Accuracy of Forest and Tree Cover Assessment

TWO SAMPLE PLOTS
JAMMU & KASHMIR
CHINA
HARYANA

Chapter 7

ACCURACY OF FOREST AND TREE COVER ASSESSMENT

Classification classes	Ground truth (based on field inventory data)					
	VDF	MDF	OF	SCRUB	NF	Total
VDF	118	6	2	0	0	127
MDF	13	1,295	70	1	24	1,403
OF	2	82	1,082	18	44	1,188
SCRUB	0	2	0	158	4	170
NF	0	11	64	13	1,317	1,405
Total	134	1,376	1,206	186	1,389	4,291

In the remote sensing literature, the term 'accuracy assessment' is used to describe the process of evaluating the quality of maps or statistical results produced from the maps. This is done by comparing the final outputs against a 'reference dataset' also called as 'the ground truth', which is established through a carefully designed and implemented control field survey or making use of remote sensing images of higher resolution or both. It is important that the classification and measurement systems in both the cases are compatible and that the 'ground truth' has much smaller errors, of classification and measurement, than those involved in producing the map.

There are many options for establishing the control data. In case of wall-to-wall mapping, ideally the sampling units could be randomly distributed over the whole assessment area. However, there are certain limitations in this approach. Firstly, it is difficult to collect data physically spread over a large area, as it would require massive manpower, time and cost. Secondly, there is a time lag of about 1 to 2 years between the date of satellite data used and the ground truth period. Thirdly, it may be time consuming to precisely register the location on the ground and that on image datasets.

After the control data have been secured, they are tabulated against the sub-set of corresponding map data in the form of an 'error or confusion matrix'. Matrix is an array of numbers arranged in rows (generally, map classification) and columns (generally, ground truth) where, the numbers of rows and columns are equal, representing different classes (dense forest, open forest, etc.). The randomly selected locations or sampling units, which are presented in the matrix, can be pixels or a group of pixels or a polygon. In this study, groups of pixels formed the sampling units. Any entry made along the major diagonal of the error matrix implies agreements and the non-diagonal elements indicate disagreements or 'wrong' classification. The percentage of matching ('correctly classified') sampling units (i.e. sum of all diagonal elements) out of the total considered sampling units in the error matrix provides a measure of 'overall accuracy'. Similarly, accuracy of each class can be measured by calculating the percentage of correctly classified sampling units (diagonal element) compared to the total sampling units in that class in that row or column.

7.1 Methodology of Assessment

As explained earlier, forest and tree cover statistics in the present Report are generated from two independent processes. The forest cover is based on the interpretation of satellite data, whereas the tree cover is based on the field inventory. The procedure of assessment is entirely different in both the cases, which necessitates two separate approaches for quantifying their accuracy.

As explained in Chapters 5 and 6, the NFI (including inventory of forests and TOF) is carried out by FSI to generate national level estimates of growing stock on a two yearly basis. For this purpose, the entire country has been divided into 14 physiographic zones on the basis of similarity of topography, climate, soil and vegetation. A sample of 10 percent of districts (60 districts in the country) distributed over all the physiographic zones are randomly selected for the field inventory during a cycle of 2 years. This inventory is done based on a sound statistical design concurrently with remote sensing based forest cover assessment. For the inventory of forest, sample points are selected using systematic sampling approach; and that for the TOF, sample points are selected randomly from Block, Linear, Scattered and urban strata. Thus the sampling design ensures a proper representation of the entire land area. As the districts are chosen randomly from each physiographic zone and sample points for preparation of error matrix are selected from these districts, the random selection criterion of sample points is fulfilled.

The accuracy assessment in the case of forest cover map makes use of the available inventory data and the higher resolution satellite data (5.8m); whereas for the TOF, it makes use of the higher resolution satellite data (5.8m) only. Out of the 16,000 sample points, a total of 4,291 were selected for preparation of error matrix for the forested and non-forested areas. Systematic sampling with random start was followed to pick up 3509 sample points from inside forests. These 3,509 points were checked for inconsistencies, wherever required, with the help of higher resolution (5.8 m) satellite data. For this purpose, the classified map data was verified on an area of 1.0 ha at the centre of each point. The ground truth data for all the points giving land use class at each point were recorded along with their geographical co-ordinates from the field inventory and higher resolution satellite data (5.8 m) and compared with the classified image to prepare the error matrix.

For accuracy assessment of TOF, 782 sampling units were selected. It may be recalled that TOF has three strata: Block, Linear and Scattered. The sample size for accuracy assessment in case of TOF is small because this constitutes only about 10 % of the total forest cover. For preparation of error matrix, sample points having area more than one hectare in block stratum which have been included in forest cover were considered. The linear stratum was not considered, as all the linear patches are less than 1.0 ha. For scattered stratum, 20 sample points were selected randomly from each selected district for verifying non-forest areas. Here again classified data was verified on an area of 1.0 ha at the centre of each sample point. The ground truth data for all the points giving land use class were recorded along with their geographical co-ordinates and compared with the classified image. These two sets of data formed parts of the error matrix for TOF.

Finally combined error matrix was prepared for all sample points from forest and outside forest areas.

7.2 Accuracy of Forest Cover Assessment:

The error matrix for a total of 4,291sample point prepared has been given in Table 7.1. The diagonal element, that is, the number 119 for very dense forest (VDF) at row 1 and column 1 implies that all the 119 sampling points have been correctly classified as VDF. Whereas, the off-diagonal number 6 in row 1 (VDF) and column 2 (MDF) implies that 6 sampling points, which are registered as MDF during the ground survey have been classified as VDF. Further, a simplified error matrix can be created by grouping land use classes into "forest" and "non-forest". This is done by combining VDF, MDF and open forest into one class viz. "forest" and scrub and non-forest classes into "non-forest". The simplified error matrix is given in Table 7.2

The error matrix given in Table 7.1 reveals that out of the total 4,219 sampling points where observations were made, classification of 3,949 sampling points (the sum of the elements along the main diagonal of the matrix) was found correct. The 'overall accuracy' of classification therefore, works out to be 92.03 percent. This is quite high implying that classification procedures followed at FSI are satisfactory. In the remote sensing technology, accuracy of more than 85% is considered satisfactory.

In the simplified error matrix, classification of 4,121 sample points was found to be correct, yielding an overall accuracy of 96.04 percent.

Besides the overall accuracy, accuracy of individual classes can be calculated in a similar manner. Two approaches are possible:

- Producer's accuracy and
- User's accuracy,

The producer's accuracy is derived by dividing the number of correct sampling points in one class divided by the total number of points as derived from reference data. The producer's accuracy measures how well a certain area has been classified. It includes the error of omission which refers to the proportion of observed features on the ground that are not classified in the map. The more is the error of omission the lower is producer's accuracy.

Similarly, user's accuracy can be obtained by dividing the correct classified units in a class by the total number of units that were classified in that class. The user's accuracy is therefore a measure of the reliability of the map. It informs the user how well the map represents what is really on the ground. One class in the map can have two types of classes on the ground. The 'right' class, which refers to the same land-cover-class in the map and on the ground, and 'wrong' classes, which show a different land-cover on the ground than predicted on the map. The latter classes are referred to as errors of commission. The more errors of commission exist, the lower the user's accuracy.

The Producer's and User's Accuracies for different classes as computed from the error matrix are given in Table no. 7.3 and 7.4 respectively

From Table 7.3 it is found that the producer's accuracy

Table 7.1: Error matrix

Classification	Ground truth (based on field inventory data)					
	VDF	MDF	OF	Scrub	NF	Total
VDF	119	6	2	0	0	127
MDF	13	1,295	70	1	24	1,403
OF	2	62	1,062	16	44	1,186
SCRUB	0	2	8	156	4	170
NF	0	11	64	13	1,317	1,405
Total	134	1,376	1,206	186	1,389	4,291

Table 7.2: Simplified error matrix

Classification classes	Ground truth (based on field inventory data)		
	Forest	Non-Forest	Total
Forest	2,631	85	2,716
Non-Forest	85	1,490	1,575
Total	2,716	1,575	4,291

for VDF, MDF, OF, Scrub and Non-forest classes are 88.81, 94.1, 88.1, 83.9 and 94.8 percent, respectively. Similarly, user's accuracy for these classes are 93.7, 92.3, 89.5, 91.8 and 93.7 percent, respectively. These levels of accuracy are satisfactory and acceptable.

Table 7.4 based on simplified error matrix (Table 7.2) shows higher accuracy levels. The producer's accuracy for forest and non-forest classes are found to be 96.9 and 94.6 percent respectively while user's accuracy for these classes are 96.9 and 94.6 percent, respectively.

To further authenticate the results of accuracy, the Kappa analysis, which is a multivariate technique, provides a statistics known as KHAT. This coefficient gives a measure of overall agreement of matrix. In contrast to the overall accuracy- the ratio of the sum of diagonal values to total number of sampling units in the matrix- the Kappa coefficient takes also non-diagonal elements into account. This statistics usually ranges between 0 and 1 and is used to indicate whether the correct values of the error matrix are due to true agreement or due to chance agreement. Any classification having kappa coefficient more than 0.6 is considered as statistically sound. KHAT calculated from the error matrix given at Table 7.1 is equal to 0.89, which indicates that an observed classification is 89 percent better than one resulting from chance.

7.3 Accuracy of Tree Cover Assessment

As stated in Chapter 5, the tree cover assessment is based on field inventory and not on wall to wall mapping. The country has been stratified into 14 physiographic zones. Sixty districts in a cycle of 2 years are randomly selected with at least two districts falling within each physiographic zone. Assessment of tree cover is done separately for rural & urban areas of the district. For rural area, TOF resources are identified & stratified into block, linear & scattered strata with the help of high resolution satellite data (5.8m). For urban areas, UFS blocks are taken as sampling units. Optimum numbers of sampling points are selected from each stratum of rural areas & UFS blocks from urban areas for field inventory. The total tree cover for a selected district is obtained by aggregation of tree cover under block, linear, scattered & urban strata. The tree cover thus obtained for selected district within a physiographic zone is used to estimate the tree cover for the physiographic zone by using ratio method of estimation. Further aggregation of the data of physiographic zones provides the national level estimate. Since two stage sampling (1st stage stratum of the selected district and 2nd

Table 7.3: Producer's and user's accuracy based on Table 7.1

	Class	VDF	MDF	OF	Scrub	NF
Producer's Accuracy	Operation	119 / 134	1295 / 1376	1062 / 1206	156 / 186	1317 / 1389
	Accuracy (%)	88.81	94.1	88.1	83.9	94.8
User's Accuracy	Operation	119 / 127	1295 / 1403	1062 / 1186	156 / 170	1317 / 1405
	Accuracy (%)	93.7	92.3	89.5	91.8	93.7

Table 7.4: Producer's and user's accuracy based on Table 7.2

	Class	Forest	Non-forest
Producer's Accuracy	Operation	2,631 / 2,716	1,490 / 1,575
	Accuracy (%)	96.9	94.6
User's Accuracy	Operation	2,631 / 2,716	1,490 / 1,575
	Accuracy (%)	96.9	94.6

stage sample point selected randomly within the district) was followed, the precision of estimate is adjudged by standard error of the estimate. The necessary formula used for estimation of standard error at physiographic zone is given as under :

The total number of stems for the Lth stratum in ith district is estimated as;

$$\hat{T}_{L_i} = M_{L_i}\bar{y}_{L_i} \qquad (1)$$

where, $\bar{y}_{L_i}$ = Mean value of L^{th} stratum in i^{th} district
M_{Li} = total no. of second stage sampling units of L^{th} stratum of i^{th} district

A ratio estimator for a physiographic zone mean for L^{th} stratum based on a two stage sample is

$$\bar{y}_{R_L} = \frac{\sum_{i=1}^{n}\hat{T}_{L_i}}{\sum_{i=1}^{n} M_{L_i}} \qquad (2)$$

The estimator of population total (volume/ stems) is

$$\hat{T}_{R_L} = M_L\bar{y}_{R_L} \qquad (3)$$

M_L = total no. of Second Stage Unit (SSU) of L^{th} stratum in physiographic zone.

The variance of $\bar{y}_{R_L}$ is

$$S^2_{\bar{y}_{R_L}} = \frac{N^2}{M_L^2\, n}\left(S^2_{W_L} + S^2_{B_L}\right) \qquad (4)$$

Where; N = No. of districts in the physiographic zone
M_L = No. of Second Stage Unit in the physiographic zone having L^{th} stratum
n = No. of districts selected at first stage.

S^2_W = variation within district

S^2_B = variation between districts

To obtain the variance of the total

$$S^2_{\hat{T}_{R_L}} = M_L^2 S^2_{\bar{y}_{R_L}} \qquad (5)$$

To combine estimates of stratum at physiographic zone level following procedure is to be followed:

The sample mean for entire physiographic zone may be calculated as:

$$\bar{y}_{P_i} = \sum \frac{M_{P_iL}}{M_{P_i}}\bar{y}_{R_L} \qquad (6)$$

where M_{P_iL} = Total area of L^{th} stratum in i^{th} physiographic zone.

Variance of sample mean for entire physiographic zone is given by

______ (7)

The sample total for the entire physiographic zone :

______ (8)

and its variance

= ______ (9)

× 100 ______ (10)

After combining estimates at physiographic zone as above, the physiographic zone level estimates were combined to get national level estimates following stratified sampling formulae.

The following table gives an idea of the precision of estimates (SE percent) at the level of physiographic zones. The overall precision of the estimate at the country level is 96.28%. It may be observed that for the physiographic zones Eastern Himalayas, East Deccan & Western Ghats the standard error is relatively high in comparison with other zones. This is because of higher variability found in tree cover in these zones and the number of samples taken in these zones were just adequate to capture the complete variability. This also indicates that a larger sample size is required for these zones if higher level of accuracy is required

7.4 Conclusion

While interpreting results of accuracy assessment, it is important to bear in mind that differences between the map and control data may be attributed to many reasons, besides actual error in mapping. The remote sensing systems have their own limitations, whereby radiometric and geometric errors creep in and reduce the quality of remotely sensed data. The radiometric errors can arise due to random variations in the functioning of the sensor or by the intervening atmosphere between the terrain and remote sensing system, i.e., the radiant flux reflected by the terrain may not resemble the energy recorded by the sensor. The geometric errors may be caused by the variations in altitude, velocity of sensor platform, panoramic distortions, earth curvature, atmospheric refraction, relief, displacement, etc. There are procedures to minimize these errors but these cannot be totally eliminated. Remote sensing system also has limitations on account of spatial, spectral, temporal, and radiometric resolutions. Besides the satellite limitations, errors in interpretation and classification may be caused due to cloud or shadow effects, or seasonal variation in the canopy of deciduous trees or bushy and agricultural vegetation getting mixed with forest crop, human errors etc. While classifying the remote sensing data all these errors influence the accuracy of the assessment.

Table 7.5: Physiographic zone wise precision of estimates

Sl. No.	Physiographic zone	Sample size	S.E.%
1	Western Himalayas	894	4.65
2	Eastern Himalayas	467	21.02
3	North East	383	10.46
4	Northern Plains	2,274	11.77
5	Eastern Plains	1,035	10.55
6	Western Plains	1,350	14.61
7	Central Highlands	2,150	13.12
8	North Deccan	2,273	10.78
9	East Deccan	1,356	15.04
10	South Deccan	1,572	11.56
11	Western Ghats	1,681	16.96
12	Eastern Ghats	1,219	5.23
13	West Coast	833	9.63
14	East Coast	1,001	12.59
	Total	18,488	3.72