Forest Carbon Measurement in Korea

Establishing Country-Specific Emission Factors for Major Tree Species in Korea

2025.07.28

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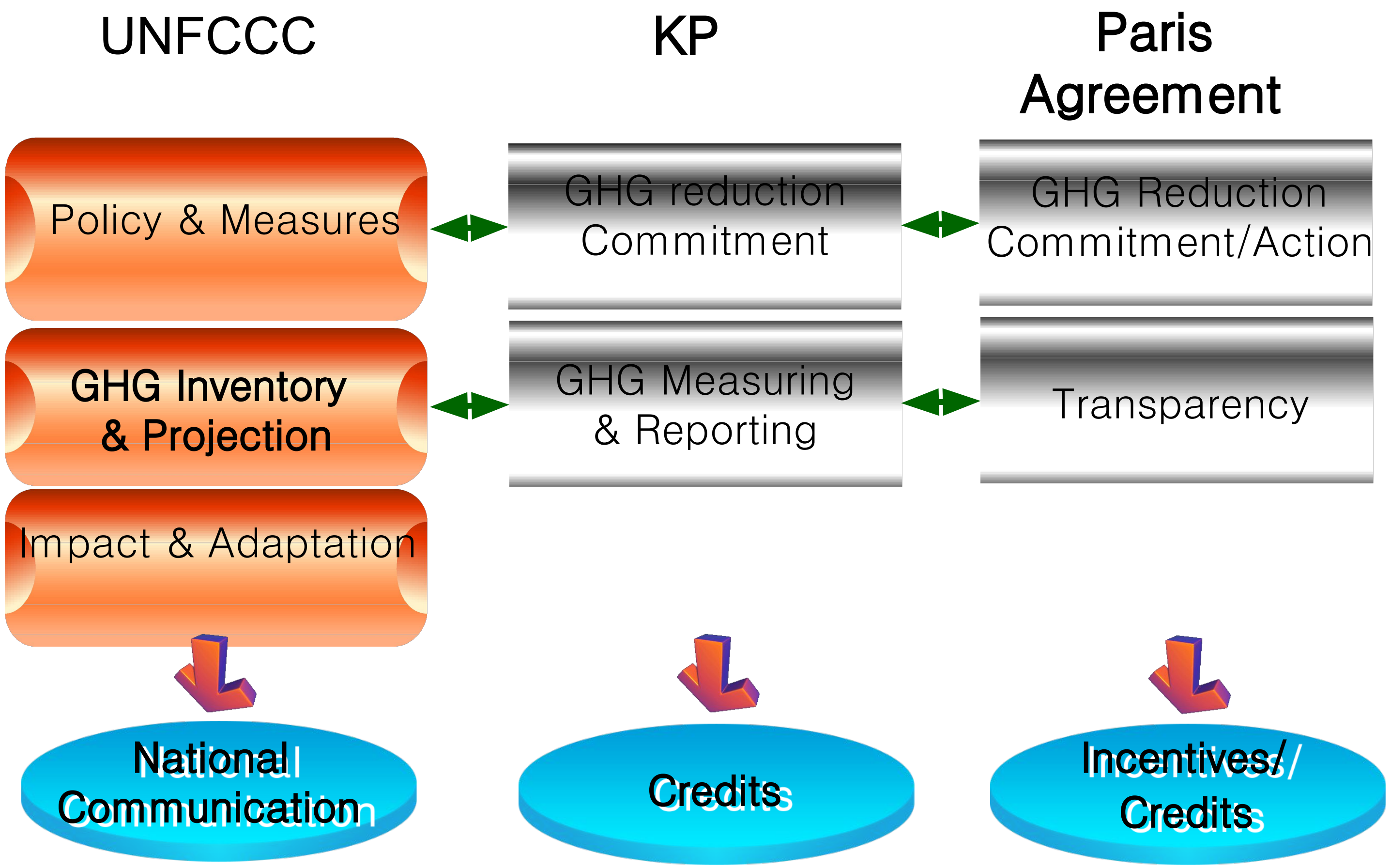
Contents

National GHG Inventory in Forest Land Sector under UNFCCC

Requirement of GHG Inventory under UNFCCC



Forests under Paris Agreement

Recognizing the importance of the conservation and enhancement, as appropriate, of sinks and reservoirs of the greenhouse gases referred to in the Convention,

Article 4

13. Parties shall account for their nationally determined contributions. In accounting for **anthropogenic emissions and** removals corresponding to their nationally determined contributions(NDC), Parties shall promote environmental integrity, transparency, accuracy, completeness, comparability and consistency, and ensure the avoidance of double counting, in accordance with **guidance adopted by the Conference of the Parties** serving as the meeting of the Parties to the Paris Agreement.

Forests under Paris Agreement

Article 4 (Mitigation)

14. In the context of their nationally determined contributions(NDCs), when recognizing and implementing **mitigation actions with respect to** **anthropogenic emissions and** **removals**, Parties should take into account, as appropriate, **existing methods and guidance under the Convention**, in the light of the provisions of paragraph 13 of this Article.

Article 5 (Forest)

1. Parties should take action to **conserve and enhance**, as appropriate, **sinks and reservoirs** of greenhouse gases as referred to in Article 4, paragraph 1(d), of the Convention, including **forests**.

Forests under Paris Agreement

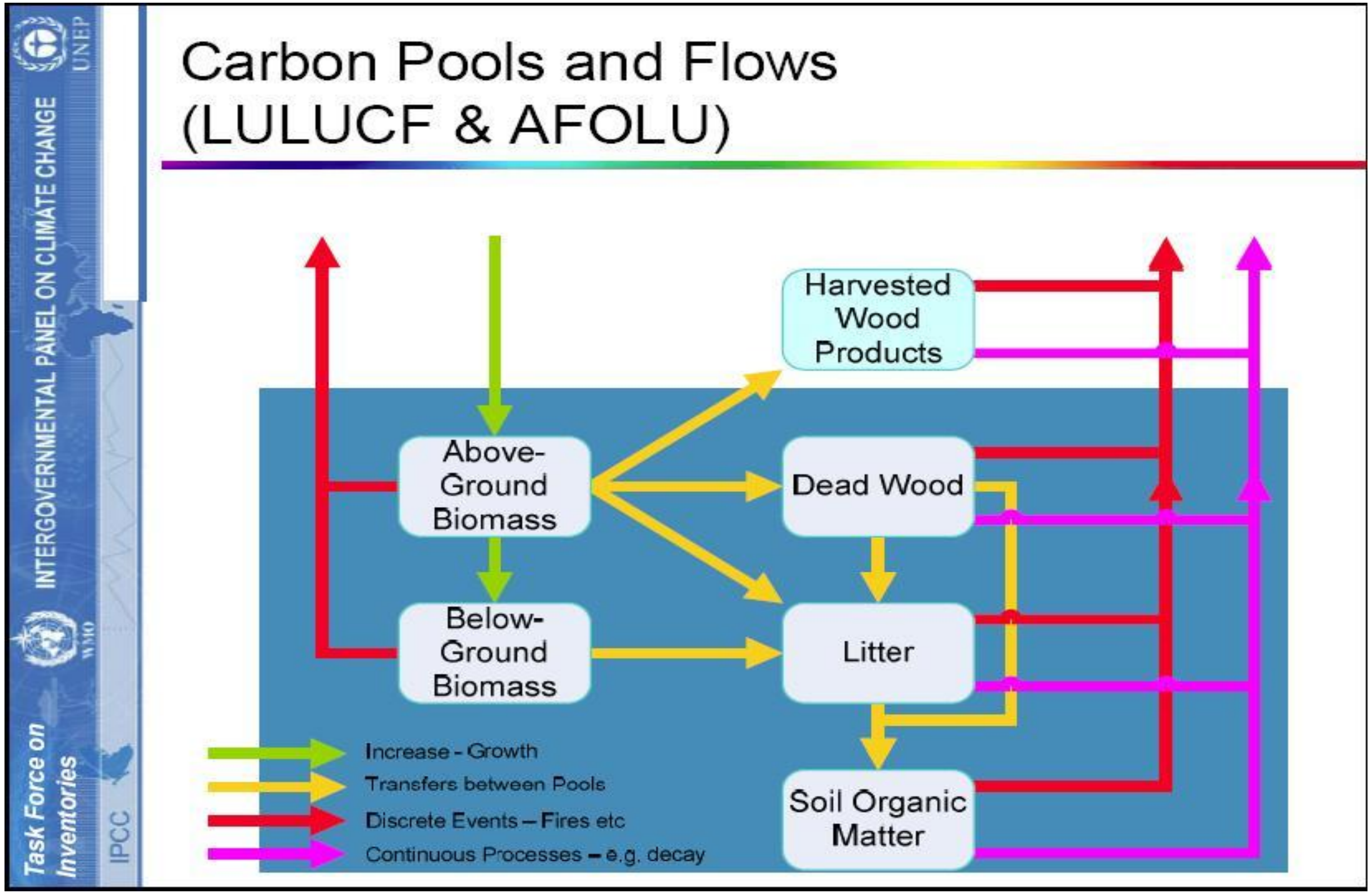
Article 13 (Transparency)

7. Each Party shall regularly provide the following information:

(a) A national inventory report of anthropogenic emissions by sources and removals by sinks of greenhouse gases , prepared using good practice methodologies accepted by the Intergovernmental Panel on Climate Change(IPCC) and agreed upon by the Conference of the Parties serving as the meeting of the Parties to the Paris Agreement;

(b) Information necessary to track progress made in implementing and achieving its nationally determined contribution under Article 4.

Carbon Pools and Flows



Carbon pools

LIVING BIOMASS	Above-ground biomass	All living biomass above the soil; Understorey may be excluded
	Below-ground biomass	Biomass of live roots. **Fine roots** are often excluded (see litter and SOM)
DEAD ORGANIC MATTER	Dead wood	all non-living woody not contained in the litter, above a chosen diameter
	Litter	all non-living plant mass with woody biomass diameter less than a chosen diameter, in various states of decomposition above the mineral or organic soil in the forest. **Live fine roots** are included
SOILS	Soil organic matter (SOM)	Includes organic carbon in mineral and organic soils (including peat) to a specified depth. **Live fine** roots are included

national circumstances may make it necessary to (slightly) modify the pool definitions

Summary equations for national GHG inventory in forest land sector

(IPCC Good Practice Guidance for LULUCF 2003)

Equation 3.2.1

Annual emissions or removals from forest land remaining forest land

$$\Delta C_{FF} = (\Delta C_{FFLB} + \Delta C_{FFDOM} + \Delta C_{FFSoils})$$

ΔC_{FF} : annual change in carbon stocks
ΔC_{FFLB} : annual change in carbon stocks in living biomass (above-, below-)
ΔC_{FFDOM} : annual change in carbon stocks in dead organic matter (dead wood & litter)
$\Delta C_{FFSoils}$: annual change in carbon stocks in soils

Equation 3.2.2

Annual change in carbon stocks in living biomass (default method)

$$\Delta C_{FFLB} = (\Delta C_{FFG} - \Delta C_{FFL})$$

ΔC_{FFLB} : annual change in carbon stocks in living biomass (above-, below-)
ΔC_{FFG} : annual increase in carbon stocks due to biomass growth
ΔC_{FFL} : annual decrease in carbon stocks due to biomass loss

Equation 3.2.3

Annual change in carbon stocks in living biomass (stock change method)

$$\Delta C_{FFLB} = (C_{t2} - C_{t1}) / (t_2 - t_1)$$

and

$$C = [V \cdot D \cdot BEF] \cdot (1+R) \cdot CF$$

ΔC_{FFLB} : annual change in carbon stocks in living biomass (above-, below-)
C_{t2} : total carbon in biomass calculated at time t_2
C_{t1} : total carbon in biomass calculated at time t_1
V : merchantable volume
D : basic wood density
BEF : biomass expansion factor for conversion of merchantable volume to aboveground tree biomass
R : root-shoot ratio
CF : Carbon Fraction

Equation 3.2.4

Annual increase in carbon stocks due to biomass increment,
by forest type and climate zone

$$\Delta C_{FFG} = \sum_{ij} (A_{ij} \cdot G_{totalij}) \cdot CF$$

ΔC_{FFG} : annual increase in carbon stocks due to biomass increment
A_{ij} : area of forest land remaining forest land
$G_{totalij}$: average annual increment rate in total biomass in units of dry matter
CF : carbon fraction of dry matter

Equation 3.2.5

Average annual increment in biomass

$$G_{total} = G_W \cdot (1+R)$$

$$G_W = [Iv \cdot D \cdot BEF]$$

G_{total} : average annual biomass increment above and below ground
G_W : average annual aboveground biomass increment in
R : root-shoot ratio appropriate to increments
Iv : average annual net increment in volume suitable for industrial processing
D : basic wood density
BEF : biomass expansion factor for conversion of annual net increment (including bark) to aboveground tree biomass increment

Equation 3.2.6

Average decrease in carbon stocks due to biomass loss

$$\Delta C_{FFL} = (L_{fellings} + L_{fuelwood} + L_{other\ losses})$$

ΔC_{FFL} : annual decrease in carbon stocks due to biomass loss
$L_{fellings}$: annual carbon loss due to commercial fellings
$L_{fuelwood}$: annual carbon loss due to fuelwood gathering
$L_{other\ losses}$: annual other losses of carbon

Equation 3.2.7

Annual carbon loss due to commercial fellings

$$L_{fellings} = H \cdot D \cdot BEF_2 \cdot (1-f_{BL}) \cdot CF$$

$L_{fellings}$: annual carbon loss due to commercial fellings
H : annually extracted volume
D : basic wood density
BEF_2 : biomass expansion factor for converting volumes of extracted roundwood to total aboveground biomass (including bark)
F_{BL} : fraction of biomass left to decay in forest(transferred to dead organic matter)
CF : carbon fraction of dry matter

Equation 3.2.8

Annual carbon loss due to fuelwood gathering

$$L_{fuelwood} = \boxed{FG} \cdot \boxed{D \cdot BEF_2 \cdot CF}$$

$L_{fuelwood}$: annual carbon loss due to fuelwood
FG : annual volume of fuelwood gathering
D : basic wood density
BEF_2 : biomass expansion factor for converting volumes of extracted roundwood to total aboveground biomass (including bark)
CF : carbon fraction of dry matter

Equation 3.2.9

Annual other losses of carbon

$$L_{other\ losses} = A_{disturbance} \cdot B_W \cdot (1-f_{BL}) \cdot CF$$

$L_{other\ losses}$: annual other losses of carbon
$A_{disturbance}$: forest areas affected by disturbances
B_W : average biomass stock of forest areas
F_{BL} : fraction of biomass left to decay in forest (transferred to dead organic matter)
CF : carbon fraction of dry matter

Equation 3.2.10

Annual change in carbon stocks in dead organic matter

$$\Delta C_{FFDOM} = (\Delta C_{FFDW} + \Delta C_{FFLT})$$

ΔC_{FFDOM} : annual change in carbon stocks in dead organic matter
ΔC_{FFDW} : change in carbon stocks in dead wood
ΔC_{FFLT} : change in carbon stocks in litter

Equation 3.2.11

Average change in carbon stocks in dead wood

$$\Delta C_{FFDW} = [A \cdot (B_{into} - B_{out})] \cdot CF$$

ΔC_{FFDW} : annual change in carbon stocks in dead wood
A : area of managed forest land remaining forest land
B_{into} : average annual transfer into dead wood
B_{out} : average annual transfer out of dead wood
CF : carbon fraction

Equation 3.2.13

Annual change in carbon stocks in litter

$$\Delta C_{FFLT} = \{\sum_{ij}[C_j - C_i) \cdot A_{ij}] / T_{ij}$$

where

$$C_i = L_{ref(i)} \cdot f_{man\ intensity(i)} \cdot f_{dist\ regime(i)}$$

ΔC_{FFLT} : annual change in carbon stocks in litter
C_i : stable litter stock, under previous state 'i'
C_j : stable litter stock, under previous state 'j'
A_{ij} : forest area under going a transition from state 'I' to 'j'
T_{ij} : time period of the transition from state 'I' to 'j'
$LT_{ref(i)}$: the reference stock of litter under native, unmanaged forest corresponding to state 'I'

Equation 3.2.16

Soil organic carbon content

$$SOC = \sum([SOC] \cdot \text{bulk density} \cdot \text{depth} \cdot (1 - \text{frag}) \cdot 10)$$

SOC : representative soil organic carbon for the forest type and soil of interest
[SOC] : concentration of soil organic carbon in a given soil mass obtained from lab
Bulk density : soil mass per sample volume
Depth : horizon depth or thickness of soil layer
Frag : % volume of coarse fragments/100

Critical emission factors

D : Basic wood density

BEF : Biomass expansion factor

R : Root-shoot ratio

CF : carbon fraction(each parts)

bulk density, coarse fragment content

- Biomass
  - Basic wood density
  - Biomass Expansion factors
  - Root-Shoot ratios
  - Carbon fraction
- Dead organic matter
  - Basic wood density
  - Carbon stock per ha
  - Carbon fraction
- Soil carbon
  - Carbon fraction
  - Carbon stock per ha
  - Bulk density
  - Coarse fragment content




Critical activity data

V : Merchantable volume

* **National Forest Inventory**

A : Area of forest land

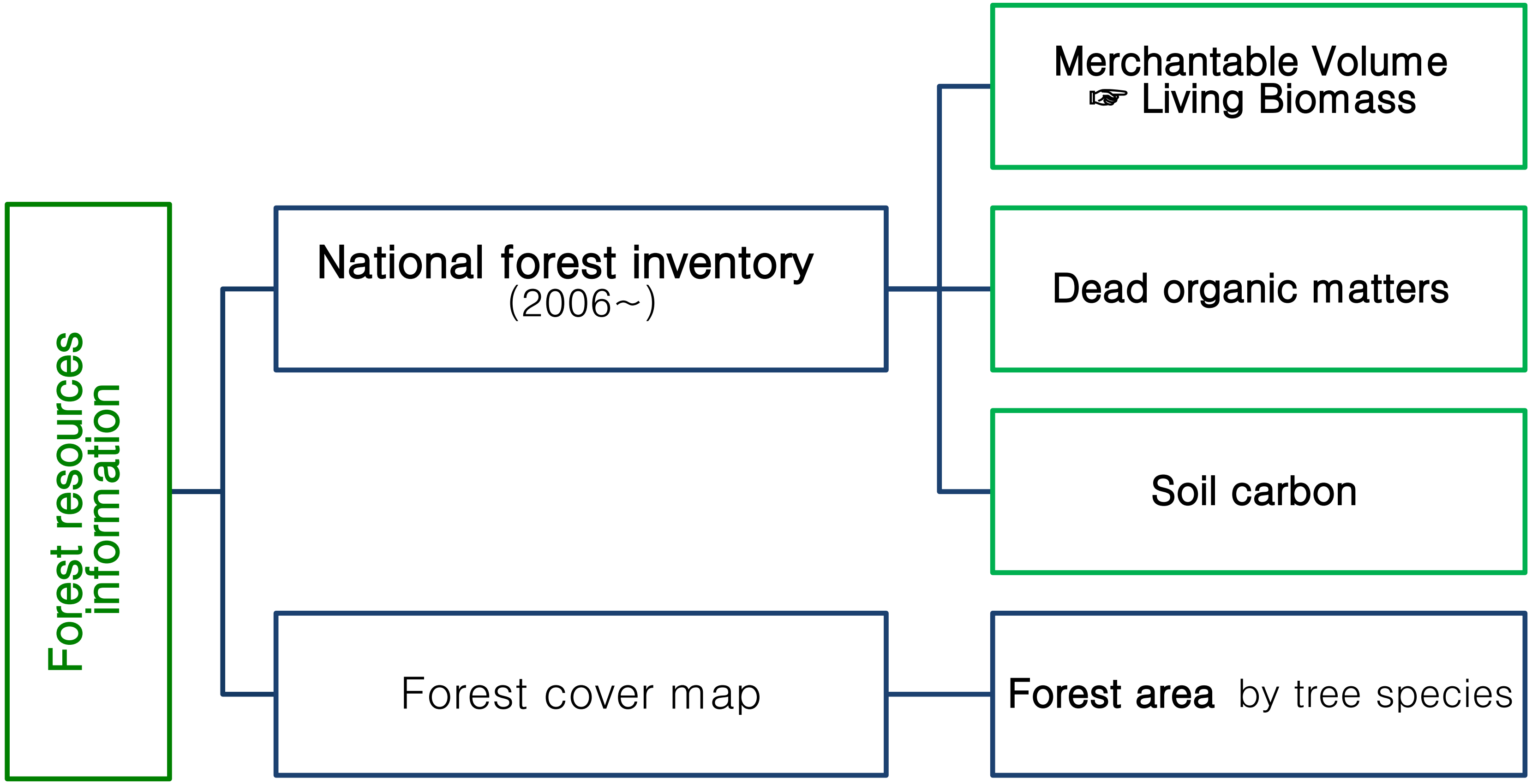
H : annually extracted volume

FG : annual volume of fuelwood gathering

$A_{disturbance}$: forest areas affected by disturbances

B_W : average biomass stock of forest areas

Activity Data (National Forest Inventory)



Summary of Carbon Stock Calculation in Living Biomass

Merchantable Volume (**NFI**) ➤➤ Carbon Stock

Stem volume ➤➤ **Stem biomass** ➤➤ **Above-biomass** ➤➤ **Total biomass** ➤➤ **Carbon stock**

D **BEF** **R** **CF**

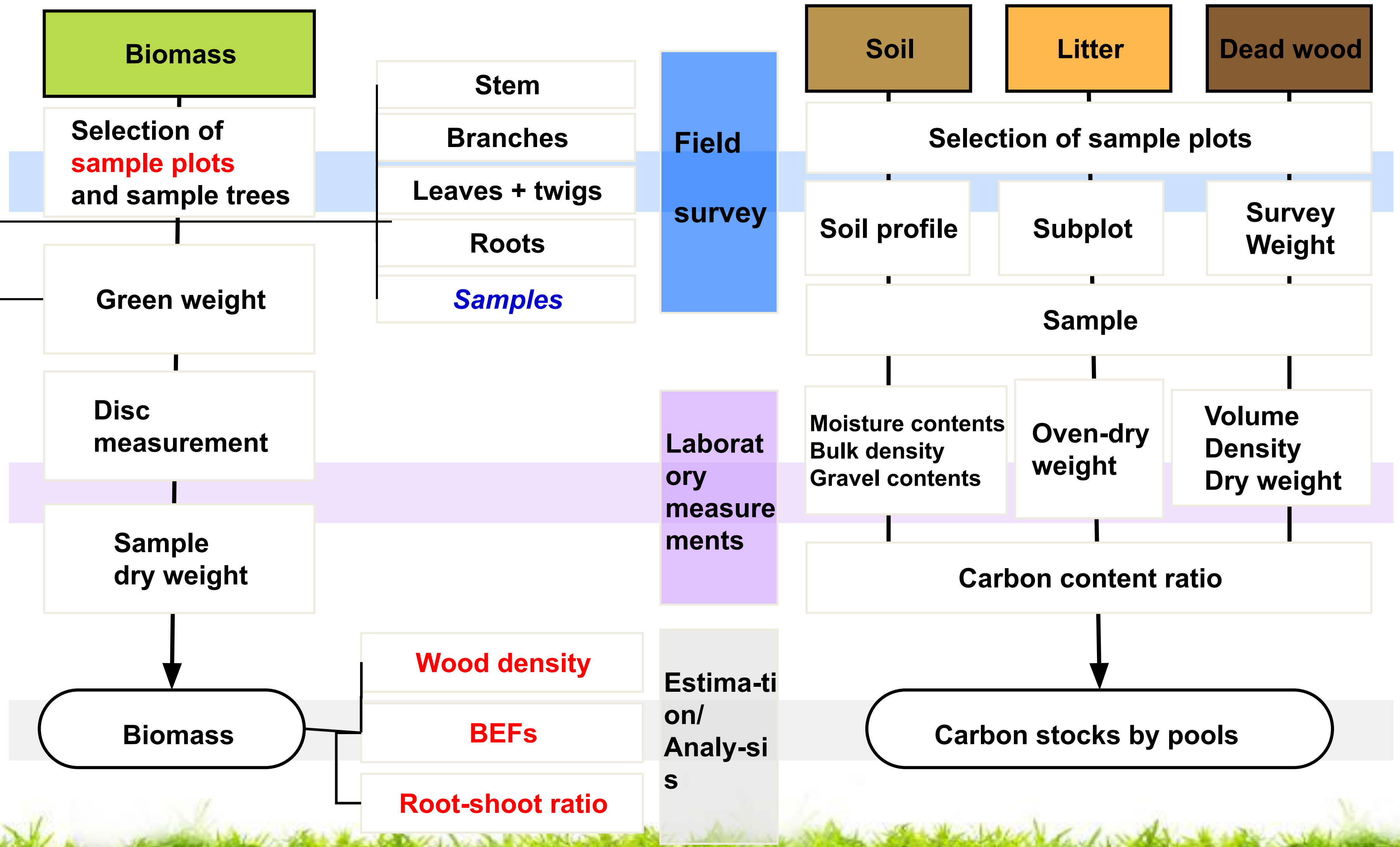

Country-Specific Emission Factors
for Major Tree Species

Research Project

- Title : (As a part of) Study of the basis of forest carbon accounting in Korea ⁎ Preparing for the requirements by Kyoto Protocol
- Period : 2007.4~2010.4 (3 years)
- Budget : USD 1.2million
- Funding organization : Korea Forest Administration
- Implementation organization : National Institute of Forest Research

  ※ Cooperation with 8 universities all over the country

Process of emission/removal factors development



The number of sample plots and their allocation for major tree species

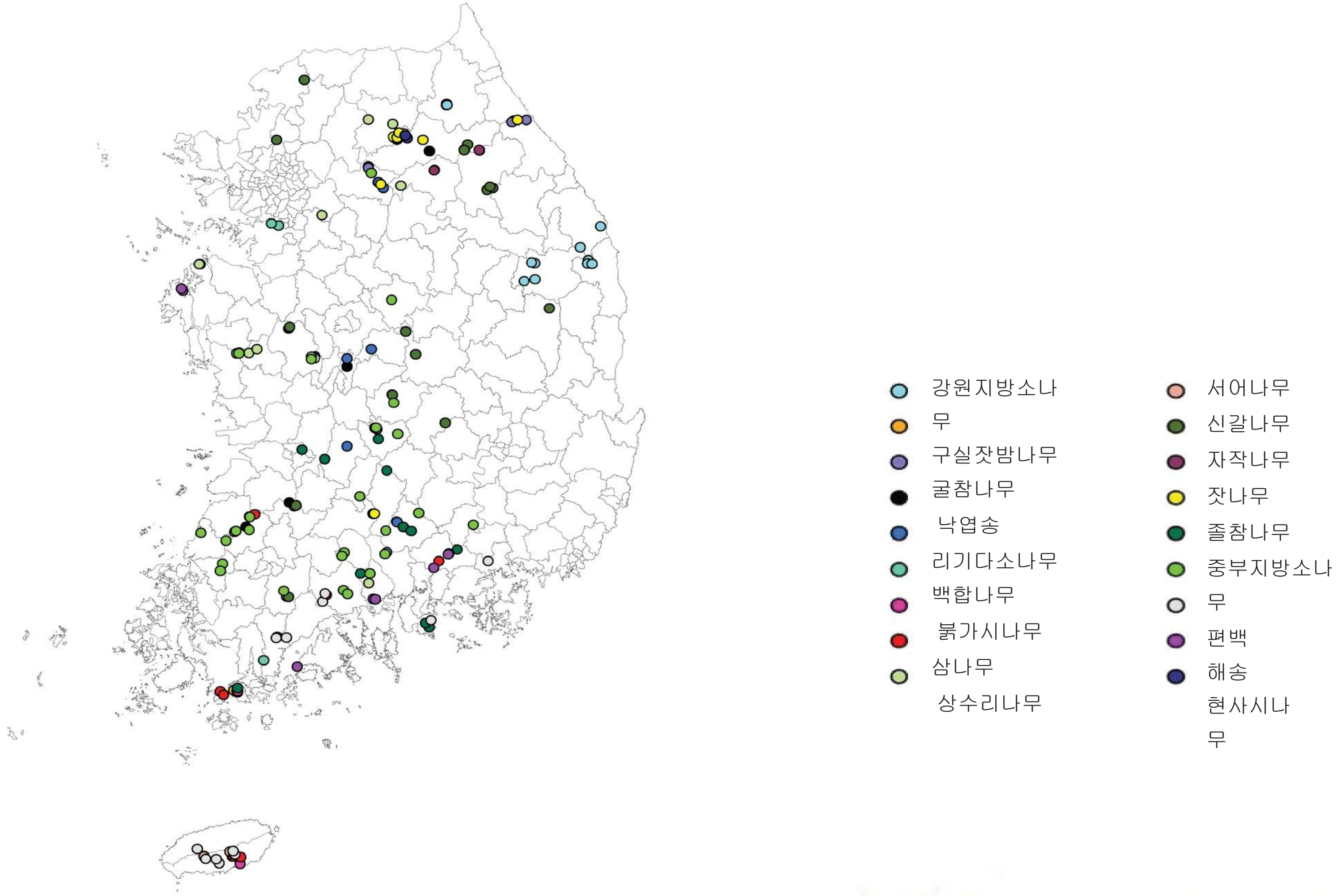
- The formula for determining the number of sample plots

$$n \geq \frac{t^2 C^2 A}{e^2 A + t^2 a C^2} \rightarrow n \geq \frac{4C^2 A}{(e^2 A + 4aC^2)},$$

Where, n : No. of sample plots, A : Total Area, C : Coefficient of variation(CV),
e : Allowable error , a : Area of a sample plot, t : Confidence level(normally 95%)

- Coefficient of variation of 15% was applied considering CV of 10% for artificial forests and CV of 20% for natural forests
- Allowable error of 3% was applied considering efforts and costs of the survey
- The calculated number of sample plots was 100
- The 150 sample plots, conservatively, were allocated for major tree species considering the **growing stock** and **geographical distribution** of each tree species

Allocation of sample plots for biomass and soil carbon survey for major tree species in Korea



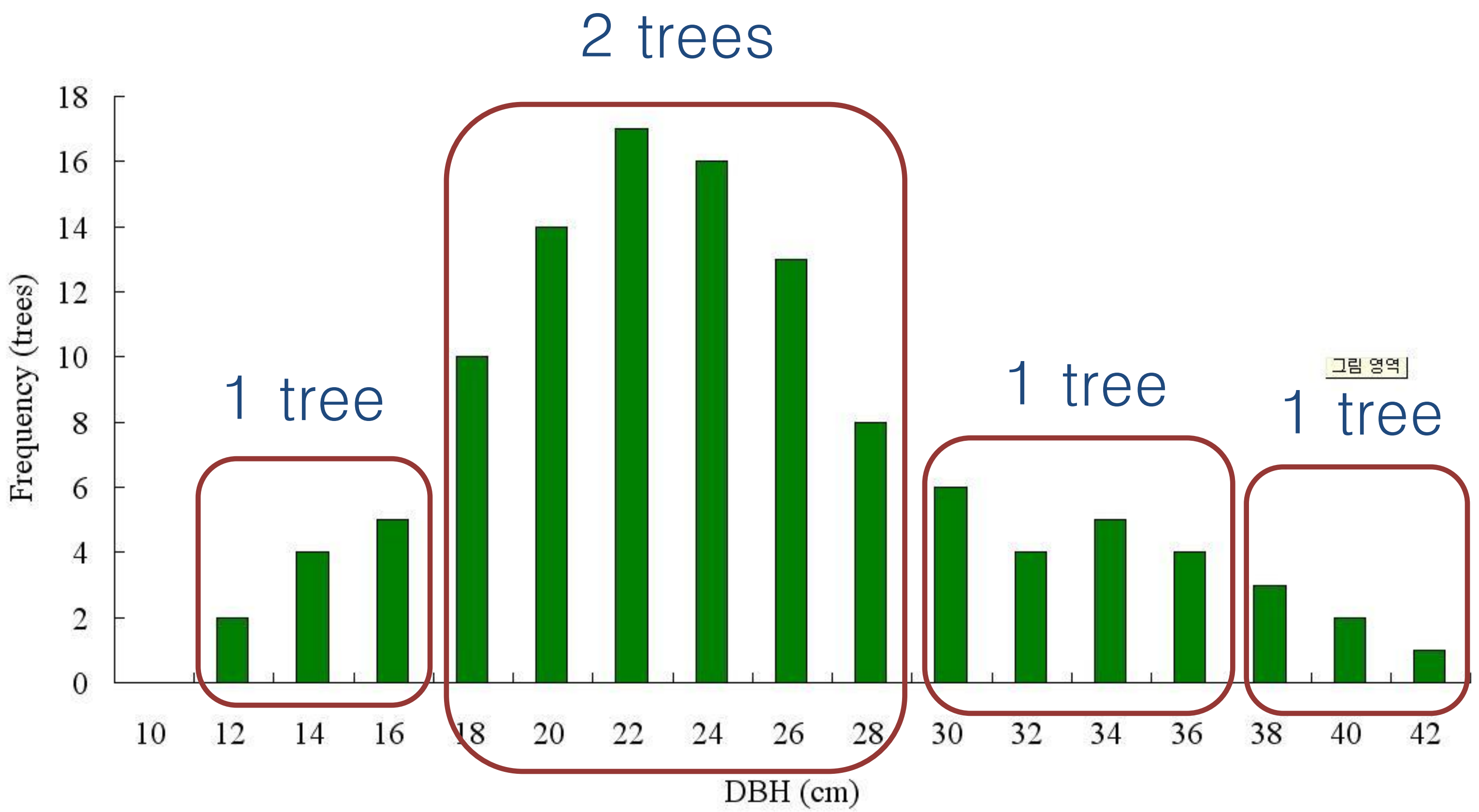
Field survey at sample plot

Above-ground Biomass

Field work

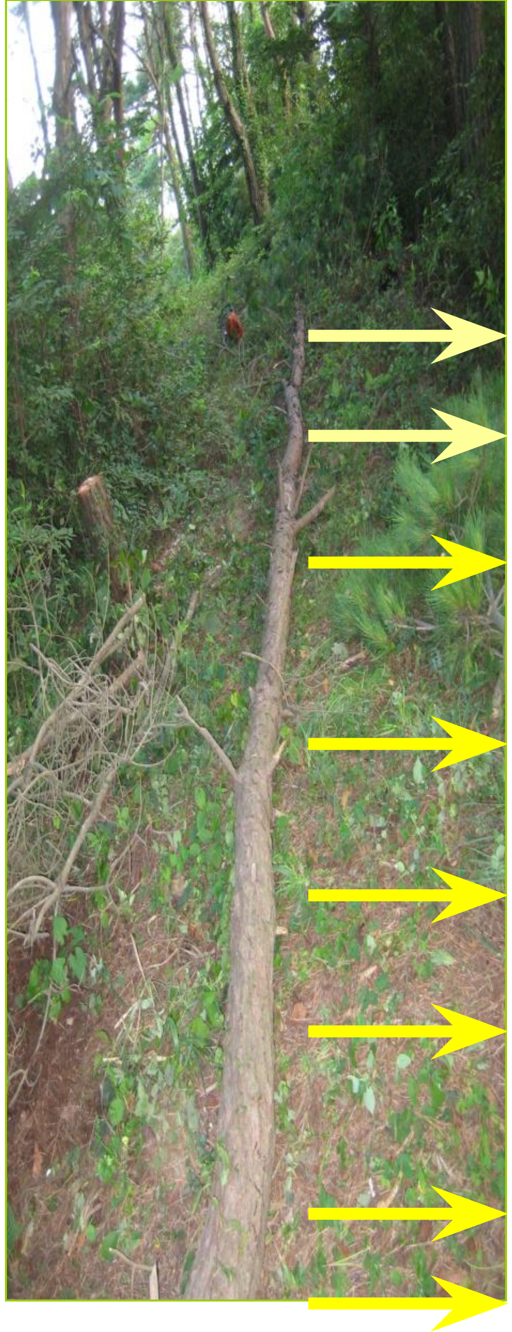
- Selecting survey area for investigation
- Establishing plot (20m x 20m)
- Measuring the basic data of all trees
  - Identifying all upper-story trees
  - Measuring DBH
- Selecting sample trees
- Measuring fresh weight of selected sample tree and collecting sample for drying from stems, branches, discs, leaves+twigs, and roots

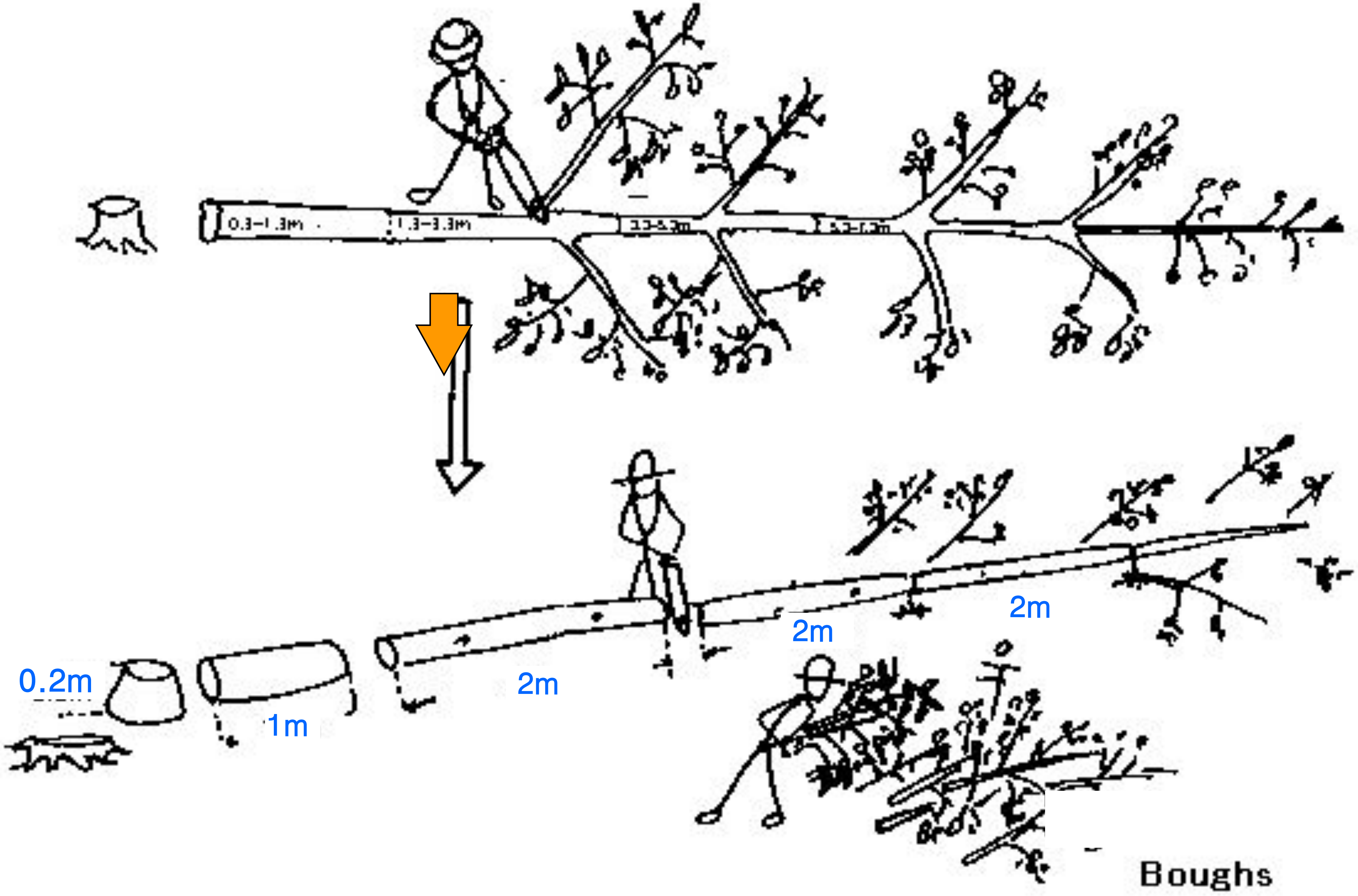
Sample tree selection



Field work

- Felling the sample tree
- Collecting the discs
- Measuring the fresh weight of
  - Stem
  - Branches, leaves+twigs, and their samples
  - Roots and their samples





Felling a sample tree and cutting into logs. Boughs must be separated

(http://www.iopp.or.jp/english/jigyo/biomassmanual/manual1.html)

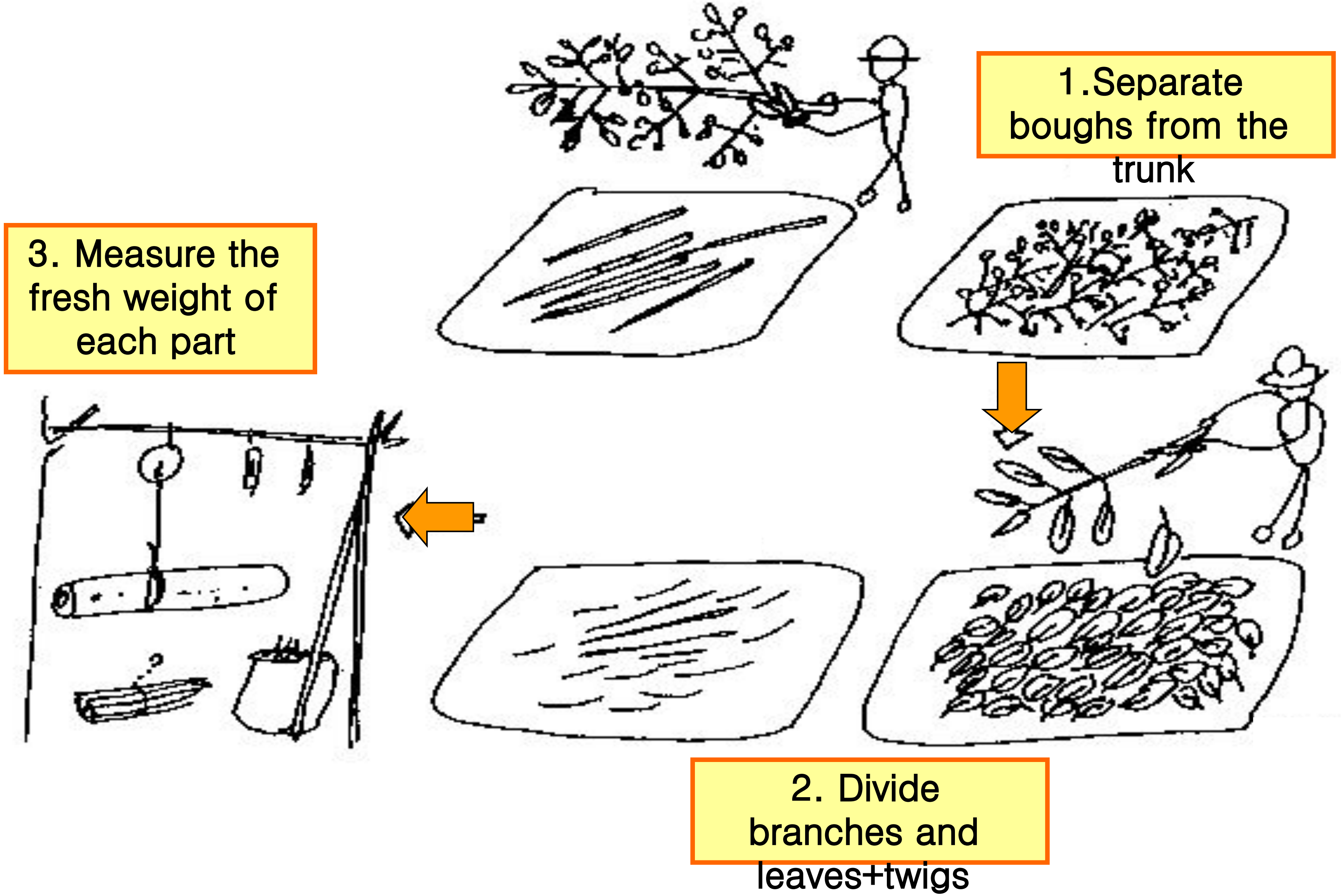


Fig 2 Clearing small branches from boughs and separating them in to twigs and leaves, then weighing them by various spring scales
(http://www.jopp.or.jp/english/jigyo/biomassmanual/manual2.html)

Below-ground Biomass

Excavation roots

- Collect roots for belowground biomass by
  - Winch
  - Excavator

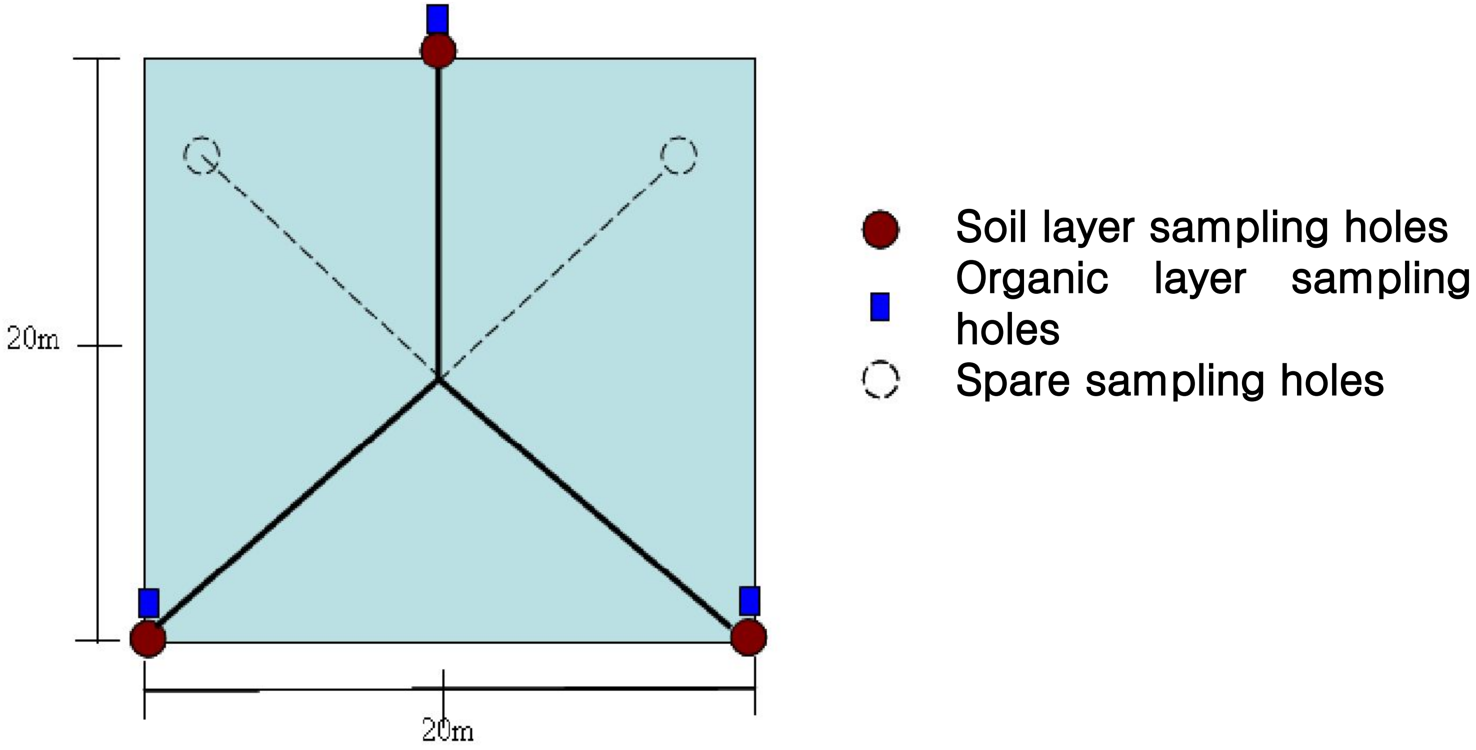


Litter & soil

Survey points

<u>Site selection</u>

- Select survey area and sample point



Litter

<u>**Collecting samples from organic layers**</u>

- Collect all living vegetation and cut litterfall outside of the frame (30 cm x 30 cm)

Soils

Collecting soil samples

- Remove the remaining humus and collect soil sample from 0–10 cm depth by the use of auger
- Collect soil samples using the same method in every depth

Dead wood


Snag

Stump

Log

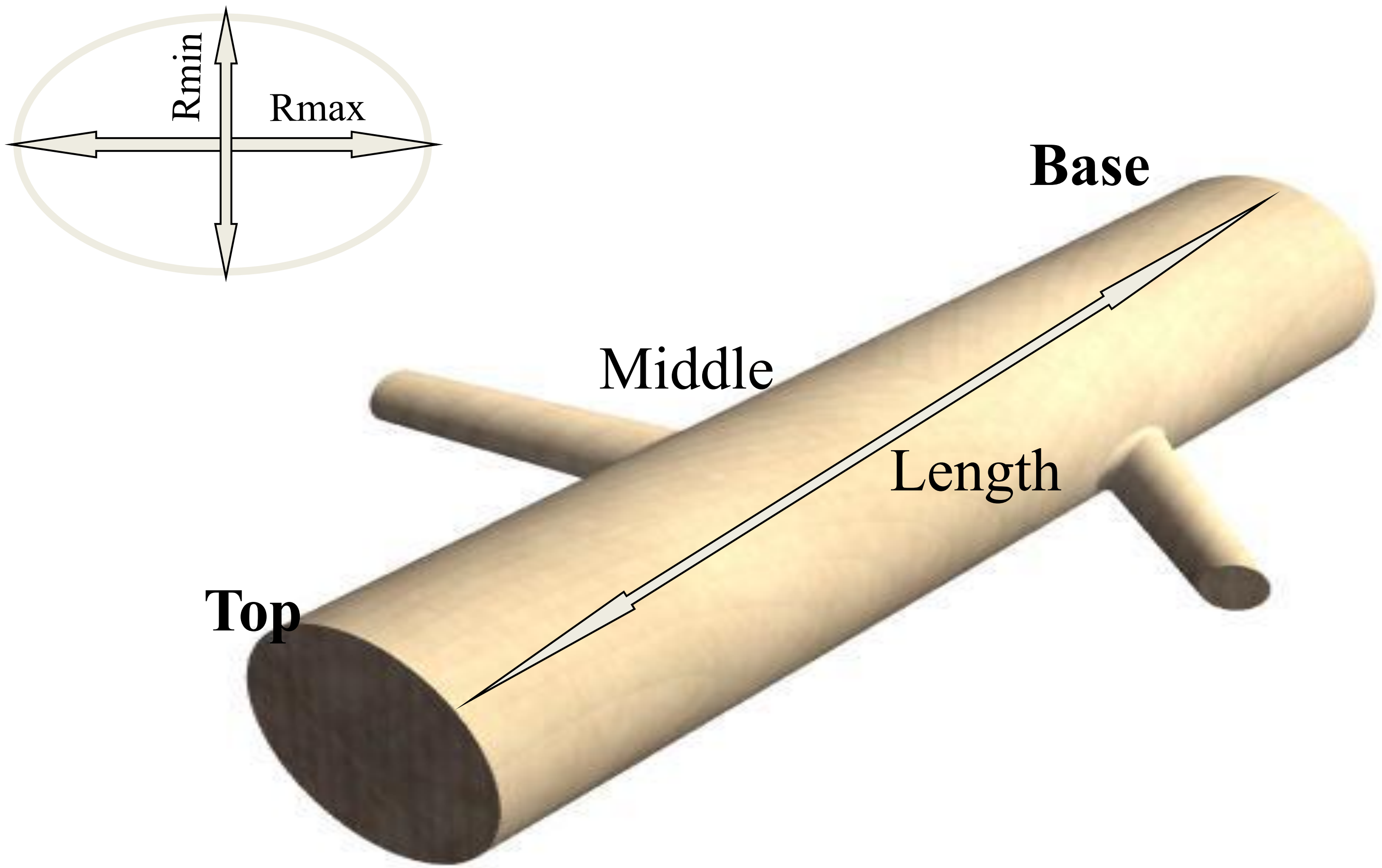
Decay class

sound

intermediate

rotten

Measure length and diameter at three point



To calculate volume

Using Newton formula & Whitemore(1984)

- Log and stump

$$V = L\,(A_b + 4A_m + A_t)/6$$

- Snag

$$V = \text{basal area} \times \text{height} \times 0.5$$

V : Volume, L : Length, Ab: Cross sectional area of bottom end
Am: Cross sectional area of middle At: Cross sectional area of top end

(A = 3.1416 x Rmin x Rmax)

Collect disc samples

Calculate density and mass

- Density (g/cm^3)
  = sample volume / dry weight
- Mass (Mg/ha)
  = volume * density

Laboratory work

Disks and samples

Disks and samples

Measuring dry weight of the samples

- Drying collected samples (stem disc, branches, leaves+twigs, and roots) at 85℃ until reaching constant weight
- Measuring the dry weight of the samples

Calculating the ratio of the dry weight to fresh weight

- Computing the ratio of dry weight to fresh weight for estimating the biomass of sample tree's components

Sample tree

- **<u>Compute the tree biomass (dry weight)</u>**
  - Stem (Wood + bark)
  - Wood of stem
  - Bark of stem
  - Branches
  - Leaves + twigs
  - Roots

Volume of stem

• **Volume of stem**

• Volume of the felled stem (㎤)

$$= \sum \{(D/2)2 \times \pi \times 200)\} + (d/2)2 \times \pi \times t \times 1/3$$

- D : Diameter of each disc except the last disc (cm)
- 200 : Length of stem after sectional measurement (cm)
- d : Diameter of the last disc (cm)
- t : Length of the last section (cm)
- 1/3 : Ratio of conical shape's volume

• Volume of the left stem (ground to 0.2 m) (㎤)

$$= (D/2)2 \times \pi \times 20$$

- D : Diameter of the section of left stem (cm)
- 20 : Length of the left stem (cm)

Calculating emission factors for biomass

Wood Density(D) of stem

- D of the trunk is the value of stem dry weight (biomass) divided by stem volume

Biomass expansion factor(BEF)

- BEF is the ratio of aboveground biomass to stem biomass

Root–shoot ratio(R)

- R is the ratio of the root biomass to aboveground biomass

Soil analysis

Soil drying

- Oven-drying soil samples at 105˚C until reaching constant weight
- Measuring the weights of the total dried soils (*WT*, g)
- Separating fine earth fragments (<2 mm) and rock fragments (>2 mm) by sieving
- Measuring the weights of rock fragments (*WF*, g).
- Calculating the weight of dried soils (fine earth fragments <2 mm: *WS*, g) with the following formula

$$W_S = W_T - W_F$$

Soil analysis

Soil analysis

Soil bulk density

= Total dry weight of soil (WT , g) / Volume of soil sample (cm^3)

Analysis of rock fragment content

- To calculate soil carbon, measuring the weights of rock fragments
  and subtracting them from the total sample mass


elementar

Carbon contents

Soils

- Calculating soil carbon stocks at each soil depth using the following formula

$$SOC_i\,(Mg/ha) = D \times BD \times C \times (1 - F)$$

D : Thickness of soil (m)
BD : Soil bulk density (g/ *cm3*)
C : Soil organic content
F : Content of rock fragments

- Calculating the total carbon stocks by summing the values at each soil depth (TCS, ton/ha)

Carbon contents

Organic layers

- Estimating the accumulated carbon content of organic layers (g/m^2) as follows;

dry weight of organic layers (g/m^2) x carbon content (C, %)/100

Dead tree

- Estimating the accumulated carbon content of dead tree (g/m^2) as follows;

dry weight of dead trees (g/m^2) × carbon content (C, %)/100

발 간 등 록 번 호
11-1400377-000173-01

산림 바이오매스 및 토양탄소 조사·분석 표준

Survey Manual for Forest Biomass and Soil Carbon

국립산림과학원
KOREA FOREST RESEARCH INSTITUTE

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11-1400377-000352-01

Survey Manual for Biomass and Soil Carbon

KOREA FOREST RESEARCH INSTITUTE

Wood density(D) and its uncertainty for major tree species in Korea

Species	n	Mean	Maximum	Minimum	Uncertainty(%)
Pinus densiflora Siebold & Zucc. (Gangwon)	5	**0.40**	0.47	0.36	**12.99**
Pinus densiflora Siebold & Zucc. (Central)	28	**0.47**	0.59	0.39	**3.80**
Pinus rigida Mill.	10	**0.51**	0.57	0.47	**4.38**
Pinus koraiensis Siebold & Zucc.	9	**0.41**	0.50	0.36	**8.20**
Pinus thunbergii Parl.	8	**0.48**	0.53	0.43	**5.73**
Chamaecyparis obtuse (Thunb. ex L.f.) D.Don	6	**0.42**	0.44	0.41	**3.34**
Larix kaempferi (Lamb.) Carrière	15	**0.45**	0.53	0.37	**6.34**
Cryptomeria japonica (Siebold & Zucc.) Endl.	11	**0.35**	0.38	0.32	**3.50**
Quercus variabilis Blume	15	**0.72**	0.76	0.70	**1.66**
Quercus acutissima Carruth.	10	**0.70**	0.73	0.65	**2.59**
Quercus mongolica Fisch. ex Ledeb.	17	**0.66**	0.75	0.60	**3.33**
Populus alba × *Populus glandulosa* Uyeki.	5	**0.36**	0.39	0.34	**7.53**

Biomass expansion factor(BEF) and its uncertainty for major tree species in Korea

Species	n	Mean	Maximum	Minimum	Uncertainty(%)
Pinus densiflora Siebold & Zucc. (Gangwon)	15	**1.47**	1.96	1.25	**7.89**
Pinus densiflora Siebold & Zucc. (Central)	33	**1.40**	2.41	1.12	**5.89**
Pinus rigida Mill.	21	**1.39**	2.05	1.13	**6.86**
Pinus koraiensis Siebold & Zucc.	21	**1.85**	2.71	1.33	**10.99**
Pinus thunbergii Parl.	11	**1.43**	1.99	1.10	**12.09**
Chamaecyparis obtuse (Thunb. ex L.f.) D.Don	9	**1.39**	1.93	1.23	**11.69**
Larix kaempferi (Lamb.) Carrière	22	**1.32**	2.00	1.10	**6.54**
Cryptomeria japonica (Siebold & Zucc.) Endl.	11	**1.31**	1.69	1.15	**6.46**
Quercus variabilis Blume	24	**1.33**	1.66	1.18	**3.53**
Quercus acutissima Carruth.	16	**1.43**	1.71	1.21	**5.48**
Quercus mongolica Fisch. ex Ledeb.	36	**1.50**	2.03	1.14	**5.86**
Populus alba × *Populus glandulosa* Uyeki.	5	**1.18**	1.28	1.11	**6.70**

Root-shoot ratio(R) and its uncertainty for major tree species in Korea

Species	n	Mean	Maximum	Minimum	Uncertainty(%)
Pinus densiflora Siebold & Zucc. (Gangwon)	12	**0.26**	0.52	0.11	**18.39**
Pinus densiflora Siebold & Zucc. (Central)	30	**0.25**	0.54	0.11	**8.69**
Pinus rigida Mill.	11	**0.43**	0.99	0.21	**38.36**
Pinus koraiensis Siebold & Zucc.	10	**0.26**	0.41	0.18	**19.48**
Pinus thunbergii Parl.	8	**0.31**	0.51	0.24	**23.83**
Chamaecyparis obtuse (Thunb. ex L.f.) D.Don	12	**0.21**	0.47	0.06	**38.93**
Larix kaempferi (Lamb.) Carrière	15	**0.28**	0.48	0.15	**18.26**
Cryptomeria japonica (Siebold & Zucc.) Endl.	11	**0.25**	0.32	0.19	**13.50**
Quercus variabilis Blume	15	**0.34**	0.47	0.19	**11.42**
Quercus acutissima Carruth.	10	**0.33**	0.76	0.13	**39.78**
Quercus mongolica Fisch. ex Ledeb.	17	**0.42**	1.06	0.21	**22.77**
Populus alba × *Populus glandulosa* Uyeki.	4	**0.16**	0.18	0.16	**8.83**

Carbon fraction(CF) of biomass and its uncertainty for major tree species in Korea

Species	n	Carbon fraction (%)
Pinus densiflora Siebold & Zucc. (Gangwon)	15	**50.4**
Pinus densiflora Siebold & Zucc. (Central)	33	**50.7**
Pinus rigida Mill.	21	**50.6**
Pinus koraiensis Siebold & Zucc.	21	**50.1**
Pinus thunbergii Parl.	11	**49.3**
Chamaecyparis obtuse (Thunb. ex L.f.) D.Don	9	**49.7**
Larix kaempferi (Lamb.) Carrière	22	**50.1**
Cryptomeria japonica (Siebold & Zucc.) Endl.	13	**50.9**
Quercus variabilis Blume	24	**49.0**
Quercus acutissima Carruth.	16	**48.0**
Quercus mongolica Fisch. ex Ledeb.	36	**48.8**
Populus alba × *Populus glandulosa* Uyeki.	5	**47.2**

Carbon fraction(CF) of litter fall for major tree species in Korea

Species	n	Carbon fraction (%)
Pinus densiflora Siebold & Zucc. (Gangwon)	12	47.18 (1.08)
Pinus densiflora Siebold & Zucc. (Central)	35	48.06 (0.79)
Pinus rigida Mill.	15	43.38 (1.01)
Pinus koraiensis Siebold & Zucc.	15	37.43 (1.34)
Pinus thunbergii Parl.	17	38.16 (2.21)
Chamaecyparis obtuse (Thunb. ex L.f.) D.Don	10	44.99 (0.84)
Larix kaempferi (Lamb.) Carrière	11	45.90 (0.61)
Cryptomeria japonica (Siebold & Zucc.) Endl.	6	44.32 (1.07)
Quercus variabilis Blume	10	34.58 (1.81)
Quercus acutissima Carruth.	6	32.03 (1.44)
Quercus mongolica Fisch. ex Ledeb.	8	46.10 (0.85)
Populus alba × *Populus glandulosa* Uyeki.	5	39.25 (1.10)

* The value in parentheses is standard error

Carbon fraction(CF) of dead wood for major tree species in Korea

Species	Decay stage					
	Sound		Intermediate		Rotton	
Pinus densiflora Siebold & Zucc. (Gangwon)	50.0 (0.00*)	(n=2)	50.0 (0.00)	(n=4)	50.0 (0.00)	(n=2)
Pinus densiflora Siebold & Zucc. (Central)	51.3 (0.00)	(n=13)	51.2 (0.00)	(n=14)	50.8 (0.00)	(n=10)
Pinus rigida Mill.	48.2 (1.10)	(n=5)	54.4 (0.44)	(n=5)	51.1 (1.07)	(n=6)
Pinus koraiensis Siebold & Zucc.	51.1 (-)	(n=1)	51.1 (0.04)	(n=2)	50.6 (0.46)	(n=2)
Pinus thunbergii Parl.	53.4 (-)	(n=1)	49.8 (0.41)	(n=2)	54.5 (-)	(n=1)
Chamaecyparis obtuse (Thunb. ex L.f.) D.Don	51.1 (0.16)	(n=3)	49.1 (0.11)	(n=3)	49.6 (-)	(n=1)
Larix kaempferi (Lamb.) Carrière	49.6 (0.22)	(n=5)	49.8 (0.20)	(n=5)	55.0 (2.09)	(n=6)
Cryptomeria japonica (Siebold & Zucc.) Endl.	50.2 (0.42)	(n=5)	51.8 (0.51)	(n=3)	52.8 (0.98)	(n=3)
Quercus variabilis Blume	49.1 (0.13)	(n=4)	49.3 (0.28)	(n=5)	49.1 (0.26)	(n=4)
Quercus acutissima Carruth.	51.2 (0.39)	(n=3)	51.3 (-)	(n=1)	-	
Quercus mongolica Fisch. ex Ledeb.	51.0 (0.17)	(n=5)	52.3 (1.14)	(n=5)	51.7 (0.81)	(n=4)
Populus alba × *Populus glandulosa* Uyeki.	48.2 (-)	(n=1)	47.9 (0.12)	(n=4)	-	

* The value in parentheses is standard error

Carbon fraction(CF) at each soil depth for major tree species in Korea

Species	Soil depth			
	0~10㎝	10~20㎝	20~30㎝	30~50㎝
Pinus densiflora Siebold & Zucc. (Gangwon)	0.0286	0.0188	0.0124	0.0081
Pinus densiflora Siebold & Zucc. (Central)	0.0302	0.0167	0.0113	0.0088
Pinus rigida Mill.	0.0304	0.0167	0.0110	0.0075
Pinus koraiensis Siebold & Zucc.	0.0322	0.0237	0.0186	0.0122
Pinus thunbergii Parl.	0.0381	0.0232	0.0159	0.0109
Chamaecyparis obtuse (Thunb. ex L.f.) D.Don	0.0158	0.0096	0.0070	0.0062
Larix kaempferi (Lamb.) Carrière	0.0211	0.0092	0.0049	0.0034
Cryptomeria japonica (Siebold & Zucc.) Endl.	0.0525	0.0303	0.0260	0.0212
Quercus variabilis Blume	0.0396	0.0240	0.0164	0.0143
Quercus acutissima Carruth.	0.0561	0.0362	0.0267	0.0182
Quercus mongolica Fisch. ex Ledeb.	0.0169	0.0076	0.0052	0.0026
Populus alba × *Populus glandulosa* Uyeki.	0.0280	0.0184	0.0117	0.0075

Allometric equations of *Pinus densiflora* Siebold & Zucc. (Gangwon province)

Organ	Allometric equations			
	$Y=aD^b$	R^2	$Y=a(D^2H)^b$	R^2
Stem (wood)	$Y=45.530D^{2.47852}$	0.9049	$Y=23.4003(D^2H)^{0.94362}$	0.9571
Stem (bark)	$Y=37.6432D^{1.87014}$	0.8654	$Y=30.2337(D^2H)^{0.68006}$	0.8497
Stem (total)	$Y=62.918D^{2.41260}$	0.9175	$Y=34.1013(D^2H)^{0.91462}$	0.9636
Branches	$Y=5.601D^{2.70749}$	0.7657	$Y=8.061(D^2H)^{0.90904}$	0.6624
Leaves	$Y=62.480D^{1.52611}$	0.6416	$Y=61.923(D^2H)^{0.53461}$	0.5824
Above-ground	$Y=80.229D^{2.41617}$	0.9482	$Y=33.815(D^2H)^{0.79167}$	0.9581
Roots	$Y=31.999D^{2.27685}$	0.8016	$Y=52.068(D^2H)^{0.89558}$	0.7556
Whole tree	$Y=92.577D^{2.44243}$	0.9412	$Y=85.749(D^2H)^{0.86522}$	0.9267

Where, Y: biomass(g), D: DBH(㎝), H: height(m), R^2: coefficient of determination

발간등록번호
11-1400377-000394-01

연구보고
10-25

산림 온실가스 인벤토리를 위한 주요 수종별 탄소배출계수

손영모 · 이경학 · 김래현 · 표정기
박인협 · 손요환 · 이영진 · 김춘식

국립산림과학원
KOREA FOREST RESEARCH INSTITUTE

Emission Factors of Major Tree Species for Greenhouse Gas Inventory in Korea

Usage of emission factors for major tree species

- National Greenhouse Gas Inventory

  * Emission factors

- Carbon Accounting for Greenhouse Gas Mitigation Projects

  * Emission factors / Allometric equations

- Energy Saving Campaign (Effect of planting trees)

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