International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 09 Issue: 06 | June 2022 www.irjet.net p-ISSN: 2395-0072

Assessment of Forest Stock and Encroachment on Forest Land in Sonbhadra Forest Division of Uttar Pradesh, Using Geo-spatial Techniques

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Abstract - *In the state of Uttar Pradesh, tribals are inhabited in certain areas of forest lands since decades. As such, the Govt. of Uttar Pradesh desired to implement the provisions under "Scheduled Tribes & Other Traditional Forest Dwellers Act, 2006" for inhabitants on forest land. Hence, in this context, it was proposed to undertake this study in order to prepare baseline information on the habitations and cultivated area, existing currently on the notified forest land.*

The study area covers Sonbhadra Forest Division which falls in Sonbhadra district of Uttar Pradesh. The present study deals with the use of high resolution Resourcesat 2 LISS-IV data of two seasons i.e. March-April, 2012 & October, 2011 for detailed forest mapping and encroachment areas in forest land. Further IRS P6 LISS IV and Cartosat–1 of January-February, 2010 merge data were also used for mapping of habitations in forest land. Erdas Imagine14 software was used for classification of different forest types and other landuse classes. ArcGIS 10.2 was used for mapping of forest density classes, habitations and base layers.

The forest/ vegetation and other landuse classes of the study area comprise of Sal Dominated, Tendu Dominated, Sidh Dominated, Arjun Dominated, Cassia Dominated, Salai Dominated, Mahua Dominated, Mahua, Miscellaneous, Bamboo Plantation, Forest Plantation, Scrub Forest, Forest Blank, Agriculture, Grassland, Rocky/ Barren, and Water Body, which are occupying 1319.29 ha, 678.80 ha, 369.03 ha, 97.86 ha, 40.04 ha 16.65 ha, 23.19 ha, 29607.98 ha, 452.89 ha, 1124.54 ha, 3694.06 ha, 10497.72 ha, 5163.28 ha, 399.22 ha, 1127.63 ha, and 307.03 ha areas respectively. Different forest types/ species with forest density classes viz. >70%, 40–70%, 10-40% and <10% were also classified and mapped, which occupied 5768.69 ha, 7972.65 ha, 8336.62 ha and 10075.90 ha areas respectively. The total timber volume in the Sonbhadra forest division has been estimated as 838526.66 m^3, based on the enumeration data of forest department. The enumeration data collected on the basis of stratified random sample points of each forest class.

In Sonbhadra Forest Division, habitations on forest land were identified and further categorized into three categories viz. grouped, scattered and single hamlet. These are observed as 38, 106 and 71 in number respectively. The encroachment on forest land was estimated 5163.28 ha as agriculture land and 20.39 ha as grouped habitation. This study could be used as a baseline study for planning & management of forest and further monitoring of any type of encroachment on forest lands in future.

Keywords: Resolution, GIS, Cartosat-1, Forest Types, Crown Density, Volume

1. Introduction

Forest is a unique gift of nature to mankind since time immemorial. Forest represents the largest, most complex and most viable self regenerating of all ecosystems. Forests have a direct and beneficial influence on all aspects of the biosphere, as a result of which heat absorption capacity and conductivity, aero-dynamic roughness and influence on the water cycle. Forest is a biological system having a vast organisation of living communities. It has a vital biological importance in the form of gene reserves of flora and fauna. These are major factors for environmental conservation and control of extremes heat and cold, rendering the climate more equable. Forests also tend to increase the relative humidity of the air and retard evaporation. However, with continuing pressures of population growth and the subsequent increasing needs of industries, food, fuel wood, fodder, small timber etc., depletion and degradation of forests are causing adverse changes in forest ecosystem. Destruction of forest for agricultural purposes in recent years dominates all other causes of deforestation. India is endowed with an immense variety of forest resources.

The tribals in Uttar Pradesh are inhabitated on forest land since decades, as such Government of Uttar Pradesh desired to implement the provisions under Scheduled Tribes & Other Traditional Forest Inhabitants Act 2006, for inhabitants on forest land. With this objective, it was proposed to undertake a study to prepare baseline information on the habitations and cultivated area existing currently on the forest land. Therefore it is necessary to monitor this renewable resource on regularly basis. The conventional methods of forest inventory are cumbersome, time consuming and the accuracy of the information is often disputable. In the present scenario of geo-spatial (Remote Sensing, GIS and GPS) techniques are widely applied in the areas of forest stock mapping, forest monitoring, assessment of forest species distribution and encroachment on forest land by any human activities. Assessment and monitoring of forests have now been easily facilitated with the advancement of these techniques. These spatial tools are helping to planners and decision makers in evolving the sustainable strategies for proper management and conservation of natural resources.

2. Study Area

The study area covers Sonbhadra forest division which falls in Sonbhadra District of Uttar Pradesh. It has an area of 82067.86 ha and lies between 24^0 29'48" to 24^0 47' 24"N latitude & 83^0 03'12" to $83^0$32'43"E longitude. Sonbhadra forest division lies between Vindhyan and Kaimur hills. It is located in the south-eastern part of the Vindhyachal range. The study area covers parts of 63L/13, 63P/01, 63P/02, 63P/05, 63P/06 and 63P/10 topographical maps of Survey of India on 1:50,000 scale. The location map of study area is shown in figure-1.

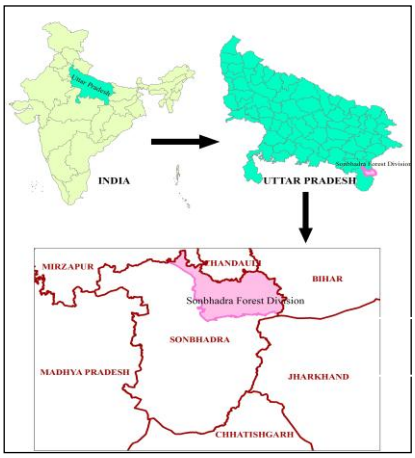

Fig.1 Location map of Study Area

3. Material and Methods

Remote Sensing Satellite RESOURCESAT 2, LISS-IV multispectral sensor data with 5.8m resolution of two seasons. March-April 2012, October, 2011 were used for detailed forest mapping, encroachment and the mapping of habitation in forest land, IRS P6 LISS IV and Cartosat–1 merged data (with resolution of 2.5m) of January, February 2010 were used. Erdas Imagine14 software (an image processing s/w) was used for geometric correction of raw images and image processing for classification of different forest/ vegetation types and other landuse classes. The ArcGIS 10.2 was used for mapping of different forest density classes, habitations and preparation of base layers i.e. rail, road, canal and also for analysis of spatial and non-spatial of data. Survey of India toposheets on 1:50,000 were used as ancillary source of information.

The recent LISS-IV image was rectified with help of existing rectified image Cartosat-1 and ground control points (GCP_S) using Erdas Imagine 14 software. The rectified and enhanced satellite data have been interpreted or analyzed to generate meaningful information. The present study adopted both types of classification methods, namely – digital image classification and visual image classification. The forest boundaries viz. division, range, section, beat, block and compartment were digitized with the help of forest maps, which were provided by Forest Deptt of Uttar Pradesh. The base layers such as roads rail, canal, settlements, etc. were generated using satellite data and survey of India (SOI) topographical maps. The different thematic maps were verified/ validated in ground also and final maps were prepared after incorporating necessary corrections. The different forest types/species with forest density classes viz. >70%, 40–70%, 10-40% & <10% were also interpreted and mapped.

The estimation of timber volume was based on systematic ground sampling and collection of enumeration data which were carried out by the Forest Department. For this purpose, an optimum number of stratified random sample points were generated after the analysis of the satellite data. In territorial forest, sampling intensity was 0.04 % and sample plot size was taken as 20 x 20 m. Each sample point coordinates were identified in the field with help of GPS and within sample plot, all the trees were recorded with their CBH & height. Appropriate volume equations (FSI, 1996) were used for estimation of timber volume of each forest tree species, which were present in study area using Microsoft excel software.

The habitations were mapped through on screen digitization within forest boundary and habitations were further categorized into three categories viz. grouped, scattered and single hamlet. The encroachments on forest land were mapped as agriculture land and grouped habitation.

4. Results and discussion

Remote Sensing and GIS techniques had been used previously also by many researchers for mapping different forest types and species identification with reliable accuracy (Kachhwaha, 1985, 1993; Roy *et al*., 1991; Prasad *et al*., 1998; Xiuwan, 2002; Krishna *et al.,* 2001; Chauhan *et al.,* 2003; Singh and Moharir, 2003; Singh *et al*., 2003[a], 2004, 2005[a], 2005[b]; Chandrashekhar *et al*., 2005; Boyd and Duana 2001; Jain *et al.,* 2003; Gates, 1970; Aplin, 2003[a], Gould, (2000). Saxena (2002) and Singh *et al*. (2003[b]) had used PAN, LISS-III merged and higher resolution satellite data for forest classification. Ghazanfari (1996) had applied Landsat TM data for forest type stratification in the Eastern Caspian range in Mazandaran Province. Abbasi (2001) had evaluated ETM+ data to identify the *Fagus orientalis* plant community as one of the most valuable forest communities in northern Iran in terms of biological and economic value. Landsat-3 MSS data had been used to draw spectral signatures of different vegetation classes in Allahabad and Mirzapur districts by Kachhwaha (1990). Kumar, *et al.* (2014) mapped forest encroachment using remote sensing and GIS techniques. L-Tayeb, *et al*. (1991) adopted multistage sampling technique to map forest encroachment in Sudan. Watson, *et al*. (2015) used visual/ manual interpretation technique to detect encroachment on the multi-temporal satellite images of protected area networks (PANs), Zambia. These studies are showing a worldwide variety of empirical approaches which had been followed to map forest cover types using digital remote sensing imagery on different scales.

The present study has attempted for the identification of different forest types and mapping of their density classes and encroachment area on forest land. The digital classification and visual interpretation of LISS-IV images has resulted for different forest/ vegetation types and density classes in Sonbhadra forest division. Various forest type with forest density and other landuse classes have been classified on the basis of Satellite remote sensing and GIS techniques, their details are as under:-

4.1 Sal Dominated forest

Sal (*Shorea robusta*) is a dominating species with other associated species viz. Asna, (*Terminalia alata),* Rohini *(Mallotus phillipensis),* Khair *(Acacia catechu),* Chironji *(Buchnania lanzan),* Arjun *(Terminalia arjuna),* Bahera *(Terminalia belerica),* Gurich *(Mitragyna parviflora),* Bargad *(Ficus bengalensis),* Gular *(Ficus glomoreta),* Haldu *(Adina cordifolia), Mahua (Madhca indica), Jamun (Syzygium cuminii)*. Sal dominated forest with other tree species occupies an area of 1319.29 ha and further classified on the basis of crown density i.e. >70%, 40–70%, 10-40% and <10%, occupying an area of 411.28 ha, 570.22 ha, 250.13 ha, and 87.66 ha respectively. Volume of Sal dominated forest has been estimated as 131877.12 m^3 in study area.

4.2 Tendu Dominated Forest

Tendu *(Diospyros exculpta)* is a dominating species of this type of forest class**.** Tendu dominated forest class occupies an area of 678.80 ha. The main associated species with Tendu are *Buchnania lanzan*, Palash (*Butea Monosperma)*, Mahua *(Madhca indica)*, Amaltas *(Cassia fistula)*, Sidh *(Hardwickia binata)*, *Acacia catech*, Awla *(Embelica officinalis)*, *Ficus glomoreta*. Tendu dominated forest has been further classified into different classes i.e. 40–70%, 10-40% and <10%, occupying area of 282.22 ha, 218.78 ha, and 177.79 ha, respectively, based on crown density. This category of forest is having volume 5050.21 m^3.

4.3 Sidh Dominated Forest

Sidh (*Hardwickia binata*) is a dominating species mainly planted in mixed forest. Sidh dominated forest occupies an area of 369.03ha. The main associated species with Sidh are *Embelica officinalis*, *Diospyros exculpta*, *Terminalia belerica, Terminalia alata, Buchnania lanzan*, *Butea monosperma.* Based on crown density, Sidh dominated forest has been further classified into different classes i.e. 40–70%, 10-40% and <10% occupying area of 50.84 ha, 111.01 ha, 207.18 ha, respectively and volume of this category is estimated as 4236.42 m^3.

4.4 Arjun Dominated Forest

Arjun *(Terminalia arjuna)* is a dominating species, which is planted in mixed forest, occupies an area of 97.86 ha. The main associated species with Arjun are *Syzygium cuminii*, *Butea monosperma*. Based on crown density, Arjun dominated forest has been further classified into different classes i.e. 40–70%, 10-40% and <10%, occupying area 26.16 ha, 66.91 ha, and 4.79 ha respectively. Volume of this class of forest is estimated as 7468.67 $m^{3.}$

4.5 Cassia Dominated Forest

Cassia mixed forest occupies an area of 40.04 ha. The associated species with Cassia spp. are Bamboo (*Dendrocalamus spp.)*, which are planted of some places Cassia dominated forest has been observed in two type of forest density classes i.e. 40–70% and 10-40%, occupying an area of 1.03 ha and 39.00 ha respectively, and this category of forest having volume is 55.29 m^3.

4.6 Salai Dominated Forest

Salai *(Boswellia serrata)* dominated species of forest are planted in mixed forest and it occupies an area of 16.65 ha. The main associated species with Salai are Jigna (*Lannea coromandelica)*, *Diospyros exculpta*, *Terminalia alata*, Koriya. Salai dominated forest is having only 40–70% forest density class, which is having timber volume 412.21 m^3.

4.7 Mahua

Mahua *(Madhca indica)* is planted at few places only and is identified as pure. Mahua forest is having low forest density, i.e.0-10%, which is occupying an area 1.04 ha and volume is estimated as 11.11 m^3.

4.8 Mahua Dominated Forest

Mahua *(Madhca indica)* dominated species of forest occupies an area of 23.19 ha. The main associated species with Mahua are *Buchnania lanzan*, *Shorea robusta*, Sidh, *Acacia catechu*, *Terminalia alata*, Cassia. Mahua has been observed and classified only in 10-40% density class, which has 379.42 $m^{3,}$ timber volume.

4.9 Miscellaneous Forest

Miscellaneous forests constitute the mixed species of forest viz. *Acacia catechu, Adina codifolia, Albizia procera, Annona squamosa, Anogeissus latifolia, Azadirachta indica, Tectona grandis, Pongamia pinnata, Buchnania lanzan, Boswellia serrata, Bridelia retusa, Butea Monosperma, Cassia fistula, Cassia siamea, Cochlospermum religiousm, Dalbergia sisso, Diospyros exculpta, Embelica officinalis, Ficus bengalensis, Flacourtia indica, Gardenia latifolia, Haplophragma adenophyllum, Garuga pinnata, Hardwickia binata, Holopteia integrifolia, Ixora arborea, Lannea coromandelica, Madhca indica, Miliusa tomentosa, Mitragyna parviflora, Pongamia pinnata, Schleichera trijuga, Shorea robusta, Sterculia urens, Tectona grandis, Terminalia alata, Terminalia arjuna, Terminalia belerica, Terminalia chebula, Zizyphus mauritiana, Zizyphus zylopyra*, *Pongamia pinnata, Syzygium cuminii, Lagerstroemia parviflora, Eucalyptus spp., Bombax ceiba, Acacia spp.* Overall miscellaneous forests occupy an area of 29607.98 ha and it has been further classified into 04 density classes of >70%, 40–70%, 10-40% and <10%, having an area of 5357.41 ha, 7025.52 ha, 7627.59 ha and 9597.45 ha respectively. Miscellaneous forest timber volume is estimated as 689036.21 m^3, which has occupied 82.17% of total geographical area of notified forest land.

4.10 Bamboo Plantation

Bamboo (*Dendrocalamus spp.)* is planted at limited forest blocks/compartments of the study area and other species of this forest class has also been observed in scattered form, i.e. *Diospyros exculpta, Butea monosperma.* This category is having an area of 452.89 ha, which constitutes only 0.82% of total geographical area of notified forest land.

4.11 Forest Plantation

Forest plantations occupied an area of 1124.54 ha, which comprises 2.05% of total geographical area of notified forest land. These are relatively younger plantations. The main species observed in forest plantation are *Cassia siamea*, *Madhca indica*, *Butea Monosperma*, *Tectona grandis.*

4.12 Scrub Forest

Scrub forest consists of stunted growth of trees and bushy shrubs, which occupies an area of about 3694.06 ha. The main species observed in scrub forests are *Holarrhena antidysentrica*, Van tulsi, Bel, Sanhi, Koriya, Murerua, Lantana camara

4.13 Forest Blank

Forest blanks are those areas, which are having no vegetative cover within the notified forest land. These areas occupy ground 10497.72 ha area which is 19.35 % of total geographical area of notified forest land.

4.14 Other Land Use Classes

Other landuse classes have also been mapped within the notified forest land viz. Agriculture, Grassland, Rocky/ Barren, and Water Body, which are occupying an area of 5163.28ha, 399.22ha, 1127.63ha and 307.03ha respectively.

The Forest type with other landuse classes of Sonbhadra Forest Division has been represented in figure-2 and Forest Density class has been represented in figure-3. Area statistics of forest type & forest density classes along with timber volume and other landuse classes is given table-1.

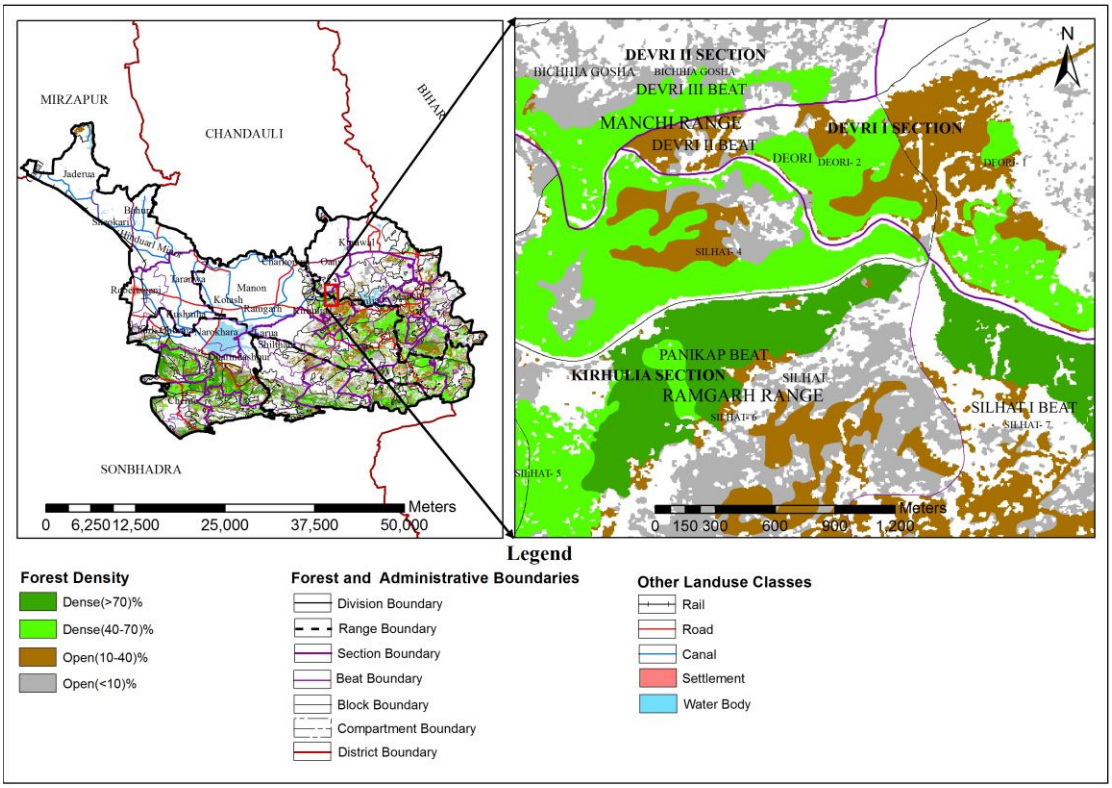

Fig. 2 Forest Type Map of Study Area

Fig. 3 Forest Density Map of Study Area

Table-1 Summary of Area and Volume of Different Forest Type, Forest Density and Other Landuse Classes

Forest Classes					
Forest Type	**Forest Density**	**Area (ha)**	**Area %**	**Volume (m^3)**	**Volume %**
Sal Dominated	<10%	87.66	0.16	1942.76	0.23
	10-40%	250.13	0.46	14094.42	1.68
	40-70%	570.22	1.04	61123.77	7.29
	70%	411.28	0.75	54716.16	6.53
Total		**1319.29**	**2.40**	**131877.12**	**15.73**
Tendu Dominated	<10%	177.79	0.32	414.61	0.05
	10-40%	218.78	0.40	802.50	0.10
	40-70%	282.22	0.51	3833.10	0.46
Total		**678.80**	**1.24**	**5050.21**	**0.60**
Sidh Dominated	<10%	207.18	0.38	32.11	0.00
	10-40%	111.01	0.20	2198.45	0.26
	40-70%	50.84	0.09	2005.86	0.24
Total		**369.03**	**0.67**	**4236.42**	**0.51**
Arjun Dominated	<10%	4.79	0.01	51.06	0.01
	10-40%	66.91	0.12	4319.64	0.52
	40-70%	26.16	0.05	3097.97	0.37
Total		**97.86**	**0.18**	**7468.67**	**0.89**
Cassia Dominated	10-40%	39.00	0.07	17.34	0.00
	40-70%	1.03	0.00	37.95	0.00
Total		**40.04**	**0.07**	**55.29**	**0.01**
Salai dominated	40-70%	16.65	0.03	412.21	0.05
Total		**16.65**	**0.03**	**412.21**	**0.05**
Mahua	<10%	1.04	0.00	11.11	0.00
Total		**1.04**	**0.00**	**11.11**	**0.00**
Mahua Dominated	10-40%	23.19	0.04	379.42	0.05
Total		**23.19**	**0.04**	**379.42**	**0.05**
Miscellaneous	<10%	9597.45	17.48	102694.87	12.25
	10-40%	7627.59	13.89	124803.89	14.88
	40-70%	7025.52	12.79	173944.33	20.74
	70%	5357.41	9.75	287593.13	34.30
Total		**29607.98**	**53.91**	**689036.21**	**82.17**
Other Classes					
Bamboo Plantation	-	452.89	0.82	-	-
Total		**452.89**	**0.82**	**-**	**-**
Plantation	-	1124.54	2.05	-	-
Total		**1124.54**	**2.05**	**-**	**-**
Scrub	-	3694.06	6.73	-	-
Total		**3694.06**	**6.73**	**-**	**-**
Forest Blank	-	10497.72	19.11	-	-
Total		**10497.72**	**19.11**	**-**	**-**
Grass	-	399.22	0.73	-	-
Total		**399.22**	**0.73**	**-**	**-**
Agriculture	-	5163.28	9.40	-	-
Total		**5163.28**	**9.40**	**-**	**-**
Rockey/Barren	-	1127.63	2.05	-	-
Total		**1127.63**	**2.05**	**-**	**-**
Water Body	-	307.03	0.56	-	-
Total		**307.03**	**0.56**	**-**	**-**
Grand Total		**54920.24**	**100.00**	**838526.66**	**100.00**

4.15 Encroachment on Forest Land

The IRS P6 LISS IV and Cartosat–1 merge data of January-February, 2010 has been used for mapping of habitations in notified forest land. For identification of habitations class Google Earth images have also been used. The cultivated area has also been mapped within notified forest land along with habitations. Habitations have been categorized into three sub categories viz. grouped, scattered and single hamlet which are of 38,106 and 71 in numbers respectively. The coordinates of each habitation were provided to forest department, U.P. and these habitations were verified by forest department in field with help of GPS. Encroachment map of Sonbhadra Forest Division is shown in figure-4

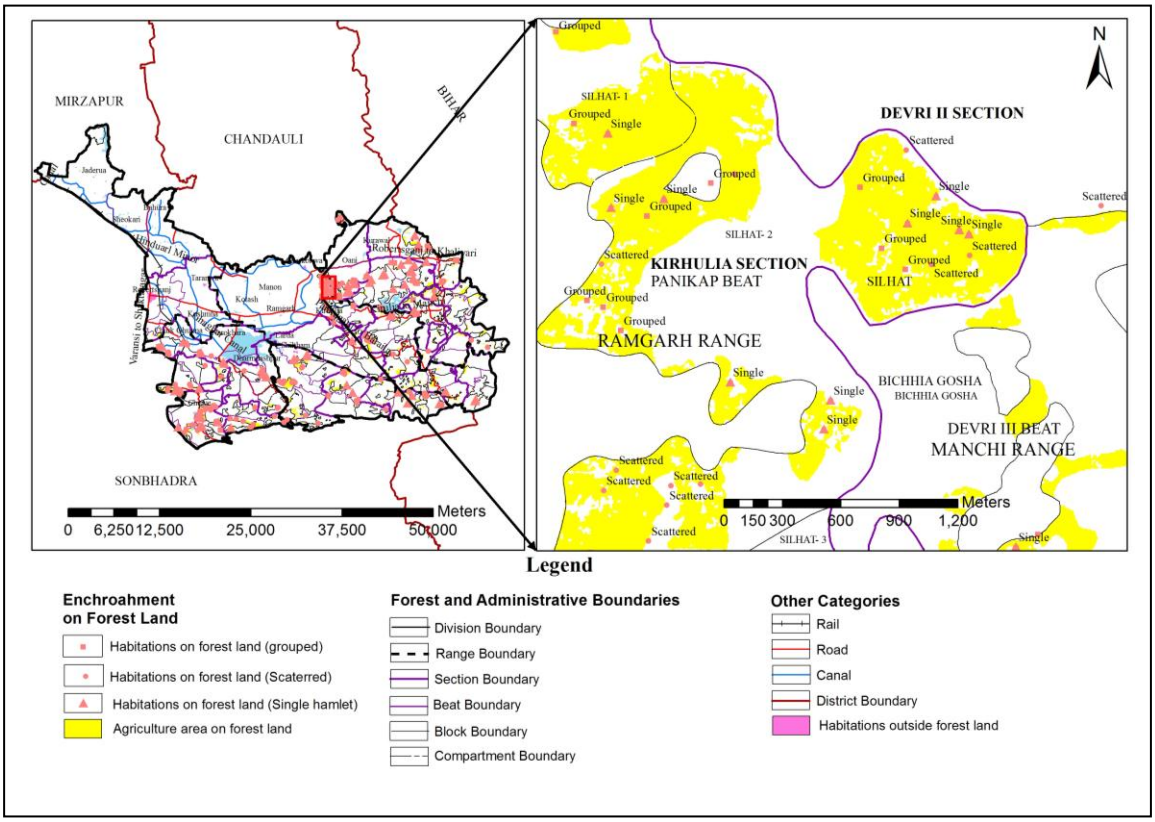

Fig.4 Encroachment Map on Forest Land

Conclusions

The present study demonstrated the vital use of geo-spatial (Remote Sensing, GIS and GPS) techniques in accessible forest area, which is cost effective too. The LISS IV data has been found very useful in identification and classification of major economically important species along with their density classes with high accuracy. The use of high resolution IRS P6 LISS IV and Cartosat–1 merge data were very well demonstrated for mapping of habitations on forest land.

Habitations and agriculture within notified forest land shows the encroachment which needs to pay attention in order to avoid further encroachment in forest land. Areas of other landuse classes like rocky/barren and grasslands should be used for afforestation, by those species which can survive on these areas in order to increase forest cover. In Sonbhadra forest division, places having forest blank area and forest density class <10% require re-plantation/ afforestation with proper management. The 10-40% density class is also required necessary action for further plantation and gap filling. The forest land classified as forest dense class viz. 40-70% and >70% should be protected for regeneration and improvement of density.

The study could be used as a baseline for forest management planning and further monitoring of any encroachment in future on forest lands. It could also be useful in implementation of different programmes of Government, related with forest management.

Acknowledgements

Authors are thankful to Director, Remote Sensing Applications Centre, Uttar Pradesh, and Lucknow for providing necessary facilities and support in carrying out this study. Sincere thanks are also due to personnel of Forest Department, Govt. of Uttar Pradesh for providing necessary enumeration data of stratified sample points and valuable support during fieldwork.

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