Identification and Quantification of Tree Species in Open Mixed Forests using High Resolution QuickBird Satellite Imagery

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Abstract

Present study deals with identification and quantification of tree species within an open mixed forest in parts of Ranchi district Jharkhand, India using high resolution QuickBird satellite data using image processing and GIS techniques. A high resolution QuickBird satellite image was used for shadow enhancement and tree crown area extraction. The First Principal Component of QuickBird satellite images was employed to enhance the shadowed area and subsequently shadow and non-shadow area were classified using ISODATA. The satellite image was used for crown area extraction with standard deviation of NDVI value and the crowns were classified into five classes using Maximum Likelihood supervised algorithm. Result shows that barring few limitation, the high resolution QuickBird image provides rapid and accurate results in terms of identification and quantification of tree species in conjugation with field verification and attained 88% of classification accuracy. It reduces the time required for obtaining inventory data in open mixed forest. Results also showed that total 5,522 trees of various species were present in the study area and dominated by *Shorea robusta* (80.48%) followed by *Ziziphus mauritiana* (16.26%), unknown tree (1.81%), *Ficus religiosa* (0.98%) and *Mangifera indica* (0.47%). The demography patterns of the locals mainly tribal (89.9%) exhibited their direct as well as indirect dependency on mixed forests resources for their subsistence and livelihood. The study necessitate towards the effective implication of policies to raise the standard of living of tribal people in the region.

Keywords: open mixed forest, tree quantification, tribal People, QuickBird, remote sensing

1. Introduction

Forests provide invaluable ecological services for the environmental security as well as provide a wide spectrum of livelihoods especially to the rural and marginalised strata of society in the form of direct employment, self-employment and secondary employment. Forests are rich sources of timber, firewood, bamboo, fodder and at the same time they provide employment opportunity to a large section

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of the tribal and other disadvantageous rural communities (FSI, 2011; Ajaz-ul-Islam, 2013). Forest is the second largest landuse in India after agriculture covering 21.05% of the total geographical area of the country. State of forest report (2011) states that Jharkhand state has 23,605 km^2 of recorded forest area, which is 3.06% of national coverage and produces 130,000 m^3yr^{-1} (i.e., 0.4% of the national estimated production). That report also indicates that 16% of total livestock depends on forests in Jharkhand against the national average of 38.49% (FSI, 2011).

Mixed forests represent significant proportion (30%) of the world's forest resources. This forest ecosystem is subjected to rapid adverse changes due to natural and anthropogenic influences due to its multifarious advantages. Various factors influencing the forest ecosystem and for proper management based on rational exploitation and development of forest resources is on scientific lines. Proper and sustainable management of forest resources require spatio-temporal coverage and species-wise vegetation quantification. There are prevalent various conventional methods of ground surveys techniques in order to collect reliable required data. However, field survey is more accurate but time consuming and remote sensing analysis together with field survey is more economical both in terms of time and money provided the precision is satisfactory. The forest cover mapping and species identification through remote sensing technology in conjugation with field inputs is very popular in recent decades using mainly courser to medium resolution satellite data (TM, LISS-III etc.). Tree counting outside forest is also in practice employing medium resolution satellite data (Seiler and Mcbee, 1992; Maco and McPherson, 2002; FSI, 2011), but identification of tree species in open mixed forest employing high resolution satellite (HRS) images remote sensing technology is under research due to spectral mixing of vegetation species and degradation (Brandtberg, 1998).

Launch of a very high spatial resolution satellites (IKONOS, QuickBird, OrbView) in the last decade, as well as development of new classification algorithms have initiated a new era in forest management using remote sensing technology (Plantier et al., 2006). Very high spatial resolution satellite images such as IKONOS and QuickBird have the potential to generate regional scale forest analysis through fusion of digital image analysis techniques with ground based forestry (Greenberg et al., 2005)**.** Moreover QuickBird satellite data is being used for Bathymetric Mapping (Lyons et al., 2011), detection of new plastic greenhouses (Agüera et al., 2006), generation of digital surface model using stereo pairs (Crespi et al., (2007), for mapping impervious surface distribution (Lu, 2011), delineation of soil erosion-prone areas (Uddin et al., 2014), stem volume estimation by tree crown area (Ozdemir, 2008), classifications for mapping and discriminating *Pyrus bourgaeana* trees within a mixed Mediterranean forest (Arenas-Castro et al., 2014).

QuickBird characteristics provide an opportunity for capturing quantitative parameters of floristic changes across small topographic gradients at a very fine spatial resolution to capture spectra from individual units such as a tree crown (Souci, 2008). Inventory attributes depend on whether the stand types were predominantly comprised of coniferous, deciduous or mixed wood species (Hall and Skakun, 2007). Tree attributes and spectral response patterns of high resolution QuickBird satellite image have shown strong association. Band 2 (green) and band 3 (red) in the visible region and band 4 (NIR) have revealed significant associations with forest parameters (Islam and Donoghue, 2004). Culvenor et al. (1999) proposed TIMBRS, a semi-automated algorithm, originally developed for *Eucalyptus* forests. Identification and quantification of trees species using high resolution satellite data have some limitations. In case of standing trees in crop field, the pixels of the tree cover mix up with the crops in the field and also in case of leaf fall, the sensor cannot capture the actual status of the tree cover (Singh et al., 2005). Although remotely sensed imagery provide an accurate total tree count, its accuracy depends upon the image resolution (spatial and spectral) properties adopted against the type of forest and its age class. On the other hand, individual tree sampling could provide an alternative method to plot-based inventory, avoiding per hectare sampling variation across the standing trees (Deadman and Goulding, 1979; Gordon et al., 1995; 2006). Mather (2004) emphasised on the multi-band visible/ near infrared images of vegetated areas that will exhibit negative correlations between the near infrared and visible red bands. Principal Component Analysis (PCA) technique is commonly used on the image to de-correlate it. PCA2 is likely to be most suitable for the vegetation features as it emphasises highly on the uncorrelated features of the bands. PCA1 contains variability due to overall scene brightness (Nag and Kudrat, 1998).

In the present study, an attempt was made to evaluate the potential of very high resolution QuickBird satellite data in identification and quantification of tree species in the open mixed forests, Ranchi, Jharkhand using shadow enhancement and crown area extraction techniques. Later, livelihood contributions of enumerated tree species to the tribal people were evaluated.

2. Methodology

2.1 Study area

This study was conducted in Numkum block, the southern region of Ranchi district of Jharkhand state, India located between $23^{o}12'$ N to $23^{o}11'$ N latitude and $85^{o}17'$ E to $85^{o}18'$ E longitude at an elevation of 510 m above mean sea level (Figure 1). It covers total area of *ca.* 332.77 ha and consists of rural set up with primarily covering Kalamati village (Khunti district) and small parts of Dundu of Ranchi district, Nehaldih and Argoi villages of Khunti district. The study area is a complex of plains and hilly region with the undulating landscape. The existing landuse pattern is as natural and open mixed forest, un-irrigated cultivable land, cultivable and uncultivable wasteland. Majority of forest area comprises of *Ziziphus mauritiana*, *Ficus religiosa*, *Shorea robusta*, *Mangifera indica* L.

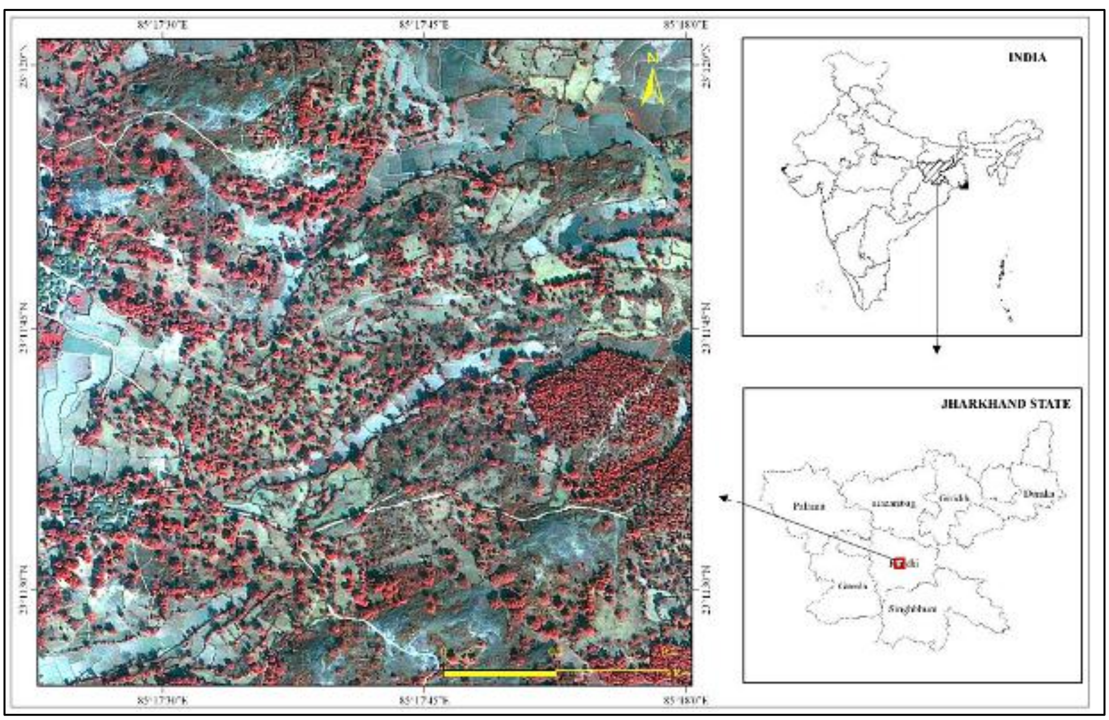

Figure 1: Location and the detailed map of the study area.

The population is 299 persons (145 males and 154 females) in Kalamati village, 625 persons (298 males and 327 females) in Dundu village, 86 persons (46 males and 40 females) in Nehaldih village and 96 persons (52 males and 44 females) in Argoi village (Census, 2001). The area falls under tropical climate with three distinct and well-marked seasons, summer, monsoon and winter. The average annual normal rainfall is 1,400 mm; the mean minimum temperature is 22° C and the mean maximum temperature is 38° C in the area. The educational, medical, social, economic, irrigation, communication and transportation facilities in these villages are very limited and in poor condition. The livelihood systems in the area are primarily dependent on combinations of forests, labouring and agriculture. The forest resources are the important contributor to the total livelihoods among the tribal communities in the area. The people are relied on diversified pattern of occupations, as no single activity provides sufficient resources to entirely ensure their livelihood (Malik et al., 2011, Sinha and Kumar, 2013).

2.2 Methodology

In the present study, a QuickBird satellite image acquired on 26th December 2006 was used. QuickBird satellite carries a single instrument capable of producing panchromatic images with a spatial resolution of between 0.61 and 0.73 m plus multispectral imagery with a spatial resolution of 2.44 and 2.88 m at nadir and off nadir respectively. The sensor has across track mode and swath of 16.5×16.5 km at nadir. It has 04 multispectral (MSS) and 01 panchromatic (PAN) bands. The spatial resolution of panchromatic image is 65 cm and multispectral image is 2.62 m. The details of the sensor are provided in Table 1.

Table 1: Sensor specification of QuickBird satellite.

Characterisation	Information	
Launched on	18 October 2001	
Orbit Altitude	450-km	
Orbit Inclination	97.2°, sun-synchronous	
Swath	16.5 km x 16.5 km at nadir	
Radiometric resolution	11-bits per pixel	
Revisit Time	1 to 3.5 days, depending on latitude (30° off-nadir)	
	Sub-meter resolution	
Spatial resolution	65 cm panchromatic at nadir	
	2.62 m multispectral at nadir	
Spectral resolution	4 Multispectral and 1 Panchromatic	
	Bands	Wavelength region (μm)
	1	0.430-0.545 (blue)
	2	0.466-0.620 (green)
	3	0.590-0.710 (red)
	4	0.715-0.918 (near-IR)
	PAN	0.405-1.053

The fusion of images can enhance the recognition ability of features (Wenbo et al., 2008). In the present study, panchromatic and multi spectral images of QuickBird satellite were fused using the principal component technique (Shamshad et al., 2004). Experimental results showed that the results from pan-sharpened images are significantly better than original multispectral images (Zhang 2002;

Wang et al., 2005). The fused image was then geo-rectified using the Cartosat-I image acquired on December 2005 (2.5 m spatial resolution) in UTM projection system and WGS 84 datum using adequate number of ground control points. The RMS error was 0.40 m. All the digital image processing and GIS analysis were carried out using ERDAS Imagine 9.2 and ArcGIS 9.2 respectively.

Later in the study, PCA 1 was performed for the shadow enhancement and the output de-correlated image was then subjected to ISODATA (Iterative Self Organizing Data Analysis Technique) classification. This technique assigns each candidate pixel to a cluster. The ISODATA algorithm was repeated by modifying the criteria until the appropriate separation of shadow enhancement was achieved. The maximum iterations were limited to 10 times with only 02 classes for shadowed and non-shadowed area. Due to the less spectral variability between the shadowed area and water body, NDVI (Normalized Difference Vegetation Index) was performed on multispectral QuickBird images to extract water bodies (pixel values ≤ 0). This image was used to mask the water body areas from the classified image (Figure 2).

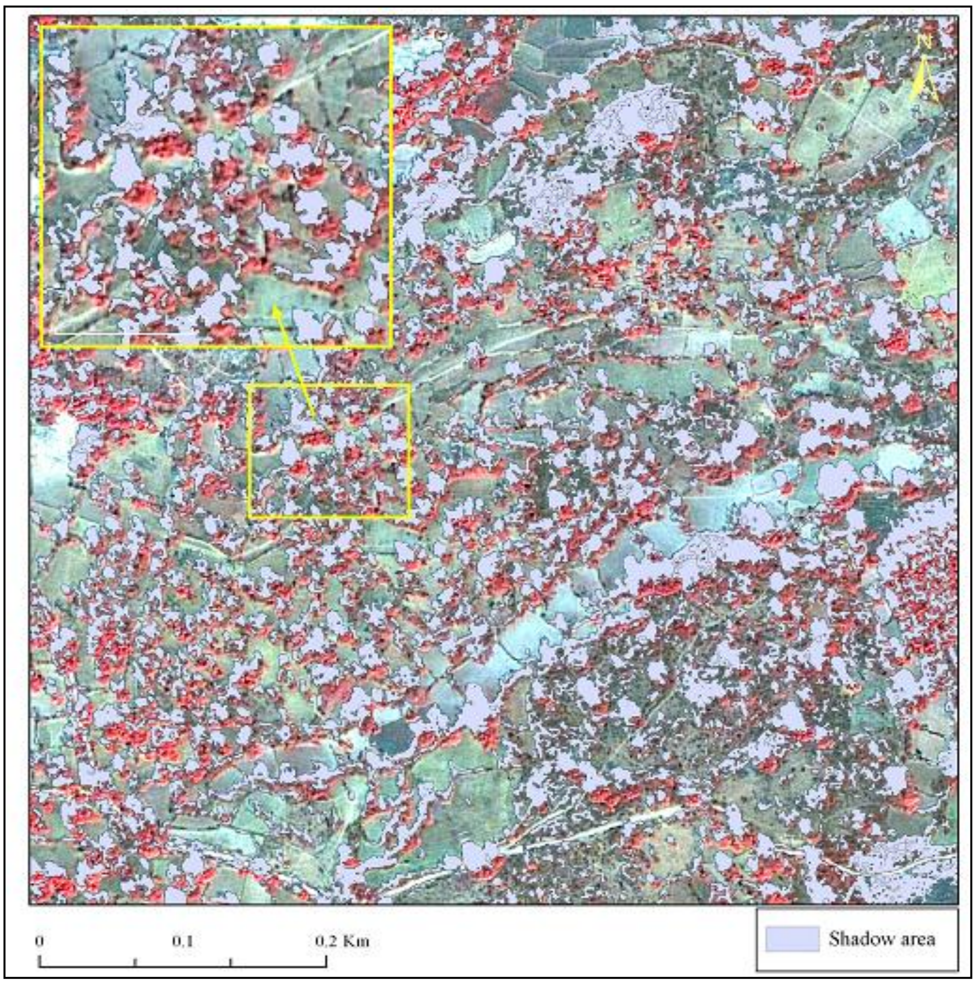

Figure 2: Shadow enhanced area of pan-sharpened QuickBird image.

In the open mixed forest while captured through the off-nadir angle, there was some overlapped crown area comprising of multiple crowns. These compactly clustered trees pose a difficulty in counting the individual number of trees. Therefore, the multispectral QuickBird satellite image was subjected to NDVI (Normalised Difference Vegetation Index). NDVI normalises the difference of brightness values from infrared and red for monitoring vegetation (Rouse et al., 1993). The standard deviation 1 (σ) of NDVI image (*i.e.*, NDVI threshold >0.028) was used to extract the tree crown area from the QuickBird satellite image. The output image has pixel values of mature trees as well as the low laying shrubs. Here, it was observed that at many places the low laying shrubs also approximately have the similar NDVI values as compare to the mature trees. Therefore, the original pixel values of tree crown cover were extracted using the NDVI threshold value from multispectral QuickBird satellite image, and thereafter subjected to supervised classification. Crown area was divided into five classes. Homogenous tree classes were extracted individually and vectorised (Figure 3). Tree crown area and enhanced shadowed area were merged. The merged image represents mature individual tree, mature clustered trees as well as crown shadow. Trees having shadow represent mature status and were retaken into consideration for the tree quantification and species identification.

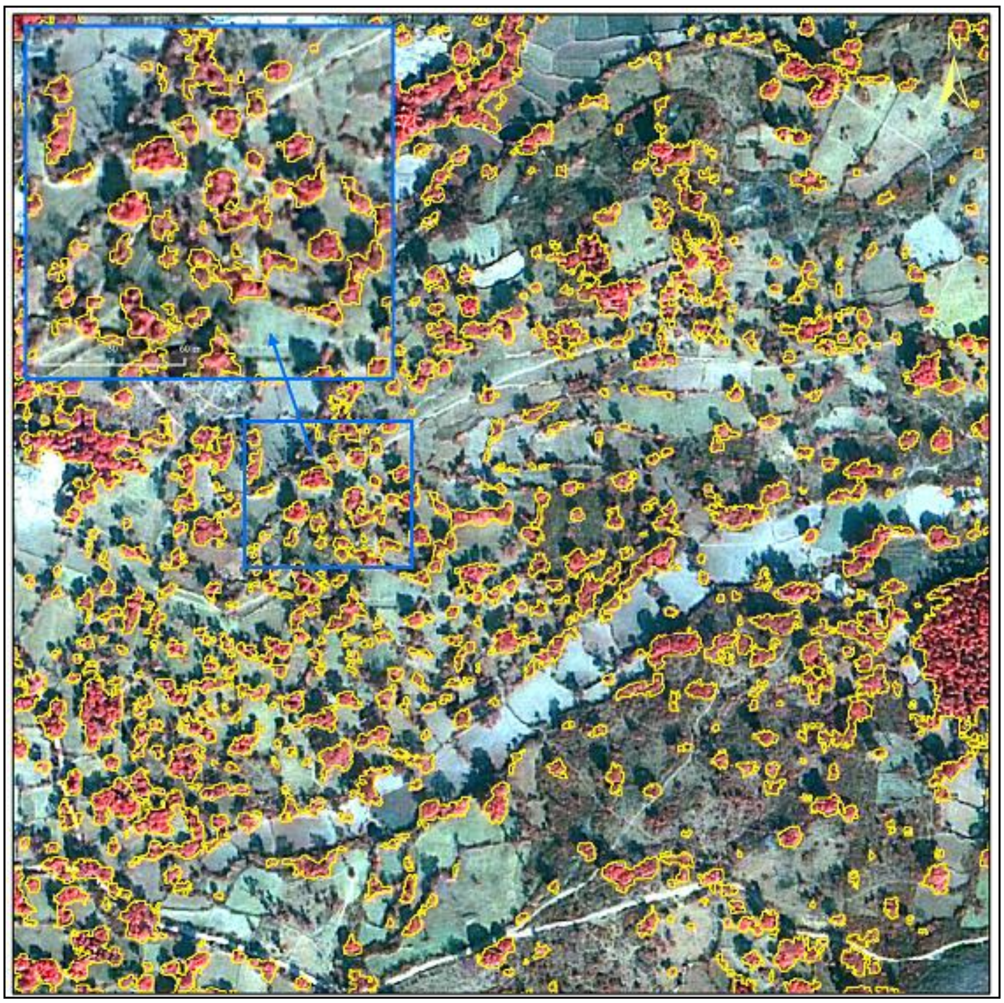

Figure 3: Extracted crown area (in vector) overlaid on high resolution QuickBird satellite image.

Supervised classification method was used in this study with the Maximum Likelihood (ML) Classifier. While working through ML algorithm, it is necessary to have well defined training areas and pure signatures to acquire an expected result (Jensen, 1996). Since QuickBird image is of a high resolution data, the signatures sites can clearly be delineated (Frick et al., 2005). As maximum number of training sites contribute to the higher classification accuracy, therefore, the types of trees were identified using the supervised classification with fifty numbers of training sites for each class (except *M. indica* L., which is less than 50 in numbers within the study area). Based on the spectral characteristics of species and adopted classification algorithm, the tree cover was regrouped into 10 classes. For accuracy assessment, 100 points were taken for ground verification (conducted on October 2009) with minimum of 15 points against each class. The overall classification accuracy was 88%. The producer accuracy of classes ranges from 60% to 97% and the user accuracy ranges from 66% to 100% with overall kappa statistic of 0.83 (Table 2). Wrong identification of pixels was corrected using recoding technique and the final classified image was used for tree quantification of particular class. Five types of tree species were present *viz.*, *Z. mauritiana*, *Ficus religiosa*, *S. robusta*, *M. indica* L. and unknown tree. Thereafter, each class was extracted individually and converted into vector format. The vector was then used in quantification of individual trees and trees in each cluster.

Table 2: Accuracy assessment of classified image.

Species	Producers Accuracy	Users Accuracy	Kappa
Ziziphus mauritiana	97.50%	88.64%	0.81
Ficus religiosa	60.00%	100.00%	1.00
Unknown tree	73.33%	91.67%	0.90
Shorea robusta	93.75%	85.71%	0.79
Mangifera indica L.	66.67%	66.67%	0.65
Overall Classification Accuracy = 88.00%			
Overall Kappa Statistics = 0.83			

All the five types of classified tree crowns were extracted separately and then converted to vector for the area based statistics calculation. Quantification of trees was based on the sample mean crown area of each type. There were at least 20 sample tree crowns selected for each type and their mean crown value were calculated, which is 48.18 m^2 *for Z. mauritiana*, 207.49 m^2 for *F. religiosa*, 35.73 m^2 for *S. robusta*, 214.81 m^2 for *M. indica* L., 82.33 m^2 for unknown tree (Table 3). The mean values (mean crown area) of sampled crown were used for quantification of each homogeneous tree type. The consideration of individual trees was made, where crown area of a particular tree falls within the mean value of that particular tree type. Whereas the consideration of tree cluster of a particular tree type were made, where the crown area value is more than the mean crown area. The tree clusters of each type were extracted from the classified image and the number of trees was derived through the following derivation (equation 1).

$$N = \frac{B}{m} \qquad (1)$$

where:

N = number of trees
B = crown area of the multiple crowns and
m = mean value of the sampled crown area

Table 3: Crown area estimation and quantification of individual tree species and tree species in cluster.

Species	Individual species		Species in clusters			Total No. of species	% of the total species
	Mean crown area (m^2)	No. of species	No. of species in clusters	Mean crown area (m^2)	No. of species		
Z. mauritiana	48.18	308	147	48.18	590	898	16.26
F. religiosa	207.49	51	03	207.49	03	54	0.98
Unknown tree	82.33	45	14	82.33	55	100	1.81
S. robusta	35.73	236	527	35.73	4208	4444	80.48
M. indica L.	214.81	23	01	214.81	03	26	0.47
Total	-	393	-	-	4859	5522	100.00

3. Results and Discussion

The tree species within an open mixed forest were identified and quantified using very high resolution QuickBird satellite data using shadow enhancement and crown area extraction techniques. The open forest comprised of matured trees, tree clusters, bushes, cultivable land and bare soil cover. The improvement in spatial resolution of satellite imageries also implies to make use of other image characteristics *viz.*, shadows (Irvin and McKeown, 1989; Arévalo et al., 2008). Shadow of the mature trees as well as tree clusters is a significant attribute associated with the satellite imagery. Therefore, the shadow was used to distinguish the matured trees from low lying vegetation (shrubs). Also, the livelihood contributions of enumerated tree species to the tribal people were studied.

3.1 Tree Species quantification

According to this study, total of 5,522 trees were present within the study area during 2006 (Table 3, Figure 4).

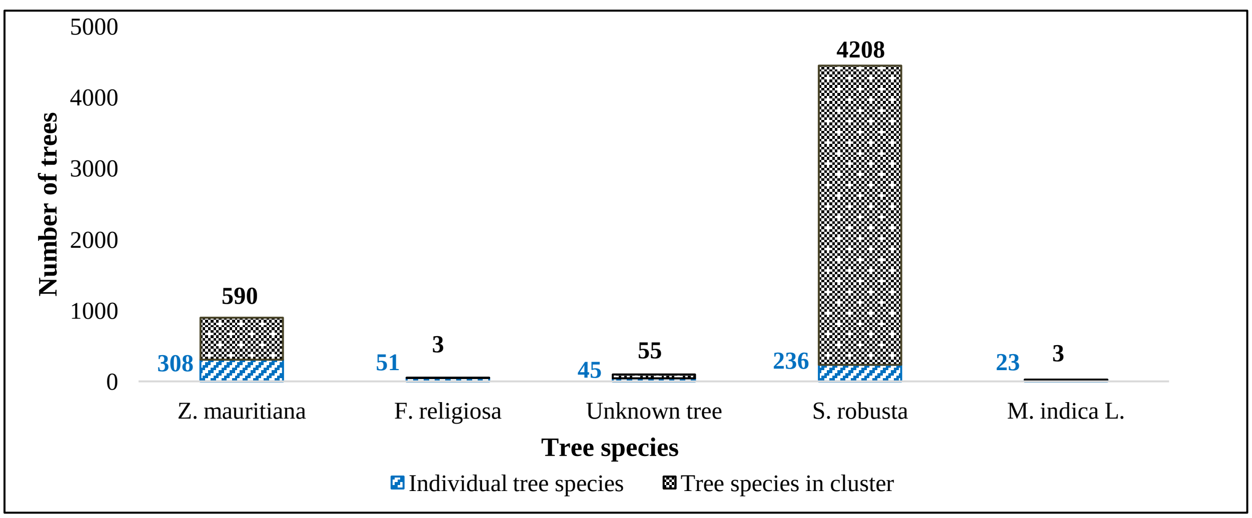

Figure 4: Quantified individual tree species and tree species in cluster as observed through high resolution QuickBird satellite data.

Among individual species within the study area, *Z. mauritiana* was counts the maximum (308) followed by *S. robusta* (236). *F. Religiosa* was 51. There were 45 unknown species. *M. indica* L. was the least among the individual tree species. Among the species in clusters, *S. robusta* had the maximum (4,208) followed by *Z. mauritiana* (590) and unknown tree (55). On the contrary, *F. Religiosa* (03) and *M. indica* L. (03) were the minimum. The total individual species and species in clusters exhibits that the majority of species in the study was *S. robusta* (80.48%; N=4,444) followed by *Z. mauritiana* (16.26%; N=898), unknown tree (1.81%; N=100), *F. Religiosa* (0.98%; N=54) and *M. indica* L. (0.47%; N=26).

3.2 *Demography pattern*

The population in these villages are very limited (1,106 persons in 2001 and 3,643 persons in 2011), though an increase (229% growth) were observed during 2001-11. Village-wise population exhibits that the maximum growth was observed in Nehadih village (459) followed by Kalamati villages (1,454), Argori (430) and Dundu (194) (Figure 5 (a) and (b)). It also exhibit that the village Dundu and Kalamati most populated village in the study area.

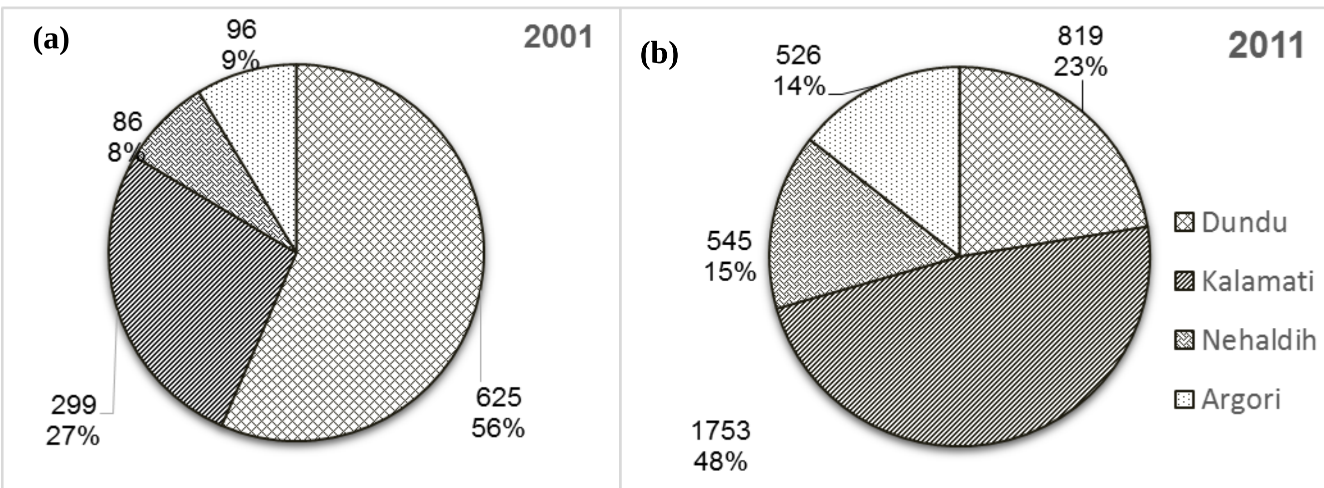

Figure 5: Human population in villages during (a) 2001 and (b) 2011.
(Source: Census of India, 2001 & 2011).

The demographic composition represents that major chunk of population in the study area belong to schedule tribe (ST). As mapped during census year, the 89.9% of population was ST in 2001 and the percent ratio increased to 90.3% in 2011, whereas the population of schedule caste (SC) was very limited to 0.6% in 2001, which increased to 1.4% in 2011. The village wise distribution exhibit that maximum increase in actual number of persons was in Kalamati Village followed by Dundu village (Figure 6 (a)). The per cent increase of total, ST and SC population represents maximum increase in Kalamati village followed by Nihaldih village and Argori village (Figure 6(b)).

The demographic composition with reference to gender in the villages exhibits comparable male female ration as surveyed during census year in 2001 (51.1% female against 48.9% male) and 2011 (50.3% females against 49.7% male). The village-wise male: female ratio represents that the female population is always higher compare to male population in the villages except Nehaldih village in 2001 and 2011 and in Argori village in 2001 (Figure 6 (c)).

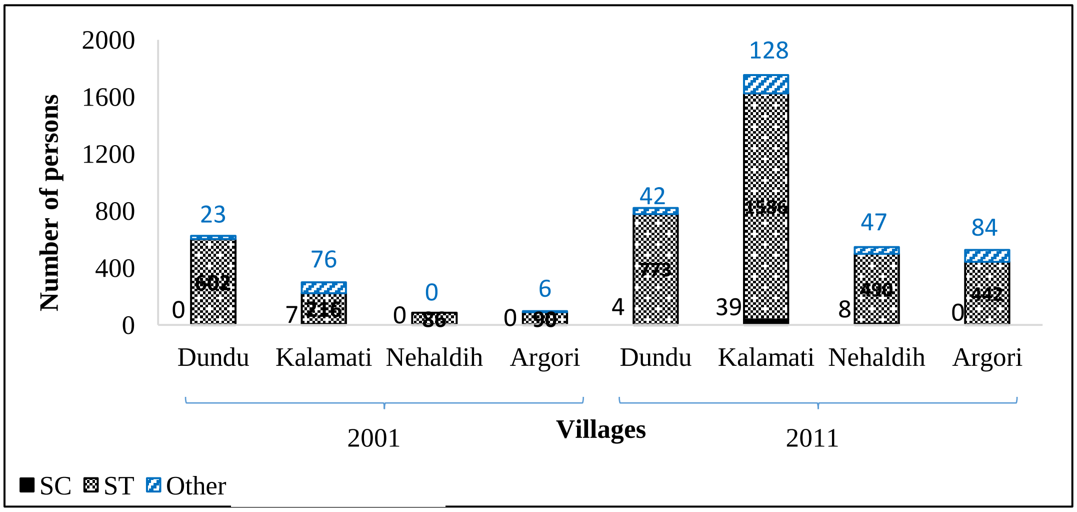

Figure 6 (a): Demographic composition (ST/ SC) during 2001-11.

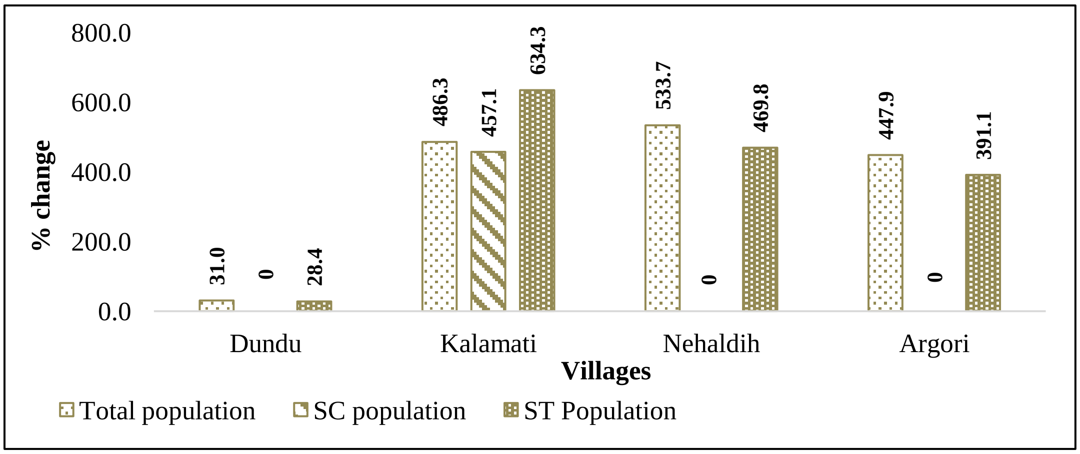

Figure (b): Percent change in total population and demography composition (ST/SC) during 2001-11.

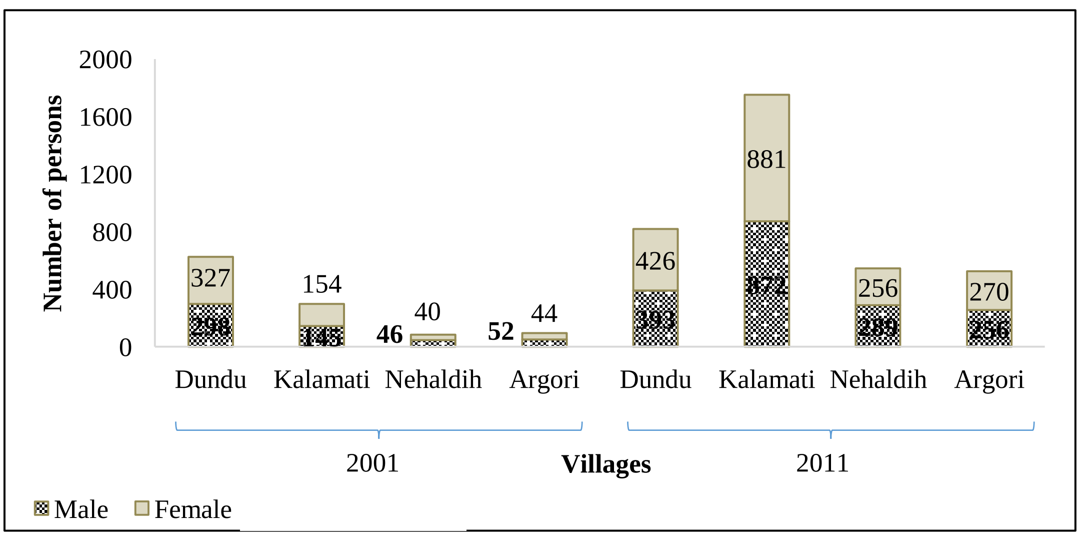

Figure 6(c): Demographic composition (male, female) during 2001-11 in the villages of study area. (Source: Census of India, 2001 & 2011).

3.3 Tree Quantification and the local people

The demography pattern in the villages exhibits that the major chunk of the population is tribe and relied on these local forest resources for their livelihoods through the sale of fuel wood and fodder, livestock rearing, grazing, forest based handicrafts and cottage industries, leaf plate making, liquor making, rope making and basketry, medicines, collection and marketing of non-timber forest products, bidi making, timber yielding, cultivation of agricultural crops etc.

Identification of tree species in the forest ensures the reliability of livelihood and income sources for the local people. *Shorea robusta* is the timber yielding tree, whereas *Mangifera indica* and *Ziziphus mauritiana* are basically fruit plant. Also *Ficus Religiosa* and *Mangifera indica* are religiously important and *Shorea robusta* and the unknown tree are being used as fuel wood by the locals. The name of tree species and their use category are listed in Table 4.

Table 4: Usage of forest species enumerated in the study.

Species	Local name	As used by the local people
Ziziphus mauritiana	Ber	Fruit
Ficus religiosa	Pipal	Religious and sacred
Unknown tree	-	Fire wood
Shorea robusta	Sal	Timber and religious
Mangifera indica L.	Mango	Multipurpose (fruit, timber, fuel wood, religious)

4. Conclusion

The study exhibits the potential of high resolution QuickBird satellite data for tree quantification in the open mixed forest area using image processing, GIS techniques. The crown area extraction and its relation with shadow area in identifying the mature tree clusters were achieved with 88% of accuracy, when compared with the field information. The high resolution QuickBird image provides accurate results in terms of identification and quantification of tree species in conjugation with field verification. The inaccuracy pertaining to the classification may be minimized through incorporating high number of training sites during post field classification process and tanking pure pixels. Though, the study represents certain limitation in quantification of species in tree clusters. The major limitation of tree quantification is obstructed in the tree clusters, where the immature trees (of varied ages) within the middle of tree clusters. Trees along with the shrubs and bushes may also reduce the accuracies of tree quantification. As the study deals with the tree identification specifically in the open mixed forest, the classification of tree types using the maximum likelihood classifier, if enhanced more than 88%, the crown area will have a more accurate result. Also the crown area measurement is sensitive to the choice of season.

Barring few limitations, the methodology may help in rapid assessment of tree cover spread in open mixed forest and trees outside forest, thus assist in decision making. It also ensures the subsistence and livelihood of the local tribal people. The demography patterns of the locals exhibited their direct as well as indirect dependency on mixed forests. And the different tree species enumerated in the study were being used to fulfill different day today need of the local people. The high resolution remotely sensed images may also necessitate towards the effective implication of various policies to uplift the standard of living of tribal people in the region.

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