ISSN (Online): 2349-1183; ISSN (Print): 2349-9265
TROPICAL PLANT RESEARCH
The Journal of the Society for Tropical Plant Research
6(1): 54–62, 2019
DOI: 10.22271/tpr.2019.v6.i1.010

Research article

Selection of suitable digital elevation model for analysis of forest cover in different agro-climatic zones of Jharkhand, India

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[Accepted: 19 March 2019]

Abstract: Digital Elevation Model (DEM) has wide ranging application in the study and analysis of various environmental and biodiversity conservation issues. Due to geographical variations, the accuracy of DEMs generated from different satellite sources needs to be ascertained for choosing the best suitable DEM for a particular study area. In the present study, the performance of DEM datasets of Cartosat-1 and Shuttle Radar Topography Mission (SRTM) has been evaluated on the basis of slope, aspect, altitude and hill-shade map generated through these DEMs for different agro-climatic zones of Jharkhand. Elevation values deduced through Cartosat-1 and SRTM datasets were compared with actual Ground Control Points (GCP) recorded using Global Positioning System (GPS) for testing their accuracy. The forest cover map was created by Landsat 7 ETM+ data and subsequently superimposed on altitude map, generated using SRTM and Cartosat-1. Further, it was visually compared with the Survey of India topo-sheet (1:50000) for analyzing undulating topography and forest cover of Jharkhand. The comparative study based on different parameters for DEM dataset from Cartosat-1 and SRTM, reveals that SRTM data performed better than Cartosat-1 for the study of forest cover in different agro-climatic zones of Jharkhand.

Keywords: DEM - Cartosat-1 - SRTM - LULC - Forest - GCP.

[Cite as: Mishra SN, Kumar D & Tiwari S (2019) Selection of suitable digital elevation model for analysis of forest cover in different agro-climatic zones of Jharkhand, India. *Tropical Plant Research* 6(1): 54–62]

INTRODUCTION

A DEM offers the most common method for extracting topographic information. It is highly used for ortho-rectification of satellite or aerial images. It is also used for creation of slope, aspect, hill shade, stream, altitude and view shade maps. Further, these maps can be used for morphologic interpretation, drought monitoring, soil-erosion, flood analysis, bioclimatic analysis, landslide studies, water shade lineament, groundwater depth and rock strata thickness and geomorphic analysis. DEM data are widely used in various geological and geomorphologic studies, substructure planning, visual analysis of topography, landforms, as well as modeling of surface processes. Over the years, the availability of high-resolution satellite imagery has unfolded new vistas for studying many geographical features and the use of Digital Elevation Model (DEM) is providing excellent data component support in the study of forestry and ecological issues. It was quite a tedious task to choose the better open source DEM dataset for the assessment of probability distribution mapping of forest species in the state of Jharkhand through Spatial Distribution Modeling approach.

Over the years, many researchers have made effort to evaluate the performance of Cartosat-1, SRTM and ASTER based products, in various application fields. Sugandh & Srinivasan (2010), used DEM datasets derived from Cartosat-1 and SRTM to study the spatial relationship between landslide-occurrence and the influencing factors in the hills of Ooty, Nilgiri District, Tamilnadu. In the study of landslides, the results of Carrtosat-1 are found better than SRTM (Sugandh & Srinivasan 2010). Forkuor & Maathuis (2012) compared ASTER and SRTM data to study implications on hydrological and environmental modeling in two regions of Ghana and found SRTM accuracy being closed to 1:50,000 topographical map series. Patel (2012) carried out comparative study for evaluating the performance of digital elevation models derived through Cartosat-1, ASTER, SRTM and SOI toposheet (1:50,000) and reported the accuracy achieved through Cartosat-1 was better as compared to

Received: 30 March 2018
Published online: 30 April 2019
https://doi.org/10.22271/tpr.2019.v6.i1.010

other datasets and found that the altitude map derived from Cartosat-1 was similar to that of SOI toposheet. Yarrakula *et al.* (2013) used Cartosat-1 and SRTM data for digital elevation modeling in Kharkai river area, Jamshedpur of Jharkhand state. Gajalakshmi & Anantharama (2015) evaluated the performance of Cartosat-1 DEM and SRTM-DEM for elevation data and terrain elements in South Pennar, Karnataka. Al-Fugara (2015) carried out study to assess the accuracy of SRTM and ASTER DEM models in calculation of elevation data of "humrratessahan" watershed, having highly varied topography on the shore of Dead Sea and reported that ASTER performed consistently lower values than SRTM for the earth's lowest elevation regions. Patel *et al*. (2016) performed study to evaluate the accuracy performance of Cartosat-1, ASTER and SRTM derived DEMs for elevation calculation of Bhopal, MP at known elevation points measured using Differential Global Positioning System (DGPS) found Cartosat-1 data product deducing better result than SRTM and ASTER in their evaluation using known DGPS points. The spot height accuracy of SRTM-DEM of 1 arc second seems to be good for all kinds of terrain modeling, Baral *et al*. (2016). SRTM DEM performs better than the ASTER and Cartosat-1 DEMs in assessing the accuracy of soil erosion Mondal *et al*. (2016) used Cartosat-1, SRTM and ASTER derived DEMs to assess the soil erosion uncertainty for Narmada river basin in Central MP. Bhadoriya (2017) attempted to study the quality of Cartosat-1, SRTM and ASTER DEM, at sub-catchment level and sensitivity of these datasets in hydrological modeling, reported that Cartosat-1 DEM appears to be fine for the requirements of the water resource management for the grass root level mapping. Subbu Laxmi & Yarrakula (2017) attempted the accuracy assessment of DEMs derived from Cartosat-1, SRTM, Google earth and Survey of India toposheet for plain and hilly terrain sites around Madduleru river.

The aim of the present study was to evaluate suitability performance of DEM generated from two different datasets one is from Indian Space Research Organization's satellite Cartosat-1 and another is international research effort satellite Shuttle Radar Topography Mission (SRTM) and to find out which one is more suitable for analyzing forest cover in different agro-climatic zones of Jharkhand, and ultimately can provide more suitable and accurate set of database for carrying out species distribution mapping studies in Jharkhand.

STUDY AREA

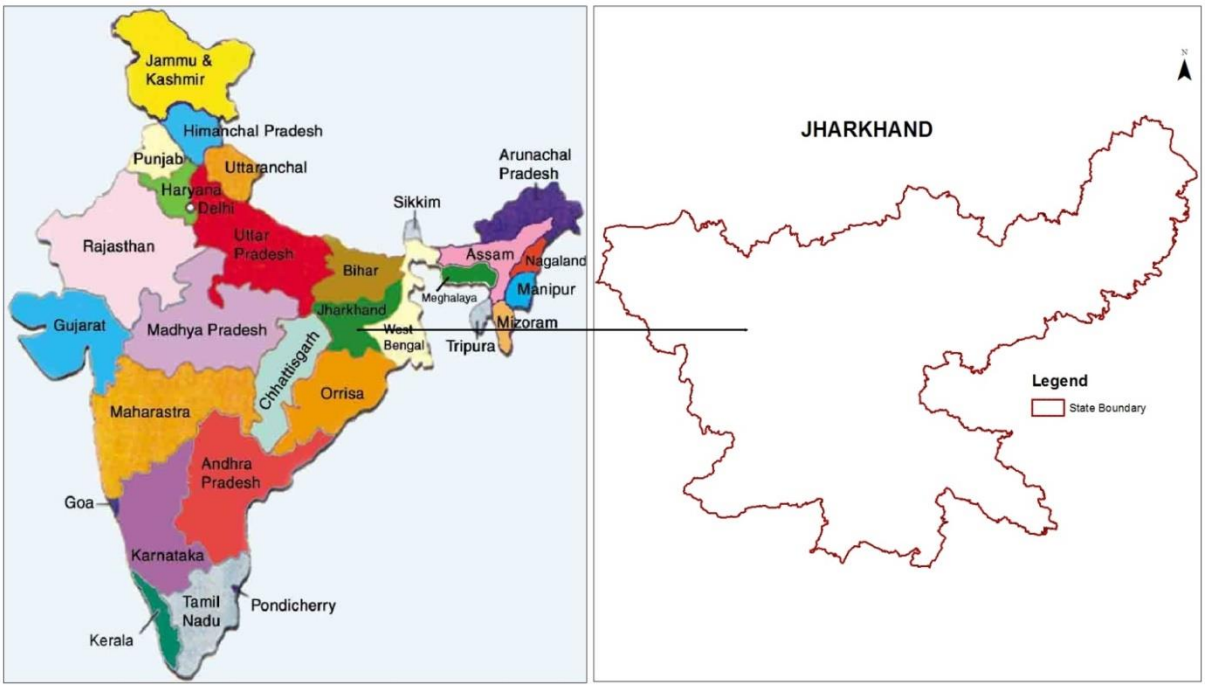

Figure 1. Study area.

The state of Jharkhand lies between latitude 22º 00′ N to 24º 37′ N and longitude 83º 15′ E to 87º 01′ E. The state is located in eastern India (Fig. 1) having 24 districts and its capital is Ranchi. The state has an area of 79,714 km^2 and is home to 32.97 million people (414 persons km^{-2}) (Anonymous 2011). The state has recorded forest of about 23,605 km^2 which is 29.61 per cent of its total geographical area based on Forest Survey of India Report (http://fsi.nic.in/forest-report-2015). Forest type mapping using satellite data shows that the state has five forest types which belong to two forest type groups, *viz*. Tropical Moist Deciduous and Tropical Dry Deciduous Forests (http://fsi.nic.in/forest-report-2015). The annual average rainfall in the state is 1400 mm; however, it varies from 1200 mm to 1800 mm. The temperature varies from 5°C to 40°C. The state possesses lateritic soil

spread all around. In the present work, two post processed datasets known for their global coverage *i.e*. Cartosat-1-DEM and SRTM-DEM have been studied and compared for suitability between DEM to DEM and Ground Control Points (GCPs) to DEM for following agro-climatic sub zones of Jharkhand (Singh 2014, Petare *et al.* 2016):

a) Central and North eastern plateau sub zone (Zone-IV- Dumka, Deoghar, Godda, Sahebganj, Pakur, Hazaribagh, Koderma, Jamtara, Chatra, Giridih, Dhanbad, Bokaro and two-third of Ranchi),
b) Western plateau sub zone (Zone-V- Palamu, Latehar, Lohardaga, Garhwa, Gumla, Simdega and one-third of Ranchi) and
c) South eastern Plateau sub zone (Zone-VI- East Singhbhum, West Singhbhum and Saraikela Kharsawan).

DATA USED

Cartosat-1 DEM

The Indian Space Research Organization (ISRO) has launched Cartosat-1 also named as IRS P5 DEM in 2005, dedicated to stereo viewing for large-scale mapping and terrain modeling applications. Cartosat-1 has panchromatic camera with spatial resolution of 2.5 m and swath about 27 km. Cartosat-1 has a GPS receiver for the position and reference for the elevation determination. The features in this dataset incorporate very advanced techniques are employed for mapping of urban areas and updating the topographic maps for various features such as local roads, parks, small ponds, play grounds, swimming pools, crop field boundaries, hydrological features, flow accumulation and stream network, for observing terrain conditions that is slope and aspect etc. (NRSC 2011). In this study a Cartosat-1 stereo-pair of 2.5 m spatial resolution covering Jharkhand State in 15 tiles (Cartosat-1 Tiles no: - F44F, G44X, F45G, F45A, G45S, F45N, F45H, F45B, G45T, F45I, F45C, G45U, F45D, G45V, G45P) have been acquired on 24.09.2014 from www.bhuvan.nrsc.gov.in website and tested for DEM creation (Fig. 2). For DEM generation Leica Photogrammetric suite (LPS) version 2011 package was used.

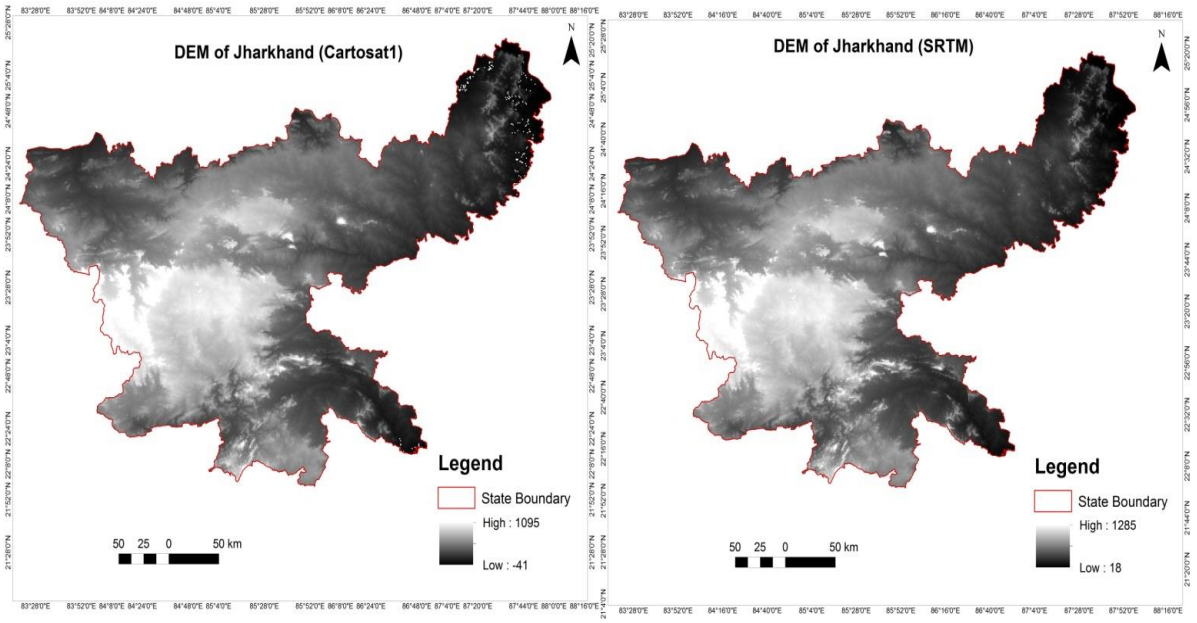

Figure 2. Maps showing Cartosat-1 and SRTM DEMs of the study area.

SRTM DEM: Shuttle Radar Topography Mission-Digital Elevation Model

SRTM is the first space-born single pass interferometric Synthetic Aperture Radar (SAR) which produces high resolution, digital elevation maps (Anonymous 2017). For the present study, SRTM world DEM was downloaded on 24.09.2014 from www.usgs.gov website and was clipped covering the Jharkhand State using ArcGIS 10.0 software (Fig. 2).

Landsat 7 ETM

The forest cover maps were created using Landsat 7 ETM data (path-row: 139–43, 139–44, 139–45, 140–43, 140–44, 140–45, 141–43, 141–44, 141–45, 142–43) for the year October, 2010. Proper season for studying Arid, semi-arid and dry deciduous natural forest and scrub vegetation in India is October to December. The tiles were downloaded from the USGS website http://earthexplorer.usgs.gov on 24.09.2014.

Topographic Map of Survey of India

Survey of India topographic map of toposheet number G-44, G-45, F-44 and F-45 at 1:50,000 scales have been used in the present study. A topographic map is a detailed and accurate graphic representation of cultural and natural features on the ground. Topographic maps render three-dimensional ups and downs of the terrain on a two-dimensional surface.

Field verification (Ground truthing)

Total 30 Ground Control Points (GCP) has been recorded, covering 10 GCP each from all the three agro-climatic zones of Jharkhand. The administrative boundary of Jharkhand state was downloaded from the website www.diva-gis.org.

METHODOLOGY

Study was carried out on two identical Digital Elevation Model (DEM) datasets one is Indian Remote Sensing Satellite Cartosat-1 and another is NASA's Global SRTM as per flow chart (Fig. 3). These satellite imageries were geometrically corrected with reference to SOI topo sheets at 1:50,000 scale and acquired in the standard projection system (UTM 45N, WGS84 datum). The two different DEM datasets were compared in three agro-climatic zones of Jharkhand on the basis of slope, hill-shade, aspect and altitude map derived from DEMs.

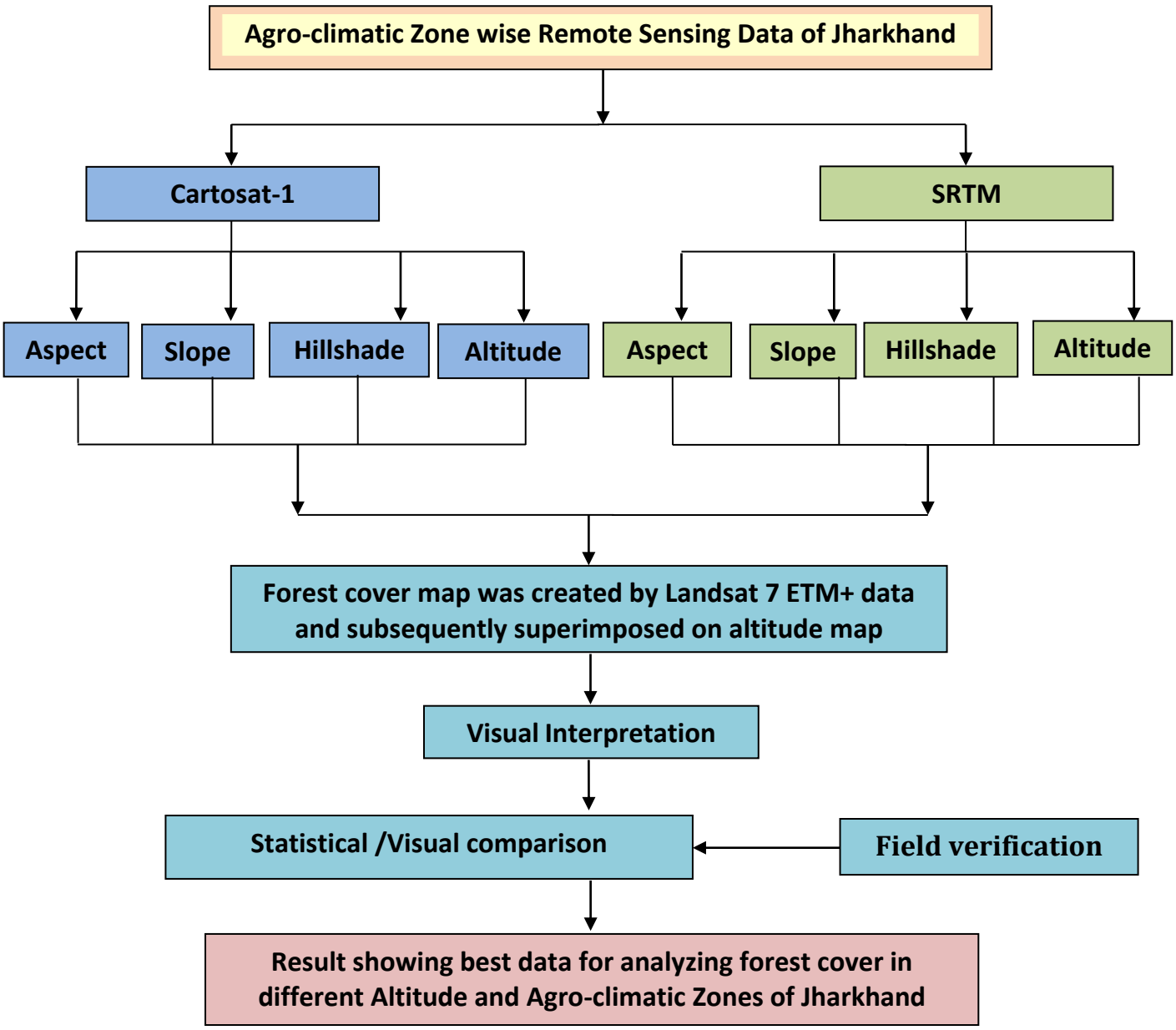

Figure 3. Methodology flow chart.

Image processing and GIS analysis was performed using ArcGIS 10.0 on the SRTM and Cartosat-1 DEM dataset. The slope, aspect, hill-shade and altitude maps were prepared using surface tool under Spatial Analyst in ArcGIS software. The slope map was prepared in ArcGIS software, describes the slope for each raster cell in degrees based on the elevation at each point. The surface analysis aspect tool was used to generate aspect map and hill-shade map from SRTM and Cartosat-1 data. The aspect map displays each raster cell grouped into compass directions (north, north-west, *etc.*); however, the hill-shade map shows shade effect based on the input parameters that are entered in the tool. The resulting map is easier to visually interpret than the original DEM because some topographic features are better visible on small scale (Sitabi 2015).

RESULT AND DISCUSSION

Present study provides an insight into various aspects of data products generated using Cartosat-1 and SRTM datasets with reference to slope (rate of maximum change in z-value from each cell), hill shade (grayscale 3D representation of the surface), aspect (identifies the down slope direction of the maximum rate of change in value from each cell to its neighbors) and elevation (the relief features of the earth's surface). Following observations are made from the study:

Visual comparison

In the present study, same protocol of remote sensing technique has been applied for both Cartosat-1 DEM and SRTM-DEM. On minutely observing the Altitude, Aspect, Slope and Hill-shade maps (Fig. 4), many visual variations are observed.

On aspect wise parameters (Flat, North, Northeast, East, Southeast, South, Southwest, West, Northwest) both SRTM and Cartosat-1 DEM show similar value (Fig. 4C, D). The minute observation of Slope map shows prominent difference in values for Flat (Green colour representation), Shallow (Yellow colour representation), Moderate (Brown colour representation) and Steep (Red colour representation), where the value varies from 0-15.27 for Cartosat-1 and 0-21.42 for SRTM DEM (Fig. 4E, F). The hill-shade map (Fig. 4G, H) of the study area also shows prominent variation in values, where it is in the range of (135–214) for Cartosat-1 and (118–222) for SRTM.

The deviation in case of SRTM-DEM for highly rugged terrains of Central and North eastern plateau climatic sub zone of Jharkhand is significant. However, for rest two climatic sub zones of Jharkhand, the deviation was identical.

Statistical comparison

Table 1. Altitude wise total area and forest cover of Jharkhand**.**

Range	Total area in km^2 (Cartosat-1)	Total area in km^2 (SRTM)	Forest Cover in km^2 (Cartosat-1)	Forest Cover in km^2 (SRTM)	Standard deviation
0–250	35953.8	26875.4	6356.2	3944.3	1705.5
251–500	30071.8	34638.7	13041.9	13620.2	408.9
501–750	12508.7	16385.7	3369.9	4973.3	1133.8
751–1500	1406.6	2029.2	1144.1	1354.7	148.9
TOTAL:	**79940.8**	**79928.9**	**23912.1**	**23892.5**	**13.9**

Table 2. Agro climatic zone wise distribution of forest cover in Jharkhand in km^2.

Agro climatic zone	Total Forest Cover (km^2)	Cartosat-1- DEM Elevation (m)		SRTM –DEM Elevation (m)		Difference in Elevation (m)		Standard Deviation	
		Max	Min	Max	Min	Max	Min	Max	Min
Zone-IV- Central and North eastern plateau sub zone	9112.8	879	-41	1355	20	-476	-61	336.6	43.1
Zone-V- Western plateau sub zone	7719.1	1095	62	1152	118	-57	-56	40.3	39.6
Zone-VI- South eastern Plateau sub zone	7086.9	858	-11	898	44	-40	-55	28.3	38.9

Figs. 5 & 6 shows altitude (Table 1) and Agro-climatic zone wise distribution of forest cover (Table 2) in different ranges from 0–250 m, 251–500 m, 501–750 m and 751–1500 m. Results show that, there is a prominent standard deviation in each range, however, SRTM showing similar value in each ranges of data obtained from Bhuvan Portal. Altitude wise analysis for forest area shows maximum variation for the range 0–250 m and minimum for the range 751–1500 m, and the standard deviation for these range stands at 1705.46 and 148.93 respectively. However, total area calculated from these DEMs are almost same and the standard

deviation for total forest area is found to be 13.9 (Table 1; Fig 5).

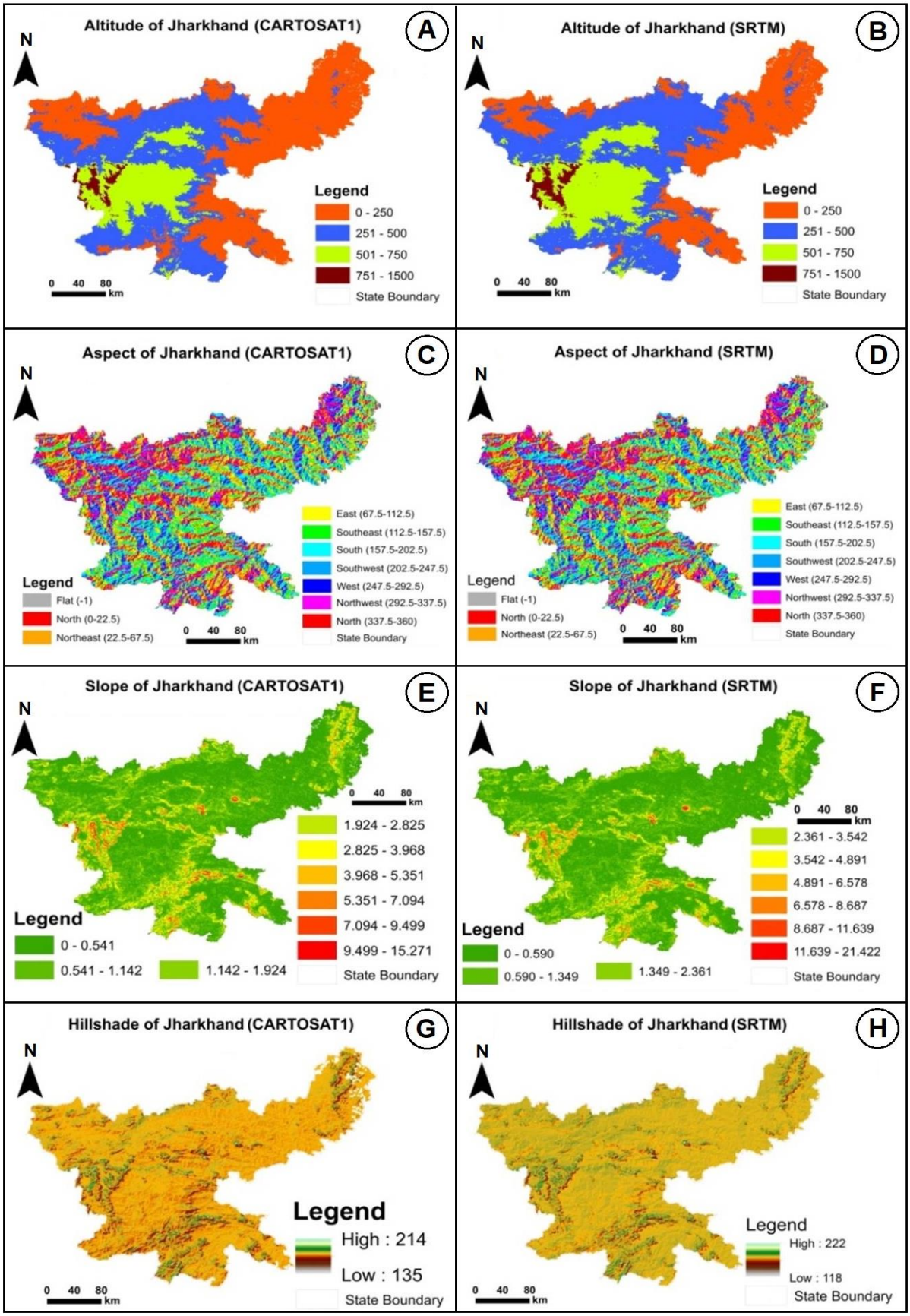

Figure 4. Altitude, Aspect, Slope and Hill-shade maps of Jharkhand, India.

The agro-climatic zone wise distribution of forest cover for the Cartosat-1 and SRTM-DEM shows that for Zone-IV- Central and North Eastern plateau sub zone, the maximum and minimum variation in standard

deviation is 336.58 and 43.13; for Zone-V- Western plateau sub zone the maximum and minimum variation in standard deviation is 40.30 and 39.59 and for Zone-VI- South Eastern plateau sub zone, the maximum and minimum variation in standard deviation is 28.28 and 38.89 (Table 2; Fig. 6).

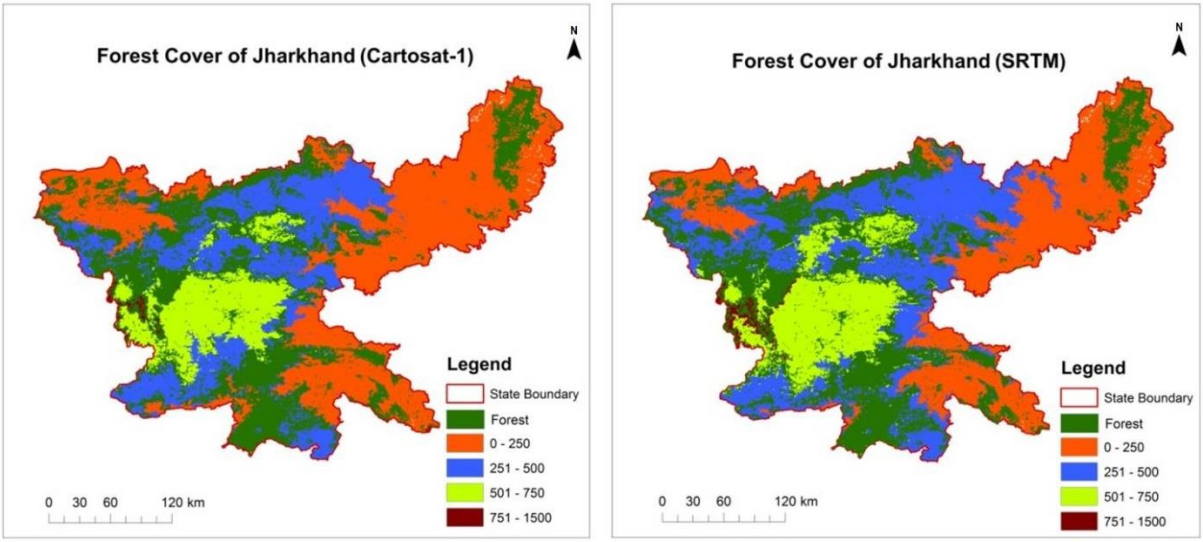

Figure 5. Forest Cover Maps of Jharkhand using Cartosat-1 and SRTM DEM.

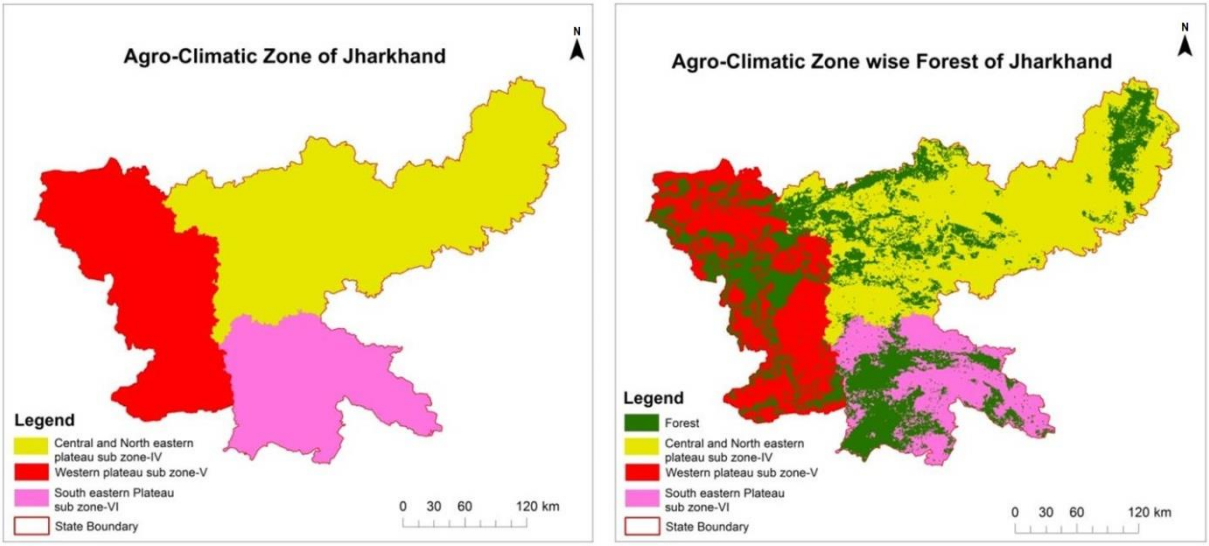

Figure 6. Agro-climatic Zone Map of Jharkhand & Agro-climatic Zone wise Forest Cover Map of Jharkhand.

Control Points

Total 30 numbers of GPS points were recorded in all the three agro-climatic zones of Jharkhand, comprising of 10 control points in each agro-climatic zone, and elevation data were recorded on these points, to validate the elevation accuracy achieved using SRTM and Cartosat-1 dataset. A comparison of elevation variation in SRTM and Cartosat-1 dataset with GPS points collected in all three agro-climatic zones has been shown in figure 7. The comparative charts show that, the elevation output achieved through SRTM data, is closer to elevation data recorded at various GPS points, in each of the agro-climatic zones. However, in another similar study conducted by Yarrakula *et al*. (2013) around Kharkai river area, Jamshedpur, where Cartosat-1 and SRTM dataset were used for digital elevation modeling, it was reported that the accuracy of Cartosat-1 DEM will be higher if proper ground control points are collected for undulating region. This variation in findings may be due to the variation in size of the study area. In the present study, we have applied the technology to a very large area *i.e.* for the entire Jharkhand state, whereas the Kharkai river area, Jamshedpur is a very small part of Jharkhand.

CONCLUSION

In the present study, various output products were derived for different agro-climatic conditions of Jharkhand using SRTM and Cartosat-1 datasets. These outputs were further verified with, ground truth data sets and comparative study reveals that as compared to Cartosat-1, the results obtained through SRTM datasets are

closer to ground truth dataset. Thus, in general, the accuracy achieved from SRTM DEM datasets would provide better results for the studies of forest cover mapping or species distribution modeling in different agro-climatic conditions of Jharkhand which is in the line of Das *et al.* (2016); although the SRTM datasets provide substantial results, the Cartosat-1 dataset does not provide reliable information, Baral *et al*. (2016); the spot height accuracy of SRTM DEM seems to be good for all kind of terrain in comparison to Cartosat-1 DEM in the study of three different terrain of India and Forkuor & Maathuis (2012); in the study of over two regions in Ghana for Hydrological and Environmental Modeling has revealed that SRTM is "closer" to the reference DEM than ASTER. For elevation parameter, study indicates that, SRTM gives better accuracy than Cartosat-1. Thus, the observation of present study suggests that, for analyzing forest cover in different agro-climatic zones of Jharkhand, the use of SRTM datasets could give better output performance and accuracy as compared to Cartosat-1.

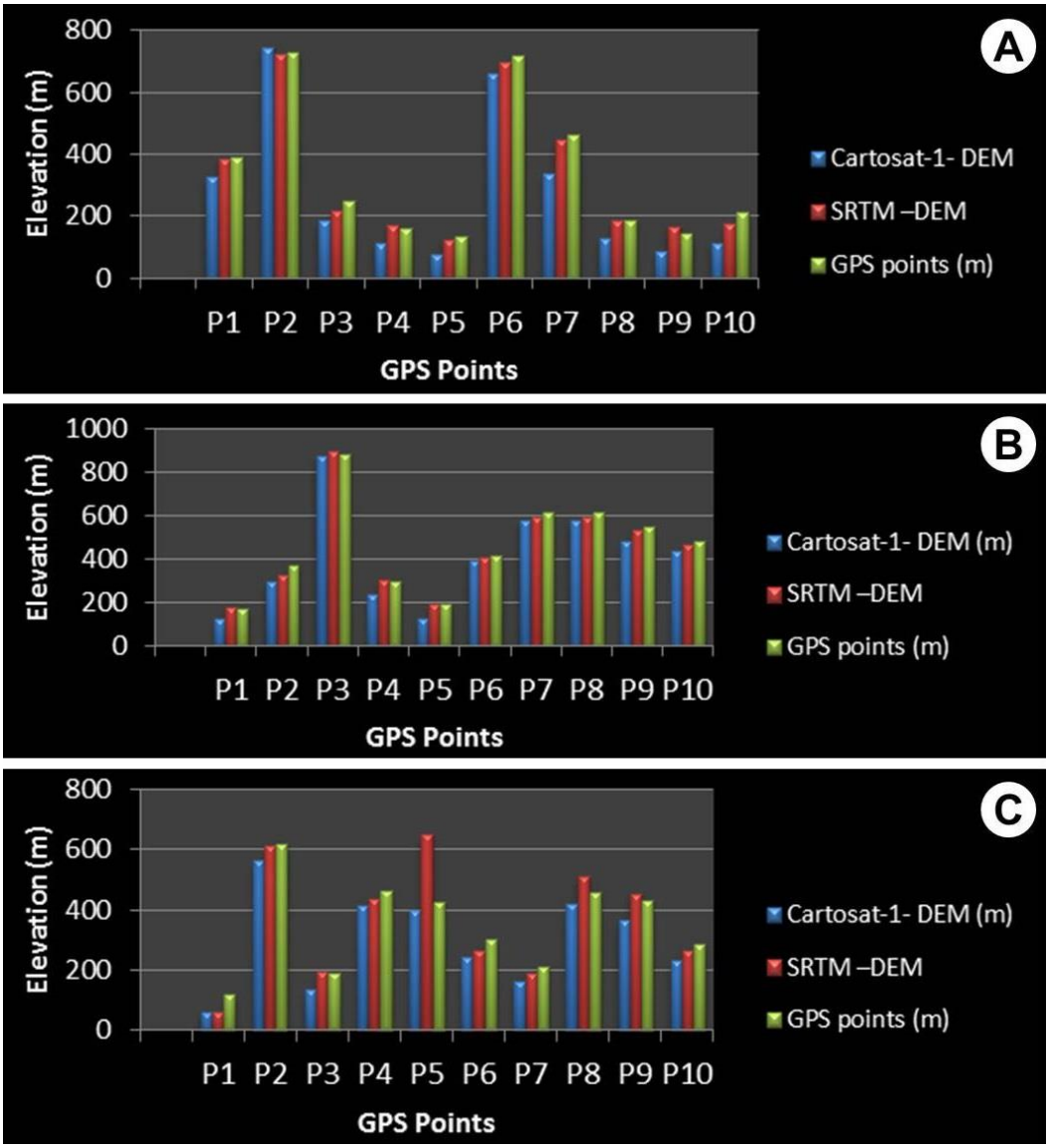

Figure 7. Elevation variation in agro-climatic zones: **A,** Zone IV- Central and North Eastern Plateau Sub Zone; **B,** Zone V- Western Plateau Sub Zone; **C,** Zone VI- South Eastern Plateau Sub Zone.

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