

Forest Carbon Measurement in Korea

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

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Kyeong-hak Lee

Kookmin University kyeonghlee@kookmin.ac.kr

Contents



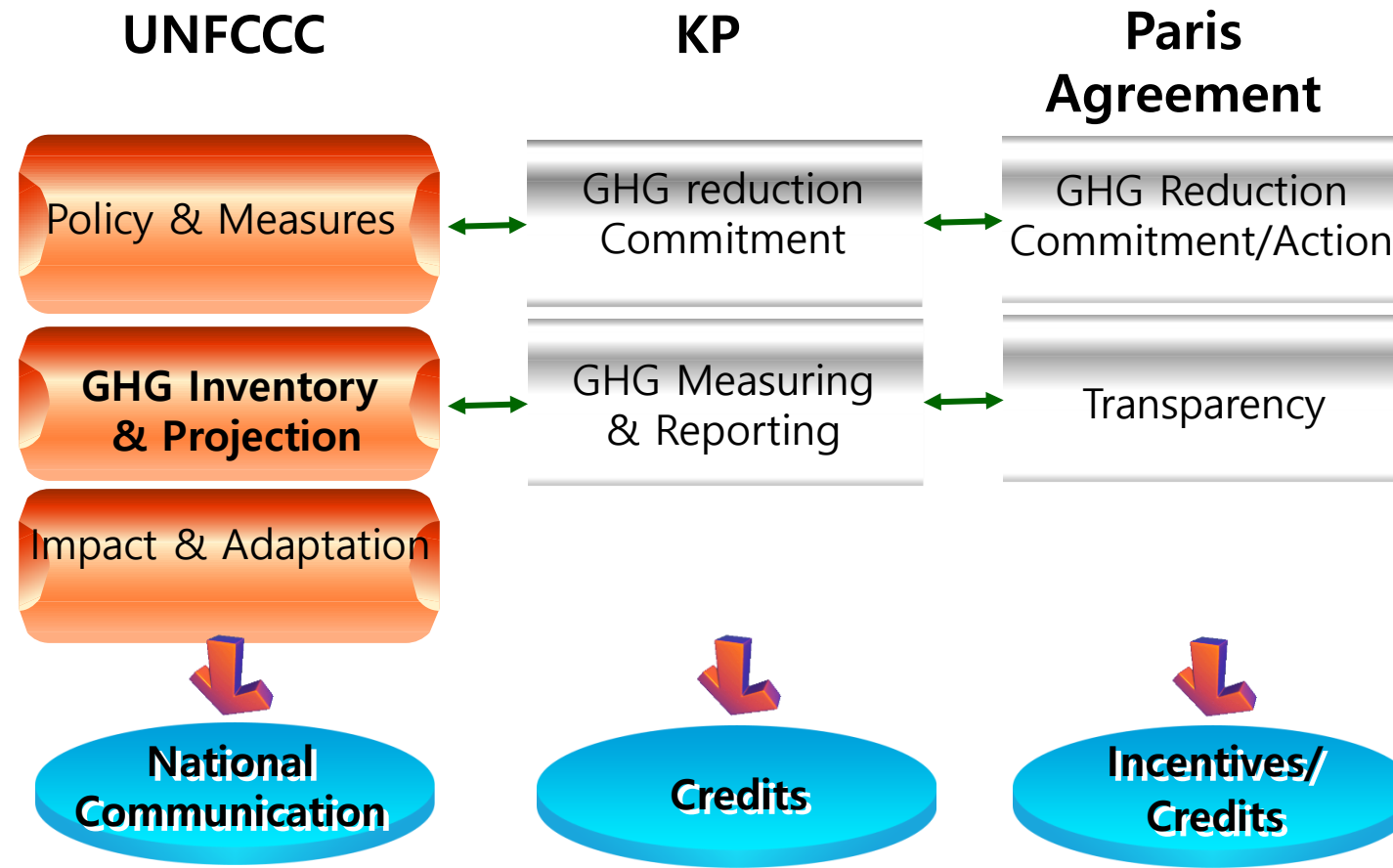
- **National GHG Inventory in Forest Land Sector under UNFCCC**
- **Country-Specific Emission Factors for Major Tree Species**



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

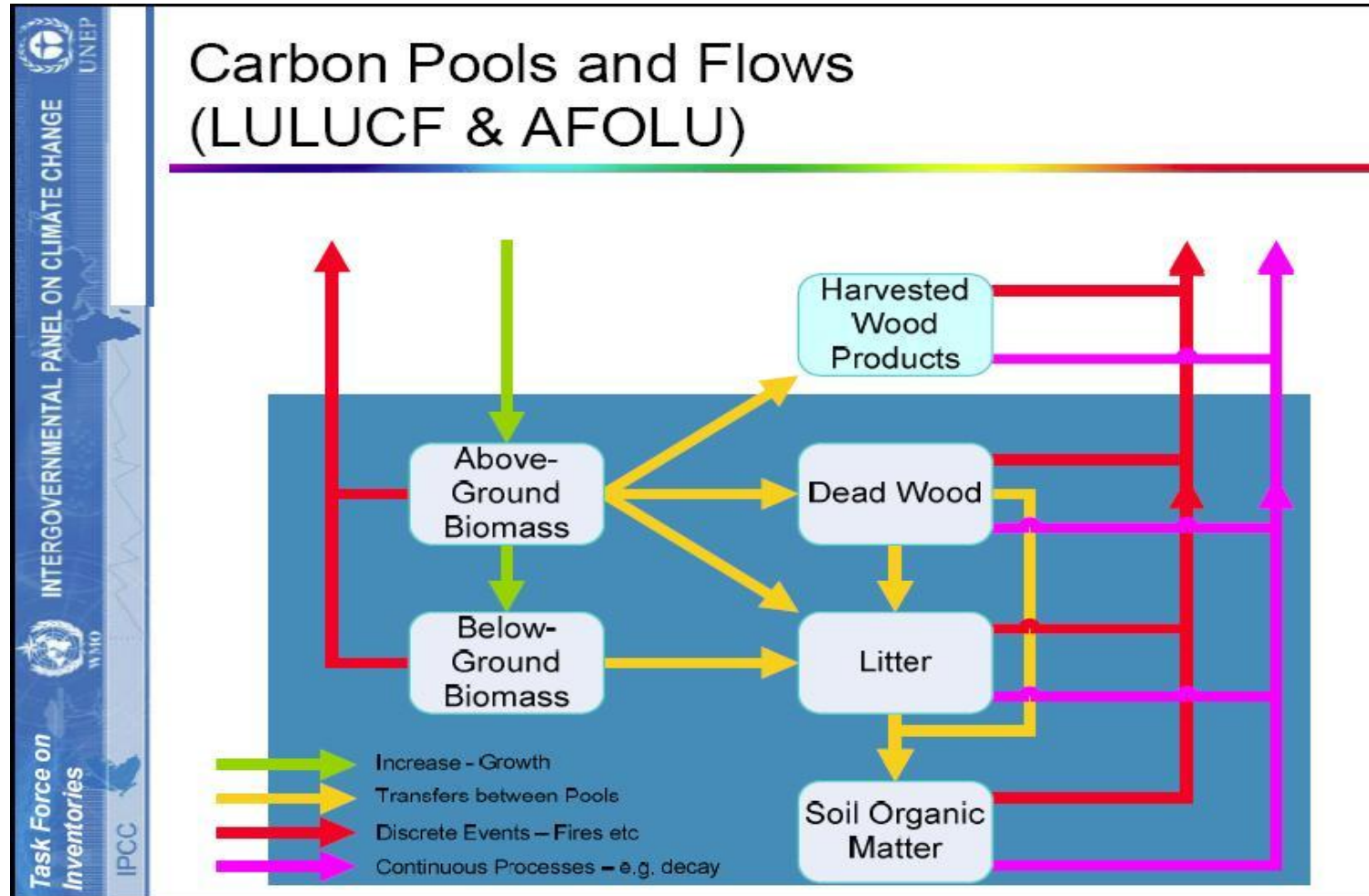


Article 13 (Transparency)

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)

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

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)

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

and

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

ΔC_{FFLB} : annual change in carbon stocks in living biomass (above-, below-)

C_{t_2} : total carbon in biomass calculated at time t_2

C_{t_1} : 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**

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

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

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

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

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

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

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

$L_{\text{other losses}}$: annual other losses of carbon



Equation 3.2.7

Annual carbon loss due to commercial fellings

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

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

$$L_{\text{fuelwood}} = \text{FG} \cdot \text{D} \cdot \text{BEF}_2 \cdot \text{CF}$$

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

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

$L_{\text{other losses}}$: annual other losses of carbon

$A_{\text{disturbance}}$: 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

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

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

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

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

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

where

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

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'

$L_{\text{ref}(i)}$: the reference stock of litter under native, unmanaged forest corresponding to state 'i'



Equation 3.2.16

Soil organic carbon content

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

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

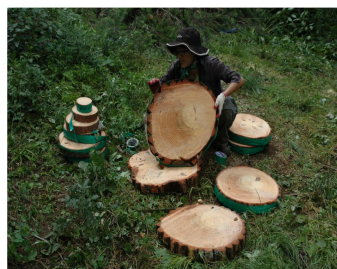
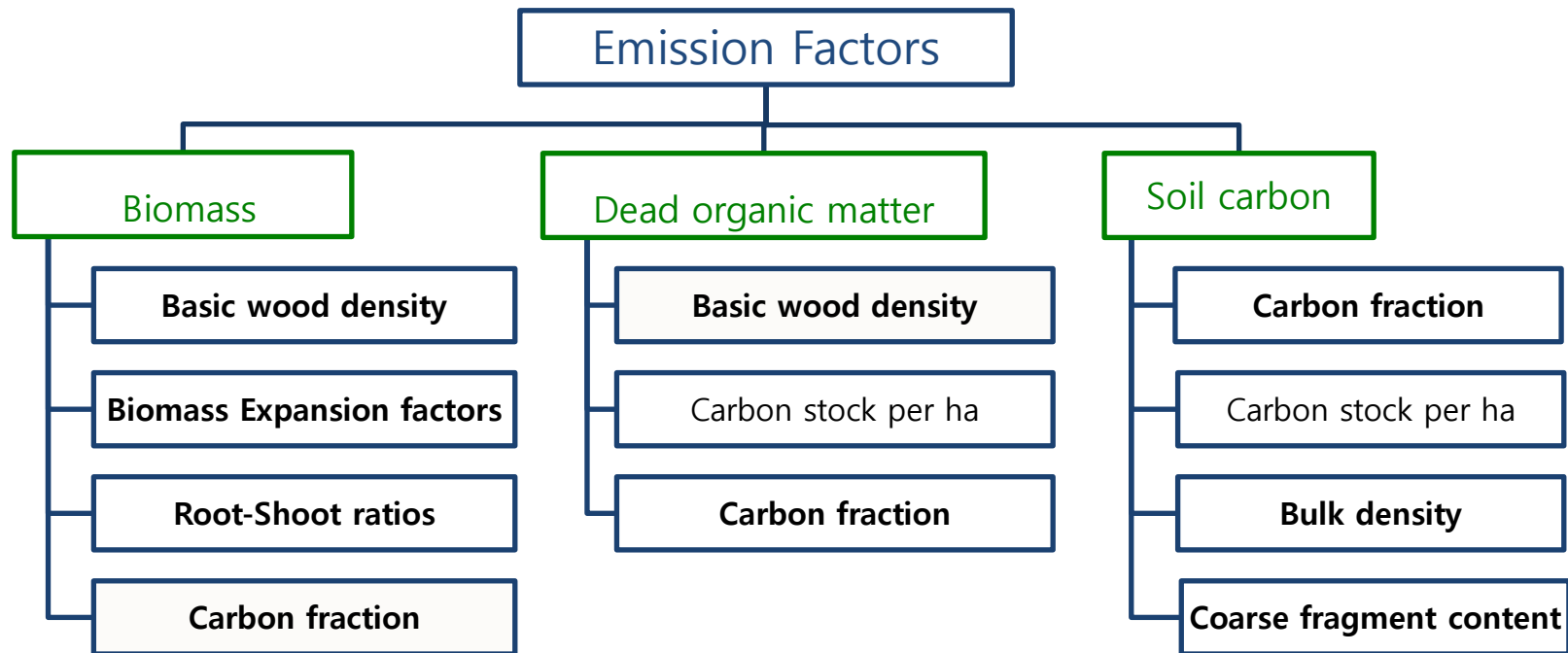
D : Basic wood density

BEF : Biomass expansion factor

R : Root-shoot ratio

CF : carbon fraction(each parts)

bulk density, coarse fragment content





Critical activity data

V : Merchantable volume

* **National Forest Inventory**

A : Area of forest land

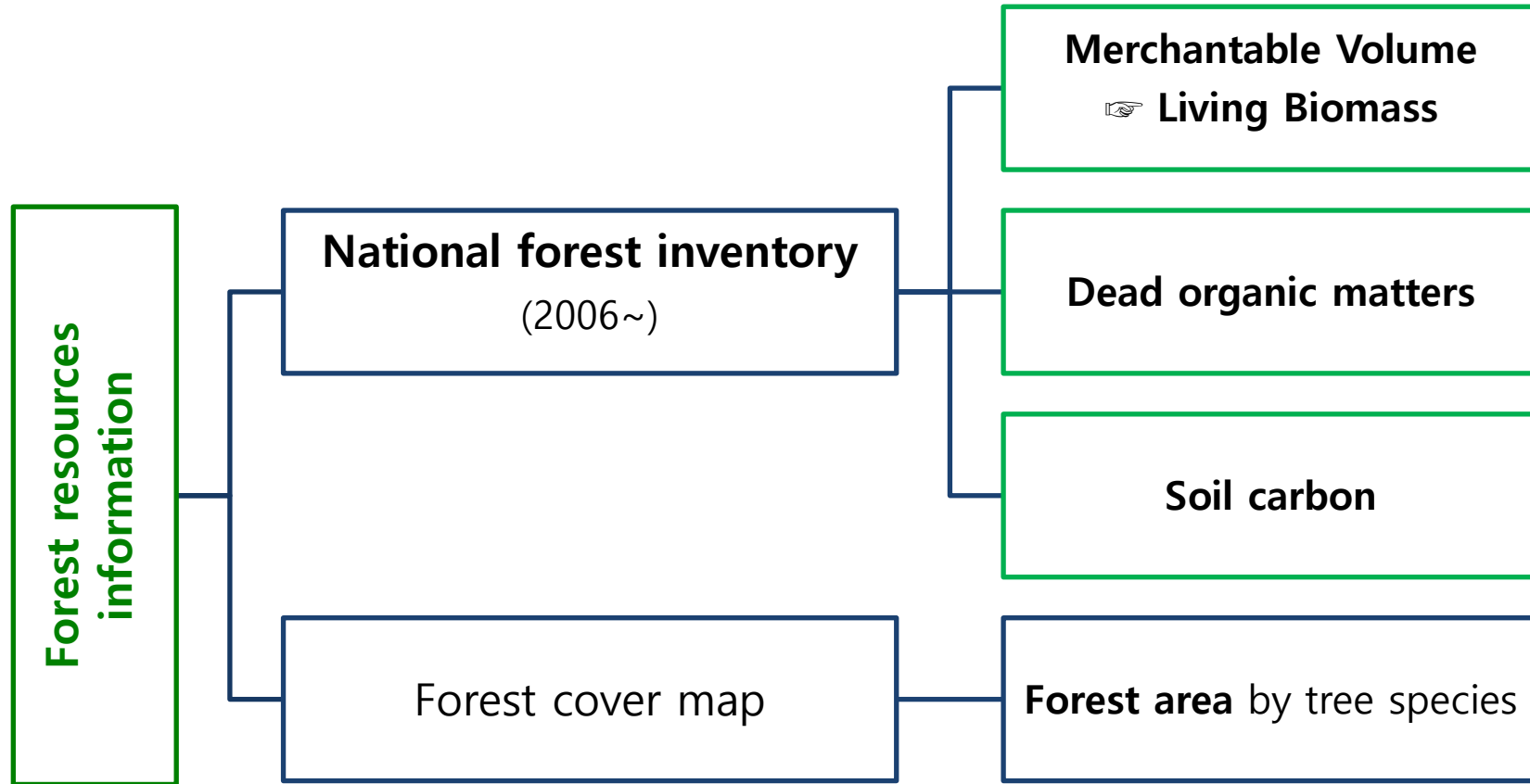
H : annually extracted volume

FG : annual volume of fuelwood gathering

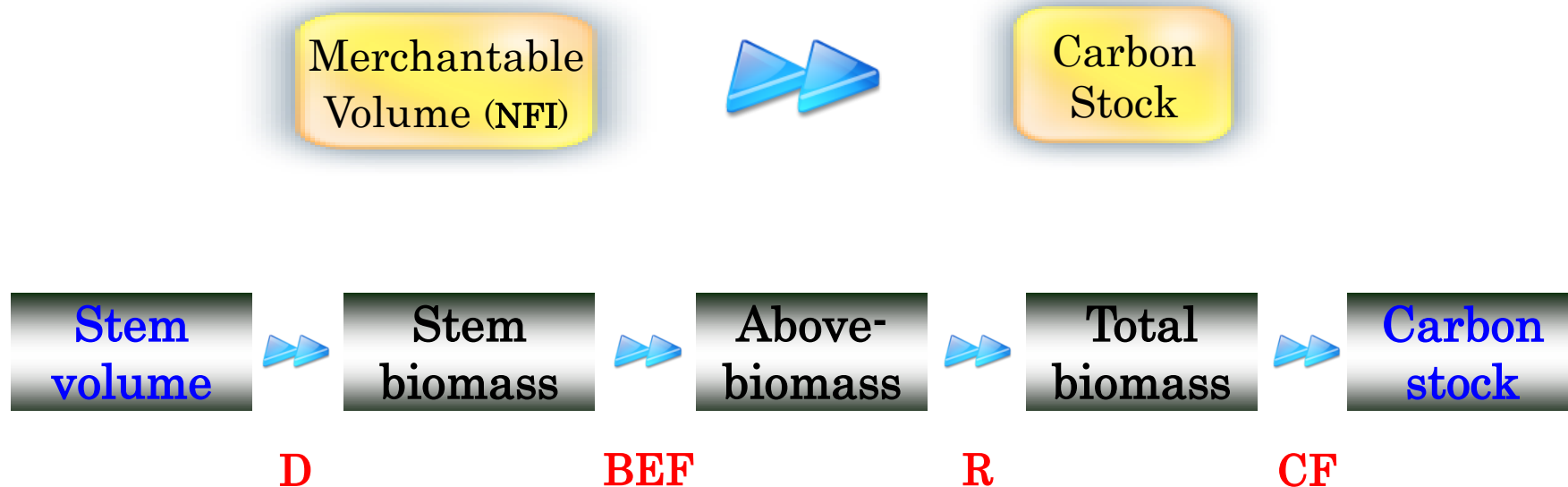
$A_{\text{disturbance}}$: forest areas affected by disturbances

B_w : average biomass stock of forest areas

Activity Data (National Forest Inventory)



Summary of Carbon Stock Calculation in Living Biomass





Country-Specific Emission Factors for Major Tree Species

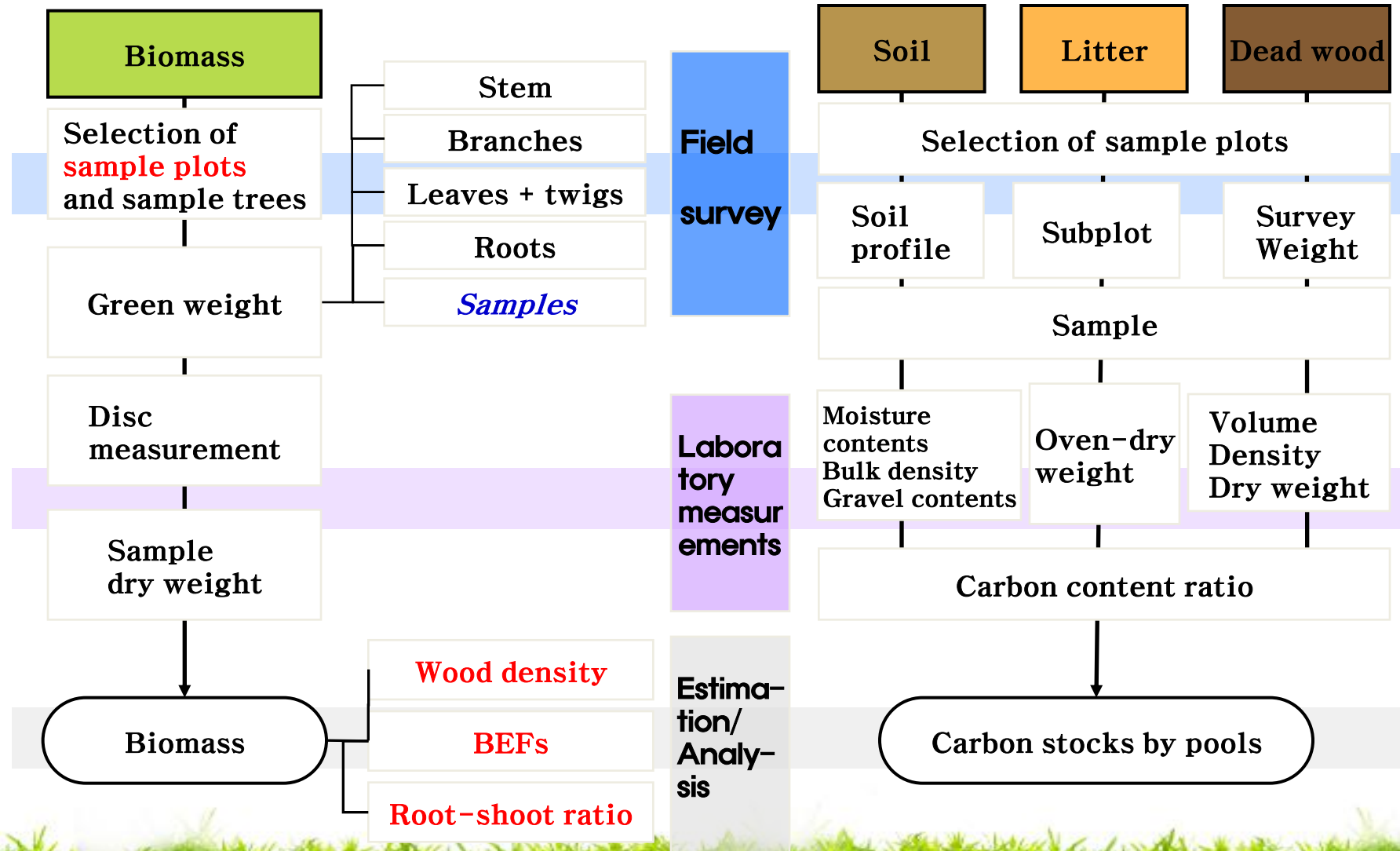


Research Project



- 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



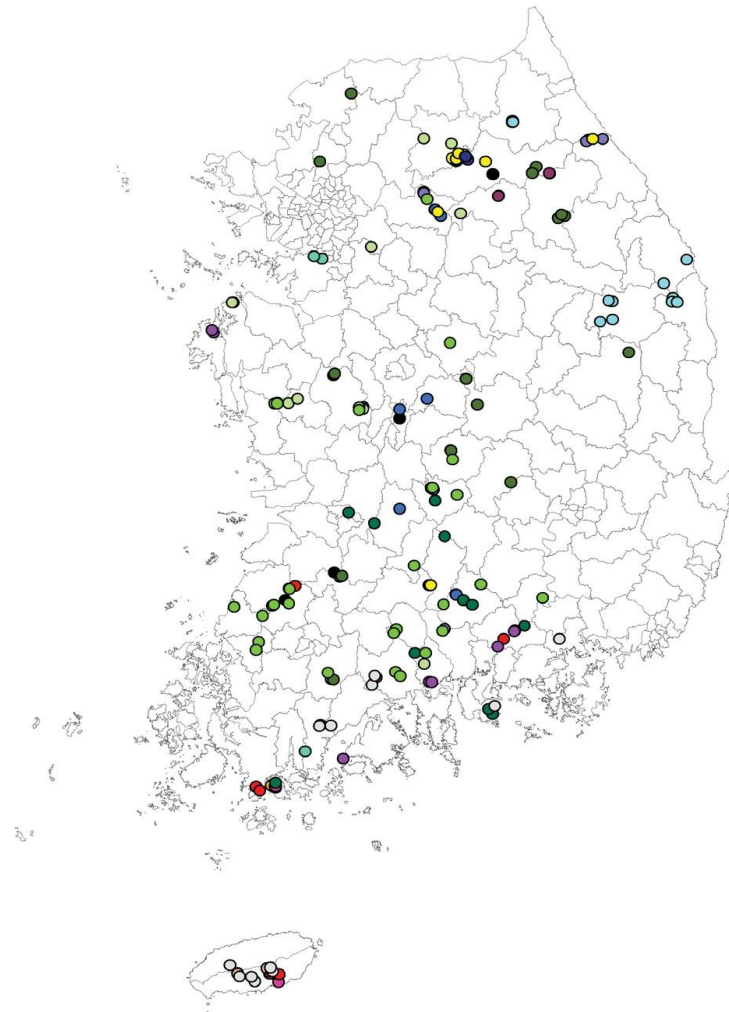
- The formula for determining the number of sample plots

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

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



- | | |
|---------|---------|
| 강원지방소나무 | 서어나무 |
| 구실잣밤나무 | 신갈나무 |
| 굴참나무 | 자작나무 |
| 낙엽송 | 잣나무 |
| 리기다소나무 | 줄참나무 |
| 백합나무 | 중부지방소나무 |
| 북가시나무 | 편백 |
| 삼나무 | 해송 |
| 상수리나무 | 현사시나무 |



Field survey at sample plot



Above-ground Biomass

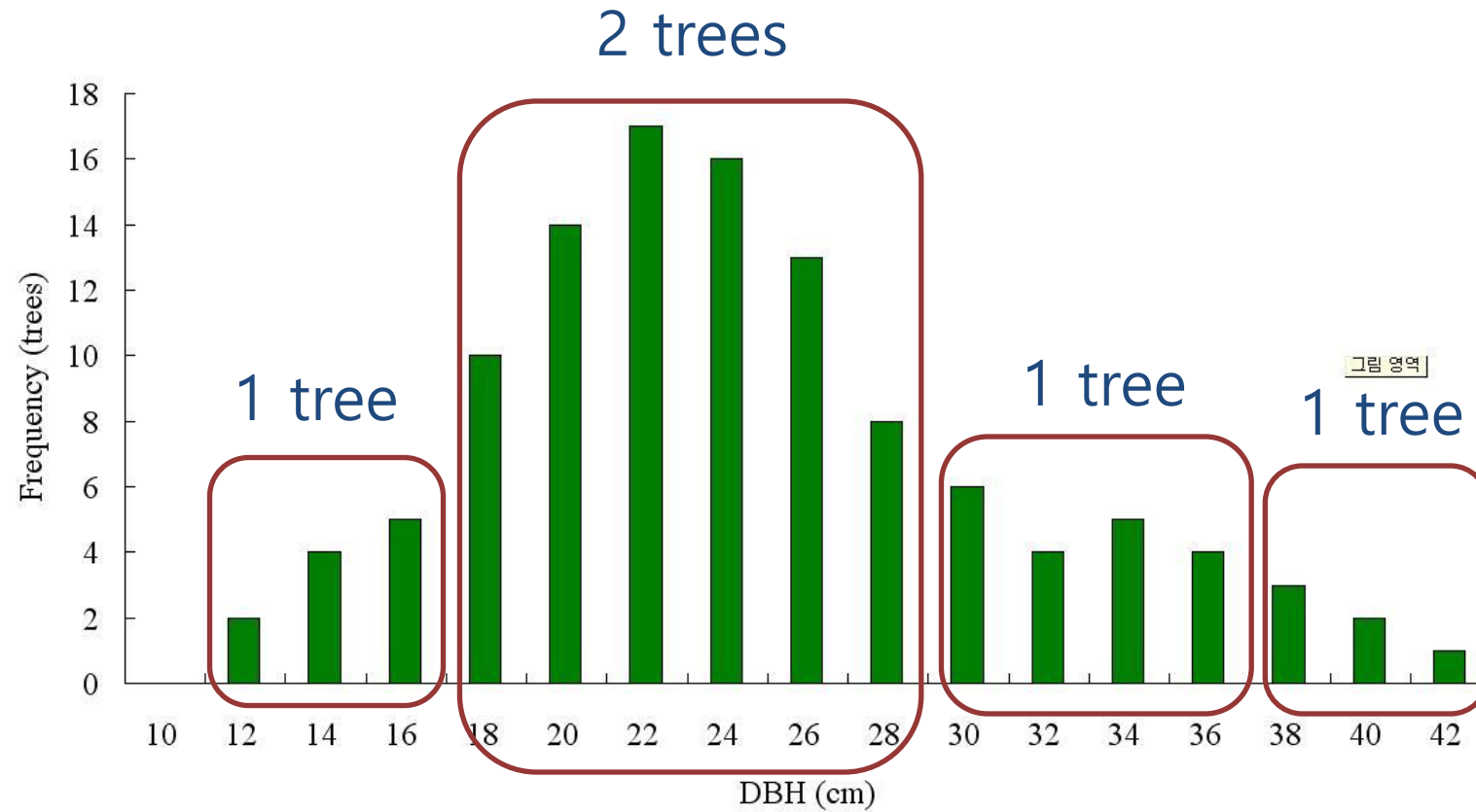
Field work



- 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



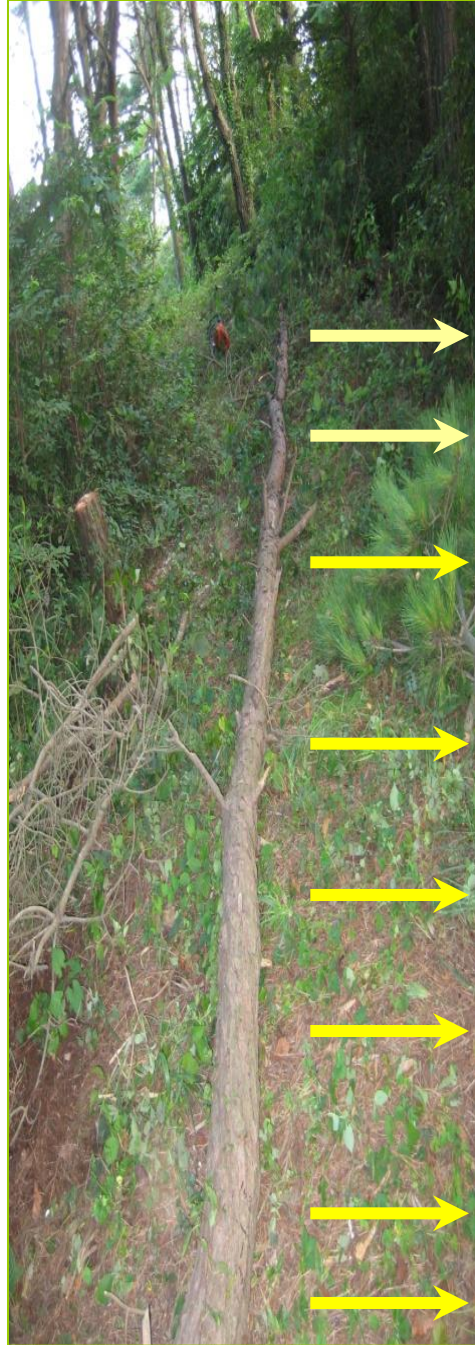
Sample tree selection



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





11.8m

10.2m

9.2m

7.2m

5.2m

3.2m

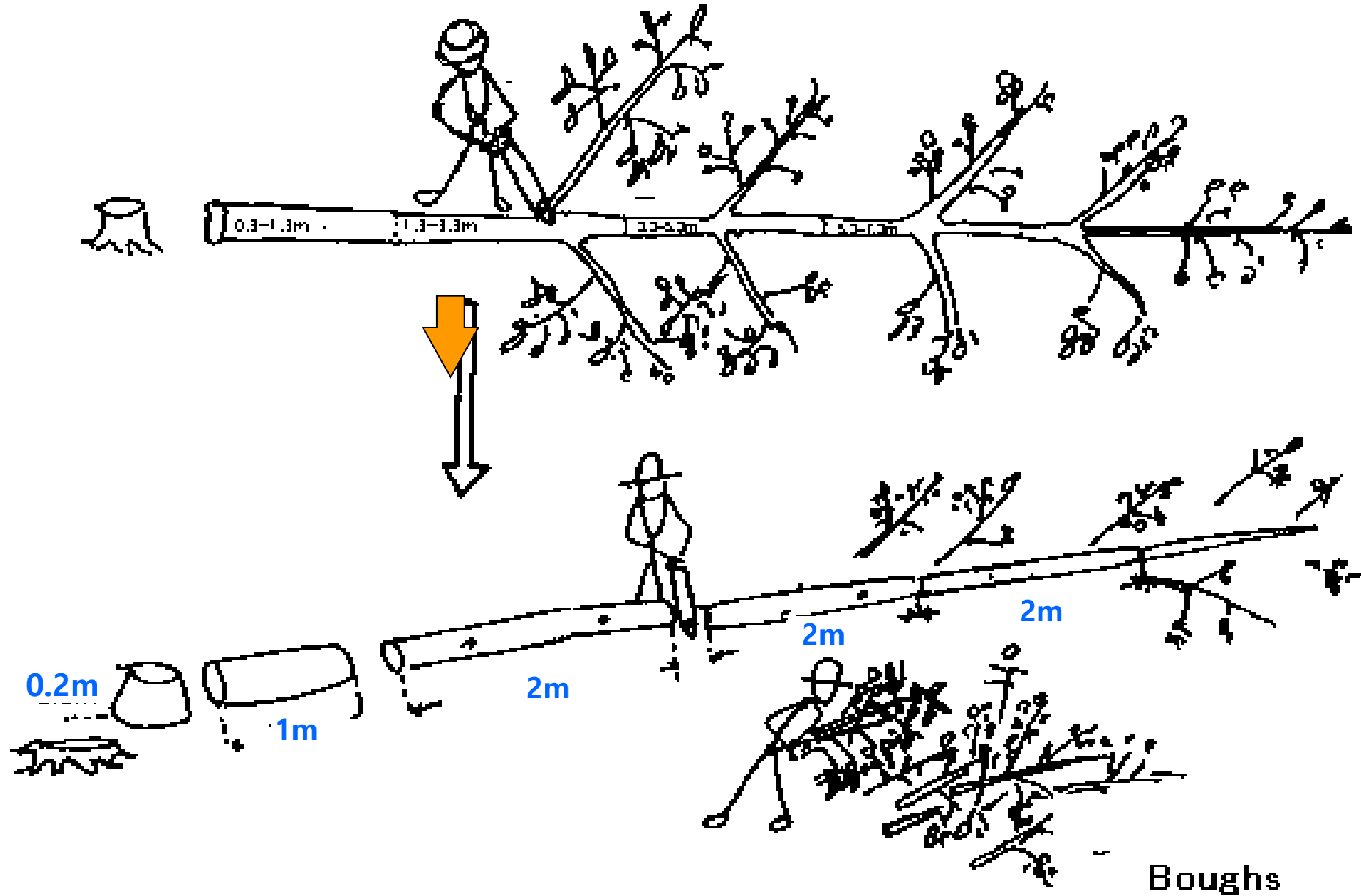
1.2m

0.2m









Felling a sample tree and cutting into logs. Boughs must be separated
(<http://www.jopp.or.jp/english/jigyo/biomassmanual/manual1.html>)

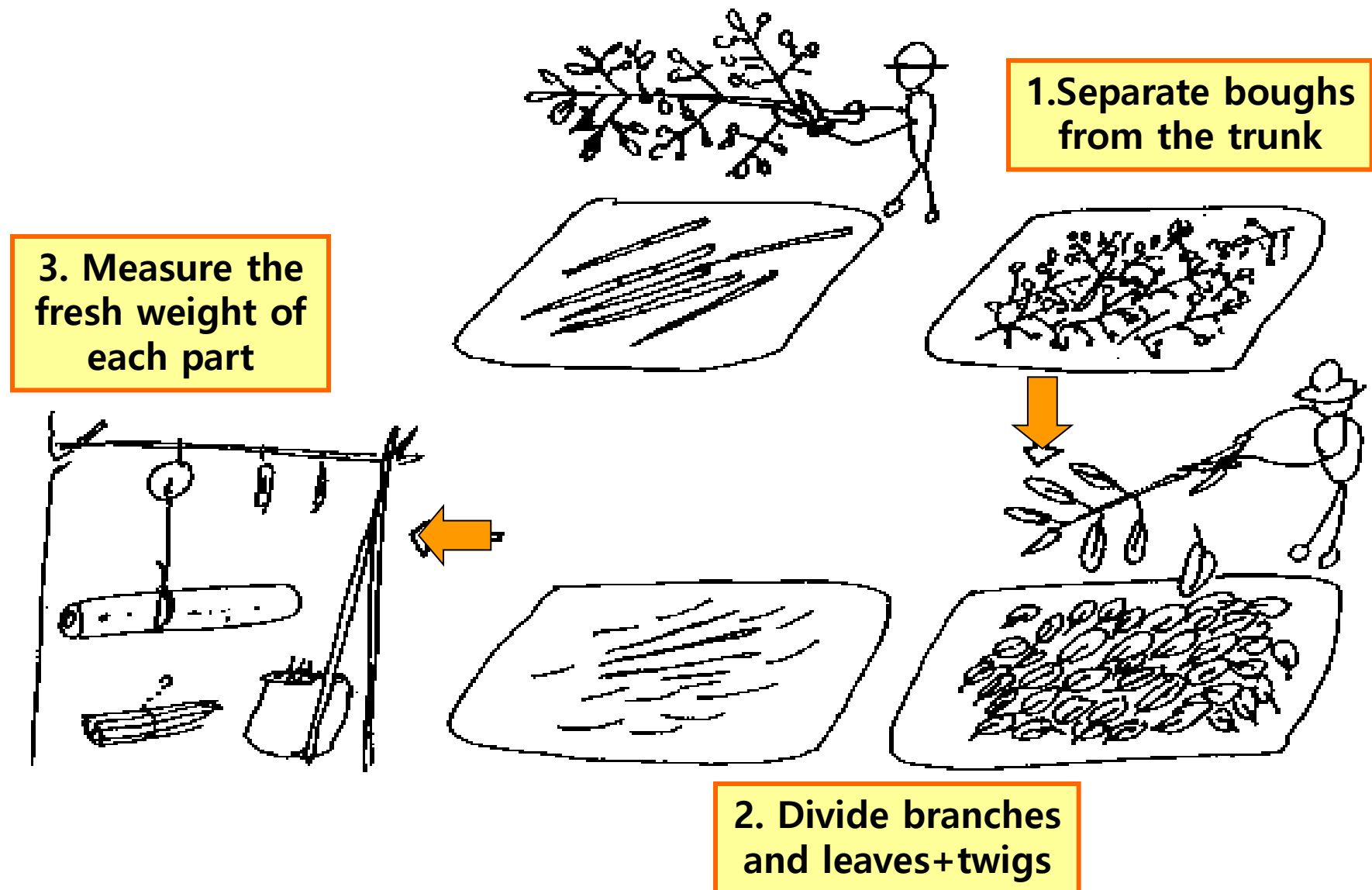


Fig 2 Clearing small branches from boughs and separating them in to twigs and leaves, then weighing them by various spring scales

(<http://www.jopp.or.jp/english/jigyo/biomassmanual/manual2.html>)



Below-ground Biomass

Excavation roots

- Collect roots for belowground biomass by
 - Winch
 - Excavator







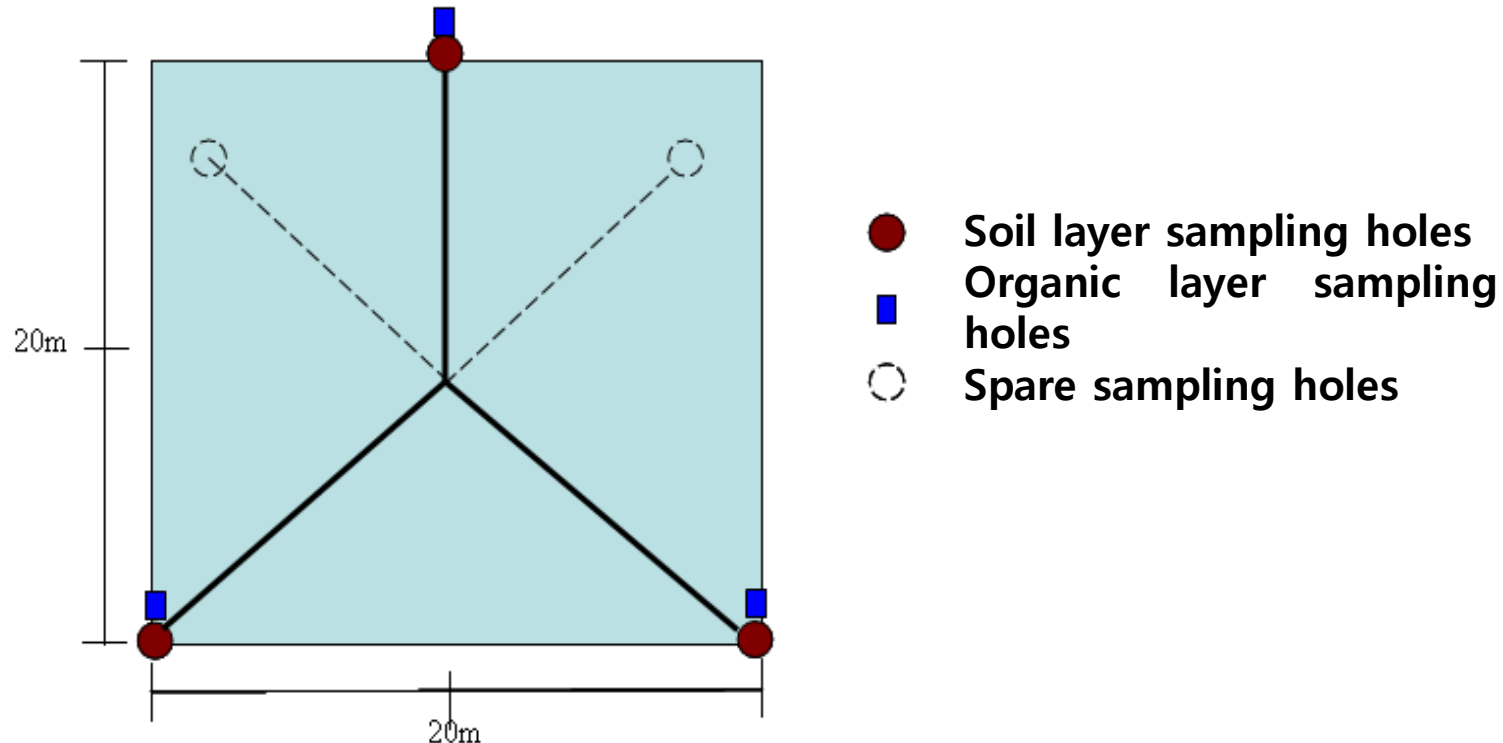


Litter & soil

Survey points

Site selection

- Select survey area and sample point



Litter

Collecting samples from organic layers

- 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





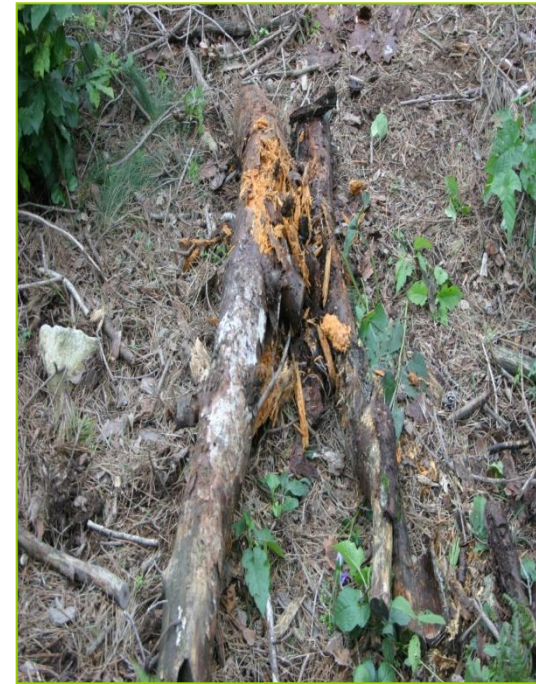
Decay class



sound

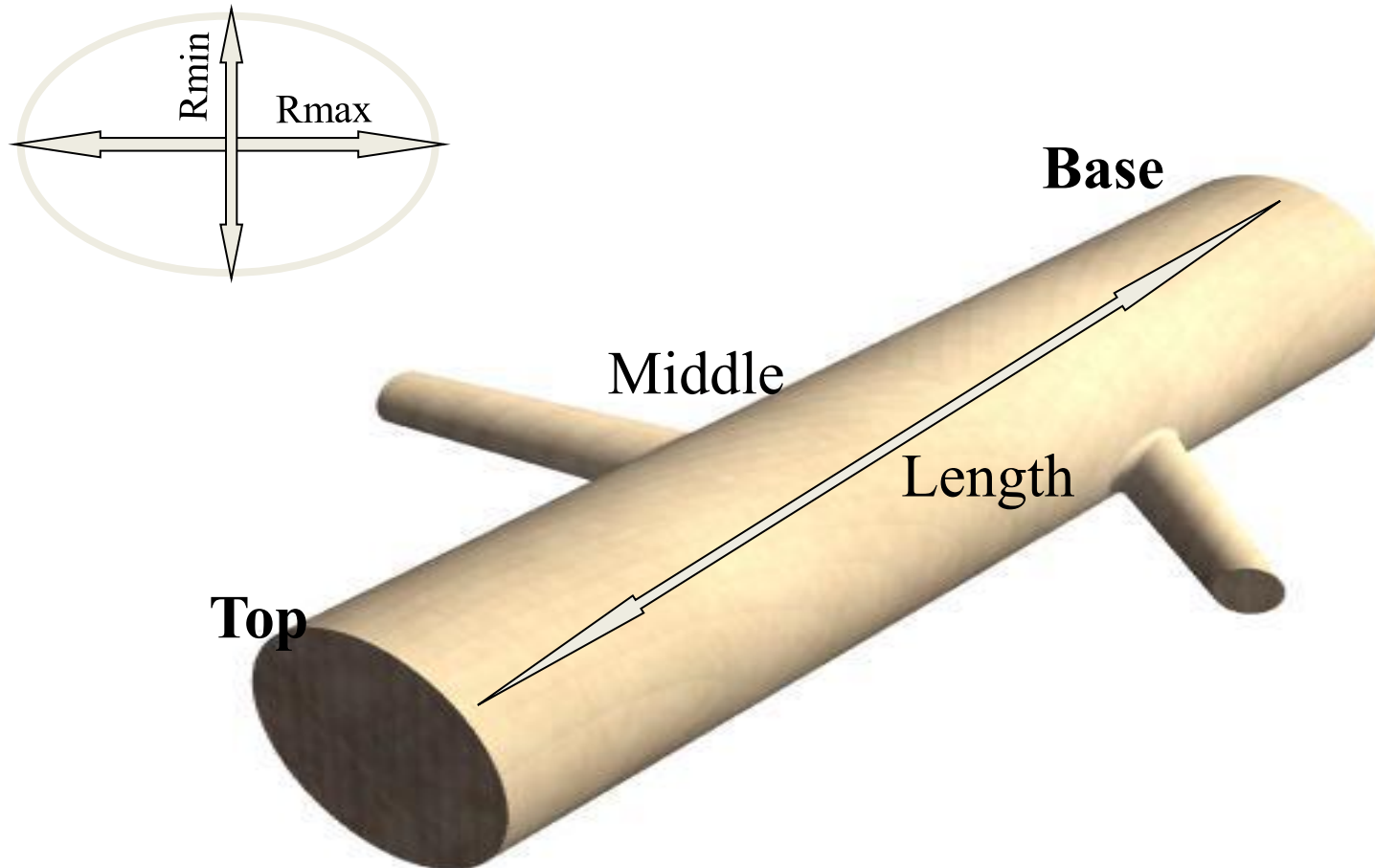


intermediate



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,

Am: Cross sectional area of middle

Ab: Cross sectional area of bottom end

At: Cross sectional area of top end

$$(A = 3.1416 \times R_{\min} \times R_{\max})$$



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°C 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



•Compute the tree biomass (dry weight)

- Stem (Wood + bark)
- Wood of stem
- Bark of stem
- Branches
- Leaves + twigs
- Roots

Volume of stem



•Volume of stem

•Volume of the felled stem (cm³)

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

- 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) (cm³)

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

- 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

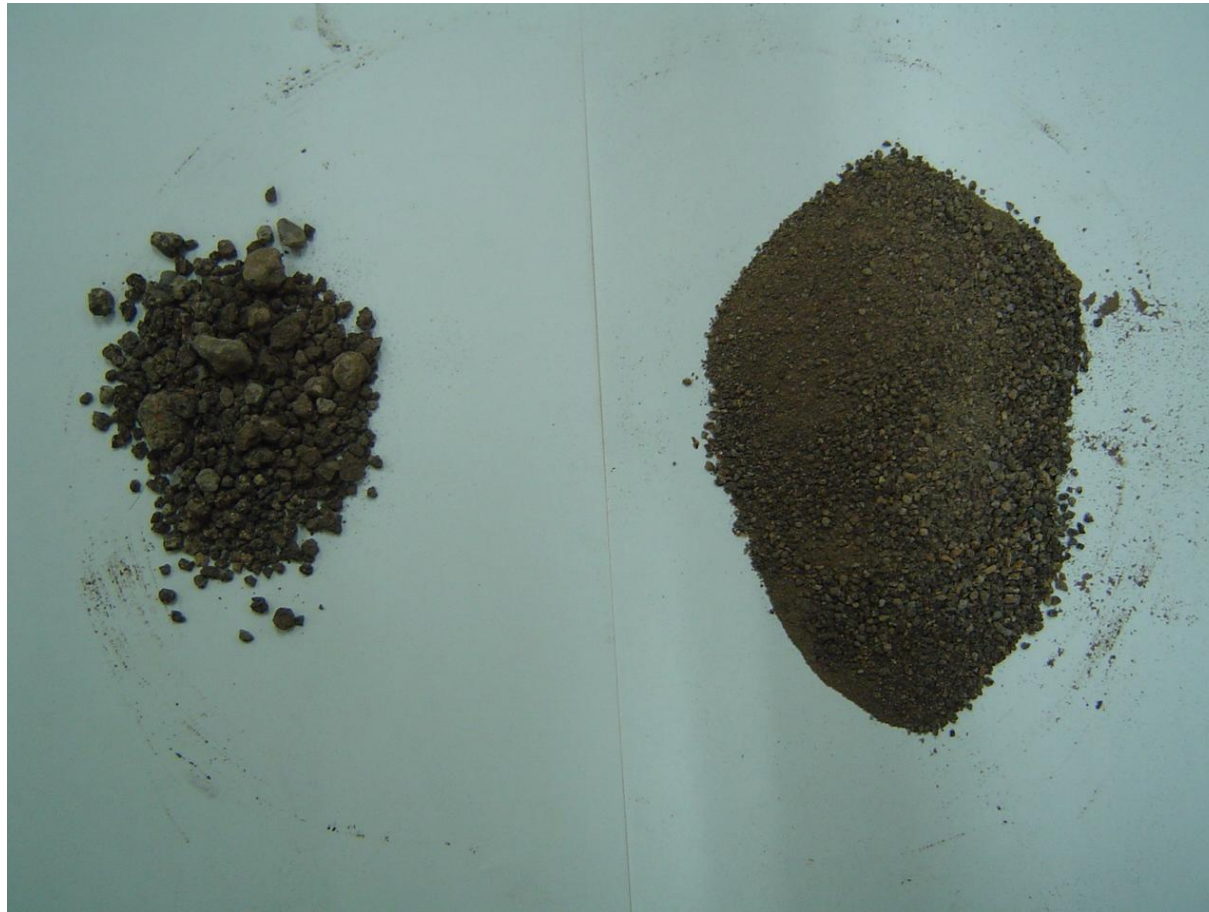


Soil drying

- Oven-drying soil samples at 105°C until reaching constant weight
- Measuring the weights of the total dried soils (W_T , g)
- Separating fine earth fragments (<2 mm) and rock fragments (>2 mm) by sieving
- Measuring the weights of rock fragments (W_F , g).
- Calculating the weight of dried soils (fine earth fragments <2 mm: W_S , 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 (cm³)

Analysis of rock fragment content

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



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/cm^3)

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;

$$\text{dry weight of organic layers (g/m}^2\text{)} \times \text{carbon content (C, \%)/100}$$

Dead tree

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

$$\text{dry weight of dead trees (g/m}^2\text{)} \times \text{carbon content (C, \%)/100}$$

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

발 간 등 록 번 호
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Survey Manual for Biomass and Soil Carbon



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

Species	n	Mean	Maximum	Minimum	Uncertainty(%)
<i>Pinus densiflora</i> Siebold & Zucc. (Gangwon)	5	0.40	0.47	0.36	12.99
<i>Pinus densiflora</i> Siebold & Zucc. (Central)	28	0.47	0.59	0.39	3.80
<i>Pinus rigida</i> Mill.	10	0.51	0.57	0.47	4.38
<i>Pinus koraiensis</i> Siebold & Zucc.	9	0.41	0.50	0.36	8.20
<i>Pinus thunbergii</i> Parl.	8	0.48	0.53	0.43	5.73
<i>Chamaecyparis obtuse</i> (Thunb. ex L.f.) D.Don	6	0.42	0.44	0.41	3.34
<i>Larix kaempferi</i> (Lamb.) Carrière	15	0.45	0.53	0.37	6.34
<i>Cryptomeria japonica</i> (Siebold & Zucc.) Endl.	11	0.35	0.38	0.32	3.50
<i>Quercus variabilis</i> Blume	15	0.72	0.76	0.70	1.66
<i>Quercus acutissima</i> Carruth.	10	0.70	0.73	0.65	2.59
<i>Quercus mongolica</i> Fisch. ex Ledeb.	17	0.66	0.75	0.60	3.33
<i>Populus alba</i> × <i>Populus glandulosa</i> 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(%)
<i>Pinus densiflora</i> Siebold & Zucc. (Gangwon)	15	1.47	1.96	1.25	7.89
<i>Pinus densiflora</i> Siebold & Zucc. (Central)	33	1.40	2.41	1.12	5.89
<i>Pinus rigida</i> Mill.	21	1.39	2.05	1.13	6.86
<i>Pinus koraiensis</i> Siebold & Zucc.	21	1.85	2.71	1.33	10.99
<i>Pinus thunbergii</i> Parl.	11	1.43	1.99	1.10	12.09
<i>Chamaecyparis obtuse</i> (Thunb. ex L.f.) D.Don	9	1.39	1.93	1.23	11.69
<i>Larix kaempferi</i> (Lamb.) Carrière	22	1.32	2.00	1.10	6.54
<i>Cryptomeria japonica</i> (Siebold & Zucc.) Endl.	11	1.31	1.69	1.15	6.46
<i>Quercus variabilis</i> Blume	24	1.33	1.66	1.18	3.53
<i>Quercus acutissima</i> Carruth.	16	1.43	1.71	1.21	5.48
<i>Quercus mongolica</i> Fisch. ex Ledeb.	36	1.50	2.03	1.14	5.86
<i>Populus alba</i> × <i>Populus glandulosa</i> 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(%)
<i>Pinus densiflora</i> Siebold & Zucc. (Gangwon)	12	0.26	0.52	0.11	18.39
<i>Pinus densiflora</i> Siebold & Zucc. (Central)	30	0.25	0.54	0.11	8.69
<i>Pinus rigida</i> Mill.	11	0.43	0.99	0.21	38.36
<i>Pinus koraiensis</i> Siebold & Zucc.	10	0.26	0.41	0.18	19.48
<i>Pinus thunbergii</i> Parl.	8	0.31	0.51	0.24	23.83
<i>Chamaecyparis obtuse</i> (Thunb. ex L.f.) D.Don	12	0.21	0.47	0.06	38.93
<i>Larix kaempferi</i> (Lamb.) Carrière	15	0.28	0.48	0.15	18.26
<i>Cryptomeria japonica</i> (Siebold & Zucc.) Endl.	11	0.25	0.32	0.19	13.50
<i>Quercus variabilis</i> Blume	15	0.34	0.47	0.19	11.42
<i>Quercus acutissima</i> Carruth.	10	0.33	0.76	0.13	39.78
<i>Quercus mongolica</i> Fisch. ex Ledeb.	17	0.42	1.06	0.21	22.77
<i>Populus alba</i> × <i>Populus glandulosa</i> 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 (%)
<i>Pinus densiflora</i> Siebold & Zucc. (Gangwon)	15	50.4
<i>Pinus densiflora</i> Siebold & Zucc. (Central)	33	50.7
<i>Pinus rigida</i> Mill.	21	50.6
<i>Pinus koraiensis</i> Siebold & Zucc.	21	50.1
<i>Pinus thunbergii</i> Parl.	11	49.3
<i>Chamaecyparis obtuse</i> (Thunb. ex L.f.) D.Don	9	49.7
<i>Larix kaempferi</i> (Lamb.) Carrière	22	50.1
<i>Cryptomeria japonica</i> (Siebold & Zucc.) Endl.	13	50.9
<i>Quercus variabilis</i> Blume	24	49.0
<i>Quercus acutissima</i> Carruth.	16	48.0
<i>Quercus mongolica</i> Fisch. ex Ledeb.	36	48.8
<i>Populus alba</i> × <i>Populus glandulosa</i> Uyeki.	5	47.2



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

Species	n	Carbon fraction (%)
<i>Pinus densiflora</i> Siebold & Zucc. (Gangwon)	12	47.18 (1.08)
<i>Pinus densiflora</i> Siebold & Zucc. (Central)	35	48.06 (0.79)
<i>Pinus rigida</i> Mill.	15	43.38 (1.01)
<i>Pinus koraiensis</i> Siebold & Zucc.	15	37.43 (1.34)
<i>Pinus thunbergii</i> Parl.	17	38.16 (2.21)
<i>Chamaecyparis obtuse</i> (Thunb. ex L.f.) D.Don	10	44.99 (0.84)
<i>Larix kaempferi</i> (Lamb.) Carrière	11	45.90 (0.61)
<i>Cryptomeria japonica</i> (Siebold & Zucc.) Endl.	6	44.32 (1.07)
<i>Quercus variabilis</i> Blume	10	34.58 (1.81)
<i>Quercus acutissima</i> Carruth.	6	32.03 (1.44)
<i>Quercus mongolica</i> Fisch. ex Ledeb.	8	46.10 (0.85)
<i>Populus alba</i> × <i>Populus glandulosa</i> 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	
<i>Pinus densiflora</i> Siebold & Zucc. (Gangwon)	50.0 (0.00*)	(n=2)	50.0 (0.00)	(n=4)	50.0 (0.00)	(n=2)
<i>Pinus densiflora</i> Siebold & Zucc. (Central)	51.3 (0.00)	(n=13)	51.2 (0.00)	(n=14)	50.8 (0.00)	(n=10)
<i>Pinus rigida</i> Mill.	48.2 (1.10)	(n=5)	54.4 (0.44)	(n=5)	51.1 (1.07)	(n=6)
<i>Pinus koraiensis</i> Siebold & Zucc.	51.1 (-)	(n=1)	51.1 (0.04)	(n=2)	50.6 (0.46)	(n=2)
<i>Pinus thunbergii</i> Parl.	53.4 (-)	(n=1)	49.8 (0.41)	(n=2)	54.5 (-)	(n=1)
<i>Chamaecyparis obtuse</i> (Thunb. ex L.f.) D.Don	51.1 (0.16)	(n=3)	49.1 (0.11)	(n=3)	49.6 (-)	(n=1)
<i>Larix kaempferi</i> (Lamb.) Carrière	49.6 (0.22)	(n=5)	49.8 (0.20)	(n=5)	55.0 (2.09)	(n=6)
<i>Cryptomeria japonica</i> (Siebold & Zucc.) Endl.	50.2 (0.42)	(n=5)	51.8 (0.51)	(n=3)	52.8 (0.98)	(n=3)
<i>Quercus variabilis</i> Blume	49.1 (0.13)	(n=4)	49.3 (0.28)	(n=5)	49.1 (0.26)	(n=4)
<i>Quercus acutissima</i> Carruth.	51.2 (0.39)	(n=3)	51.3 (-)	(n=1)	-	
<i>Quercus mongolica</i> Fisch. ex Ledeb.	51.0 (0.17)	(n=5)	52.3 (1.14)	(n=5)	51.7 (0.81)	(n=4)
<i>Populus alba</i> × <i>Populus glandulosa</i> 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			
	0~10cm	10~20cm	20~30cm	30~50cm
<i>Pinus densiflora</i> Siebold & Zucc. (Gangwon)	0.0286	0.0188	0.0124	0.0081
<i>Pinus densiflora</i> Siebold & Zucc. (Central)	0.0302	0.0167	0.0113	0.0088
<i>Pinus rigida</i> Mill.	0.0304	0.0167	0.0110	0.0075
<i>Pinus koraiensis</i> Siebold & Zucc.	0.0322	0.0237	0.0186	0.0122
<i>Pinus thunbergii</i> Parl.	0.0381	0.0232	0.0159	0.0109
<i>Chamaecyparis obtuse</i> (Thunb. ex L.f.) D.Don	0.0158	0.0096	0.0070	0.0062
<i>Larix kaempferi</i> (Lamb.) Carrière	0.0211	0.0092	0.0049	0.0034
<i>Cryptomeria japonica</i> (Siebold & Zucc.) Endl.	0.0525	0.0303	0.0260	0.0212
<i>Quercus variabilis</i> Blume	0.0396	0.0240	0.0164	0.0143
<i>Quercus acutissima</i> Carruth.	0.0561	0.0362	0.0267	0.0182
<i>Quercus mongolica</i> Fisch. ex Ledeb.	0.0169	0.0076	0.0052	0.0026
<i>Populus alba</i> × <i>Populus glandulosa</i> 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(cm), H: height(m), R^2 : coefficient of determination

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연구보고
10-25

산림 온실가스 인벤토리를 위한 주요 수종별 탄소배출계수

손영모 · 이경학 · 김태현 · 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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Thank you!!