# GEOSPATIAL APPROACH FOR RECONCILIATION OF NOTIFIED FOREST LANDS AT CADASTRAL LEVEL

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**KEYWORDS:** Notified forest lands, high resolution, GAGAN, GCP, reconciliation

**ABSTRACT:** Forest lands are unique natural resources which are vulnerable to degradation and encroachment. Spatial maps indicating ownership along with jurisdictional boundaries are important for enforcing forest conservation and protection. In this context, a pilot study was carried out to generate geospatial database for forest lands in collaboration with Karnataka forest Department (KFD) for reconciliation of notified forest lands at the cadastral level. The pilot study was carried out in four forest ranges covering 220 villages representing overall diversity in terms of terrain and forest types. The major input for the study included high resolution data (Cartosat-1, LISS-IV), GAGAN based GPS, cadastral and notified forest land maps. GAGAN based GPS devise was used for collection of accurate GCPs. One set of GCPs were used in the photogrammetric block adjustment of Cartosat-1 stereo images for generation of DEM and orthorectification. Fusion of Cartosat-1 and LISS-IV data was carried out using Brovey technique. The results indicated reasonable positional accuracy of the orthoproducts showing potential use of low cost GAGAN based GPS for photogrammetry. The scanned village cadastral maps were georeferenced using second set of GCPs. The georeferenced cadastral maps were overlaid on the merged data to compare the extent of matching between parcel boundaries with field boundaries as manifested on high resolution data. The results are quite encouraging with 80.2 per cent of the cadastral maps showing better than 5.0 m accuracy along the field boundaries. Two season LISS-IV and Cartosat-1 merged data was used for reconciliation of notified forest land boundaries. A comparative study was carried out to analyze the land use change within notified forest lands (As per KFD records) which indicated significant diversion of forest lands to agriculture. Further, decadal changes in the forest lands were analyzed using historical satellite database from 1965 to 2015 to study the diversion.

## 1 INTRODUCTION

Forests are very unique amongst natural resources, and these forest lands are being rediscovered as global resources of local significance. Managing and conserving vast tracks of natural resources such as forest are an important responsibility. These tracks are vulnerable to degradation / deterioration and encroachment without proper stewardship. Maps indicating ownership along with jurisdiction boundaries are therefore of paramount importance for enforcing forest conservation and protection measures.

Honorable Supreme Court in order dated 6.7.2011 (IA Nos. 1868,2091, 2225-2227, 2380, 2937 in writ petition (C) No. 202 of 1995 -LAFARGE matter) has mandated the following: “Creation and regular updating of GIS based decision support database, tentatively containing inter-alia the district-wise details of the location and boundary of (i) each plot of land that may be defined as forest for the purpose of the FCA 1980, (ii) the core buffer and eco-sensitive zone of the protected areas constituted as per the provisions of the Wildlife (Protection) Act, 1972; (iii) the important migratory corridors for wildlife; (iv) the forest land diverted for non-forest purpose in the past in the district. Therefore all the State Forest Departments are now mandated to create a robust and reliable geo-spatial database of all parcels of land (Land such as Notified forest, Diverted forest Land, Compensatory forestation Land and area under JFPM) that may be defined as forest for the purpose of the FCA 1980. The advanced geospatial technology has immense potential for mapping and monitoring of natural resources at different spatial hierarchies. A collaborative pilot study with Karantaka forest Department was taken up for geospatial database generation for two forest ranges in Karnataka state so that the procedure followed could be extended to all the forest ranges in the state.

The GPS technology has improved the accuracy, and reduced time and cost of ground control surveys (Eugene H. Silayo 2005). In this project GCPs collected using GAGAN enabled receiver Parishud was used for the processing. GPS Aided Geo Augmented Navigation (GAGAN) system is a Satellite Based Augmentation System (SBAS) developed jointly by ISRO and Airports Authority of India (AAI) to render GPS signal suitable for civil aviation applications such as seamless navigation and approach over the Indian airspace and its surroundings. GAGAN system improves accuracy, integrity, availability and continuity of GPS solution by providing necessary correction signals for ionospheric interference, clock and ephemeris errors. The location accuracy from GAGAN system after 15 minutes of observation is 50-60cms in planimetry and 1-2m in elevation and thus GAGAN derived GCPs can replace existing practice of relative positioning GPS surveys to generate elevation products in quicker and efficient manner (Rani T.E., 2013). The GCPs collected has been used for photogrammetric processing to generate DEM and ortho images and geo-referencing of cadastral maps of the villages pertaining to the forest ranges.

## 2 OBJECTIVE OF THE STUDY

In collaboration with KFD, the following objectives were defined for two forest ranges viz. Chennagiri - Tarikere and Bidar :

- Generation of geo-spatial database for the two forest ranges
- Cadastral map geo-referencing in and around the forest ranges using GCPs collected using GAGAN
- Updation of forest boundaries at village cadastral level

## 3 STUDY AREA AND DATA USED

Chennagiri- Tarikere forest ranges located in Bhadravathi forest division fall in the magnificent Western Ghats and categorized under evergreen forests. The study area is shown in the Figure 1.

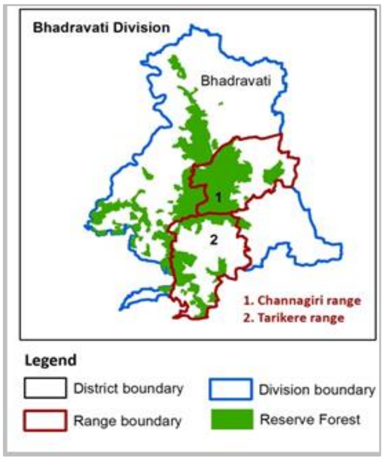


Figure 1: Study area showing different forest boundaries

Satellite remote sensing data acquired by IRS series were used for the generation of geo-spatial database. Cartosat-1 stereo data was used to generate DEM and ortho images. Cartosat 1 Mono and LISS-IV datasets were used to prepare current year base maps for further geo-referencing of village cadastral maps. In addition to the above satellite datasets, the following ancillary data from different sources and digital devices has been used directly, as reference and also for field data collection in the study. Parishud (GAGAN based GPS instrument) for collection of GCPs for geospatial database generation and geo referencing of village cadastral maps.

## 4 METHODOLOGY

The methodology has been divided in to three components a) generation of geospatial database using satellite data b) geo-referencing of village cadastral maps and c) reconciliation of the forest boundaries. The overall methodology adopted is as shown in Figure 2.

### 4.1 Generation of geospatial database

Ground Control Points were collected using GAGAN based GPS device for achieving better location accuracy which was necessary for improved photogrammetric bundle block adjustment and geo-referencing of cadastral maps. Commercially available Parishud GPS receiver uses GAGAN SBAS signal for correcting the co-ordinates and thus, providing accurate geo coordinates. A total number of 413 GCPs were collected for block triangulation and 1627 GCP for village cadastral geo- referencing.

Photogrammetric processing of Cartosat-1 stereo data was done to generate DEM and ortho images for Chennagiri and Tarikere forest ranges. The generated DEM was validated with respect to ground points in terms of LE 90 and RMSE. The DEM generated has been used to generate ortho-products of Cartosat-1 mono images and Liss-IV images for the forest ranges. Cartosat-1 mono images and corresponding Liss-IV images (two seasons) were ortho-rectified and has been fused using Brovey transform technique to generate high resolution images for the forest range. The geospatial database generated for the forest range is as shown in Figure 3.

## 4.2 Cadastral geo-referencing

The Cadastral scanned maps has been provided by ICT, KFD for geo-referencing along with GCPs collected using Parishud. Field visit for each village cadastral has been conducted by KFD team using Parishud GPS receiver for collection of GCPs. All the village cadastral maps were geo-referenced using survey points and tri-junction points using Cartosat-1 and LISS-IV fused data as reference base map using first order polynomial transformation following nearest neighbor resampling technique. Initially, geo-referencing of cadastral maps was carried out using X and Y locations of well-defined GCPs and refined subsequently using additional GCPs till the cadastral map had the best fit with the ortho data when overlaid. Edge matching of adjacent village boundaries has been carried out for seamless mosaicking of village cadastral maps. Spatial dimensional integrity of geo-referenced cadastre was validated using the survey number wise land record details available under Government of Karnataka Bhoomi website. The portal hosts details of the survey number wise land records and holdings for the entire state of Karnataka.

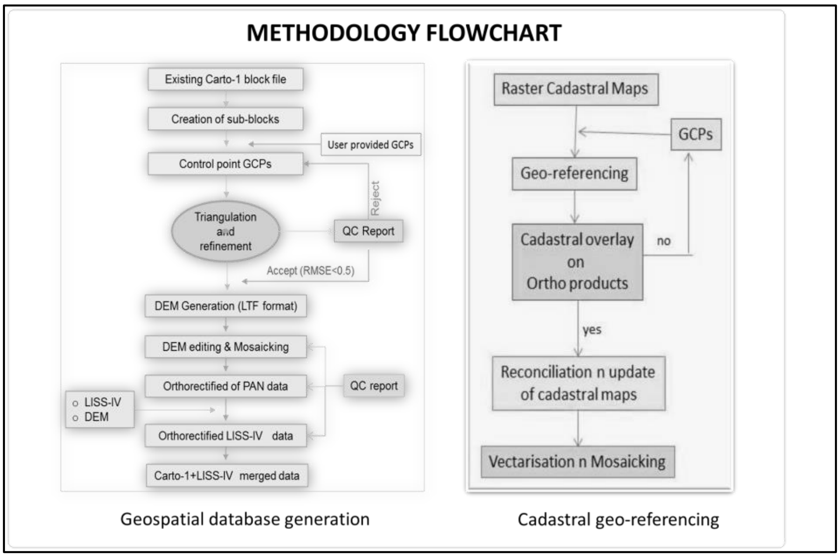


Figure 2: Overall methodology of the study

## 4.3 Visual interpretation

Two season multi-spectral LISS-IV datasets corresponding to November-December and March-April periods have been used for differentiating forest land cover from non-forest landuse/landcover categories across all the 04 forest ranges. This was primarily essential for establishment of current day forest land cover boundaries within the notified forest regions. These datasets have been studied for interpretation of forest and other categories using tone, texture, pattern, tree composition and terrain conditions.
For interpretation, 2.5 m merged data was displayed at approximately 1:5,000scales. Based on the varying spectral signature as manifested on the merged data, forest and other non-forest categories have been delineated

## 4.4 Updation and Re-conciliation of Forest Land Cover Boundary

The geo-referenced cadastral maps have been overlaid on the ortho rectified data to check the extent of matching between cadastral maps and ortho images. Geo-referenced Notified Forest boundary as marked on the cadastral maps is vectorised to generate the forest boundary vector layer. The notified forest boundary vector is overlaid on the two season high-resolution (2.5m) merged data (Cartosat-1 + LISS-IV) and interpreted for the current forest land cover boundary which could be considered subsequently, on revenue department ratification, as re-conciliated forest boundary. These two forest vector layers viz. forest department furnished and subsequently geo-referenced

notified forest boundary layer and the re-conciliated forest boundary as delineated through satellite data interpretation are differenced through digital techniques. This technique provides spatial details of areas which were otherwise with forest land cover during earlier periods but have now undergone transformations in to non-forest landuse categories.
The changes in LULC noticed through this technique along with the final geo-referenced cadastral Maps overlaid on image along with vectorised forest boundary in village map scale shall be followed up for Verification with respect to Revenue aspects by KFD, with SSLR.

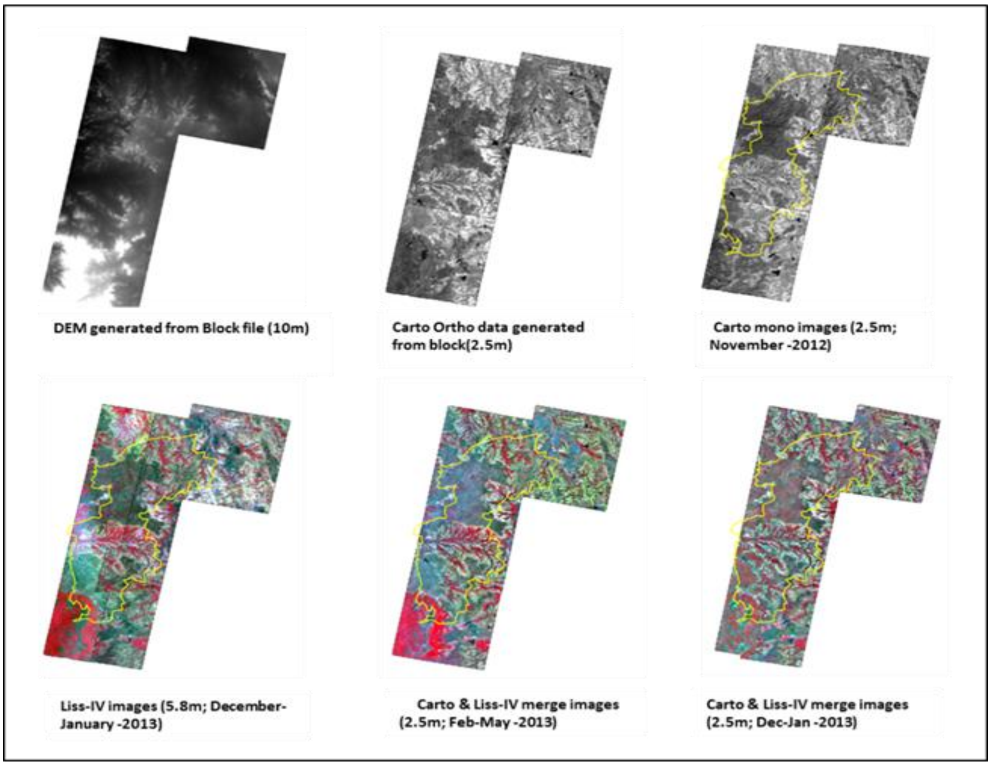

Figure 3 : Ortho database generated for Chennagiri-Tarikere Range

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## 5 RESULTS AND DISCUSSIONS

The results obtained during the pilot study are discussed below:

### 5.1 Validation of DEM and Ortho-image database

The DEM and ortho-image generated using the photogrammetric technique from Cartosat-1 stereo data was validated with few ground control points collected over the area. 11 well distributed and sharply identifiable ground points were chosen for the forest range and at each point planimetric and height accuracies were checked. The RMSE in X direction and Y direction has been observed to be 4.19m and 3.75m respectively for the ortho image generated. RMSE and LE90 for the DEM generated were 3.16m and 6.2m respectively. The details are as given in Table 1.

Table 1: Validation of DEM and Ortho images generated w.r.t. Ground Points

| Sl no. | X error(m) | Y error(m) | Z error(m) |
|---|---|---|---|
| 1 | 5.307191 | -2.63664 | -1.52923 |
| 2 | -6.49849 | 0.309001 | -4.17695 |
| 3 | -4.44213 | 1.864017 | -1.63785 |
| 4 | 5.501982 | 1.90021 | -2.6945 |
| 5 | 4.550297 | -2.63918 | -1.53023 |
| 6 | -5.63218 | 0.312041 | -4.17695 |
| 7 | -4.00942 | 1.865602 | -1.63785 |
| 8 | 6.47412 | 1.903724 | -2.6945 |
| 9 | 4.289695 | 6.986496 | -2.09352 |
| 10 | -3.71214 | 8.167306 | -3.01277 |
| 11 | 3.685677 | -2.85773 | -2.99611 |

### 5.2 Cadastral Geo-referencing

56 village cadastre of Chennagiri range and 61 village cadastre of Tarikere range were accomplished. Edges matching between the village cadastre were carried out and are shown in Figure 4.

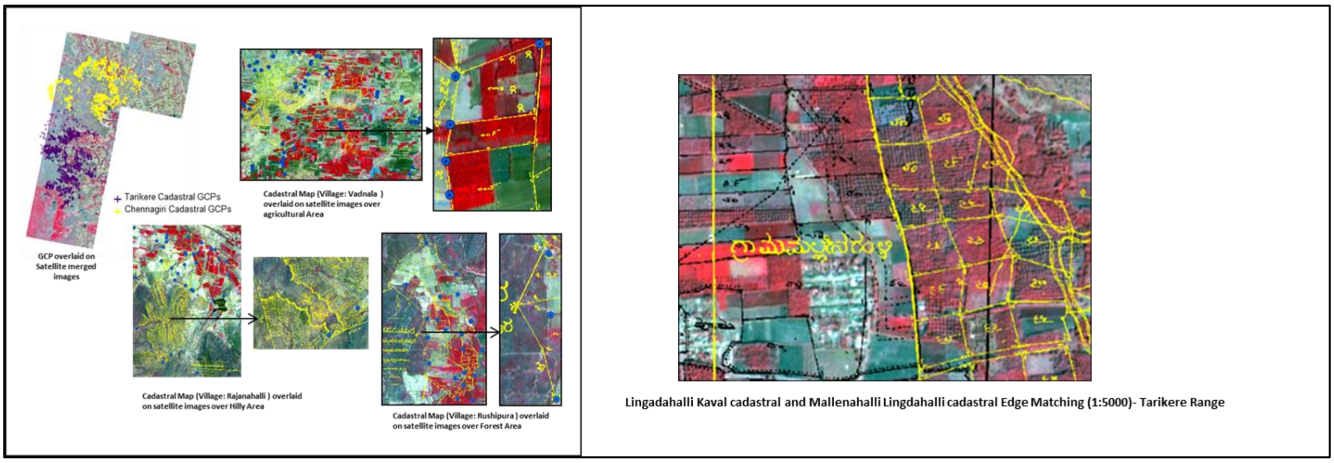


Figure 4: Geo-referenced Village Cadastral overlaid on satellite data for Chennagiri-tarikere Range

### 5.3 Validation of Cadastral Area

The validation exercise has indicated very low deviations (below ±3%) with respect to majority of cadastre. Only in extreme cases up to 5% deviation was observed.

### 5.4 Updation and reconciliation of forest land cover boundaries

Two season multi-spectral LISS-IV datasets corresponding to November-December and March-April periods have been used for differentiating forest land cover from non-forest landuse/landcover categories. This has helped in establishment of current day forest landcover boundaries within the notified forest regions. These datasets have been interpreted for forest and other categories using tone, texture, pattern, tree composition and terrain conditions. For interpretation, 2.5 m merged data was displayed at approximately 1:5,000 scales. Based on the varying spectral signature as manifested on the merged data, forest and other non-forest categories have been delineated.

The geo-referenced cadastral maps have been overlaid on the ortho rectified data to check the extent of matching between cadastral maps and ortho images. Geo-referenced Notified Forest boundary as marked on the cadastral maps has been vectorised to generate the forest boundary vector layer. The notified forest boundary vector has been overlaid on the two season high-resolution (2.5m) merged data (Cartosat-1 + LISS-IV) and interpreted for the current forest land cover boundary which could be considered subsequently, on revenue department ratification, as re-conciliated forest boundary. These two forest vector layers viz. forest department furnished and subsequently geo-referenced notified forest boundary layer and the re-conciliated forest boundary as delineated through satellite data interpretation are differenced through digital techniques. This technique has provided spatial details of areas which were otherwise with forest land cover during earlier periods but have now undergone transformations in to non-forest landuse categories.

This comparison has been carried out at cadastral level for each of the notified villages and it has been observed that the changes have basically occurred in the fringes of the notified forest boundary areas. The major transformation noticed is from a forest land cover category to agriculture landuse category and to some extent towards agriculture plantations. The results of the exercise as carried out for one of the villages viz. Joladalu in Chennagiri and Tarikere Forest ranges respectively is presented as Figure 5.

### 5.5 Forest Cover change study using Historical Dataset

An attempt has been made to study the forest cover change using historical remote sensing datasets from 1965 – 2015. Declassified Corona images of the year 1965, Landsat TM for the year 1990 and IRS images for the year 1998, 2004 and 2015 has been used. The subsequent change in the landuse pattern is as shown in the Figure 6. The area statistics is given in Table 2.

It has been observed that the change in the landuse patteren has taken place in the Mini Forest areas mainly. In some villages it was observed that the whole of mini forest areas have been converted to agricultural fields. Even landuse changes have been observed in the reserved forest areas.

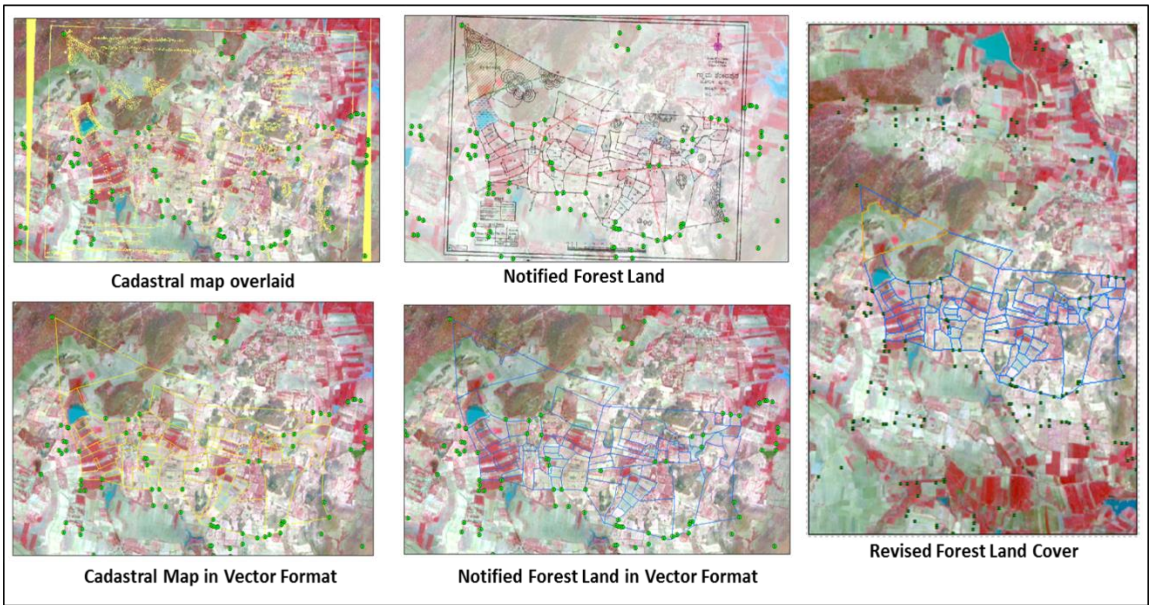


Figure 5: Updation of forest land for Shankarpura Village Cadastres- Tarikere Range

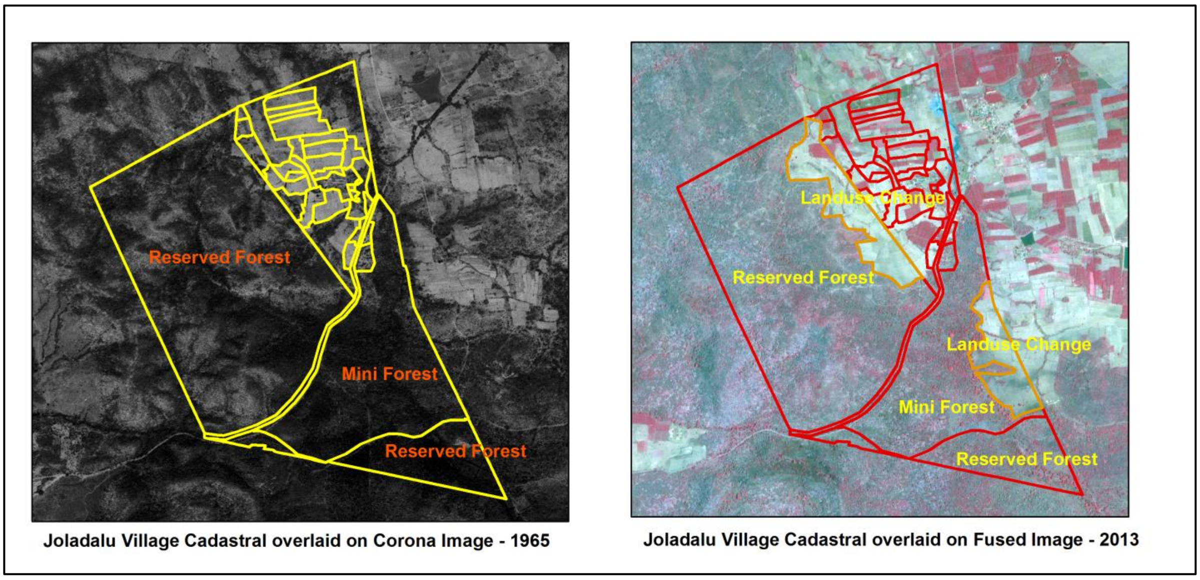


Figure 6: Forest Landuse change – Joladalu Village Cadastral

Table 2: Area statstics indicating the landuse change in the Forest areas at Village Cadastral level

| Village Name | Forest Type | Area of Forest Cover(sq km) 1965 | Area of Forest Cover (sq km) 2013 | Area of Landuse change (sq km) |
|---|---|---|---|---|
| Joladalu | Reserved Forest | 3.34 | 2.91 | 0.43 |
| | Mini Forest | 1.55 | 1.26 | 0.29 |
| | Reserved Forest | 0.5 | 0.5 | 0.0 |
| Gopalanala | Mini Forest | 0.45 | 0.12 | 0.33 |
| | Mini Forest | 0.69 | 0.05 | 0.64 |
| Komaranahalli | Mini Forest | 0.48 | 0.38 | 0.1 |
| | Mini Forest | 0.94 | 0.0 | 0.94 |
| Yarihalli | Mini Forest | 1.89 | 0.0 | 1.89 |
| | Mini Forest | 0.23 | 0.23 | 0.0 |
| K.Ganadakatte | Mini Forest | 0.86 | 0.0 | 0.86 |
| | Mini Forest | 0.13 | 0.13 | 0.0 |

## 6 CONCLUSION

In the present pilot study, of multi-resolution satellite datasets has been used for generation of geospatial database of Chennagiri and Tarikere forest ranges, Karnataka State. Cartosat-1 stereo data was used to generate ortho database for the forest ranges. The results are quite encouraging with 80.2 per cent of the cadastral maps showed better than 5.0 m accuracy along the field boundaries. Two season LISS-IV and Cartosat-1 merged data was used for reconciliation of notified forest land boundaries. A comparative study was carried out to analyse the land use change within notified forest lands (As per KFD records) which indicated significant diversion of forest lands to agriculture. Further, decadal changes in the forest lands were analysed using historical satellite database 1965 – 2015 to study the diversion.

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