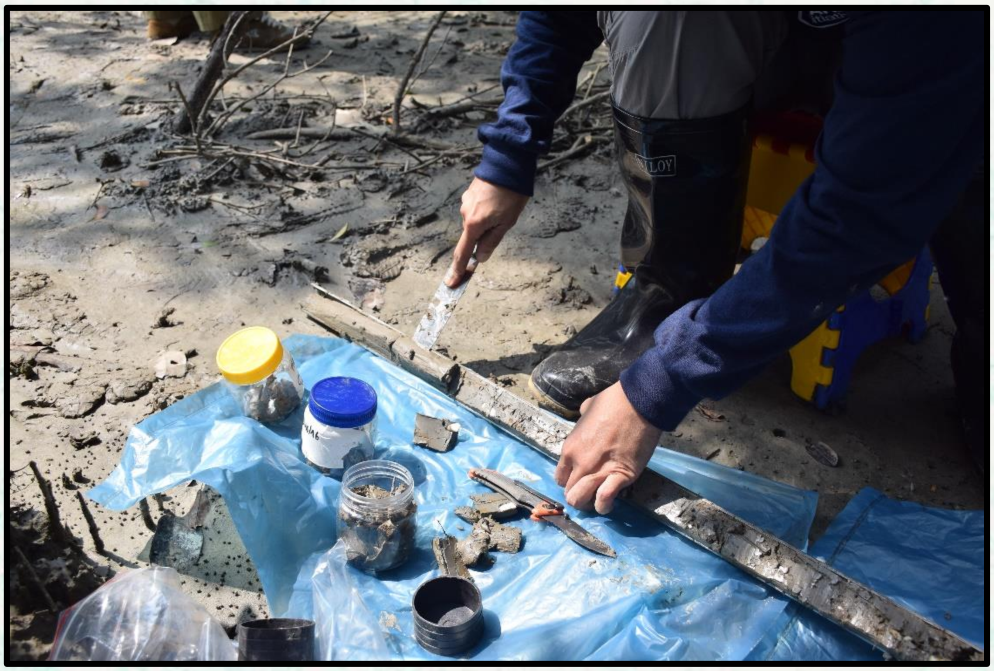
Report on quality assurance and quality control of the soil and litter samples collection and data analysis



Bangladesh Forest Department

October 2017

The Forest Department of Bangladesh leads actions to improve forest management and conservation, adopting forward thinking, innovative approaches in its management of approximately 1.55 million hectares of land across the country.

In 2015, the Forest Department began a process to establish a National Forest Inventory and Satellite Land Monitoring System for improved forest and natural resource management. The process supports national objectives related to climate change mitigation and provides information in support of the UN-REDD programme aimed at Reducing Emissions from Deforestation and Forest Degradation (REDD+). The process also addresses domestic information needs and supports national policy processes related to forests and the multitude of interconnected human and environmental systems that forests support.

The activities implemented under the Bangladesh Forest Inventory process are collaboration between several national and international institutions and stakeholders. National partners from multiple government departments and agencies assist in providing a nationally coordinated approach to land management. International partners, including the United Stated Agency for International Development (USAID) and the Food and Agriculture Organization of the United Nations (FAO) are supporting the development of technical and financial resources that will assist in institutionalizing the process.

The results will allow the Forest Department to provide regular, updated information about the status of trees and forests for a multitude of purposes including for assessment of role of trees for firewood, medicines, timber, and climate change mitigation.

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DISCLAIMER

Executive Summary

Bangladesh Forest Inventory recognized soil as one of the major components to survey in order to support the Government's activities towards sustainable forest management by producing reliable datasets on soil bulk density, soil texture and soil organic carbon. Soil and litter both are important carbon pools in forest.

This report presents the quality of the soil and litter sample collected by the field teams as per BFI design as well as the consistency of data generated through analyzing the soil samples in laboratory. The quality checks were done as per the following process i) identifying the BFI soil and litter survey design, ii) listing the quality checks in terms of number of samples received per subplot, plot, land feature in different zones and value ranges of soil parameters, iii) gathering appropriate literature and formula for assessing soil and litter carbon per hectare, v) preparing a script in R software to do the checks and analysis, vi) identifying the gaps/deviations from BFI soil survey design in soil sample collection, vii) varying the results with the teams and laboratory, viii) recommending for further action.

A total of 15 quality checks for soil and litter were listed preliminarily and checked though r-script. The quality checking indicated that 2 layers with very high value of bulk density (more than 2.65 g/cc). There some sampling error in soil survey. Soil sample from only 1 layer was collected in subplots 3 of plot 1580. In 28 subplots of 9 plots under coastal zone, soil sample was collected from only 2 soil layers. Bulk density samples from 30-100 cm layer was collected unnecessarily from 134 subplots of 18 plots. The soil organic carbon percentage seems very high (>5% organic carbon) than the average value in 3 soil layers of Sundarbans and 9 layers of village zone. The relationship between bulk density and organic carbon follows the general trend if outliers in both bulk density and organic carbon is removed. Few outliers in the soil organic carbon (t/ha) was observed in 0-15 cm depth of Village zone and 15-30 cm depth of both hill and village zone. The quality checks also indicated that 58 soil carbon data from 46 plots are reported from 30-100cm soil depth in village zone which was is out of BFI soil survey design and thus analyzed unnecessarily. Similarly, 58 soil texture data was reported from 30-100 cm soil depth of village zone which seemed as a result of unnecessary sample collection not following the BFI design.

The unknown soil layer (i.e. 15-13cm, 300-100cm) was found representing soil texture data, subsequently which were identified as typos and corrected by the laboratory. Litter organic carbon also showed some outliers in mangrove forests and rubber plantations which may be due to the decomposed leaf that resulted because of late in sending the samples. On the other hand higher leaf dry weight in plain land Sal forest and rubber plantation was understood as a result of leaf shedding in dry season. But the reason of higher leaf dry weight in some land classes i.e. hilly forest, forest plantation, single crop was not clearly explained. The laboratory also noticed some problems regarding soil and litter sample quality, labelling and packaging methods. Some

measures were recommended at the end of this report. It is to be noted that, mistakes or data related problems are usual for any forest inventory. This effort of data quality checking is expected to help in correction measures, identifying the sources of errors, checking errors in the fields and increasing the efficiency of field crews to ensure quality data. It also wort to mention that the r-script was very helpful in checking the data repeatedly and prepared in such a way that it can be used in future for the same purpose.

Acronyms

BD = Bulk Density

BFD = Bangladesh Forest Department

BFI = Bangladesh Forest Inventory

BFRI = Bangladesh Forest Research Institute

CHT = Chittagong Hill Tracts

cm = Centimeter

FAO = Food and Agriculture Organization

FT = Field Teams

ID = identity

m = Meter

NDL = Nutrient Dynamics Laboratory

OC = Organic Carbon

QAQC = Quality Assurance and Quality Control

SOC = Soil Organic Carbon

t/ha = Ton per Hectare

UN = United Nations

USAID = United States Agency for International Development

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1. Introduction

Bangladesh Forest Department (BFD) with the technical support from Food and Agricultural Organization (FAO) of the UN conducting Bangladesh Forest Inventory (BFI) with cross-disciplinary collaboration from affiliated government agencies, academic institutions, non-government organizations, private industry and development partners. BFI is aimed at supporting the Government´s action towards sustainable forest management through the development of regular, reliable datasets related to trees and forests. Soil is an important component of forest work as one of the carbon sink, support trees with nutrients and indicates changes in the forest health. Bangladesh Forest Inventory (BFI) has recognized the soil properties and litter in different zones of Bangladesh as essential tools for evaluating forests, identifying and assessing changes in forests and after all tracing the national development over time.

Soil is one of the major carbon pools among the five pools i.e. i) aboveground and belowground biomass of live trees, ii) non-tree vegetation, iii) dead wood, iv) forest floor (litter), and v) soil. One of the aims of BFI is to provide harmonized soil and litter data with other related information for national and international purposes in order to support quantification of carbon and greenhouse gas emission factors due to degradation and possibly deforestation, and contribute to the improvement of C forest data that can increase the importance of the forest sector.

The first session of the field survey of BFI, which started in November 2016, has been completed in April 2017. A total of eleven teams consisting of 7 members each as field team conducted the field survey. The quality assurance and quality control (QA/QC) is an essential process for any inventory in order to ensure the generation of reliable and consistent data for assessment of the important variables as well as to compare with future inventory data to trace the changes over time. The QA/QC process during a survey helps in identifying the faults in data collection and taking immediate actions. QA/QC process of soil and litter focuses on the qualitative and quantitative specifications required to meet the current field manual and data standards. In BFI the preliminary quality of the soil and litter samples were assessed prior to laboratory analysis in terms of number of sample in specified depths, physical damage and usability for analysis. After quality checking the soil and litter data is analyzed by Nutrient Dynamics Laboratory of Khulna University. Soil samples were analyzed to determine soil texture, bulk density and organic carbon. The litter data were analyzed to assess carbon stock in litter.

This report presents the quality of the soil and litter sample collected by the field teams in the 1st session of data collection as per BFI design as well as the data standards. The quality checks were done as per the following process i) identifying the BFI soil and litter survey design, ii) listing the quality checks in terms of the number of samples received per subplot, plot, land feature in different zones and value ranges of soil parameters, iii) gathering appropriate literature and formula for assessing soil and litter carbon per hectare, v) preparing a script in R software to do the checks and analysis, vi) identifying the gaps/deviations from BFI soil survey design in soil sample collection, vii) varying the results with the teams and laboratory, viii) recommending for further action.

The report aims at ensuring standards of soil and litter data as per BFI manual (BFD 2016b) through identification of errors/flaws in soil or litter data and recommending necessary actions for maintaining data quality and standards.

2. Methodology

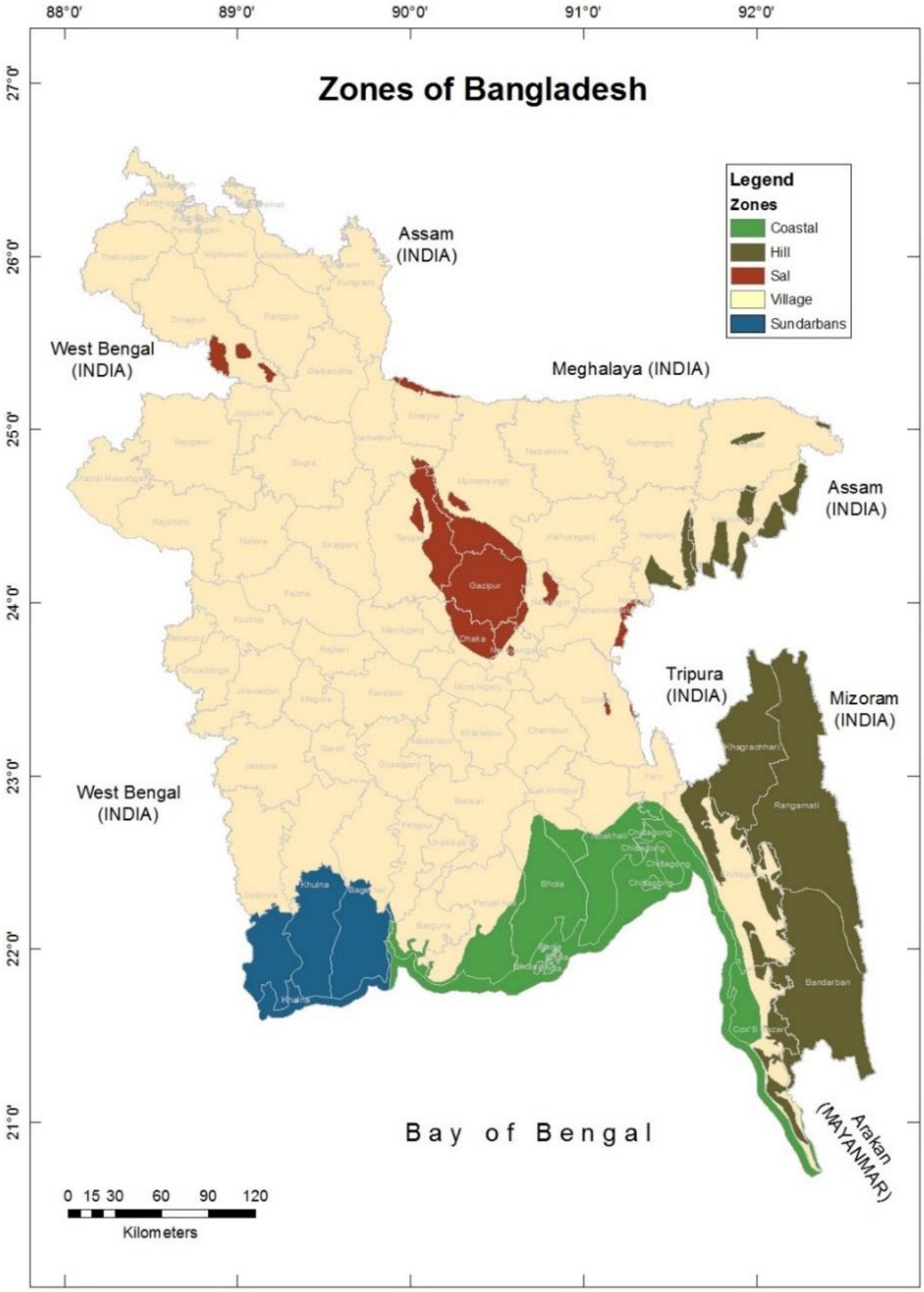
There are numbers of methods for measuring soil and litter properties for assessing carbon and emission factors; however, focus of this report is to adapt international standards that enable to compare the data with previous years.

2.1 Sampling design

BFI divided the whole country into five forest zones named i) Hill forest zone, ii) Sal forest, iii) Villages, iv) coastal, and v) mangroves (Figure 1). Soil samples have been collected from surveyed plots in all the five zones of Bangladesh by the field teams.

2.1.1 Sampling design at plot level

In BFI a plot is situated in a systematic grid across the forest, at regular intervals of latitude and longitude, and consist of five circular subplots in Hill, Sal and Village zones but in case of Sundarbans and Coastal zones a plot is composed of three subplots. As per the soil survey design, the plot oriented as a center subplot with two subplots oriented in two cardinal directions from the center (north and east). This clustered sample units gives a composite sample for three subplots for each plot in the case we have only one land feature, if different land features at the center of each selected subplot exist, soil samples for soil OC and bulk density are not composed (Figure 2) (Sidik et al. 2016).



Source: Akhter, M., Jalal, R., Costello, L., Rahman, L., & Tasnuva, U. (2016). Zoning for Tree and Forest Assessment in Bangladesh.Retrieved from Dhaka

Figure 1: Zones used for stratifying Bangladesh Forest Inventory

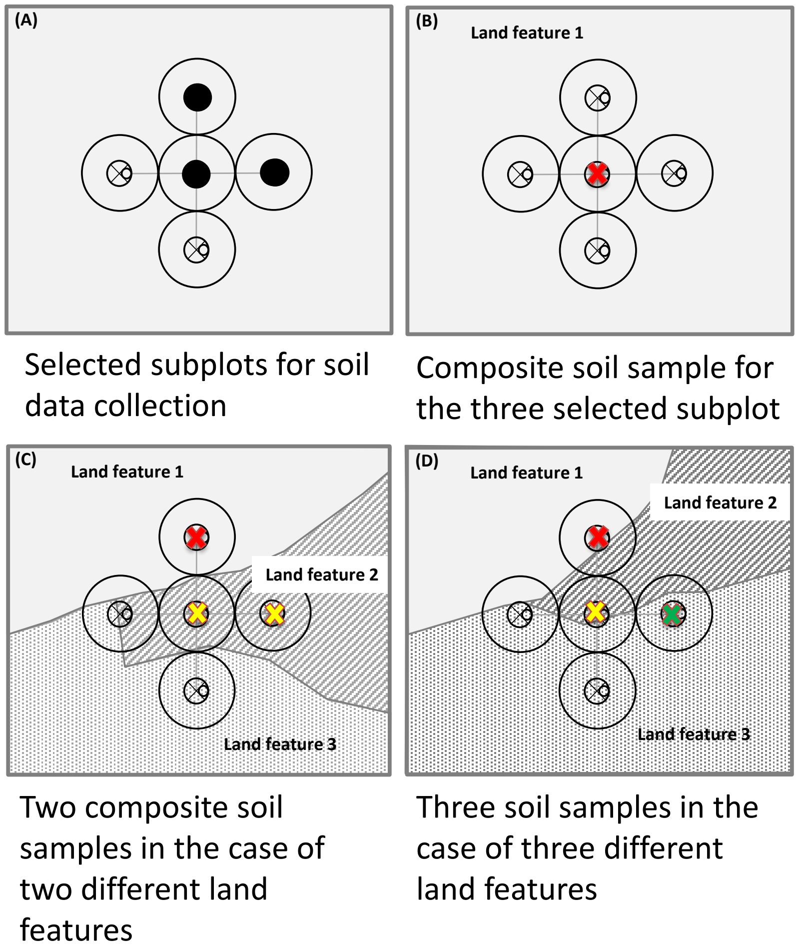


Figure 2: Composition of soil samples depending on the presence of land features

2.1.2 Sampling design at subplot level

Soil and litter samples are collected from 8 m distance at 270 bearing from the center of each three subplots (Figure 3). Systematically generated code for the soil and litter samples to be tagged on the samples until laboratory analysis. The samples are labeled with plot number, subplot number, land feature identity, sample type, soil depth, core size (i.e. half core or half core) (BFD 2016).

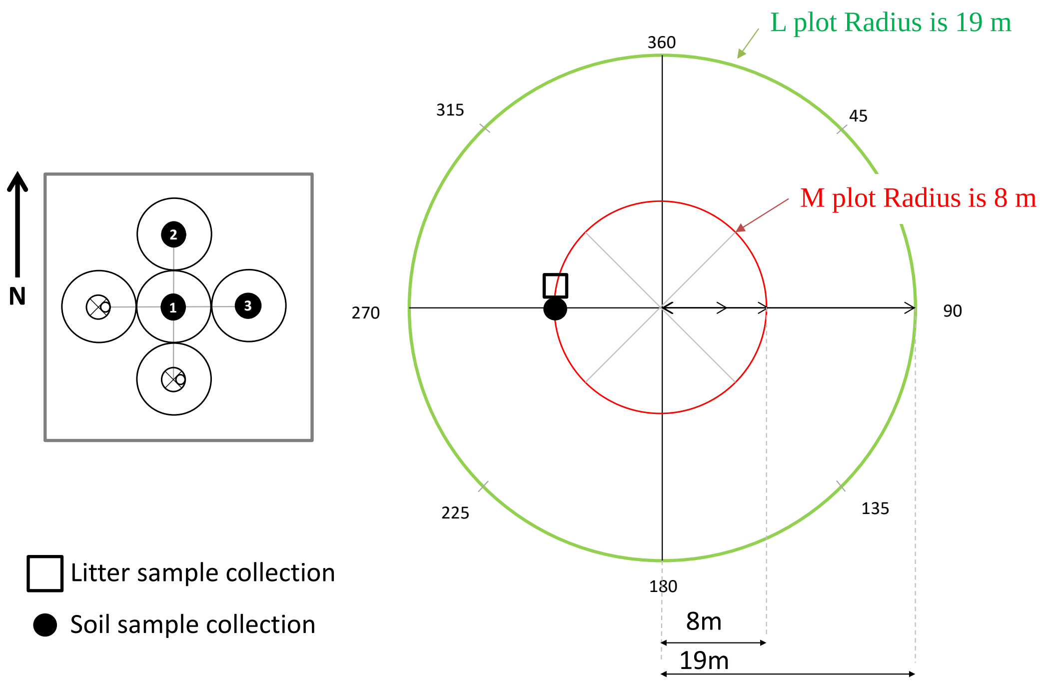


Figure 3: Soil and litter samples are collected in subplots 1-3 in all zones

2.2 Data collection method

In each subplot soil samples were collected in two major ways. Samples for bulk density is collected from 5-10 cm, 20-25 cm depths in all forest zones with an additional sample from depth 65-70 cm in Sundarbans and Coastal zones. Another type of sample, for texture and soil carbon analysis, is taken from 0-15 cm, 15-30 cm depths from all zone with an additional sample from 30-100 cm depth in Sundarbans and Coastal zone (Figure 4).

At first the surface litter and weeds from the sampling spot are scraped away with the help of a spade/*belcha*. An augur is inserted into ground by rotating for soil texture and organic carbon sample collection. Cylindrical steel ring of 5 cm length used for collecting bulk density samples from different depths. If in any case the soil is hard enough and the augur or steel ring cannot be intruded into soil for sample collection in that case pit method is used to collect samples from prescribed depth using a shovel or spade. In the coastal and Sundarbans, the soil muddy, an open faced long augur is used for collection of soil. A plastic container is used to securely pack each soil texture sample. Litter is collected from 1m×1m square plot adjacent to soil collection point and packed in a perforated polythene. Immediately after collection, the samples were sent to the laboratory for analysis.

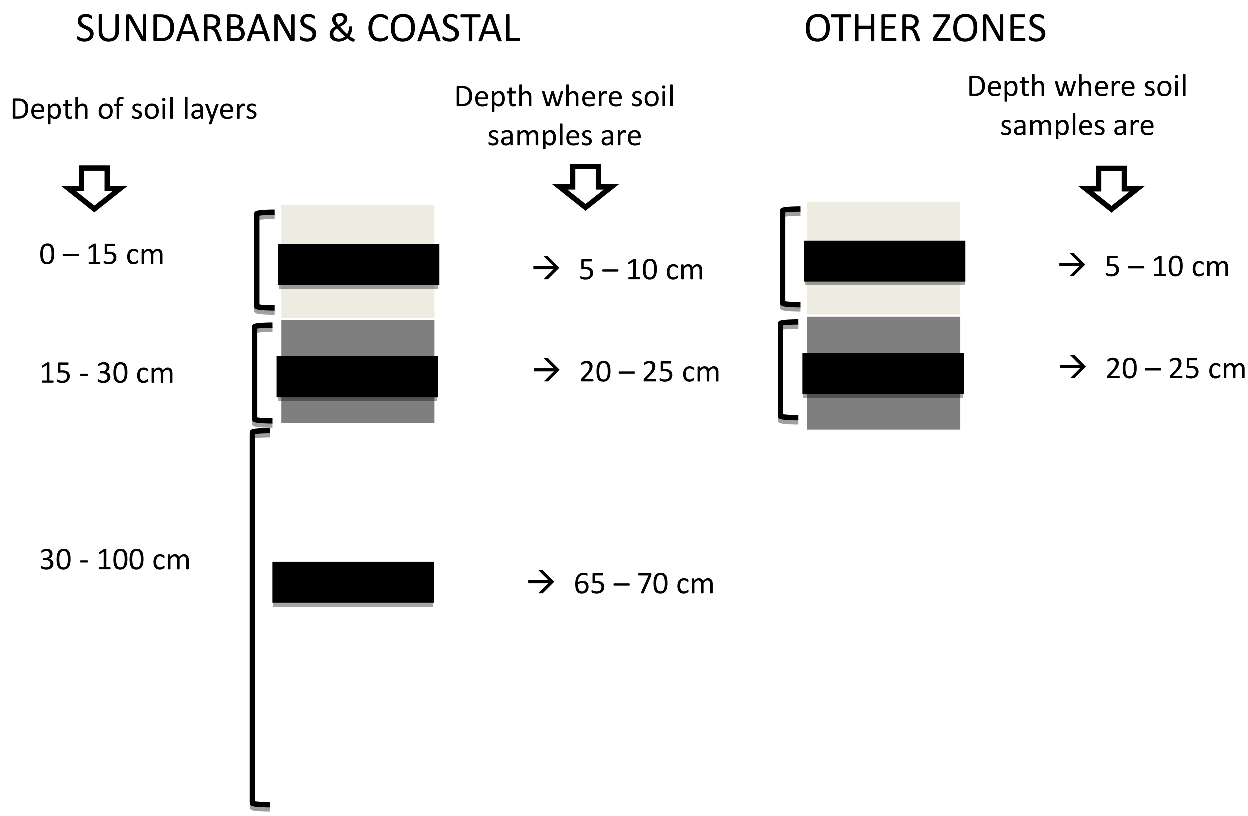


Figure 4: Collection of soil samples for bulk density measurement in different zones

2.3 Soil and litter analysis

After the preliminary quality checking, the soil samples were analyzed for bulk density, soil texture and soil organic carbon in the Nutrition Dynamics Laboratory (NDL) of Khulna University. The whole analysis process followed the procedure mentioned in the soil measurement manual for Bangladesh Forest Inventory (BFD, 2016a).

Soil organic carbon percentage is converted into soil organic carbon t/ha using the following formula-

soil organic carbon (t/ha) = Bulk density (g/cm3) × OC (%) × Soil depth interval (cm) × 10^2

Here, soil depth interval is 15 cm for 0-15 cm depth interval, 15 cm for soil depth 15-30 cm depth interval, and 70 cm for 30-100 cm interval. OC (%) is expressed as a decimal fraction (e.g., 5% is expressed as 0.05) and 10^2 is a conversion factor to convert the units to t/ha. The calculation method followed the protocol of Donato et al. (2009).

2.4 Data quality checking

After getting the laboratory data, we have checked the data from different point of view i.e. i) if the number of samples received from the field teams is match with the survey design, ii) if the data is within the standard range applicable for Bangladesh that means if there is any outlier, iii) if the relationships between soil organic carbon and bulk density is usual, iv) if the soil sample collection depths are consistent with BFI manual. Based on the points we determined some quality checks as mentioned below-

CHECK 01: Check the compatibility of bulk density data by forest zone considering the soil condition of Bangladesh in order to identify the outliers

CHECK 02: Check if the number of bulk density data for different soil depths/layer in different forest zones is appropriate or not as per BFI manual

CHECK 03: If the number of subplots from which soil bulk density data was reported is 3 in all plots that were accessible or surveyed completely

CHECK 04: To check the soil organic carbon values, if they are within acceptable range or not

CHECK 05: To identify i) plots having only soil carbon data but no BD data, andii) plots with mismatched land feature in bulk density and soil carbon data

CHECK 06: To see the relationship between bulk density and soil carbon and evaluate visually if there is any abnormal relationship

CHECK 07: To see if there is any outlier in amount of soil carbon (t/ha) in the five forest zones

CHECK 08: To check if any soil organic carbon data is reported from any soil or layers that is outside the specified soil layers in BFI manual

CHECK 09: To identify the plots and subplots in which the soil sample is collected from layers other than specified by BFI manual in different forest zone [2 defined layers in hill, village and Sal forests are 0-15cm and 15-30 cm; 3 specified layers in Sundarbans and coastal forests are 0-15 cm, 15-30cm and 30-100 cm]

CHECK 10: To identify the layers if it is not matched with BFI soil survey design or if any unknown layers is written in the data sheet

CHECK 11: To identify the outliers in percentages of clay, silt and sandy particles in soil [i) if the sum of sand, silt and clay percentage is 100 or not; ii) if there are any outliers/negative values.]

CHECK 12: To see if there is any outlier in the litter carbon (%)

CHECK 13: To see the relationship in order to check the consistency between canopy coverage and leaf oven dry weight

CHECK 14: To see if there are any subplots having more than one litter dry weight data

CHECK 15: Identify the plots with mismatched land feature id in litter carbon and litter dry weight data

The quality checking was using R software, a R-script has been prepared to check the data quality and data consistency (Appendix 1).

3. Results of the Quality Checks

The outputs of the data quality checking are broadly categorized based on bulk density, soil texture, soil organic carbon and litter carbon. The following parts of the results section presents the findings of the quality check.

3.1 Soil Bulk Density

CHECK 01: Check the compatibility of bulk density data by forest zone considering the soil condition of Bangladesh in order to identify the outliers

[***input****: soil bulk density data;* ***output****: list of plots, subplot with strange value (value > 2.0 g/cc) of bulk density data*]

Bulk density data revealed that there are 13 soil layers with very higher (from 2 - 14.09 g/cc) bulk density values. As per the BFI manual in Bangladesh the normal soil has lower bulk density (0.1 - 0.6 g cm-3) than minerals (1.0 - 1.8 g cm-3). After being informed about the outliers the authority of Nutrition Dynamics Laboratory responded that the bulk density value 14.09 g/cc was a typing mistake and corrected as 1.41. The laboratory also explained that bulk density greater than 2 g/cc may due to the samples contained gravels. Especially the plots in Sylhet, Dinajpur, Thakurgaon and Panchagarh may contain small garbles which may increase the bulk density value. Theoretically, bulk density depends on soil organic matter, soil texture, the density of soil mineral (sand, silt, and clay) and their packing arrangement. As a rule of thumb, most rocks have a density of 2.65 g/cm3 so ideally, a silt loam soil has 50% pore space and a bulk density of 1.33 g/cm3. Sandy soils have relatively high bulk density since total pore space in sands is less than silt or clay soils, hence the value lies between 1.3-1.7 g/cm^3. Peat soil have very low bulk density close to 0.11 g.cm^3. However, bulk density values >2.0 g/cc needs to be checked with location and quality of core samples. Considering the rule of thumb and the corrected data was check again bulk density outliers. Following figures (Figure 6 and Table 1) presents the outliers.

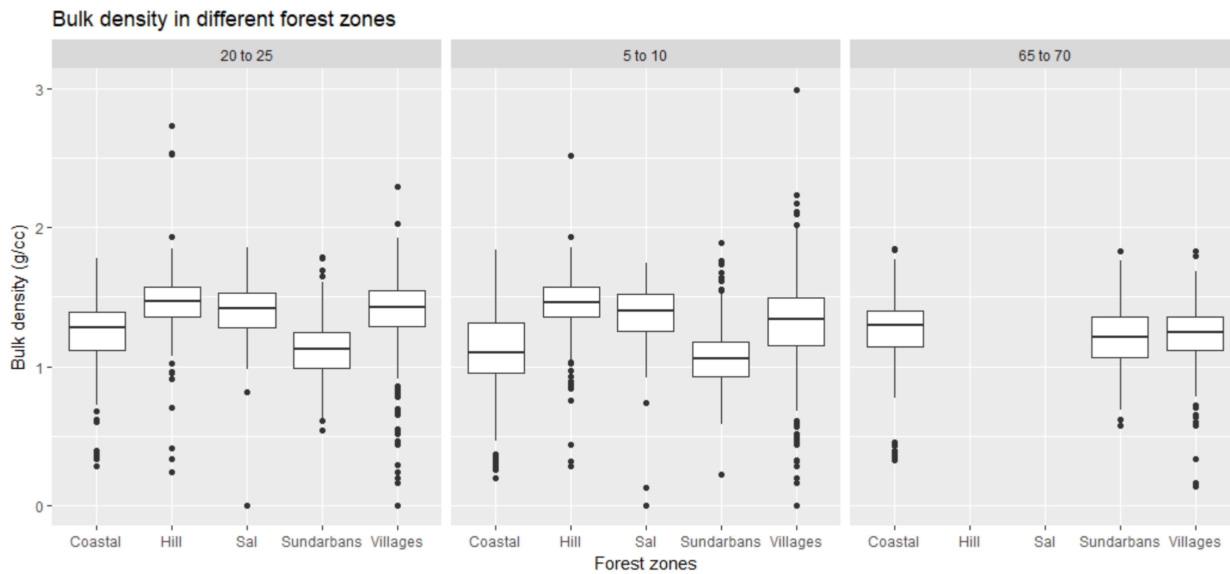


Figure 5: Bulk density of soil in different soil depths of five forest zones

However, considering the rule of thumb, 2 soil depths have bulk density more than 2.65 g/cc which seemed outliers (Figure 2). Moreover, there are 38 more soil layers for which bulk density is reported to be 0 which is strange (Figure 1). The laboratory authority explained that the zero values was by mistake these would be removed from the database. Since, the zero values are still in the last database provided by laboratory officially. The Detail list of plots with strange values/outliers are shown in the Appendix 1.

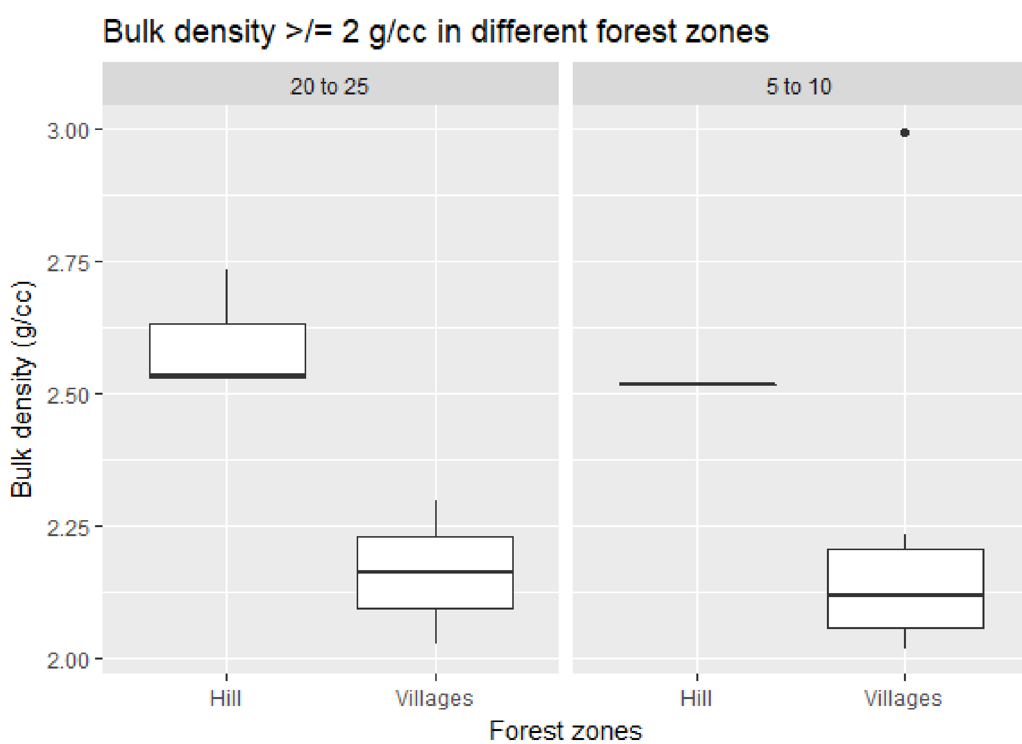


Figure 6: Bulk density ≥2 g/cc in different forest zones that seems outlier [*Detail in Table 1*]

Table 1: Plots, subplots and soil depths with bulk density ≥ 2.65 g/cc and zero

SN	Plot id	Subplot no	Depth (cm)	Land feature no	Bulk density (g/cc)	Location zone	Team
1	196	3	5 to 10	1	2.995521	Villages	13
2	947	2	20 to 25	1	2.73215	Hill	1
3	1204	1	5 to 10	1	0	Sal	6
4	1204	2	5 to 10	1	0	Sal	6
5	1204	3	5 to 10	1	0	Sal	6
6	1204	1	20 to 25	1	0	Sal	6
7	1204	2	20 to 25	1	0	Sal	6
8	1204	3	20 to 25	1	0	Sal	6
9	1207	1	5 to 10	1	0	Sal	6
10	1207	2	5 to 10	1	0	Sal	6
11	1207	3	5 to 10	1	0	Sal	6
12	1207	1	20 to 25	1	0	Sal	6
13	1207	2	20 to 25	1	0	Sal	6
14	1207	3	20 to 25	1	0	Sal	6
15	1210	1	5 to 10	1	0	Sal	6
16	1210	2	5 to 10	1	0	Sal	6
17	1210	3	5 to 10	1	0	Sal	6
18	1210	1	20 to 25	1	0	Sal	6
19	1210	2	20 to 25	1	0	Sal	6
20	1210	3	20 to 25	1	0	Sal	6
21	1211	1	5 to 10	1	0	Sal	6
22	1211	2	5 to 10	1	0	Sal	6
23	1211	3	5 to 10	1	0	Sal	6
24	1211	1	20 to 25	1	0	Sal	6
25	1211	2	20 to 25	1	0	Sal	6
26	1211	3	20 to 25	1	0	Sal	6
27	1213	1	5 to 10	1	0	Villages	6
28	1213	2	5 to 10	1	0	Villages	6
29	1213	3	5 to 10	1	0	Villages	6
30	1213	1	20 to 25	1	0	Villages	6
31	1213	2	20 to 25	1	0	Villages	6
32	1213	3	20 to 25	1	0	Villages	6
33	1217	1	5 to 10	1	0	Sal	6
34	1217	3	5 to 10	1	0	Sal	6
35	1217	1	20 to 25	1	0	Sal	6
36	1217	3	20 to 25	1	0	Sal	6
37	1246	2	5 to 10	1	0	Villages	6
38	1246	3	5 to 10	1	0	Villages	6
39	1246	2	20 to 25	1	0	Villages	6

SN	Plot id	Subplot no	Depth (cm)	Land feature no	Bulk density (g/cc)	Location zone	Team
40	1246	3	20 to 25	1	0	Villages	6
41	1366	3	5 to 10	1	0	Villages	6

The following Figures (Figure 7 and

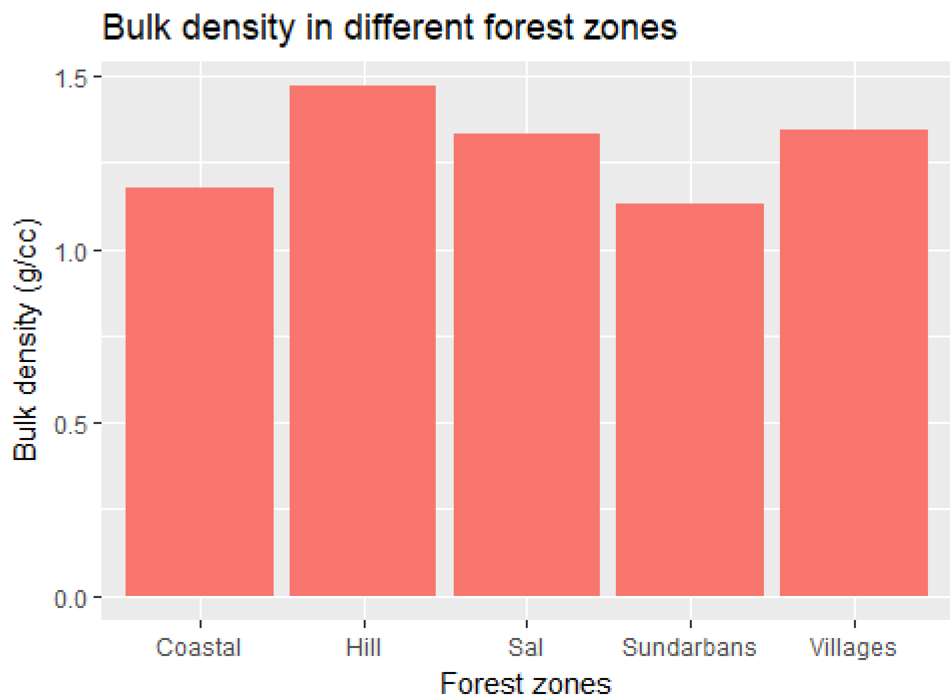


Figure *8*) presents average bulk density in different soil layers of the five forest zones.

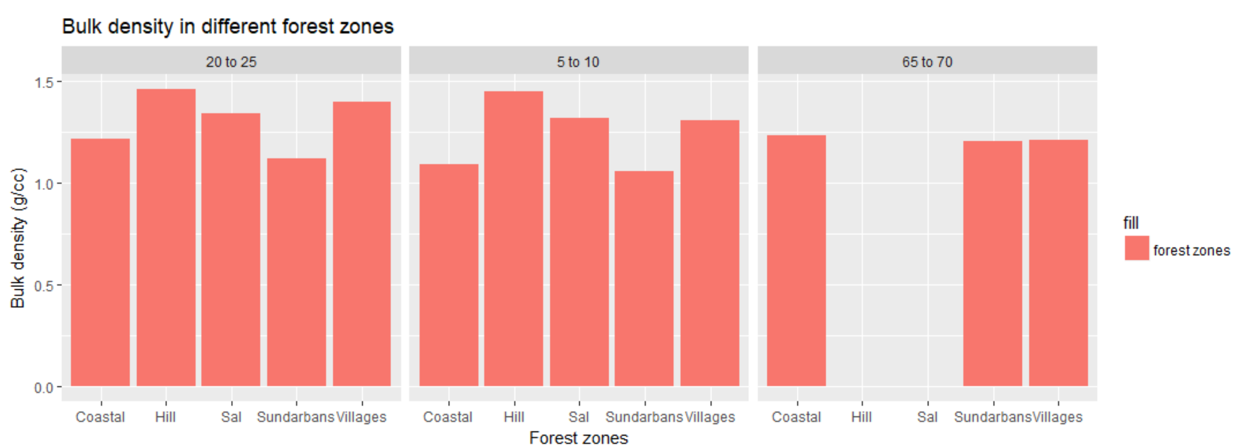


Figure 7: Average bulk density in different soil layers of different forest zones

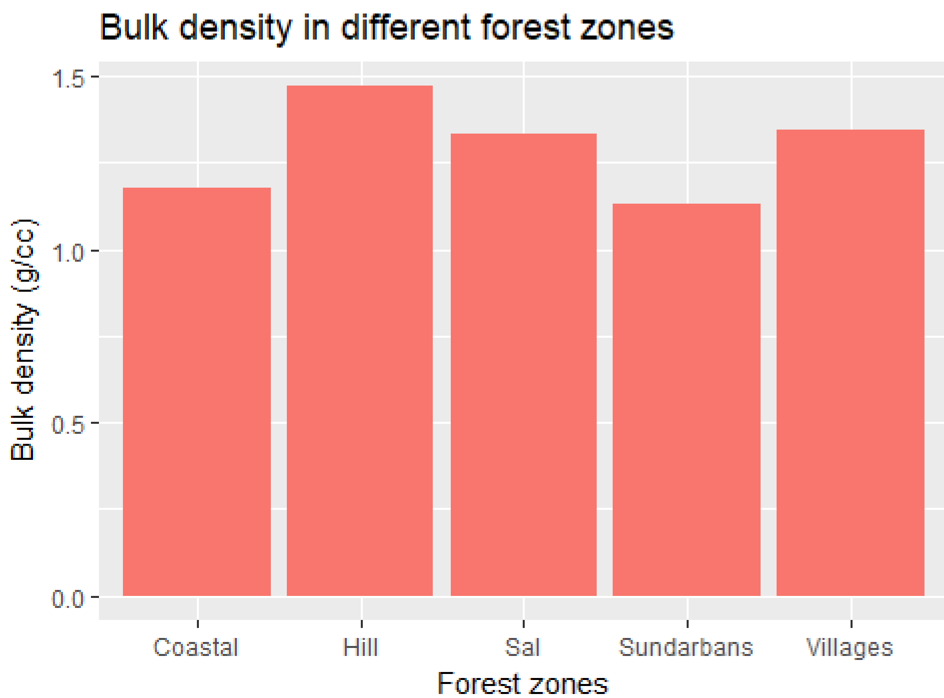


Figure 8: Average bulk density per soil depth in different forest zones

CHECK 02: Check if the number of bulk density data for different soil depths/layer in different forest zones is appropriate or not as per BFI manual

[***input***: *bulk density data;* ***output***: *the number of soil depth/layer not appropriate as per BFI manual]*

As per design of BFI manual soil sample for bulk density analysis is need to collect from two layers (5-10 cm and 20-25 cm) of Hill Forest, Sal Forest and Village Forest zone. For Sundarbans and Coastal zones, the layer number is three layers (5-10 cm, 20-25 cm and 65-70 cm). But bulk density data is available for-

i. only 1 soil layer in a subplot from Sal zone,
ii. only 2 soil layers in 28 subplots from coastal zone
iii. 3 soil layers in 134 subplots from village zone (Figure 9)

List of the subplots with necessary details is given in the appendix 1.

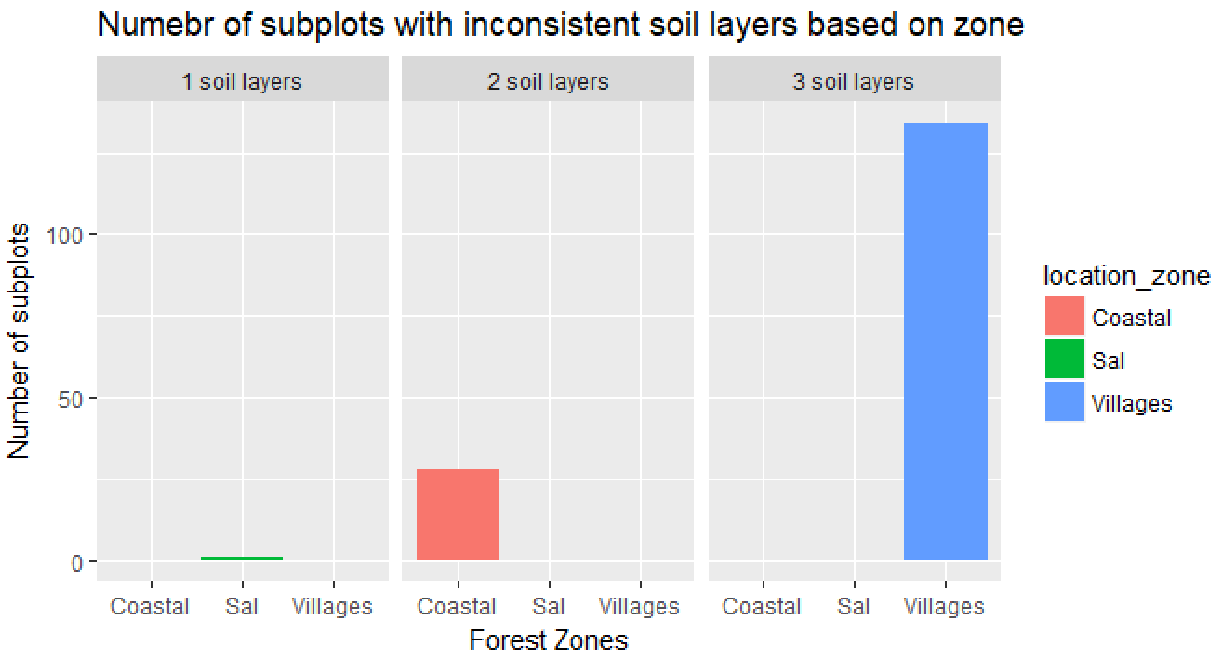


Figure 9: Number of subplots in which inconsistency in number of soil layers found based on forests zones [*Details in Appendix 1*]

CHECK 03: To check, in case of completely accessible or surveyed plots, whether the number of bulk density data reported from 3 subplots or not.

[***input***: *bulk density data;* ***output***: *number of completely sampled plots with < 3 subplots from which soil bulk density was reported and list of those plots]*

It was supposed to take soil sample from first three subplots (1-3) for analyzing bulk density. So, the number of bulk density data from different plots indicated that there were some plots that sampled completely but bulk density data is available for only two subplots (Figure 10). May soil sample was not collected from all three (1-3) subplots or there was mistake in the data input. The list of the plots is given in the appendix 2.

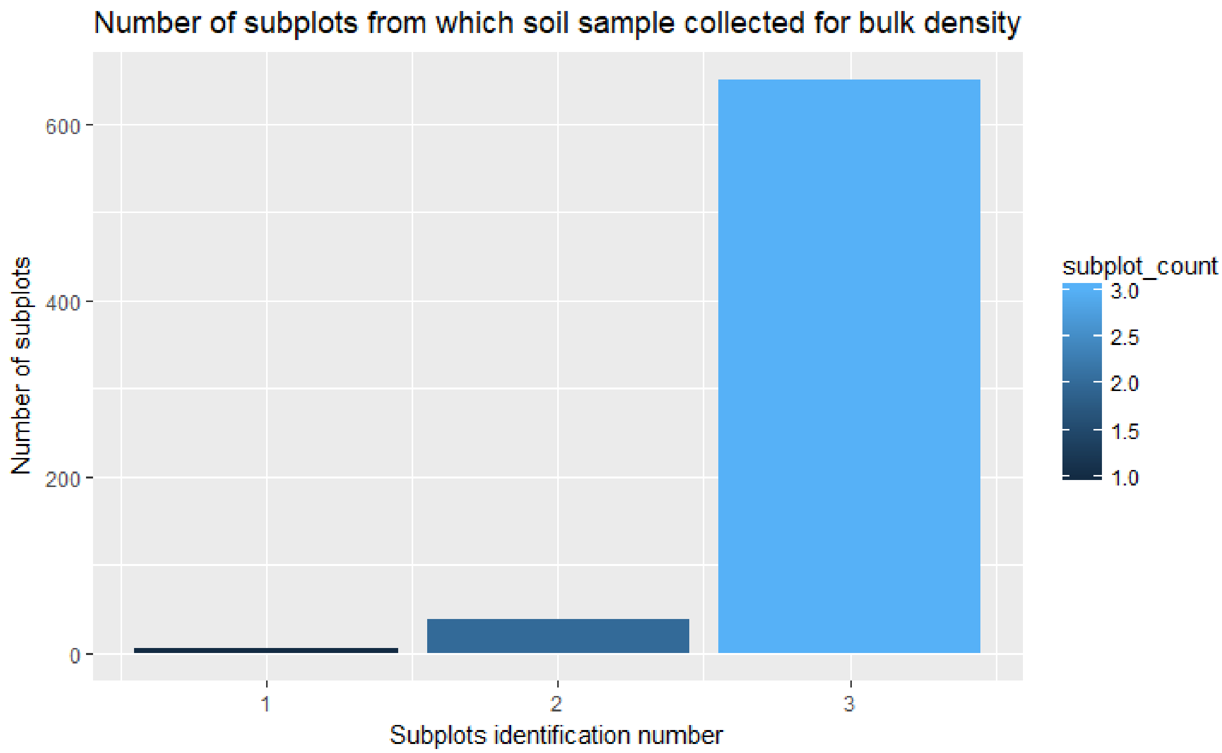


Figure 10: Number of completely sampled plots in which soil sample was collected (for bulk density) from only 1 and 2 subplots [*Details in Appendix 2*]

3.2 Soil organic carbon

Soil organic carbon was assessed from the soil samples collected for soil texture. The soil organic carbon data is checked with the following processes.

CHECK 04: To see the soil organic carbon values, if they are within normal range or not

[***input****: Soil organic carbon data;* ***output****: unusual presence soil layers, outliers in organic carbon data and number of soil layers in which outliers (strange) data was found]*

Soil Organic Carbon (SOC) data were first checked with the number of soil depths. It was found that some plots and land features are associated with unusual number and depth of layer (Table 2). In some cases, plots have SOC (%) data for 15-30 cm and 30-100 cm layer but lacking same data for 0-15 cm layer (i.e. plot id 201). Some plots are having 4 soil layers (i.e. 854 plots have 4 layers).

Table 2: Strange number and presence of soil layer in soil carbon data

Plot id	Lf id	Issue	Team	Soil layer	SOC (%)	Location zone

201	1	Strange number of soil layer	11	30-100	3.538103	Villages
201	1	Strange number of soil layer	11	15-30	1.935946	Villages
530	1	Strange number of soil layer	4	30-100	1.484859	Sundarbans
530	1	Strange number of soil layer	4	15-30	1.873476	Sundarbans
534	1	Strange number of soil layer	4	15-30	1.442735	Sundarbans
541	1	Strange number of soil layer	4	15-30	1.425377	Sundarbans
854	1	Strange number of soil layer	9	0-15	0.216382	Villages
854	1	Strange number of soil layer	9	15-30	1.69127	Villages
854	1	Strange number of soil layer	9	15-30	0.182523	Villages
854	1	Strange number of soil layer	9	0-15	2.246498	Villages
1369	1	Strange number of soil layer	6	0-15	0.981758	Villages
1369	2	Strange number of soil layer	6	0-15	0.95304	Villages
1369	2	Strange number of soil layer	6	15-30	0.672854	Villages
1369	2	Strange number of soil layer	6	15-30	0.727491	Villages
1457	2	Strange number of soil layer	8	0-15	1.838041	Sal
1457	1	Strange number of soil layer	8	0-15	1.48108	Sal
1457	1	Strange number of soil layer	8	15-30	1.551481	Sal

Quality check of the value of soil organic carbon data showed that some organic carbon data are too high than the average or normal range. It is not necessarily true that the soil organic carbon >/= 5% is outlier but seems abnormal in comparison to the average range. The following graph (Figure 11 and Figure 12) presents the organic carbon (%) in different layers. A detail list is also provided in the Appendix 3.

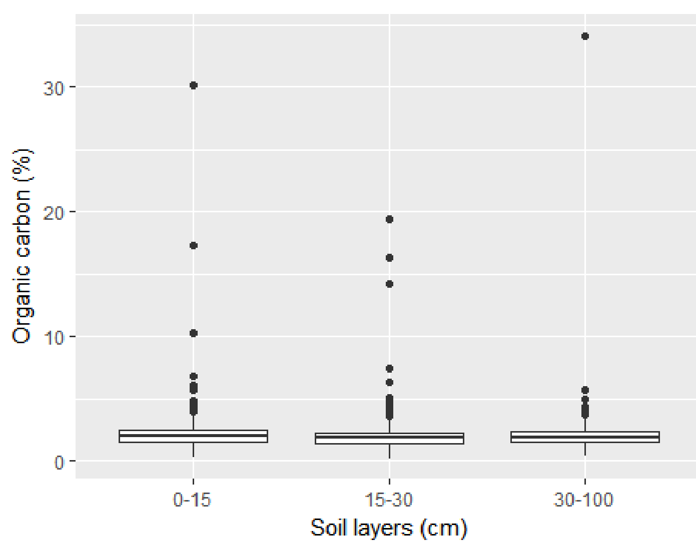


Figure 11: Average organic carbon (%) in different soil layers

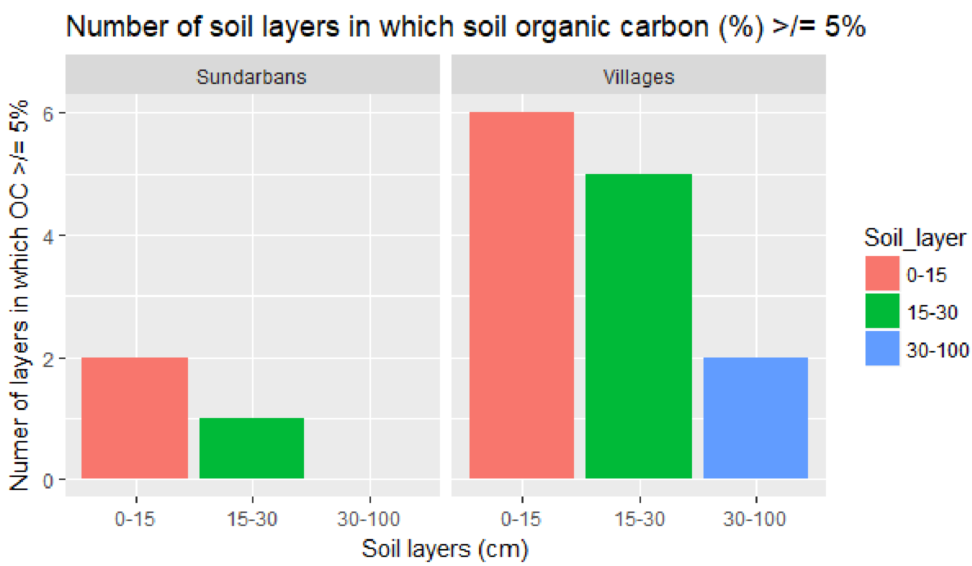


Figure 12: Number of strange values of organic carbon in different soil layers [Details in Appendix 3]

CHECK 05: To identify-i) plots having only soil carbon data but no BD data, and, ii) plots with mismatched land feature in bulk density and soil carbon data

[***input:*** *Soil BD and organic carbon data,* ***output:*** *list of plots with only organic carbon data but no BD data, plots with nonmatching land feature number*]

The check is done in order to identify the mismatches in land feature of soil carbon and soil bulk density data tables. However, the check indicated that for 5 plots there is some mismatches of land features (Table 3). For example, bulk density data is given for land feature 1 and 2 but soil carbon data is given only for land feature 3. Since, all the soil samples are yet to be analyzed and delivered to FAO by the NDL, so the mismatches may be due to the supply of partial data for some plots by the laboratory.

Table 3: List of plots with mismatches in land features in soil carbon and soil bulk density data

SN	Plot id	Issue	Team
1	188	Soil carbon data available for LF 3 but BD is available for LF 2	13
2	188	Soil carbon data available for LF 3 but BD is available for LF 1	13
3	225	Soil carbon data available for LF 2 but BD is available for LF 1	2
4	368	Soil carbon data available for LF 2 but BD is available for LF 1	7
5	368	Soil carbon data available for LF 2 but BD is available for LF 3	7
6	373	Soil carbon data available for LF 1 but BD is available for LF 2	7
7	1030	Soil carbon data available for LF 3 but BD is available for LF 1	10

CHECK 06: To see the relationship between bulk density and soil carbon and evaluate visually if there is any abnormal relationship

[***input:*** *Soil organic carbon data,* ***output:*** *graphs indicating the relationship between soil organic carbon and bulk density]*

In general, there is inverse relationship between the soil organic carbon and bulk density. The following graphs (Figure 13) presents the relationship between Bulk density and soil organic carbon. The graph was supposed to show some sorts of pattern but the pattern is not clear may be because of the outliers in bulk density and soil organic carbon.

However, while the outliers are removed and the data with bulk density < 2 g/cc and soil organic carbon < 5 % was considered and plotted, the pattern of relationship between bulk density and soil organic carbon is appeared as more regular (inverse relationship) which is depicted in the Figure 14.

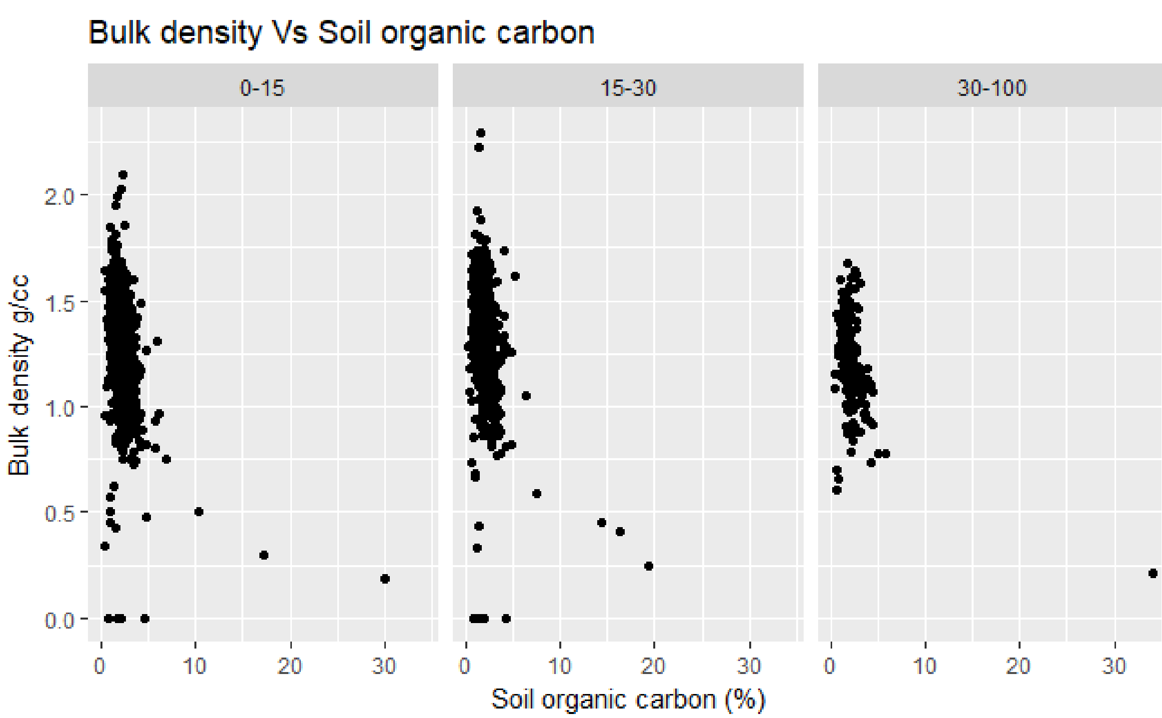


Figure 13: Soil bulk density Vs soil organic carbon

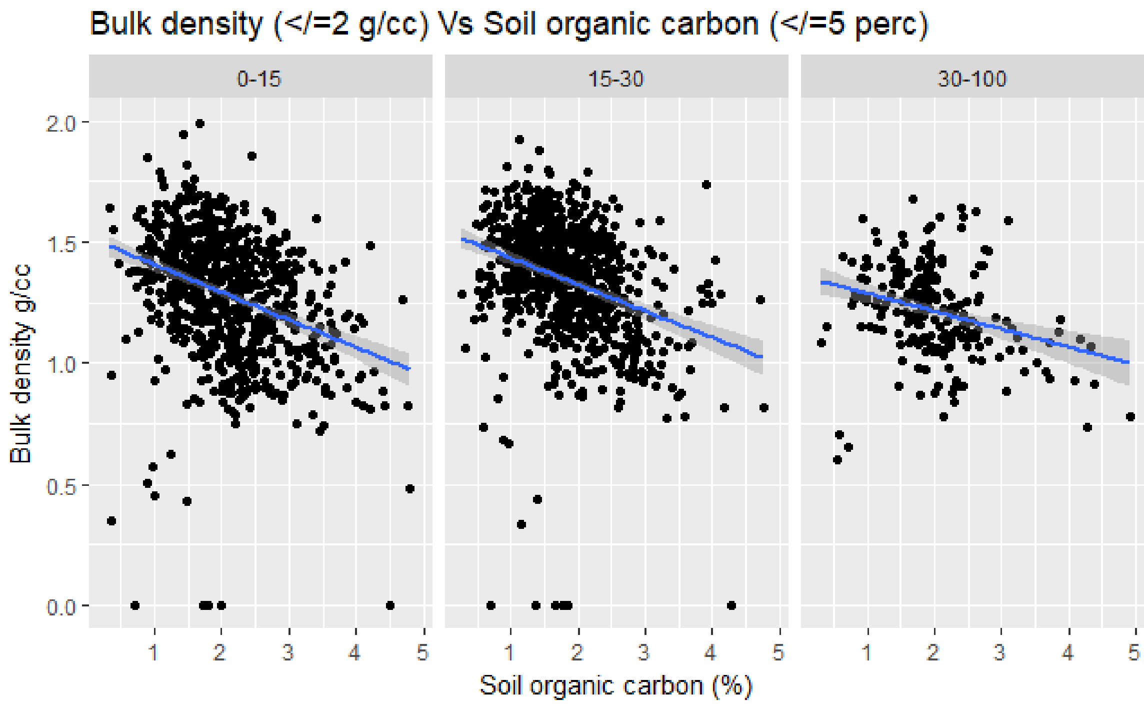


Figure 14: The relationship between soil bulk density and soil organic carbon

CHECK 07: To see if there is any outlier in soil carbon (t/ha) at different forest zones

[***Input****: soil organic carbon data;* ***output****: soil organic carbon in t/ha by soil depths and forest zones]*

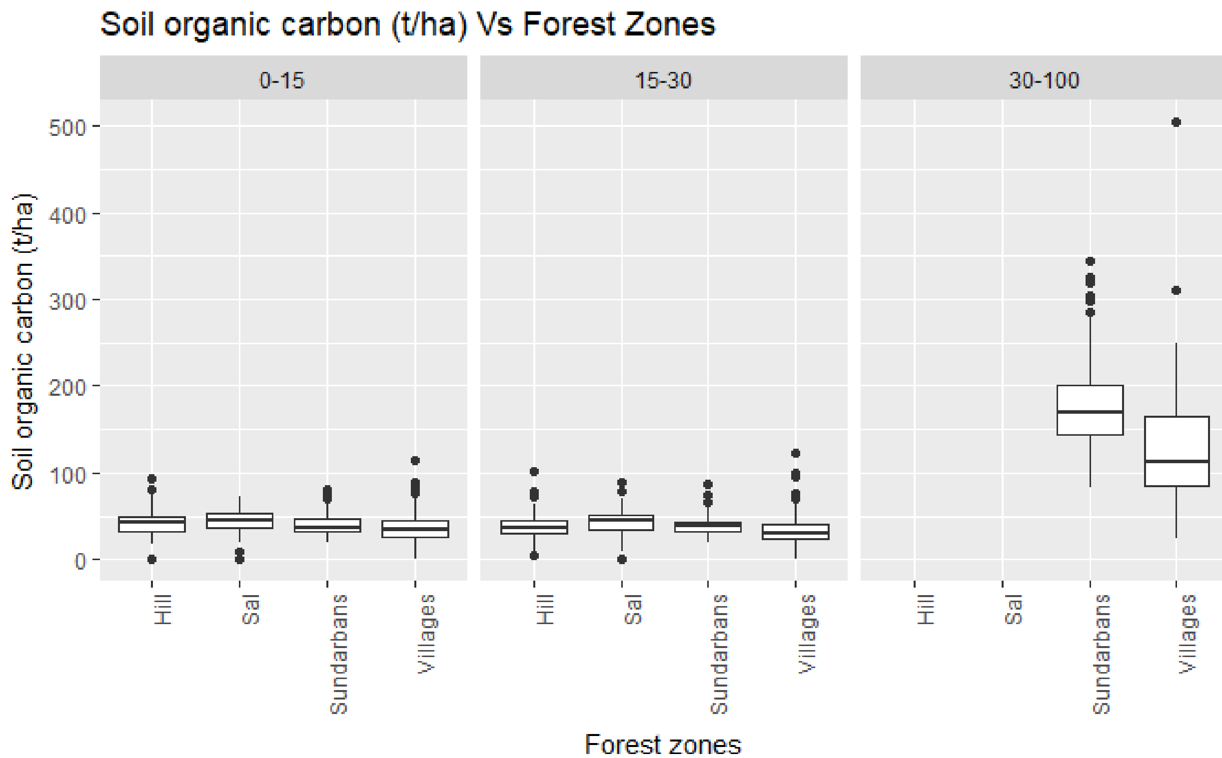


Figure 15: Soil organic carbon (t/ha) in different forest zones and soil layers

The Figure 15 shows the average soil carbon (t/ha) in different zones and layers. Some values with higher deviations from the average were found in the 15-30 cm soil depth of village and hill forests. In the 30-100cm soil layer the carbon content was higher as indicated by the graph it is mainly due to the higher depth range. Soil sample from 30-100 cm depth was collected by a field teams by mistake (it is listed in the following check) hence the soil organic carbon t/ha data is shown in the Figure 15. Overall, the average value of soil organic carbon is in acceptable range.

CHECK 08: To identify the plots in different zone from which soil carbon data is reported other than the specified soil layers as per BFI manual

[*Input: soil organic carbon, output: list of plots where soil organic carbon is reported from soil layers other than specified by BFI manual*]

Findings of the check indicated that 58 soil carbon data from 46 plots are reported from 30-100cm soil depth in village zone. But as per BFI design, soil samples from only two depths is to be collected in Village zone. Since, soil samples were reported from only two depths in all other plots of village zone so this data seems unnecessary. The list of plots having soil carbon data from 30-100cm depth is presented in appendix 4.

3.3 Soil texture

CHECK 09: To identify the plots and subplots in which the soil sample is collected from layers other than specified by BFI manual in different forest zone [2 defined layers in hill, village and Sal forests are 0-15cm and 15-30 cm; 3 specified layers in Sundarbans and coastal forests are 0-15 cm, 15-30cm and 30-100 cm]

[***Input****: Soil texture data;* ***output****: graph presenting soil texture sample collection outside the specified soil depths and number of subplots and plots where sample was collected outside the specified soil layers/depths as per BFI manual*]

The check showed that in the village forest zone soil texture data including sandy, silty and clayey particles was reported from 30-100 cm soil depth (Figure 16, Figure 17, Figure 18). But, BFI manual didn't suggest to collect any soil sample for texture analysis from this layer of Village forest zone. The detail list of the plots where soil sample of village zone is collected form 30-100 cm layer is provided in Appendix 4.

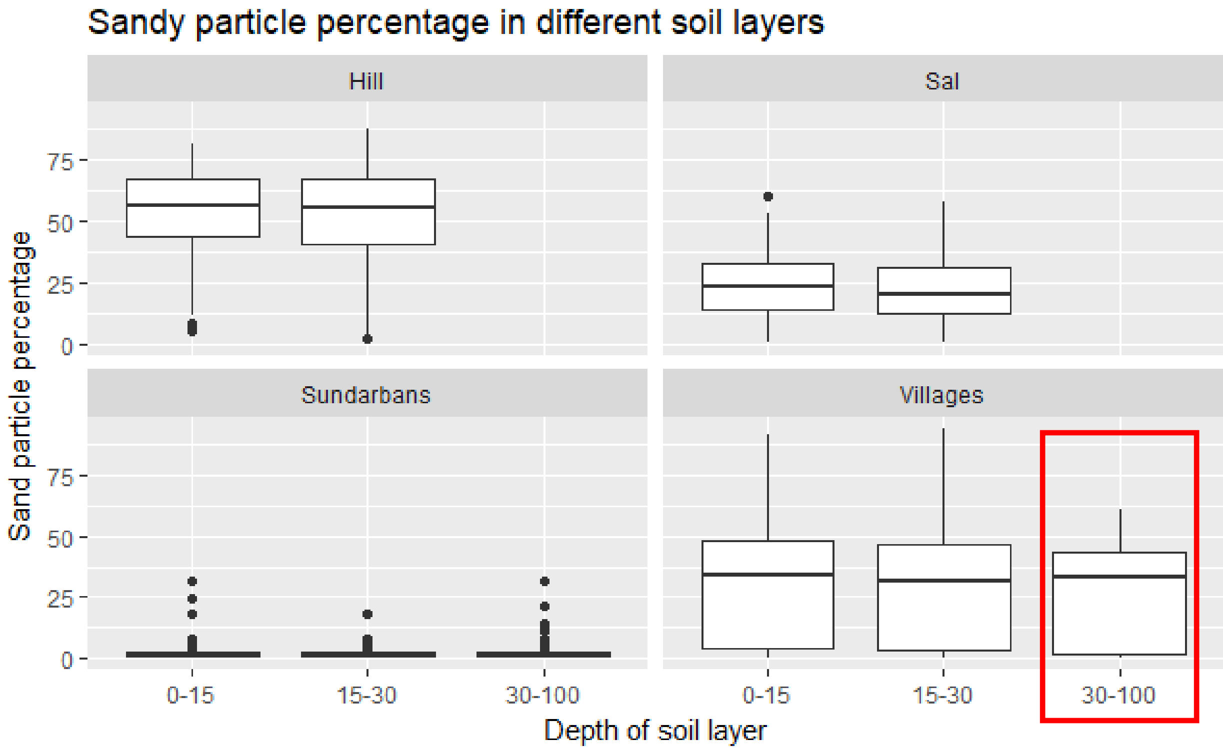


Figure 16: Sandy particle percentage in all three soil layers in different forest zones (Details in Appendix 5)

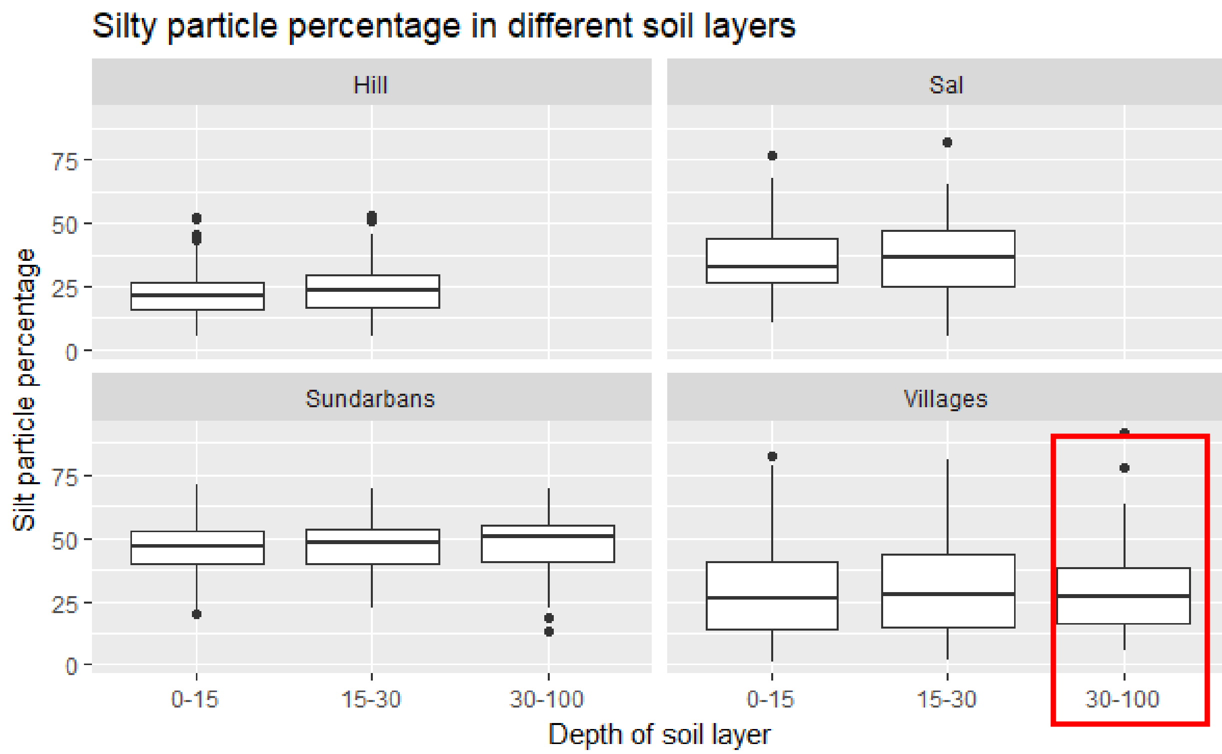


Figure 17: Silty particle percentage in all three soil layers in different forest zones (Details in Appendix 5)

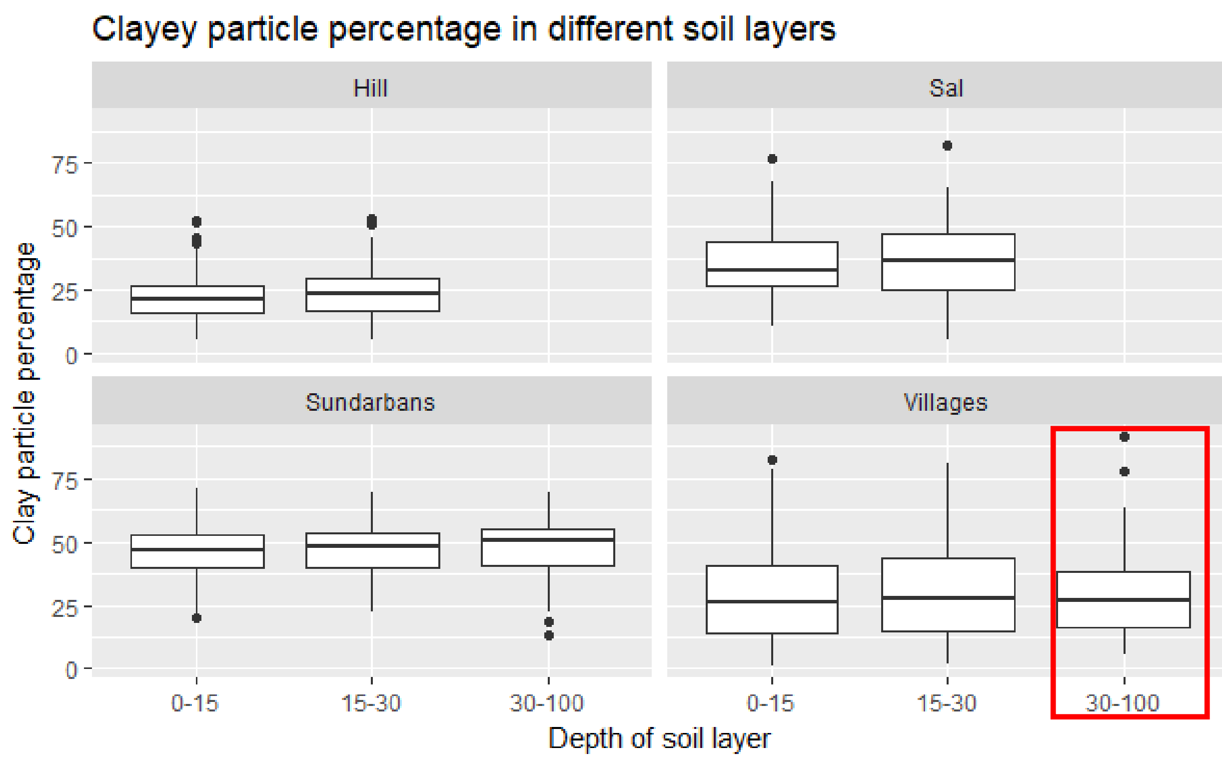


Figure 18: Clayey particle percentage in all three soil layers in different forest zones (Details in Appendix 5)

CHECK 10: To identify the layers if it is not matched with BFI soil survey design or if any unknown layers is written in the data sheet

[**Input**: Soil texture data; **Output**: list of plots in which soil is collected from undefined soil layers]

The check with preliminary data indicated to soil texture data undefined soil layers. The two soil layers are titled as 15-13 cm and 100-300 cm from which texture data was reported (Table 4). But, there is no such layer in the BFI design. May be reported by mistake.

Table 4: List of plots with two unknown layers

Plot id	Layer	Land feature no	Sand (%)	Clay (%)	Silt (%)	Texture	Team
199	15-13	1	33.05	50.2	16.75	Clay	11
393	300-100	1	0.17	63.08	36.75	Clay	11

However, after reviewing the problem and data the Nutrition Analysis Laboratory identified typing mistake behind the error and corrected. The updated database was checked again and no such undefined soil layer was found.

CHECK 11: To identify the outliers in percentages of clay, silt and sandy particles in soil [i) if the sum of sand, silt and clay percentage is 100 or not; ii) if there are any outliers/negative values.]

[***Input****: soil texture data;* ***output****: List of plots and layers where the percentages of clay, silt and sand particles of same sample is not 100*]

This test is to identify if there is any calculation mistake in the percentage of sand, silt and clay. Each soil texture sample was analyzed for percentages of the sand, silt and clay. So, their sum should be 100. This check with the preliminary data revealed that in the soil texture table there is some negative values of sand percentage (Table 5). But, there is no scope for sand percentage being negative value.

Table 5: List of plots having negative values in soil texture data

Plot id	Layer	Sand (%)	Clay (%)	Silt (%)	Sum of sand, clay and silt percentage	Team
68	15-30	-3.45	27.7	75.75	100	9
68	30-100	-0.58	27.7	72.88	100	9
68	0-15	-0.95	25.58	75.38	100	9
490	15-30	-1.33	45.58	55.75	100	12

After being informed about the error, the NDL authority checked the data and mentioned that "This is a calculation error and has been corrected, however, the texture of this soil has remained same". The laboratory provided an updated database after correcting the data. The updated database was checked again with this test and no such problem (negative percentage values) exists with the data anymore.

3.4 Litter

CHECK 12: To see if there is any outlier in the litter carbon (%)

[***Input:*** *Litter carbon data;* ***output:*** *graph (boxplot) presenting outliers in the litter carbon data*]

The litter carbon (%) data was checked to identify the outliers. Burghouts (1992) and Pereira Junior (2016) reported litter carbon 46.90% and 42.76% respectively. Based on that the outliers were identified if the value is more than 55%. The boxplot (Figure 19) with litter carbon (%) based on national land class legends indicates some outlier for Natural Mangrove Forests (NMF), Rubber Plantation (FPr), Hilly Forest (FEh), Single crops (PCs) and Rural Settlement (RS).

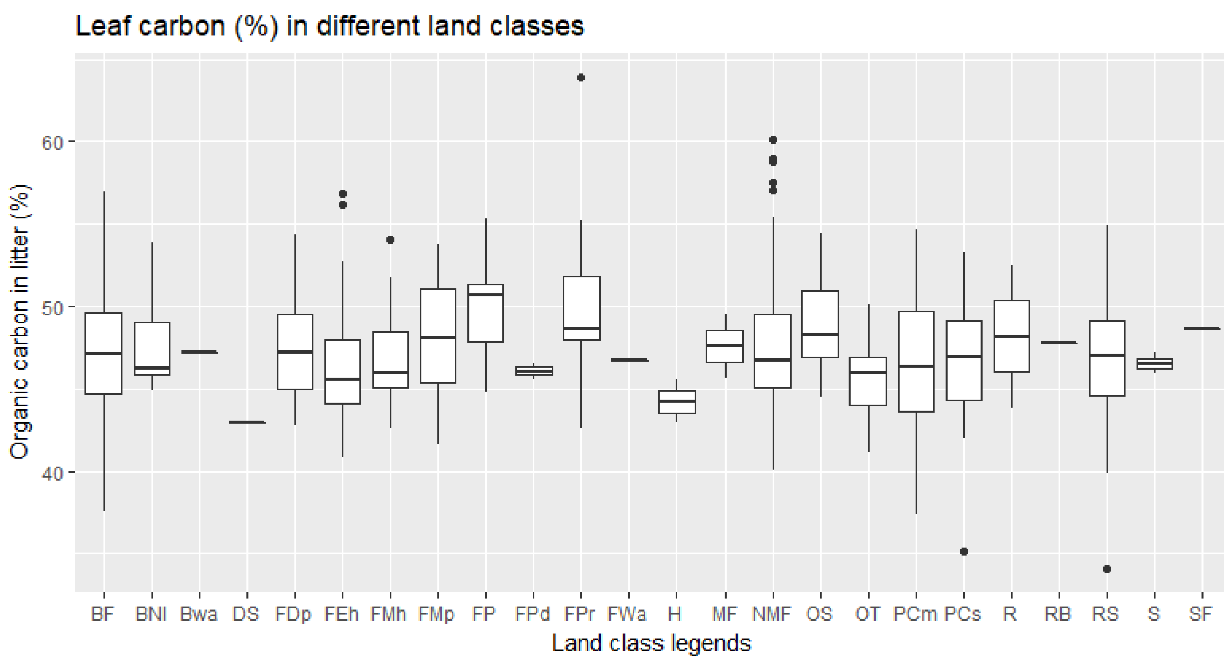


Figure 19: Litter carbon in different land class legends

The following table represents the list of plots with 5 maximum values of litter carbon (Table 6). During the survey in Mangrove forests, late sending of the litter samples after collection to the laboratory is usual phenomena. Higher carbon content in the litter of mangrove forest may be the result of partial decomposition before arrival of those in the laboratory.

Table 6: Five maximum values of organic carbon in litter (%)

Plot id	Organic carbon in litter (%)	Issue	Team	Location zone	NLCL
1072	55.205	litter carbon is 55.205 (>55%)	2	Hill	FPr
1181	56.98	litter carbon is 56.98 (>55%)	10	Hill	BF
1216	55.33	litter carbon is 55.33 (>55%)	10	Sal	FP
268	63.89	litter carbon is 63.89 (>55%)	1	Hill	FPr
306	56.845	litter carbon is 56.845 (>55%)	3	Hill	FEh
313	56.18	litter carbon is 56.18 (>55%)	3	Hill	FEh
485	57.545	litter carbon is 57.545 (>55%)	12	Sundarbans	NMF
488	58.96	litter carbon is 58.96 (>55%)	12	Sundarbans	NMF
508	57.055	litter carbon is 57.055 (>55%)	12	Sundarbans	NMF
54	55.235	litter carbon is 55.235 (>55%)	9	Sundarbans	NMF
67	58.78	litter carbon is 58.78 (>55%)	9	Sundarbans	NMF
68	57.52	litter carbon is 57.52 (>55%)	9	Sundarbans	NMF
813	55.37	litter carbon is 55.37 (>55%)	12	Sundarbans	NMF
822	55.3	litter carbon is 55.3 (>55%)	4	Sundarbans	NMF
829	55.055	litter carbon is 55.055 (>55%)	12	Sundarbans	NMF
830	60.165	litter carbon is 60.165 (>55%)	12	Sundarbans	NMF

However, when the outliers are shared with the NDL authority they said that partially decomposed litter samples were received in some cases. That decomposed litter gave higher carbon concentration.

CHECK 13: To see the relationship in order to check the consistency between canopy coverage and leaf oven dry weight

[***Input:*** *Litter dry weight data;* ***output****: Box plot with outliers in litter dry weight data based on land class legends and list of plots with strange values in litter weight*)

The following figure indicated some apparent outliers in the litter dry weight when placed against the land class legends (Figure 20). It seems that the outliers in litter dry weight was mostly observed in FDp (Plain Land Forest (Sal Forest)), FEh (Hilly Forest), FMh (Mixed Hill Forest), FP (Forest Plantation), FPr (Rubber Plantation), NMF (Mangrove Forest), PCs (Single Crop), RS (Rural Settlement) land class legends. In some cases, i.e. Sal Forest and Rubber Plantation seasonal influence (due to leaf shedding of trees in dry season) on amount of litter is great which may result in some outliers in litter dry weight and is a natural phenomenon.

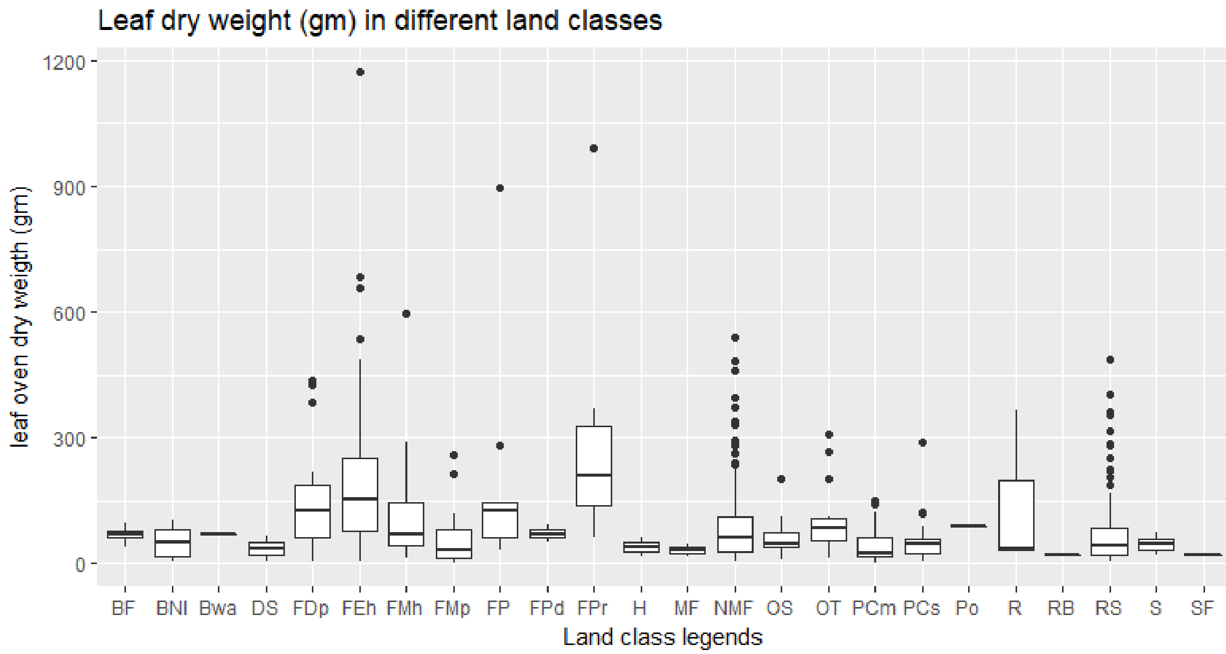


Figure 20: Leaf oven dry weight (gm) in different land class legends

The values of the litter dry weight indicated one very high value and one zero which seems strange (Table 7).

Table 7: Strange values in the litter oven dry weight

Plot id	Land feature no	Subplot id	Litter dry eight (g)	Leaf cover plot	Crown coverage average	NLCL	Team
233	1	2	0	0.02	10	FEh	2
790	1	1	485.6	0.43	45	RS	9

After being informed about the strange values, the NDL replied that the in plot 233, litter dry weight 0 g is a typical mistake and the very high value of litter weight in plot 790 is need to be checked. However, field team (FT 9) who surveyed the plot 233 was contacted. The team informed that in a subplot of that plot, the litter quadrat at pre-defined bearing and distance was on a litter stake of a household. Because of that they had to collect much amount of litter in a subplot of that plot.

CHECK 14: To see if there any subplots having more than one litter dry weight data

[***Input***: *Litter dry weight data;* ***output***: *list of plots and subplots having more than one littre_dry_wt data*]

As seen in some cases, data for same variable is repeated with different values. Considering that possibility this check is conducted. However, the check revealed that there is no subplots with repeated litter dry weight value.

CHECK 15: Identify the plots with mismatched land feature id in litter carbon and litter dry weight data

[***Input****: lit_car.csv and lit_dry_wt.csv, lf.csv;* ***Output****: list of plots with mismatches with lf.csv by land feature id*]

The check is conducted to identify the plots and land features in litter dry weight and litter carbon data which are mismatched in this two-data table and not present in the land feature database. That means this check will identify the land features under different plots that written by mistake. However, the check revealed that there are 17 rows (plot_id + lf_id) in litter carbon is not present in the litter dry weight data. Similarly, there are 54 rows (plot_id + lf_id) in litter weight data is not present in the litter carbon data. But, all the land features under different plots in both litter weight and litter carbon data tables are present in the land feature data base. Since, the litter samples are still undergoing through analysis for carbon and dry weight, hence the data tables are yet to be complete. After getting data for all the litter samples the mismatches between the litter carbon and litter dry weight database can be said more precisely.

4. Recommendations

Mistakes in different part of any national inventory are not unusual. What we can do is to check the mistakes as much as possible by undertaking some precautionary measures. The following are some recommendations to reduce the occurrence of error in sampling and data.

i. Collect the soil samples for bulk density, organic carbon and texture analysis from the missed layers of coastal zone.
ii. The typos should be checked by the laboratory (NDL) (i.e. negative values, decimals, zero in bulk density etc.) repeatedly before delivering to the BFI headquarter.
iii. The field teams need to be provided with sufficient number of quality containers for soil samples in order to avoid damages of samples due to be breakage of containers.
iv. The laboratory (NDL) may provide notes about the reasons (based on their observations in samples) beside the possible outliers (extremely high or low values). For example, decomposed litter (in case of very high litter carbon), stony soil (beside very high bulk density value).
v. The laboratory (NDL) reported repeated mistakes by FTs in labelling of the soil samples. The field team need to be careful about perfectly labelling of the soil and litter samples.

vi. In some plots, the laboratory provided partial data instead of all relevant data (i.e. for some plot SOC (%) data is given but litter dry weight is not given). For QA/QC and analysis, it's better to have complete data for any plots instead of partial data. So, the laboratory can be requested to consider this during delivery of data.
vii. If any unusual situation occurs about the sampling of soil (higher humus content, stony soils) or litter (decomposed litter, higher amount of litter), the field teams should mention that as notes.
viii. The field teams should not use garbage bags for collecting and sending the litter samples. To ensure this they should be supplied with sufficient number of perforated polythene and the FTs should also conduct surveys as per the movement plan.
ix. The field teams can be communicated with the mistakes in sampling and outliers/strange values in the data so that they become well informed about the sources of mistakes and strange data. It will be helpful for checking the errors in the field.

5. Conclusion

As expected the quality checks identified substantial number of errors, mistakes in sampling, outliers, typical mistakes etc. in data along with other problems. Some problems (i.e. typos) were already corrected by the NDL and some outliers were explained by the FT and NDL authority. However, we still have some outliers in the data which may be due to the misconception about the sampling strategy, lack of caution during sampling, seasonal fluctuation in the tree physiology etc. Surveying during the dry season may result in higher litter dry weight in the deciduous forest. In the remote areas i.e. Mangrove forests where facilities for sending the soil and litter sample is scarce may result in outliers in litter and soil carbon. Because, moistened litter and soil sample with roots may decompose with time if there late in sending the samples to the laboratory. The r-script is helpful to check and control the quality of data repeatedly and instantly.

However, the mistakes are part of any forest inventory. The field teams should be more careful about checking the mistakes in the field. The laboratory authority also need to be more careful about the typos. It also needs regular checking and controlling the quality of the data until the completion of the inventory.

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Appendices

Appendix 1: List of plots with number of soil depth that are inconsistent for plots sampled completely [inconsistencies: i) 3 soil layers in a subplot from village zone, ii) 2 soil layers in a subplot from coastal zone and iii) 1 soil layers in a subplot from Sal zone]

Plot no	Subplot no	Soil depth no. from which soil collected	Zone	Issue	Team
1580	3	1 soil layers	Sal	bulk density data in only 1 soil layer under subplot 3 in Sal zone	10
1531	2	2 soil layers	Coastal	bulk density data in 2 soil layers under subplot 2 in Coastal zone	2
1531	3	2 soil layers	Coastal	bulk density data in 2 soil layers under subplot 3 in Coastal zone	2
1531	1	2 soil layers	Coastal	bulk density data in 2 soil layers under subplot 1 in Coastal zone	2
1532	2	2 soil layers	Coastal	bulk density data in 2 soil layers under subplot 2 in Coastal zone	2
1532	1	2 soil layers	Coastal	bulk density data in 2 soil layers under subplot 1 in Coastal zone	2
1533	1	2 soil layers	Coastal	bulk density data in 2 soil layers under subplot 1 in Coastal zone	1
1533	3	2 soil layers	Coastal	bulk density data in 2 soil layers under subplot 3 in Coastal zone	1
1533	2	2 soil layers	Coastal	bulk density data in 2 soil layers under subplot 2 in Coastal zone	1
1534	2	2 soil layers	Coastal	bulk density data in 2 soil layers under subplot 2 in Coastal zone	1

Plot no	Subplot no	Soil depth no. from which soil collected	Zone	Issue	Team
1534	1	2 soil layers	Coastal	bulk density data in 2 soil layers under subplot 1 in Coastal zone	1
1534	3	2 soil layers	Coastal	bulk density data in 2 soil layers under subplot 3 in Coastal zone	1
1535	2	2 soil layers	Coastal	bulk density data in 2 soil layers under subplot 2 in Coastal zone	1
1535	3	2 soil layers	Coastal	bulk density data in 2 soil layers under subplot 3 in Coastal zone	1
1535	1	2 soil layers	Coastal	bulk density data in 2 soil layers under subplot 1 in Coastal zone	1
1536	1	2 soil layers	Coastal	bulk density data in 2 soil layers under subplot 1 in Coastal zone	2
1536	2	2 soil layers	Coastal	bulk density data in 2 soil layers under subplot 2 in Coastal zone	2
1543	3	2 soil layers	Coastal	bulk density data in 2 soil layers under subplot 3 in Coastal zone	1
1543	1	2 soil layers	Coastal	bulk density data in 2 soil layers under subplot 1 in Coastal zone	1
1543	2	2 soil layers	Coastal	bulk density data in 2 soil layers under subplot 2 in Coastal zone	1
1544	3	2 soil layers	Coastal	bulk density data in 2 soil layers under subplot 3 in Coastal zone	3
1544	2	2 soil layers	Coastal	bulk density data in 2 soil layers under subplot 2 in Coastal zone	3
1544	1	2 soil layers	Coastal	bulk density data in 2 soil layers under subplot 1 in Coastal zone	3
1548	1	2 soil layers	Coastal	bulk density data in 2 soil layers under subplot 1 in Coastal zone	3
1548	2	2 soil layers	Coastal	bulk density data in 2 soil layers under subplot 2 in Coastal zone	3
1548	3	2 soil layers	Coastal	bulk density data in 2 soil layers under subplot 3 in Coastal zone	3
1549	1	2 soil layers	Coastal	bulk density data in 2 soil layers under subplot 1 in Coastal zone	3
1549	2	2 soil layers	Coastal	bulk density data in 2 soil layers under subplot 2 in Coastal zone	3
1549	3	2 soil layers	Coastal	bulk density data in 2 soil layers under subplot 3 in Coastal zone	3
193	2	3 soil layers	Villages	bulk density data in 3 soil layers of subplot 2 in Villages zone	11
193	3	3 soil layers	Villages	bulk density data in 3 soil layers of subplot 3 in Villages zone	11
193	1	3 soil layers	Villages	bulk density data in 3 soil layers of subplot 1 in Villages zone	11
194	2	3 soil layers	Villages	bulk density data in 3 soil layers of subplot 2 in Villages zone	11
194	1	3 soil layers	Villages	bulk density data in 3 soil layers of subplot 1 in Villages zone	11
194	3	3 soil layers	Villages	bulk density data in 3 soil layers of subplot 3 in Villages zone	11
197	3	3 soil layers	Villages	bulk density data in 3 soil layers of subplot 3 in Villages zone	11
199	2	3 soil layers	Villages	bulk density data in 3 soil layers of subplot 2 in Villages zone	11
199	1	3 soil layers	Villages	bulk density data in 3 soil layers of subplot 1 in Villages zone	11
199	3	3 soil layers	Villages	bulk density data in 3 soil layers of subplot 3 in Villages zone	11
200	1	3 soil layers	Villages	bulk density data in 3 soil layers of subplot 1 in Villages zone	11
200	3	3 soil layers	Villages	bulk density data in 3 soil layers of subplot 3 in Villages zone	11
200	2	3 soil layers	Villages	bulk density data in 3 soil layers of subplot 2 in Villages zone	11
201	1	3 soil layers	Villages	bulk density data in 3 soil layers of subplot 1 in Villages zone	11
201	3	3 soil layers	Villages	bulk density data in 3 soil layers of subplot 3 in Villages zone	11
201	2	3 soil layers	Villages	bulk density data in 3 soil layers of subplot 2 in Villages zone	11
202	3	3 soil layers	Villages	bulk density data in 3 soil layers of subplot 3 in Villages zone	11
202	2	3 soil layers	Villages	bulk density data in 3 soil layers of subplot 2 in Villages zone	11
202	1	3 soil layers	Villages	bulk density data in 3 soil layers of subplot 1 in Villages zone	11
203	2	3 soil layers	Villages	bulk density data in 3 soil layers of subplot 2 in Villages zone	11

Plot no	Subplot no	Soil depth no. from which soil collected	Zone	Issue	Team
203	1	3 soil layers	Villages	bulk density data in 3 soil layers of subplot 1 in Villages zone	11
203	3	3 soil layers	Villages	bulk density data in 3 soil layers of subplot 3 in Villages zone	11
204	1	3 soil layers	Villages	bulk density data in 3 soil layers of subplot 1 in Villages zone	11
204	2	3 soil layers	Villages	bulk density data in 3 soil layers of subplot 2 in Villages zone	11
204	3	3 soil layers	Villages	bulk density data in 3 soil layers of subplot 3 in Villages zone	11
205	2	3 soil layers	Villages	bulk density data in 3 soil layers of subplot 2 in Villages zone	11
205	1	3 soil layers	Villages	bulk density data in 3 soil layers of subplot 1 in Villages zone	11
205	3	3 soil layers	Villages	bulk density data in 3 soil layers of subplot 3 in Villages zone	11
392	3	3 soil layers	Villages	bulk density data in 3 soil layers of subplot 3 in Villages zone	11
392	1	3 soil layers	Villages	bulk density data in 3 soil layers of subplot 1 in Villages zone	11
392	2	3 soil layers	Villages	bulk density data in 3 soil layers of subplot 2 in Villages zone	11
393	2	3 soil layers	Villages	bulk density data in 3 soil layers of subplot 2 in Villages zone	11
393	1	3 soil layers	Villages	bulk density data in 3 soil layers of subplot 1 in Villages zone	11
393	3	3 soil layers	Villages	bulk density data in 3 soil layers of subplot 3 in Villages zone	11
394	3	3 soil layers	Villages	bulk density data in 3 soil layers of subplot 3 in Villages zone	11
394	2	3 soil layers	Villages	bulk density data in 3 soil layers of subplot 2 in Villages zone	11
394	1	3 soil layers	Villages	bulk density data in 3 soil layers of subplot 1 in Villages zone	11
395	2	3 soil layers	Villages	bulk density data in 3 soil layers of subplot 2 in Villages zone	11
395	1	3 soil layers	Villages	bulk density data in 3 soil layers of subplot 1 in Villages zone	11
395	3	3 soil layers	Villages	bulk density data in 3 soil layers of subplot 3 in Villages zone	11
396	2	3 soil layers	Villages	bulk density data in 3 soil layers of subplot 2 in Villages zone	11
396	1	3 soil layers	Villages	bulk density data in 3 soil layers of subplot 1 in Villages zone	11
397	2	3 soil layers	Villages	bulk density data in 3 soil layers of subplot 2 in Villages zone	11
397	3	3 soil layers	Villages	bulk density data in 3 soil layers of subplot 3 in Villages zone	11
397	1	3 soil layers	Villages	bulk density data in 3 soil layers of subplot 1 in Villages zone	11
398	1	3 soil layers	Villages	bulk density data in 3 soil layers of subplot 1 in Villages zone	11
398	2	3 soil layers	Villages	bulk density data in 3 soil layers of subplot 2 in Villages zone	11
399	2	3 soil layers	Villages	bulk density data in 3 soil layers of subplot 2 in Villages zone	11
399	1	3 soil layers	Villages	bulk density data in 3 soil layers of subplot 1 in Villages zone	11
399	3	3 soil layers	Villages	bulk density data in 3 soil layers of subplot 3 in Villages zone	11
400	1	3 soil layers	Villages	bulk density data in 3 soil layers of subplot 1 in Villages zone	11
400	2	3 soil layers	Villages	bulk density data in 3 soil layers of subplot 2 in Villages zone	11
401	3	3 soil layers	Villages	bulk density data in 3 soil layers of subplot 3 in Villages zone	11
401	1	3 soil layers	Villages	bulk density data in 3 soil layers of subplot 1 in Villages zone	11
401	2	3 soil layers	Villages	bulk density data in 3 soil layers of subplot 2 in Villages zone	11
402	2	3 soil layers	Villages	bulk density data in 3 soil layers of subplot 2 in Villages zone	11
402	3	3 soil layers	Villages	bulk density data in 3 soil layers of subplot 3 in Villages zone	11
402	1	3 soil layers	Villages	bulk density data in 3 soil layers of subplot 1 in Villages zone	11
434	2	3 soil layers	Villages	bulk density data in 3 soil layers of subplot 2 in Villages zone	11

Plot no	Subplot no	Soil depth no. from which soil collected	Zone	Issue	Team
434	3	3 soil layers	Villages	bulk density data in 3 soil layers of subplot 3 in Villages zone	11
434	1	3 soil layers	Villages	bulk density data in 3 soil layers of subplot 1 in Villages zone	11
435	2	3 soil layers	Villages	bulk density data in 3 soil layers of subplot 2 in Villages zone	11
435	3	3 soil layers	Villages	bulk density data in 3 soil layers of subplot 3 in Villages zone	11
435	1	3 soil layers	Villages	bulk density data in 3 soil layers of subplot 1 in Villages zone	11
575	1	3 soil layers	Villages	bulk density data in 3 soil layers of subplot 1 in Villages zone	11
575	2	3 soil layers	Villages	bulk density data in 3 soil layers of subplot 2 in Villages zone	11
575	3	3 soil layers	Villages	bulk density data in 3 soil layers of subplot 3 in Villages zone	11
576	2	3 soil layers	Villages	bulk density data in 3 soil layers of subplot 2 in Villages zone	11
576	1	3 soil layers	Villages	bulk density data in 3 soil layers of subplot 1 in Villages zone	11
576	3	3 soil layers	Villages	bulk density data in 3 soil layers of subplot 3 in Villages zone	11
577	2	3 soil layers	Villages	bulk density data in 3 soil layers of subplot 2 in Villages zone	11
577	1	3 soil layers	Villages	bulk density data in 3 soil layers of subplot 1 in Villages zone	11
577	3	3 soil layers	Villages	bulk density data in 3 soil layers of subplot 3 in Villages zone	11
578	1	3 soil layers	Villages	bulk density data in 3 soil layers of subplot 1 in Villages zone	11
578	2	3 soil layers	Villages	bulk density data in 3 soil layers of subplot 2 in Villages zone	11
578	3	3 soil layers	Villages	bulk density data in 3 soil layers of subplot 3 in Villages zone	11
579	2	3 soil layers	Villages	bulk density data in 3 soil layers of subplot 2 in Villages zone	11
579	1	3 soil layers	Villages	bulk density data in 3 soil layers of subplot 1 in Villages zone	11
579	3	3 soil layers	Villages	bulk density data in 3 soil layers of subplot 3 in Villages zone	11
580	2	3 soil layers	Villages	bulk density data in 3 soil layers of subplot 2 in Villages zone	11
580	3	3 soil layers	Villages	bulk density data in 3 soil layers of subplot 3 in Villages zone	11
580	1	3 soil layers	Villages	bulk density data in 3 soil layers of subplot 1 in Villages zone	11
581	3	3 soil layers	Villages	bulk density data in 3 soil layers of subplot 3 in Villages zone	11
581	1	3 soil layers	Villages	bulk density data in 3 soil layers of subplot 1 in Villages zone	11
581	2	3 soil layers	Villages	bulk density data in 3 soil layers of subplot 2 in Villages zone	11
582	3	3 soil layers	Villages	bulk density data in 3 soil layers of subplot 3 in Villages zone	11
582	2	3 soil layers	Villages	bulk density data in 3 soil layers of subplot 2 in Villages zone	11
582	1	3 soil layers	Villages	bulk density data in 3 soil layers of subplot 1 in Villages zone	11
583	2	3 soil layers	Villages	bulk density data in 3 soil layers of subplot 2 in Villages zone	11
583	3	3 soil layers	Villages	bulk density data in 3 soil layers of subplot 3 in Villages zone	11
583	1	3 soil layers	Villages	bulk density data in 3 soil layers of subplot 1 in Villages zone	11
584	2	3 soil layers	Villages	bulk density data in 3 soil layers of subplot 2 in Villages zone	11
584	1	3 soil layers	Villages	bulk density data in 3 soil layers of subplot 1 in Villages zone	11
584	3	3 soil layers	Villages	bulk density data in 3 soil layers of subplot 3 in Villages zone	11
585	1	3 soil layers	Villages	bulk density data in 3 soil layers of subplot 1 in Villages zone	11
585	2	3 soil layers	Villages	bulk density data in 3 soil layers of subplot 2 in Villages zone	11
585	3	3 soil layers	Villages	bulk density data in 3 soil layers of subplot 3 in Villages zone	11
586	3	3 soil layers	Villages	bulk density data in 3 soil layers of subplot 3 in Villages zone	11

Plot no	Subplot no	Soil depth no. from which soil collected	Zone	Issue	Team
586	2	3 soil layers	Villages	bulk density data in 3 soil layers of subplot 2 in Villages zone	11
586	1	3 soil layers	Villages	bulk density data in 3 soil layers of subplot 1 in Villages zone	11
681	1	3 soil layers	Villages	bulk density data in 3 soil layers of subplot 1 in Villages zone	11
681	2	3 soil layers	Villages	bulk density data in 3 soil layers of subplot 2 in Villages zone	11
681	3	3 soil layers	Villages	bulk density data in 3 soil layers of subplot 3 in Villages zone	11
682	2	3 soil layers	Villages	bulk density data in 3 soil layers of subplot 2 in Villages zone	11
682	1	3 soil layers	Villages	bulk density data in 3 soil layers of subplot 1 in Villages zone	11
682	3	3 soil layers	Villages	bulk density data in 3 soil layers of subplot 3 in Villages zone	11
683	2	3 soil layers	Villages	bulk density data in 3 soil layers of subplot 2 in Villages zone	11
683	1	3 soil layers	Villages	bulk density data in 3 soil layers of subplot 1 in Villages zone	11
683	3	3 soil layers	Villages	bulk density data in 3 soil layers of subplot 3 in Villages zone	11
684	3	3 soil layers	Villages	bulk density data in 3 soil layers of subplot 3 in Villages zone	11
684	1	3 soil layers	Villages	bulk density data in 3 soil layers of subplot 1 in Villages zone	11
684	2	3 soil layers	Villages	bulk density data in 3 soil layers of subplot 2 in Villages zone	11
872	2	3 soil layers	Villages	bulk density data in 3 soil layers of subplot 2 in Villages zone	11
872	1	3 soil layers	Villages	bulk density data in 3 soil layers of subplot 1 in Villages zone	11
873	1	3 soil layers	Villages	bulk density data in 3 soil layers of subplot 1 in Villages zone	11
873	3	3 soil layers	Villages	bulk density data in 3 soil layers of subplot 3 in Villages zone	11
874	1	3 soil layers	Villages	bulk density data in 3 soil layers of subplot 1 in Villages zone	11
874	2	3 soil layers	Villages	bulk density data in 3 soil layers of subplot 2 in Villages zone	11
874	3	3 soil layers	Villages	bulk density data in 3 soil layers of subplot 3 in Villages zone	11
875	2	3 soil layers	Villages	bulk density data in 3 soil layers of subplot 2 in Villages zone	11
875	1	3 soil layers	Villages	bulk density data in 3 soil layers of subplot 1 in Villages zone	11
875	3	3 soil layers	Villages	bulk density data in 3 soil layers of subplot 3 in Villages zone	11
876	3	3 soil layers	Villages	bulk density data in 3 soil layers of subplot 3 in Villages zone	11
876	1	3 soil layers	Villages	bulk density data in 3 soil layers of subplot 1 in Villages zone	11
876	2	3 soil layers	Villages	bulk density data in 3 soil layers of subplot 2 in Villages zone	11
878	2	3 soil layers	Villages	bulk density data in 3 soil layers of subplot 2 in Villages zone	11
878	3	3 soil layers	Villages	bulk density data in 3 soil layers of subplot 3 in Villages zone	11
878	1	3 soil layers	Villages	bulk density data in 3 soil layers of subplot 1 in Villages zone	11
879	1	3 soil layers	Villages	bulk density data in 3 soil layers of subplot 1 in Villages zone	11
879	2	3 soil layers	Villages	bulk density data in 3 soil layers of subplot 2 in Villages zone	11
879	3	3 soil layers	Villages	bulk density data in 3 soil layers of subplot 3 in Villages zone	11
880	2	3 soil layers	Villages	bulk density data in 3 soil layers of subplot 2 in Villages zone	11
880	3	3 soil layers	Villages	bulk density data in 3 soil layers of subplot 3 in Villages zone	11
880	1	3 soil layers	Villages	bulk density data in 3 soil layers of subplot 1 in Villages zone	11

Appendix 2: Inconsistency in number of subplots from which bulk density data was reported [*inconsistency: bulk density data was reported from 2 subplots but respective plots were surveyed completely*]

Plot id	Issue	Zone	Team
1	plot sampled completely but soil bulk density data available for only 2 subplots	Villages	9
6	plot sampled completely but soil bulk density data available for only 2 subplots	Villages	9
59	plot sampled completely but soil bulk density data available for only 2 subplots	Sundarbans	9
86	plot sampled completely but soil bulk density data available for only 2 subplots	Hill	3
103	plot sampled completely but soil bulk density data available for only 2 subplots	Hill	2
104	plot sampled completely but soil bulk density data available for only 2 subplots	Hill	3
225	plot sampled completely but soil bulk density data available for only 2 subplots	Villages	2
228	plot sampled completely but soil bulk density data available for only 2 subplots	Villages	2
232	plot sampled completely but soil bulk density data available for only 2 subplots	Villages	2
236	plot sampled completely but soil bulk density data available for only 2 subplots	Villages	2
252	plot sampled completely but soil bulk density data available for only 2 subplots	Villages	2
258	plot sampled completely but soil bulk density data available for only 2 subplots	Villages	2
260	plot sampled completely but soil bulk density data available for only 2 subplots	Villages	2
263	plot sampled completely but soil bulk density data available for only 2 subplots	Villages	2
269	plot sampled completely but soil bulk density data available for only 2 subplots	Villages	1
372	plot sampled completely but soil bulk density data available for only 2 subplots	Sal	7
396	plot sampled completely but soil bulk density data available for only 2 subplots	Villages	11
398	plot sampled completely but soil bulk density data available for only 2 subplots	Villages	11
475	plot sampled completely but soil bulk density data available for only 2 subplots	Sundarbans	12
666	plot sampled completely but soil bulk density data available for only 2 subplots	Villages	13
798	plot sampled completely but soil bulk density data available for only 2 subplots	Villages	9
799	plot sampled completely but soil bulk density data available for only 2 subplots	Villages	9
872	plot sampled completely but soil bulk density data available for only 2 subplots	Villages	11
873	plot sampled completely but soil bulk density data available for only 2 subplots	Villages	11
977	plot sampled completely but soil bulk density data available for only 2 subplots	Villages	13
1024	plot sampled completely but soil bulk density data available for only 2 subplots	Hill	10
1201	plot sampled completely but soil bulk density data available for only 2 subplots	Sal	6
1212	plot sampled completely but soil bulk density data available for only 2 subplots	Sal	6
1227	plot sampled completely but soil bulk density data available for only 2 subplots	Villages	6
1246	plot sampled completely but soil bulk density data available for only 2 subplots	Villages	6
1456	plot sampled completely but soil bulk density data available for only 2 subplots	Villages	8
1462	plot sampled completely but soil bulk density data available for only 2 subplots	Villages	8
1490	plot sampled completely but soil bulk density data available for only 2 subplots	Coastal	11
1493	plot sampled completely but soil bulk density data available for only 2 subplots	Coastal	11
1508	plot sampled completely but soil bulk density data available for only 2 subplots	Coastal	11
1509	plot sampled completely but soil bulk density data available for only 2 subplots	Coastal	11
1511	plot sampled completely but soil bulk density data available for only 2 subplots	Coastal	11

Plot id	Issue	Zone	Team
1512	plot sampled completely but soil bulk density data available for only 2 subplots	Coastal	11
1513	plot sampled completely but soil bulk density data available for only 2 subplots	Coastal	11
1514	plot sampled completely but soil bulk density data available for only 2 subplots	Coastal	11
1536	plot sampled completely but soil bulk density data available for only 2 subplots	Coastal	2
1546	plot sampled completely but soil bulk density data available for only 2 subplots	Coastal	3
1547	plot sampled completely but soil bulk density data available for only 2 subplots	Coastal	3

Appendix 3: Soil layers in which soil organic carbon is seems outlier [*Inconsistency: Organic carbon percentage (≥ 5%) seems outlier*]

Plot id	Soil layer	Land feature no	Organic carbon percent	Location zone
402	0-15	1	30.13	Villages
402	15-30	1	19.38	Villages
402	30-100	1	5.73	Villages
489	0-15	1	6.81	Sundarbans
489	15-30	1	7.45	Sundarbans
548	0-15	1	6.06	Villages
548	15-30	1	6.32	Villages
674	0-15	1	5.87	Villages
683	0-15	2	5.8	Villages
837	0-15	1	5.73	Sundarbans
872	0-15	1	17.27	Villages
872	15-30	1	14.28	Villages
880	0-15	1	10.27	Villages
880	30-100	1	34.18	Villages
880	15-30	1	16.27	Villages
1131	15-30	2	5.13	Villages

Appendix 4: List of plots under Village Forest Zone where soil organic carbon was reported from 30-100 cm layer

Plot id	Land feature no	Soil layer (cm)	Organic carbon percent	Location zone	Team
193	1	30-100	1.24	Villages	11
194	1	30-100	0.89	Villages	11
197	2	30-100	0.93	Villages	11
199	1	30-100	1.82	Villages	11
200	1	30-100	1.53	Villages	11
201	1	30-100	3.54	Villages	11
202	1	30-100	1.94	Villages	11
203	1	30-100	2.42	Villages	11

Plot id	Land feature no	Soil layer (cm)	Organic carbon percent	Location zone	Team
205	1	30-100	0.95	Villages	11
205	2	30-100	0.98	Villages	11
392	1	30-100	1.21	Villages	11
393	1	30-100	1.83	Villages	11
394	1	30-100	1.48	Villages	11
395	1	30-100	0.55	Villages	11
396	2	30-100	0.57	Villages	11
396	1	30-100	0.71	Villages	11
397	1	30-100	2.18	Villages	11
397	2	30-100	0.79	Villages	11
398	1	30-100	0.98	Villages	11
399	1	30-100	0.98	Villages	11
400	1	30-100	1.92	Villages	11
401	1	30-100	0.87	Villages	11
402	1	30-100	5.73	Villages	11
434	1	30-100	1.77	Villages	11
435	1	30-100	1.84	Villages	11
575	1	30-100	1.12	Villages	11
576	1	30-100	0.89	Villages	11
577	2	30-100	1.94	Villages	11
577	1	30-100	1.43	Villages	11
578	1	30-100	1.9	Villages	11
578	2	30-100	2	Villages	11
579	2	30-100	1.51	Villages	11
579	1	30-100	0.32	Villages	11
580	2	30-100	0.95	Villages	11
580	1	30-100	0.76	Villages	11
581	1	30-100	0.4	Villages	11
581	2	30-100	0.9	Villages	11
582	1	30-100	1.13	Villages	11
583	1	30-100	0.83	Villages	11
584	1	30-100	1.49	Villages	11
585	1	30-100	0.96	Villages	11
586	1	30-100	1.69	Villages	11
681	1	30-100	2.32	Villages	11
682	1	30-100	1.69	Villages	11
682	2	30-100	1.93	Villages	11
683	1	30-100	2.05	Villages	11
683	2	30-100	2.69	Villages	11
684	1	30-100	1.49	Villages	11

Plot id	Land feature no	Soil layer (cm)	Organic carbon percent	Location zone	Team
872	1	30-100	3.65	Villages	11
873	1	30-100	1.01	Villages	11
874	2	30-100	0.94	Villages	11
874	1	30-100	1.36	Villages	11
875	1	30-100	0.63	Villages	11
876	1	30-100	0.87	Villages	11
878	2	30-100	2.13	Villages	11
878	1	30-100	0.77	Villages	11
879	1	30-100	1.1	Villages	11
880	1	30-100	34.18	Villages	11

Appendix 5: List of plots and subplots in village zone in which the soil texture sample is collected from 30-100 cm depth

Plot id	Layer	Land feature no	Sand (%)	Clay (%)	Silt (%)	Zone
193	30-100	1	33.425	26.95	39.625	Villages
194	30-100	1	54.8	15.575	29.625	Villages
197	30-100	2	11.55	15.95	72.5	Villages
199	30-100	1	31.925	38.825	29.25	Villages
200	30-100	1	32.675	27.7	39.625	Villages
201	30-100	1	1.925	45.2	52.875	Villages
202	30-100	1	0.8	31.7	67.5	Villages
203	30-100	1	8.675	50.95	40.375	Villages
205	30-100	1	11.175	18.075	70.75	Villages
205	30-100	2	10.425	13.825	75.75	Villages
392	30-100	1	58.425	11.2	30.375	Villages
393	30-100	1	0.175	63.075	36.75	Villages
394	30-100	1	40.925	21.95	37.125	Villages
395	30-100	1	46.3	8.325	45.375	Villages
396	30-100	1	41.3	25.825	32.875	Villages
396	30-100	2	45.55	12.325	42.125	Villages
397	30-100	1	43.8	13.7	42.5	Villages
397	30-100	2	43.8	6.2	50	Villages
398	30-100	1	43.8	8.7	47.5	Villages
399	30-100	1	40.925	11.575	47.5	Villages
400	30-100	1	41.3	20.825	37.875	Villages
401	30-100	1	36.55	33.45	30	Villages
402	30-100	1	56.3	25.825	17.875	Villages
434	30-100	1	1.55	50.575	47.875	Villages
435	30-100	1	1.55	48.075	50.375	Villages

Plot id	Layer	Land feature no	Sand (%)	Clay (%)	Silt (%)	Zone
575	30-100	1	53.05	16.95	30	Villages
576	30-100	1	43.425	19.075	37.5	Villages
577	30-100	2	4.8	29.45	65.75	Villages
577	30-100	1	8.675	25.575	65.75	Villages
578	30-100	1	35.55	29.45	35	Villages
578	30-100	2	35.925	38.7	25.375	Villages
579	30-100	1	43.425	11.95	44.625	Villages
579	30-100	2	38.8	23.325	37.875	Villages
580	30-100	1	51.3	5.825	42.875	Villages
580	30-100	2	38.425	21.95	39.625	Villages
581	30-100	1	58.05	7.325	34.625	Villages
581	30-100	2	51.3	11.2	37.5	Villages
582	30-100	1	38.05	26.95	35	Villages
583	30-100	1	33.675	21.325	45	Villages
584	30-100	1	6.925	25.575	67.5	Villages
585	30-100	1	60.925	11.95	27.125	Villages
586	30-100	1	45.925	16.575	37.5	Villages
681	30-100	1	0.05	91.7	8.25	Villages
682	30-100	1	1.175	33.45	65.375	Villages
682	30-100	2	0.8	56.7	42.5	Villages
683	30-100	1	0.175	45.2	54.625	Villages
683	30-100	2	1.55	78.075	20.375	Villages
684	30-100	1	0.175	40.2	59.625	Villages
872	30-100	1	40.925	29.075	30	Villages
873	30-100	1	0.175	62.7	37.125	Villages
874	30-100	1	1.175	35.95	62.875	Villages
874	30-100	2	0.175	30.2	69.625	Villages
875	30-100	1	15.8	26.325	57.875	Villages
876	30-100	1	6.175	36.7	57.125	Villages
878	30-100	2	1.175	45.95	52.875	Villages
878	30-100	1	1.925	34.825	63.25	Villages
879	30-100	1	0.05	44.575	55.375	Villages
880	30-100	1	51.06667	31.76667	17.16667	Villages

Appendix 6: The r-script used for QA/QC of the soil and litter data

It is uploaded in the respective folder of BFI dropbox. The dropbox directory is “F:\Dropbox (BGD_058)\BGD Forest Inventory Team Folder\24_BFI_Data QC and Analysis\QAQC_Soil and litter”.