GLOBAL ENVIRONMENT FACILITY
INVESTING IN OUR PLANET

Ministry of Agriculture, Forestry and Water Management of the Republic of Serbia

Food and Agriculture Organization of the United Nations

ANALYSIS METHODOLOGY FOR NFI-2 IN SERBIA

DAMJAN PANTIĆ

MATTHIAS DEES

DRAGAN BOROTA

BELGRADE-ROME, 2020

ANALYSIS METHODOLOGY FOR NFI-2 IN SERBIA

Client

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS

Project

Contribution of Sustainable Forest Management to a Low Emission and Resilient Development

Programme/Project Number: GCP/SRB/002/GFF

Beneficiary

State Administration in Forestry. Ministry of Agriculture, Forestry and Water Management

Authors

Damjan Pantić

Matthias Dees

Dragan Borota

Date: 16.08.2020

Contact

Prof. Dr. Mathias Dees
Institute of Forest Science
University of Freiburg
Tennenbacher Str. 4
79085 Freiburg, Germany
Tel. +49 (0) 761 203 3697
Email: mathias.dees@felis.uni-freiburg.de

Prof. Dr. Damjan Pantić
Chair for Forest Management and Planning
Faculty of Forestry University of Belgrade
Kneza Viseslava Str.1
11000 Belgrade, Serbia
Tel. +381 (0) 63 87 95 654
Email: damjan.pantic@sfb.bg.ac.rs

Recommended Citation

Pantić, D., Dees, M., & Borota, D. (2020): Analysis Methodology for the Second National Forest Inventory of the Republic of Serbia. The Food and Agriculture Organization of the United Nations, Rome, 97 p.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS

DoF	Forest Directorate
EAP	Euro-American POPLAR
ENFIN	European National Forest Inventory Network
FAO	Food and Agricultural Organization, a sub-organization of the United Nations
FMP	Forest Management Planning
GEF	Global Environment Facility
GIS	Geographic Information System
GPS	Global Positioning System
IPCC	Intergovernmental Panel on Climate Change
LULUCF	Land Use, Land-Use Change and Forestry
MRV	Measurement, Reporting and Verification
NFI	National Forest Inventory
NFI-1	1st National Forest Inventory of the Republic of Serbia
NFI-2	2nd National Forest Inventory of the Republic of Serbia
OLWTC	Other land with a tree cover
OWL	Other wooded land
RGZ	Republic Geodetic Authority
TOF	Trees outside the forest
UNFCCC	United Nations Framework Convention on Climate Change

1. INTRODUCTION

This report describes dendrometric and mathematical-statistical methods of processing numerical data collected within NFI-2. The goal is to acquaint the professional and scientific public with the applied methods, as well as to provide the basis to adopt existing and develop new modules and procedures of computer data processing in the NFI-Software package “OSNOVA NFI-2”. Within NFI-1, Serbia has developed the "OSNOVA NFI-1" software for data processing. Based on this report, its performance will be improved in line with the new requirements imposed by the NFI-2 methodology.

The main reference of this report is “Pantić, D., Dees, M. & Borota, D. (2020): Methodology of the Second National Forest Inventory of the Republic of Serbia. The Food and Agriculture Organization of the United Nations. Rome: Italy. 185 p.”

Foci of the NFI-2 Analysis

The focus of the analysis is on obtaining a wide range of results on:

- National information needs for monitoring the state of forests, analysis of trends over time and development of strategic national documents in the forestry and contact sectors.
- International reporting requirements for the formation of regional and global databases, analysis of experts, development of strategies and making recommendations and decisions on the protection of existing forests and the establishment of new areas under forests, increasing biodiversity, etc.

Both national and international attribute nomenclature and definitions are addressed. In the special topics section both special topics relevant for national information needs and topics mainly driven by international policy resulting in reporting requirements are presented.

Structure of this Report

After the introduction and a chapter on the notation used in formulae and when referring to terms used on formulae in this report, the following chapters are presented in the sequence below:

- Element level (elements that are information carrier, such as plots or trees)

  On the element level an overview on information collected in the field is provided and reference is made to the methodology report of Pantić, Dees & Borota (2020).

  Next an overview on information retrieved from other sources is provided and when applicable, reference is made to the methodology report of Pantić, Dees & Borota (2020).

  Further, the methods and algorithms to complement information that was only assessed on part of the number of trees on the sample plot (e.g. radial diameter increment) as well as the methods to provide derived information will be considered (e.g. tree volume that was not measured in the field or classification attributes that where not assessed as such in the field but derived from one or several attributes).

  This allows the reader to have a one-source overview on all attributes of the NFI at element level that is available for the analysis.

- Inventory design

A brief overview of the selected of elements is given to the reader as one-source background information on this inventory aspect. This is necessary for the understanding of the methodology used for the statistical analysis to derive information on target areas and entities such as e.g. entire Serbia, the national parks of Serbia or the oak dominated forest types of Vojvodina.

- Statistical analysis

Analysis methods including methods using statistical inference are the third major information presented in this report. This section describes how, based on the information available at element level and, under consideration of the inventory design, the statistical results and their estimation error is determined.

- Special analysis topics

In this section, the focus is on special analysis topics that require specific methods and/or follow a specific nomenclature.

- Quality assurance

In the last chapter, measures to ensure the quality of the results are described.

Consideration of the NFI-1 in this Report

As the NFI-2 is the second national inventory, further major aspect of this analysis reports is:

- Securing the comparability of the results of NFI-1 and NFI-2:

E.g. comparability of definitions of attributes and methods of their assessment (calculation) in NFI-2 in relation to NFI-1 (volume, increment, etc.). In case of differences, they should be explained and overcome by appropriate methods

- Facilitating information on changes using information assessed in NFI-1 and NFI-2,
- Allometric Information:

Major criterion for the selection of allometric tables and formulae is the quality of the results.

Therefore, where available national level information sources are considered that are based on a sound empirical basis. Where such information is not available, most adequate of allometric tables and formulae from international literature considering the applicability in Serbia is used.

Consideration of Initiatives to make NFIs in Europe Comparable

In this report several conceptual elements to make NFI results from different countries comparable are considered:

- The idea of harmonized attribute definitions,
- The idea of a clear definition of attributes to enable the use of bridging functions.

Thus, the following references originating from UNECE/FAO and from ENFIN are taken into account when preparing the analysis methodology:

United Nations Economic Commission for Europe [UN-ECE] & Food and Agriculture Organization of the United Nations [FAO] (2000) that describes the need for harmonization of definitions and result presentations.

Ståhl *et al.* (2012) and Tomter *et al*. (2012) who introduced the approach of bridging where harmonization of definitions is not adequate, feasible or achievable.

Vidal *et al.* (2008) who focused on forest inventory reference definitions for forest and growing stock. The common tree definition developed by Gschwantner *et al.* (2009). Considerations on naturalness (McRoberts, Winter, Chirici & LaPoint, 2012), on dead wood (Rondeux *et al.,* 2012) and considerations on bridging functions for harmonizing growing stock estimates (Tomppo & Schadauer, 2012).

2. ATTRIBUTES AND THEIR NOTATION

The notation used in formulae for attributes and entities is presented in tables in this chapter.

All notations used are presented in *italic* to allow a good identification in the text.

Further, acronyms and abbreviations for major attributes, such as diameter at breast height or volume, are given in *italic* for the same reason.

For attributes that are not presented in this report with a specific notation such as ownership or tree health are not presented in the tables below.

Table 1. The numerical attributes of the tree and the sample plot assessed in the field and their notation

Notation in this report	Reference to the Methodology of the Second National Forest Inventory of the Republic of Serbia	Characterization	Entity
t; T	Ch. 4.4.2. Age of the tree and stand	Age	Tree and Sample plot
n	Ch. 4.5.3. Number of small trees d ≤ 5 cm	Number of small trees	Sample plot
dbh	Ch. 4.5.5. Diameter at breast height (*dbh*) or diameter of a fallen tree at 1,3 m from the thicker side	Diameter at breast height	Tree
$d_{1/2L}$	Ch. 4.5.5. Diameter in the middle of a tree part	Diameter in the middle of a part of the lying tree	Tree
h	Ch. 4.5.7. Total height of a standing tree or total length of a laying tree	Tree height (length)	Tree
l	Ch. 4.5.7. The length of tree part	Length of lying tree part	Tree
id	Ch. 4.5.9. Periodic diameter increment (width of 10 growth rings x 2)	Diameter increment	Tree
d_s	4.5.19./B. Stump diameter	Stump diameter	Tree
h_s	4.5.19./C. Stump height	Stump height	Tree

Table 2. Derived numeric attributes and their notation

Notation in this report	Characterization	Entity
N	Number of trees per ha of a defined area	Area
g	Basal area of a single tree	Tree
G	Basal area per ha of a defined area	Area
d_g	Diameter of the middle tree	Tree
h_g	Height of the middle tree	Tree
v	Volume of a single living tree, dead tree, part of tree or felled (cut) tree	Tree

Notation in this report	Characterization	Entity
V	Volume per ha of a defined area	Area
v_k	Volume of trees to the beginning of the crown	Tree
V_k	Volume to the beginning of the crown per ha of a defined area	Area
v_s	Stump volume	Tree
i_v	Volume increment of a single tree	Tree
I_v	Volume increment per ha of a defined area	Area
AG	Above ground biomass	Tree
BG	Below ground biomass	Tree
c	Carbon of a single tree	Tree
C	Carbon per ha of a defined area	Area

3. SINGLE ELEMENTS

3.1. Introduction

The following elements are information carrier for different sets of information:

- Living trees with *dbh* > 5 cm
- Dead trees with *dbh* > 5 cm
- Living trees *dbh* ≤ 5 cm
- Regeneration
- Plot level information

3.2. Living trees with *dbh* > 5 cm

3.2.1. Tree Level Attributes Collected in the Field

The following attributes are assessed in the field on tree level, see Table 3.

Table 3. Tree level attributes assessed in the field of living trees with *dbh* > 5 cm

Reference to Methodology of the Serbian NFI-2	Serbian name	English name	Scope
4.5.2.	Врста дрвећа	Tree species	All trees
4.5.6.	Азимут и удаљеност стабла од центра круга	Azimuth and distance of a tree from the sample plot center	All trees
4.5.4.	Статус стабала на поновно мереним круговима	Tree status on re-measured sample plots	Trees on re-measured plots only
4.5.5.	Прсни пречник	Diameter at breast height	All trees
4.5.7.	Укупна висина дубећег стабала	Total height of a standing tree	All trees
4.5.8.	Почетак крошње (дужина дебла)	Crown base (length of the stem)	Only trees *dbh* >25 cm
4.5.9.	Периодични прираст пречника (ширина 10 годова x 2)	Periodic diameter increment (width of 10 growth rings x 2)	Selected trees only
4.5.10.	Биолошки (социјални) положај стабла	Biological (social) status of a tree	All trees
4.5.11.	Здравствено стање стабла	Health condition of a tree	All trees
4.5.12.	Узрок оштећења стабала	Causing agents of tree damage	All trees
4.5.13.	Степен оштећења стабла	Degree of tree damage	All trees
4.5.14.	Технички квалитет стабла	Technically good/quality trees	All trees
4.5.15.	Пробна дознака	Virtual marking	All trees

3.2.2. Derived Attributes on the Tree Level

The following attributes of trees are derived using allometric equations and functions. The approach used is described in the following chapters:

- Age class
- Basel area
- Volume
- Stem Volume up to Crown Base
- Volume of virtual marcation
- Preliminary assortments structure
- Volume of harvested trees
- Stump volume
- Volume of felled (cut) tree
- Biomass and Carbon
- Volume increment

In addition to the elements listed above, a relationship of the type *h = f (dbh)* – height curve, i.e. *id = (dbh)* – line of diameter increment will be modelled at the level of tree species, certain ecological and territorial. The height curve and the line of diameter increment are elements necessary for calculating the volume, i.e. volume increment.

In this chapter on single living trees reference is made to the common tree definition developed for national forest inventories in Europe by Gschwantner *et al.* (2009).

3.2.2.1. Height Curve

Tree height is defined as vertical distance between tree top and ground level at the stem base.

Height measurement of the single tree is an important variable in forest management, as it allows the quantification of tree growth and volume. The range of tree heights across the plot will indicate the diversity in the canopy structure. Also, height is the most common element for determining the site potential for certain tree species (site class, site index, etc.).

Tree height is measured with an accuracy of 1 *dm* for all trees in the sample plot.

Since trees of the same diameter can have different heights depending on a number of exogenous and endogenous factors, it was necessary to model the relationship *h = f (dbh)* - height curve. The selected model allows the prediction of height for each diameter. The estimated hight then can be used for further calculations.

The height curve is modelled for each tree species found in the plot. For volume calculation, the *h*-curve is only used when the height of a tree was not measured to draw back height from the measured diameter . For trees where *dbh* and *h* are measured, the real (measured) height is used to calculate the volume: *v = f (dbh, h)*.

On the plot, as a rule of thumb, there are never enough heights measured to model a good height curve. For that reason, the measured heights can be grouped as follows:

Tree species – Stand categories – Forest region

According to NFI-1, the forest area in Serbia (excluding Kosovo) is 2,252,400 ha. It is divided into seven forest regions of different sizes. Therefore, the assumption is that, by measuring all heights on the plots belonging to one forest region, a sufficient number of data will be provided for the production of quality *h*-curves within each stand category.

For modeling the *h*-curve, data from trees with 10 – 100 cm diameter is used. Outside of this interval, heights are usually extreme values, which impair the natural *h*-curve flow as well as the quality of regression and correlation analysis parameters.

Different functions for modeling the height curve were tested:

2-Parameter Functions

Linear function $h = a + b \cdot dbh$ (3-1)

Näslund $\mathrm{h}_{calc} = b \cdot h + \frac{dbh^2}{(a+b \cdot dbh)^2}$ (3-2)

Levaković $h = a \cdot \left(\frac{dbh}{1+dbh}\right)^b + 1.3$ (3-3)

Michailoff $h_{calc} = b \cdot h + a \cdot e\big(-b \cdot d_{DBH}(-1)\big)$ (3-4)

Meyer $h_{calc} = b \cdot h + a \cdot \big(1 - exp(-b \cdot d_{DBH})\big)$ (3-5)

Power $h_{calc} = b \cdot d_{DBH} + a \cdot d_{DBH} \cdot b$ (3-6)

3-Parameter Functions

Second degree polynomial function $h = a + b \cdot dbh + c \cdot dbh^2$ (3-7)

Terezaki-Mihajlov $h = a \cdot e^{\left(\frac{-b}{dbh^r}\right)}$ (3-8)

Prodan $h = \frac{dbh^2}{a+b \cdot dbh+c \cdot dbh^2} + 1.30$ (3-9)

Levaković $h = a \cdot \left(\frac{dbh}{1+dbh}\right)^b + 1.30$ (3-10)

$h = a_1 + \frac{a_2}{dbh} + \frac{a_3}{dbh^2}$ (3-11)

$h = a + b \cdot dbh^r$ (3-12)

Logistic $h_{calc} = b \cdot h + \frac{a}{(1+b \cdot exp(-c \cdot d_{DBH}))}$ (3-13)

Chapman-Richards $h_{calc} = b \cdot h + a \cdot \big(1 - exp(-b \cdot d_{DBH})\big) \cdot c$ (3-14)

Selection of the best-fitting function is done based on:

1. R^2 – coefficient of determination
2. RMSE – Root Mean Square Error like a standard way to measure the error of a model in predicting quantitative data,
3. The shape and flow/direction of the h-curve

The function that has the highest value of R^2 and the lowest RMSE with the natural flow/direction of the *h-curve* is selected (with increasing diameters, continuously also the height curve is increasing). In case that the third condition is not satisfied (Figure 1), the function, which has poorer statistical parameters (lower R^2 and higher RMSE) but a shape that characterizes the nature of this relationship better, has to been chosen.

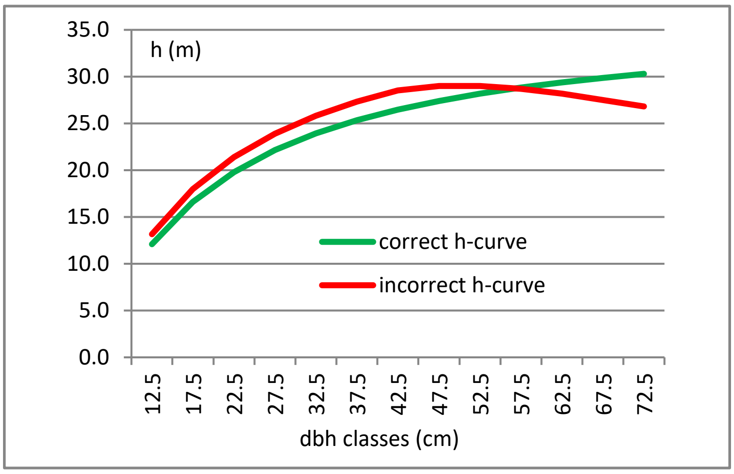


Figure 1. Height Curve

Temporary Note:

The current approach described here explains how the final approach and the functions to be actually used will be determined based on the full data set, in ca. 2021. Only then current description can be replaced or accomplished with the final approach and functions actually used.

Note:

Unlike for the methodology for data collection within an NFI, which after the start of field work should not be changed because it creates an inconsistent data base, data processing procedures, in the searching of optimal solutions, can be changed during or at the end of the NFI

3.2.2.2. Line of Diameter Increment

The diameter increment is the pure increase of diameter over a certain period of time. It has a very wide application in forestry as an indicator of the production potential of habitats, an indicator of tree vitality, for monitoring changes in the state of forests, etc. It is also used as an element in certain methods of calculating volume increments.

In accordance with the NFI-2 data collection methodology, periodic diameter increment (width of 10 growth rings x 2) is determined on three trees on the sample plot (two trees of the main tree species and one tree of the most common supporting tree species: 2 + 1). In even-aged forests, which are otherwise dominant in Serbia, the increment is determined with data from three more trees of the dominant species per plot (3 + 0). From these, samples are taken by an increment borer for age determination. Therefore, the maximum number of diameter increment data on a plot is 5 + 1, which is certainly not enough to obtain quality models for the prediction of *id* depending on *dbh*. Therefore, as is done with the *h*-curve, it is recommended to group data at the level of

tree species – stand category – forest region

with the possibility of correction during NFI-2.

Tested functions are:

$$id = a + b \cdot dbh \quad (3\text{-}15)$$

$$id = a + b \cdot dbh + c \cdot dbh^2 \quad (3\text{-}16)$$

$$id = a + b \cdot \frac{1}{dbh} \quad (3\text{-}17)$$

$$ln_{dbh} = a + \frac{b}{dbh} \quad (3\text{-}18)$$

$$id = \frac{1}{a + b \cdot e^{-dbh}} \quad (3\text{-}19)$$

$$id = a \cdot e^{-\frac{b}{dbh^S}} \quad (3\text{-}20)$$

$$id = a \cdot \left(1 - e^{b \cdot x}\right)^c \quad (3\text{-}21)$$

$$id = a \cdot \left(1 - e^{b \cdot x^c}\right) \quad (3\text{-}22)$$

Selection of function is performed based on:

- R^2 – coefficient of determination
- RMSE - Root Mean Square Error like a standard way to measure the error of a model in predicting quantitative data

The function that has the highest R^2 value and the lowest RMSE is selected.

Temporary Note:

The current approach described here describes how the final approach and the functions to be actually used will be determined based on the full data set, in ca. 2021. Only then current description can be replaced or accomplished with the final approach and functions actually used.

3.2.2.3. Age Class

The age is determined by drilling a core of three trees of the main tree species on each plot belonging to the even-aged forests. Afterwards, growth rings are counted thus age is determined. The average age is calculated in the field, in the data entry module. Based on this age and the origin of the stand, the age class is determined. The approach is described in Pantić, Dees & Borota (2020).

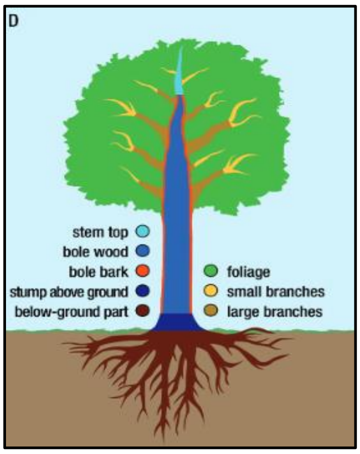
3.2.2.4. Basal Area

Based on *dbh*, assuming a circular shape, the basal area of tree in m² is calculated by the formula:

$$g = \frac{\pi}{4} \cdot \left(\frac{dbh}{100}\right)^2 \quad (3\text{-}23)$$

In the case when the tree is irregularly shaped at breast height, several cross diameters are measured, so the basal area of the tree is calculated by the formula:

$$g = \left[\frac{\pi}{4} \cdot \sum_{i=1}^{n} \left(\frac{dbh}{n}\right)^2\right] / 100 \quad (3\text{-}24)$$



3.2.2.5. Tree Volume

Prior to calculating the volume of a tree, it is necessary to define which parts of the tree are considered as part of the timber volume. Depending on which components of a tree are included into the definition of the timber volume, the calculation needs to be adjusted.

Figure 2. Wood components of a living tree

Source: Gschwantner et.al., 2009.

These definitions are related to the regional management approach, especially regarding the question which part of the tree can be and is used and thus is normally harvested. Figure 2 shows all components of a complete tree.

A comparison of 24 European countries on this question shows how different the definition of the tree volume is done (Table 4).

In Serbia the volume includes the stump above ground (including bole wood, stem top, bole bark and branches) with a diameter greater than 3 cm. Details are given in Table 5. Table 6 presents the national definition vs. the reference definition of the ENFIN group labelled „E43 reference definition" (Vidal et al., 2008)

Table 4. Tree volume definition in Europe

Tree part	Number of countries	%
Bole wood	24	100.0
Bole bark	21	87.5
Stem top	16	66,7
Stump above-ground	12	50.0
Large branches	4	16.7
Small branches	0	0.0
Foliage	0	0.0
Below ground part	0	0.0

Source: Gschwantner et.al., 2009

Table 5. Consideration of tree components in Serbia

Part of tree	Considered for Volume of trees
Bole wood (top diameter threshold with bark 3 cm)	YES
Bole bark	YES
Large branches (branch diameter threshold 3 cm)	YES
Small branches	YES
Stem top (above 3 cm diameter)	YES
Stump above ground (stump height 0 - ⅓ of *dbh*)	YES
Below ground wood including bark	No

Table 6. Growing stock definition compared with E43 definition

E43 reference definition	Serbian National definition
Growing stock is the volume of living and standing stems over a specified land area. Includes: stem volume above stump measured over bark to top (0 cm), all trees with *dbh* over 0 cm	Growing stock is the volume of living and standing stems over a specified land area. Includes volume of all trees with dbh over 5 cm with the elements given in Table 5

The volume of trees is calculated in two ways:

Option 1 - Volume Table (Function) Methods *v = f (dbh, h)*

Serbia has volume functions for numerous tree species in its forest fund. These are functions with two independently variables (*dbh, h*), mostly of local character. The functions were modeled by professors of the Chair of Forest Management and Planning, Faculty of Forestry in Belgrade namely Prof. Mirković, Prof. Banković and Prof. Pantić, references of this work are given in the list of references), and were integrated into the "Osnova" software. The function that best estimate the dependence of the volume on the diameter and height of the tree is:

Schumacher-Hall function $v = a \cdot dbh^b \cdot h^c$

Parameters of this function for some tree species are shown in Table 7.

Table 7. Parameters of Schuhmacher-Hall function (*Source: Software "Osnova"*)

Function code	Tree species	Parameters $v = a \cdot dbh^b \cdot h^c$ function		
		a	*b*	*c*
1	Beech (high forest) - Serbia	0.318055072	1.997946168	1.066845781
2	Beech (coppice forests) - Fruska Gora	0.576446485	1.849032992	0.819070521
5	Beech (coppice forests) - Serbia	0.482935195	1.83648885	0.819672895
6	Beech (high forest) - Eastern Serbia	0.00004	2.0584	0.96443
7	Beech (high forest) - Southern Serbia	0.00005	1.98222	0.94918
8	Beech (high Forest) - Central Serbia	0.00006	1.95285	0.94036
9	Beech (high Forest) - Western Serbia	0.00006	1.88652	0.97552
10	Beech (coppice forests) - Serbia, 2008.	0.00005	1.8594	1.03464
11	Common oak (high Forest) - Ravni Srem	0.212463712	1.503522364	1.091647347
12	Narrow-leaved ash flooded part (high Forest) – Ravni Srem	0.43533	1.91647	0.85554
13	Narrow-leaved ash (high Forest) - Ravni Srem	0.2833834	1.356759266	0.929585099
14	Hornbeam (coppice forest) – Serbia	0.251843802	1.586373878	0.893303217
15	Hornbeam (high forest) - Ravni Srem	0.260056192	1.462258771	0.981932097
16	Hornbeam (coppice forest) - Fruška Gora	0.299256463	1.605355101	0.899047245
17	Turkey oak - Hungarian oak (coppice forest) - Serbia	0.236343452	1.354912587	0.890026635
18	Turkey oak (high forest) - Ravni Srem	0.304711525	1.725564443	1.054513527
19	Turkey oak (coppice forest) - Fruška Gora	0.281058615	1.366168328	0.891811947
20	Narrow-leaved ash non flooded part (high forest) – Ravni Srem	0.28694	1.92243	1.06064
21	Sessile oak (high forest) - Serbia	0.719589695	1.910405442	0.758793138
22	Sessile oak (coppice forest) - Fruška Gora	0.416792298	1.715938324	0.86900371
23	Sessile oak (coppice forest) - Serbia	0.346107374	1.69617924	0.868718242
28	Black locust (artificially established forest) - Srem	0.407630402	2.048699982	0.996805759
30	Poplar (artificially established forest) - Srem	0.345230306	1.999903626	0.999856138
31	EA Poplar - Vojvodina	0.535304782	2.032937365	0.856152562

Function	Tree species	Parameters $v = a \cdot dbh^b \cdot h^c$ function		
32	Black poplar - Vojvodina	0.266666369	1.94425194	1.013632745
33	White poplar - Vojvodina	0.558074242	2.020152934	0.835726639
34	Willow - Vojvodina	0.97241588	2.088916233	0.669708515
35	Poplar I-214 - Vojvodina	0.57697696	1.932238	0.915707
36	Poplar robusta- Vojvodina	0.57697696	1.932238	0.915707
37	Deltoids poplar - Vojvodina	0.57697696	1.932238	0.915707
38	Deltoids poplar - Vojvodina, 2013.	0.90971	2.15845	0.74932
39	Poplar I-214, Danube alluvium – Vojvodina, 2013.	0.72085	2.15197	0.83334
40	Poplar I-214, Sava river alluvium – Vojvodina, 2013.	0.33618	2.03873	1.00598
41	Poplar I-214, alluvium Tisa and Tamiš – Vojvodina, 2013.	0.26622	1.93892	1.05534
42	Poplar M-1 – Vojvodina, 2013.	0.59343	2.00101	0.82395
45	Birch	2.78201E-05	1.960478	1.091992
51	American aspen	0.465143	1.988724	0.788606
81	Fir - Tara	0.241927538	1.497537144	1.057435328
82	Spruce - Tara	0.267368948	1.480005129	0.985782809
83	Fir - Goč	0.216916402	1.690731699	1.109127613
85	Fir (artificially established stands) - Kopaonik	0.298753	1.62245	0.92674
86	Spruce (high forest, mounting area) - Kopaonik	0.32887	1.73294	0.96409
87	Spruce (high forest, subalpine area) - Kopaonik	0.41521	1.84357	0.88498
88	Fir - Kopaonik	0.28466	1.71193	1.02212
90	Black pine - Serbia	0.641747249	2.085654534	0.859779642
91	White pine - Serbia	0.60860484	2.081061278	0.853223185

Depending on the stand origin and the region of validity (local or general function), for each tree species on the plot it is necessary to define the volume function to be used in the volume calculation. In the case that the function is not defined in the module for data entry, for the calculation of the volume a default function will be used (see Table 8).

Table 8. The default function for calculation the volume of individual tree species

Code	Tree species	Volume function code	Code	Tree Species	Volume function code
11	White willow	34	63	European ash	21
12	Almonds willow	34	64	Norway maple	21
13	Brittle willow	34	65	Maple	21
14	Grey willow	34	66	Mountain maple	21
21	Black alder	33	67	Fir	81
22	White alder	33	68	Spruce	82
23	White poplar	33	69	Serbian spruce	82
24	Black poplar	32	70	Black pine	90
25	EA Poplar	31	71	Scots pine	91

Code	Tree species	Volume function code	Code	Tree Species	Volume function code
32	Grey poplar	31	72	Macedonian pine	91
37	Domestic nut	31	73	Bosnian pine	91
38	Field elm	21	74	Mountain pine	90
39	European white elm	21	75	Black locust	28
41	Narrow-leaved ash	13	76	Black walnut	21
42	Common oak	11	77	American ash	14
43	Hornbeam	14	78	Honey (Thorny) locust	14
44	Turkey oak	19	79	Red oak	21
45	Small-leaved lime	23	80	Oriental plane	21
46	Large-leaved lime	23	81	Tree of heaven	14
47	Silver lime	23	82	Boxelder	17
48	European Nettle Tree	23	83	Douglas-fir	17
49	Hungarian oak	17	84	Eastern white pine	90
50	Cherry	1	85	Grand fir	81
51	Other broadleaves (OB)	21	86	Caucasian fir	81
52	Chestnut	21	87	Larch	81
53	Pubescent oak	21	88	Jeffrey’s pine	81
54	Flowering ash	14	89	Ponderosa pine	81
55	Oriental hornbeam	14	90	Atlas cedar	81
56	European hop hornbeam	14	93	Other conifers (OC)	91
57	Sessile oak	21	94	Rowan	21
58	European Aspen	33	95	Field maple	45
59	Silver birch	33	96	Chinese scholar tree	28
60	Turkish hazel	21	97	Macedonian oak	21
61	Beech	1	98	Virginia bird cherry	14
62	Mountain elm	21	99	Wild service tree	14

Option 2 - Method of Tariffs *v = f (dbh)*

For NFI-1 the volume was calculated according to the method of tariff. In order to avoid the aggregation of errors of using two different methods in the comparative analysis of the volume of two consecutive inventories, the volume in the NFI-2 will be converted as an second option by the tariff method as well. The procedure is very similar to the method of volume functions, except that the *h*-curve is used instead of the height of individual trees in this case. For each tree in the plot, based on its *h*-curve, the affiliation to the height degree in accordance to the tariff series is determined. On the basis of the *dbh* of a specific tree species and the determined tariff series the volume is determined.

Table 9 shows the tariffs for the calculation of the volume of individual tree species.

Table 9. Tariffs for the calculation of the volume of individual tree species

Code	Tariff	Code	Tariff
1	Beech (high forest) - Serbia	29	Black locust – Vojvodina
2	Beech (coppice forests) - Fruska Gora	30	Poplar (artificially established forest) - Srem
3	Beech (high forest) – Tara	31	EAP - Vojvodina
4	Beech (high forest) - Goč	32	Black poplar - Vojvodina
5	Beech (coppice forests) - Serbia	33	White poplar - Vojvodina
6	Beech (high forest) - Eastern Serbia	34	Willow - Vojvodina
7	Beech (high forest) - Southern Serbia	35	Poplar I-214 - Vojvodina
8	Beech (high Forest) - Central Serbia	36	Poplar robusta- Vojvodina
9	Beech (high Forest) - Western Serbia	37	Deltoids poplar - Vojvodina
10	Beech (coppice forests) - Serbia, 2008.	45	Silver Birch
11	Common oak (high Forest) - Ravni Srem	51	American aspen
12	Narrow-leaved ash flooded part (high forest) – Srem	81	Fir - Tara
13	Narrow-leaved ash (high Forest) – Srem	82	Spruce - Tara
14	Hornbeam (coppice forest) – Serbia	83	Fir - Goč
15	Hornbeam (high forest) – Srem	84	Fir and spruce – Tara
16	Hornbeam (coppice forest) - Fruška Gora	85	Fir (artificially established stands) - Kopaonik
17	Turkey oak - Hungarian oak (coppice forest) – Serbia	86	Spruce (high forest, mounting area) - Kopaonik
18	Turkey oak (high forest) - Ravni Srem	87	Spruce (high forest, subalpine area) - Kopaonik
19	Turkey oak (coppice forest) - Fruška Gora	88	Fir - Kopaonik
20	Narrow-leaved ash non flooded part (high forest) – Srem	90	Black pine - Serbia
21	Sessile oak (high forest) - Serbia	91	White pine - Serbia
22	Sessile oak (coppice forest) - Fruška Gora	92	Black pine – Goč
23	Sessile oak (coppice forest) - Serbia	93	White pine (artificially established forest) – Kopaonik
26	Lime (coppice forest) - Fruška Gora	94	Black pine (artificially established forest) – Kopaonik
28	Black locust (artificially established forest) – Srem		

The volume function method, as a more precise method, will primarily be used to calculate the volume in NFI-2. However, in order to enable a comparative analysis with the volume from NFI-1, the tariff method will also be used for the reasons stated above.

3.2.2.6. Stem Volume up to Crown Base

Stem Volume up to crown base is determined only for trees whose *dbh* > 25 cm. There are two possibilities for calculating the volume of these trees:

- Using volume functions $v = f(dbh, h)$ – see chapter 3.2.2.5., option 1.

The height to the beginning of the crown base in some trees can be very small value, below the range covered by the volume function, which makes it possible to incorrectly calculating their volume.

- Using formula with form factor (Table 10).

$$v_k = g \cdot h \cdot f = \frac{\pi}{4} \cdot \left(\frac{dbh}{100}\right)^2 \cdot h \cdot f \qquad (3\text{-}25)$$

where:

g – basal area of tree *dbh > 25 cm*

h – high of stem until beginning of crown

f – form factor

Table 10. Values of the form factor (volume coefficient**)** *Source: Osnova software-TarifaSR.mdb*

Code	Species	f	Code	Species	f	Code	Species	f
11	White willow	0.4264	45	Small-leaved lime	0.4376	73	Heldreich's pine	0.4563
12	Almonds willow	0.4264	46	Large-leaved lime	0.4376	74	Mountain pine	0.3778
13	Brittle willow	0.4264	47	Silver lime	0.4900	75	Black locust	0.4843
14	Grey willow	0.4264	48	European hackberry	0.4203	76	Black walnut	0.5129
15	Bald cypress	0.4264	49	Hungarian oak	0.4203	77	White ash	0.5129
20	White Poplar Pannonia and -57/58	0.4301	50	Cherry	0.5129	78	Honey locust (thorny locust)	0.5129
21	Black alder	0.4264	51	Other hard broadleaves (OB)	0.5129	79	Red oak	0.5129
22	White alder	0.4264	52	Chestnut	0.5129	80	Plane tree	0.5129
23	White poplar	0.4172	53	Pubescent oak	0.3778	81	Sour tree	0.4843
24	Black poplar	0.3704	54	Flowering ash	0.3778	82	Ash-leaved maple	0.4843
25	EA Poplar	0.6021	55	Oriental hornbeam	0.3778	83	Douglas-fir	0.4563
26	Black Italian poplar	0.6021	56	Hop hornbeam	0.3778	84	Weymouth pine	0.4563
27	Marilandica	0.6021	57	Sessile oak	0.5129	85	Grand fir	0.4563
28	Poplar cl. Ostia	0.4172	58	Aspen	0.4722	86	Nordmann fir	0.4563
29	Poplar I-154	0.4301	59	Birch	0.4722	87	Larch	0.4563
30	Poplar I-214	0.6021	60	Turkish hazel	0.4900	88	Džefrej	0.4563
31	Deltoid poplar	0.6021	61	Beech	0.4900	89	Ponderosa pine	0.4563
32	Gray poplar	0.4172	62	Wych elm	0.4900	90	Cedar	0.4563
33	Poplar M1	0.6021	63	White ash	0.4862	91	Yew	0.4563
34	Siberian elm	0.4900	64	Norway maple	0.4900	92	Catalpa	0.4563
37	Common walnut	0.5681	65	Maple	0.4900	93	Other conifers OC)	0.4974
38	Smooth-leaved elm	0.5129	66	Balkan maple	0.4900	94	Mountain ash	0.4974
39	European white elm	0.4172	67	Fir	0.5200	95	Field maple	0.4974
40	Other soft broad leaves	0.4172	68	Spruce	0.4888	96	Sophora	0.4974
41	Narrow-leaved ash	0.4862	69	Serbian spruce	0.4888	97	Macedonian oak	0.4974
42	Common oak	0.5681	70	Austrian pine	0.4974	98	Virginia bird cherry	0.4974

43	Hornbeam	0.3778	71	Scots pine	0.4563	99	Wild service tree.	0.4974
44	Turkey oak	0.4203	72	Macedonian pine	0.4563			

In the following an alternative option is described. It will be considered in the context of the analysis for it's applicability:

Considering a function for the shape of the tree will allow the estimation of the diameter at the crownbase and at the nominal stump level.

Based on these two measurements Huber's formula can be applied (see dead wood section, there the formula is presented).

A generic function to determine then diameter at different heights of a tree was developed in the course of the NFI in Germany (Kublin, 2011; Riedel *et al.,* 2017) for diameter measurement in deviating heights:

$$d_{DBH} = d_{measured\ at\ deviating\ height} \cdot \left[1 + \left(0.0011 \cdot h_{d\ measurement\ height} - 1.30\right)\right] \quad (3\text{-}26)$$

where:

d_{DBH} – diameter at breast height

$d_{measured\ at\ deviating\ height}$ – diameter measured at different height

$h_{d\ measurement\ height}$ – tree height

Inverting this formula can be used to estimate the diameter at any tree height based on the *dbh* and the approach described can be applied.

3.2.2.7. Volume of Virtual Marking

In accordance with the NFI-2 methodology, a virtual marking of trees is performed on the sample plot in order to determine the potential yield at the level of different ecological or territorial categories. The following codes are assigned to the trees:

- Indifferent tree
- Without status
- Potential future crop tree
- Competitor
- For harvest
- Mature

As stated in chapter 3.2.2.5 the volume of each tree is primarily calculated by the method of volume tables (functions) of type *v = f (dbh, h)*.

3.2.2.8. Preliminary Assortments Structure

Serbia has assortment tables only for poplar and beech. Therefore, assortment tables of authors from the surrounding countries were used to calculate the potential assortment structure and, for certain trees species, the structure was determined on the basis of the experience of colleagues from public enterprise. Table 11 gives assortment structure by diameter classes (I-IX).

Table 11. Assortment shares of volume as currently used in software OSNOVA

Species Code	Vrsta drveta	Tree species	No	Detailed assortment	Assortmant	Sortiment SR	%_0	%_I	%_II	%_III	%_IV	%_V	%_VI	%_VII	%_VIII	%_IX
11	bela vrba	white willow	1	I	2. Sawmill logs	Trupac za rezanje	0	0	10	12	15	15	10	5	2	0
			2	II	2. Sawmill logs	Trupac za rezanje	0	0	10	15	18	15	10	5	3	5
			3	Cellulose	5. Cellulose	Celuloza	0	5	10	15	15	15	10	10	10	10
			4	Fuel wood, soft wood	6. Fuel wood (soft)	Ogrevno drvo (meki.l.)	20	75	50	38	32	35	50	60	65	65
			5	Residue	9. Residue	Drvni ostatak	80	20	20	20	20	20	20	20	20	20
13	krta vrba	brittle willow	1	I	2. Sawmill logs	Trupac za rezanje	0	0	10	12	15	15	10	5	2	0
			2	II	2. Sawmill logs	Trupac za rezanje	0	0	10	15	18	15	10	5	3	5
			3	Cellulose	5. Cellulose		0	5	10	15	15	15	10	10	10	10
			4	Fuel wood, soft wood	6. Fuel wood (soft)	Ogrevno drvo (meki.l.)	20	75	50	38	32	35	50	60	65	65
			5	Residue	9. Residue	Drvni ostatak	80	20	20	20	20	20	20	20	20	20
23	bela topola	white poplar	1	I	2. Sawmill logs	Trupac za rezanje	0	0	9	15	20	17	15	12	8	0
			2	II	2. Sawmill logs	Trupac za rezanje	0	0	12	14	12	14	18	19	18	26
			3	Cellulose	5. Cellulose	Celuloza	0	4	16	21	25	26	22	19	17	17
			4	Fuel wood, soft wood	6. Fuel wood (soft)	Ogrevno drvo (meki.l.)	20	76	43	30	23	23	25	30	37	37
			5	Residue	9. Residue	Drvni ostatak	80	20	20	20	20	20	20	20	20	20
24	crna topola	black poplar	1	I	2. Sawmill logs	Trupac za rezanje	0	0	9	15	20	17	15	12	8	0
			2	II	2. Sawmill logs	Trupac za rezanje	0	0	12	14	12	14	18	19	18	26
			3	Cellulose	5. Cellulose	Celuloza	0	4	16	21	25	26	22	19	17	17
			4	Fuel wood, soft wood	6. Fuel wood (soft)	Ogrevno drvo (meki.l.)	20	76	43	30	23	23	25	30	37	37
			5	Residue	9. Residue	Drvni ostatak	80	20	20	20	20	20	20	20	20	20
25	topola robusta	EA poplar	1	I	2. Sawmill logs	Trupac za rezanje	0	0	9	15	20	17	15	12	8	0
			1	F 35-39	1. Veneer logs	Furnirski trupac	0	0	0	2	1	2	2	0	0	0
			2	F 40-49	1. Veneer logs	Furnirski trupac	0	0	0	0	3	2	2	1	1	0
			3	F > 50	1. Veneer logs	Furnirski trupac	0	0	0	0	0	1	1	1	1	0
			4	Fk 35-39	1. Veneer logs	Furnirski trupac	0	0	0	3	4	3	3	1	1	0

Species Code	Vrsta drveta	Tree species	No	Detailed as-sortment	Assortmant	Sortiment SR	%_0	%_I	%_II	%_III	%_IV	%_V	%_VI	%_VII	%_VIII	%_IX
			5	Fk 40-49	1. Veneer logs	Furnirski trupac	0	0	0	0	2	4	4	1	1	0
			6	Fk > 50	1. Veneer logs	Furnirski trupac	0	0	0	0	0	3	3	1	1	0
			7	K	2. Sawmill logs	Trupac za rezanje	0	0	2	3	3	4	4	4	4	4
			8	I	2. Sawmill logs	Trupac za rezanje	0	0	3	10	12	14	16	17	17	16
			9	II	2. Sawmill logs	Trupac za rezanje	0	0	5	12	15	17	20	24	24	20
			10	K	2. Sawmill logs	Trupac za rezanje	0	0	15	5	0	0	0	0	0	0
			11	Fuel wood, hard wood	7. Fuel wood (hard)	Ogrevno drvo (tvrdi.l.)	30	75	65	55	50	40	35	40	40	50
41	poljski jasen	narrow-leaved ash	12	Residue	9. Residue	Drvni ostatak	70	25	10	10	10	10	10	10	10	10
			1	FI 40-49	1. Veneer logs	Furnirski trupac	0	0	0	0	2	2	2	1	1	1
			2	FI 50-59	1. Veneer logs	Furnirski trupac	0	0	0	0	0	3	2	2	1	1
			3	FI 60-69	1. Veneer logs	Furnirski trupac	0	0	0	0	0	0	3	3	2	2
			4	FI > 70	1. Veneer logs	Furnirski trupac	0	0	0	0	0	0	0	1	1	1
			5	FII 40-49	1. Veneer logs	Furnirski trupac	0	0	0	0	3	2	3	3	1	1
			6	FII 50-59	1. Veneer logs	Furnirski trupac	0	0	0	0	0	3	3	3	2	2
			7	FII > 60	1. Veneer logs	Furnirski trupac	0	0	0	0	0	0	2	2	2	2
			8	K	2. Sawmill logs	Trupac za rezanje	0	0	0	1	3	3	3	3	3	3
			9	I	2. Sawmill logs	Trupac za rezanje	0	0	1	3	5	7	7	7	8	8
			10	II	2. Sawmill logs	Trupac za rezanje	0	0	1	4	6	9	9	9	10	10
			11	III	2. Sawmill logs	Trupac za rezanje	0	0	3	7	11	16	16	16	19	19
			12	K	2. Sawmill logs	Trupac za rezanje	0	0	15	15	10	0	0	0	0	0
			13	Fuel wood, hard wood	7. Fuel wood (hard)	Ogrevno drvo (tvrdi.l.)	30	75	60	60	50	45	40	40	40	40
42	lužnjak	pedunculate oak	14	Residue	9. Residue	Drvni ostatak	70	25	20	10	10	10	10	10	10	10
			1	F	1. Veneer logs	Furnirski trupac	0	0	0	0	5	5	0	0	0	0
			2	I	2. Sawmill logs	Trupac za rezanje	0	0	1	4	3	3	4	1	1	1
			3	II	2. Sawmill logs	Trupac za rezanje	0	0	9	31	27	27	31	14	9	4
			4	Fuel wood, hard wood	7. Fuel wood (hard)	Ogrevno drvo (tvrdi.l.)	20	30	80	55	55	55	55	75	80	85
43	grab	hornbeam	5	Residue	9. Residue	Drvni ostatak	80	70	10	10	10	10	10	10	10	10
			1	Fuel wood,	7. Fuel wood	Ogrevno drvo (tvrdi.l.)	30	90	90	90	90	90	90	90	90	90

Species Code	Vrsta drveta	Tree species	No	Detailed as-sortmant	Assortmant	Sortiment SR	%_0	%_I	%_II	%_III	%_IV	%_V	%_VI	%_VII	%_VIII	%_IX
				hard wood	(hard)											
44	cer	turkey oak	2	Residue	9. Residue	Drvni ostatak	70	10	10	10	10	10	10	10	10	10
			1	F	1. Veneer logs	Furnirski trupac	0	0	0	0	2	2	2	1	1	1
			2	L	1. Veneer logs	Furnirski trupac	0	0	0	0	5	5	5	4	4	4
			3	I	2. Sawmill logs	Trupac za rezanje	0	0	2	5	7	6	6	5	4	4
			4	II	2. Sawmill logs	Trupac za rezanje	0	0	8	10	6	7	7	5	6	6
			5	Cellulose	5. Cellulose	Celuloza	30	65	55	55	50	50	50	50	50	50
			6	Fuel wood, soft wood	6. Fuel wood (soft)	Ogrevno drvo (meki.l.)	0	15	15	10	10	10	10	15	15	15
45	sitnolisna lipa	small-leaved lime	7	Residue	9. Residue	Drvni ostatak	70	20	20	20	20	20	20	20	20	20
			1	Fuel wood, hard wood	7. Fuel wood (hard)	Ogrevno drvo (tvrdi.l.)	20	90	90	90	90	90	90	90	90	90
48	koprivić	european nettle tree	2	Residue	9. Residue	Drvni ostatak	80	10	10	10	10	10	10	10	10	10
			1	L	1. Veneer logs	Furnirski trupac	0	0	3.6	3.6	4.8	4.8	4.8	4.8	3.8	3.8
			2	I	2. Sawmill logs	Trupac za rezanje	0	0	6.6	6.6	11	11	11	11	10.3	10.3
			3	II	2. Sawmill logs	Trupac za rezanje	0	4	16.3	16.3	21.8	21.8	21.8	21.8	20.2	20.2
			4	III	2. Sawmill logs	Trupac za rezanje	0	5.5	20.1	20.1	15.2	15.2	15.2	15.2	16.4	16.4
			5	Tt	3. Mine poles	Rudno drvo	0	0	0	0	0	0	0	0	0	0
			6	Jd	3. Mine poles	Rudno drvo	0	0	0	0	0	0	0	0	0	0
			7	St	4. Thin wood	Sitno tehničko	0	0	0	0	0	0	0	0	0	0
			8	Cellulose	5. Cellulose	Celuloza	31.85	31.1	19.1	19.1	10.6	10.6	10.6	10.6	15.8	15.8
			9	Fuel wood, hard wood	7. Fuel wood (hard)	Ogrevno drvo (tvrdi.l.)	60.75	49.9	24.2	24.2	26.3	26.3	26.3	26.3	23.7	23.7
49	sladun	hungarian oak	10	Residue	9. Residue	Drvni ostatak	7.4	9.5	10.1	10.1	10.3	10.3	10.3	10.3	9.8	9.8
			1	F	1. Veneer logs	Furnirski trupac	0	0	0	0	0	5	5	5	5	5
			2	I	2. Sawmill logs	Trupac za rezanje	0	0	0	3	7	9	11	11	11	11
			3	II	2. Sawmill logs	Trupac za rezanje	0	0	0	7	18	21	24	24	24	24
			4	K	2. Sawmill logs	Trupac za rezanje	0	0	10	10	5	5	5	5	5	5
			5	Fuel wood, hard wood	7. Fuel wood (hard)	Ogrevno drvo (tvrdi.l.)	30	80	80	70	60	50	45	45	45	45
50	trešnja	cherry	6	Residue	9. Residue	Drvni ostatak	70	20	10	10	10	10	10	10	10	10

Species Code	Vrsta drveta	Tree species	No	Detailed assortment	Assortmant	Sortiment SR	%_0	%_I	%_II	%_III	%_IV	%_V	%_VI	%_VII	%_VIII	%_IX
			1	II	2. Sawmill logs	Trupac za rezanje	0	0	0	20	25	25	25	25	25	25
			2	Fuel wood, hard wood	7. Fuel wood (hard)	Ogrevno drvo (tvrdi.l.)	30	90	90	70	65	65	65	65	65	65
51	OTL	OHB	3	Residue	9. Residue	Drvni ostatak	70	10	10	10	10	10	10	10	10	10
			1	Fuel wood, hard wood	7. Fuel wood (hard)	Ogrevno drvo (tvrdi.l.)	30	80	90	90	90	90	90	90	90	90
54	crni jasen	flowering ash	2	Residue	9. Residue	Drvni ostatak	70	20	10	10	10	10	10	10	10	10
			1	Fuel wood, hard wood	7. Fuel wood (hard)	Ogrevno drvo (tvrdi.l.)	30	80	90	90	90	90	90	90	90	90
55	grabić	oriental hornbeam	2	Residue	9. Residue	Drvni ostatak	70	20	10	10	10	10	10	10	10	10
			1	F	1. Veneer logs	Furnirski trupac	0	0	0	0	0	0	0	0	0	0
			2	L	1. Veneer logs	Furnirski trupac	0	0	0	0.2	0.2	5.166667	6.625	6.625	4.625	4.625
			3	K	2. Sawmill logs	Trupac za rezanje	0	0	0	0	0	0	0	0	0	0
			4	I	2. Sawmill logs	Trupac za rezanje	0	0	0	1.8	1.8	8.5	7.375	7.375	7.25	7.25
			5	II	2. Sawmill logs	Trupac za rezanje	0	0	4.525	9.8	9.8	10.4	11.85	11.85	13.95	13.95
			6	III	2. Sawmill logs	Trupac za rezanje	0	0	6.85	15.4	15.4	15.3	16	16	17.025	17.025
			7	Tt	3. Mine poles	Rudno drvo	0	0	0	0	0	0	0	0	0	0
			8	Jd	3. Mine poles	Rudno drvo	0	0	0	0	0	0	0	0	0	0
			9	St	4. Thin wood	Sitno tehničko	0	0	0	0	0	0	0	0	0	0
			10	Cellulose	5. Cellulose	Celuloza	33.15	33.15	32.725	25.5	25.5	18.93333	15.85	15.85	11.175	11.175
			11	Fuel wood, hard wood	7. Fuel wood (hard)	Ogrevno drvo (tvrdi.l.)	57.0625	57.0625	45.075	35.2	35.2	29.83333	29.05	29.05	31.25	31.25
57	kitnjak CG	sessile oak MN	12	Residue	9. Residue	Drvni ostatak	9.7875	9.7875	10.825	12.1	12.1	11.86667	13.25	13.25	14.725	14.725
			1	F	1. Veneer logs	Furnirski trupac	0	0	0	0	1.089913	1.563583	1.46424	1.165254	1.057573	1.057573
			2	L	1. Veneer logs	Furnirski trupac	0	0	0	1.945764	4.205666	5.870946	7.18667	8.272139	8.750493	8.750493
			3	K	2. Sawmill logs	Trupac za rezanje	0	0	0	1.377066	0.992783	0.520698	0.1906479	0.2324698	0.4646568	0.4646568
			4	I	2. Sawmill logs	Trupac za rezanje	0	0	0	6.180539	7.659166	6.935691	5.202559	3.652217	3.318231	3.318231
			5	II	2. Sawmill logs	Trupac za rezanje	0	0	29.21033	29.2227	28.95053	30.11841	32.03717	33.2567	33.10047	33.10047
			6	III	2. Sawmill logs	Trupac za rezanje	0	0	0.55	7.912279	12.45606	15.4375	17.56606	19.17476	19.84309	19.84309
			7	Tt	3. Mine poles	Rudno drvo	0	0	0	0	0	0	0	0	0	0

Species Code	Vrsta drveta	Tree species	No	Detailed assortment	Assortment	Sortiment SR	%_0	%_I	%_II	%_III	%_IV	%_V	%_VI	%_VII	%_VIII	%_IX
			8	Jd	3. Mine poles	Rudno drvo	0	0	0	0	0	0	0	0	0	0
			9	St	4. Thin wood	Sitno tehničko	0	22.14243	19.2957	10.2619	5.482125	2.604509	0	0	0	0
			10	Cellulose	5. Cellulose	Celuloza	0	0	0	0	0	0	0	0	0	0
			11	Fuel wood, hard wood	7. Fuel wood (hard)	Ogrevno drvo (tvrdi.l.)	59.67738	62.74985	36.79604	28.8046	25.22109	23.71583	24.04469	22.93606	22.63665	22.63665
61	bukva visoke šume Srbija	beech high forest Serbia	12	Residue	9. Residue	Drvni ostatak	40.32262	15.10772	14.14792	14.29515	13.94267	13.23283	12.30796	11.3104	10.82884	10.82884
			1	F	1. Veneer logs	Furnirski trupac	0	0	0	0	0	0	0	0	0	0
			2	L	1. Veneer logs	Furnirski trupac	0	0	0	0	0	0	0	0	0	0
			4	I	2. Sawmill logs	Trupac za rezanje	0	0	2.0475	7.82	7.82	22.28857	22.28857	22.28857	22.28857	22.28857
			5	II	2. Sawmill logs	Trupac za rezanje	0	0	16.18	14.78	14.78	31.58714	31.58714	31.58714	31.58714	31.58714
			6	III	2. Sawmill logs	Trupac za rezanje	0	0	3.4025	14.56	14.56	10.68286	10.68286	10.68286	10.68286	10.68286
			7	Tt	3. Mine poles	Rudno drvo	4.04375	4.04375	22.6125	0	0	0.8757143	0.8757143	0.8757143	0.8757143	0.8757143
			8	Jd	3. Mine poles	Rudno drvo	49.86875	49.86875	20.055	5.59	5.59	3.907143	3.907143	3.907143	3.907143	3.907143
			9	St	4. Thin wood	Sitno tehničko	10.6925	10.6925	1.645	0.05	0.05	0.1871428	0.1871428	0.1871428	0.1871428	0.1871428
			10	Cellulose	5. Cellulose	Celuloza	17.43	17.43	14.51	22.68	22.68	11.13857	11.13857	11.13857	11.13857	11.13857
			11	Fuel wood, conifers	8. Fuel wood (con)	Ogrevno drvo (čet)	0.4875	0.4875	0.8225	4.02	4.02	0.8042857	0.8042857	0.8042857	0.8042857	0.8042857
67	jela CG	fir MN	12	Residue	9. Residue	Drvni ostatak	17.4775	17.4775	18.725	30.5	30.5	18.52857	18.52857	18.52857	18.52857	18.52857
			1	F	1. Veneer logs	Furnirski trupac	0	0	0	0	0	0	0	0	0	0
			2	L	1. Veneer logs	Furnirski trupac	0	0	0	0	0	0	0	0	0	0
			4	I	2. Sawmill logs	Trupac za rezanje	0	0	2.0475	7.82	7.82	22.28857	22.28857	22.28857	20.36714	0
			5	II	2. Sawmill logs	Trupac za rezanje	0	0	16.18	14.78	14.78	31.58714	31.58714	31.58714	28.77	0
			6	III	2. Sawmill logs	Trupac za rezanje	0	0	3.4025	14.56	14.56	10.68286	10.68286	10.68286	10.92429	0
			7	Tt	3. Mine poles	Rudno drvo	4.24125	4.04375	22.6125	0	0	0.8757143	0.8757143	0.8757143	1.485714	4.24125
			8	Jd	3. Mine poles	Rudno drvo	51.40875	49.86875	20.055	5.59	5.59	3.907143	3.907143	3.907143	4.224286	51.40875
			9	St	4. Thin wood	Sitno tehničko	5.96875	10.6925	1.645	0.05	0.05	0.1871428	0.1871428	0.1871428	0.2042857	5.96875
			10	Cellulose	5. Cellulose	Celuloza	18.70125	17.43	14.51	22.68	22.68	11.13857	11.13857	11.13857	11.01	18.70125
			11	Fuel wood, conifers	8. Fuel wood (con)	Ogrevno drvo (čet)	0.67	0.4875	0.8225	4.02	4.02	0.8042857	0.8042857	0.8042857	0.6285714	0.67
68	smrča CG	spruce MN	12	Residue	9. Residue	Drvni ostatak	19.01	17.4775	18.725	30.5	30.5	18.52857	18.52857	18.52857	22.38571	19.01

Species Code	Vrsta drveta	Tree species	No	Detailed as-sortment	Assortment	Sortiment SR	%_0	%_I	%_II	%_III	%_IV	%_V	%_VI	%_VII	%_VIII	%_IX
70	crni bor CG	black pine MN	4	I	2. Sawmill logs	Trupac za rezanje	0	0	1.814	8.94	8.94	26.726	0	0	0	0
			5	II	2. Sawmill logs	Trupac za rezanje	0	0	14.46	33.95	33.95	31.114	11.87	11.87	11.87	11.87
			6	III	2. Sawmill logs	Trupac za rezanje	0	0	9.408	13.95	13.95	10.13	11.87	11.87	11.87	11.87
			7	Tt	3. Mine poles	Rudno drvo	4.24125	4.24125	14.666	1.26	1.26	1.828	0	0	0	0
			8	Jd	3. Mine poles	Rudno drvo	51.40875	51.40875	22.63	6.71	6.71	3.99	2.91	2.91	2.91	2.91
			9	St	4. Thin wood	Sitno tehničko	5.96875	5.96875	1.276	0.31	0.31	0.204	0.1	0.1	0.1	0.1
			10	Cellulose	5. Cellulose	Celuloza	18.70125	18.70125	12.878	12.94	12.94	8.006001	24.1	24.1	24.1	24.1
			11	Fuel wood, conifers	8. Fuel wood (con)	Ogrevno drvo (čet)	0.67	0.67	1.006	2.09	2.09	0.36	30.55	30.55	30.55	30.55
			12	Residue	9. Residue	Drvni ostatak	19.01	19.01	21.862	19.85	19.85	17.642	18.6	18.6	18.6	18.6
71	beli bor	scots pine	1	I	2. Sawmill logs	Trupac za rezanje	0	0	0	6	6	7	7	7	7	7
			2	II	2. Sawmill logs	Trupac za rezanje	0	0	0	8	8	8	8	9	9	9
			3	III	2. Sawmill logs	Trupac za rezanje	0	0	0	9	9	10	10	10	10	10
			4	Fuel wood, conifers	8. Fuel wood (con)	Ogrevno drvo (čet)	0	0	0	16	16	16	16	17	17	17
			5	Cellulose	5. Cellulose	Celuloza	0	20	20	20	20	21	19	19	19	19
			6	Fuel wood, conifers	8. Fuel wood (con)	Ogrevno drvo (čet)	30	60	60	21	21	18	20	18	18	18
			7	Residue	9. Residue	Drvni ostatak	70	20	20	20	20	20	20	20	20	20
75	bagrem	black locust	2	I	2. Sawmill logs	Trupac za rezanje	0	0	6.6	6.6	11	11	11	11	10.3	10.3
			3	II	2. Sawmill logs	Trupac za rezanje	0	4	16.3	16.3	21.8	21.8	21.8	21.8	20.2	20.2
			4	III	2. Sawmill logs	Trupac za rezanje	0	5.5	20.1	20.1	15.2	15.2	15.2	15.2	16.4	16.4
			6	Jd	3. Mine poles	Rudno drvo	0	0	3.6	3.6	4.8	4.8	4.8	4.8	3.8	3.8
			8	Cellulose	5. Cellulose	Celuloza	31.85	31.1	19.1	19.1	10.6	10.6	10.6	10.6	15.8	15.8
			9	Fuel wood, hard wood	7. Fuel wood (hard)	Ogrevno drvo (tvrdi.l.)	60.75	49.9	24.2	24.2	26.3	26.3	26.3	26.3	23.7	23.7
			10	Residue	9. Residue	Drvni ostatak	7.4	9.5	10.1	10.1	10.3	10.3	10.3	10.3	9.8	9.8
			1	F I	1. Veneer logs	Furnirski trupac	0	0	0	0	5	10	3	3	3	3
			2	F II	1. Veneer logs	Furnirski trupac	0	0	0	0	0	0	7	7	7	7
			3	I	2. Sawmill logs	Trupac za rezanje	0	0	6	8	10	12	14	14	14	14

Species Code	Vrsta drveta	Tree species	No	Detailed as-sortment	Assortmant	Sortiment SR	%_0	%_I	%_II	%_III	%_IV	%_V	%_VI	%_VII	%_VIII	%_IX
76	crni orah	black walnut	4	II	2. Sawmill logs	Trupac za rezanje	0	0	9	12	15	18	21	21	21	21
			5	K	2. Sawmill logs	Trupac za rezanje	0	15	20	20	10	0	0	0	0	0
			6	Fuel wood, hard wood	7. Fuel wood (hard)	Ogrevno drvo (tvrdi.l.)	30	75	55	50	50	50	45	45	45	45
			7	Residue	9. Residue	Drvni ostatak	70	10	10	10	10	10	10	10	10	10
77	američki jasen	american ash	1	K	2. Sawmill logs	Trupac za rezanje	0	0	0	2	2	3	3	3	3	3
			2	Fuel wood, hard wood	7. Fuel wood (hard)	Ogrevno drvo (tvrdi.l.)	30	80	90	88	88	87	87	87	87	87
			3	Residue	9. Residue	Drvni ostatak	70	20	10	10	10	10	10	10	10	10
88	džefrej	Jeffrey’s pine	1	Fuel wood, hard wood	7. Fuel wood (hard)	Ogrevno drvo (tvrdi.l.)	30	90	90	90	90	90	90	90	90	90
			2	Residue	9. Residue	Drvni ostatak	70	10	10	10	10	10	10	10	10	10
89	ponderoza	ponderosa pine	1	Fuel wood, hard wood	7. Fuel wood (hard)	Ogrevno drvo (tvrdi.l.)	30	90	90	90	90	90	90	90	90	90
			2	Residue	9. Residue	Drvni ostatak	70	10	10	10	10	10	10	10	10	10
91	tisa	english yew	1	Fuel wood, hard wood	7. Fuel wood (hard)	Ogrevno drvo (tvrdi.l.)	30	90	90	90	90	90	90	90	90	90
			2	Residue	9. Residue	Drvni ostatak	70	10	10	10	10	10	10	10	10	10

3.2.2.9. Volume of Harvested Trees

For harvested trees, based on the measurement of the stump diameter and stump height the stump volume and the volume of the felled tree is determined.

A. Stump volume

$$v_s = g_s \cdot h_s = \frac{\pi}{4} \cdot \left(\frac{d_s}{100}\right)^2 \cdot h_s \qquad (3\text{-}27)$$

where

gs – Stump basal area

ds – Stump diameter

hs – Stump height

According to the NFI-2 Methodology, stumps are defined as:

1. Stump of coniferous tree species
2. Stump of deciduous tree species
3. Determination is not possible

The volume of all three categories of stumps are calculated.

B. Volume of Felled Tree

<u>Option 1</u>

Based on the measured diameter of the stump, the *dbh* of the felled tree is determined (for broad-leaves Table 12 and for conifers Table 13 is used). The obtained *dbh* is introduced into the *h*-curve model and the height of the felled tree is determined.

The *h*-curve for broadleaves is modelled on the basis of all measured heights of beech trees in Serbia. The *h*-curve for conifers is modeled on the basis of all measured heights of spruce trees in Serbia. These two species were selected as they are the most represented broadleaved or coniferous species respectively in the Serbian Forest Fund by volume. The functions given in Chapter 3.2.2.1. are used to model the *h*-curve for beech and spruce. Based on the R^2, RMSE and shape of curve, the highest quality model is selected.

The volume of felled trees is calculated according to the method of volume functions *v = f (dbh, h)* for beech (high forest) – Serbia (No=1, Table 7 when it comes to broadleaves), and for Spruce-Tara (No=82, Table 7), when it comes to conifers.

According to the position of the stumps defined by the azimuth and the horizontal distance from the center of the circle, it is determined in which concentric circle the stump is located in (r = 3, 10 or 15 m). Depending on this, as well also on the status of the plot (1 - a complete sample plot or 2 - part of a sample plot), the volume of the single felled tree is converted to the total harvested volume per ha. Summing up volumes obtained within the defined categories and dividing by the number of circles in them, the average volume of felled trees per ha is obtained.

According to the harvesting regulations a regularly harvests stump requires a mark that is then visible on each stump and that’s existence is assessed by the field teams for each stump.

Depending on whether a harvested marking sign recorded on the stump or not, the volume of felled trees can be differentiated into regular (planned) felling or forest theft.

Stumps that are already in a advanced decay state (according to the recorded decay status) will not be considered in this analysis.

Option 2

The calculation of the volume felled tree on the basis of the measured stumps is done by tariffs. Before calculating the volume, the measured diameter of the stump is reduced to the breast height (1.3 m). Reduction is made on the basis of tables for predicting breast diameter from stump diameter that are defined in the data base of tariff, especially for broadleaves and conifers (see Table 12 and Table 13). As for the stumps the tree species is not known, just if they are conifers or broadleaves stumps, for calculation the tariffs for spruce are used for conifer stumps and the tariffs for beech for broadleave trees (tarif series 11 for both species).

Option 1 is significantly better.

Table 12. Value of dbh based on stump diameter of broadleaves

dbh = f (d0.3h) **- broadleaves**											
d0.3h	*dbh*	*d0.3h*	*dbh*	*d0.3h*	*dbh*	*d0.3h*	*dbh*	*d0.3h*	*dbh*	*d0.3h*	*dbh*
10	9	27	22.5	44	36	61	49.5	78	63	95	77
11	9.5	28	23	45	36.5	62	50	79	64	96	78
12	10	29	24	46	37	63	51	80	65	97	78.5
13	11	30	25	47	38	64	52	81	65.5	98	79
14	12	31	25.5	48	39	65	52.5	82	66	99	80
15	12.5	32	26	49	40	66	53	83	67	100	81
16	13	33	27	50	41	67	54	84	68	101	82
17	14	34	28	51	41.5	68	55	85	68.5	102	83
18	15	35	28.5	52	42	69	56	86	69	103	84
19	16	36	29	53	43	70	57	87	70	104	85
20	17	37	30	54	44	71	57.5	88	71	105	85.5
21	17.5	38	31	55	44.5	72	58	89	72	106	86
22	18	39	32	56	45	73	59	90	73	107	87
23	19	40	33	57	46	74	60	91	73.5	108	88
24	20	41	33.5	58	47	75	60.5	92	74	109	89
25	21	42	34	59	48	76	61	93	75	110	90
26	22	43	35	60	49	77	62	94	76		

Table 13. Value of dbh based on stump diameter of conifers

dbh = f (d0.3h) **- conifers**											
d0.3h	*dbh*	*d0.3h*	*dbh*	*d0.3h*	*dbh*	*d0.3h*	*dbh*	*d0.3h*	*dbh*	*d0.3h*	*dbh*
10	7	27	21	44	36	61	50	78	64	95	78.5
11	8	28	22	45	36.5	62	51	79	65	96	79
12	9	29	23	46	37	63	52	80	66	97	80
13	9.5	30	24	47	38	64	53	81	67	98	81
14	10	31	25	48	39	65	53.5	82	68	99	82
15	11	32	26	49	40	66	54	83	68.5	100	83
16	12	33	26.5	50	41	67	55	84	69	101	83.5
17	13	34	27	51	41.5	68	56	85	70	102	84
18	14	35	28	52	42	69	57	86	71	103	85
19	14.5	36	29	53	43	70	58	87	72	104	86
20	15	37	30	54	44	71	58.5	88	73	105	87
21	16	38	31	55	45	72	59	89	73.5	106	88
22	17	39	31.5	56	46	73	60	90	74	107	88.5

23	18	40	32	57	46.5	74	61	91	75	108	89
24	19	41	33	58	47	75	62	92	76	109	90
25	19.5	42	34	59	48	76	63	93	77	110	91
26	20	43	35	60	49	77	63.5	94	78		

3.2.2.10. Volume Increment

Volume increment is calculated by two methods:

1. **Mayer Differential Method** (Banković, Pantić, 2006)

Volume increment is calculated for every single tree on the sample plot.

$$i_v = \frac{\Delta_v}{a} \cdot i_d \qquad \Delta_v = \frac{v_{d+a} - v_{d-a}}{2} \qquad i_v = \frac{v_{d+a} - v_{d-a}}{10} \cdot i_d \quad \text{actually} \quad i_v = \frac{v_{d+5} - v_{d-5}}{10} \cdot i_d \qquad (3\text{-}28)$$

where

a – the *dbh* class, *a* = 5 cm.

From the model *h = f (d)* for specific trees the following is determined:

$h_1 = f\,[d+5\ (cm)]$

$h_2 = f\,[d-5\ (cm)]$

From the defined volume function for a specific tree species the volumes of trees are determined:

$v_{d+5} = f\,[d+5\ (cm),\ h_1\ (m)]$

$v_{d-5} = f\,[d-5\ (cm),\ h_2\ (m)]$

Volume for 1 cm of diameter = $(v_{d+5} - v_{d-5})/10$

From the model *id = f (d),* diameter increments are determined for a concrete tree species.

2. **Percentage Increment Method**

The annual volume increment in NFI-1 was calculated using the percentage increment method. In order to avoid the accumulation of errors by different methods in the comparative analysis of the volume increment of two consecutive inventories, the NFI-2 volume increment will be as a second option, converted by the percentage increment method.

$$i_v = V \cdot \frac{p_{iv}}{100} \qquad (3\text{-}29)$$

$$p_{iv} = a \cdot N^b \cdot h_g^c \cdot d_g^e \cdot s^f \qquad (3\text{-}30)$$

where:

N – number of trees per ha

hg –height of mean stand tree by basal area,

dg –diameter of mean stand tree by basal area

s – share of the tree in mixture

The model parameters for calculating the percentage increment are given in Table 14.

Table 14. Parameters of models *piv = f (N, hg, dg, s)* by tree species

Code	Species	*a*	*b*	*c*	*e*	*f*
11	White willow	2,15789	0,02159	-0,25612	-0,93712	0,03025
21	Black alder	0,39958	0,00164	0,03375	-0,85348	-0,02188
22	White alder	0,39958	0,00164	0,03375	-0,85348	-0,02188
23	White poplar	2,15789	0,02159	-0,25612	-0,93712	0,03025
24	Black poplar	2,15789	0,02159	-0,25612	-0,93712	0,03025
25	Euramerican poplar	2,15789	0,02159	-0,25612	-0,93712	0,03025
26	Black Italian poplar	1,43971	-0,02651	0,01305	-0,75295	0,08946
27	Marilandica	2,15789	0,02159	-0,25612	-0,93712	0,03025
28	Poplar cl. Ostia	2,15789	0,02159	-0,25612	-0,93712	0,03025
29	Poplar I-154	2,15789	0,02159	-0,25612	-0,93712	0,03025
30	Poplar I-214	2,15789	0,02159	-0,25612	-0,93712	0,03025
32	Gray poplar	2,15789	0,02159	-0,25612	-0,93712	0,03025
34	Siberian elm	0,65168	-0,02651	0,01305	-0,75295	0,08946
37	Common walnut	0,65168	-0,09215	0,11519	-1,03374	0,1005
38	Smooth-leaved elm	1,38542	-0,09217	-0,017264	-0,88234	0,16193
39	European white elm	1,38542	-0,09217	-0,017264	-0,88234	0,16193
40	Other soft broad leaves	0,39958	0,00164	0,03375	-0,85348	-0,02188
41	Narrow-leaved ash	1,38542	-0,09217	-0,017264	-0,88234	0,16193
42	Common oak	0,65168	-0,09215	0,11519	-1,03374	0,1005
43	Hornbeam	0,33964	0,00164	0,03375	-0,85348	-0,02188
44	Turkey oak	0,32538	0,00591	0,22647	-0,834014	-0,052097
45	Small-leaved lime	0,47264	0,02131	0,10977	-0,744457	-0,01656
46	Large-leaved lime	0,62465	-0,03367	0,14394	-0,94807	0,08944
47	Silver lime	0,42293	0,0015	0,17052	-0,64839	-0,06951
48	European hackberry	1,38542	-0,09217	-0,017264	-0,88234	0,16193
49	Hungarian oak	0,32538	0,00591	0,22647	-0,834014	-0,052097
50	Cherry	1,17761	-0,09217	-0,017264	-0,88234	0,16193
51	Other hard broadleaves (OB)	0,32538	0,00591	0,22647	-0,834014	-0,052097
52	Chestnut	0,26959	-0,01068	0,32152	-0,97675	0,00118
53	Pubescent oak	0,32538	0,00591	0,22647	-0,834014	-0,052097
54	Flowering ash	0,06597	0,08855	0,26513	-0,92341	-0,05461
55	Oriental hornbeam	0,06597	0,08855	0,26513	-0,92341	-0,05461
56	Hop hornbeam	0,86037	0,03875	0,01935	-0,49562	-0,09362
57	Sessile oak	0,26959	-0,01068	0,32152	-0,97675	0,00118
58	Aspen	1,22375	-0,02651	0,01305	-0,75295	0,08946
59	Birch	1,35124	0,00075	-0,11956	-0,64883	-0,00714
60	Turkish hazel	0,85643	-0,11558	0,08838	-0,90925	0,07056
61	Beech	0,85643	-0,11558	0,08838	-0,90925	0,07056

Code	Species	a	b	c	e	f
62	Wych elm	0,81863	0,08767	-0,00463	-0,34172	-0,15095
63	White ash	0,43834	-0,02574	0,24793	-0,81962	0,04512
64	Norway maple	0,27818	0,00043	0,34184	-0,86318	-0,00124
65	Maple	0,7177	-0,02464	0,152232	-0,76257	0,06999
66	Balkan maple	0,41507	-0,04901	0,35769	-0,7529	0,04446
67	Fir	1,78576	-0,04246	-0,13173	-0,67479	0,05627
68	Spruce	3,88566	-0,13535	-0,21194	-0,8129	0,19504
69	Serbian spruce	3,88566	-0,13535	-0,21194	-0,8129	0,19504
70	Austrian pine	1,83421	0,02159	-0,25612	-0,93712	0,03025
71	Scots pine	2,42204	-0,00991	-0,29532	-0,84797	0,04077
72	Macedonian pine	1,83421	0,02159	-0,29532	-0,84797	0,04077
73	Heldreich’s pine	1,83421	0,02159	-0,29532	-0,84797	0,04077
74	Mountain pine	1,83421	0,02159	-0,25612	-0,93712	0,03025
75	Black locust	1,54096	0,01482	-0,09213	-0,59536	0,05258
76	Black walnut	1,17761	-0,09217	-0,017264	-0,88234	0,16193
77	White ash	1,17761	-0,09217	-0,017264	-0,88234	0,16193
78	Honey locust (thorny locust)	1,54096	0,01482	-0,09213	-0,59536	0,05258
79	Red oak	0,26959	-0,01068	0,32152	-0,97675	0,00118
80	Plane tree	0,26959	-0,01068	0,32152	-0,97675	0,00118
81	Sour tree	1,38542	-0,09217	-0,017264	-0,88234	0,16193
82	Ash-leaved maple	1,38542	-0,09217	-0,017264	-0,88234	0,16193
83	Douglas-fir	1,3443	0,17274	-0,19943	-0,49377	-0,06708
84	Weymouth pine	1,29609	0,23176	0,07342	-0,00541	-0,13193
85	Grand fir	1,78576	-0,04246	-0,13173	-0,67479	0,05627
87	Larch	1,29609	0,23176	0,07342	-0,00541	-0,13193
90	Cedar	1,29609	0,23176	0,07342	-0,00541	-0,13193
91	Yew	1,78576	-0,04246	-0,13173	-0,67479	0,05627
92	Catalpa	0,26959	-0,01068	0,32152	-0,97675	0,00118
93	Other conifers (OC)	1,3443	0,17274	-0,19943	-0,49377	-0,06708
94	Mountain ash	0,26959	-0,01068	0,32152	-0,97675	0,00118
95	Field maple	0,7177	-0,02464	0,152232	-0,76257	0,06999
97	Macedonian oak	0,32538	0,00591	0,22647	-0,834014	-0,052097
99	Wild service tree.	0,7177	-0,02464	0,152232	-0,76257	0,06999

The Mayer differential method, as a more precise method, will primarily be used to calculate the annual volume increment in NFI-2. However, in order to enable a comparative analysis with the volume increment from NFI-1, the percentage increment method will also be used for the reasons stated above.

3.2.2.11. Biomass and Carbon

The total aboveground and belowground carbon stock for a specific species can be calculated by formula:

total (AG + BG) C = TSW-volume × WD × BEF1 × (1 + BEF2) × CC

or

total (AG + BG) C = TSW-volume × WD × BEF3 × CC

with:

total (AG + BG) C: total C-stock in the aboveground and below-ground biomass (t C),

TSW-volume: total volume of the solid wood (m^3),

WD: wood density (t DM m^{-3})

BEF1: ratio aboveground dry mass to total solid wood dry mass (t AG DM t^{-1} TSW DM),

BEF2: ratio belowground dry mass to aboveground dry mass(t BG DM t^{-1} AG DM),

BEF3: ratio aboveground and belowground dry mass to total solidwood dry mass (t (AG + BG) DM t^{-1} TSW DM), and

CC: carbon content (t C t^{-1} DM).

The calculation is made on the basis of the conversion factors (Table 15).

Source in Table 15 for:

WD 1. Vande Walle I., Van Camp N., Perrin D., Lemeur R., Verheyen K., Van Wesemael B. and Laitat E. (2005): Growing stock-based assessment of the carbon stock in the Belgian forest bio-mass, Annals of Forest Science. 62(8): (853-864). *https://hal.archives-ouvertes.fr/hal-00883936/document*

WD 2. Šoškić B., Popović Z. (2002): Svojstva dreveta, Univerzitet u Beogradu-Šumarski fakultet, Beograd, 303 p.

Value 0.5 tons C/tons of dry mass is assigned on all tree species

IPCC (2006): Good Practice Guidance for Land Use, Land-Use Change and Forestry

https://www.ipcc-nggip.iges.or.jp/public/gpglulucf/gpglulucf_contents.html

Table 15. Coefficients for calculating biomass and carbon content

Code	Species	*WD_1*	*BEF*	*CC*	*WD_2*	Code	Species	*WD_1*	*BEF*	*CC*	*WD_2*
11	White willow	0.52	1.434	0.5	0.36	59	Birch	0.45	1.434	0.5	0.48
12	Almonds willow	0.52	1.434	0.5	0.36	60	Turkish hazel	0.69	1.610	0.5	0.50
13	Brittle willow	0,52	1.434	0.5	0.36	61	Beech	0.69	1.610	0.5	0.59
14	Gray willow	0.52	1.434	0.5	0.36	62	Wych elm	0.59	1.434	0.5	0.58
15	Bald cypress	0.50	1.434	0.5	-	63	White ash	0.59	1.434	0.5	0.56
20	White Poplar cl I 57	0.50	1.434	0.5	-	64	Norway maple	0.59	1.434	0.5	0.52
21	Black alder	0.50	1.434	0.5	0.43	65	Maple	0.59	1.434	0.5	0.52
22	White alder	0.50	1.434	0.5	0.43	66	Balkan maple	0.59	1.434	0.5	-
23	White poplar	0.50	1.434	0.5	0.36	67	Fir	0.41	1.680	0.5	0.37
24	Black poplar	0.50	1.434	0.5	0.36	68	Spruce	0.43	1.680	0.5	0.39

25	Euramerican poplar	0.50	1.434	0.5	EAP 0.36	69	Serbian spruce	0.43	1.680	0.5	0.39
26	Black Italian *poplar*	0.50	1.434	0.5		70	Austrian pine	0.52	1.434	0.5	0.47
27	Marilandica	0.50	1.434	0.5		71	Scots pine	0.43	1.680	0.5	0.42
28	Poplar cl. Ostia	0.50	1.434	0.5		72	Macedonian pine	0.49	1.610	0.5	0.42
29	Poplar I-154	0.50	1.434	0.5		73	Heldreich's pine	0.49	1.610	0.5	0.42
30	Poplar I-214	0.50	1.434	0.5		74	Mountain pine	0.49	1.610	0.5	-
31	Deltoid poplar	0.50	1.434	0.5		75	Black locust	0.69	1.610	0.5	0.59
32	Gray poplar	0.50	1.434	0.5	0.36	76	Black walnut	0.69	1.610	0.5	0.50
33	Poplar M1	0.50	1.434	0.5	0.36	77	White ash	0.69	1.610	0.5	0.56
34	Siberian elm	0.64	1.434	0.5	0.56	78	Honey thorny locust	0.69	1.610	0.5	0.50
37	Common walnut	0.64	1.434	0.5	0.50	79	Red oak	0.65	1.610	0.5	0.55
38	Smooth-leaved elm	0.64	1.434	0.5	0.58	80	Plane tree	0.52	1.434	0.5	0.50
39	European white elm	0.64	1.434	0.5	0.58	81	Sour tree	0,52	1.434	0.5	0.48
40	Other soft broad leaves	0.64	1.434	0.5	0.39	82	Ash-leaved maple	0.52	1.434	0.5	0.52
41	Narrow-leaved ash	0.79	1.434	0.5	0.56	83	Douglas-fir	0.49	1.610	0.5	0.37
42	Common oak	0.65	1.610	0.5	0.57	84	Weymouth pine	0.57	1.610	0.5	0.42
43	Hornbeam	0.79	1.434	0.5	0.58	85	Grand fir	0.57	1.610	0.5	-
44	Turkey oak	0.79	1.434	0.5	0.64	86	Nordmann fir	0.57	1.610	0.5	0.37
45	Small-leaved lime	0.50	1.434	0.5	0.48	87	Larch	0.57	1.610	0.5	0.49
46	Large-leaved lime	0.50	1.434	0.5	0.48	88	Džefrej	0.57	1.610	0.5	0.57
47	Silver lime	0.50	1.434	0.5	0.48	89	Ponderosa pine	0.57	1.610	0.5	0.57
48	European hackberry	0.50	1.434	0.5	0.50	90	Cedar	0.57	1.610	0.5	0.37
49	Hungarian oak	0.65	1.610	0.5	0.55	91	Yew	0.57	1.610	0.5	-
50	Cherry	0.69	1.610	0.5	0.50	92	Catalpa	0.69	1.610	0.5	-
51	Other hard broad-leaves (OB)	0.79	1.434	0.5	0.50	93	Other conifers (OC)	0.57	1.610	0.5	0.37
52	Chestnut	0.79	1.434	0.5	0.50	94	Mountain ash	0.69	1.610	0.5	0.50
53	Pubescent oak	0.79	1.434	0.5	0.55	95	Field maple	0.69	1.610	0.5	0.52
54	Flowering ash	0.79	1.434	0.5	0.56	96	Sophora	0.69	1.610	0.5	0.50
55	Oriental hornbeam	0.79	1.434	0.5	-	97	Macedonian oak	0.65	1.610	0.5	
56	Hop hornbeam	0.79	1.434	0.5	-	98	Virginia bird cherry	0.57	1.610	0.5	0.37
57	Sessile oak	0.65	1.610	0.5	0.61	99	Wild service tree.	0.65	1.610	0.5	0.50
58	Aspen	0.45	1.434	0.5	0.36	100					

There are significant differences between the frequency of WD_1 and WD_2 for the same tree species. After more detailed analyzes and consultations, the choice of values for Wood density will be made.

3.2.3. Trees Outside the Forest (TOF) and on Other Land with Tree Cover (OLWTC)

Previous procedures are related for single trees on the plots which fall on Forest and OWL. The same procedures, but with fewer numerical elements and statistical estimates, can also be used for trees on the plots which belong to the TOF and OLWTC land use categories.

An approach commonly used in absence of allometric equations for trees outside of forest, is to use equations for forest trees but with reductions in the range of 20 % (McHale *et al.*, 2009), as these trees grow solitary. Such approach was used by FAO (2015) that used a 10 % reduction for these trees.

To be conservative, it was decided to use a reduction factor of 20 % for trees growing outside forest, except for trees that occur on small forest patches, where a reduction of 10 % is applied. This, since it is assumed that small forest patches show intermediate properties closer to forest than to open land even though they do not reach the minimum area of 0.5 ha – which is applied to define forest. To live up to this intermediate type, the mean value of 10 % between forest (0 % reduction) and open land (20% reduction) is assumed. This differentiation is possible based on the assessment of the "Type of trees outside forests /OLWTC" (see Table 18).
This assumption is applied or the attributes volume, volume increment, assortments, biomass and carbon.

3.3. Dead Trees with *dbh* > 5 cm

3.3.1. Introduction

Dead tree attributes originate either from data collected in the field or they are derived from these using allometric equations and functions.

3.3.2. Attributes Collected in the Field

The following attributes are assessed on tree level (Table 16.)

Table 16. Tree level attributes assessed in the field of dead trees with *dbh* > 5 cm

Reference to Methodology of the Serbian NFI-2	Serbian name	English name	Scope
4.5.2.	Врста дрвећа	Tree species	All trees
4.5.6.	Азимут и удаљеност стабла од центра круга	Azimuth and distance of a tree from the sample plot center	All trees
4.5.4.	Статус стабала на поновно мереним круговима	Tree status on re-measured sample plots	Trees on re-measured plots only
4.5.5.	Прсни пречник, пречник на 1,3 m удаљености од дебљег краја лежећег стабла или пречник у	Diameter at breast height (*dbh*), diameter of a fallen tree at 1,3 m from the thicker side or diameter in	All trees

	средини дужине дела стабла	the middle of a tree part	
4.5.7.	Укупна висина дубећег стабала или укупна дужина лежећег стабла/дела стабла	Total height of a standing tree or total length of a lying tree/part of tree	All trees
4.5.11.	Здравствено стање стабла	Health condition of a tree	All trees
4.5.16.	Сува (мртва) стабла	Dry (dead) trees	All trees
4.5.17.	Група врста дрвећа мртвог дрвета	Group of tree species for dead wood	All trees
4.5.18.	Употребљивост сувог (мртвог) дрвета	Usability of dry (dead) trees	All trees

3.3.3. Derived Attributes on the Tree Level

The following numerical attributes related to dead wood are derived from the measured elements:

- Volume of dead wood
- Biomass of dead wood

3.3.3.1. Volume of Dead Wood

In accordance with the NFI-2 methodology, four categories of dead trees are distinguished:

1. a completely dry (dead) standing tree
2. a broken dry (dead) standing tree
3. a completely dry (dead) lying tree
4. a part of a lying tree

Which are classified in:

1. Coniferous trees species
2. Broadleaf tree species
3. Determination is not possible

The volume of dead trees of categories 1 and 3 is calculated on the basis of the volume function *v = f (dbh, h)* for beech (high forests) - Serbia (No = 1,Table 7) when it comes to broadleaves, for spruce-Tara (No = 82, Table 7), when it comes to coniferous respectively.

For category 2, volume is calculated using the formula:

$$v_k = g \cdot h \cdot f = \frac{\pi}{4} \cdot \left(\frac{dbh}{100}\right)^2 \cdot h \cdot f \qquad (3\text{-}31)$$

g – basal area of broken standing trees

h – high of dead standing tree to the breakpoint of tree

f – form factor– from Table 10, beech *f* = 0.4900; spruce *f* = 0,4888

Volume of category 4 is calculated using the Huber's formula

$$v = g_{1/2L} \cdot l = \frac{\pi}{4} \cdot \left(\frac{d_{1/2\,l}}{100}\right)^2 \cdot l \qquad (3\text{-}32)$$

$d_{1/2L}$ – diameter in the middle of a part of trees

$g_{1/2L}$ – basal area in the middle of part of trees

l – Length of part of tree

If it is not possible to determine the trees species of a single tree within a group of dead trees, this tree will be assigned to the species which is dominant in the plot. Further calculation will be based on this assigned species.

Depending on the *dbh* of trees category 1, 2, and 3, or the diameter in the middle of the part length tree of a category 4, as well as the status of the circle (1 or 2), the volume of dead wood is calculated per hectare. Summing up these volumes within the defined group (territorial and/or ecological category) and dividing by the number of plots gives the average volume of dry (dead) wood per ha in the defined group, or in Serbia respectively.

The volume of dead wood at different levels can be differentiated into:

- Volume of usable wood
- Volume of unusable wood

3.3.3.2. Biomass of Dead Wood

See chapter 3.2.2.11. “Biomass and Carbon”

3.4. Living Trees *dbh* ≤ 5 cm

Trees ≤ 5 cm *dbh* are defined as trees with a *dbh* ≤ 5 cm and *dbh* > 0 cm but of a minimum height of 1.3 m.

In order to achieve a conservative estimate of the wood volume and biomass for each tree the volume of a tree with *dbh* = 2.5 cm and a height of 2 m is assumed and applied considering the standard functions for broad leaved trees and conifer trees.

To derive area related values, the area of the circle and the number of broad leaved trees and conifer trees is considered

Analysis scope:

- Number of small tress per plot (per ha),
- Number of small trees in total,
- Number of small trees per species group in %,
- Biomass of small trees per plot (per ha),
- Biomass of small trees in total,
- Biomass of small trees per species group in %.

3.5. Regeneration

As a very important indicator of the condition, stability and perspective of the forest, the regeneration, in accordance with the Serbian forestry practice, is observed through several mainly qualitative elements:

- Tree species
- Origin of small trees/regeneration
- Abundance of regeneration
- Quality of regeneration
- Conditions for regeneration development
- Height of regeneration
- Damage on small trees/regeneration
- Cause of damage to small trees/regeneration

Therefore, no specific algorithms need to be developed.

4. PLOT LEVEL INFORMATION

4.1. Introduction

Plot level information can have different origin:

1. It can be assessed in the field:
   - Under the term "plot level information" both information that characterizes the site or the stand.
2. It can originate from GIS-layers:
   - Legal status GIS layers: It is retrieved via the location in GIS layers of non-natural information, such as location in a cadastral cell (ownership), location in a formally protected site (e.g. national park) or location in administrative area (e.g. municipality, forest area).
   - Thematic GIS layers used to provide information on the site, such as elevation or proximity to a road that is mapped in a GIS layer or information on soil from a soil map.
3. It can originate from visual interpretation of remote sensing images:
   - E.g. historic land use, land use changes or an estimate of the number of trees on the plot.
4. It can originate from aggregation of information from elements that occur on the plot and are assessed:
   - Attributes derived from one element type: E.g. the total basal area or the basal area per ha determine based on tree measurements (trees > 5 cm *dbh*)
   - Attributes derived from several element types: E.g. the total above ground biomass originating from living trees > 5 cm *dbh*, dead trees > 5 cm *dbh*, small trees ≤ 5 cm *dbh*, down dead wood, stumps.
   - Attributes derived via complex classification systems: E.g. Biodiversity value or conservation status determined based on various attributes that are indicators for biodiversity.

For attributes, this information is originating from several element types, such as the total above ground biomass. It is necessary to make this aggregation at plot level as only using this approach the estimates for analysis units and sampling errors can be determined both easy (considering the complexity of the algorithm) and correctly (as any correlation between the subcomponents is considered).

4.2. Attributes Assessed in the Field at Plot Level

The following attributes are assessed on plot level in the field (Table 17).

Table 17. Attributes assessed in the field at plot level

Reference to NFI-2 Field methodology	Serbian name	English name
4.1.6.	Инвентурни статус круга	Inventory status of a sample plot
4.1.7.	Статус круга	Status of a sample plot

Reference to NFI-2 Field methodology	Serbian name	English name
4.1.8.	Приступачност круга	Accessibility of a sample plot
4.1.17.	Удаљеност центра круга од најближег пута	Distance of the sample plot center from the nearest road
4.1.18.	Тип подлоге пута	Type of the road substrate
4.2.1.	Врста (начин коришћења) земљишта	Land use category
4.2.2.	Промена категорије начина коришћења земљишта	Land use category changed
4.2.3.	Обрасло и необрасло земљиште унутар шуме и осталог шумског земљишта	Wooded ground and non-wooded ground inside the forest and other wooded land
4.2.5.	Надморска висина	Altitude
4.2.6.	Нагиб терена	Slope
4.2.7.	Аспект	Aspect
4.2.8.	Ерозиони облик	Erosion
4.2.9.	Дубина земљишта	Depth of soil
4.2.10.	Мртви покривач	Litter (Dead cover)
4.2.11.	Просечна дебљина мртвог покривача	Mean litter depth
4.2.12.	Процес хумификације	The process of humification
4.2.13.	Приземна вегетација (жива)	Ground vegetation (living)
4.2.14.	Бројност врста приземне вегетације	Number of ground vegetation species
4.2.15.	Жбуње (живо)	Shrubs (living)
4.2.16.	Бројност врста жбуња	Number of shrub species
4.3.1.	Фотографисање приземне вегетације	Photographing of ground vegetation
4.3.2.	Врсте индикатори кључних шумских станишта	Indicator species of key forest habitats
4.3.3.	Инвазивне врсте	Invasive Species
4.3.4.	Присуство кључних биотопа	Presence of key biotopes
4.3.5.	Присуство вештачких конструкција	Presence of artificial constructions
4.3.6.	Стабло са лишајима на деблу	Trees with lichens on the stem
4.3.7.	Облици (форме) лишаја	Forms of lichens
4.3.8.	Стабло са маховинама на деблу	Trees with mosses on the stem
4.3.9.	Стабло са гљивама на деблу	Trees with fungi on the stem
4.3.10.	Специјална жива стабла	Living special trees
4.4.1.	Врсте дрвећа	Tree species
4.4.2.	Старост састојине	Age of the stand
4.4.3.	Редни број добног разреда	Age class identification number

Reference to NFI-2 Field methodology	Serbian name	English name
4.4.4.	Састојинска целина	Stand categories
4.4.5.	Газдински тип	Management types
4.4.6.	Узгојна група	Treatment phase
4.4.7.	Порекло састојине	Stand origin
4.4.8.	Спратовност састојине	Stand layers
4.4.9.	Структурни облик састојине	Stand structure
4.4.10.	Очуваност састојине	Stand preservation status
4.4.11.	Мешовитост састојине	Stand mixture
4.4.12.	Склоп	Stand canopy
4.4.13.	Природност	Naturalness
4.4.14.	Основне карактеристике подмладка	Basic characteristics of the young crop
4.4.15.	Здравствено стање састојине	Health condition of the stand
4.4.16.	Узроци оштећења састојине	Causes of damage to the stand
4.4.19.	Потенцијални узгојни третман	Potential silvicultural treatment
4.4.20.	Нужност узгојног третмана	Need for a silvicultural treatment
Table 18 in this report	Tip drveća izvan šume/OLWTC	Type of trees outside forests/OLWTC

On plots where trees outside forest occur, the type of trees is assessed (Table 18).

Table 18. Attribute „Type of trees outside forests /OLWTC“

ID	Attribute	Serbian Name
1	Orchards (predominantly composed of trees for production of fruits, nuts)	Voćnjaci
2	Agroforestry (Land with tree cover and with agricultural crops and/or pastures/animals)	Poljoprivreda
3	Wind brake, hedge row	Vetrozaštitni pojasevi, ograde
4	River / water flow side vegetation	Stabla uz obalu reka
5	Small patch of trees (forest characteristics, min area 5 a, min cover 30%, but not meeting the minimum area of 0.5 ha of the forest definition applied for forest in the course of the NFI). Please note: Such area fulfils the forest definition given in the national forest law.	Male grupe stabala
6	Other	Ostalo

4.3. Attributes Originating from GIS at Plot Level

The following attributes are assessed on plot level from GIS layer (Table 19).

Table 19. Attributes Originating from GIS at Plot Level

Reference to NFI-2 Field methodology	Serbian Name	English Name	Data Origin
4.1.10.	НСТЈ	NUTS	Republic Geodetic Authority
4.1.11.	Округ	District	Republic Geodetic Authority
4.1.12.	Политичка општина	Political municipality	Republic Geodetic Authority
4.1.13.	Шумска област	Forest region	Ministry agriculture, forestry and water management – Forest directorate
4.1.14.	Национални парк	National park	Ministry agriculture, forestry and water management – Forest directorate; Public enterprises, Ministry of Environmental Protection
4.1.15.	Натура 2000 станишта	Natura 2000 habitats	N2000 project " EU for Serbia - Continued support to implementation of Chapter 27 in the area of nature protection (NATURA 2000)"
4.1.16.	Емералд подручја	Emerald areas	Ministry of Environmental Protection
4.2.4. in this report: Table 20.	Власништво	Land ownership	Republic Geodetic Authority
4.4.17.	Глобална намена шума	General forest purpose	Public enterprises Field work estimation, GIS layers
4.4.18.	Режим заштите	Protection regime	Public enterprises; Ministry of Environmental Protection, GIS layers
in this report: Table 21.		Land use of the land parcel the plot is located in	Republic Geodetic Authority
in this report: Table 22.		Land class of the land parcel the plot is located in	Republic Geodetic Authority

The data on ownership in the cadaster provided by Republic Geodetic Authority provides more detail compared to the listing in Pantić, Dees and Borota (2020, chapter 4.2.4) and will be fully made available. The classes are presented in Table 20.

The ownership is of relevance to perform an ownership specific analysis, a topic that is of high interest not only in Serbia (FAO & UNECE, 2020)

Land use (Table 21) and land class (Table 22), recorded for each land parcel by Republic Geodetic Authority (RGA) in the digital land cadaster
(https://a3.geosrbija.rs/,
https://geosrbija.rs/usluge/servis-za-preuzimanje/)
are of relevance for the NFI-2 analysis since there are both legal and management consequences associated with single classes.

Table 20. Ownership of the parcel the plot is located in from RGA land cadaster

RGA-Code	Class English	Class Serbian	Comment
1	State ownership	Државно власништво	When data on the ownership of each plot are obtained from the RGA, they will be grouped into two categories that exist in the RS Constitution.
2	Private ownership	Приватно власништво	

Source: Republic Geodetic Authority, https://a3.geosrbija.rs/

Table 21. Land use of the parcel the plot is located in from RGA land cadaster

RGZ-Code	Class English	Class Serbian
10	Artificial surfaces	Вештачке површине
20	Bare land	Неплодне површине
30	Agricultural land	Пољопривредно земљиште
50	Grassland	Ливаде
60	Bushes	Жбуње
70	Deciduous forests	Лишћарске шуме
75	Mixed forests	Мешовите шуме
80	Evergreen forests	Стално зелене /четинарске шуме
90	Wetlands	Влажна земљишта
100	Water surfaces	Водене површине

Source: Republic Geodetic Authority, https://a3.geosrbija.rs/

Table 22. Land class of the parcel the plot is located in from RGA land cadastre

RGZ Code	Class	Description
1	I quality class	lands in the plains and on very slight slopes, deep and medium deep, exposed to floods
2	II quality class	lands of lowland and hilly climatic-production region, on flat or slight slope up to 3% in plains or up to 8% on hilly terrains, medium deep and deep soils 80-110 cm deep, in plains exposed to floods
3	III quality class	lowland and hilly lands of climate-production region, on flat relief and slope up to 3% in plains or up to 16% on hilly terrains, medium deep or deep lands over 60 cm deep, in plains exposed to floods
4	IV quality class	Lands of hilly, hilly-mountainous and plain climate-production region, shallow and medium-deep soils with a depth less than 60 cm, on slopes exposed to more furrowed erosion with difficult conditions for mechanized cultivation, land reclamation and flood protection measures in the plains slope and on the slopes anti-erosion protection measures are need-ed.

RGZ Code	Class	Description
5	V quality class	lands of hilly, hilly-mountainous and lowland climate-production region, in plains or on moderately steep slopes with a slope of up to 45%, medium-deep and shallow soils 30-50 cm deep, in plains exposed to harmful and prolonged floods, and on steep slopes exposed more furrowed and less ravine erosion, almost unfavourable for cultivation, and especially for mechanized cultivation, with the necessary reclamation and flood protection in the plains and anti-erosion measures on steep slopes
6	VI quality class	lands of hilly-mountainous and mountainous climatic-productive region, lands of hilly and plain climatic-productive region, on flat terrain or on a slope of 45% and more, shallow soils with a depth 20 to 30 cm, exposed to all degrees of erosion, except stronger ravine , and in the plains exposed to frequent and prolonged floods, moderately damaged by waste water, anti-erosion measures and flood protection are necessary, drainage and desalination in the plains, conditionally used as arable land, and widely used as pastures, meadows and forests.
7	VII quality class	lands of mountain and hilly-mountainous, hilly and plain climate-production region that are very shallow with a depth less than 20 cm, in plains or on a slope up to 65%, exposed to very frequent and harmful floods, very damaged by hazardous and harmful substances, air pollution, waste and polluted waters, and on slopes exposed to all types of erosion to a stronger ravine, with the necessary flood protection measures, drainage measures, and on slopes with necessary erosion protection measures, land used exclusively as pastures and forests.
8	VIII quality class	Very shallow soils with a depth less than 10 cm, located in the hilly-mountainous and mountainous climate-production region, on a slope over 65%, exposed to all types of erosion, used exclusively as very poor pastures, devastated forests and ecologically polluted soils.

Note: *A more detailed description of each soil grade, including soil types, physical-mechanical and chemical characteristics, can be found at web site Republic Geodetic Authority, https://a3.geosrbija.rs/*

4.4. Attributes Assessed by Remote Sensing Image Interpretation

The following attributes are assessed on plot level by remote sensing are of relevance for the analysis (Table 23). The attribute classes of the attribute “Land Use Category 2019” are presented in Table 24, of the “UNFCCC-IP land use classes 2019” in Table 25, of “Land use change 2006 to 2019 considering UNFCCC-IP land use classes “ in Table 26.

Table 23. Attributes Assessed by Remote Sensing Image interpretation

Reference to NFI-2 Field methodology	English Name	Serbian Name	Comment
Chapter 2.1, Section A., Table 1 and in this report: Table 24.	Land Use Categories 2019.	Klase korišćenja zemljišta 2019	Classification field combining land use relevant for the NFI and UNFCCC-IPCC classes
Chapter 2.1, Section B and in this report: Table 25	UNFCCC-IP land use classes 2019.	UNFCCC-IP klase korišćenja zemljišta 2019.	
Chapter 2.1, Section B and in this report: Table 26	Land use change 2006 to 2019 considering UNFCCC-IP land use classes	Promene korišćenja zemljišta u periodu 2006-2019. u skladu sa UNFCCC-IP klasama	

Chapter 2.1, Section B	Year of land use change	Godina promene načina korišćenja zemljišta	Assessed based on available imagery in Open Foris collect earth when first time visible on the image time series
Chapter 2.1, Section F	Estimated number of trees 2019.	Procena broja stabala 2019.	The estimate considered a radius of 15 m round the sample plot center and aimed at the consideration of trees with a *dbh* that is exceeds 5 cm. This attribute is assessed when the land use category "Other land with tree cover" was assessed, but as well in other cases where trees occurred on land other than "Forest" or "Other wooded land" and "Other land with tree cover".

Table 24. Classes of Land Use Category 2019.

ID	English name	Serbian name	Comment
10	F - Forest	Šuma	
20	OWL - other wooded land	Ostalo šumsko zemljište	Is grassland under UNFCCC IPPC land use classes 2019. classification
31	OLWTC - Other Land With Tree Cover	Ostalo zemljište obraslo stablima	Can be all land use classes except for forest under UNFCCC IPPC land use classes 2019. classification
33	Barren land	Neplodno zemljište	Is class "other" under UNFCCC IPPC land use classes 2019. classification
34	Agricultural land	Poljopirvredno zemljište	Is cropland under UNFCCC IPPC land use classes 2019. classification
35	Meadows/pastures	Livade i pašnjaci	Is grassland under UNFCCC IPPC land use classes 2019. classification
36	Built-up land	Urbano zemljište	Is settlement under UNFCCC IPPC land use classes 2019. classification
37	Inland water	Vodene površine	Is wetland under UNFCCC IPPC land use classes 2019. classification

Table 25. Classes of UNFCC-IPCC land use classes 2019.

Codes in OS-NOVA	English name	Serbian name	Codes in OF field "land_use_category"
10	Forest	Šuma	F
20	Cropland	Poljoprivredno zemljište	C
30	Grassland	Pašnjaci	G
40	Settlement	Naselje	S
50	Wetland	Vodene površine	W
60	Other	Ostalo	O

Table 26. Landuse change 2006 to 2019 assessed in UNFCCC-IP CC land use classes

To / From	Forest 2019.	Cropland 2019.	Grassland 2019.	Settlement 2019.	Wetland 2019.	Other 2019.
Forest 2006.	FF	FC	FG	FS	FW	FO
Cropland 2006.	CF	CC	CG	CS	CW	CO
Grassland 2006.	GF	GC	GG	GS	GW	GO
Settlement 2006.	SF	SC	SG	SS	SW	SO
Wetland 2006.	WF	WC	WG	WS	WW	WO
Other 2006.	OF	OC	OG	OS	OW	OO

4.5. Aggregation of Information from Elements that Occur on the Single Plot

4.5.1. Attributes Derived from Single Tree Measurements

4.5.1.1. Correction Factor for Calculation of Numerical Elements on the Area of one Hectare

In NFI-2, using the options ANGLE and DISTANCE on a Vertex device, the sample plot radiuses are automatically reduced to the horizon.

A. Status of sample plot = 1 – a complete sample plot

r_1 = 3 m → p_1 = 0.0028274 ha → $1/p_1$ = 353.68183

r_2 = 10 m → p_2 = 0.0314159 ha → $1/p_2$ = 31.83102

r_3 = 15 m → p_3 =0.0706858 ha → $1/p_3$ =14.14711

with

r - the radius of the concentric circle

p - the surface of a concentric circle

B. Status of sample plot = 2 – part of sample plot

In accordance with the Methodology of collecting data to NFI-2 and the procedure in the software "Osnova", in some cases (e.g. sample plot is divided by a boundaries of different land use categories, boundary of different ownerships, age class, etc., see Chapter 4.1.7. Methodology NFI-2), reduction of the area of a circle in % and in absolute value is necessary, resulting in a change in the size of the correction factors. Example:

p_1 = 0.0028274 ha = 100% → $1/p_1$ = 353.68183

p_2 = 0.0293980 ha = 93.58% → $1/p_2$ = 34.01592

p_3 = 0.055667 ha =78.75% → $1/p_3$ = 17.96396

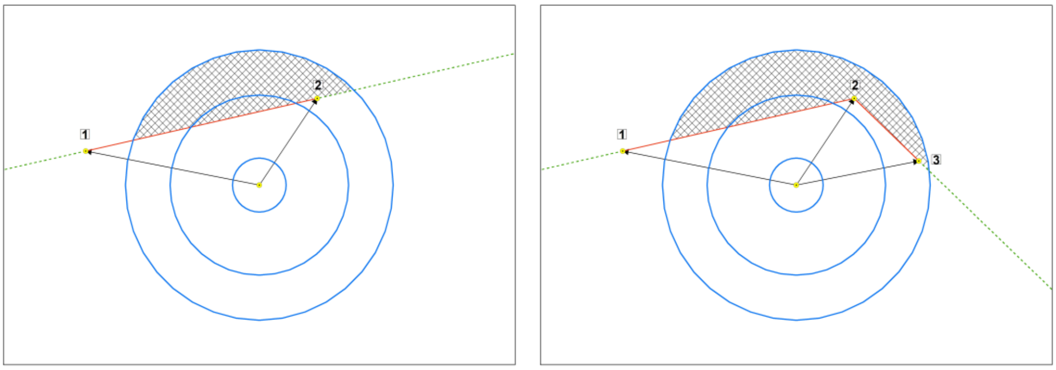


Figure 3. Reduction of concentric sample plot area with 2 or 3 points

By reducing the area one of the concentric circles, the correction factor for calculating the numerical elements on the area of 1 ha is increased.

4.5.1.2. Number of Trees with DBH > 5 cm

r_1 = 3 m → 5 cm < *dbh* ≤ 10 cm

r_2 = 10 m → 10 cm < *dbh* ≤ 30 cm

r_3 = 15 m → *dbh* > 30 cm

In Table 27 the status of sample plot = 1. The procedure is identical when the status of a sample plot = 2 but depending on the percentage of reduction of a circle, the value of the correction factor is increases.

Table 27. Calculating the number of trees per ha (*N*)

dbh class		*1/p*	*dbh* class		*1/p*	*dbh* class		*1/p*
6			11			16		
7			12			17		
8	**7.5**	353.68183	13	**12.5**	31.83102	18	**17.5**	31.83102
9			14			19		
10			15			20		
21			26			31		
22			27			32		
23	**22.5**	31.83102	28	**27.5**	31.83102	33	**32.5**	14.14711
24			29			34		
25			30			35		
						and larger classes		14.14711

Table 28 shows that each tree on the circle, depending on its area (status of circle 1 or 2), is recalculated to ha by the correction factor. Summing up this number of trees and dividing the resulting sum by the number of plots in a territorial and/or ecological category, gives the average number of trees per ha in that category. Essentially, it is the average number of trees in a sample, on whose basis the average number of trees in a set are estimated and the standard error of that estimate is determined.

Table 28. Average distribution of the number of trees by diameter classes in different territorial (municipality, district, forest region, etc.) and/or ecological categories (stand categories, origin, mixture etc.)

dbh class	*1/p*	Ordinary number of the sample plot									*ΣNi*	$\bar{N} = \frac{\sum Ni}{n}$
		1	2	3	4	5	6	7	8	9		
7.5	353.68183	III 3 1,061	IIII 4 1,415								2,476	275
12.5	31.83102	III 3 95	IIII 5 159								254	28
17.5												distribution of the number of trees by *dbh* classes - example figure 4.
22.5												
27.5												
32.5	14.14711 and larger classes											
37.5												
42.5												
∑		6	9								2,730	303
∑/ha		1,156	1,574								2,730	303

Assumptions: status of sample = 1; one tree species

n – Number of plots in sample

$\bar{N}$ **–** Arithmetic mean of sample

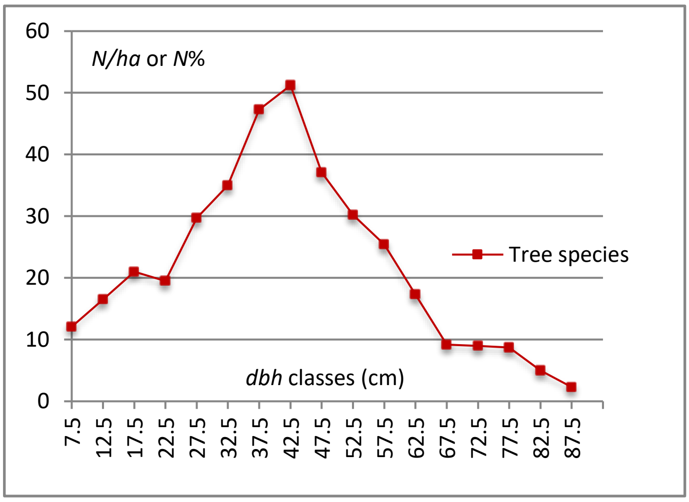


Figure 4. Distribution of number of trees per *dbh* classes - example

Standard deviation:

$$S_N = \sqrt{\frac{\sum Ni^2 - \bar{N} \cdot \sum Ni}{n-1}} \qquad (4\text{-}1)$$

Estimation of arithmetic mean of the basic set (territorial and/or ecological categories) based on the arithmetic mean of the sample:

$$M_{\overline{N}} = \overline{N} \pm t \cdot \frac{S_N}{\sqrt{n}} \qquad (4\text{-}2)$$

The standard error of estimation, actually, the error with which the arithmetic mean of the basic set is estimated:

$$S_{\overline{N}} = \frac{t \cdot \frac{S_N}{\sqrt{n}}}{\overline{N}} \cdot 100 \qquad (4\text{-}3)$$

The standard error of estimation *N*, *G*, *V* etc. is calculated for each territorial (municipality, district, forest region, national park, etc.) or ecological category (ecological unit, management type, origin, preservation status etc.) and their mutual combinations, which are defined through query of the database. If none of the attributes (categories) is defined, the analysis will be performed for the entire database - the level of Serbia.

More precise statistical procedures for calculating the quantitative elements and their average values with the errors which the assessment was performed are given in Chapter 6.

4.5.1.3. Basal Area

Basal area per ha based on plot:

$$G_{plot} = \sum_{i=1}^{k} gi \cdot 1/p \qquad (4\text{-}4)$$

Average basal area per ha in the sample:

$$\bar{G}_{sample} = \frac{\sum_{i=1}^{n} G_{plot}}{n} \qquad (4\text{-}5)$$

k – number of trees on a plot

n – number of plots in the sample

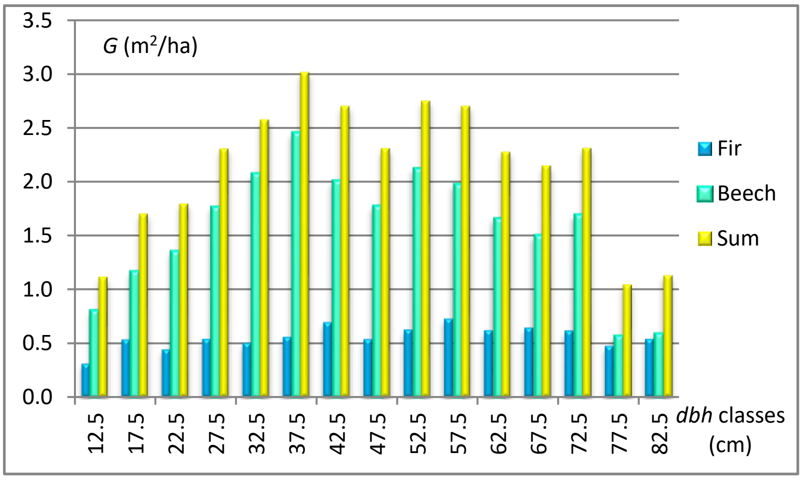


Figure 5. Distribution of basal area per diameter classes - example

The estimation of the average basal area in the set, with the determination of the error of that estimate, is made in different territorial and/or ecological categories, as well as the number of trees, where is the figure *G* instead of *N* by the formulas in Chapter 4.5.1.2.

More precise statistical procedures for calculating the quantitative elements and their average values with the errors which the assessment was performed are given in Chapter 6.

4.5.1.4. Dimensions of Mean Tree

The mean tree (representative tree) with its dimensions represents the volume or some of its elements (diameter, height, etc.) in the statistical set (Banković, Pantić, 2006). The division was made according to:

- dimension they represent,
- a group of trees (set) that is represented,
- mode of choice,
- character, etc.

We opted for a representative tree whose diameter is calculated from the stand basal area, and the height from the model *h* curve. Based on the volume of this tree (*vg*) and the number of trees (*N*) on an area (territorial or ecological unit), the volume of trees on that area can be determined.

<u>Diameter</u>

$$\bar{g}_{sample\ or\ set} = \frac{\bar{G}_{sample}}{\bar{N}_{sample}}\ or\ \frac{\bar{G}_{set}}{\bar{N}_{set}} \rightarrow dg_{sample\ or\ set} = 200 \cdot \sqrt{\frac{\bar{g}_{sample\ or\ set}}{\pi}} \quad (4\text{-}6)$$

<u>Height</u>

Introducing the value of the diameter of the middle tree by the basal area of a particular tree species in the model of height curve, height is determined.

4.5.1.5. Volume

Based on the measured *dbh* and *h*, the volume of each tree on the plot is calculated, and then, depending on the size of the circle (status 1 or 2) and the correction factor, it is calculated per hectare:

$$V_{plot} = \sum_{i=1}^{k} vi \cdot 1/p \quad (4\text{-}7)$$

Average volume per ha on sample:

$$\bar{V}_{sample} = \frac{\sum_{i=1}^{n} V_{plot}}{n} \quad (4\text{-}8)$$

k –number of trees on plot

n –number of plot in the sample

Estimation of average volume of a set, with the determination of the error of that estimates, is made in different territorial and/or ecological categories, as well as the number of trees and basal area, where instead of *N* in the above formulas in Chapter 4.5.1.2.

More precise statistical procedures for calculating the quantitative elements and their average values with the errors which the assessment was performed are given in Chapter 6.

<u>Note</u>: Essentially, there are two variants for determining the arithmetic mean $\bar{N}, \bar{G}, \bar{V}, \overline{BM}$ in sample.

1. The elements *n, g, v, bm* of each tree on the plot, depending on the size of the circle and correction factor *1/p*, are calculated on hectare and summed. In this way for each plot is obtained *N, G, V,* and *BM* per hectare. Summing of these values and dividing values with number of plots in sample, $\bar{N}, \bar{G}, \bar{V}, \overline{BM}$ of sample are obtained, which based on which is estimated $\bar{N}, \bar{G}, \bar{V}, \overline{BM}$ of set and determines the error with which the assessment was made.

2. Elements *n, g, v, bm* of each tree on sample, with *1/p*, are calculated on hectare. Summing up the values thus obtained for all the trees in the sample and dividing that sum by the number of plots in the sample, we obtain $\overline{N}, \overline{G}, \overline{V}, \overline{BM}$ of the sample. On the basis, as in the first case, the mean of the basic set is estimated and the error of that estimate is determined.

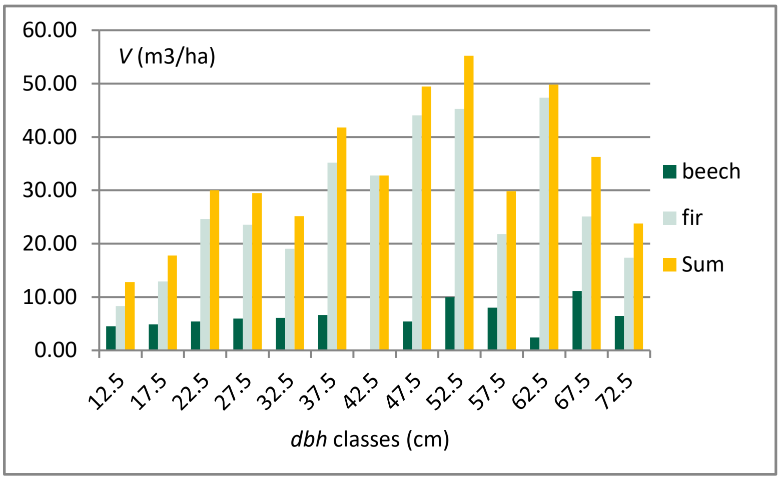


Figure 6. Volume distribution by diameter classes – example

4.5.1.6. Stand Mixture

According to the NFI-2 methodology, stand mixture is determined by the proportion of the volume of another species/species of trees in the average volume per ha or in the total volume of the defined category. There are two criteria:

- Limit value for share in the total volume is ≥ 25%
- Limit value for share in the total volume is ≥ 10%

In both cases, forests that belonging to stand category **357, 358, 363, 393, 394, 395, 396, 404** and **405** are considered as mixed forests of deciduous trees and conifers regardless of the limit values indicated.

4.5.1.7. Volume Increment

The following Table 29 presents the national definition vs the Reference definition oft he ENFIN group labeled „E43 reference definition" (Vidal *et al.,* 2008).

Table 29. Gross annual increment definition compared with E43 definition

E43 reference definition	Serbian National definition
Gross annual increment is the average annual volume of increment over the reference period of all trees measured to a minimum *dbh* = 0 cm	Gross annual increment is average annual volume of increment over the reference period of all trees measured to a minimum *dbh* = 5 cm

$$Iv_{plot} = \sum_{i=1}^{k} i_{vi} \cdot {}^{1}/_{p} \qquad (4\text{-}9)$$

Average volume increment per ha on sample:

$$\overline{Iv}_{sample} = \frac{\sum_{i=1}^{n} Iv_{plot}}{n} \qquad (4\text{-}10)$$

k –number of trees on the plot

n –number of plot in the sample

Estimation of average volume increment of a set, with the determination of the error of that estimates, is made in different territorial and/or ecological categories, as well as the number of trees, basal area and volume, where instead of *N* in the above formulas in Chapter 4.5.1.2

More precise statistical procedures for calculating the quantitative elements and their average values with the errors which the assessment was performed are given in Chapter 6.

4.5.1.8. Attribute "False Coppice" to Analyze the Status and Development of High Forest, Actual and False Coppice

In order to identify the amount of false coppice and their characteristics the attribute "False coppice" is defined. The class attributes are given in Table 30 and the assignment rules n Table 31.

Table 30. Attribute False Coppice

ID	Code Serbian	Serbian name	Code English	Long Name
1	VŠ	Visoke šume	HF	High forest - Not coppice
2	IŠ	Izdanačke šume	CF	Actual Coppice – forest with origin coppice with strong coppice characteristics
3	LIŠ	Lazne Izdanačke šume	FCF	False Coppice – forest with origin coppice with high quality characteristics
4	Šib.	Šibljaci/Šikare/Zbunasta vegetacija - nema klasifikacija	Shr.	Shrubs & bush vegetation - no classification possible

Table 31. Dependence of the Attribute False Coppice from the Attribute Management Type

ID	Gazdinski tip	Management Types	Code Serbian
1110	Visoke mešovite šume OML	High mixed forests of soft broadleaved species (OSB)	VŠ
1120	Izdanačke mešovite šume OML	Coppice mixed forests of soft broadleaved species (OSB)	IŠ
1121	Izdanačke mešovite šume OML - Visoke mešovite šume OML	Coppice mixed forest of OSB - to High mixed forests of OSB	LIŠ
1210	Veštački podignute plantaže topola	Poplar plantations	VŠ
2310	Visoke mešovite šume poljskog jasena	High mixed forests of fraxinus angustifolia	VŠ
2410	Visoke mešovite šume lužnjaka	High mixed forests of Quercus robur	VŠ
2510	Visoke mešovite šume kitnjaka, sladuna i cera	High mixed forests of Quercus petraea, Q. frainetto & Q. cerris	VŠ
2620	Izdanačke mešovite šume hrastova	Coppice mixed forests of Quercus petraea, Q. frainetto & Q. cerris	IŠ
2621	Izdanačke mešovite šume hrastova - Visoke šume hrastova i ostalih lišćara	Coppice mixed forests of Quercus species - to High mixed forests of oaks	LIŠ
2721	Izdanačke mešovite šume lipa - Visoke šume lipe i ostalih lišćara	Coppice mixed forests of Tilia - to High forest of Tilia	LIŠ
2810	Visoke mešovite šume OTL	High mixed forests of other hard broadleaved	VŠ

		species (OHB)	
2820	Izdanačke mešovite šume OTL	Coppice mixed forests of OHB	IŠ
2821	Izdanačke mešovite šume OTL - Visoke mešovite šume OTL	Coppice mixed forests of OHB – to High mixed forests of OHB	LIŠ
2920	Izdanačke mešovite šume bagrema	Coppice mixed forests of Robinia	IŠ
21010	Visoke mešovite šume javora i jasena	High mixed forests of Acer pseudop. and Frax. nigra	VŠ
21110	Visoke mešovite šume bukve	High mixed forests of Beech (F. moesiaca)	VŠ
21120	Izdanačke mešovite šume bukve	Coppice mixed forests of Beech	IŠ
21121	Izdanačke mešovite šume bukve - Visoke šume bukve i ostalih lišćara i četinara	Coppice mixed forests of Beech - to High forest of Beech	LIŠ
31210	Visoke mešovite šume borova	High mixed forests of Pinus species	VŠ
31211	Visoke mešovite šume borova - Visoke šume lišćara i četinara	High mixed forests of Pinus - to high forests of conifers & broadleaves	VŠ
31510	Visoke mešovite šume smrče	Mixed forests of Picea abies	VŠ
31511	Visoke mešovite šume smrče - Visoke šume četinara i liščara	High mixed forests of Picea species - to high forests of Picea & broadleaves	VŠ
31610	Visoke mešovite šume ostalih četinara	High mixed forests of other conifers (Douglas, Larix)	VŠ
41310	Visoke šume bukve i jele	High mixed forests of Fir & Beech	VŠ
41410	Visoke šume bukve, jele i smrče	High mixed forests of Fir, Spruce & Beech	VŠ
51730	Šibljaci / Šikare / Zbunasta vegetacija	Shrubs & bush vegetation	Šib
51731	Šibljaci / Šikare / Zbunasta vegetacija - za rekonstrukciju	Shrubs & bush vegetation - for reconstruction	Šib

4.5.1.9. European Forest Types

The European forest types are defined by Forest Europe/MCPFE (EEA 2006). Under Forest Europe/MCPFE there exist reporting obligations considering these European Forest types. For the final analysis, an attribute will be created together with assignment rules based on field attributes to enable such analysis taking into account recent considerations for such assignment rules (Giannetti et al., 2108).

4.5.1.10. Biodiversity Assessment at Plot Level

The nature value assessment methodology is explained in "BIODIVERSITY MANUAL 1- Nature Value Assessment of forest plots; Biodiversity indicators and field guides for the NFI in Serbia” (Kitnaes, Miletic & Lazarevic, 2019).

Each attribute related to biodiversity is either present or absent on the sample plot and receives a score of +1 or -1, Table 32). The total score in a plot is an indication of relative nature value (preliminary index, see Table 33).

Table 32. Relative Nature Value Score Table

Relative Nature Value	Score
A. Highest nature value	> 20
B. High nature value	12-20
C. Average nature value	4-12
D. Low nature value	< 4

Table 33. Stand level field attributes used in the context of this analysis

Nature Value Assessment - Scoring instruction					
Link with NFI CODE	**Indicators**		**Attribute present or absent in plot**	**Positive score**	**Negative score**
4.4.1.	**Structures and Composition**	Tree Species (composition)	More than 3 tree species (≥ 3)	+1	
4.4.9. (10)		Stand struc-ture	Even aged stand		-1
4.4.9. (20)			Uneven-aged stand	+1	
4.4.9. (30)			Selection stand	+1	
4.4.9. (40)			Virgin forest	+1	
4.4.8. (1)		Stand layers	Single layered forest stand		-1
4.4.8. (2)			Multi-layered forest stands (>2 layers)	+1	
4.4.14. (B1 + F4)		Regeneration	Natural regeneration > 3 m, *dbh* ≤ 5 cm (more than 25% coverage)	+1	
4.4.14. (B3)			Planted regeneration		-1
4.5.16. (1 + *d* > 30)		Dead wood/ Litter	Standing dead wood ≥ 1 trees larger than 30 cm *dbh*	+1	
4.5.16. (3 + *d* > 30)			Laying dead wood ≥ 1 full length stems larger than 30 diam.	+1	
4.5.16. (4 + *d* > 50)			Laying dead wood ≥ 1 large (50 cm diam.) stems longer than 2 m	+1	
4.5.16. (2)			≥ 1 standing high stumps/trunks higher than 1 m	+1	
			Absence of any dead wood		-1
4.2.10. (7,8,9,10)			Litter cover on plot > 60%	+1	
4.5.13.(1,2,3,4, *d* > 80)		Dying wood/ Coarse bark	Standing but clearly visible dying trees (old growth)	+1	
4.5.13. (5)			Trees with broken / damaged top	+1	
4.3.10. (7)			Any stages of deterioration or clearly coarse bark	+1	
4.4.1. (1)		Naturalness (Stand origin)	Forest stand undisturbed by man	+1	
4.4.7. (1)			Natural high stand	+1	

Nature Value Assessment - Scoring instruction					
Link with NFI CODE	**Indicators**		**Attribute present or absent in plot**	**Positive score**	**Negative score**
4.4.7. (2)			Coppiced forest stand	+1	
4.4.13. (2)			Forest stand semi-natural	+1	
4.4.13. (3)			Plantations		-1
4.4.10. (1)		Stand preservation status	Well-preserved stand	+1	
4.4.10. (3)			Devastated stand		-1
4.2.16. (1)		Shrubs and herb vegetation	Presence of > 2 shrub species	+1	
4.2.14. (1)			> 50% cover of rich ground vegetation/herb species (> 3 species)	+1	
4.3.10. (1)	**Valuable Biodiversity Trees**	Living special trees	Large dimension trees	+1	
4.3.10. (2)			Large solitary, sun-exposed trees with wide crown	+1	
4.3.10. (3)			Trees with epiphytic plants/parasites/semi-parasites	+1	
4.3.10. (4)			Nesting trees (birds and insect nests or holes)	+1	
4.3.10. (5)			Hollow trees (cavities) *dbh* >30 cm	+1	
4.3.6. (1)		Trees with lichens /moses/fungi on stem	> 50% lichen cover on any tree stem in plot	+1	
4.3.6. (2)			2-3 different lichen forms on any tree stem 0-3 m in plot	+1	
4.3.8. (1)			> 50% moss cover on any tree stem in plot	+1	
4.3.9. (0)			No fungi on tree stems or branches		-1
4.3.9. (1)			Presence of fungi species on tree stem 0-3 m in plot	+1	
4.3.4. (1)	**Other key biotopes**	Other valuable key biotopes present in forest	Natural light gaps (not artificial)	+1	
4.3.4. (2)			Small wetlands (marsh, fen; small pools/ponds/wet zones)		
4.3.4. (3)			Natural springs		
4.3.4. (4)			Seasonal / permanent streams		
4.2.6. (> 30°)			Steep slopes >30 degrees		
4.3.4. (5)			Cliffs, ravines		
4.3.4. (6)			Caves		
4.3.4. (7)			Large rocks with moses/lichens coverage		

Nature Value Assessment - Scoring instruction					
Link with NFI CODE	**Indicators**		**Attribute present or absent in plot**	**Positive score**	**Negative score**
4.3.2. (1-20)	**Focal species**	Selected indicator species of forest key habitats	Any of these species: Leucojum aestivum/Glechoma hede-racea/Mentha agg./Equisetum agg., Ruscus aculeatus/Helleborus odorus/Lithospermum purpureo-careuleum/Campanula persicifo-lia/Geranium sanguineum, Asperula odora-ta/Neottia nidus-avis/Lamium galeob-don/Luzula luzuloides, Erica carnea/Daphne blagayana/Vaccinium myrtillus/Oxalis acetosel-la, Lycopodium clavatum/Ramonda serbi-ca/Sphagnum spp.	+1	
4.5.19 (F1) + 4.4.12. (3, 4)	**Impacts and Threats**	Unauthorised logging	Clear cut plot from unauthorized/illegal logging		-1
4.5.19. (F1)			Any other signs of unauthorized/illegal logging.		-1
4.3.5. (1)		Human construction	Any presence of constructions or artificial struc-tures		-1
4.3.3. (21,22,75,23,24)		Invasive Species	Amorpha fruticosa, Reynoutria japonica, Robin-ia pseudoacacia, Aster lanceolatus, Echinocystis lobata		-1
See list in separate sheet		Introduced Tree Species (non-native)	Any non-native or introduced tree species		-1
Nature Value Score (Ssum of positive and negative indicators)					

Scenarios for analysis of plot data for Biodiversity Assessment and Monitoring are found in Annex 1.

4.5.1.11. Preparing the Plot Level for an Analysis of the Harvesting Potential of the Next Decade

In the field, the field teams conducted a virtual marking on each plot located in forest. This simulates the selection of trees for harvesting in the next decade. The trees to be harvested are selected based on a selection of future crop trees, both future crop trees, trees potentially to be harvested and indifferent trees are identified in the attribute “virtual marking”.

Based on this classification of the trees, the potential amount of harvests of the next decade, first on plot level, can be assessed.

Based on the identification of future crop trees, volume and volume structure of these future crop trees can be analyzed as well.

Based on this plot level data, considering plot attributes for an analysis entity and therein for various groupings of plots, an analysis can be made.

The information presented in Table 34 and Table 35 is used to derive the attribute at plot level.

Table 34. Tree level field attributes used in the context of this analysis

Reference to NFI-2 Field methodology	Serbian name	English name	Scope
4.4.1.	Врсте дрвећа	Tree species	All trees
4.5.15.	Пробна дознака	Virtual marking	All trees

Table 35. Tree level derived attributes used in the context of this analysis

Attribute	Scope
Volume	All trees
Assortment	All trees

Before all, the plot level field attributes presented in Table 36 that classify the plots by stand characteristics, can be utilized to analyze the harvesting potential and further aspects.

Table 36. Stand level field attributes used in the context of Harvesting Potential analysis

Reference to NFI-2 Field methodology	Serbian name	English name	Scope
4.4.5.	Газдински тип	Management types	All plots
4.4.6.	Узгојна група	Treatment phase	Plots where then concept of treatment phases is applicable

On the plot level, based on this information, the potential harvests of the next decade can be determined in total by tree species and management type expressed as

- Wood volume
- Harvesting volume (considering harvesting losses of 10%)
- And by assortment

The equivalent methodology of virtual marking is used in the FMP context for yield assessment and planning purposes. The methodology was developed in a project entitled "Implementation of an innovative forest management planning considering economic, ecological and social aspects in Serbia" during 2015-2019. The rationale for the virtual marking is described in Ministry of Agriculture, Forestry and Water Management (MAFWM) – Directorate of Forestry (DF) (2018) and the entire concept is integrated in FMP related guidelines in MAFWM-DF (2019a, 2019e). This methodology of virtual marking is applied since 2018/2019 in Forest Management Planning (FMP) based on the actual Bylaw for Forest Management Planning in Serbia (under adoption).

4.5.1.12. Wood Volume and Other Attributes that are Determined Based on Totals from Different Element Types

Volume and biomass from living trees, dead standing trees, downy dead wood, and stumps is totaled up at plot level to allow a sampling error estimation of these quantities. This is described in chapter 6 "Statistical Estimators Addressing the Two-Phase Sampling Design".

5. BRIEF SUMMARY OF THE DESIGN OF NFI-2 AND MAJOR DIFFERENCES OF NFI-1 AND NFI-2 OF RELEVANCE FOR THE ANALYSIS-PR

The NFI-2 is characterized by the following elements used to assess a certain type of information. An overview is given in the following together with a specification of clusters and plots that are subject to the element, the purpose of the element and guidance to the chapter the element is in the context of the NFI-2 analysis. An overview is provided in Table 37.

Table 37. Overview on assessment assessments used in NFI-2

Element	Specification of clusters & plots	Purpose	Statistical analysis approach
Phase 1 clusters and sample plots used to assess attributes using visual interpretation of remote sensing images to assess the current land uses status (ca. 2019.)	All Phase 1 clusters and plots (1 km by 1 km cluster grid with 4 plots at each cluster location)	(1) Reduction of the sampling error of the estimates for the analysis entities for forest and other wooded land. (2) Provide the basis for solid information on land use dynamics for national forest policy and for reporting under the UN-FCCC (including MRV).	RE (1): Two phase sampling design and analysis, see chapter 6 “Statistical Estimators Addressing the Two-Phase Sampling Design“ RE (2): See chapter07.2. “Information on Changes from Forest and Other Wooded Land to Other Land Use Classes Relavant for National Policy and for UNFCCC/MRV“
Phase 1 clusters and sample plots used to assess attributes using visual interpretation of remote sensing images to assess the changes of the land use from the NFI 1 reference year (ca. 2006.) and the current status (ca. 2019.)	All Phase 1 clusters and plots. Focus of the assessment are changes to and from forest & other wooded land to other land use clases.	Provide information on land use dynamics for national forest policy and for reporting under the UNFCCC (including MRV).	
Phase 1 clusters and sample plots used to assess attributes using visual interpretation of remote sensing images to assess the current number of trees on a plot that is not located in forests or other wooded land (ca. 2019.)	All Phase 1 clusters and plots that area not classified as forest or other wooded land.	Is an auxiliary variable to estimate information on all kinds of TOF	See chapter 7.3 “Information Assessed on Trees Outside Forests“

Element	Specification of clusters & plots	Purpose	Statistical analysis approach
Phase 2 clusters and sample plots, a subset of phase 1 clusters and sample plots used to assess information on the land category that was pre-assessed by remote sensing already (Table 24)	First step for all field clusters is the assessment	Clarification if the protocol for forest and other wooded land is applied or the protocol for TOF.	(a) Discrepancies of the remote sensing assessment and the field will be made subject to the error budget where this is of relevance: For land use change assessment and the assessment of TOF and OLWTC. (b) For the estimates of properties on forest and other wooded land: See Chapter Two phase sampling design and analysis, see chapter 6 "Statistical Estimators Addressing the Two-Phase Sampling Design"
Phase 2 clusters and sample plots, a subset of phase 1 clusters and sample plots used to assess information on forests and other wooded land	All phase 2 plots located in forest or other wooded land. (4km by 4 km grid) This element is identical with NFI-1 except for some discrepancies in the field protocol.	Provide information on forests and other wooded land.	See chapter 6 „Statistical Estimators Addressing the Two-Phase Sampling Design"
Phase 2 clusters and sample plots, a subset of phase 1 clusters and sample plots used to assess information on TOF and trees in OLWTC on plots that fall on agricultural land.	All phase 2 plots located in forest or other wooded land. (8 km by 8 km grid)	Assessment of trees outside forests and properties of Other Land with Tree Cover.	See chapter 7.3 "Information Assessed on Trees Outside Forests"

Differences in the design and the field protocol of NFI-1 and NFI-2 have to be regarded in the analysis. In Table 38 the aspect that is different is characterized together with an explanation of the consequence for the analysis and the necessary measures to be addressed in this report or elsewhere.

Table 38: Differences between NFI-1 and NFI-2 and their consideration in the analysis

Aspect	Difference	Consequence	Necessary measure
Sampling error determination	NFI-1 report does not include sampling errors	NFI-1 reanalysis necessary as is of relevance for NFI-2 results and their interpretation	NFI-1 reanalysis necessary and to be included in NFI-2 report
Description of algorithms to determine the sampling error and implementation in the software	NFI-1 methodology does not describe algorithms to determine the sampling error, the function to determine the sampling error in the NFI software did not consider the cluster design and could thus not be used.	Needs to be described as such for NFI-1 reanalysis and as an input to the NFI-2 OS-NOVA software specification	Description of algorithms to determine the sampling error forNFI-1 to be included in this report and in the NFI-2 software
Increment drilling/ taking bore cores	Not used in NFI-1 but in NFI-2 Functions have been used in stead	Increment at status of NFI-1 in 2006 to be estimated based on functions determined using drilling from NFI-2 to allow a comparison over time from NFI-1 to NFI-2	Methods report and Software need to address this.
Volume determination	NFI-1 used at least for large parts of the trees the tariff method (option 2 in chapter 3.2.2.5.), NFI-2 will not use the tariff but the volume functions (option 1 in chapter 3.2.2.5)	To allow a comparison of NFI-1 and NFI-2 that is uninfluenced by this methodological advancement, NFI-1 data need to be reanalysed.	NFI-1 reanalysis necessary and to be included in NFI-2 report
Age assessment	NFI1 drilled only one tree and where is possible counted the growing rings on the stump and in some cases, where possible age was taken from FMP book, In NFI 2 the assessment of the age is based on drilling of three trees. Same is: Only in even aged stands we determine the age, in uneven aged or selection forest we don't estimate age. Stand age is based on the assessment of the main species only, this has not changed. Age is assessed in forest and OWL in both inventories.	As the difference in years between NFI-1 and NFI-2 is known for re-measured plots the age can be taken for each of the inventories from the other one considering the difference in years between NFI-1 and NFI.2 Thus, inconsistencies in the age assessment can result.	Approach to address the issue needs to be identified, described in this report and implemented in the software. In the analysis the age is not used directly but the age class. This has to be regarded in this context. (chapter 4.4.2 and 4.4.3.)

Use of metal stakes to assist re-finding of the plot in the forthcoming inventory cycles	NFI-2: metal stakes on all plots used. No metal stakes on plots 2,3 and 4 of a cluster to support re-finding of the plot in NFI-1, quality of location in NFI-1 due to use of moderate quality GPS	Only part of plot type "1" per each cluster can be re-measured. This needs to be addressed in complex change assessment approach	Complex change assessment approach to be described in this report and to be considered in the software.

The necessary measures that are of relevance for this report are all described in chapter 7.1. "Estimation of Changes Over Time in Forest and Other Wooded Land.

Note:

Methodological differences between two consecutive NFIs are a normal occurrence and occur as a consequence of increased requirements for the scope and accuracy of information by different users and new knowledge in this area. In order to enable comparative analysis of successive NFIs and analysis of forest fund development trends, in addition to new methods in the current NFI, some methods used in the previous inventory are retained (eg volume and volume increment are calculated by two methods, etc. thus enabling comparative analysis).

Using constantly the same methods and principles in successive nfi is a retrograde process. The evolution of NFIs is necessary over time

6. STATISTICAL ESTIMATORS ADDRESSING THE TWO-PHASE SAMPLING DESIGN

6.1. Introduction

In this chapter statistical estimators are described to estimate area totals, totals of quantitative attributes and ratios considering the design of the NFI-2 in Serbia.

In the context of the NFI-2, the following types of information need to be estimated:

1. Totals (Area totals and totals of quantitative attributes)

   Examples for entire Serbia: Total forest area in Serbia, total standing volume in Serbia, change in total standing volume in Serbia vs. NFI-1.

   Examples for domains inside Serbia, e.g. an administrative area such as a ”Forest Area” defined in the forest law, e.g. “Forest Area Western Serbia”: Total forest area in “Forest Area Western Serbia”, total standing volume in “Forest Area Western Serbia”, change in total standing volume in “Forest Area Western Serbia” vs. NFI-1.

2. Ratios (Total A/Totals B)

   Examples: Total standing volume (Total A) per forest area in Serbia (Total B); total standing volume per forest area in the “Forest Area Western Serbia”
   This kind of ratios can as well be interpreted as mean values within a certain class of land, e.g. within forest, but as e.g. the area of forest in Serbia is estimated by the inventory the volume per ha in forests in Serbia is a ratio that needs to be estimated.

The design of the NFI-2 is prepared for an estimation using estimators for 2-phase sampling for stratification. Estimators considering the specific design of the NFI-2 in Serbia are presented in this report. In this report further options for the definition of strata based on the remote sensing assessment made in Phase 1 are presented. In the course of the analysis, a final decision upon the strata definitions to be used will need to be made, considering the frequency of observations in the strata and the strata characteristics. The motivation to add this Phase 1 was to reduce the sampling error of the estimates at moderate cost compared to an increase of the number of field clusters.

6.2. Two-Phase Design

As the design of NFI-1 was a cluster design and as the clusters from that inventory will be remeasured in NFI-2, this basic design has been maintained and has been supplemented by a first phase with the objective to increase the precision of NFI-2.

The NFI-2 in Serbia thus utilises a two-phase design for stratification where in “phase 1” in a 1 km by 1 km grid at a large number of clusters auxiliary variables are assessed at plot level. In the second phase of clusters in a 4 km by 4 km grid, that is a subset of the “phase 1” clusters in the 1 km by 1 km grid, field work is conducted to assess plots that fall in forest and other wooded land. In a 8 km by 8 km grid, as well a subset of the phase 1 grid and the 4km by 4 km grid, field work is conducted in addition on grassland (other than other wooded land) and cropland to assess trees outside forest and the land use class “other land with tree cover”.

The fact that clusters are used in both phases allows a grouping of clusters into strata. If merely plots in a systematic grid would have been sampled in phase 1, and clusters in phase 2, the clusters would have to be assigned to one stratum based on the information of one of the plots only, as e.g. applied in the Rumanian National Forest Inventory. This later approach can lead to a higher variance inside the strata as stated by Bouriaud *et al*. (2018[1]) in a reflection upon the design of the Rumanian National Forest Inventory. Thus, for the NFI-2 in Serbia, clusters have been used in both phases.

To establish strata at cluster level the attributes assessed at plot level need to be aggregated. To achieve an efficient estimation the strata established at cluster level need to explain the target variable variation at cluster level as good as possible (Särndal, 1992).

In "phase 1" each plot is assigned to a land use class considering the plot centre location[2]. "Forest" is one such class.

For the definition of strata, the number of plots that fall into forest in the "phase 1" assignment could be used, since this number is correlated with forest quantities of e.g. the amount of standing volume observed in forests at a such a cluster. An option to be evaluated will thus be the following stratification:

1. Stratum 1: Clusters with 4 plots with land use class F or OWL
2. Stratum 2: Clusters with 3 plots with land use class F or OWL
3. Stratum 3: Clusters with 2 plots with land use class F or OWL
4. Stratum 4: Clusters with 1 plot with land use class F or OWL
5. Stratum 5: Clusters with 0 plots with land use class F or OWL

This draft stratification will be explored for its applicability. A final stratification approach will be defined based on a preliminary data analysis and implemented for the final analysis.

The final stratification might differ for the different land use classes and needs to consider that within all strata a sufficient number of clusters is required.

---

[1] "Thefact that the first phase is constituted by a population of single plots while the second phase is constituted by a population of clusters has forced to classify the entire cluster to the same stratum. While no bias is expected since the assignment is uniform throughout the entire country, this sampling may have a higher variance" (Bouriaud *et al.,* 2018).

[2] It has to be noted that this assignment is used for the purpose to identify strata only, whereas in the field the assessment of the plots of the 4 km by 4km grid the land use class "forest" is assigned as well as part of the field attributes. To ensure that all plots that fall into forest or other wooded land in the 4 km by 4 km grid two types of plots where visited in the field: (1) Plots that have been assigned to these classes forest or other wooded land in phase 1. (2) Plots that have been assigned to another land use class but where there was some uncertainty that they may be actually forest or other wooded land. In the 8 km by 8 km grid the same is applied for grassland and cropland at the clusters foreseen for field assessments of these land use classes.

6.3. Aggregation at Plot Level and Cluster Level

It is assumed that at plot level the plot is assigned to a land use class, e.g. is classified as forest and that at plot level a value for quantitative attributes are available derived from the assessments on the plot, e.g. volume per ha.

The assessment elements per plots are circles of different radii. Per such circle for tree attributes, considering the measurement rules per circle, an expansion factor to a density value (standard area [e.g. 1 ha]/ area of the respective circle). Totals over all circles, e.g. for trees that are selected in concentric circles, are determined on that basis.

Further, in the analysis each plot represents the same area. This is due to the approach used for plots that are intersected by different land use types: Plots that are intersected by a forest border are merely measured if the centre of the plot is located in forest. The attributes assessed on these plots receive a higher weight. This higher weight compensates for the fact that the area measured by plots that intersect with the forest border have lower selection probability. Several approaches have been developed to consider this forest edge issue (Gregoire & Valentine, 2008). The selected approach is the option recommended by Köhl & Mangussen (2015) and Köhl *et al.* (2006) for fixed area plots. The approach can be illustrated by the following examples:

1. Situation 1: Plot (respective circle of the concentric plot) is completely located in the forest. Weight for plot properties: 1.
2. Situation 2: 50 % of the plot area (respective circle of the concentric plot) is located in the forest. Weight for plot properties: 1/0.5 = 2.
3. Situation 3: 80 % of the plot area (respective circle of the concentric plot) is located in the forest. Weight for plot properties: 1/0.8 = 1.25.

This can be simply implemented by the following approach: At plot level per attribute a density value (e.g. for a standard area of 1 ha) is determined for each plot as follows: the total observed on the plot (e.g. the total volume observed on the plot) is divided by the area of the plot located actually in forest.

This approach makes use of the forest borders that are measured in on the plot in case of an intersection and that are used to determine the part of the plot actually located in the forest.

For each cluster data are aggregated based on the plot level assessments in preparation for the statistical estimation, as described in the following chapter. A cluster consists regularly of four plots; along the country borders clusters can be incomplete and consist of less than four plots.

6.4. Estimators

6.4.1. Basic Definitions

The NFI-2 design fulfills the criteria for a statistical analysis of two-phase sampling of clusters for stratification. Estimators and their variances for that design are described in the following.

In the first phase n clusters are sampled,

each cluster $c_j; j = 1, \dots, n$ is consisting of u_j plots $p_i,\ i = 1, \dots, u_j$; if the number of plots is constant it is denoted u

Based on attributes assessed at plot level and aggregated at cluster level

each first phase cluster is assigned to one of L strata h, $h = 1, \dots, L$,

and the number of clusters per stratum h is n_h and $\sum_{h=1}^{L} n_h = n$.

In the second phase m of the n clusters are sampled,

and the number of clusters per stratum h is m_h and $\sum_{h=1}^{L} m_h = m$

and clusters per stratum h in the second phase are referred to as $j = 1, \dots, m_h$.

For the statistical estimation, the systematic sampling in phase 1 and phase 2 is interpreted as simple random sampling, all plots having an identical inclusion probability.

Let x_{ijkh} be a quantitative attribute at plot i within cluster j in stratum h expressed as a density value per ha (e.g. the volume per ha at plot level is determined based on all trees that fulfil a certain tree related condition, e.g. a tree of a certain tree species, or e.g. all trees) on a plot that's area belongs to a certain area class k (e.g. is forest or e.g. falls into a certain area class inside forest or is e.g. forest in a certain Forest Area or administrative district); on a plot not belonging to the area class $x_{ijkh} = 0$.

Then, at cluster level, the corresponding total of plots that fall in class k within cluster j in stratum h is

$$x_{jkh} = \sum_{i=1}^{u_j} x_{ijkh} \qquad (6\text{-}1)$$

Let a_{ijkh} be $a_{ijkh} = 1$ if the plot i within cluster j in stratum h belongs to a certain area class k and $a_{ijkh} = 0$ if not (e.g. is forest or e.g. falls into a certain area class inside forest or is not forest in a certain Forest Area or administrative district).

Then, at cluster level, the corresponding total of cluster j in stratum h in the sample is

$$a_{jkh} = \sum_{i=1}^{u_j} a_{ijkh} \qquad (6\text{-}2)$$

6.4.2. Estimation of an Area Covered by Land of Class k

The area covered by class k (e.g. the area of forest in Serbia, the area of a certain forest type in Serbia, the area of forest in a Forest Area) A_k can be expressed by a multiplication of the known country land area A and the true area proportion $\bar{a}_{kr}$ of class k inside the study/country land area

$$A_k = A \times \bar{a}_k \qquad (6\text{-}3)$$

As the total area A is known, it is sufficient to use this formula to determine A_k and to estimate the true area proportion $\bar{a}_k$ based on the definition of a_{jkh} presented above with estimators as presented in the next paragraph.

6.4.3. Estimation of an Area Proportion

Clusters of Equal Size

If the number of plots u_j per cluster is constant u, a simple estimator, based on the mean per stratum, could be used to estimate the true area proportion of class k $\bar{a}_k$:

$$\hat{\bar{a}}_k^{const} = \frac{1}{u} \sum_{h=1}^{L} \left(\frac{n_h}{n \times m_h} \sum_{jh=1}^{m_h} a_{jkh} \right) \qquad (6\text{-}4)$$

If we define $w_h = \frac{n_h}{n}$ and the estimate of the mean per stratum

$$\bar{a}_{kh}^{const} = \frac{1}{u \times m_h} \sum_{jh=1}^{m_h} a_{jkh} \tag{6-5}$$

the estimator $\hat{\bar{a}}_k^{const}$ can be expressed as

$$\hat{\bar{a}}_k^{const} = \sum_{h=1}^{L} (w_h \times \bar{a}_{kh}^{const}) \tag{6-6}$$

The Variance of $\hat{\bar{a}}_k^{const}$ consists of two terms, one originating from the estimation of w_h in phase 1 and one from the estimation of the strata means in phase 2. An estimator for the variance, derived by Rao (1973) and as well described in Särndal *et al.* (1996, p. 353), without consideration of the finite population correction that can be neglected in case of an NFI, the variance can be estimated as

$$\hat{V}(\hat{\bar{a}}_k^{const}) = \sum_{h=1}^{L} \left(\frac{n_h - 1}{n-1}\right)\left(\frac{w_h}{m_h} \times s_h^2\right) + \frac{1}{n-1} \sum_{h=1}^{L} w_h \times (\bar{a}_{krh}^{const} - \hat{\bar{a}}_{kr}^{const})^2 \tag{6-7}$$

and can be simplified further when n is large and $\left(\frac{n_h-1}{n-1}\right)$ is approxiately $\mathrm{w_h}$ (Särndal, 1996, p 353) to

$$\hat{V}(\hat{\bar{a}}_k^{const}) = \sum_{h=1}^{L} \left(\frac{w_h^2}{m_h} \times s_h^2\right) + \frac{1}{n} \sum_{h=1}^{L} w_h \times (\bar{a}_{kh}^{const} - \hat{\bar{a}}_k^{const})^2 \tag{6-8}$$

with

$$s_h^2 = \frac{1}{m_h + 1} \times \sum_{jh=1}^{m_h} \left(a_{jkh}/u - \hat{\bar{a}}_{kh}^{const}\right)^2 \tag{6-9}$$

As the weights w_h are identical for all estimates, when for all estimates the same strata are used, the estimates for the high-level area categories (e.g. forest area) are additive with the estimates of single subcategories (e.g. area of forest types).

Clusters of Unequal Size

If the clusters are not of equal size, this needs to be considered to achieve approximately unbiased estimates (Cochran, 1976). For the true area proportion of class k $\bar{a}_k$ the estimate is

$$\hat{\bar{a}}_k^{unequal} = \frac{\sum_{h=1}^{L} (\frac{n_h}{n * m_h} \sum_{jh=1}^{m_h} a_{jkh})}{\sum_{h=1}^{L} (\frac{n_h}{n * m_h} \sum_{jh=1}^{m_h} u_{jkh})} \tag{6-10}$$

The variance estimator of $\hat{\bar{a}}_k^{unequal}$ can then be estimated approximately, considering the variance for unequal size of plots per stratum and the variance component from phase 1 sampling, assuming n is large and $\left(\frac{n_h-1}{n-1}\right)$ is approximately $\mathrm{w_h}$, based on Särndal *et al.* (1996) and Scott *et al.* (2005) as

$$\hat{V}(\hat{\bar{a}}_k^{unequal}) = \sum_{h=1}^{L} \left(\frac{w_h^2}{m_h} \times V_{inside}\right) + \frac{1}{n \bar{u}_k^2} \left(\sum_{h=1}^{L} w_h (\bar{a}_{hk} - \bar{a}_k)^2 + \hat{\bar{a}}_k^{unequal} \sum_{h=1}^{L} w_h (\bar{u}_{hk} - \bar{u}_k)^2 - \right.$$

$$2\,\hat{\bar{a}}_k^{unequal} \sum_{h=1}^{L} w_h\,(\bar{u}_{hk}-\bar{u}_k)(\bar{a}_{hk}-\bar{a}_k)) \qquad (6\text{-}11)$$

and

$$V_{inside} = \frac{1}{m_h \bar{u}_{hk}^2} \frac{\sum_1^{m_h} a_{jkh}{}^2 - 2\,\hat{\bar{a}}_{kh}^{unequal} \sum_1^{m_h} a_{jkh} u_{jh} + \hat{\bar{a}}_{kh}^{unequal} \sum_1^{m_h} u_{jh}{}^2}{m_h - 1} \qquad (6\text{-}12)$$

where

m_h is number of clusters per stratum in the phase 2 sample,

a_{jhk} is the total of variable a per cluster in stratum h in the phase 2 sample,

u_{jh} is the number of plots per cluster in stratum h in the phase 2 sample,

and

$\hat{\bar{a}}_{kh}^{unequal} = \frac{\sum_{jh=1}^{m_h} a_{jkh}}{\sum_{jh=1}^{m_h} u_{jkh}}$ is the ratio (mean area estimate) in stratum *h*

and

$$\bar{a}_{hk} = \frac{1}{m_h} \sum_{jh=1}^{m_h} a_{jkh} \qquad (6\text{-}13)$$

$$\bar{u}_{hk} = \frac{1}{m_h} \sum_{jh=1}^{m_h} u_{jkh} \qquad (6\text{-}14)$$

$$\bar{a}_k = \sum_{h=1}^{L} (w_h \times \bar{a}_{kh}) \qquad (6\text{-}15)$$

$$\bar{u}_k = \sum_{h=1}^{L} (w_h \times \bar{u}_{kh}) \qquad (6\text{-}16)$$

As the weights w_h are identical for all estimates, when for all estimates the same strata are used, the estimates for the high-level area categories (e.g. forest area) are additive with the estimates of single sub categories (e.g. area of forest types).

6.4.4. Estimation of a Total of a Quantity

An example is the estimation of the total standing volume in forest in Serbia. Another example is the estimation of the total standing volume in a certain forest type Serbia.

The total of a quantitative attribute in the area of class k X_k that can be expressed by a multiplication of the area A of Serbia with the mean area related density of that quantity $\bar{x}_k$ in Serbia:

$$X_k = A \times \bar{x}_k \qquad (6\text{-}17)$$

Thus, the estimation of a total is equivalent to the estimation of a national level mean $\bar{x}_k$ using the known total area A of Serbia. The mean $\bar{x}_k$ can be estimated based on the sample using the definition of x_{jkh} presented above and with estimators as presented in the next paragraph.

6.4.5. Estimation of a Mean Density Value

Clusters of Equal Size

If the number of plots u_j per cluster is constant u, a simple estimator based on the mean per stratum, could be used to estimate the true national level mean area related density of class k $\bar{x}_k$:

$$\hat{\bar{x}}_k^{const} = \frac{1}{u} \sum_{h=1}^{L} \left(\frac{n_h}{n \times m_h} \sum_{jh=1}^{m_h} x_{jkh}\right) \qquad (6\text{-}18)$$

If we define w_h=$\frac{n_h}{n}$ and the estimate of the mean per stratum

$$\hat{\bar{x}}_{kh}^{const} = \frac{1}{u \times m_h} \sum_{jh=1}^{m_h} x_{jkh} \qquad (6\text{-}19)$$

the estimator $\hat{\bar{x}}_k^{const}$ can be expressed as

$$\hat{\bar{x}}_{kh}^{const} = \sum_{h=1}^{L} (w_h \times \hat{\bar{x}}_{kh}^{const}) \qquad (6\text{-}20)$$

with

$$w_h = \frac{n_h}{n \times m_h} \qquad (6\text{-}21)$$

The variance of $\hat{\bar{x}}_k^{const}$ consists of two terms, one originating from the estimation of w_h in phase 1 and one from the estimation of the strata means in phase 2. An estimator for the variance, derived by Rao (1973) and as well described in Särndal *et al.* (1996) without consideration of the finite population correction that can be neglected in case of an NFI, the variance can be estimated as

$$\hat{V}(\hat{\bar{x}}_k^{const}) = \sum_{h=1}^{L} \left(\frac{n_h - 1}{n-1}\right)\left(\frac{w_h}{m_h} \times s_h^2\right) + \frac{1}{n-1} \sum_{h=1}^{L} w_h \times (\bar{x}_{krh}^{const} - \hat{\bar{x}}_{kr}^{const})^2 \qquad (6\text{-}22)$$

and can be simplified further when n is large and $\left(\frac{n_h-1}{n-1}\right)$ is approxiately $\mathrm{w_h}$ (Särndal, 1996) to

$$\hat{V}(\hat{\bar{x}}_k^{const}) = \sum_{h=1}^{L} \left(\frac{w_h^2}{m_h} \times s_h^2\right) + \frac{1}{n} \sum_{h=1}^{L} w_h \times (\bar{x}_{kh}^{const} - \hat{\bar{x}}_{k}^{const})^2 \qquad (6\text{-}23)$$

with

$$s_h^2 = \frac{1}{m_h + 1} \times \sum_{jh=1}^{m_h} \left(x_{jkh}/u - \hat{\bar{a}}_{kh}^{const}\right)^2 \qquad (6\text{-}24)$$

As the weights w_h are identical for all estimates, when for all estimates the same strata are used, the sum of the estimates of attributes that total up by definition (e.g. the estimates for the volume by tree species) and the estimate of the corresponding total (e.g. volume over all species) are additive.

<u>Clusters of Unequal Size</u>

If the clusters are not of equal size, this needs to be considered to achieve approximately unbiased estimates (Cochran, 1976). For the true national level mean area related density class k $\bar{x}_k$ the estimate is

$$\hat{\bar{x}}_k^{unequal} = \frac{\sum_{h=1}^{L} (\frac{n_h}{n * m_h} \sum_{jh=1}^{m_h} x_{jkh})}{\sum_{h=1}^{L} (\frac{n_h}{n * m_h} \sum_{jh=1}^{m_h} u_{jkh})} \qquad (6\text{-}25)$$

The variance estimator of $\hat{\bar{x}}_k^{unequal}$ can then be estimated approximately, considering the variance for unequal size of plots per stratum and the variance component from phase 1 sampling, assuming n is large and $\left(\frac{n_h-1}{n-1}\right)$ is approximately $\mathrm{w_h}$, based on Särndal *et al.* (1996) and Scott *et al.* (2005) as

$$\hat{V}\left(\hat{\bar{x}}_k^{unequal}\right) =$$
$$\sum_{h=1}^{L} \left(\frac{w_h^2}{m_h} \times V_{inside}\right) + \frac{1}{n\bar{u}_k^2}$$
$$(\sum_{h=1}^{L} w_h \, (\bar{x}_{hk} - \bar{x}_k)^2 +$$

$$\hat{\hat{x}}_k^{unequal} \sum_{h=1}^{L} w_h \, (\bar{u}_{hk} - \bar{u}_k)^2 -$$

$$2 \, \hat{\hat{x}}_k^{unequal} \sum_{h=1}^{L} w_h \, (\bar{u}_{hk} - \bar{u}_k)(\bar{x}_{hk} - \bar{x}_k)) \quad (6\text{-}26)$$

with

$$V_{inside} = \frac{1}{m_h \bar{u}_{hk}^2} \frac{\sum_1^{m_h} x_{jkh}{}^2 - 2\, \hat{\hat{x}}_{kh}^{unequal} \sum_1^{m_h} x_{jkh} u_{jh} + \hat{\hat{x}}_{kh}^{unequal} \sum_1^{m_h} u_{jh}{}^2}{m_h - 1} \quad (6\text{-}27)$$

where,

m_h is number of clusters per stratum in the phase 2 sample,

x_{jhk} is the total of variable x per cluster in stratum h in the phase 2 sample,

u_{jh} is the number of plots per cluster in stratum h in the phase 2 sample

and

$\hat{\hat{x}}_{kh}^{unequal} = \frac{\sum_{jh=1}^{m_h} x_{jkh}}{\sum_{jh=1}^{m_h} u_{jkh}}$ is the ratio (mean estimate) in stratum *h*

and

$$\bar{x}_{hk} = \frac{1}{m_h} \sum_{jh=1}^{m_h} x_{jkh} \quad (6\text{-}28)$$

$$\bar{u}_{hk} = \frac{1}{m_h} \sum_{jh=1}^{m_h} u_{jkh} \quad (6\text{-}29)$$

$$\bar{x}_k = \sum_{h=1}^{L} (w_h \times \bar{x}_{kh}) \quad (6\text{-}30)$$

$$\bar{u}_k = \sum_{h=1}^{L} (w_h \times \bar{u}_{kh}) \quad (6\text{-}31)$$

As the weights w_h are identical for all estimates, when for all estimates the same strata are used, the sum of the estimates of attributes that total up by definition (e.g. the estimates for the volume by tree species) and the estimate of the corresponding total (e.g. volume over all species) are additive.

6.4.6. Estimation of a Ratio

Examples for ratios are the estimation of the mean standing volume in a certain forest type in Serbia. In this case a ratio is estimated: the ratio of a quantity divided by an area. Other examples are any ratios of attributes *x* and *y* subject to estimation, e.g. the share of wood of damaged trees out of all trees or the area of regeneration in a certain forest type.

This ratio of a quantity (e.g. standing volume) occurring on the area of class *k (e.g. forest)* and the area covered by that class is defined as

$$R_k = \frac{X_k}{A_k} \quad (6\text{-}32)$$

with

X_k the total of the quantitative attribute in the area of class *k* and

A_k the area of class *k* in the inventory area (Serbia).

Ratios of variables *x* and *y* could be estimated accordingly by replacing the area variable *A* by the quantitative attribute *Y*.

No matter, if the number of plots per cluster is constant or not, the ratio can be estimated as

$$\hat{R}_k = \frac{\sum_{h=1}^{L}(\frac{n_h}{n*m_h}\sum_{jh=1}^{m_h} x_{jkh})}{\sum_{h=1}^{L}(\frac{n_h}{n*m_h}\sum_{jh=1}^{m_h} a_{jkh})} \quad (6\text{-}33)$$

The variance estimator of $\hat{R}_k$ can then be estimated approximately, assuming n is large and $\left(\frac{n_h-1}{n-1}\right)$ is approximately $\mathrm{w_h}$, based on Särndal *et al.* (1996) and Scott *et al.* (2005) as

$$\hat{V}(\hat{R}_k) = \sum_{h=1}^{L}\left(\frac{w_h^2}{m_h}\times V_{inside}\right) + \frac{1}{n\bar{u}_k^2} \left(\sum_{h=1}^{L} w_h\,(\bar{x}_{hk}-\bar{x}_k)^2 + \hat{R}_k \sum_{h=1}^{L} w_h\,(\bar{a}_{hk}-a_k)^2 - 2\,\hat{R}_k \sum_{h=1}^{L} w_h\,(\bar{u}_{hk}-\bar{u}_k)(\bar{a}_{hk}-\bar{a}_k)\right) \quad (6\text{-}34)$$

with

$$V_{inside} = \frac{1}{m_h\bar{a}_{hk}^2}\frac{\sum_1^{m_h} x_{jkh}{}^2 - 2\,\hat{R}_{hk}\sum_1^{m_h} x_{jkh}a_{jh} + \hat{R}_{hk}\sum_1^{m_h} a_{jh}{}^2}{m_h-1} \quad (6\text{-}35)$$

where,

m_h is number of clusters per stratum in the phase 2 sample,

x_{jhk} is the total of variable x per cluster in stratum h in the phase 2 sample,

a_{jh} is the total of variable a per cluster in stratum h in the phase 2 sample,

$\hat{R}_{hk}$is the ratio in the phase 2 sample in stratum.

and

$$\hat{R}_{hk} = \frac{\sum_{jh=1}^{m_h} x_{jkh}}{\sum_{jh=1}^{m_h} a_{jkh}} \text{ is the ratio estimate in stratum h} \quad (6\text{-}36)$$

and

$$\bar{x}_{hk} = \frac{1}{m_h}\sum_{jh=1}^{m_h} x_{jkh} \quad (6\text{-}37)$$

$$\bar{a}_{hk} = \frac{1}{m_h}\sum_{jh=1}^{m_h} a_{jkh} \quad (6\text{-}38)$$

$$\bar{x}_k = \sum_{h=1}^{L}(w_h \times \bar{x}_{kh}) \quad (6\text{-}39)$$

$$\bar{a}_k = \sum_{h=1}^{L}(w_h \times \bar{a}_{kh}) \quad (6\text{-}40)$$

6.4.7. Estimation of Domains

Domains are spatial subunits of Serbia of known area (e.g. districts) or of unknown area (e.g. land covered with a specific forest type). For both approaches are presented and discussed by Särndal *et al.* (1992) and Birigazzi *et al.* (2018). The approach applied in the Serbian second NFI is giving prefer-ence to additivity over domains and is the following: For the analysis of spatial subunits with known area, the identical approach as the one for unknown areas is applied. This approach allows, while ensuring additivity, a flexible definition of domains and a straight forward and simple software implementation. Thus, for estimates of a domain with known area as well as for domains with unknown area, the respective target area is defined via the index *k in* chapters 6.4.1. to 6.4.5. This variable definition per plot using index *k* as defined in chapter 6.4.2. can be applied for any domain by considering if the plot is located in a domain *d* or not.

Then, the area covered, e.g. by forest in domain *d*, the total volume of forest in domain *d* and ratio values such as volume per forest area in domain *d* can be directly determined by the formulae given in 06.4.3. to 6.4.5. Merely in cases where a mean value over the land area of a specific domain is required, e.g. the forest cover percentage of a certain district or forest area, a specific additional calculation step is needed: the estimated total forest area of that domain needs to be divided by the actual and known domain area.

The same general approach to estimate domain results was already used in NFI-1.

6.4.8. Sampling Error, Confidence Level and Confidence Intervals

The accuracy or precision of the estimates is qualified in chapters 6.4.2 to 6.4.5. by the estimate of the variance of the estimators:

$$\hat{V}_{estimator}$$

It is usual and recommended practice to express the accuracy or precision of the estimates by the sampling error

$$SE_{Estimator} = \sqrt{\hat{V}_{estimator}} \qquad (6\text{-}41)$$

The accuracy or precision can as well be expressed by the relative sampling error in percent where the sampling error is divided by the estimate of the estimator

$$SE\%_{Estimator} = 100 * \frac{\sqrt{\hat{V}_{estimator}}}{Estimate\ of\ the\ estimator} \qquad (6\text{-}42)$$

for example, for the estimator $\hat{\hat{x}}_k^{unequal}$

$$SE\%_{\hat{\hat{x}}_k^{unequal}} = 100 * \frac{\sqrt{\hat{V}_{\hat{\hat{x}}_k^{unequal}}}}{\hat{\hat{x}}_k^{unequal}} \qquad (6\text{-}43)$$

Confidence intervals identify an interval where the true value is located with a certain probability named confidence level or confidence coefficient (Thomson, 2012).

Using the absolute or relative sampling error to identify such interval in the form

$$Estimator +/- SE_{Estimator}$$

$$Estimator + SE\%_{Estimator}$$

is equivalent to a confidence interval with a confidence level of approximately 68 %. Thus, the true value of the estimator within such an interval is with a probability of approximately 68 %.

For explicitly specified confidence levels, confidence intervals can be determined using

$$Estimator +/- SE_{Estimator} *\ t_{1-S;\, n-1,\ two-tailed}$$

or to express the interval in percent relative to the estimator by

$$Estimator +/- SE\%_{Estimator} *\ t_{1-S;\, n-1,\ two-tailed}$$

where n is the number of clusters and t is the percentile of Students t-distribution of a certain confidence level S.

It is recommended to provide as standard information both the absolute and the relative sampling error and as well confidence intervals at 95 % confidence level. This approach is used in many national forest inventory results presentations, e.g. the one for the German Federal Inventory (see https://bwi.info/).

7. SPECIAL ANALYSIS TOPICS

7.1. Estimation of Changes Over Time in Forest and Other Wooded Land

7.1.1. Introduction

There are several options to assess changes that need to be combined:

- The remeasurement of a subset of the NFI-plots and of the trees therein (possibly in the range of 20% of all plots if we assume that 80% of the one plot out of the 4 of a cluster that is intended to be re-measured (Pantić, Dees and Borota, 2020) can actually be re-measured).
- The simple comparison of NFI-2 and NFI-1 results assuming they have been implemented independently.
- The utilization of the increment measurement for the change items that can be addressed by this measurement. The estimation of the increment of survivor trees that has been presented in chapter 3.2.2.2., 3.2.2.10. and 4.5.1.7.
- The assessment of harvests based on trees cut on re-measured plots is described in this chapter, an alternative approach is described in chapter 07.6.

In the following paragraph 7.1.2. the assessment of changes at tree and plot level of re-measured plots is described.

In paragraph 7.1.3. a synthesis of all approaches to estimate the changes at analysis entity level is made.

The change of totals both depends on the assessment of change of forest remaining forest (applies for OWL as well) and on area changes (losses and gains). Both aspects will be analyzed to allow an insight in both change drivers.

7.1.2. Changes at Tree and Plot Level on Re-Measured Plots

The assessment of changes at tree level is based on the identification of trees with different effects in growth and mortality. A classification of trees presented by Martin (1982) is presented in Table 39.

Table 39. Components of forest growth and their definitions

Growth component	Definition
Survivor trees	Trees which are above the minimum *dbh* and in the sample at both measurements t_1 and t_2
Ingrowth trees	Trees which are below the minimum *dbh* and in the sample at the first measurement t_1 but exceed the minimum *dbh* at the second measurement t_2
Ongrowth trees	Trees which are below the minimum *dbh* and out of the sample at the first measurement t_1 but are above the minimum *dbh* and in the sample at the second measurement t_2
Non-growth trees	Trees which are above the minimum *dbh* and out of the sample at the first measurement t_1 but are in the sample at the second measurement t_2

Cut trees	Trees which are above the minimum *dbh* and in the sample at the first measurement t_1 but are cut prior to the second measurement t_2
Mortality trees	Trees which are above the minimum *dbh* and in the sample at the first measurement t_1 but die prior to the second measurement t_2

Out of these tree types the increment is measured at all these tree categories except or dead and mortality trees.

Generally, there exist from the theoretical point of view three options to determine the periodic increment, the end-approach, considering surviving trees with their final *dbh*, the start approach, considering surviving trees with their initial *dbh* or the comparison approach of total volume at the two occasions.

As the measurements of NFI-2 are more reliable the end-approach is selected. This will then require using the *dbh*-increment relation to determine the correct contribution of cut and mortality trees (they are considered with their initial *dbh* in terms of assigning them to a concentric circle) by estimating the *dbh* at the half period and the height at that time using the dbh-height function). For ongrowth trees as well as for trees that have not been measured in NFI-1 although they were in the *dbh* at NFI-1 and the height at NFI-1 have to be estimated as well utilizing the increment and height models. These trees are then handled as well survivor trees in NFI-1 and NFI-2 considering the *dbh* at NFI-2 to assign them to one of the concentric circle.

For each concentric circle, the growth (gross growth including ingrowth) is estimated by the following formula:

$$G = V_{s2} - V_{s1} + VCM_{1.5} - VCM_1 + I \qquad (7\text{-}1)$$

where

- V_{s1} – Volume of the survivor trees in the first inventory
- V_{s2} – Volume of the survivor trees in the second inventory
- VCM_1 – Volume of the cut and mortality trees in the first inventory
- $VCM_{1.5}$ – Volume of the cut and mortality trees including their growth up to half of the inventory interval
- I – Volume of the trees ingrown over the *dbh* threshold of the respective inventory circle.

Considerations on trees that change in diameter and belong to a different circle in NFI-1 and NFI-2 by Kändler (2014) will be taken into account and the “End value” approach, that was developed by Roesch et al. 1989 will be utilized.

The increment can be negative for a single survivor tree, this is possible both from the perspective of the measurement in the field but as well from the estimation theory and does not result in the need of a correction (unless an obvious measurement error exists, that will require a re-estimate of the NFI-1 *dbh* and height).

In order to identify the average annual gross growth including ingrowth, the periodic annual gross growth including ingrowth is divided by the length of the period between NFI-2 and NFI-1 in years.

7.1.3. Changes over Time at Analysis Entity Level Based on Re-Measured Plots

Once the change is assessed on plot level, the same procedures for estimating quantities at analysis entity level are applied e.g. for the estimation of the tree volume.

7.2. Information on Changes from Forest and Other Wooded Land to Other Land Use Classes, Relevant for National Policy and for UNFCCC/MRV

The assessment of area changes from forest and OWL to other land use and vice versa will be based on the phase 1 assessment of land use category changes.

As phase 1 is based on a single stage cluster design, estimators for the area estimates need to consider this design. Such estimators will be applied and are described by many authors, among others by Riedel (2017), Schmitz *et al.* (2008), Schmitz *et al.* (2006), Dees (2006), Särndal *et al.* (1992) and Cochran (1977). Such single stage cluster estimators have also been considered to be used in the NFI of Montenegro besides post-stratification for single stage cluster sampling that was finally applied (Dees, Anđelić *et a*l., 2013); both these options have been implemented in the NFI software utilized in Montenegro.

Besides the area changes, the losses and gains in biomass and carbon due to the changes will be determined based on average values from forests, other wooded land and, utilizing the information on TOF on other land from the results of the assessment of TOF.

7.3. Information Assessed on Trees Outside Forests

Generally, there are two approaches to assess trees outside forests:

- The assessment of trees on other wooded lands
- The assessment of trees on all lands that are not forest nor other wooded lands.

The approach to assess trees on other wooded land is identical to the one used for the assessment of trees in the forest.

The approach to assess trees on all lands that are not forest nor other wooded lands is sketched in chapter 5 and in Pantić, Dees and Borota (2020).

The analysis for to assess trees on all lands that are not forest nor other wooded lands is described below.

<u>Plot level analysis</u>

3 step plot level analysis:

- Expansion factor / regression model on tree volume on plot level to be established on plots located in agricultural land (where field measurements are available),
- Standard analysis on field plots on TOF,
- Expansion to all phase 1 plots with TOF using the expansion factor / regression model.

<u>Analysis entity level analysis</u>

5 step entity level analysis:

- Area of OLWTC,

- Area of UNFCCC land use classes from phase 1 assessment,
- Volume per ha for OLWTC,
- Area% of UNFCCC land use classes from phase 1 assessment where TOF occur,
- Total volume, increment, biomass etc.

For the analysis of OLWTC outside of settlements (OLWTC in urban areas and settlement areas are not assessed in the field) the estimation approach is as well based on a two phase design and the estimators from chapter 6 “Statistical Estimators Addressing the Two-Phase Sampling Design-RD” will be applied.

For OLWTC in urban areas and settlements, no plots have been assessed in the field and the estimation of the area is thus just based on phase 1, thus on a single stage cluster design estimators. Such estimators will be applied and are described by many authors, among others by Riedel (2017), Schmitz et al. (2008), Schmitz et al. (2006), Dees (2006), Särndal et al. (1992) and Cochran (1976). Such single stage cluster estimators have also been considered to be used in the NFI of Montenegro besides post-stratification for single stage cluster sampling that was finally applied (Dees, Anđelić et al., 2013); both these options have been implemented in the NFI software utilized in Montenegro.

7.4. Biodiversity

Reference is made to chapter 4.5.1.10. Biodiversity Assessment at Plot Level” and Annex 1. “Scenarios for analysis of plot data for Biodiversity Assessment and Monitoring”

7.5. N2000 Forest Habitat Monitoring

NFI data can be used to provide valuable information on N2000 Forest Habitats. Thus, e.g. the NFI data are used to describe and evaluate the N2000 Forest Habitats in Germany (Kroiher et al., 2017).

As at the time of the start of the NFI field work in 2019 the final habitat characterization was not yet available, the N2000 Forest Habitats could not be assessed as a field attribute.

Still once the characterization is available, using field attributes and GIS data an assignment of plots to N2000 Forest Habitats is regarded feasible. Such approach was used in the NFI of Montenegro where a similar situation existed (Dees, Anđelić et al., 2013).

Currently withing the NATURA 2000 project in Serbia “EU FOR SERBIA - CONTINUED SUPPORT TO IMPLEMENTATION OF CHAPTER 27 IN THE NATURE PROTECTION - NATURA 2000” (EuropeAid / 139336 / DH / SER / RS) the following results are close to finalization:

- National Manual for NATURA2000 habitat types with concise data regarding all forest habitat types from the Habitats Directive.
- A key for the conversion of several types of forest classifications (Tipološka, Sastojinska, Cenoekološka) into NATURA 2000 and National Habitat Types.

Thus, it is expected that using these results it will be possible to assign to each plot located in forest or OWL, the Natura 2000 habitat types. Then, provided a sufficient number of sample plots located in single Natura 2000 habitat types, for these types a descriptive analysis using the NFI-2 data is possible.

7.6. Information on Harvests

Information on harvests will be available from the repeated measurement of NFI-1 plots as described in chapter 7.1. “Estimation of Changes Over Time in Forest and Other Wooded Land”.

As the number of plots that are available for remeasurement, a method that utilizes the assessment of the harvesting marking on the stump and official harvesting statistics is foreseen to be used in addition (see chapter ”3.2.2.9. Volume of Harvested Trees”). This method was applied in the NFI of Montenegro and is described in Dees, Anđelić *et al.* (2013) and utilizes the assumption that the recorded harvests over, e.g. the last 5 years, record correctly marked harvests. Thus the share of unmarked harvests can thus be used to conclude on the actual total harvests per year (assuming this share is roughly constant over the last years).

As the amounts of harvests revealed from the NFI-2 with either of the two approaches can be substantially higher compared to official statistics, it is recommended to conduct in parallel a study on the consumption of wood as this will, together with the NFI-2 results provide a solid understanding of the forest business sector in Serbia. Similar approach was applied in Montenegro, where, in parallel to the NFI, such study was conducted (Statistical Office of Montenegro, 2013).I provided an important additional insight in wood harvests and consumption of wood from forests, from trees outside forests and other sources.

7.7. Future Potential Wood Supply

What Kilham *et al*. (2018) point out for Europe:

“The supply of wood in Europe on a sustainable basis is highly relevant for forestry and related policies, particularly in relation to (i) analysing global change mitigation strategies and carbon accounting (ii) establishing realistic forecasts and targets for wood resources, biomass and renewable energy and (iii) assessing and supporting strategies for an increased use of wood.” (p. 1) applies as well for Serbia.

Kilham *et al.* (2018) and Alberdi *et a*l. (2016) both emphasize the importance of the concept of ‘forest available for wood supply’ (FAWS) that aims at considering all ecological and legal constraints that apply for forest harvesting. Further they give recommendations on the consideration of such harvesting constrains.

The analysis will be made using the virtual marking of trees. The harvesting of all wood marked for harvesting by the attribute “virtual marking” can be used as one scenario of many, others can be based on more differentiated planning over management types and treatment phases. For details on the “virtual marking” we referred to chapter 4.5.1.11. “Preparing the Plot Level for an Analysis of the Harvesting Potential of the Next Decade”, where the concept of virtual marking is explained. Constraints for harvesting will be considered based on legal constraints and the forest function that will be assessed using GIS and field attributes. Growth and mortality of the trees over the next 10 years will be considered.

The potential supply - if wood from trees outside forests - will be considered in addition.

The wood supply over the next decades will not be part of the standard NFI analysis as it requires forest growth modelling over the next decades as well but is suggested as a top on analysis once the basic NFI Analysis is finished. Such analysis can e.g. replace the study of Panoutsou *et al.* (2018) on the woody biomass potential for energy purpose in Serbia with more accurate estimates.

8. QUALITY ASSURANCE

8.1. QA Addressing the Application of Allometric Functions

The software "Osnova" was developed in 2005 for data processing and analysis of the first NFI of Serbia. From that period until today, NFIs in Europe have developed significantly, primarily in terms of increasing requests for information expressed by various users. With the development of data collection technologies, the requirements for information reliability are also increasing. The issue of harmonization of European NFIs is still relevant. The ultimate goal of this process is a functional database on Europe's forests, which provides the possibility of permanent monitoring, expert analysis and, on the basis of them, binding policy decisions.

These trends are also characteristic of the Serbian NFI. In relation to NFI-1, a set of information related to the biodiversity of forest ecosystems, dead wood, biomass, carbon storage, etc. is integrated. In addition to F, OWL, within NFI-2, information is also collected for the plot falling on OLWTC and TOF.

Special attention is paid to the control of field works. A three-level control system has been developed, which significantly reduces errors during information collection.

Due to all the changes, it was necessary to correct and improve the performance of the "Osnova" software. In accordance with the requirements of NFI-2, the existing mathematical and statistical procedures were checked and improved, and new procedures were developed for processing numerical elements related to individual trees, as well as to the sample plot. For derived elements, such as the average number of trees, basal area, volume, volume increment per ha, etc., within different ecological and territorial units, a statistical error of estimation is determined.

By combining numerical and attributive information through various queries in the database, one can get an extremely large number of reliable views on the state of the Serbian forest fund, important for various national users of information, as well as for reporting to international associations that focus on forests.

8.2. QA Addressing the Statistical Estimators

The analysis algorithms will be implemented in the OSNOVA-NFI-Serbia software. Quality assurance of the software implementation will be ensured by providing illustrations of the algorithms in spread sheet examples that will be used for the software testing. Further OSNOVA-NFI-Serbia will allow in the advanced software version the use of simple one-phase estimators and the formulae for clusters of equal size that are less complex estimators. These alternative estimates will be used for plausibility checks of the software.

An important feature of the statistical results of the NFI is additivity: In tables independent estimates of cell values (e.g. domain results such as all forest areas) shall sum up to the estimates of the totals (e.g. total for entire Serbia).

Such additivity shall be ensured for

- additive quantities measured on the plots, e.g. estimates of the volumes of tree species groups sum up to the estimate of the total volume at a given spatial entity;

- entities with unknown area, e.g. the estimates for the volume of a set of forest types sum up to the estimated volume of all forest types;
- entities with known area, such as administrative regions, that's totals estimates should sum up to the estimates of all regions.

Additivity is ensured both at the level of the statistical estimators (see chapters 6) and specifically for domains by the approach described to estimate domain results.

This additivity will be a criterion for the check of the software outputs, whereas by the software in addition rounding issues need to be addressed.

REFERENCES[3]

Alberdi I., Michalak R., Fischer C., Gasparini P., Brändli U., & Tomter S. et al. (2016): Towards harmonized assessment of European forest availability for wood supply in Europe. Forest Policy And Economics, 70, 20-29. https://doi.org/10.1016/j.forpol.2016.05.014

Andersson L., Ek T. & Martverk R. (1999): Inventory of Woodland Key Habitats. The National Forestry Board, Estonia, and the Country Forestry Board, Sweden.

Banković S., Jović D., Medarević M.(1989): Zapreminske tablice za srebrnastu lipu (Tilia tomentosa Moench.). Šumarstvo, XLII (6): 3-21.

Banković S., Jović D., Medarević M. (1990/a): Zapreminske tablice za hrast kitnjak (Quercus petraea Liebl.). Šumarstvo, XLIII (1): 29-39.

Banković S., Jović D., Medarević M. (1990/b):: Zapreminske tablice za cer (Quercus cerris L.). Šumarstvo, XLIII (5): 21-32.

Banković S., Jović D., Medarević M. (1990/c): Dvoulazne zapreminske tablice za jelu na Goču. Rukopis Šumarski fakultet Beograd, Beograd.

Banković S. (1991): Zapreminske tablice za jelu (Abies alba Mill.) i smrču (Picea excelsa Link.) u šumamam nacionalnog parka Tara. Univerzitet u Beogradu-Šumarski fakultet, Nacionalni park Tara, Bajina Bašta, 1-106.

Banković S., Jović D., Medarević M., Pantić D. (2000): Tablice procenta zapreminskog prirasta za hrast lužnjak, poljski jasen, cer i grab u šumama Ravnog Srema. Glasnik Šumarskog fakulteta 82, Univerzitet u Beogradu-Šumarski fakultet, Beograd, 25-39.

Banković S., Jović D., Medarević M., Pantić D. (2000): Regresioni modeli procenta zapreminskog prirasta u čistim i mešovitim sastojinama bukve i hrasta kitnjaka u Srbiji. Glasnik Šumarskog fakulteta 83, Univerzitet u Beogradu-Šumarski fakultet, Beograd, 21-31.

Banković S., Medarević M., Pantić D. (2002): Regresioni modeli procenta zapreminskog prirasta u najzastupljenijim sastojinama četinarskih vrsta drveća u Srbiji. Glasnik Šumarskog fakulteta 85, Univerzitet u Beogradu-Šumarski fakultet, Beograd, 25-35.

Banković S., Medarević M., Pantić D., Filipović M. (2003): Zapreminske tablice za smrču na području Nacionalnog parka Kopaonik. Šumarstvo 3-4, UŠITS, Beograd, 51-60.

Banković S., Medarević M., Pantić D., Filipović M. (2003): Zapreminske tablice za jelu na području Nacionalnog parka Kopaonik. Šumarstvo 1-2, UŠITS, Beograd, 27-34.

[3] The list of references includes references that are explicitly cited in the text, as well as those that have been additional used but not cited.

Banković S., Medarević M., Pantić D. (2006): Regresioni modeli procenta zapreminskog prirasta za sastojine krupnolisne, sitnolisne i srebrne lipe na Fruškoj Gori. Šumarstvo 4, UŠITS, Beograd, 37-46.

Banković, S., Pantić, D. (2006): Dendrometrija. Univerzitet u Beogradu-Šumarski fakultet, Beograd, 556 p.

Bechtold W.A., & Patterson P.L. (2005): The enhanced forest inventory and analysis program: national sampling design and estimation procedures. US Department of Agriculture Forest Service, Southern Research Station.

Böhl J., & Brändli, U. (2007): Deadwood volume assessment in the third Swiss National Forest Inventory: methods and first results. European Journal Of Forest Research, 126 (3): 449-457. https://doi.org/10.1007/s10342-007-0169-3

Bouriaud O., Marin G., Hervé J.-C., Riedel T. & Lanz, A. (2018): The estimation methods in the Romanian National Forest Inventory. 26 p.

Brassel P., Lischke H. (Ed.) (2001): Swiss National Forest Inventory: Methods and Models of the Second Assessment. WSL Swiss Federal Research Institute. Birmensdorf: Switzerland.

Birigazzi, L., Gamarra, J. G., & Gregoire, T. G. (2018). Unbiased emission factor estimators for large-area forest inventories: domain assessment techniques. Environmental and Ecological Statistics, 25(2), 199-219

Cochran W.G. (1977): Sampling Techniques (3. Edition). John Wiley and Sons, New York, 428 p.

Dahm S. (2006): Auswertungsalgorithmen für die zweite Bundeswaldinventur. Arbeitsbericht des Instituts für Waldökologie und Waldinventuren Nr. 2006 / 1. Eberswalde: Deutschland.

Dees M. (2007): Kombination von Fernerkundung und Stichprobeninventur bei betrieblichen und nationalen Waldinventuren. Engl.: „Combination of remote sensing and sampling inventories in national forest inventories and inventories on forest enterprise level“. Schriftenreihe Freiburger Forstliche Forschung. Volume 37, 194 p.

Dees M., Anđelić M., Fetic A., Jakonovic B., Tepanovic, V., Borota D., Vasiljevic A., Weinreich A. Hahn N., Markovic D, & Terzic D. (2013): First Methodology of the National Forest Inventory of Montenegro. Ministry of Agriculture and Rural Development of Montenegro. ISBN 978-86-85799-07-05. COBISS.CG-ID 18503952, 347p.

Food and Agriculture Organization of the United Nations (FAO) (2015): Wisdom Serbia: Spatial wood fuels production and consumption analysis. Rome: Italy.

Food and Agriculture Organization of the United Nations (FAO) & United Nations Economic Commission for Europe (UNECE) (2020): Who owns our forests? Forest ownership in the ECE region. Information Service UNECE: Geneva, Switzerland.

Food and Agriculture Organization of The United Nations (FAO), International Tropical Timber Organization (ITTO), United Nations Economic Commission for Europe (UNECE) (2020). Forest product conversion factors. Rome: Italy. https://doi.org/10.4060/ca7952en

Forfang A., & Kitnaes K. (2001): Two woodland habitat mapping methods and their applications. In Tools for preserving woodland biodiversity, NACONEX.

Gregoire T.G. & Valentine H. T. (2008): Sampling strategies for natural resources and the environment. Chapman Hall/CRC Press. 496 p.

Gschwantner T., Schadauer K., Vidal C., Lanz A., Tomppo E., di Cosmo L., Robert N., Englert Duursma D., Lawrence M. (2009): Common tree definitions for national forest inventories in Europe. Silva Fennica 43(2): 303–321.

Kändler, G. (2014): Überlegungen zum Problem der Schätzung des periodischen Zuwachses bei permanenten Inventuren mit Winkelzählprobe – dargestellt am Beispiel der Bundeswaldinventur. Internal report, forest research station of Baden-Württemberg. 14 p.

Hilt D. (1983). Individual-tree diameter growth model for managed, even-aged, upland oak stands. [Broomall, Pa.]: U.S. Dept. of Agriculture, Forest Service, Northeastern Forest Experiment Station.

Hübertz H., Pedersen L.R. & Rune F. (2000): Nøglebiotoper I Skov (key biotopes in forest). The Danish Forest and Nature Agency, Ministry of Environment.

IPCC (2006). Good Practice Guidance for Land Use, Land-Use Change and Forestry. Retrieved from https://www.ipcc-nggip.iges.or.jp/public/gpglulucf/gpglulucf_contents.html

Kilham P., Kändler G., Hartebrodt C., Stelzer A.-S., Schraml U. (2018): Designing Wood Supply Scenarios from Forest Inventories with Stratified Predictions. Forests 9 (2): 77. https://doi.org/10.3390/f9020077

Kitnaes K.S. (2004): Adapted method for nature value assessment and mapping of key biotopes in forests. Orbicon, Denmark.

Kitnaes K.S., Miletic D., Lazarevic P., Zingstra H. (2019): BIODIVERSITY MANUAL 1- Nature Value Assessment of forest plots; Biodiversity indicators and field guides for the NFI in Serbia, under project: Contribution of Sustainable Forest Management to a Low Emission and Resilient Development, p. 1-24.

Koehl M., Magnussen S. & Marchetti M. (2006): Sampling methods, remote sensing and GIS multiresource forest inventory. Springer. 373 p.

Köhl M. & Magnussen S. (2015): Sampling in forest inventories. In: Köhl M., Pancel L. (eds): Tropical Forestry Handbook. Berlin, Heidelberg, Springer: 1–50.

Kroiher F., Müller-Kroehling S., Schmitz F. & Sukopp U. (Ed.) (2017): Methode zur Erfassung und Bewertung der FFH-Ealdlebensraumtypen im Rahmen der dritten Bundeswaldinventur (BWI-2012). Thünen Working Paper 69. Eberswalde: Deutschland.

Kublin E. (2011): Methodenentwicklung für die dritte Bundeswaldinventur. Modul 1: Schaftformmodellierung: BDAT-Aktualisierung. Technischer Bericht, Forstliche Versuchs- und Forschungsanstalt Baden-Württemberg, Freiburg.

Lindhe A & Drakenberg B. (1996): Nature Value Assessment form and guidelines adapted for boreal forests in Sweden.

Lindhe A & Drakenberg, B. (2016): Forest Integrity Assessment – A simple and user-friendly tool for assessing and monitoring biodiversity conditions in forests and forest remnants, February 2016. The HCV Resource Network,Proforest and WWF.

Martin G. L. (1982): A method for estimating ingrowth on permanent horizontal sample points. For. Sci. 28(1):110-114.

McHale M.R., Burke I.C., Lefsky M.A. *et al.* (2009): Urban forest biomass estimates: is it important to use allometric relationships developed specifically for urban trees?. *Urban Ecosyst* 12, 95–113. https://doi.org/10.1007/s11252-009-0081-3

McRoberts R.E., Winter S., Chirici G. & LaPoint E. (2012): Assessing Forest Naturalness. Forest Science, 58(3): 294-309. https://doi.org/10.5849/forsci.10-075

Mehtätalo L., de-Miguel S. & Gregoire, T. (2015): Modeling height-diameter curves for prediction. Canadian Journal Of Forest Research, 45(7): 826-837. https://doi.org/10.1139/cjfr-2015-0054

Nikolić S., Banković S. (2009): Tablice i tehničke norme u šumarsvu. Treće izdanje, Zavod za udžbenike Beograd, 257 p.

Panoutsou C., Stojadinovic D., Vasiljevic A. for Exergia S.A & Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH (2018): Woody Biomass Potential for Energy Purpose in Serbia and Methodology Assessment. Eschborn: Germany.

Pantić D. (1995): Zapreminske tablice za hrast lužnjak u šumama Ravnog Srema. Šumarstvo 4, UŠITS, Beograd, 61-72.

Pantić D. (1996): Zapreminske tablice za poljski jasen u šumama Ravnog Srema. Šumarstvo 1-2, UŠITS, Beograd, 58-62.

Pantić D., Dees M. & Borota, D. (2020): Methodology of the Second National Forest Inventory of the Republic of Serbia. The Food and Agriculture Organization of the United Nations. Rome: Italy. 185 p.

Riedel T., Hennig P., Kroiher F., Polley H., Schmitz F., Schwitzgebel F. (2017): Die dritte Bundeswaldinventur (BWI 2012). Inventur- und Auswertemethoden. Thünen–Institut für Waldökosysteme. Eberswalde: Deutschland.

Riley D R., Snell K.IE., Ensor J., Burke D.L, Harrell Jr F.E., Moons K. GM., Collins G. S. (2019): Minimum sample size for developing a multivariable prediction model: PART II-binary and time-to-event outcomes. Statistics in medicine, 38 (7):, 1276-1296. https://doi.org/10.1002/sim.7992

Roesch, F.A.; Green, E. J.; Scott, C.T. 1989. New compatible estimators for survivor growth and ingrowth from remeasured horizontal point samples. Forest Science, 35 (2): 281-293

Rondeux J., Bertini R., Bastrup-Birk A., Corona P., Latte N, & McRoberts R. et al. (2012). Assessing Deadwood Using Harmonized National Forest Inventory Data. Forest Science, 58 (3):, 269-283. https://doi.org/10.5849/forsci.10-057

Särndal C. E., Swenson B. & Wretman J. (1992). Model Assisted Survey Sampling. Springer-Verlag, New York, 694 p.

Schelhaas M. J., et al. (2018): Species-specific, pan-European diameter increment models based on data of 2.3 million trees. Forest Ecosystems, 5 (1): 21. https://doi.org/10.1186/s40663-018-0133-3

Scott C.T., Bechtold W. A., Reams G.A., Smith W.D., Westfall J.A., Hansen M.H. & Moisen G.G. (2005): Sample-based estimators used by the forest inventory and analysis national information management system. Gen. Tech. Rep. SRS-80. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station, p. 53-77.

Schmitz F., Polley H., et al. (2006): The Second National Forest Inventory – NFI2. Inventory and Evaluation Methods. BMELV.

Schmitz F., Polley H., Henning P., Dunger K. & Schwitzgebel F. (2008): Die zweite Bundeswaldinventur – BWI Inventur und Auswertungsmethoden: Zu den Bundeswaldinventuren 2001 bis 2002 und 1986 bis 1988. Arbeitsbericht aus dem Institut für Waldökologie und Waldinventuren Nr.2008/1.

Sharma R., Brunner A., Eid T. & Øyen B. (2011): Modelling dominant height growth from national forest inventory individual tree data with short time series and large age errors. Forest Ecology And Management, 262 (12): 2162-2175. https://doi.org/10.1016/j.foreco.2011.07.037

Ståhl G., Cienciala E., Chiric, G., Lanz A., Vidal C, & Winter, S. et al. (2012). Bridging National and Reference Definitions for Harmonizing Forest Statistics. Forest Science, 58 (3):, 214-223. https://doi.org/10.5849/forsci.10-067

Statistical Office of Montenegro (2013): Wood Fuel Consumption In 2011 In Montenegro: New energy balances for wood fuels. Podgorica: Montenegro

https://www.monstat.org/eng/novosti.php?id=840

Šijak M., Dinić A. (2007): Bibliography of Published Papers in the Journal "Šumarstvo" (1948-2007), on zhe Occasion of 60th Anniversary. Šumarstvo, LIX. Belgrade: Serbia.

Šijak M. & Dinić A. (2007) provide an overview of references on volume functions established from 1948 to 2007 in Bibliography of Published Papers in the Journal "Šumarstvo" (1948-2007), on the Occasion of 60th Anniversary. Šumarstvo, LIX. Belgrade, Serbia. http://www.srpskosumarskoudruzenje.org.rs/pdf/Bibliografija.pdf and that are partly used by OSNOVA NFI: Excerpt from this Šijak & Dinić (2007) publication of publications that address volume functions.

Šoškić B., Popović Z. (2002): Svojstva dreveta, Univerzitet u Beogradu-Šumarski fakultet, Beograd, 303 p.

Thomson S.K. (2012): Sampling. 3rd Edition. Wiley, 436 p.

Tomppo E. & Schadauer K. (2012): Harmonization of National Forest Inventories in Europe: Advances under COST Action E43. Forest Science, 58 (3): 191-200. https://doi.org/10.5849/forsci.10-091

Tomter S., Gasparini P., Gschwantner T., Hennig P., Kulbokas G. & Kuliešis A. et al. (2012): Establishing Bridging Functions for Harmonizing Growing Stock Estimates: Examples from European National Forest Inventories. Forest Science, 58 (3): 224-235. https://doi.org/10.5849/forsci.10-068

United Nations Economic Commission for Europe [UN-ECE] & Food and Agriculture Organization of the United Nations [FAO] (2000). Reliability and Comparability of TBFRA-2000 Results. In Forest Resources of Europe, CIS, North America, Australia, Japan and New Zealand (industrialized temperate/boreal countries): UN-ECE/FAO Contribution to the Global Forest Resources Assessment 2000 (pp. 27-41). United Nations Publication. Sales No. 99-II-E-36, ISBN 92-1-116735-3, ISSN 1020-2269. Retrieved from http://www.unece.org/forests/fra/pdf/contents.html

Uzoh F. & Oliver W. (2008): Individual tree diameter increment model for managed even-aged stands of ponderosa pine throughout the western United States using a multilevel linear mixed effects model. Forest Ecology And Management, 256 (3): 438-445.

https://doi.org/10.1016/j.foreco.2008.04.046

Vasiljević A. (2020). Uputstvo za upotrebu softvera „Osnova“. Rukopis.

Vidal C., Lanz A., Tomppo E., Schadauer K., Gschwantner T., di Cosmo L. & Robert N. (2008): Establishing forest inventory reference definitions for forest and growing stock: a study towards common reporting. Silva Fennica, 42 (2): https://doi.org/10.14214/sf.255

Wang W., et al. (2019): Development of a Mixed-Effects Individual-Tree Basal Area Increment Model for Oaks (Quercus spp.) Considering Forest Structural Diversity. Forests, 10 (6): 474.

https://doi.org/10.3390/f10060474

Zhao D., Borders B. & Wilson M. (2004): Individual-tree diameter growth and mortality models for bottomland mixed-species hardwood stands in the lower Mississippi alluvial valley. Forest Ecology And Management, 199 (2-3): 307-322. https://doi.org/10.1016/j.foreco.2004.05.043

Giannetti, F., Barbati, A., Mancini, L.D. et al. European Forest Types: toward an automated classification. Annals of Forest Science 75, 6 (2018). https://doi.org/10.1007

EEA (2006) European forest types. Categories and types for sustainable forest management and reporting. European Environment Agency, EEA Technical report No. 9/2006. ISSN 1725-2237 Available at:
http://www.foresteurope.org/docs/other_meetings/2006/wfc/WFC_4_eea_technical_report_9 2006.pdf. Accessed 20 November 2017

*** Ministry of Agriculture, Forestry and Water Management (MAFWM) – Directorate of Forestry (2018). Changes in the sample inventory and stand description (Version 6). Serbian-German cooperation project: Implementation of an innovative forest management planning considering economic, ecological and social aspects in Serbia. Project report, MAFWM – Directorate of Forestry, Belgrade, Serbia.

*** Ministry of Agriculture, Forestry and Water Management (MAFWM) – Directorate of Forestry (2019/a): Forest Management Planning Manual. Serbian-German cooperation project: Implementation of an innovative forest management planning considering economic, ecological and social aspects in Serbia. Internet address to the document on the website of the Forest Directorate and Serbian document title on the website: 1 Упутство Технолошки процес планирања:
https://upravazasume.gov.rs/sumarstvo/dokumenti-i-propisi-sumarstvo/

*** Ministry of Agriculture, Forestry and Water Management (MAFWM) – Directorate of Forestry (2019e). Manual for management practice - describing the Management Type system, definitions of silvicultural systems and management practices. Serbian-German cooperation project: Implementation of an innovative forest management planning considering economic, ecological and social aspects in Serbia. Општа Упутства за газдовање шумама.
https://upravazasume.gov.rs/sumarstvo/dokumenti-i-propisi-sumarstvo/

*** Rulebook on cadastral classification and land valuation Official Gazette of RS no. 63/2014

ANNEX

Annex 1. Scenarios for analysis of plot data for Biodiversity Assessment and Monitoring

Table A. Analyze Nature value assessment category vs other Plot level NFI attributes

CROSS TABLE ANALYSIS			Total Number of plot	Total score per plot (average)	A. Highest nature value			B. High nature value			C. Average nature value			D. Low nature value		
					Total N of plot	ha	%	Total N of plot	ha	%	Total N of plot	ha	%	Total N of plot	ha	%
4.2. SITE INFORMATION	4.2.4. LAND OWNERSHIP	State														
		Private														
	4.2.5. ALTITUDE	0-200														
		201-500														
		501-1000														
		>1001														
	4.2.6. SLOPE	< 5°														
		6° - 15°														
		16° - 35°														
		> 36°														
4.4. STAND INFORMATION	4.4.3. AGE CLASS ID NUM.	I-X age class														
	4.4.4. STAND CATEGORIES	Alder forests														
		Willow forests														
		Poplar forests														
		Narrow-leaved ash forests														
		Common oak forests														
		Hornbeam forests														
		Turkey oak forests														
		Hungarian oak forests														
		Pubescent oak forests														
		Forests of Grayish & Macedonian oak														
		Forests of Oriental hornbeam, Hophornbeam and flowering ash														
		Lime forests														
		Sessile oak forests														

		Birch, Aspen and Black locust forests														
		Ash and Maple forests														
		Beech forests														
		Pine forests														
		Fir forests														
		Spruce forests														
		Forests of Serbian spruce														
		Bosnian pine (Heldreich's pine) forests														
		Macedonian pine forests														
		Forests of mountain pine														
		Shrub formations														
		Artificially established stands														
	4.4.7. STAND ORIGIN	Natural high stand														
		Coppice stand														
		Artificially established stand														
	4.4.8. STAND LAYERS	Single layered stand														
		Multi-layered stands (≥ 2 layers)														
	4.4.9. STAND STRUCTURE	even-aged stand														
		uneven-aged stand														
		selection stand														
		virgin forest														
	4.4.10. STAND PRESERVATION STATUS	Well-preserved stand														
		Insufficiently stocked stand														
		Devastated stand														
	4.4.11. STAND MIXTURE	Pure broadleaved stand														
		Mixed broadleaved stand														
		Mixed broadleaved and coniferous stand														
		Mixed coniferous stand														
		Pure coniferous stand														
	4.4.13. NATURALNESS	Forest without anthropogenic interventions														
		Semi-natural forest														
		Plantation														
	4.4.18. PROTECTION REGIME	1st degree protection regime														
		2nd degree protection regime														
		3rd degree protection regime														

Explanatory notes:

- *Using for analyze average score per different categories for checking if there some category has more Nature values than other, also analyzing distribution of NVA category (A, B, C, D) per each NFI data*
- *Example: private forests are in average have lower nature values then state forest, or to check if altitude, stand class or age class have influence on biodiversity status.*

Table B. Nature Value Assessment - Attribute presence analysis versus Serbian protection regime

Biodiversity Indicators		**Feature or structure (attribute) on plot**	**Total Number of plots with attribute presents**		**Total number of plots with attribute present/Protection regime**					
					1st degree protection regime		**2nd degree protection regime**		**3rd degree protection regime**	
			N	**%**	**N**	**%**	**N**	**%**	**N**	**%**
Structures and Composition	Tree Species (composition)	More than 3 tree species (≥3)								
	Stand structure	Even aged stand								
		Uneven-aged stand								
		Selection stand								
		Virgin forest								
	Stand layers	Single layered forest stand								
		Multi-layered forest stands (>2 layers)								
	Regeneration	Natural regeneration >3 m, dbh ≤5cm (more than 25% coverage)								
		Planted regeneration								
	Dead wood/ Litter	Standing dead wood ≥ **1** trees larger than 30cm d.b.h.								
		Laying dead wood ≥ 1 full length stems larger than 30 diameter								
		Laying dead wood ≥ 1 large (50 cm diam) stems longer than 2m								
		≥ 1 standing high stumps/trunks higher than 1 m								
		Absence of any dead wood								
		Litter cover on plot > 60%								
	Dying wood/ Coarse bark	Standing but clearly visible dying trees (old growth)								
		Trees with broken / damaged top								
		Any stages of deterioration or clearly coarse bark								
	Naturalness	Forest stand undisturbed by man								
		Natural high stand								

		Coppiced forest stand									
		Forest stand semi-natural									
		Plantations									
	Stand preservation status	Well-preserved stand									
		Devastated stand									
	Shrubs and herb vegetation	Presence of >2 shrub species									
		>50% cover of rich ground vegetation/herb species (>3 species)									
Valuable Biodiversity Trees	Living special trees	Large dimension trees									
		Large solitary, sun-exposed trees with wide crown									
		Trees with epiphytic plants/parasites/semi-parasites									
		Nesting trees (birds and insect nests or holes)									
		Hollow trees (cavities) DBH >30 cm									
	Trees with lihens/moses/ fungi on stem	>50% lichen cover on any tree stem in plot									
		2-3 different lichen forms on any tree stem 0-3m in plot									
		>50% moss cover on any tree stem in plot									
		No fungi on tree stems or branches									
		Presence of fungi species on tree stem 0-3m in plot									
Other key biotopes	Other valuable key biotopes present in forest	Natural light gaps (not artificial)									
		Small wetlands (marsh, fen; small pools/ponds/wet zones)									
		Natural springs									
		Seasonal / permanent streams									
		Steep slopes >30 degrees									
		Cliffs, ravines									
		Caves									
		Large rocks with moses/lichens coverage									
Focal species	Selected indicator species of forest key habitats	Any of these species: *Leucojum aestivum/Glechoma hederacea/Mentha agg./Equisetum agg., Ruscus aculeatus/Helleborus odorus/Lithospermum purpureo-careuleum/Campanula persicifolia/Geranium sanguineum, Asperula odorata/Neottia nidus-avis/Lamium galeobdon/Luzula luzuloides, Erica carnea/Daphne blagayana/Vaccinium myrtillus/Oxalis acetosella, Lycopodium clavatum/Ramonda serbica/Sphagnum spp.*									
Impacts and Threats	Unauthorised logging	Clear cut plot from unauthorized/illegal logging									
		Any other signs of unauthorized/illegal logging.									
	Human construction	Any presence of constructions or artificial structures									

	Invasive Species	Amorpha fruticosa, Reynoutria japonica, Robinia pseudoacacia, Aster lanceolatus, Echinocystis lobata								
	Introduced Tree Species (non-native)	Any non-native or introduced tree species								

Explanatory notes:

- *Total Number of plots with attribute presents - Using for analyzing the frequency of the presents the attribute on all plots. It will give us information does this attribute is common or very rare in Serbian forests. We can use this result to revise our scoring system and to give more importance to rare attributes and less for common.*
- *The total number of plots with attribute present/Protection regime – Using for checking methodologies. It will be correct if we record more BD attributes in I regime protection than in other protection regimes. It also could be used for analyzing what is a common attribute for I regime protection, and we could use this information to revise our scoring system.*
- *Example: In I regime protection will be surprising low presents of Standing dead wood ≥ 1 trees larger than 30cm d.b.h., Laying dead wood ≥ 1 full length stems larger than 30 diameter, >50% lichen cover on any tree stem in plot,…*

Table C. Nature Value Assessment - Specific biodiversity attribute vs Stand category

Biodiversity Indicators		**Attribute in plot**	**4.4.4. STAND CATEGORIES**						
			Alder forests			**Willow forests**			**….**
			Total N of plots	**N of plots with presence of BD attribute**	**% of plot with presence of BD attribute**	**Total N of plots**	**N of plots with presence of BD attribute**	**% of plot with presence of BD attribute**	
Structures and Composition	Dead wood / Litter	Standing dead wood ≥ 1 trees larger than 30cm d.b.h.							
		Laying dead wood ≥ 1 full length stems larger than 30 diameter							
		Laying dead wood ≥ 1 large (50 cm diam) stems longer than 2m							
		≥ 1 standing high stumps/trunks higher than 1 m							
		Absence of any dead wood							
		Litter cover on plot > 60%							
	Naturalness	Forest stand undisturbed by man							
		Natural high stand							
		Coppiced forest stand							
		Forest stand semi-natural							
		Plantation							

Valuable Biodiversity Trees	Living special trees	Large dimension trees							
		Large solitary, sun-exposed trees with wide crown							
		Trees with epiphytic plants/parasites/semi-parasites							
		Nesting trees (birds and insect nests or holes)							
		Hollow trees (cavities) DBH >30 cm							
	Trees with lihens/ moses/ fungi on stem	>50% lichen cover on any tree stem in plot							
		2-3 different lichen forms on any tree stem 0-3m in plot							
		>50% moss cover on any tree stem in plot							
		No fungi on tree stems or branches							
		Presence of fungi species on tree stem 0-3m in plot							
Other key biotopes	Other valuable key biotopes present in forest	Natural light gaps (not artificial)							
		Small wetlands (marsh, fen; small pools/ponds/wet zones)							
		Natural springs							
		Seasonal / permanent streams							
		Steep slopes >30 degrees							
		Cliffs, ravines							
		Caves							
		Large rocks with moses/lichens coverage							
Focal species	Selected indicator species of forest key habitats	Any of these species: *Leucojum aestivum/Glechoma hederacea/Mentha agg./Equisetum agg., Ruscus aculeatus/Helleborus odorus/Lithospermum purpureo-careuleum/Campanula persicifolia/Geranium sanguineum, Asperula odorata/Neottia nidus-avis/Lamium galeobdon/Luzula luzuloides, Erica carnea/Daphne blagayana/Vaccinium myrtillus/Oxalis acetosella, Lycopodium clavatum/Ramonda serbica/Sphagnum spp.*							
Threats and Impacts	Invasive Species	*Amorpha fruticosa, Reynoutria japonica, Robinia pseudo-acacia, Aster lanceolatus, Echinocystis lobata*							
	Intro-duced Tree Species (nonative)	Any non-native or introduced tree species							

Explanatory notes:

- *Using for analyzing presents of specific important BD attribute in different forest types. Could use for different reports and analyzes.*
- *Example: Large dimension trees, or tree with lichen are present very often in oak forest, less in beach forest and very less in popular.*