Forest Canopy Cover Assessment Guidelines

Forest Monitoring and Information Division

Department of Forests and Park Service

Ministry of Energy and Natural Resources

Thimphu Bhutan

2024

Report Prepared by
Dorji Wangdi, Principal Forest Officer
Kinley Dem, Chief Forestry Officer

Citation: FMID 2024. Forest Canopy Cover Assessment Guidelines 2024.

ISBN: 978-99980-791-4-4

Forest Canopy Cover Assessment Guidelines

Forest Monitoring and Information Division
Department of Forests and Park Service
Ministry of Energy and Natural Resources
Thimphu Bhutan
2024

Foreword

Realizing the importance of the forests for a small and land locked country, the constitution of Kingdom of Bhutan mandates to maintain a minimum of 60% of surface area under forest cover all times to come. Therefore, monitoring and assessing forest canopy cover is a critical aspect of forest management, conservation, and restoration efforts. As global environmental challenges intensify, the need for precise, standardized, and practical guidelines for assessing forest canopy cover becomes ever more imperative.

Therefore, the "*Forest Canopy Cover Assessment Guidelines*" have been developed to provide a comprehensive framework for accurately measuring and analyzing canopy cover under different forested landscapes. By standardizing methodologies, these guidelines aim to enhance the consistency and comparability of canopy cover data across different regions and forest managers.

The structured approach presented here facilitates the reliable assessment of canopy cover, supporting informed decision-making for forest management and conservation. Forestry officials can, accordingly, better monitor forest health, understand the impacts of human activities and natural disturbances, and help in planning and developing strategies address forest loss.

I extend our gratitude to all the contributors who have dedicated their expertise and effort to the creation of these guidelines. I hope that this document will serve as a valuable resource, fostering greater understanding and stewardship of our forest resources.

(Lobzang Dorji)
Director

Table of Contents

1 INTRODUCTION

1.1 Background

Forest constitutes the dominant land cover in Bhutan, comprising of approximately 69.7% of the country's total area. These forests are managed sustainably through different forest management regimes and by the application of technical prescriptions following of the Forest and Nature Conservation Code of Best Management Practices 2021. This is also consistent with the Forest and Nature Conservation Act of Bhutan (FNCA) 2023, wherein all State Reserved Forest Land (SRFL) are to "*be managed and protected under different forest management regime for effective and efficient management as per the Forest and Nature Conservation Code of Best Management Practices of Bhutan*". These managed areas meet the demand of the people on forest produce or through the allotment of the SRFL for development activities. Accordingly, **3,551.753 ha** of SRFL land and around 273,750.60 m^3 of timber are allotted annually from the SRF for developmental purposes and to meet the demand of people on natural resources from 2015 to 2023. And there is also an increasing demand of the SRFL for developmental activities. This will have a significant impact on the overall forest cover of the country and also, on the constitutional requirement of maintaining a minimum of 60 % forest cover for all times to come.

Therefore, the FNCA 2023 provide guidance on the sustainable use of natural resources through effective governance mechanisms in place for the management of the SRFL, wherein Section 46 (2) under Chapter 3 of the FNCA mainly focuses on "*high forest*" for allotment of SRFL for developmental activities.

> *46. (2) Forestry clearance shall not be issued for any activity in State Reserved Forest Land which fall in: (a) high forest*[1]

Given the importance of canopy cover assessment for classification of SRFL into Forests, Non-Forest and further into high forest, it is important to have an accurate and uniform method of estimation of forest canopy cover percent. Accurate estimation of canopy cover percentage is also crucial for understanding forest extent, condition, and changes in forest cover. It also aids in comprehending forest stand structure, biodiversity, microclimate regulation, and land use planning, among other factors.

1.2 Forest Canopy Cover Percent

Forests are defined as any land with trees spanning more than 0.5 hectares, with trees exceeding 5 meters in height and canopy cover of more than 10%. While the measurement of area and height

[1] "*high forest*" means trees grown by means of natural seedling or by plantation and when the forest canopy cover is 40% and more, if trees are of economic values and social benefits (FNCA 2023)

is straight forward, Canopy cover, which refers to the proportion of the forest floor covered by the vertical projection of tree crowns, is often poorly understood.

In addition, Canopy cover is also, many a times, loosely interpreted similarly to the canopy closure. However, Canopy closure is referred to the proportion of the sky hemisphere obscured by vegetation when viewed from a single point. Further, various methods and standards are employed by forest managers to measure canopy cover, resulting in inconsistency in the methodologies and variable estimates. Therefore, this Guidelines shall provide detail guidance on the estimation of forest canopy cover for guidance in planning, policy formulation and implementation of plans, programs as well as Forest and Nature Conservation Act (2023) and Forest and Nature Conservation Rules and Regulations (2023).

2 OBJECTIVES

Assessing canopy cover is essential for comprehending various aspects of the forest ecosystem, including its health, climate regulation, urban planning, water resources management, climate change analysis, carbon sequestration, biodiversity conservation, land use planning, and natural resources management. However, the objectives of this guideline is to:

- Standardize the methodology for assessment of canopy cover across all SRF;
- Efficiently and accurately assess forest canopy cover;
- Effectively manage SRFL through designation into either forested or non-forested areas; and to
- Aid in land use planning for urban development, implementing developmental activities, and conserving the environment.

3 METHODS OF CANOPY COVER ASSESSMENT

The canopy cover of forest stands can be estimated through various methods including line transect sampling, angle count method/crown relascope, Cajanus tube (Stenberg, Korhonen & Rautiainen, 2008), Beta regression models (Korhonen, et al., 2007), remote sensing, ocular method, field measurement (Fiala, Garman & Gray et al., 2006), and Smart Phone applications (Lust, 2022). Among these methods, ground measurement using appropriate equipment is recommended for canopy cover measurement in five Douglas-fir/western hemlock structure types in western Oregon (Fiala, Garman & Gray et al., 2006). Studies in Mexico, Nepal and Viet Nam have identified the Line Intercept Sampling (LIS) method as the most accurate, valid and cost-effective method of estimating canopy cover (FAO 2015). Similarly, the LIS method using GRS Densitometer was accordingly adopted for canopy cover assessment in National Forest Inventory (NFI) and Forest Management Unit (FMU) inventories in Bhutan. This method has been found to be highly accurate in numerous studies.

Therefore, LIS combined with GRS crown densitometer is recommended for canopy cover assessment in various ecosystems within SRFL, with detailed procedures outlined in subsequent sections.

4 PRINCIPLES OF CANOPY COVER ASSESSMENT

Canopy cover assessment may be required for small and large SFRL depending on the objective of the assessment. It is relatively easier to assess the canopy cover for large areas through sampling approach and can achieve required accuracy with large sample size (>30). However, in small areas, accuracy can be achieved only through total count and/or total measurement. Therefore, canopy cover assessment shall be defined by area and type of area. Depending on the size or acreage of the area of interest (AOI) under investigation, the canopy cover assessment may be conducted with direct measurement for smaller area and with sampling in large areas. Table 1 may be used to decide whether the canopy cover can be measured directly, or measurement be taken from the sample plots.

Table 1: Observation points and sampling

Area (m^2)	**No. of observation points**	**Remarks**
<=500	100	Direct measurement
>500 to 2500	150	Direct measurement
>2500 to 5000	200	Direct measurement
>5000		Establish Sampling plot

Currently, transect sampling method using GRS crown densitometer is adopted in the forest resources and management inventories in Bhutan. The observation points are laid in circular plot of 500 m^2 and similar approach shall also be used in the estimation of canopy cover. However, there are instances when the circular plot established in the proposed study area may lead to over or underestimation of canopy cover. Therefore, depending on the proposed study area, a rectangular plot maybe recommended.

4.1 Circular Plot

4.1.1 Direct Measurement

As it is clear from the Table 1 above, direct measurement or observation shall be taken for AOI with total area upto 5000 m^2. Based on the area, canopy cover shall be assessed with observation of 100 to 200 observation points which are laid systematically across the proposed land. The point to point to distance for tally and non-tally should be determined as follows:

a) A minimum of 100 readings shall be recorded in the circular plots of 12.62 m radius with plot area of 500 m^2.
b) In order to determine the point-to-point distance, calculate the grid area, wherein,
   Grid area = Area/no. of points
   = 500/100 = 5 m^2

Now calculate point-to point distance

Point to point to distance = $\sqrt{}$ Grid area

$= \sqrt{5}$

= 2.23 m ~2.5 m

c) Layout the systematic points using GIS or any other survey method at 2.5 m x 2.5 m. Accordingly, record 89 regular points (black) and 11 random points (red) to have a total of 100 readings.

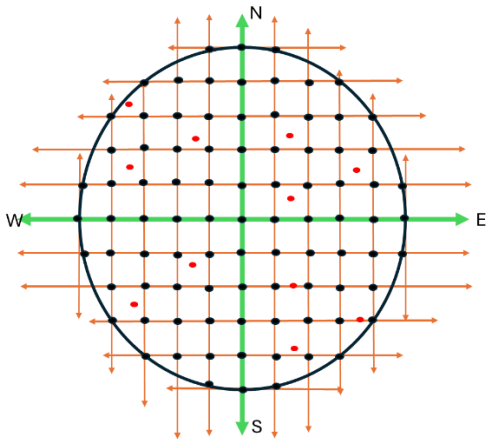


Figure 1: General Grid for Canopy Cover Assessment

d) The 11 random points shall be in taken from the same quadrant for all plots. If the random points are taken from NE, SE, SW, NW in 1st plot, then same shall be repeated in rest of the plots to avoid potential bias arising from convenience approach.

e) Measure tally and non-tally for each point using crown densitometer and determine canopy cover percent

Determination of canopy cover percentage using crown densitometer

a) Measure tally and non-tally for each point using crown densitometer. The parts of the densitometer is shown in Figure 2.

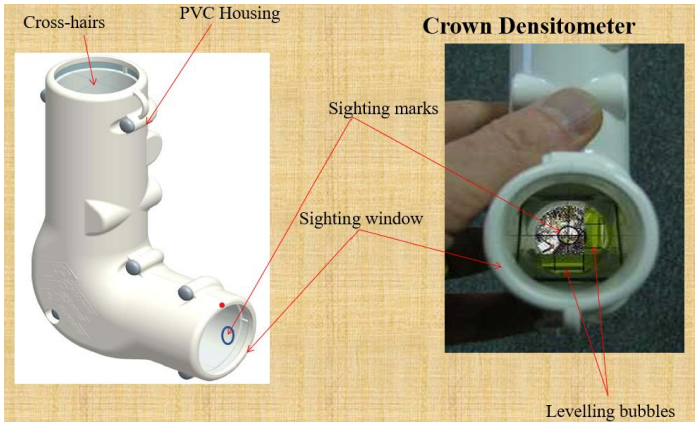


Figure 2: GRS Densitometer (left)

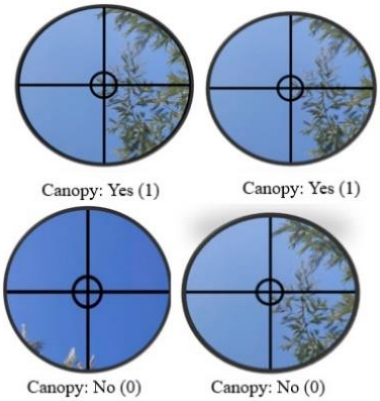


Figure 3: Tally and non-tally rules (right)

b) To take the correct reading, see through the densitometer and align the sighting level and the bubble levels.

c) Then check the black inner circle and record '1' if more than 50% of inner black circle is covered by canopy and '0' if no canopy is observed in less than 50% of the black circle (Figure 2 and 3).

d) The tally and non-tally rules are shown in Figure 3. Accordingly, tabulate the tally and non -tally in tally sheet using Boolean number of 1 and 0 respectively.

e) The canopy cover percentage is thereafter calculated as:

$$\text{Canopy cover } \% = \frac{\text{Total1s}}{100} * 100$$

Note: Hundred independent reading, every reading shall constitute a percentage.

f) If the canopy tally and non-tally is recorded using the sampling plot, the canopy cover percent shall be estimated as

$$\text{Canopy cover } \% = \frac{\text{Total1s}}{100 \text{ x No of sample plots}} * 100$$

Similar approaches shall be taken for areas more than 500 m^2 but less than 5000 m^2 wherein for areas larger than 500 m^2, observation points shall be laid across the area (Figure 4) as per the point-to-point distance generated as discussed above.

Figure 4: Systematic observation point for direct measurment

The minimum of 1m distance shall be maintained between two observation points and shall not exceed 2.5 m. In the event, point to point distance exceeds 2.5 m, sample plots may be established for canopy cover assessment.

4.1.2 Sampling with Sample Plots (Area larger than 5000 m2 (>0.5 ha, >1.24 acres)

If the proposed area is more than 5000 m^2, canopy cover shall be assessed using the sample plot. In each sample plot, a minimum of 100 observations shall be taken systemically as discussed in 4.1.1 and illustrated in Figure 1.

In general, circular plots shall be adopted and a minimum sample size for canopy cover assessment is determined based on standard plot to plot distance adopted in forest management inventories, which is 100 m x 100 m. Therefore, number of plots should be determined as follows:

1. Determine the area of assessment (e.g., 12 ha (120,000 m^2) SFRL for construction of School)
2. Calculate sampling grid area for plots of 100 m x 100 m

   Grid Area (m^2) = 100 m x 100m

   = 10,000 m^2
3. Minimum number of sampling plot

$$= \frac{Area\ Under\ Assesment}{Grid\ Area}$$

$$= \frac{120{,}000}{10{,}000}$$

$$= 12$$

The actual number of sample plots will depend on regular points generated from the GIS which is affected by the shape and size of the area. Therefore, the no. of plots can be more or less than the estimated sample size.

4. Systematically, layout the plots in the land under assessment and ensure that all plots are within the boundary of the land under assessment as far as possible. For example, all 12 plots generated for assessment of canopy cover for 12 ha land should fall within the boundary of the 12 ha. However, if a boundary of plot may overlap with the adjoining area under unavoidable circumstances, observation will be taken irrespective of the boundary of plot if the plot centre is within the area of interest.
   The intersection of the grid is the centre of the plot for canopy cover assessment and circular plot of 12.62 m should be established around the plot centre.

5. In each circular plot, Canopy tally and non-tally shall be recorded for 100 observation points (89 systematic observation points at 2.5 m apart and 11 random points) as discussed in Section 4.1.

In the event, minimum plots as determined step 3 cannot be accommodated within the boundary of land under assessment, canopy cover assessment may be conducted following the method described in section 4.1.1. Further, If the sample size is very large (more than 30 plots for any given area), the plot-to-plot distance may be increased to 200 m X 200 m.

4.2 Rectangular Plots

In cases where the establishment of circular plot with 12.62 m is not possible due to orientation or shape of the landscape or the proposed area, a rectangular shaped plot may be used but point for canopy reading shall be distributed systematically within the plot. Rectangular plots shall only be laid in the SRFL land proposed for linear infrastructure such as farm road, forest road, low tension transmission lines, irrigation channels, wherein laying out a circular plot may not be feasible. However, circular plots can be laid out easily for the high-tension transmission lines.

Each rectangular plot shall have a **minimum of three transect lines** and the sum of observation points along the transect lines shall not be less than 100 observation points, distributed systematically along each transect line.

1. In each rectangular plot of 500 m^2, a minimum of 3 transect lines shall be laid with a spacing of 1 – 2.5 m apart.

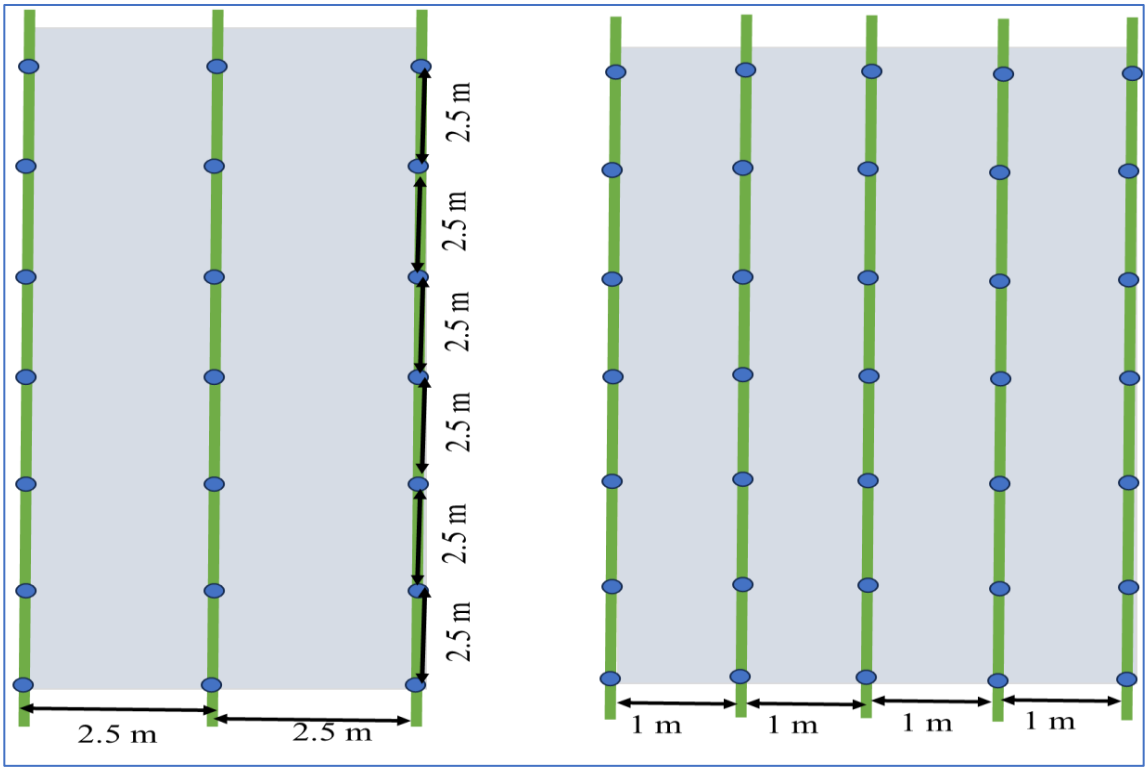


Figure 5: Transect for canopy cover assessment

2. The first transect shall be laid on the upper or lower edge. Then, divide the total width and by 2 for smaller width or 2.5 for road/transmission alignments with width more than 6 m to determine the no. of transect lines. Ideally, one transects line should be centrally located. Figure 6 shows the illustration of transect lines for rectangular plot

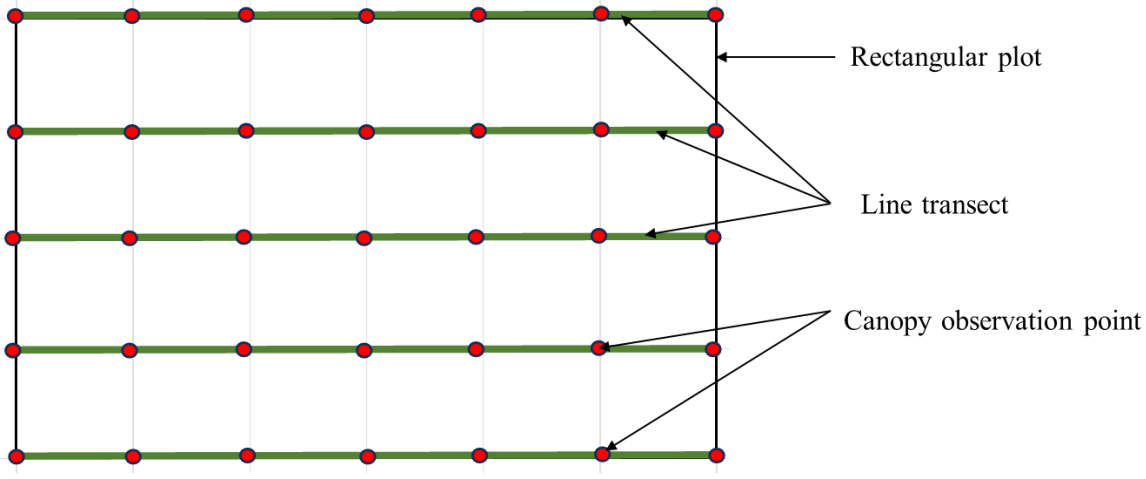


Figure 6: Rectangular Plot for Canopy Cover Assessment

3. Along each transect, a canopy observation point shall be determined at regular interval of 2.5 m or distance determined based on the number of transect lines in the rectangular plot.

4. If the area of rectangular plot is more than 500 m^2, then the number of rectangular plots and number transect in each rectangular plot shall be determined as follows:

   If the length and width of the proposed road is 1000 m and 5 m respectively, then the area shall be calculated as:

   A= LW

   L = 1000 x 5 = 5000 m^2

5. The first rectangular plot shall be established from the starting point and subsequent plot shall be established at an interval of 500 m from the edge of the preceding plot. Figure 7 and 8 shows the illustration of layout of rectangular plot.

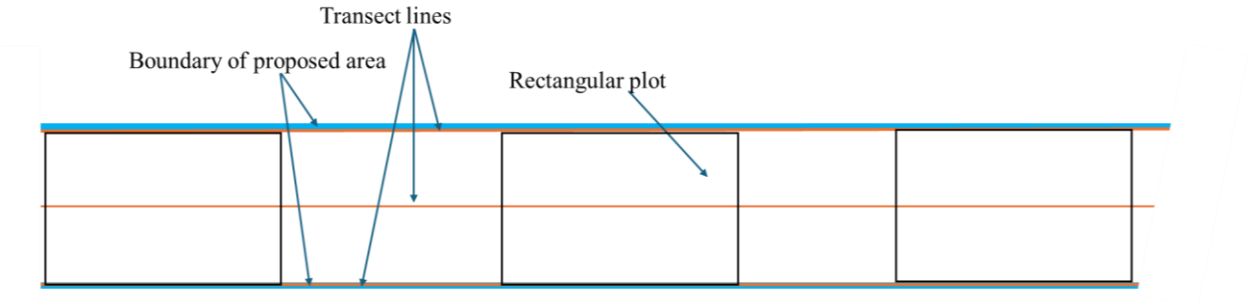
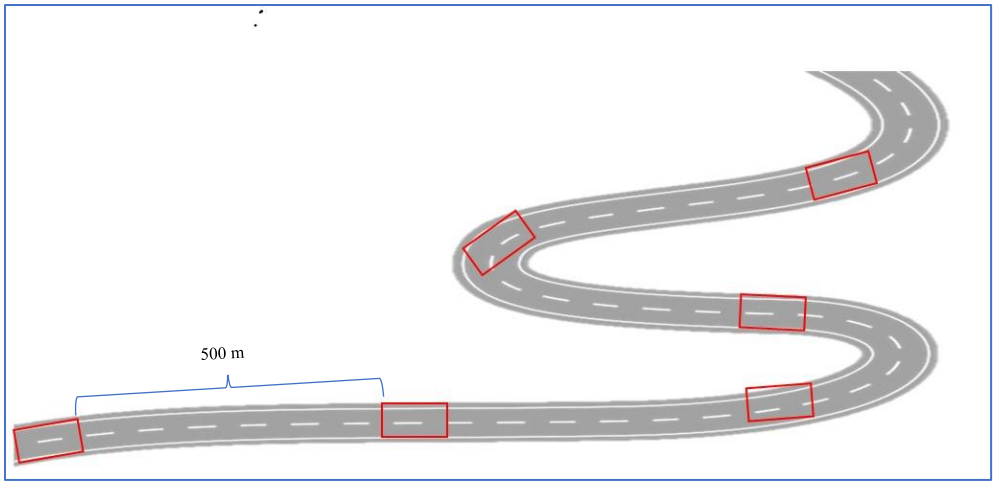


Figure 7: Layout of transect lines and rectangular plot



6. In each rectangular plot, a minimum of 3 transect lines shall be laid with a spacing of 1 – 2.5 m apart (Figure 8) and the transect shall be established and reading taken as discussed in Section 4.2 (2) and (3).

The canopy cover percentage shall be estimated similar to that in circular plots. However, in cases where the observation points are more than 100, the denominator for crown cover percentage formula shall be replaced by total observation points and **NOT** 100. Further, there may be cases

where the boundary of the sample plot overlaps with the adjoining areas. In such cases, the observation shall be taken from the entire plot boundary whether the observation point is within or outside the boundary area of interest.

5 CONCLUSION

The Guidelines for Canopy Cover Assessment in SRFL for Developmental Activities is developed to assist the Divisional Forest and Protected Area Offices in estimation of canopy cover and accordingly delineation of the SRFL into Forests and Non-Forests. This is developed mainly to aid the forest officials in the issuance of forestry clearance with respect to the increasing demand for allotment of the SRFL for many purposes. The principles of canopy cover assessment are in line with current practices adopted in line with Volume II and Volume III of the Forest and Nature Conservation Code of Best Management Practices 2021. However, there are additional provisions and guidance for canopy cover assessment in areas where establishment of circular plots is not feasible. In such cases, rectangular plots are established. Further, there is an increase in the minimum number of observations prescribed for an area of 500 m^2 ; a minimum observation point of 100 is recommended for accurate estimation of canopy cover. The guideline is developed after comprehensive literature review and field testing in Thimphu by FMID, followed by field test by all field offices and final consultation workshop held in Haa in May 2024. However, it is a dynamic document and shall be updated as and when required.

6 ANNEXURE

Annexure 1: Data Collection Form

Data Recording Form for Canopy Cover Assessment																	
Name of Area									**Date**								
Plot No.									**Data Recorder**								
Obser-vation	**C/tally-non-tally**		**Obser-vation**	**C/tally-non-tally**		**Obser-vation**	**C/tally-non-tally**		**Obser-vation**	**C/tally-non-tally**		**Obser-vation**	**C/tally-non-tally**		**Obser-vation**	**C/tally-non-tally**	
1			21			41			61			81			101		
2			22			42			62			82			102		
3			23			43			63			83			103		
4			24			44			64			84			104		
5			25			45			65			85			105		
6			26			46			66			86			106		
7			27			47			67			87			107		
8			28			48			68			88			108		
9			29			49			69			89			109		
10			30			50			70			90			110		
11			31			51			71			91			111		
12			32			52			72			92			112		
13			33			53			73			93			113		
14			34			54			74			94			114		
15			35			55			75			95			115		
16			36			56			76			96			116		
17			37			57			77			97			117		
18			38			58			78			98			118		
19			39			59			79			99			119		
20			40			60			80			100			120		
Total																	

Note: This tally sheet should be used for each sample plot and if there are more than 100 observation points, an additional tally sheet should be used

7 REFERENCE

Albuquerque et al. 2022. A protocol for canopy cover monitoring on forest restoration projects using low-cost drones. Open Geosciences 2022; 14: 921–929.

FAO. 2015 Testing field methods for assessing the forest protective function for soil and water, Forest Resources Assessment Working Paper No. 185, FAO, 2015

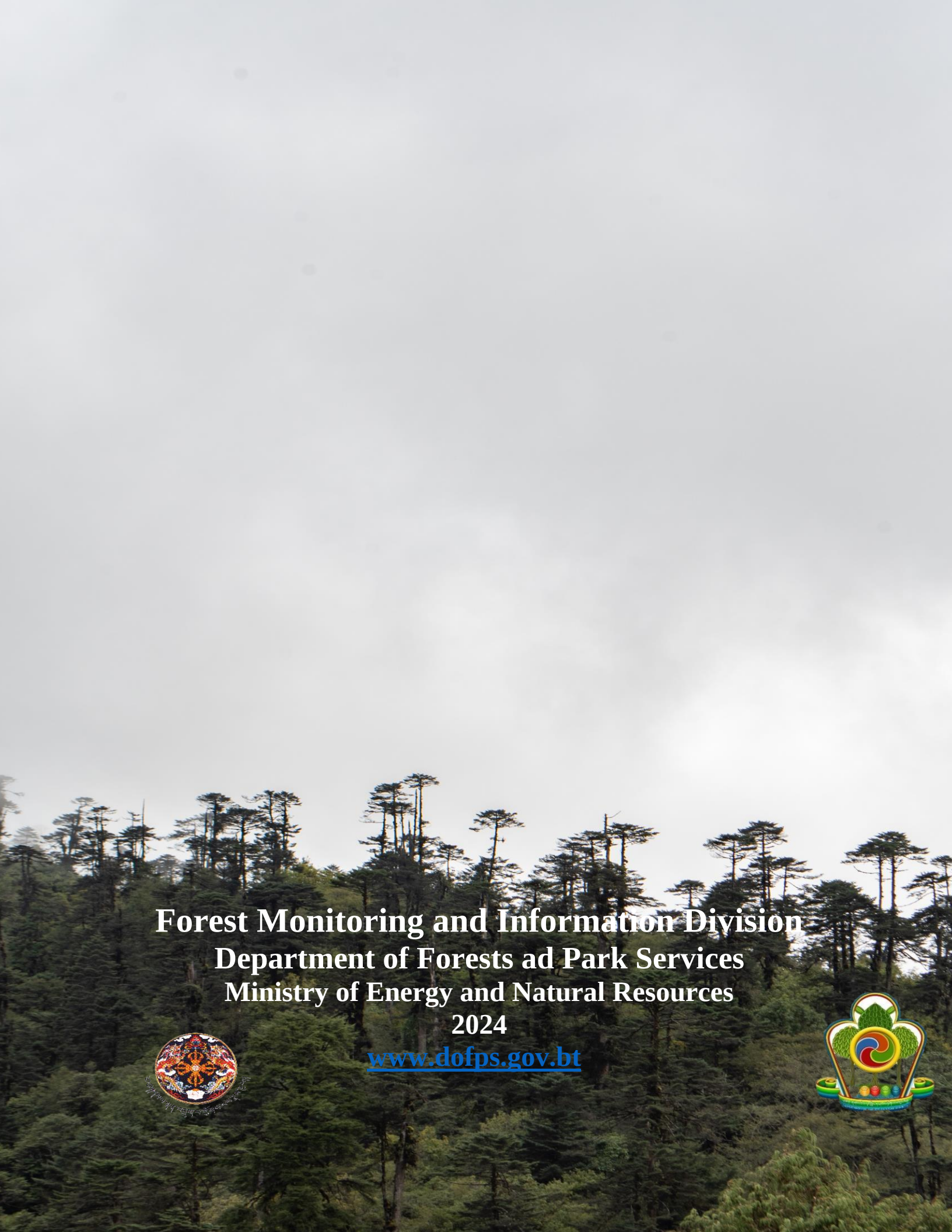
Fiala, A.C.S., Garman, S/L. & Gray, A.N. 2006. Comparison of five canopy cover estimation techniques in the western Oregon Cascades. Forest Ecology and Management 232 (2006) 188-197.

Huynh, M. L. 2005. Assessment of various methods of canopy over estimation that yield accurate results with field repeatability. Northern Arizona University, Flagstaff, AZ 86001-5018 USA. URL. https://nau.edu/wp-content/uploads/sites/140/2005.MHuynh.AssessmentVariousMethodsCanopyCover.pdf

Korhonen, L., Korhonen, K.T., Stenberg, P., Maltamo, M. & Rautiainen, M. 2007. Local models for forest canopy cover with beta regression. Silva Fennica 41(4): 671–685.

Lusk CH. 2022. A field test of forest canopy structure measurements with the Canopy Capture smartphone application. PeerJ 10:e13450 DOI 10.7717/peerj.13450

Stenberg, P., Korhonen, L. & Rautiainen, M. 2008. A relascope for measuring canopy cover. Canadian Journal of Forest Research. Vol. 38: 2545–2550.



Forest Monitoring and Information Division

Department of Forests ad Park Services

Ministry of Energy and Natural Resources

2024

www.dofps.gov.bt