MANUAL FOR THE PREPARATION OF WORKING PLAN UNDER NATIONAL WORKING PLAN CODE 2023

Unit 4

ANALYSIS OF DATA, DESCRIPTION AND MANAGEMENT OPTIONS

4.1 Data Processing Estimation Procedure for Working Plan Preparation

4.1.1 Introduction:

The data has been captured from Recorded Forest Area (RFA) and from outside the RFA of the Division. The purpose of data collection from RFA is to describe the status of forest with the help of various parameters. One set of parameters provides forest enabling conditions viz. soil depth, humus, soil organic carbon, presence of grasses and undergrowth (as indicator of moisture regime) etc; second set provides information about Forest vegetation viz, origin of stand, regeneration status, diameter distribution, crop composition, canopy layers, basal area etc.; and the third set provides information about disturbances to forests viz. damage by wind, grazing or browsing by wild animals etc. or anthropogenic e.g. forest fire, grazing, logging, lopping, girdling, development activities, invasive species etc.

The purpose of data collection from outside RFA is to ascertain the influence of people on forests through socio-economic survey. Survey will provide the consumption level of small timber, fuel-wood, fodder, grasses, bamboo and other NTFPs as well as their trading by households. It will also provide information about tree resources available outside RFA.

4.1.2 Data processing for forest inventory

For processing of inventory data, in the working plan division, per plot area may be calculated on the basis of inventoried plots in RFA and total area (in hectare) of RFA. Then they can be grouped into two broad classes; vegetated (very dense forest, moderately dense forest and open forest) and less vegetated (canopy cover less than 10% viz. scrub, shifting cultivation areas, etc). These plots can be further classified into different crop composition. The areas under these classes can be calculated using corresponding area factors. The plots corresponding to vegetated area, post-stratified according to crop composition (stratum) based on dominant species appearing in a particular division. Plot volume may be calculated with the help of volume equations developed by FSI/ state forest department for each tree species found in the plot. All sample plots may be grouped according to crop composition to estimate growing stock for the working plan division. Before processing the data, it should be cleaned after reconciliation of discrepancies if any during the collection of data. The main processing steps involved in data processing and outcomes which can be generated are given in the following paragraphs.

Generally, stratification is used to address the heterogeneity available in the sampling units (say in case of forest type/density classes in a forest). By segregating the sampling units into homogeneous sub-groups (strata), a gain in precision of estimation can be achieved. As we all know that the natural populations (say forest resources) have peculiarities of spatial auto-correlation and spatial heterogeneity. Therefore, for forest resource assessment of large forest areas like a division, systematic sampling gives quite precise estimates of population parameters (NWPC, 2014). It is pertinent to mention here that precision of estimates may further be improved using Post-Stratification technique.

Post-stratification may be carried out using field survey or using GIS tools or using GIS tools in conjunction with classified maps based on remotely sensed satellite data. For example; the carbon stored in the vegetation largely depends upon canopy density and forest type. Therefore, these two layers/stratums can be used as stratification variables. Canopy density wise spatial information can be obtained from the latest 'forest cover mapping'. This is supplemented with the forest type wise information generated under the national forest type mapping project carried out by FSI. Overlaying the forest cover layer (three canopy density classes) and forest type groups will result into several number of strata. The area statistics for each stratum (after overlaying) may be generated using GIS tools. This may be used for further analysis/estimation of parameters. The SFDs may utilise such data layers developed by FSI based on forest type, density, land use using GIS for increasing the precision of the estimates.

4.1.3 Estimation of growing stock: The estimation procedure for preparation of growing stock tables is described below:

A) Distribution of area of different parameters of the Plot Description Form (PDF) and calculation of per plot area:

The area of working plan division will be distributed on basis on Land Uses class (as recorded in PDF) to know extent of area under each class. For example: the working plan division area is 'x' and the total number of plots 'y', then the per plot area will be x/y.

Firstly, land use wise number of plots will be arranged and then multiplied by per plot area to the total number of plots falling in that class which will give total area under that land use, as given in the table below:

Say

Forest Division area	=	5000 sq km
Total number of plots in the division	=	200
Per plot area	=	5000/200=25 sq km

Distribution of Forest Area (in sq km) by Land Use Classes

Sl. No.	Description of Land Use classes	Number of plots	Area (No. of plots X per plot area)	Percentage
1	Closed forest	15	375	7.50
2	Dense forest	20	500	10.00
3	Open forest	35	875	17.50
4	Scrub	25	625	12.50
5	Bamboo Brakes	10	250	5.00
6	Shifting cultivation	20	500	10.00
7	Young crop plantations of forestry species	15	375	7.50
8	Trees in line	5	125	2.50
9	Forest roads	2	50	1.00
10	Govt. grass lands	1	25	0.50
11	Barren lands	10	250	5.00
12	Agricultural land without trees in surround	10	250	5.00
13	Agricultural land with trees in surround	5	125	2.50

14	Non forestry plantations	15	375	7.50
15	Habitation	10	250	5.00
16	Water bodies	2	50	1.00
	Total	200	5000	100.00

This way tables can be created on different parameters as per requirement for all the parameters in PDF as well as other field forms by linking with PDF.

B) *Distribution of total inventory area into vegetated area, less vegetated area and area not supporting vegetation: -*

The forest division area may further be segregated in to different classes i.e. vegetated area, less vegetated area and area not supporting vegetation. For example:

a) Vegetated Area can be obtained by summing areas under Closed forest, Dense forest, Open forest, Young plantation of forestry species and Non-forestry Plantations (Sl. No. 1-3, 7 & 14)**.**

b) Less Vegetated area: Vegetated Areas in the forest division having canopy density less than 10% (inferior growth). Such land class included Scrub land, Trees in line, agriculture land with trees in surround, habitation, shifting cultivation etc. (Sl. No. 4, 6, 8-10, 12, 13, 15).

c) Area not supporting vegetation: Area in the forest division which does not support any vegetation such as barren lands, water bodies etc. (Sl. No. 11, 16).

C) Calculation of per plot volume:

The Plot volume can be calculated with the help of volume equations for each tree species found in the Plot Enumeration Form (PEF). Aggregating the volume of each tree in a sampled plot will give volume of the plot. For example, there are n numbers of trees in a plot, first of all volume of each tree calculated using the respective species volume equations and by adding the volume of each tree will give volume of that plot. An example of plot having plot volume 16.08 m^3 is given below:-

Spp Code	Botanical name	dia_cm	Volume Equation	Dia (Meter)	Tree Volume (Cum)
0001	*Abies densa*	65	√V= -0.084305+3.060072*D	0.65	3.63
0003	*Picea smithiana*	33	V=11.770869*D^2+0.163269-2.232068*D+1.06041*D^3	0.33	0.75
0001	*Abies densa*	70	√V= -0.084305+3.060072*D	0.70	4.23
0001	*Abies densa*	42	√V= -0.084305+3.060072*D	0.42	1.44
0001	*Abies densa*	26	√V= -0.084305+3.060072*D	0.26	0.51
0001	*Abies densa*	52	√V= -0.084305+3.060072*D	0.52	2.27
0001	*Abies densa*	40	√V= -0.084305+3.060072*D	0.40	1.30
0001	*Abies densa*	26	√V= -0.084305+3.060072*D	0.26	0.51
0001	*Abies densa*	42	√V= -0.084305+3.060072*D	0.42	1.44

D) Estimation of per ha trees (stems) and their volume

The vegetated area may be post-stratified according to density class/ crop composition/ forest type. For a particular stratum so formed, all the enumerated trees in all the sample plots will be aggregated in a tabular form having species wise distribution of number of trees. The number of trees in this table, when divided by total area of all enumerated plots provides estimated number of trees per hectare. Similarly, in the case of volume, similarly, if volume of trees is arranged instead of number of trees in the above table, information can be generated for volume of trees in the plots, which may further be classified according to species & diameter class distribution. An example is given below for total sampled area of 2.5 ha:

i) Enumerated trees by species and diameter class

Spp. Code	Species	Dia class in cm			
		10-30	30-60	60 and above	Total
929	*Pinus roxburghii*	125	68	2	195
1014	*Quercus leucotrichophora*	157	25	0	182
Total		282	93	2	377

ii) Trees per ha by species and diameter class

Spp. Code	Species	Dia class in cm			
		10-30	30-60	60 and above	Total
929	*Pinus roxburghii*	50	27.2	0.8	78
1014	*Quercus leucotrichophora*	62.8	10	0	72.8
Total		112.8	37.2	0.8	150.8

iii) Enumerated volume in cum by species and diameter class

Spp. Code	Species	Dia class in cm			
		10-30	30-60	60 and above	Total
929	*Pinus roxburghii*	32.131	61.114	8.857	102.102
1014	*Quercus leucotrichophora*	31.11	11.074	0	42.184
Total		63.241	72.188	8.857	144.286

iv) Volume per ha by species and diameter class

Spp. Code	Species	Dia class in cm			
		10-30	30-60	60 and above	Total
929	*Pinus roxburghii*	12.85	24.45	3.54	40.84
1014	*Quercus leucotrichophora*	12.44	4.43	0.00	16.87
Total		25.30	28.88	3.54	57.71

g) Estimation of the total growing stock for working plan division level

For estimation at division level**,** all sampled plots are grouped according to working circle or crop composition as per requirement to estimate the growing stock. By multiplying the working circle area (Vegetated/ less vegetated area) from the per ha volume or trees i.e. multiplying factor will give total growing stock of that circle and adding these figures will result in total growing stock.

H) Standard Error calculation:

The precision of estimates generated through sampling method is very necessary for any estimation procedure to be complete. It helps in understanding the error contained in the generated estimates. For a particular stratum, the standard error is calculated by dividing the standard deviation of the statistic (say Volume per hectare) by the sample size's square root i.e. standard error of sample mean depends on both the standard deviation and the sample size, by the simple relation SE = SD/√ (sample size).

Standard error is an implication of the expected precision of the sample statistic (say volume/ha in a plot) as compared with the population parameter. The bigger the value of standard error, the more the spread and likelihood that any sample means are not close to the population's mean. A high standard error shows that sample means are widely spread around the population mean (i.e. the sample is not closely representing the population). A small standard error is thus a good attribute.

4.1.4 Volume Equations:

Volume of trees can be obtained using volume equations. In case, volume equations are not available with SFD, then it may be borrowed from FSI. FSI has developed about 800 volume equations, both Local Volume Equations & General Volume Equations, of around 200 tree species of India, which can be used. In Local Volume Equation (LVE), volume (under bark) is a function of DBH (over bark): V=f (D) and in General Volume Equations (GVE), volume (under bark) is a function of DBH (over bark): and height of tree: V= f (D, H).

For example, for *Shorea robusta* (Sal)

G.V.E is $V/D^2H = 0.0041834/ D^2 H+0.37802$ and

L.V.E is $V/ D^2 = 0.022585/ D^2 - 0.70158/D+8.714$

4.2 Estimation of biomass and carbon stock in different pools

4.2.1 *Above Ground Biomass (AGB) of trees having dbh ≥ 10 cm*

For calculation of biomass of trees having at each sample plot, all trees of diameter 10 cm and above are to be measured. The woody volumes of trees for each sample plot are to be calculated using volume equations. The volume equation provides above ground woody volume i.e. above ground volume, which includes volume of main stem measured upto 10 cm diameter and volume of all branches having diameter 5 cm or more. Volume of wood so obtained can be converted to biomass by multiplying by specific gravity/ wood density. Data of specific gravity and percentage carbon content of most of the tree species may be obtained from different published literature. Using carbon content percent of that species, carbon stored in wood will be estimated.

For estimating volume of the bark, the double bark thickness (DBT) of trees is to be measured during field inventory and volume equations of trees are to be used. Using species - volume equation once with dbh and again with DBH+DBT, two volumes are obtained. The difference will provide the gross bark volume which is to be adjusted for 'bark void factor' (measured

during data collection) to estimate the bark volume of the tree. With the help of the specific gravity of bark, the volume will be converted into biomass. Using carbon content percent of wood, carbon stored in bark will be estimated.

4.2.2 *Above ground biomass of trees having dbh < 10 cm*

Using the plot level regeneration data from working plan of a division i.e. recruits, un-established, established and all trees having dbh between 5 to 10 cm, biomass and carbon content at plot level is to be calculated.Biomass equations developed by FSI may be used for the calculation.

4.2.3 *Above Ground Biomass of branches, foliage of trees having dbh ≥ 10 cm*

FSI developed biomass equations for small wood (wood in main stem of less than 10 cm and branches less than 5 cm) and foliage for the trees having DBH ≥10 cm published in "Carbon Stocks in India's Forests". The plot level data collected during working plan survey with biomass equations developed by FSI will provide biomass which will be multiplied by species wise carbon content to calculate, carbon at plot level for branches and foliage etc.

4.2.4 *Dead Organic Matter (DOM: dead wood and litter)*

For collection of data within a subplot, two concentric plots of size 1.7m and 2.8m radius are to be laid out and data on dead wood & (woody) litter are to be collected. In 2.8m radius plot, all dead wood (standing or lying on ground) above 5 cm diameter are to be collected, weighed and recorded. In 1.7m radius plot, all woody litter i.e. all branches below 5 cm diameter are to be collected, weighed and recorded. Dry biomass will be converted to carbon stock.

4.2.5 *Organic matter in Soil and Forest Floor*

The data on forest floor (non-woody litter and humus) and soil carbon is also to be collected from each sample plot. For data collection on humus and soil carbon, two sub-plots of size 1m x 1m are to be laid out within the main plot. The forest floor from both the plots is to be first swept and material so collected is to be weighed and a portion of the same is to be kept for carbon analysis. Further, at the center of these two sub-plots, a pit of 30cm x 30cm x 30cm is to be dug and a composite sample of soil of 200 gm is to be kept for organic carbon analysis. Samples of soil and humus are to be analysed from the standard soil labs and are to be used for the calculation and estimation.

4.2.6 *Below ground biomass*

The most difficult pool to measure and is generally not measured in forest inventory by FSI. It is to be estimated using a relationship, root-to-shoot ratio which gives a relationship between aboveground biomass (AGB) to the below ground biomass (BGB) which have been established by various researchers. IPCC - GPG, 2003 also provides default values of root-to-shoot ratios for six major global forest types.

4.2.7 *Use of FSI data of Carbon estimation by WPO*

SFDs may note that FSI provides estimates of 'Carbon Stock in India's Forest' for different carbon pools under different forest types and density, in its ISFR, following methodology given by UNFCCC. In addition, the per hectare value of carbon stock for different carbon pools (for each forest type and density) is also generated by FSI that can be used by SFDs for assessment of available carbon stock in respective forest divisions. SFDs may use such information on carbon stock in different pools, from ISFR, for the working plan preparation. They are advised to consult FSI for this information.

(Remark:- The estimates of forest carbon are derived by FSI, following a post sampling stratification approach in which data of sample plots of NFI used along with forest cover and forest type layers. The sample plots of inventory are overlaid on different strata and biomass for each pool is determined.)

4.3 Estimation Procedure of Bamboo

The processing of Bamboo data mainly involves following steps:

- Distribution of bamboo area by density class.
- Distribution of bamboo area by quality class.
- Distribution of bamboo clumps by quality and size class.
- Distribution of bamboo clumps per ha by bamboo quality and size class.
- Distribution of bamboo bearing area by quality and density class.
- Distribution of bamboo culms /clumps by age, quality and size class.
- Mean number of bamboo culms /clumps by age, soundness of culms, quality and size class.
- Mean number of bamboo culms per ha by age, soundness of culms, quality and size class.
- Total no. of bamboo culms in the bamboo area by quality and size class.
- Estimation of green bamboo stock by soundness of culms quality and size class.
- Estimation of dry bamboo stock by soundness of culms quality and size class.
- Carbon estimates are generated by multiplying dry bamboo stock by carbon content percentage.

4.3.1 *Bamboo Clump Analysis for Clump forming Bamboos*

The data regarding total number of bamboo clumps and their respective diameters occurring in each sub-plot is to be recorded in the Plot Enumeration Form. The data is also to be collated in a separate field form called as Bamboo Clump Analysis Form in which data of each individual culm, occurring in certain selected clumps in each subplot is to be recorded. For carrying out this analysis, it is first to be determined whether a culm is green sound, green damaged, dry or dry damaged; these are then further classified as current years' culms, one to two-year-old culms and over two years old culms. In case of dry and decayed culms (both sound as well as damaged), however, the age classification is not necessary. The culms, other than that of current year and decayed culms, both green and dry, are to be further grouped under different diameter classes i.e. 1 cm to under 2 cm, 2 cm to under 5 cm, 5 cm to under 8 cm and 8 cm and above.

All culms occurring in the clump selected for analysis are to be enumerated and each enumerated culm is to be recorded by 'dot-dash' method (*dots represents counts from 1 to 4, lines 5 to 8, and diagonal lines 9 and 10)* under its appropriate class. The total number of culms found under each class is to be recorded in two digits.

4.3.2 *Bamboo Enumeration and Analysis for Non-Clump Forming Bamboo*

The data is to be collected for non-clump forming bamboos occurring in the sample subplot 2 i.e. western half of the subplot 2. For the purpose of counting the culms, the subplot 2 is to be dissected by taking a bearing of 360 from the center of subplot. A rope is to be put on this bearing upto the point where this bearing crosses the subplot circumference in North and South direction. All culms falling in western half of north subplot are to be counted and categorized in five classes viz. Green Sound, Green Damaged, Dry Sound, Dry Damaged & Decayed.

These are to be further classified as current year's culms, one to two-year-old culms, over two-year-old culms. In case of dry (both sound as well as damaged) and decayed culms, the age classification is not necessary. The culm, other than the current years and decayed culm, both green and dry are further grouped under diameter at breast height classes, 1 cm to under 2 cm, 2 cm to under 5 cm, 5 cm to under 8 and 8 cm and over.

4.3.3 *Bamboo Weight*

For determining correlation between green and dry weights for utilizable bamboo culm length, data is to be collected in 'Bamboo Weight form'. This form is, however, to be filled up for plots, in which bamboo has actually been found in an area of 60 m radius from the center of subplot 1. One mature bamboo culm from each culm diameter class 1 cm to 2 cm, 2 cm to 5 cm, 5 cm to 8 cm, and 8 cm and over, is to be selected for felling from the first clump enumerated in the plot. If, however, the required number of culms of any diameter class is not available in the first clump, the shortfall is to be made good from the clump next in the serial order of enumeration. Further, if the necessary numbers of culms are not available from any other clump of the plot, the required number of culms is to be obtained from the area in the immediate vicinity of the plot. This estimation of bamboo weight has to be done species wise.

4.4 *Estimation Procedure for Socio-economic survey*

4.4.1 The multipliers (weights) are used with the responses from the sampling units division level estimates are to be generated. The multipliers are generated at sub-stratum level (APL & BPL) within each stratum (1, 2 & 3). For this, district (division) wise projected population of the survey year may be acquired from the Directorate of Census Operations of the respective states/UTs.

4.4.2*Multipliers (weight):* The multipliers at stratum and sub-stratum (BPL/APL household) level are formed by multiplying proportion of enumerated population (BPL or APL) observed from the study with projected population of the Division (at stratum 1, 2, 3). The various formulae for multipliers at stratum and sub-stratum level are given below.

a) Projected population of HHs of BPL or APL for survey year (at stratum 1, 2, 3) = total enumerated population (BPL or APL) (at stratum 1, 2, 3) / total enumerated population (BPL + APL) (at stratum 1, 2, 3) x projected population of the Division (at stratum 1, 2, 3), where

Projected population of the survey year of the Division (at stratum 1, 2, 3) = Enumerated FFV's population (at stratum 1, 2, 3)/2011 census population x projected population of the survey year

b) For Adult Cattle Unit (ACU), Ratio (at stratum 1, 2, 3) = total enumerated ACUs population (BPL or APL) (at stratum 1, 2, 3) / total enumerated ACUs population (BPL + APL) (at stratum 1, 2, 3) x projected population of the survey year

c) Projected total number of HHs of BPL or APL for survey year (at stratum 1, 2, 3) = total enumerated household (BPL or APL) (at stratum level 1, 2, 3) / total enumerated household (BPL + APL) (at stratum 1, 2, 3) x projected households of the Division (at stratum 1, 2, 3), where

Projected households of the Division (at stratum 1, 2, 3) = 2011 census households/2011 census population x projected population of the survey year of the Division (at stratum 1, 2, 3)

d) Projected total area of landholdings of HHs of BPL or APL for survey year (at stratum 1, 2, 3) = total enumerated landholdings of household (BPL or APL) (at stratum level 1, 2, 3) / total enumerated landholdings of household (BPL + APL) (at stratum 1, 2, 3) x landholdings of households of the Division (at stratum 1, 2, 3), where

4.4.3 ***Estimation of Energy consumption***: For processing of data on consumption of energy sources in FFVs, the Fuel Consumption (Form 2(C)) information of households was merged with stratum code (Form 1: Village Information Form) and household status (Form 2A: Particulars of Households). The estimates were generated for sub stratum of household (APL and BPL) within each stratum (1, 2 and 3). Detailed estimation steps are described below (If FFVs data is used, the estimates would be for Rural Sector and If UFS data is used then the estimates would be for Urban Sector and summation will provide complete estimate for the Division):

a) Quarterly consumption of energy sources of all the HHs in a particular FFV/UFS blocks is enumerated.

b) Based on summation of quarterly data, household's annual consumption is calculated for each energy source.

c) The consumption of various energy sources for different fuel usages categories (cooking, heating, lighting and other purposes) are computed separately for each sub-stratum (APL and BPL) in each Stratum (1, 2 and 3).

d) Per capita consumption of a particular energy source for each sub-stratum (APL and BPL) in each Stratum (1, 2 and 3) is obtained by dividing its total consumption by total number of persons (population) in the surveyed villages/UFS blocks.

e) Thereafter, ratio factors (refer 2.2 a) were applied to per capita consumption values to generate energy consumption estimates for each sub-stratum (APL and BPL) in each Stratum (0, 1, 2 and 3).

f) Division level estimated energy consumption is obtained by adding the energy consumption estimates for each sub-stratum (APL and BPL) in each Stratum (1, 2 and 3).

4.4.4***Estimation of fodder consumption***: In the study, information on occurrence of fodder consuming animals and sources of livestock feed at household level in FFVs are recorded. Major categories of fodder consuming livestock namely cow, bull, buffalo, horse, camel, mule, donkey, goat, sheep other big and small animals are recorded for each household. Thereafter, the source of collection of livestock feed such as grazing (forest, outside forest), stall feeding (market, own farm, forest) and lopping are recorded for each selected household.

For processing of information on numbers of livestock and its dependence on forest for feed, the Fodder Consumption information (Form 2(D)) is considered with stratum code (Form 1: Village Information Form) and household status (Form 2: Particulars of Households). The estimates on number of livestock, adult cattle unit (ACU) and quantity consumption of fodder are generated for sub-stratum (APL and BPL) within each Stratum (1, 2 and 3). Detailed estimation procedure is described below (If FFVs data is used, the estimates would be for Rural Sector and If UFS data is used then the estimates would be for Urban Sector and summation will provide complete estimate for the Division.):

a) At the household level, total enumerated animals are converted into adult cattle units (ACUs). A detailed methodology of conversion of animals to ACU is given below:

Livestock (Conversion factors)

Factors for converting different livestock into Adult Cattle Units

Animal Code	Animal	Big Animal Equivalence to ACU	Small Animal Equivalence to ACU
01	Cow	1.00	0.33
02	Bull	1.50	0.50
03	Buffalo	1.375	0.46
04	Horse	1.25	0.42
05	Camel	1.375	0.46
06	Mule	1.25	0.42
07	Donkey	1.25	0.42
08	Other big animal	1.50	0.50
09	Goat	0.125	0.04
10	Sheep	0.125	0.04
11	Other small animals	0.0625	0.02

Source: Assessment of dependence of inhabitants of forest fringe villages (FFVs) on forests for fuel wood, fodder, small timber and bamboo (FSI, 2020)

b) Based on studies from the region, how much Kgs of green fodder is sufficient for an ACU may be used to estimate the quarterly fodder consumption from estimated number of ACUs dependent on forest.

c) Based on summation of quarterly data, household's annual consumption was calculated for each house in FFVs/ UFS Blocks.

d) Thereafter, annual quantities of fodder consumption at household level are distributed according to sources of fodder collection (grazing, stall feeding) reported by households. This was further used to work out quantitative dependence of ACU on forest, market and farm.

e) The above quantities were computed for sub stratum (APL and BPL) within each Stratum (1, 2 and 3).

f) Per capita (ACU) fodder consumption for sub stratum (APL and BPL) in each Stratum (1, 2 and 3) is obtained by dividing its total consumption of fodder by total number of ACUs.

g) Thereafter, ratio factors (refer 2.2 b) were applied to per capita fodder consumption values to generate fodder consumption estimates for sub stratum (APL and BPL) in each Stratum (1, 2 and 3).

h) Division level estimated fodder consumption is obtained by adding the above estimates for each sub stratum (APL and BPL) in each Stratum (1, 2 and 3).

4.4.5 ***Estimation of Small Timber***: To estimate volume of small timber consumed in FFVs/UFS Blocks, the information on items used in construction of houses, furniture, agriculture implements and fencing were recorded for each household in FFVs/UFS Blocks,. The items used in the house construction were ballies, furnitures, chauki, fencing and other agricultural implements (plough, leveller, harrow and others). Enumeration of above items is carried out for each selected household.

For processing of information on consumption of small timber (vol. in cum), the Small Timber Consumption information (Form 2(B)) was merged with stratum code (Form 1: Village Information Form) and household status (Form 2: Particulars of Households). The estimates on volume of small timber available in households in FFVs/UFS Blocks were generated for sub-stratum (APL and BPL) within each Stratum (1, 2 and 3). Detailed estimation procedure is described below (If FFVs data is used, the estimates would be for Rural Sector and If UFS data is used then the estimates would be for Urban Sector and summation will provide complete estimate for the Division.):

a) Count of various small timber items used for house construction, furniture, fencing and other agricultural implements, present in the selected households in FFVs/UFS Blocks, is enumerated for each household.

b) Volume (cum) of various items of small timber (described above) was already worked out for fixed dimensions.

c) Thereafter, the count of various items observed in households were is multiplied by their individual volumes thereby giving total volume of small timber used in that household.

d) Addition of the volumes, obtained above constituted total volume of small timber items at household level. These quantities were computed for sub stratum (APL and BPL) within each stratum (1, 2 and 3).

e) Consumption of small timber (in cum) per household for sub stratum (APL and BPL) within each stratum (1, 2 and 3) is determined by dividing total volume of consumed small timber by total number of households.

f) Accordingly, ratio factors (refer 2.2 c) were applied to consumption of small timer per household to generate consumption estimates for small timber for sub stratum (APL and BPL) within each stratum (1, 2 and 3).

g) Addition of these estimates yielded Division level consumption of small timber.

h) For conversions of these consumptions into annual consumption, it was presumed that lifespan of small timber is 7 years. Therefore, the estimated small timber divided by 7 yielded the annual consumption of small timber.

4.4.6 ***Estimation of Bamboo Consumption***: To estimate the quantity of bamboo consumed by the inhabitants of fringe areas, information of bamboo is collected only for items used in construction of the houses, furniture, agricultural implements and fencing of the houses. The items used in the house construction are ballies furniture; fencing and other agricultural implements are recorded at selected HHs. (If FFVs data is used, the estimates would be for Rural Sector and If UFS data is used then the estimates would be for Urban Sector and summation will provide complete estimate for the Division.)

The number of different items used (made of bamboo) was collected from sampled HHs.

a) Dry weight (kg) of each of above-mentioned items were calculated mathematically as per pre-decided sizes of the items given in the manual. Dry weight of bamboo culms of different sizes were recorded and compiled from Range office,

b) Number of items multiplied by their calculated individual dry weight yielded total dry weight of bamboo items.

c) The summation of dry weight of all the bamboo items constituted the total dry weight of bamboo items.

d) The average bamboo per capita consumption at HH level is determined by dividing total dry weight of Bamboo consumed by total number of HHs using these items respectively.

e) Estimates were obtained by using ratio factor (refer 2.2 c) with the average bamboo calculated at per capita level as mentioned above.

f) Addition of these estimates yielded state level consumption.

For conversion of these consumptions into annual consumption, lifespan of bamboo is to be assumed as 'X' years and therefore the estimated dry bamboo weight divided by 'X' provides the annual consumption of Bamboo.

4.4.7 ***Estimation of NTFP (including MADPs):*** To estimate quantity of NTFPs collected/consumed/traded in FFVs/UFS Blocks, the information on all collected NTFPs are recorded for each household of selected FFVs/UFS Blocks.

For processing of information so recorded in (Form 2(E)) is merged with stratum code (Form 1: Village Information Form) and household status (Form 2: Particulars of Households). The estimates on quantity of NTFPs collected/consumed/traded in households in FFVs/UFS Blocks are generated for sub-stratum (APL and BPL) within each Stratum (1, 2 and 3). Detailed estimation procedure is described below (If FFVs data is used, the estimates would be for Rural Sector and If UFS data is used then the estimates would be for Urban Sector and summation will provide complete estimate for the Division.):

a) Quantity of NTFPs collected/consumed/traded in the selected households in FFVs/UFS Blocks, is enumerated for each household.

b) Addition of the quantity of NTFPs collected/consumed/traded, obtained above constituted total of respective NTFPs quantities are computed for sub stratum (APL and BPL) within each stratum (1, 2 and 3).

c) Quantity of NTFPs collected/consumed/traded per household for sub stratum (APL and BPL) within each stratum (1, 2 and 3) is determined by dividing total quantity of respective NTFPs by total number of selected households.

d) Accordingly, Projected number of HHs (refer 2.2 c) is multiplied by the quantity of NTFPs collected/consumed/traded per household to generate estimates at sub stratum (APL and BPL) within each Stratum (1, 2 and 3).

e) Addition of these estimates yielded Division level estimates of total quantity of NTFPs collected/consumed/traded.

4.4.8 ***Estimation of Availability of Timber from TOF from HHs***: To estimate availability of timber from TOF data on trees available with HHs in FFVs/UFS Blocks, are recorded for each selected household of FFVs/UFS Blocks. For processing of information so recorded in (Form 2(F)) is merged with stratum code (Form 1: Village Information Form) and household status (Form 2: Particulars of Households). The estimates are generated for sub-stratum (APL and BPL) within each Stratum (1, 2 and 3). Detailed estimation procedure is described below (If FFVs data is used, the estimates would be for Rural Sector and If UFS data is used then the estimates would be for Urban Sector and summation will provide complete estimate for the Division.):

a) The desired data of all trees available on the land of selected households in FFVs/UFS Blocks, is enumerated for each household.

b) The number of trees, species and diameter-class wise data is tabulated by adding data of all the selected households in selected FFVs/UFS Blocks for sub stratum (APL and BPL) within each Stratum (1, 2 and 3).

c) Enumerated number of species and diameter-class wise trees per hectare is calculated by dividing the above information by the total land possessed by all the selected households in selected FFVs/UFS Blocks for sub stratum (APL and BPL) within each Stratum (1, 2 and 3).

d) The estimates of TOF are computed by multiplying the information generated in c) above with Projected area of landholdings of HHs (refer 2.2 d, which is based on total private land holdings available from land-use statistics of villages) for sub stratum (APL and BPL) within each stratum (1, 2 and 3).

e) Addition of these estimates yielded Division level estimates of total trees available in households of TOF area of The Division.

f) Using this information with Von Mantel's Formula (Annual Availability =2 GS/R, Here GS is growing stock of particular species and R is rotation period of that species) annual availability of timber is calculated.

4.4.9 ***Estimation of TOF from Non-Private lands***: To estimate the tree resources available in Public land outside RFA, data on trees available in FFVs/UFS Blocks, are recorded for each selected FFVs/UFS Blocks,

For processing of information so recorded in (Form 1(A)) is merged with stratum code (Form 1: Village Information Form). The estimates are generated for each Stratum (1, 2 and 3). Detailed estimation procedure is described below (If FFVs data is used, the estimates would be for Rural Sector and If UFS data is used then the estimates would be for Urban Sector and summation will provide complete estimate for the Division.):

a) The desired data of all trees available on the land of selected FFVs/UFS Blocks, is enumerated.

b) The number of trees, species and diameter-class wise data is tabulated by adding data of all the selected FFVs/UFS Blocks for each Stratum (1, 2 and 3).

c) Enumerated number of species and diameter-class wise trees per hectare is calculated by dividing the above information by the total public land outside RFA in selected FFVs/UFS Blocks for each Stratum (1, 2 and 3).

d) The estimates of TOF are computed by multiplying the information generated in c) above with total public land outside RFA for each Stratum (1, 2 and 3).

e) Addition of these estimates provides Division level estimates of total trees available in public area outside RFA of The Division.

4.5 Analysis of the forest crop

A compartment is the basic unit of management which is uniform with regards to the crop composition and as far as possible homogenous as regards soil, species composition and age of the forest crop. If the growing stock and quality of the site varies significantly, sub-compartments are formed.

The composition of the standing crop must be examined and recorded in detail. This is done during the field inventory exercise (Form 2). The composition of the species, their relative proportion, age, canopy density, status of regeneration, presence and absence of weed, origin of the forest (seedling/coppice) are analysed. Based on this the WPO may assess the treatment for which the forest may best respond to.

a. ***Composition of the crop***: The species found in a compartment must be described as principal species (when there is a predominant economically/ecologically important species), associates, and their relative proportion in terms of (pure/mixed/miscellaneous). The presence of the associate may be described as abundant/rare.
b. ***Age of the crop***: If the crop is composed of two or more distinct classes, the respective ages of each should be given. If the crop is uneven aged, the dominant age is to be given. In case of uneven-aged forests, the data on the dia class in Col 33 of Form 2 may be used to obtain the relative age of the crop.
c. ***Canopy Density***: The canopy may be described as very dense (>70%), moderately dense (40-70%) and open forests (10-40%).

4.5.1 Stock maps: Detailed descriptions of a forest crop are tedious to write and at times bulky. Stock maps are tools that can be used by the working plan officer along with the area statement of working circles to determine the method of treatment. It is possible to capture various parameters as explained above and stock maps can be prepared using GIS. Stock map data has been captured in Plot Description Form (field form no. 2).

GIS should be used to prepare these stock maps. Different layers of the compartment viz relative age of the crop, composition of the crop, canopy density, presence and absence of regeneration, presence of invasive alien species, site quality (wherever applicable) etc. Besides, the WPO may also use other layers such as slope, erodibility, aspect etc while making decisions.

The stock maps are tools to visualise the status of a forest crop and is used by WPO to decide about the future management of the forests. Once decided, these along with the n-D curves, assist the WPO to decide about the option of forest management (even aged/uneven aged). If the chosen option is even aged under shelter wood system of management, these tools are helpful to assign compartments to different periodic blocks depending on their relative age, presence and absence of regeneration etc.

Composition of species may be classified as pure, mixed or miscellaneous depending upon the proportion of the principal species and their associates. Generally, a crop with more than 75 % of principal species is termed as pure and 50% to 75% as mixed. If none of the species constitutes 50%, then the crop is termed as miscellaneous. However, the States may fix their own percentage of the main species for classification of the composition of species as Pure, Mixed and Miscellaneous.

The presence or absence of regeneration is required to be captured in the stock maps. The classification to be adopted is:

- Regeneration Adequate (a total of 9 established individuals in all the regeneration sub-plots put together)
- Regeneration Non-adequate (a total of 1-8 established individuals in all the regeneration sub-plots put together)
- Regeneration absent (Nil)

4.6 Method of treatment

An understanding of the forest, its growth and its response to disturbances is essential for forest management. The trees that constitute a forest grow continuously, change over time and ultimately die. The open spaces created by the death of the trees are taken over by new vegetation. The change in the structure of the forest crop is the primary factor which alters the goods and services provided by the forests. The forest crop changes over time, though not perceived by naked eyes. This understanding of the dynamic nature of the forest crop and the goods and services provided by the forests guides the forester in setting the management objectives.

Since all benefits cannot be maximised, there are trade-offs that are to be decided considering societal needs. A young forest crop with relatively open canopy may provide more grass compared to a matured, old aged forest, forms a habitat of a particular kind of fauna, and grows fast resulting in a higher sequestration of carbon per unit area. A matured forest with multi layered crop structure provides clear water and it acts as a habitat for a certain other kind of fauna where the volume increment of the forest crop may be comparatively low and thus a comparatively less carbon sequestration. A monocrop or a forest crop with a gregarious species provides one particular kind of good but a forest crop with multiple species composition is more diverse and is expected to give more ecosystem services and multiple goods especially in the form of NTFPs.

The prescription for the management of a forest crop depends on the management objective and the condition of the forest crop. If the management of the forest crop is for maintaining healthy productive crop and entails regeneration felling to ensure proper regeneration, it will result in production of timber and other forest produce such as firewood, NTFP, grass etc then, the standard silvicultural treatments with local modifications will apply. For areas where the primary objective is the ecological services viz hydrological functions, preserving biodiversity etc., then the treatments would vary accordingly.
A systematic approach is to be drawn for achieving the agreed trade-offs in forest management planning. For this purpose, the forester shall identify various management objectives which will result in different goods and services that the forest crop could provide and the trade-offs among them.

4.6.1 *Management of forests for maintaining a healthy productive crop:*

Obtaining regeneration of the principal species and their associates is one of the main objectives of forest management. The opening of the canopy, either on account of natural disturbances or through management interventions, provide suitable condition for obtaining the natural regeneration. When forests are primarily managed for maintaining healthy productive crop and entails regeneration felling to ensure proper regeneration, it will result in production of timber as yield and other goods, NTFPs or grass for the locals and the wild herbivores, then the working circle shall be required to be based on standard silvicultural systems such as selection system, shelter wood system or coppice system with their local modifications. The sustainable yield of such regeneration felling in all such cases can be controlled by area, volume or both.
Any plan aimed at sustained yield cannot be achieved without considering a desired forest crop structure. For maintaining sustainable yield, the principles of normal forests shall apply. For this purpose, the existing forest crop shall be assessed and prescriptions shall be aimed at bringing it to the normal form as far as possible. In India, most of the forests are irregularly arranged which has been aggravated with suspension of silvicultural operations in most of the natural forests in the past few decades which warrants necessary remedial interventions.

The silviculture systems prescribing sustainable yield dependupon the increment of the forest crop, nature of the principal species (light demander/ shade bearer etc) status of the forest crop, frequency of felling, etc.

4.6.2 Management of forests for their ecological functions:

Forest management provides goods and services as by-products of management. Even when forests are managed primarily for maintaining healthy productive forest crop as discussed above, they provide ecological functions viz hydrological functions, conservation of biodiversity etc., in addition to sustainable yield of timber. However, when forests are managed primarily for the ecological functions that they provide, the prescriptions vary considerably. Under those circumstances, sustainable yield of timber and others goods will not be the by-products of the treatment proposed though there may be yield of tangible forest produce to maintain a particular canopy/crop density for maintaining ecological functions of the forest at the optimum level.

4.7 Constitution of Working Circle and calculation of yield of goods or services or both

Based on the object of management, the forest area is divided into different zones where different management prescriptions would be made. The principles on the zonation have been discussed above. Once it is decided and zonation completed for the forest area, working circles are constituted according to the management objective. The management of such forests would depend upon the nature of the crop, condition of the crop among other things.

Once decided on the approach to the forest management, the possible yield in the form of goods and services are to be ascertained using standard methodologies. For the estimation of yield of forest produce especially for timber, standard management principles and methodologies have been evolved. For regulating the yield of timber, generally the control is effected by area, volume or with both. The WPO shall choose appropriate standard method or adopt it to the suitability of the situation.

After deciding on the possible yield, the WPO shall make prescription for the management of the forests so that the goods and services so decided are obtained from the patch of the forest in a sustained manner. The possible yield of goods and services is dependent on the present condition of the forest especially its composition, both species and age. In order to obtain the goods and services in a sustained manner, the WPO shall aim at a desired forest crop structure and all the prescriptions shall be aimed at achieving that structure. If a forest is managed primarily for timber production, it is comparatively easier to aim at a desired forest crop structure and making prescriptions. The standards or the ideal state of the future forest crop which is generally referred to Normal Forests for timber production can be worked out using Yield Tables, where ever available or using data from the permanent preservation plots etc.

In case, the forest crop is primarily managed for ecosystem function and its services, even then determining the desired forest crop structure and prescribing treatments to achieve the same are equally important. In the absence of any standard, if the WPO desires to keep the present forest crop structure as the desired forest crop structure, the prescriptions are to be in such a way that the stand remains in its present form. As discussed earlier, forest stands grow and change all the time and so to maintain them in any form, proper silvicultural interventions is necessary. Any stand which is left to itself without any intervention slowly changes to a new structure, thus shifting from the desired stand forest structure. Thus, if unattended, the forest will not be able to provide the goods or services or both in future.

One of the tools available with the forester to manipulate the forest crop to achieve the desired forest crop structure is through periodic removal of trees based on silvicultural principles. For

this, the WPO shall indicate the duration of felling, area where felling is to be done, nature of felling etc. By nature of felling, it is referred to whether the felling is done successively as in the case of shelter wood system or at one time or regularly/ periodically as in selection system. This would include the interval between two subsequent felling in the area and rules for the material to be removed etc.

Supplementary provisions: The method of treatments proposed above may involve other supplementary activities in the form of thinning, cleaning etc. Regulation of grazing, removal of forest produce especially the dead and fallen material by the local communities under their rights, sowing and planting to augment regeneration, protection from fire are such operations that the WPO may prescribe under a working circle so that the object of management is obtained.

a. Thinning and cleaning
b. ANR through sowing and planting
c. Regulation of grazing
d. Regulation of rights of the local communities
e. Other cultural operations
f. Fire management
g. Riparian zone management
h. Soil and water conservation
i. Management of invasive alien species

4.8 Constitution of overlapping WC:
Overlapping working circles are constituted to meet specific objectives over forest areas that are primarily managed for certain other purposes as discussed above. This is aimed at multiple use forest management. These working circles are also constituted for the management of understorey crop like bamboo and rattans, and other special habitats. As per the requirement of the crop and management objectives, the WPO is at liberty to constitute one or many of the overlapping working circles to prescribe management prescriptions which are in addition to the primary prescriptions given in the WC of the previous section.

4.9 Management of Wetlands within forests:
Forest landscapes include wetlands as important ecosystems. Most of these wetlands are pristine and need little or no management interventions. However, periodic assessment of the wetlands, especially water quality testing among other things may indicate the health of the wetlands. The WPO may prepare a document on each of the wetlands on their status, need for any active management interventions etc based on the wise use principle.

4.10 Biodiversity Conservation:
Forests provide habitat for many plant and faunal species. The contribution of individual species to the overall diversity within a community or ecosystem varies to a great extent. The coexistence of organisms that differ widely from each other contributes more to overall diversity than the co-existence of very similar species. Functional diversity is considered to be one of the main factors determining the long-term stability of an ecosystem and its ability to recover from major disturbances. Assessment of status of plant and faunal species and their periodic monitoring can be helpful in formulating strategies for conservation, maintenance and enhancement of overall biodiversity through sustainable management and use practices. The BD indices estimated using the field data are to be assessed, and management prescriptions provided to meet the objective.

However, the prescriptions in the management plans of protected areas, eco-sensitive zones/areas, biodiversity heritage sites and wetlands of significance that are in or near the forests are to be harmonized while making prescriptions.

4.11 Forest fires and protection

Forest fires are as old as the forests themselves. They sometime pose a serious threat to the biodiversity and ecology. Forest fires have environmental impact in terms of tropical biomass burning, which produce large amounts of trace gases, aerosol particles, and play a pivotal role in tropospheric chemistry and climate aberrations. Thus, there is a need to carry out fire frequency and burnt area mapping for fire vulnerability on one hand and operational fire monitoring in real time/near real time for effective response on the other. Real time monitoring of forest fires is being carried out by FSI or other national/state agencies. The processed signals on forest hot-spots are being transmitted to state forest departments on regular basis during fire season. Hence real time monitoring of forest fires is a process now in operation to curtail fire severity and sensitize SFDs at operational level to prevent normal fires in getting converted into wild fires. The online feedbacks on forest fires which are a part of this system could help estimate the actual loss of forest strata as well as the loss caused to top-soil. The WPO may propose an overlapping WC wherever fire is a major feature in the forest management. The assessment of damage by fire, fire frequency, burnt area mapping, fire vulnerability mapping etc will be used to prescribe management interventions.

4.12 Carbon Sequestration

Forests and wood products can effectively reduce the process of climate change in several ways. Growing trees absorb carbon dioxide from the atmosphere and store the carbon so efficiently that about half the dry weight of a tree is carbon. This carbon remains locked up in the form of wood and wood products. Sustainably grown and harvested wood (and other biomass) also provides a renewable alternative to fossil fuels and enhance carbon storage. Enhanced carbon sequestration through recognised and innovative silvicultural practices, eco-restoration of degraded/mined out forestlands, improved biomass productivity; etc results in improving forest health and vitality. Forest soil must be kept healthy and fertile. When carbon sequestration is the primary objective to manage a particular patch of forest, then it would be in the fitness of things to keep the forest in the actively growing stage with a high proportion of young and middle-aged crop. In such situations, the growth of forest crops must be kept vigorous to attain the most desirable level of biomass production within an optimal time scale.

4.13 Trees outside forests (TOF) and Forest Enterprises

Trees Outside Forests (TOF) are located on land other than forests, including agricultural land (e.g. agro-forestry systems, hedgerows, woodlots), built-up areas such as settlements and infrastructure (e.g. street trees, parks and other urban tree systems), and bare land (e.g. dunes, both abandoned and accomplished mining sites) forming part of the forest landscape. They contribute nearly one fourth of the total growing stock of the country. So there is a need to describe and comprehend the dynamics of trees and shrubs on rural and urban land, and their interaction with forest ecosystems. This will lead to a better understanding of off-forest tree management and towards integrated and sustainable management of forests as natural resources. The focus of forestry outside forest areas is on production forestry, revitalization of rural economy and expanding economic opportunities through innovations. This requires inter-sector synergy and convergence. WPO may therefore prepare a separate strategy as a new chapter, not being part of general prescription of working plan to address the concepts and issues related to TOF and forest enterprises.