Session 11

How the National Forest Inventory Supports Better Forest Carbon Data

Applications of the National Forest Inventory for Enhancing Forest Carbon Data Quality

Insights from Data Gap Analysis and Improvement Plan

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WORLD BANK GROUP

AFoCO

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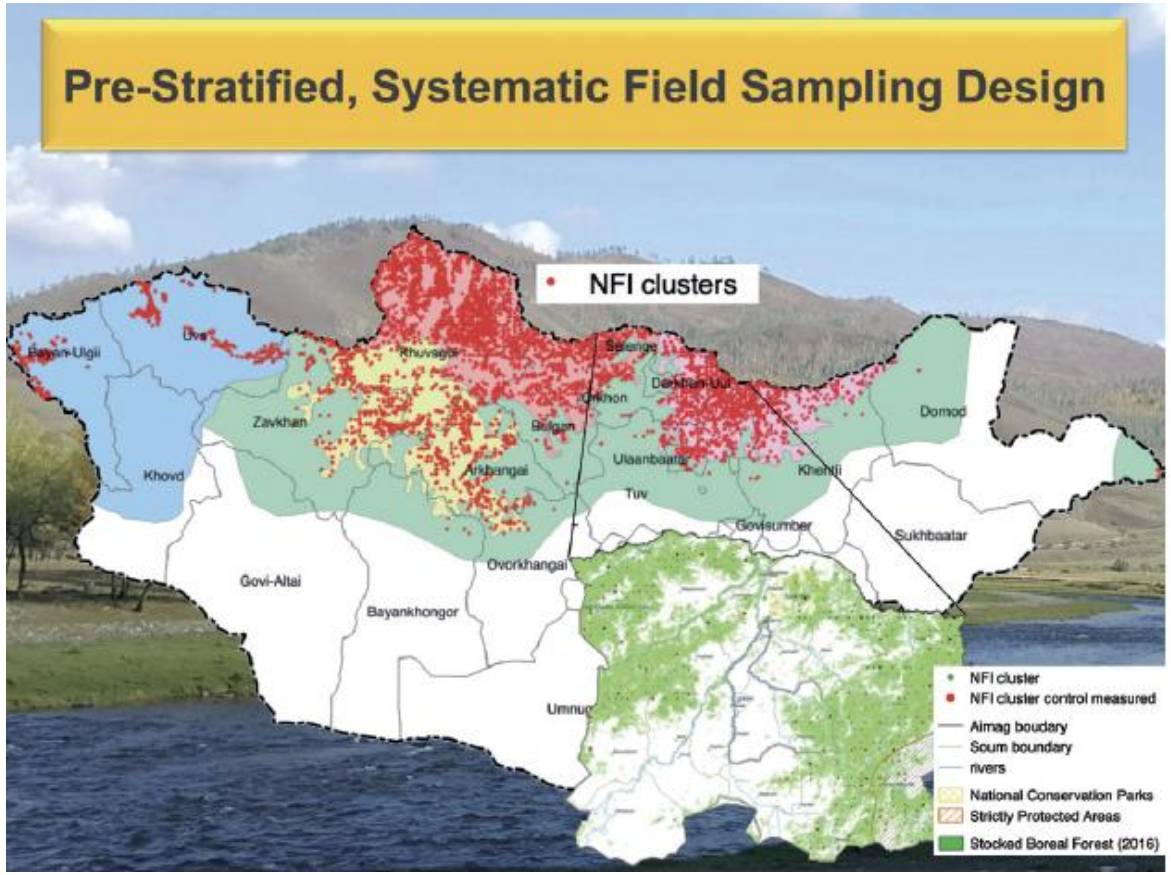
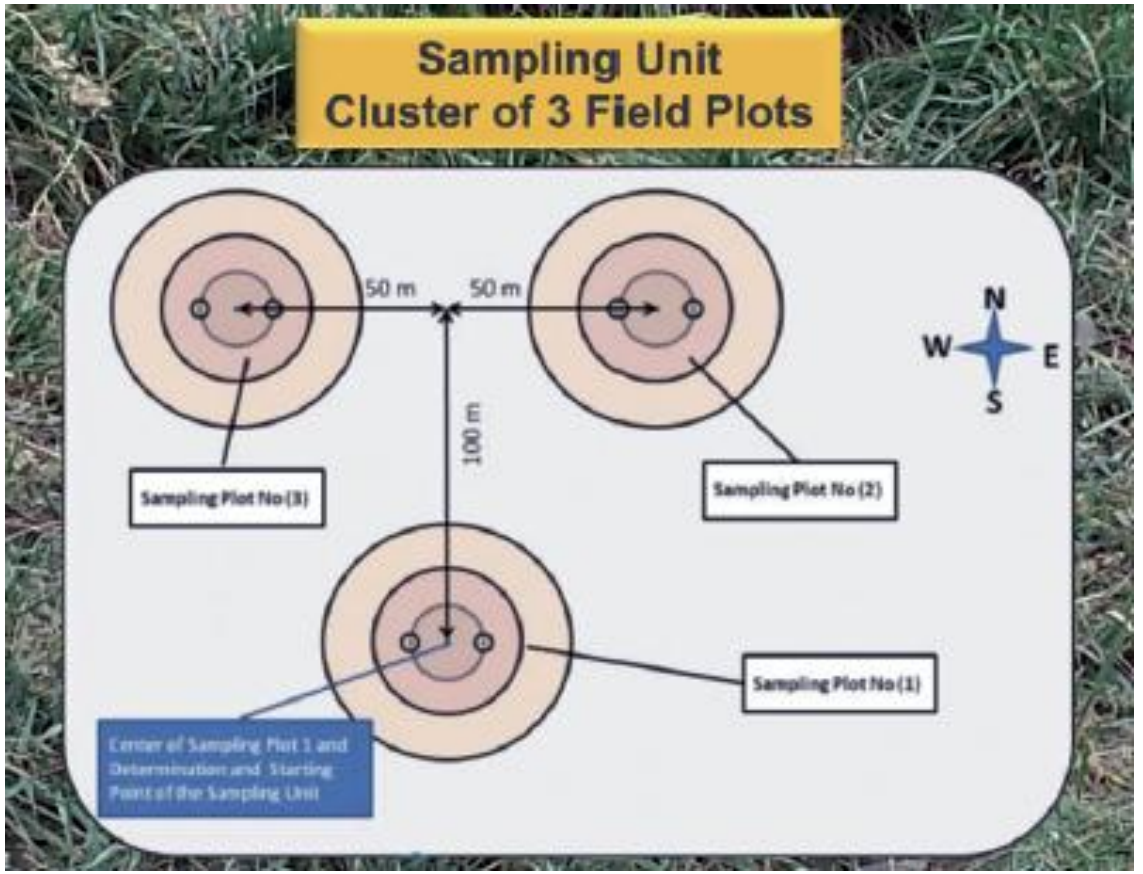
What is the current status of forest data in Mongolia and where do the key data gaps remain?

1. Biomass Estimation Practices and Data Sources in Mongolia

- *National Forest Inventory in MN*
  - *4,367 field clusters distributed across boreal forest zones using a stratified sampling design*

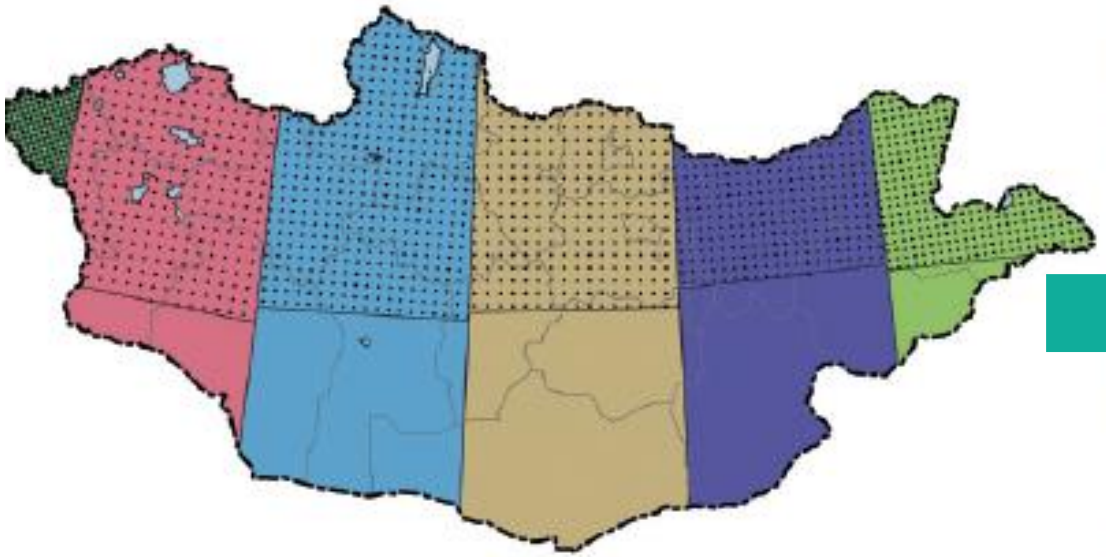




Source : Dan Altrell (2019)

1. Biomass Estimation Practices and Data Sources in Mongolia

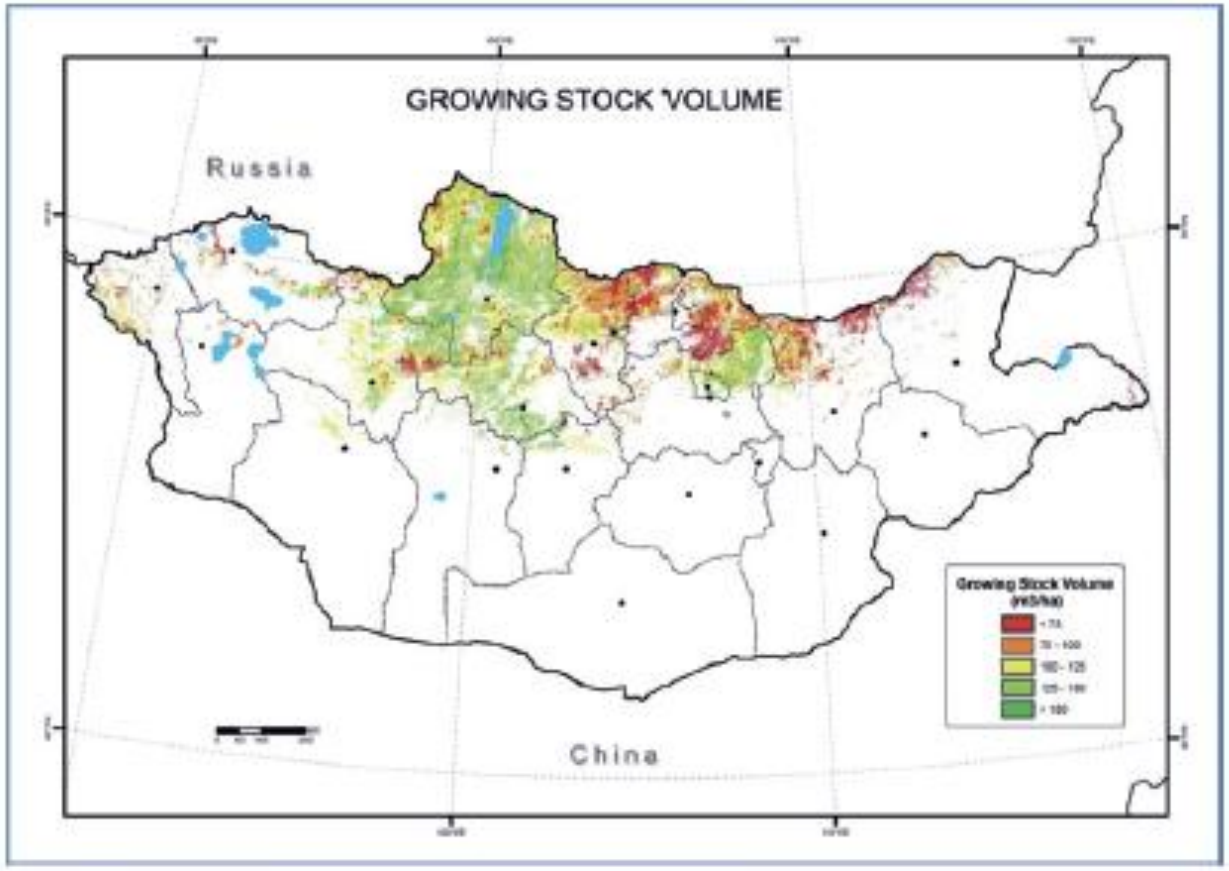
- *National Forest Inventory in MN*
  - *Over 123,000 remote sensing sample plots were interpreted to assess forest cover change across Mongolia*

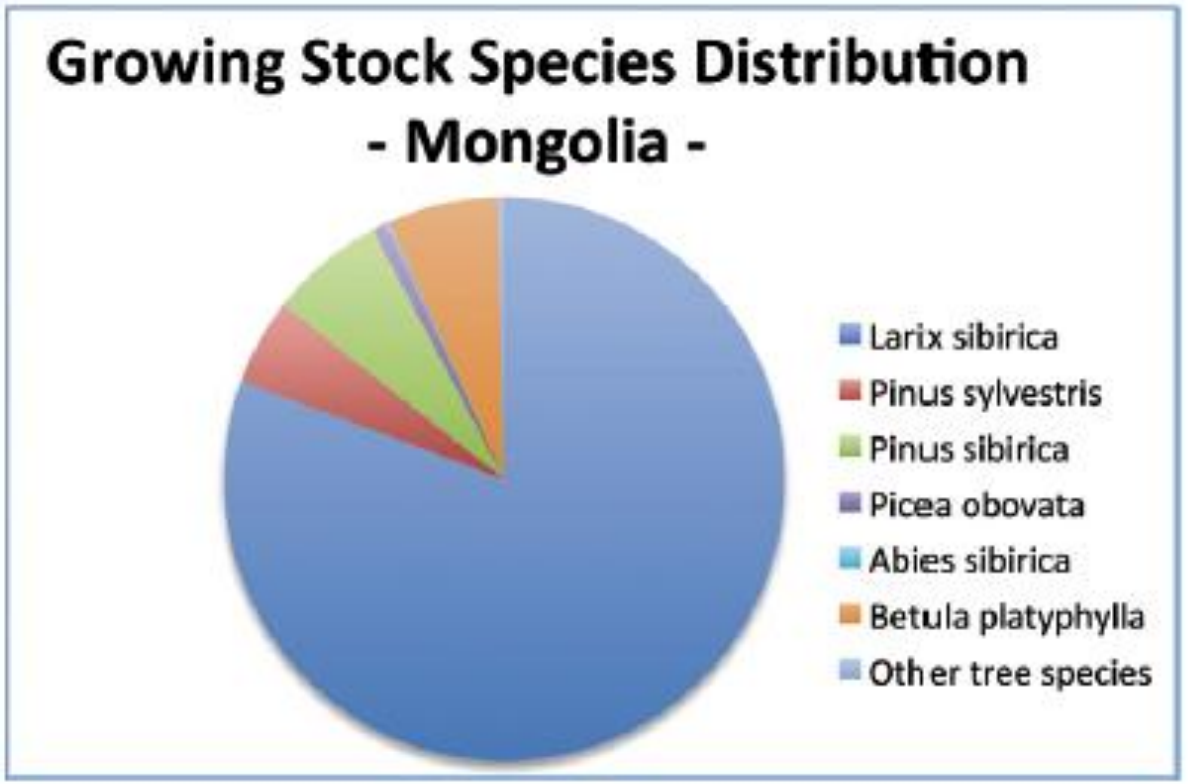


Source : Dan Altrell (2019)

1. Biomass Estimation Practices and Data Sources in Mongolia

- *The average growing stock in stocked forests was estimated at 114 m^3 per hectare in boreal forests*
- *Larix sibirica accounted for more than 80 percent of total growing stock volume, followed by Pinus sibirica, Betula platyphylla, and Pinus sylvestris*





Source : Dan Altrell (2019)

1. Biomass Estimation Practices and Data Sources in Mongolia

- *Mongolia's national inventory*

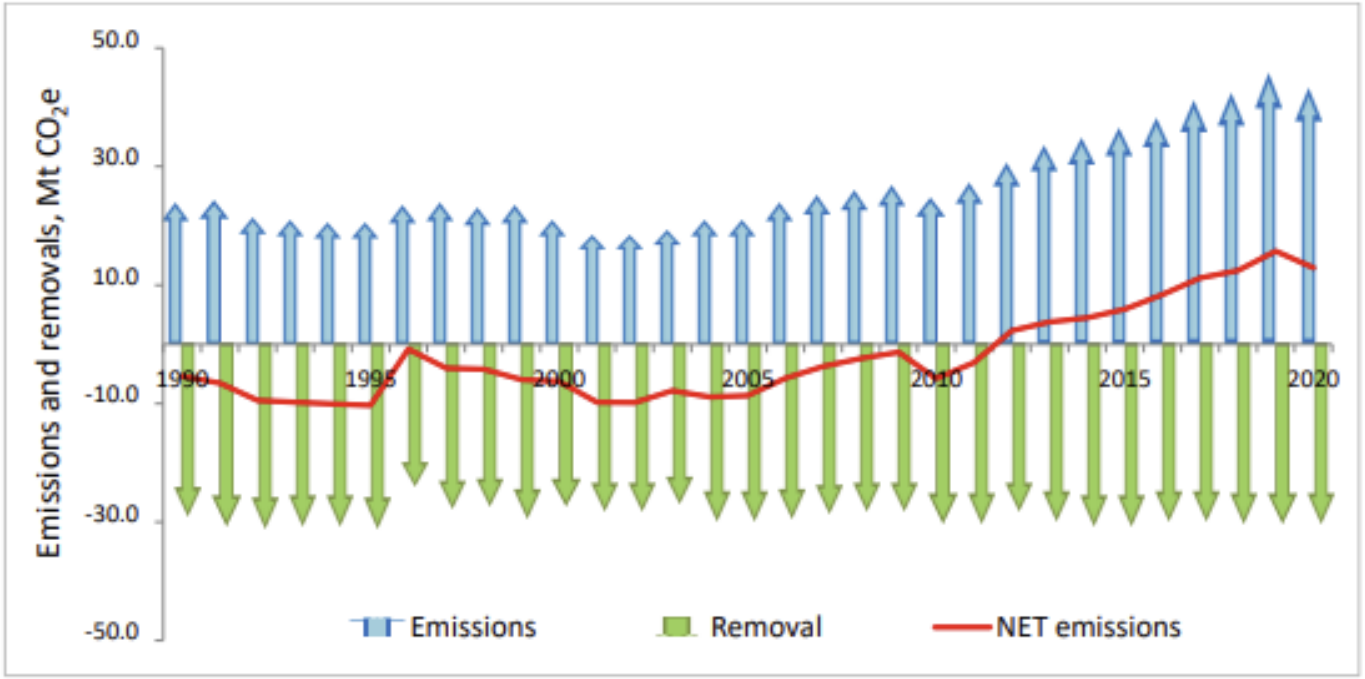


Figure 2-1: Mongolia's total and net GHG emissions and removals, 1990-2020 (Mt CO_2e)

Table 2-1: Mongolia's GHG emissions/removals by sectors in 1990 and 2020

Sector	*Emissions and removals, (Gg CO_2e)*		*Change from 1990 (Gg CO_2e)*	*Change from 1990 (%)*
	1990	*2020*		
Energy	12,086.55	19,292.48	7,205.92	59.62%
IPPU	284.98	1,147.75	862.77	302.75%
Agriculture	11,221.64	22,390.57	11,168.93	99.53%
Waste	55.62	250.82	195.20	350.95%
Total (excluding LULUCF)	23,648.79	43,081.62	19,432.82	82.17%
LULUCF	-29,027.19	-30,172.52	-1,145.33	3.95%
Net total (including LULUCF)	-5,378.40	12,909.10	18,287.49	340.02%

2. Data Gap Analysis for Data Collection and Data Improvement Plan

- *A total of sixteen studies published between 2013 and 2024 were reviewed*
  - Species, sample size, biomass component, range of DBH & tree height, coordinates of sample plots

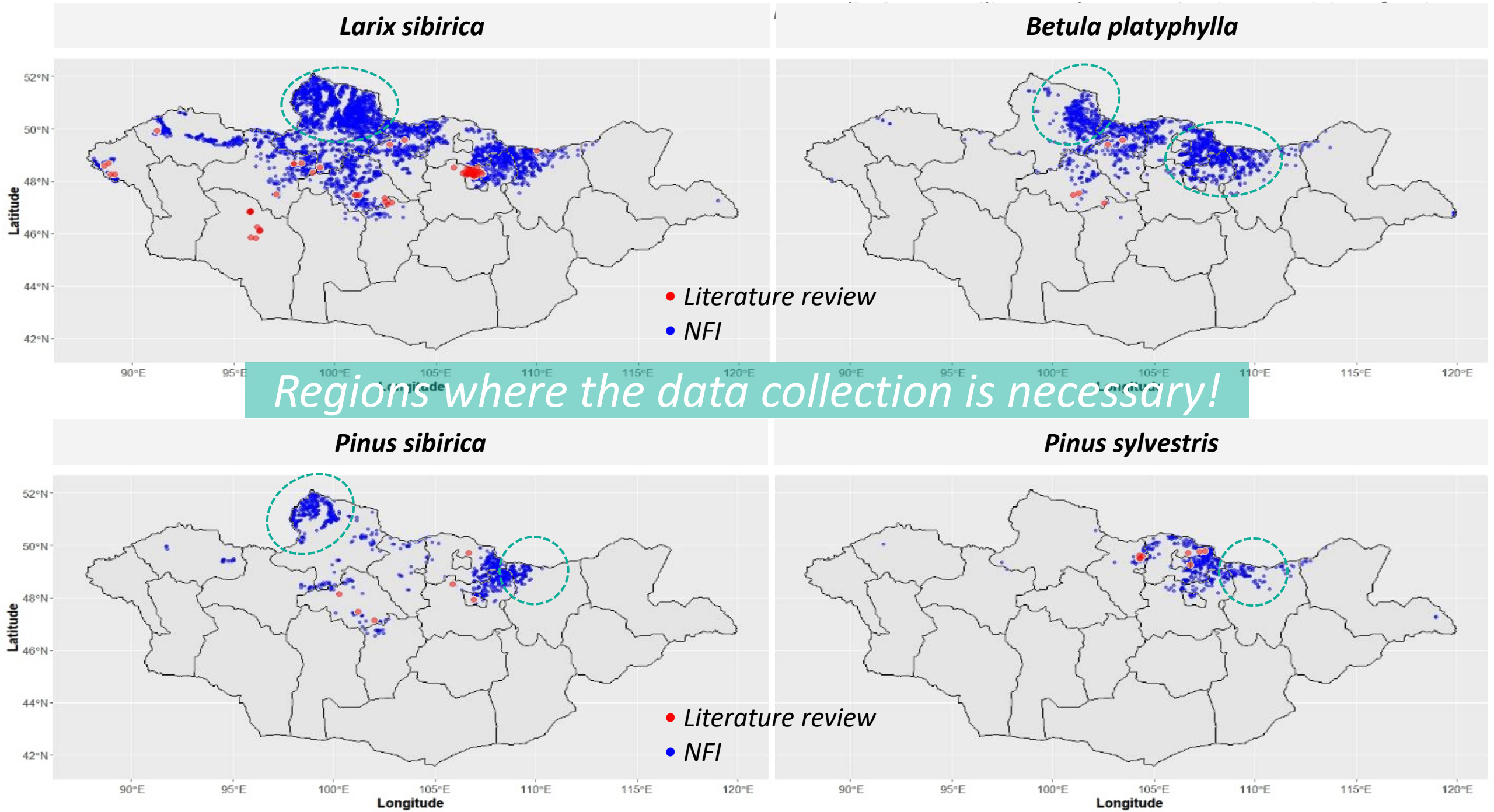
No.	Author	Year	Title
1	Altanzagas et al.	2019	Allometric equations for estimating the above-ground biomass of five forest tree species in Khangai, Mongolia
2	Battulga et al.	2013	Equations for estimating the above-ground biomass of Larix sibirica in the forest-steppe of Mongolia
3	Dorjsuren	2017	Estimation of aboveground biomass and carbon stock in Mongolian boreal forest
4	Dorjsuren & Khongor	2018	Allometric model development for above ground biomass of saxaul (Haloxylon ammodendron (C.A.May) Bunge.)
5	Dulamsuren et al.	2016	Carbon pool densities and a first estimate of the total carbon pool in the Mongolian forest-steppe
6	Gerelbaatar	2018	Estimating the belowground biomass and root/shoot ratio of larch forest in northern Mongolia
7	Gerelbaatar et al.	2023	Allometric equations for the estimation of above- and below-ground biomass for Larix sibirica Ledeb. in Northern MN
8	Government of MN	2018	Mongolia's forest reference level submission to the United Nations Framework Convention on Climate Change
9	Nyamjav et al.	2018	Allometric equations for estimating above-ground biomass of Nitraria sibirica Pall. in Gobi Desert of Mongolia
10	Usoltsev et al.	2019	Aboveground biomass of Mongolian larch (Larix sibirica Ledeb.) forests in the Eurasian region
⋮			⋮

2. Data Gap Analysis for Data Collection and Data Improvement Plan

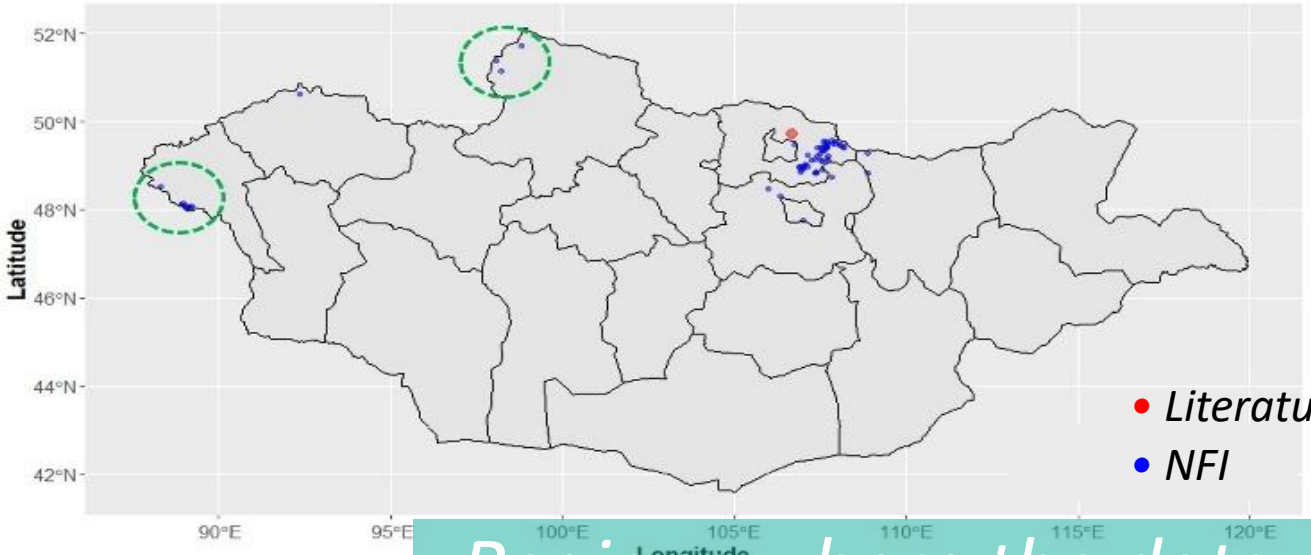
- *The table below shows the summary of data from literature review by species*
  - *Most studies have been conducted on Larix sibirica*
  - *Almost no data for bark and root except Larix sibirica: those bark and root data also small sample size*

Species	Sample size	Biomass Components						DBH (cm)		Height (m)	
		Stem	Branch	Foliage	Bark	Root	Fruit	Min	Max	Min	Max
Abies sibirica	19	O	O	O				4.0	39.0	3.23	27.6
Betula platyphylla	27	O	O	O				6.0	35.4	6.2	22.5
Larix sibirica	187	O	O	O	O	O		0.5	52.5	1.5	31.4
Picea obovata	22	O	O	O				5.6	43.7	5.8	27.0
Pinus sibirica	23	O	O	O				2.0	42.0	2.5	17.6
Pinus sylvestris	35	O	O	O				4.7	55.0	4.6	23.0
Populus suaveolens	37	O	O	O				5.2	68.0	5.1	25.5
Populus tremula	9	O	O	O				3.8	35.0	5.62	20.6
Populus sibirica	135	O	O	O		O		77.6* ± 4.40		384.3 ± 30.88	
Ulmus pumila		O	O	O		O		44.28* ± 2.73		217.8 ± 12.25	
Haloxylon ammodendron	46	O	O	O				0.71	25.5	0.22	5.65
Nitraria sibirica Pall.	35	O	O	O			O	0.19	0.67	0.4	1.94

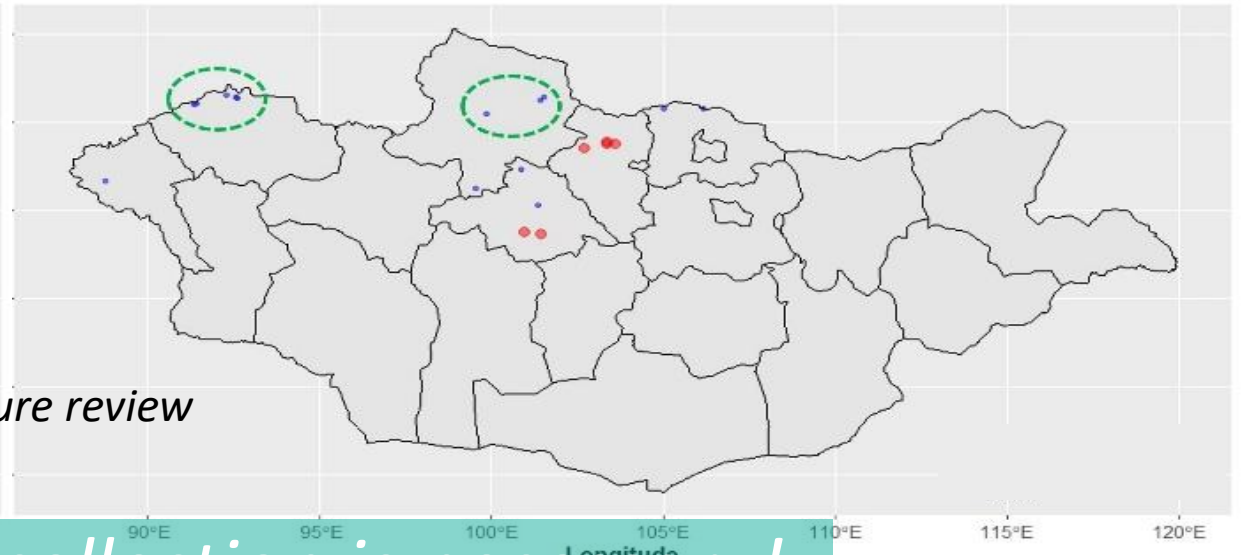
*Diameter at Root Collar


Larix sibirica
Betula platyphylla
Pinus sibirica
Pinus sylvestris
Literature review
NFI
Regions where the data collection is necessary!
Latitude
Longitude
52°N
50°N
48°N
46°N
44°N
42°N
90°E
95°E
100°E
105°E
110°E
115°E
120°E

Abies sibirica



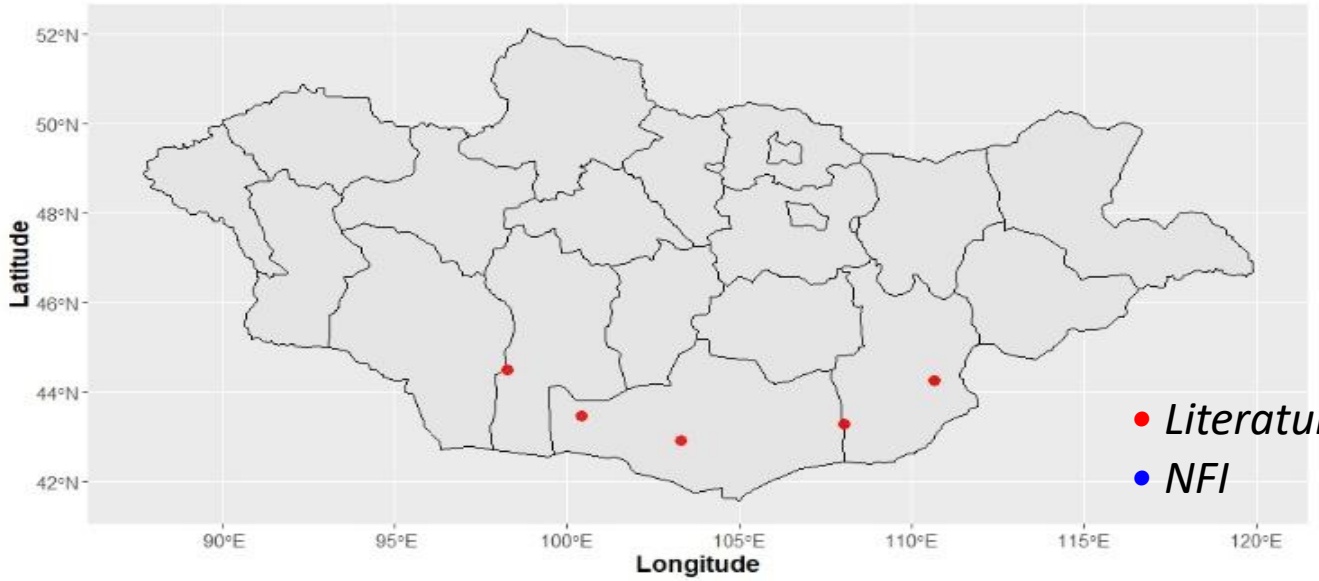
Pupulus sauveolens



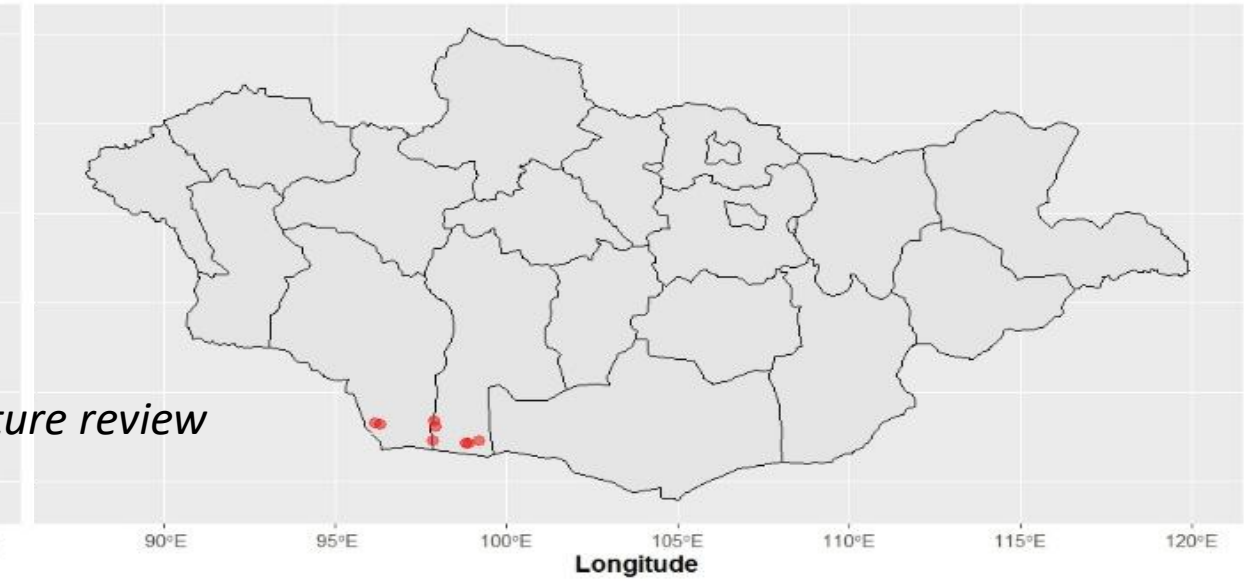
- *Literature review*
- *NFI*

Regions where the data collection is necessary!

Haloxylon ammodendron



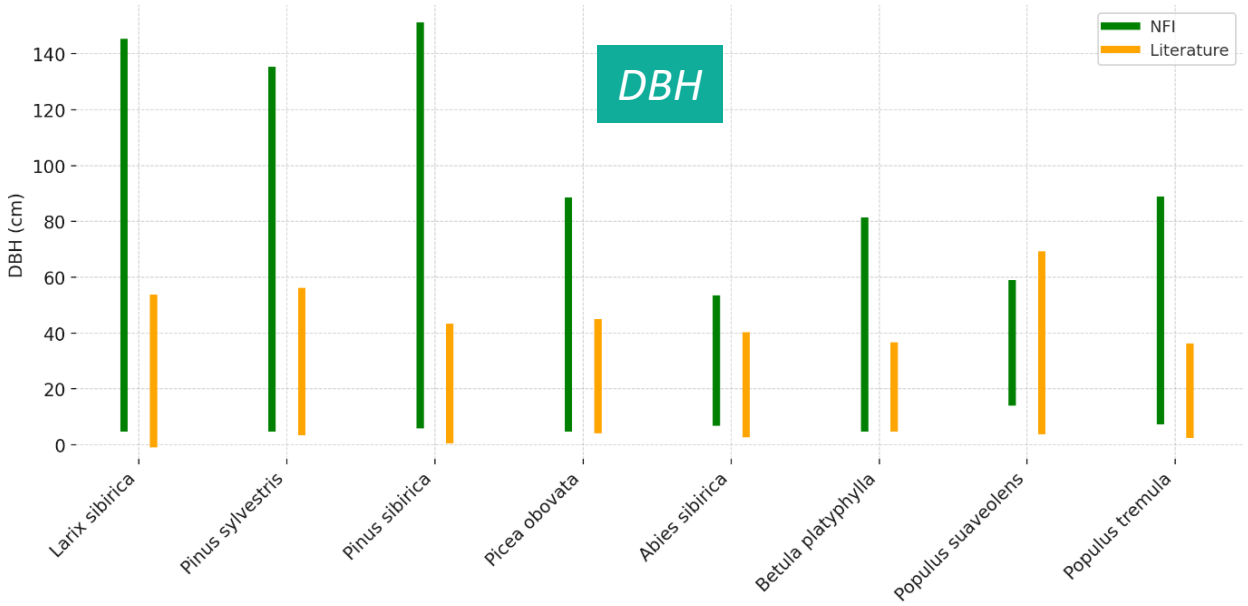
Nitraria sibirica

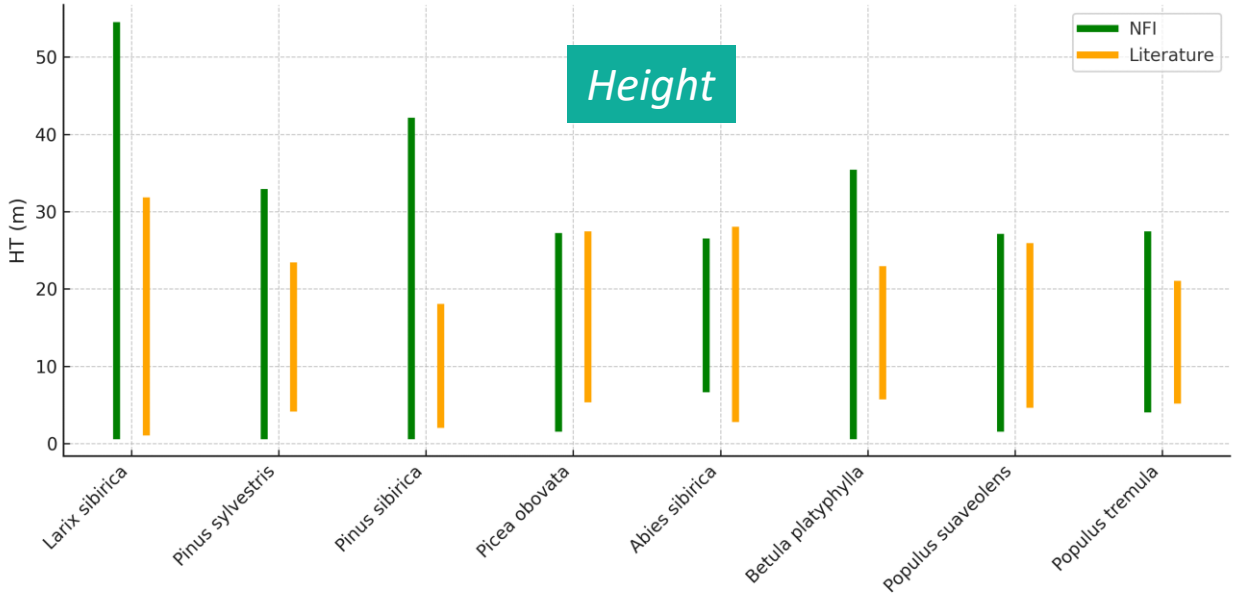


- *Literature review*
- *NFI*

2. Data Gap Analysis for Data Collection and Data Improvement Plan

- *Comparing the ranges of DBH and tree height from literature review and NFI*
  - *Found a lack of data on large trees (even for Larix sibirica with the largest sample size)*
  - *Hard to evaluate range of saxaul because there are no saxaul data in NFI – Also needs to be improved*
- *Larix sibirica accounted for 80% of basal area based on NFI, followed by Betula platyphylla (8.3%), Pinus sibirica (6.1%), and Pinus sylvestris (3.6%)*



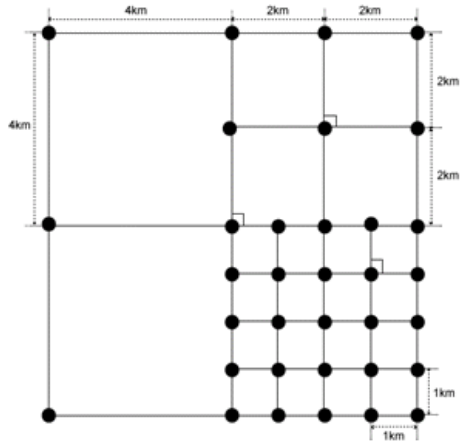


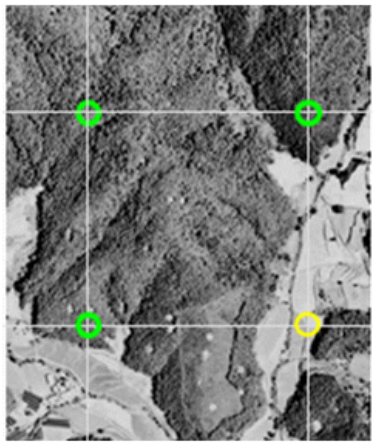
How is the NFI system in Korea?

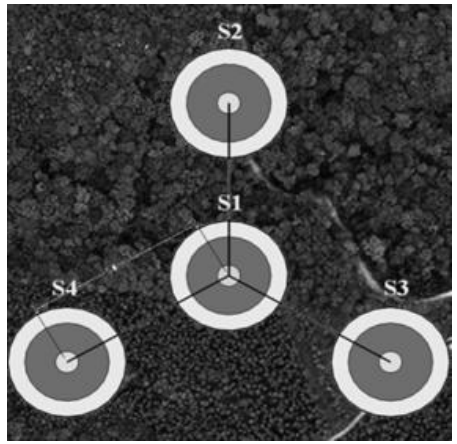
3. NFI system and Its application in S. Korea

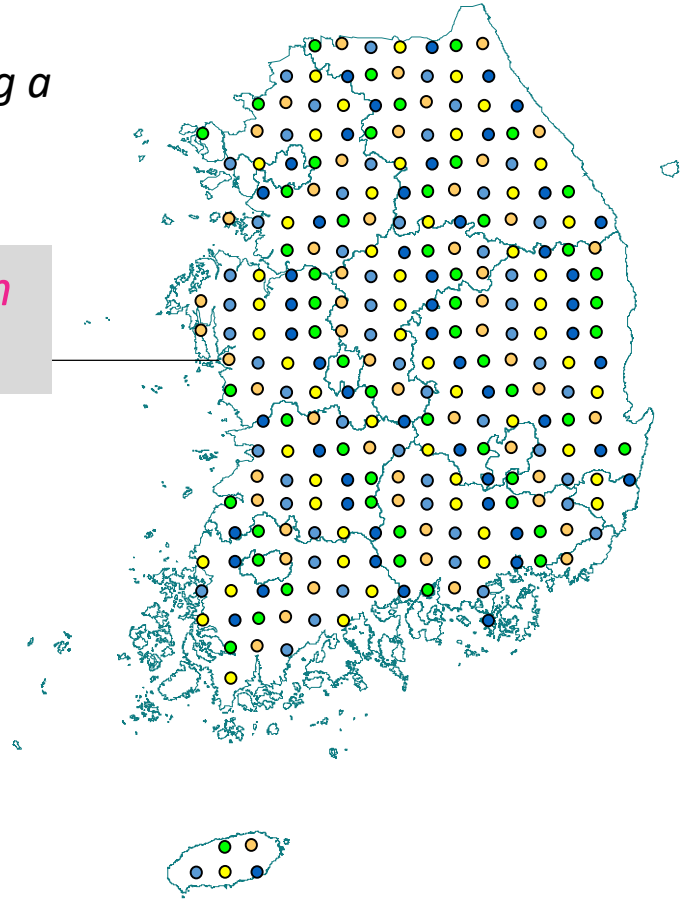
- *The 1st NFI begun in 1971 in S. Korea, the country was divided into 4 × 4 km squares and a sample point was placed at each intersection on the grid*
  - *The design included the flexibility to acquire sufficient sample points, such as using a 2 km or 1 km grid, where it is difficult to acquire a suitable sample point*

A continuous annual survey system completed over a five-year cycle!









"Systematic" sampling design

3. NFI system and Its application in S. Korea

- The current NFI covers a wider range of carbon pools (biomass, deadwood, litter, and soil) and includes uncertainty analysis, enhancing the accuracy of GHG inventories
- Sample plot design has improved from temporary to permanent plots, allowing for more consistent and long-term forest monitoring

GHG Inventory Coverage	Past NFI (1st–4th)	Current NFI (5th and after)
Biomass	O	O
Deadwood	X	O
Litter	X	O
Soil	X	O
Uncertainty	X	O
Sample Plot Design	Temporary Plots	Permanent Plots

3. NFI system and Its application in S. Ko

- Main survey items and categories included in the NFI
  - It covers a wide range of forest attributes such as plot characteristics, tree and shrub data, deadwood, regeneration, and soil
- The comprehensive set of 61 survey items allows for detailed monitoring and assessment of forest resources and ecosystem health

Category	No. of Items	Survey Items
General Info	1	- Plot location information
	1	- Plot type
	2	- Project history / Land use classification
	5	- Topographic information (elevation, slope…)
Stand Info	6	- Stand information (forest type, stand density, age class, diameter class, species, regeneration type)
	4	- Other surveys (forest damage type and ratio, wildlife traces, special notes)
	1	- Forest area ratio within the plot
Tree Survey in NFI	5	- Species, diameter class, height class, crown class, count
	4	- Standard tree survey (distance, azimuth, height, diameter)
	4	- New tree plot (species, growth, crown width, tree height)
Tree Survey in FHM	5	- Species, diameter class, height class, crown class, count
	2	- Tree location survey (distance, azimuth)
	2	- Crown class, crown ratio
	3	- Tree combination (species, value, count)
Shrub Survey	3	- Species, base diameter class, count
Deadwood/ Standing Dead	3	- Deadwood survey (species, count, diameter class)
	7	- Standing dead survey (species, count, central diameter, length, decay class, crown class, cause of death)
Forest Regeneration	3	- Seedling density, species, emergence rate
Soil Survey	2	- Soil thickness survey (organic layer thickness…)
	5	- Soil sample survey (A and B horizon thickness, sample collection for lab analysis)
Total	61	

Building Digital Maps of the Status and Changes of Various Forest Components

What is the Forest Geospatial Information System in S. Korea?

Forest Geospatial Information System

Customized Forest Plantation Map → Forest Use Map → Landslide Risk Map → Forest Weather Map → Forest Carbon Map

Forest Type Map

A map that shows the status of land use, forest type, stand type, tree species, diameter class, age, and density using remote sensing techniques and field surveys

Used as basic data for the creation of various forest thematic maps

Above: Forest/Non-Forest | Forest Type | Stand Type | Species | Age class | DBH class | Density class

Moisture Environ.

Below: Parent Rock | Elevation | Slope | Aspect | Topo-graphy | Climate zone | Slope position | Slope shape

Volumetric Water Content | Saturated Hydraulic Conduct.

Forest Soil Map & Hydrological Map

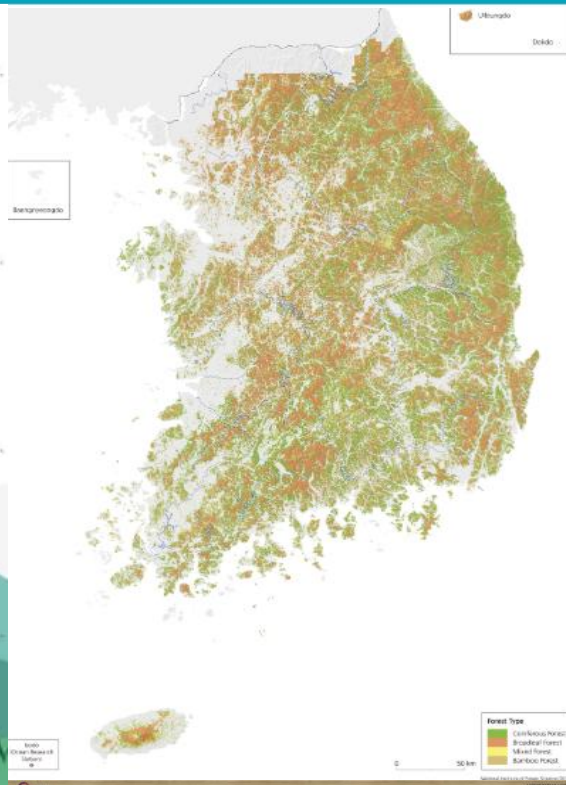
A map showing the water conservation function that supplies water resources for systematic management of water conservation forests and scientific forest watershed management

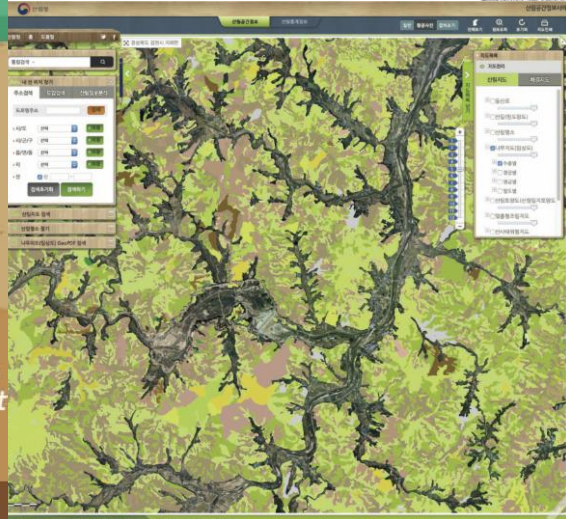
Site Environ.

Below: Soil Type | Soil Depth | Soil Texture

Forest Site Map

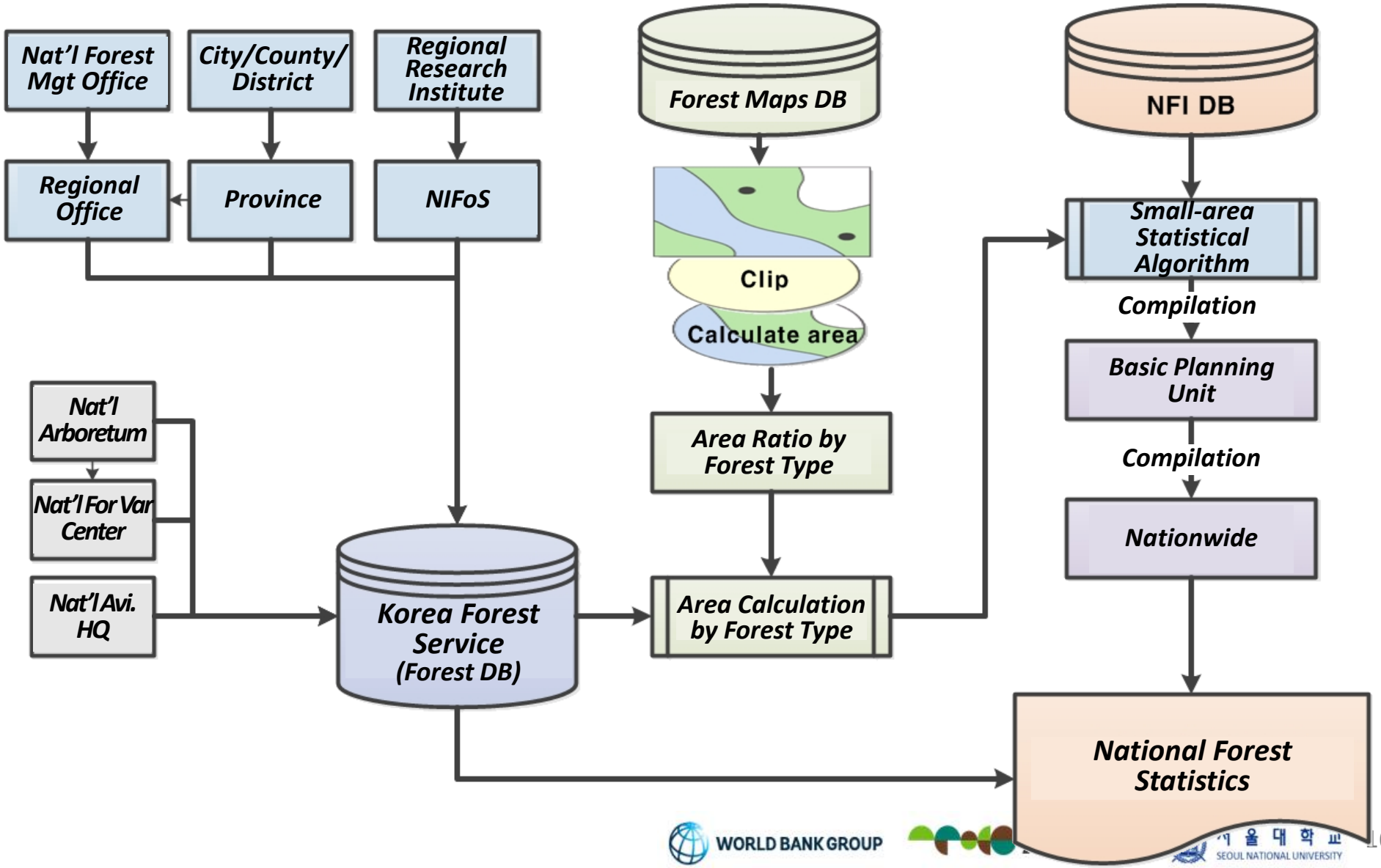
A map showing the water conservation function that supplies water resources for systematic management of water conservation forests and scientific forest watershed management





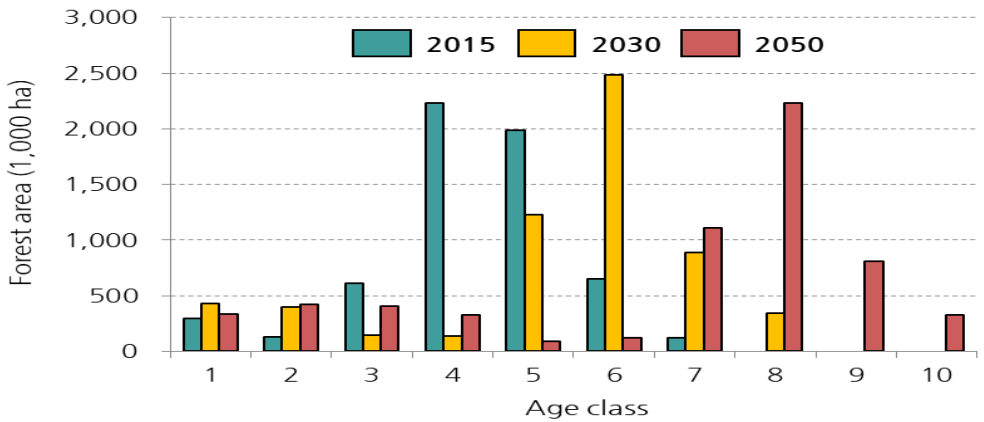
3. NFI system and Its application in S. Korea

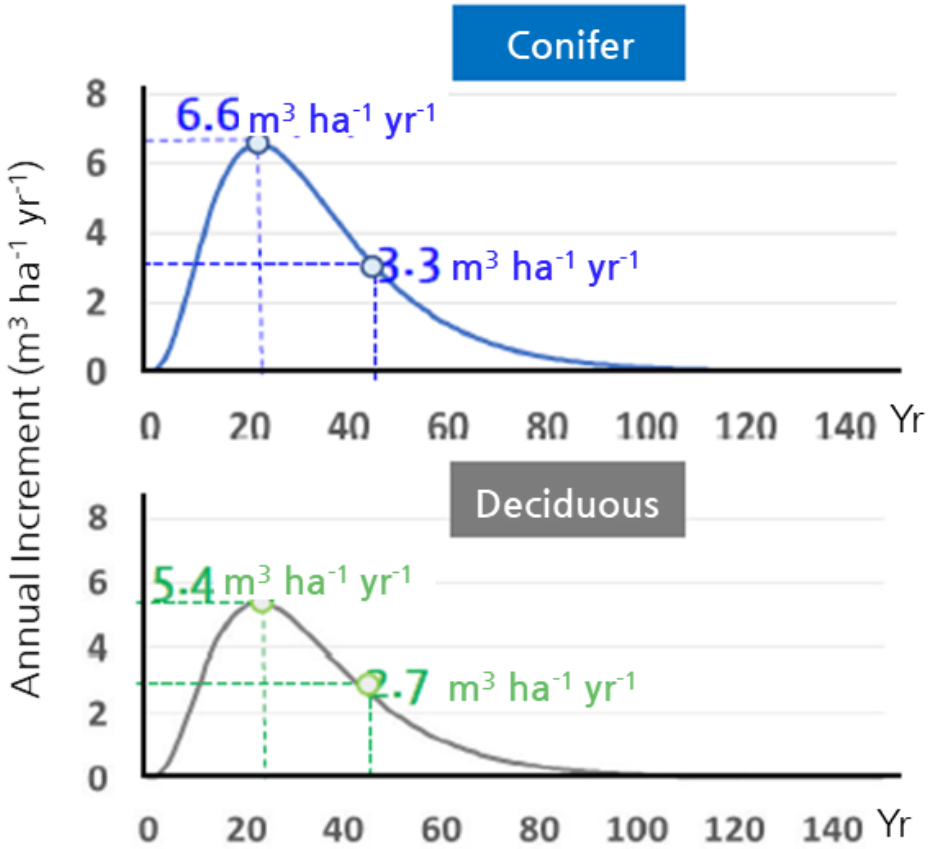
- *Forest statistics compilation procedure*



3. NFI system and Its application in S. Korea

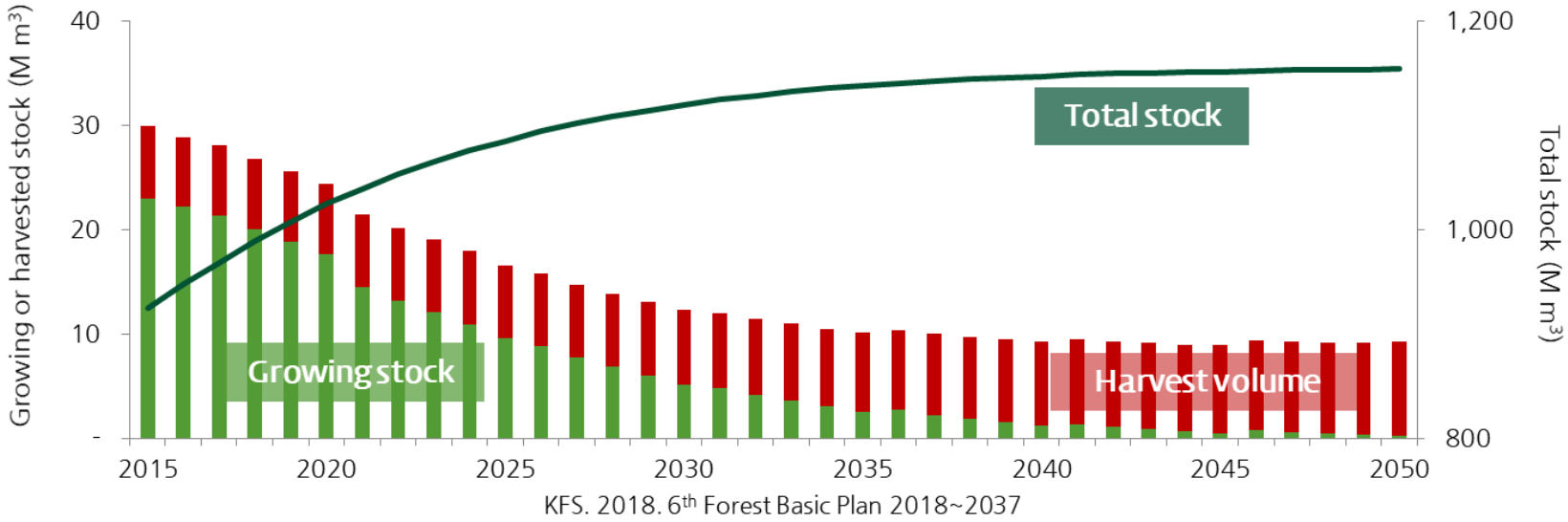
- *Analyze the current status, changes, and future outlook of forest resources*



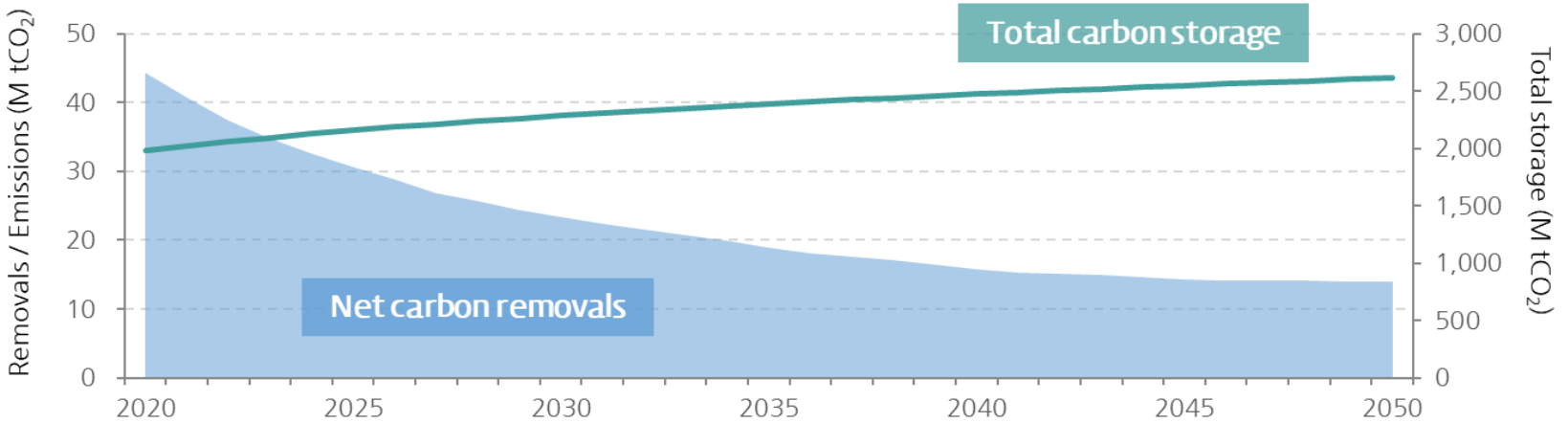


3. NFI system and Its application in S. Korea

- *Analyze the current status, changes, and future outlook of forest resources*

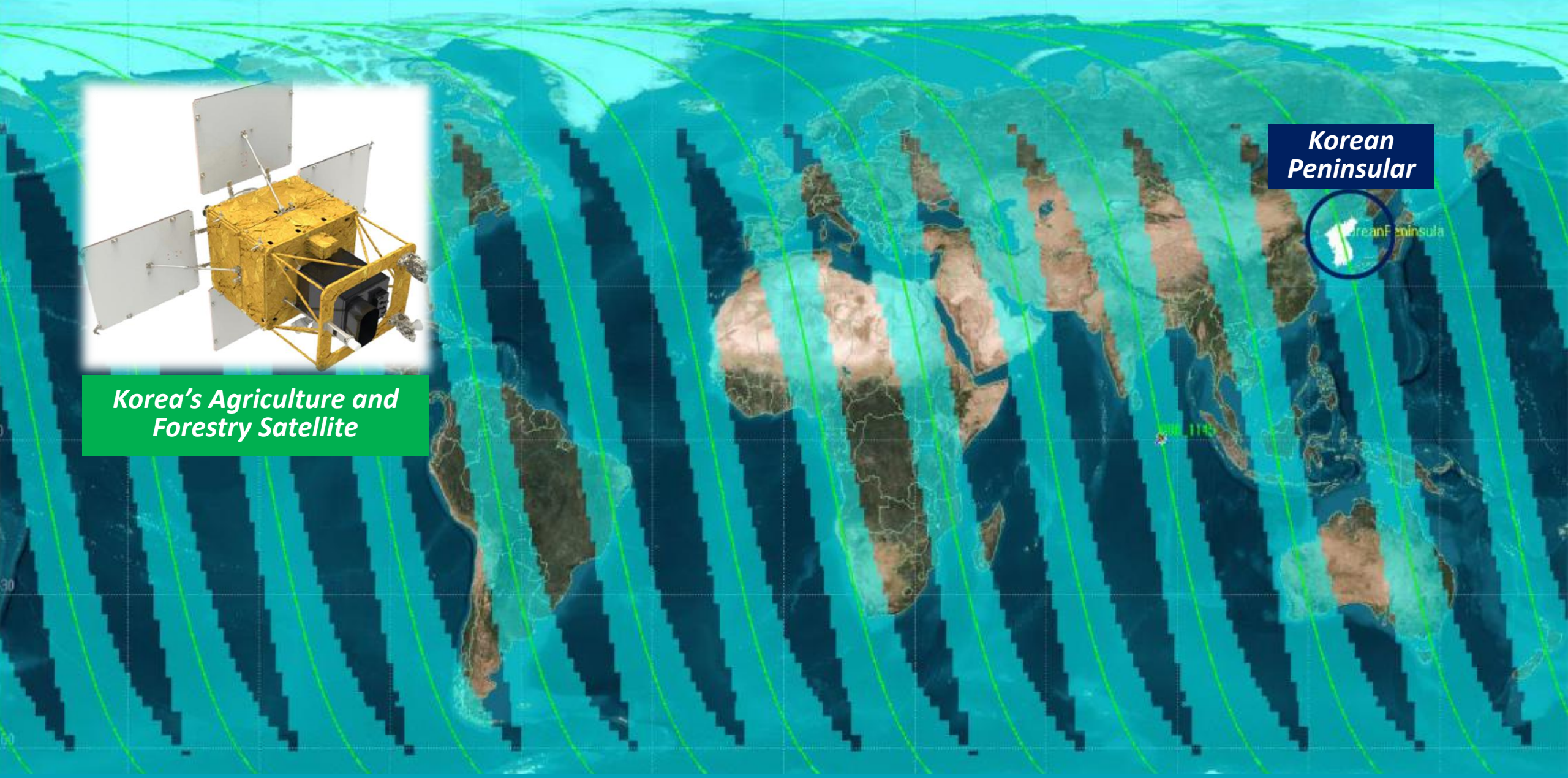


KFS. 2018. 6th Forest Basic Plan 2018~2037



Han et al. 2020. Outlook of Carbon Removals and Total Carbon Storage in Korea


국립산림과학원



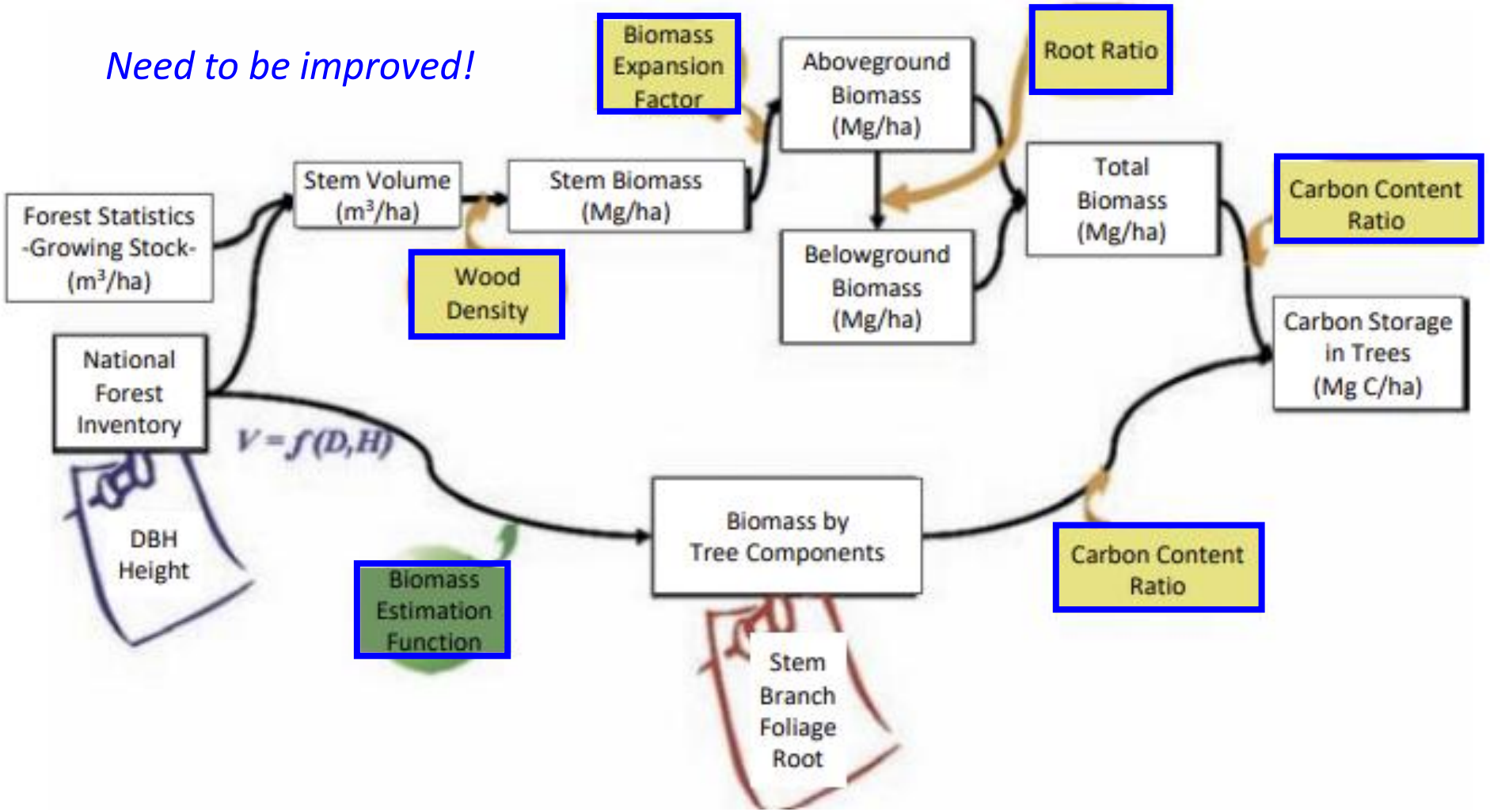
Korea's Agriculture and Forestry Satellite

The Korean Peninsula is observed every three days, and up to 60% of the Earth's surface can be monitored

How did Korea develop Tier 2 level data based on the NFI system?

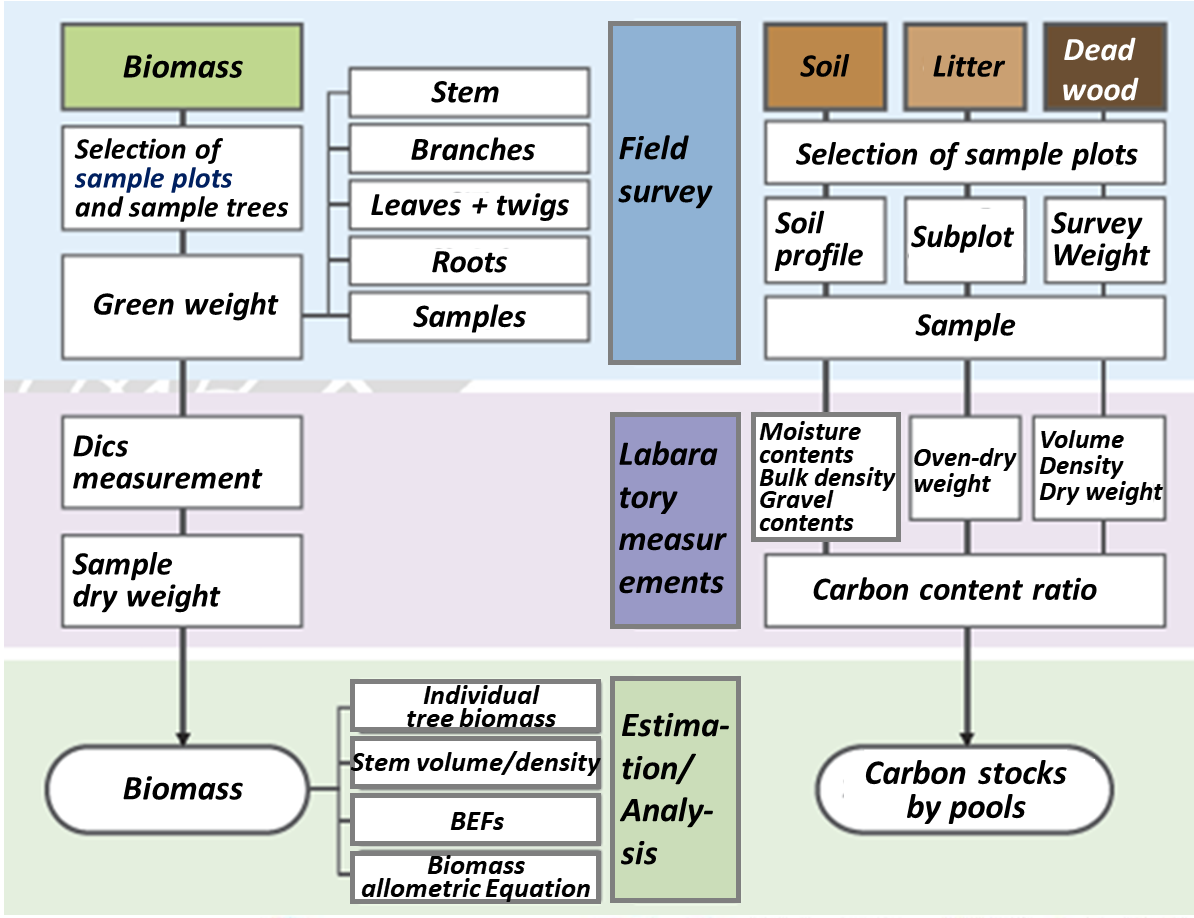
4. Forest Carbon Data Development in S. Korea

- *Procedures for Measuring Carbon Storage in Trees (NIFoS, Korea)*



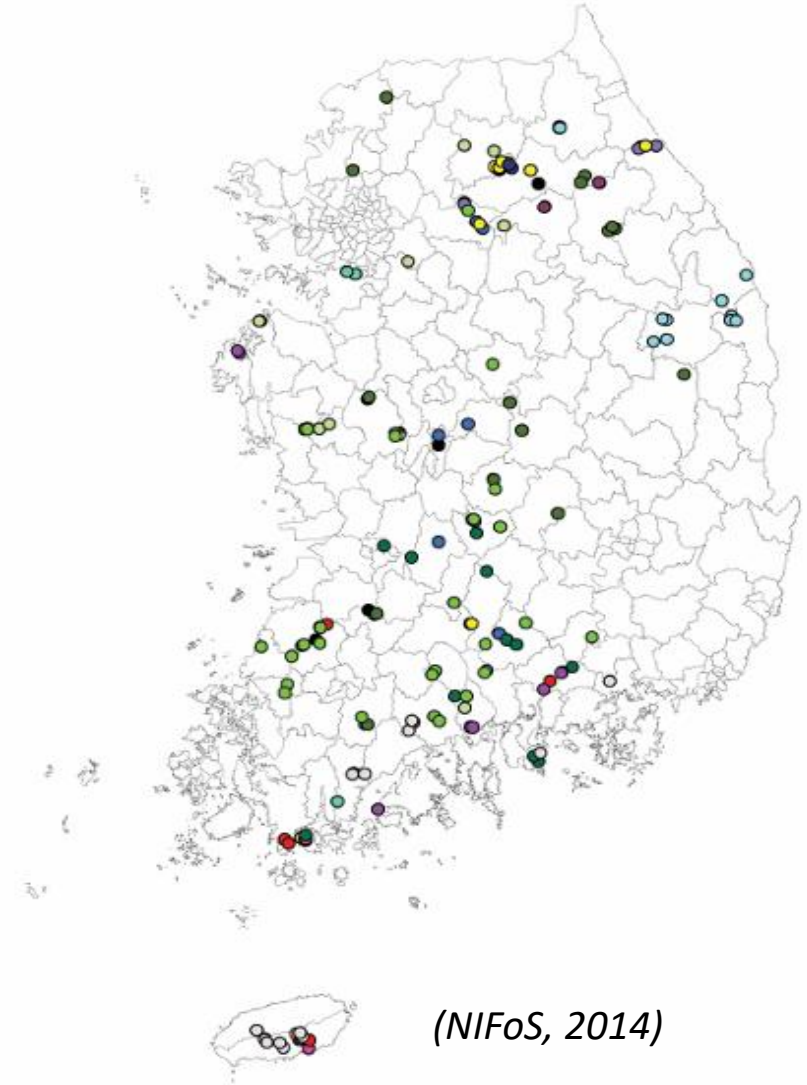
4. Forest Carbon Data Development in S. Korea

- *Having country-specific carbon emission factors is essential for compiling a more accurate national greenhouse gas inventory*



4. Forest Carbon Data Development in S. Korea

- *Sampling site distribution for developing country-specific carbon emission factors*



- *Pinus densiflora in Gangwon region*
- *Castanopsis cuspidata*
- *Quercus variabilis*
- *Larix kaempferi*
- *Pinus rigida*
- *Liriodendron tulipifera*
- *Quercus acuta*
- *Cryptomeria japonica*
- *Quercus acutissima*
- *Carpinus laxiflora*
- *Quercus mongolica*
- *Betula spp.*
- *Pinus koraiensis*
- *Quercus serrata*
- *Pinus densiflora in Central region*
- *Chamaecyparis obtusa*
- *Pinus thunbergii*
- *Populus alba × Populus glandulosa*

(NIFoS, 2014)

Photo credit: Prof. Lee, Kyunghak

4. Forest Carbon Data Development in S. Korea

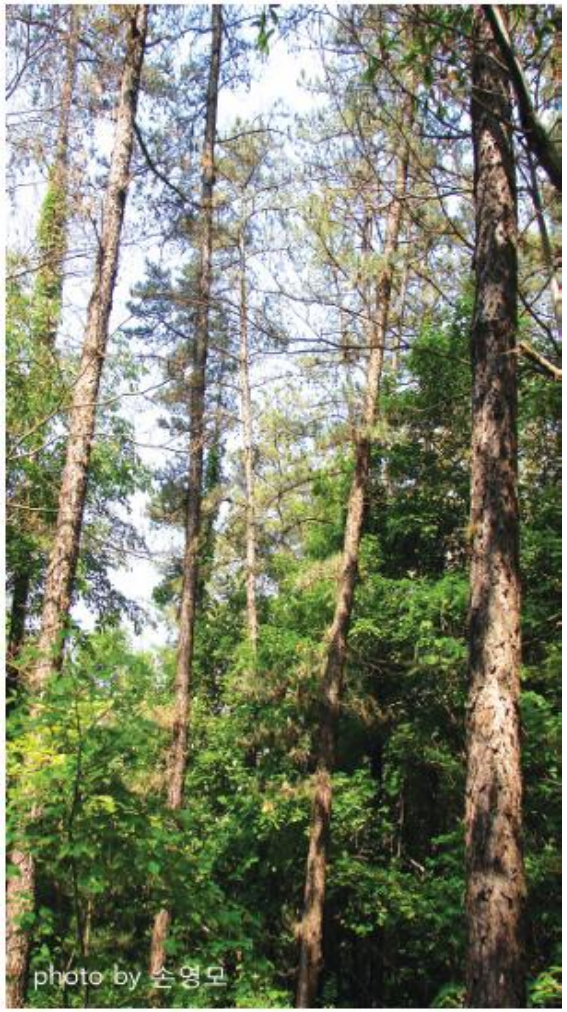
- *Carbon Emission Factors by Major Tree - **Pinus densiflora in Gangwon region***

Category	Korea	Comparison/Verification - IPCC defaults
Stand Type	Conifers	Conifers
Species	Pinus densiflora in Gangwon region	Pinus spp.
Basic Wood Density	0.419	0.32~0.44
Uncertainty (%)	11.904%	-
Biomass Expansion Factor	1.483	1.15~3.4
Uncertainty (%)	11.621%	-
Root to Shoot Ratio	0.258	0.24~0.50
Uncertainty (%)	13.534%	-

※ For comparison/reference, IPCC defaults are from IPCC 2003 GPG and IPCC 2006 GL.

4. Forest Carbon Data Development in S. Korea

- *Carbon Emission Factors by Major Tree - **Pinus rigida***



Category	Korea	Comparison/Verification - IPCC defaults
Stand Type	Conifers	Conifers
Species	Pinus rigida	Pinus spp.
Basic Wood Density	0.504	0.32~0.44
Uncertainty (%)	4.319%	-
Biomass Expansion Factor	1.325	1.15~3.4
Uncertainty (%)	12.070%	-
Root to Shoot Ratio	0.362	0.24~0.50
Uncertainty (%)	29.144%	-

※For comparison/reference, IPCC defaults are from IPCC 2003 GPG and IPCC 2006 GL.

4. Forest Carbon Data Development in S. Korea

- *Carbon Emission Factors by Major Tree – **Quercus acutissima***

Category	Korea	Comparison/Verification - IPCC defaults
Stand Type	hardwoods	hardwoods
Species	Quercus acutissima	Quercus spp.
Basic Wood Density	0.721	0.58
Uncertainty (%)	5.780%	-
Biomass Expansion Factor	1.450	1.15~3.2
Uncertainty (%)	5.646%	-
Root to Shoot Ratio	0.313	0.20~1.16
Uncertainty (%)	26.181%	-

※For comparison/reference, IPCC defaults are from IPCC 2003 GPG and IPCC 2006 GL.

4. Forest Carbon Data Development in S. Korea

- *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	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

4. Forest Carbon Data Development in S. Korea

- *Next steps for improving forest carbon data*
- *More plots need to be investigated by growing stock!*

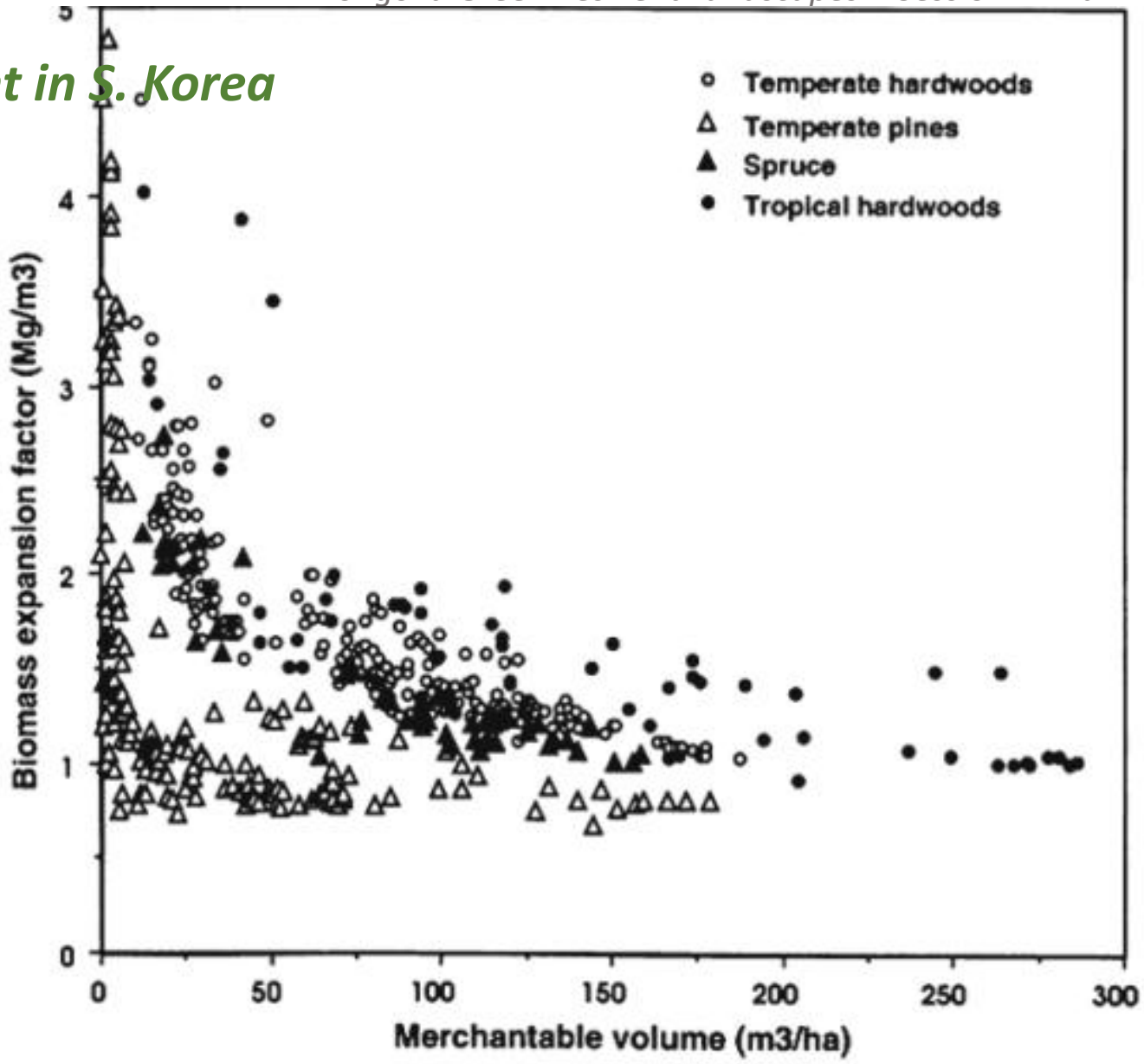


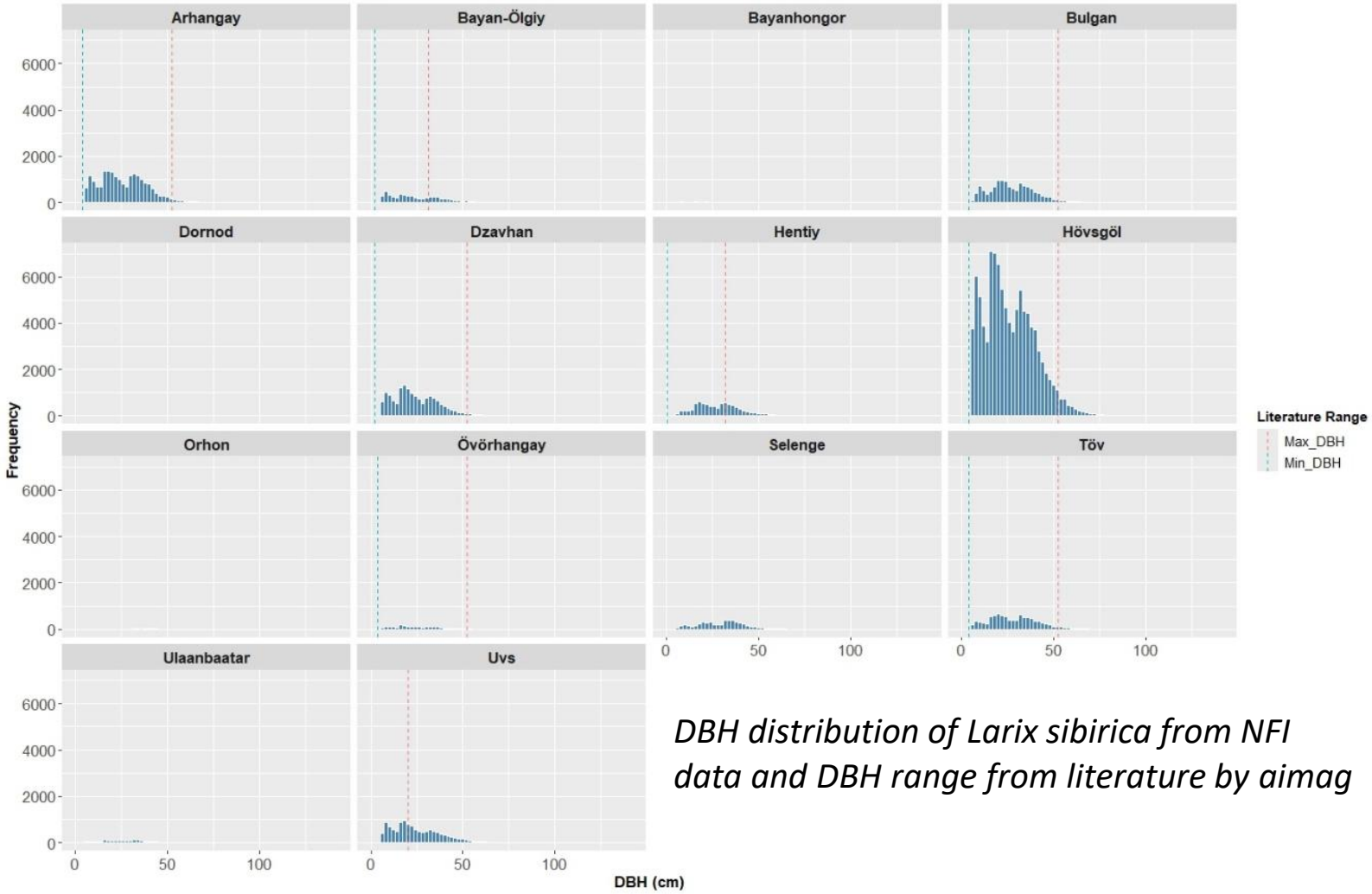
Fig. 7.2 Relationship between BEF for temperate hardwoods, pines and spruce, and tropical hardwoods (*Source*: From Brown (2002). Reprinted with permission)

Then, what is needed to improve Mongolia's forest carbon data?

5. Strategic Options for Improving Forest Carbon Data Development in MN

1) Field Sampling Strategy by Species, Region, and Size Class

- *Expands field sampling to underrepresented species, regions, and large tree size classes*
- *Prioritizes key species in boreal and temperate zones, and addresses gaps in dryland species*



DBH distribution of Larix sibirica from NFI data and DBH range from literature by aimag

5. Strategic Options for Improving Forest Carbon Data Development in MN

2) Sample Size Considerations for Key Species

- Determines minimum sample sizes for priority species (e.g., Larix sibirica, Haloxylon ammodendron) to achieve reliable biomass estimates
- Encourages oversampling and phased implementation to support model validation and regional calibration

Species	Target Error Margin	Confidence Level	Estimated Sample Size (AGB*)	Estimated Sample Size (BGB**)	Notes
Larix sibirica	±10%	95%	48	56	Higher variance in foliage and root components
Haloxylon ammodendron	±10%	95%	35	40	Sparse data; prioritize belowground sampling

5. Strategic Options for Improving Forest Carbon Data Development in MN

3) Allometric Model Development and Metadata Standards

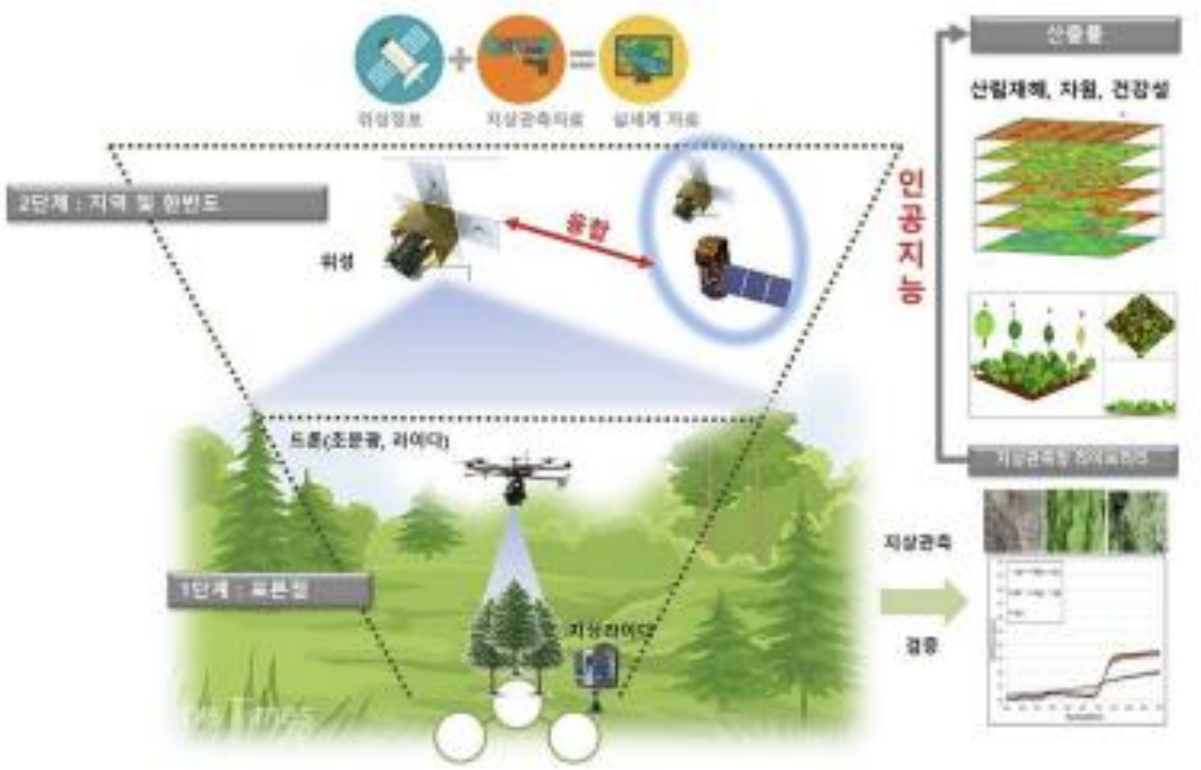
- Develops robust, component-level allometric models tailored to local species and site conditions
- Ensures all models are accompanied by standardized metadata and periodic updates for scientific rigor and interoperability

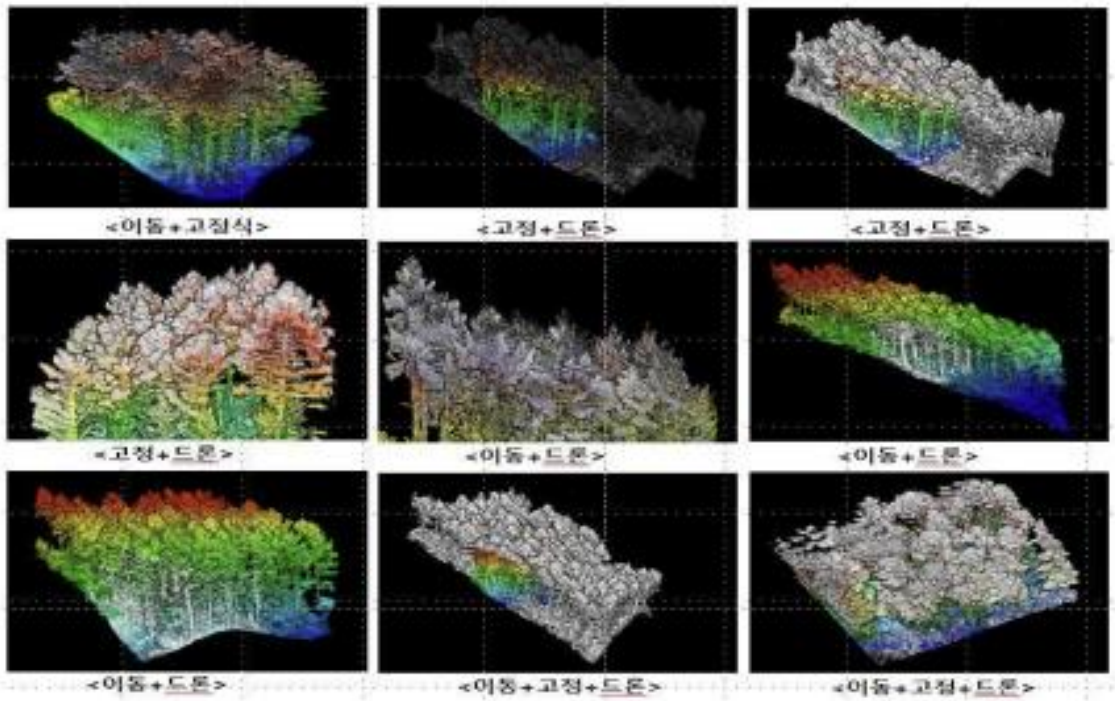
Component	Allometric Equation ($Y = aD^b$)	R^2	Allometric Equation ($Y = a(D^2H)^b$)	R^2
Stem (wood)	$Y = 45.530D^{2.47852}$	0.9049	$Y = 23.4003(D^2H)^{0.94362}$	0.9571
Stem (bark)	$Y = 37.6432D^{1.87014}$	0.8654	$Y = 30.2337(D^2H)^{0.68006}$	0.8497
Stem (total)	$Y = 62.918D^{2.41260}$	0.9175	$Y = 34.1013(D^2H)^{0.91462}$	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

5. Strategic Options for Improving Forest Carbon Data Development in MN

4) Integration of Remote Sensing and Ground Data

- *Integrates satellite and UAV data with field measurements to improve spatial resolution and national applicability of biomass estimates*
- *Utilizes remote sensing for areas difficult to access and supports continuous monitoring and reporting needs*





5. Strategic Options for Improving Forest Carbon Data Development in MN

5) Centralized Platform and Institutional Framework

- *Establishes a centralized data platform to coordinate, store, and manage biomass data from various sources*
- *Assigns institutional responsibility, standardizes metadata, and formalizes protocols for data validation and updates to support long-term sustainability*

Korean National Forest Inventory Data Management Platforms

Platforms	Key Features and Functions
Forest Statistical System	• ***Primary platform for data access*** • *Provides **aggregated statistics** and **raw data,** not exact coordinates of plots* • *Available for the general public and researchers*
Forest Geospatial Information System	• *Dedicated platform for GIS data* • ***High-resolution spatial data**, including thematic maps of forest resources and land use*

5. Strategic Options for Improving Forest Carbon Data Development in MN

6) Quality Assurance & Control (QA/QC) Process for the MN's NFI system

- *Phase 1* ***Pre-Survey****: Thorough Preparation & Standardization*
  - ✓ *Enhancing Expertise: Intensive training is conducted annually to improve the professional skills of field surveyors and enhance data quality.*
  - ✓ *Training Content: The curriculum covers all necessary skills and knowledge, including forest mensuration theory, operation of GPS and modern equipment, aerial photo interpretation, and hands-on field practice.*
  - ✓ *Ensuring Consistency: All surveyors are trained to measure and record data according to a single, standardized manual, minimizing errors between individuals.*

5. Strategic Options for Improving Forest Carbon Data Development in MN

6) Quality Assurance & Control (QA/QC) Process for the MN's NFI system

- Phase 2 **Field Survey**: A Multi-layered Verification System

✓ External Auditing Service (Third-party Expert Review)

- Objective: To enhance data reliability by having a third party objectively assess survey quality.
- Method: Each year, 3% of all sample plots are randomly selected. An external professional audit team re-surveys and inspects these plots to verify that the original survey was conducted accurately according to the field manual.

✓ On-site Guidance and Inspection by the Managing Institution (Internal Joint Review)

- Objective: To have the responsible institution, the National Institute of Forest Science, directly manage quality by inspecting fieldwork.
- Method: Approximately 3% of the sample plots are inspected annually, with the inspection team accompanying the field crews. This process aims to enhance the expertise and efficiency of the surveyors.

5. Strategic Options for Improving Forest Carbon Data Development in MN

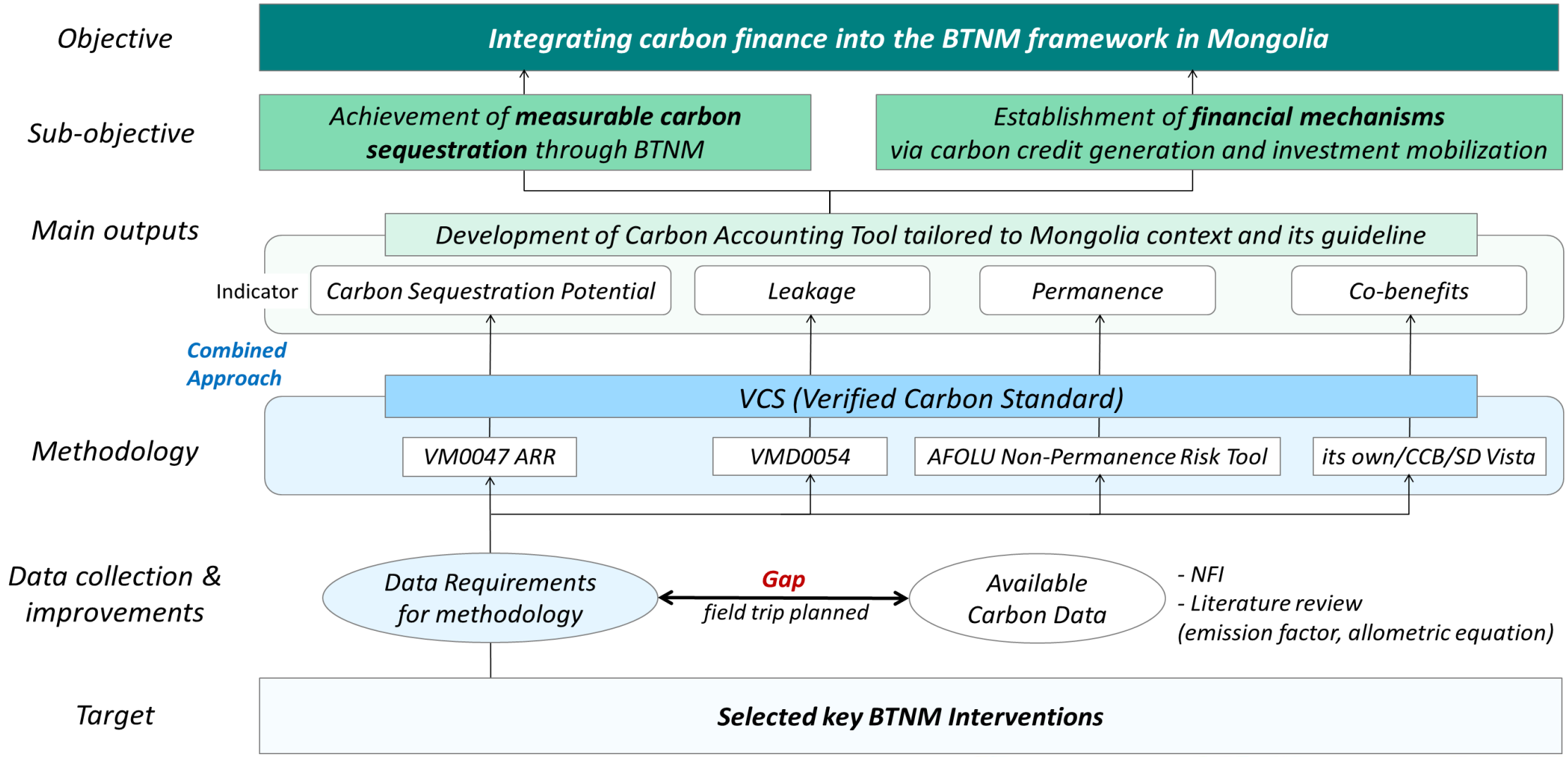
6) Quality Assurance & Control (QA/QC) Process for the MN's NFI system

- Phase 3 **Post-Survey**: Systematic Error Verification

  - ✓ Input Error Checks: Once data is transmitted to the National Forest Information System (NFIS), it is checked for logical inconsistencies or input mistakes by comparing it with existing values
  - ✓ Comparative Analysis with QC Data: The original data is cross-referenced with the control data obtained from both the external audit and internal inspections. Discrepancies are analyzed, and data is corrected as needed
  - ✓ History Management: All modifications and corrections to the data are logged within the system, ensuring data transparency and consistency over time

What we aim to do in this project to improve forest carbon data in Mongolia

6. Developing a Carbon Accounting Tool for Mongolia's BTNM



6. Developing a Carbon Accounting Tool for Mongolia's BTNM

- *Tree Species for Planting (Office of the President of Mongolia, 2023)*
  - *Elm and poplar are the most commonly planted tree species, but there is a lack of related data*

No.	Tree Species	Number of Trees for Planting
1	Pine	132,345,344
2	Larch	220,979,781
3	Spruce	18,685,931
4	Siberian Pine	26,753,173
5	Fir	3,077,131
6	Elm	308,380,884
7	Poplar	176,217,648
8	Willow	104,217,134
9	Saxaul	179,249,400
10	Tamarisk	44,676,000
11	Others/Selection	257,342,770
12	Fruit Trees	37,674,804
Total		1,509,600,000

Field visit site tomorrow in Lum soum, Tüv aimag

Wrap-up and key messages for the Mongolia's forest carbon data

7. Key Messages

I. *Reliable, country-specific forest carbon data are urgently needed to support national GHG inventories and effective carbon projects, but current data remain insufficient*

II. *Integrating improved field surveys, remote sensing, and robust allometric models will strengthen Mongolia's capacity for accurate forest carbon monitoring and international reporting*

III. *Stronger institutional frameworks, international cooperation, and centralized data management are critical to ensure the long-term success and credibility of Mongolia's forest carbon initiatives*

Thank You

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