patterns, shifts and trajectory of data deviations. Besides

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these kind of corrections should be implemented in micro sectors (Sectors or areas belonging to a shorter distance) to achieve fine grid high resolution datasets.

Finally it can be concluded that, the satellite datasets can be used as an alternative to field data, provided it should be calibrated validated and corrected.

9.0 CONCLUSIONS

Disaster risk assessment is mandatory for the mitigation of coastal population.The information must be prepared and executed quickly with accuracy.Different satellite data set showing different elevation along Kollam & Alappuzha coast. Each data sets shows drastic variation in comparison with each other and also with the field data.If we prepare vulnerability maps, the maps will be varying interms of inundation and run-up fpr same disaster. This can be attributed to the variation in elevation.Before utilising these datasets for field investigation, hazard assessment or modelling, we have to field investigate each and every datasets and field calibration should be conducted.Based on this, appropriate correction should be incorporatedwith satellite data.After these procedures, these data can be used for modelling prediction, issuing advisories and further for mitigation purposes.

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