Development of standing-tree carbon equations to improve the accuracy of forest-cover carbon stock estimates in Thailand






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Outlines

1. Background and Rationale
2. Goal and Objectives
3. Research Methodology
4. Results and Discussion
5. Conclusion

Background and Rationale

Biased Equations

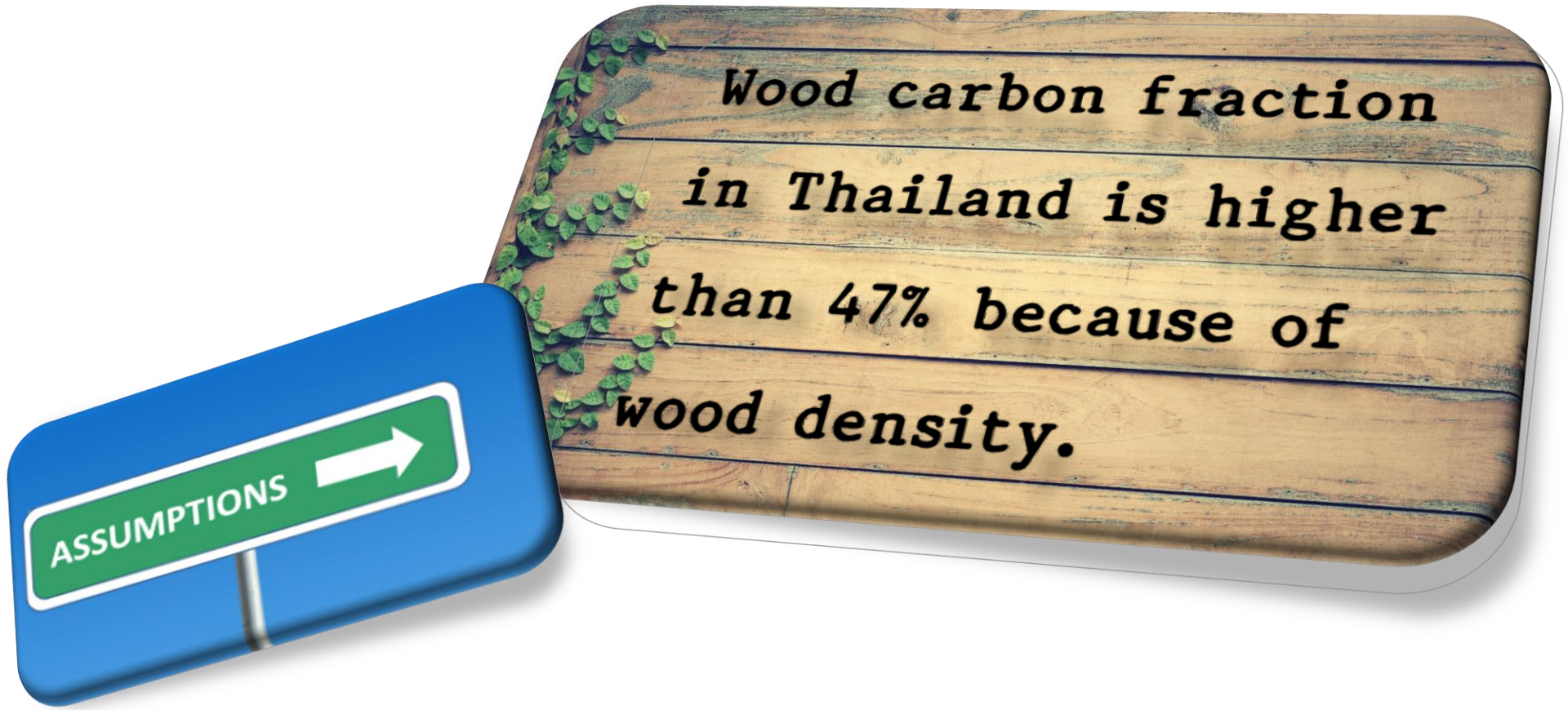
1) Few sample trees were collected to develop the previous equations because of the need to minimize the sample tree destruction and the lack of accurate instruments to measure the upper stem diameters of standing trees.

2) Some of the equations were local volume equations (required only DBH as the independent variable for tree volume estimations).

3) The previous equations were focused on areas to be logged (mainly focused on big trees).

4) The species grouping was too broad (e.g., volume equations by tree family)

Background and Rationale



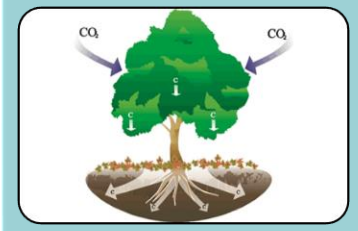
Background and Rationale

- Uncertainty in the accuracy of national estimates of Thailand's forest-cover carbon stocks
- Incomplete report of carbon stocks
- Limited knowledge of the methods of carbon stocks assessment

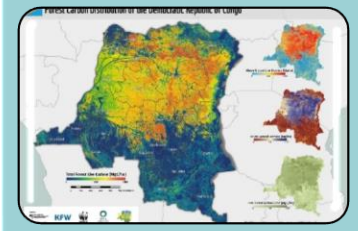
Affects national planning and other policy decisions that rely on the information on national carbon stocks

Background and Rationale

A new and novel approach has been developed to estimate standing tree carbon content using sample tree increment cores for carbon content analysis.



The new approach could be used to develop new national standing-tree carbon equations.



These equations could be used to estimate carbon stocks in the study area and further applied to Thailand's national forests.

Goal and Objectives

Overall Goal

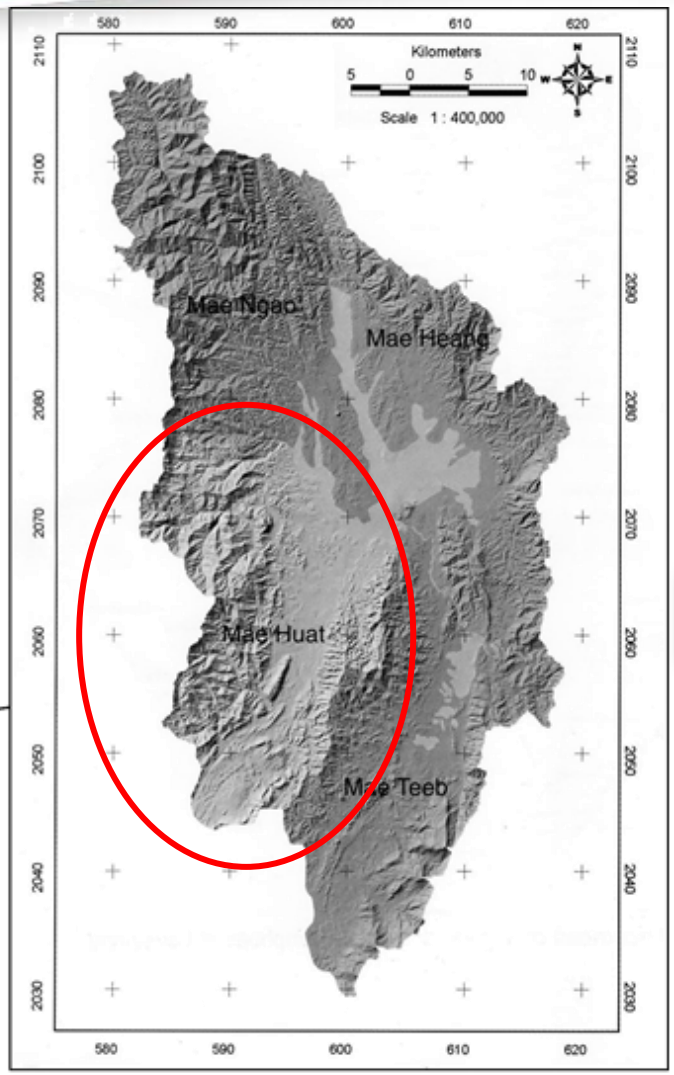
- To provide accurate information on national forest carbon stocks to support SFM policy-decision making.

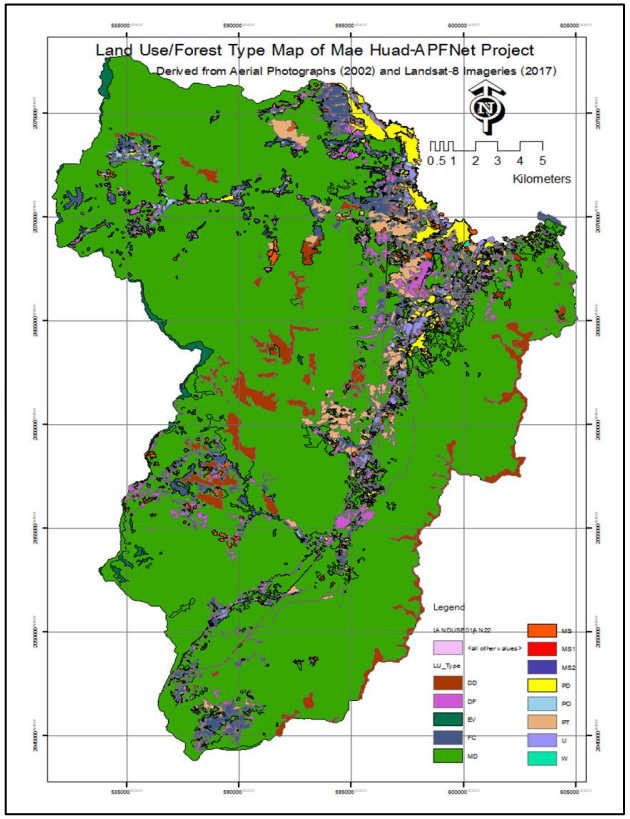
Specific Objective

- To demonstrate the development of accurate standing tree-carbon equation and their application to the preparation of a forest-cover carbon stock map.

Project Site

Ngao Demonstration Forest





Mae Huad Sector

Total area: 43,431.75 hectares

Research Methodology

Activities	Techniques	Outputs
1 Review secondary data	Basic literature review	- Ngao Demonstration Forest - Wood density - Existing carbon/biomass equations and wood carbon fraction, etc.
2 Field forest inventory for Species list collection	- Landuse cartography - Forest Inventory - Point sampling - Tree identification - Forest mensuration	Primary data: - Study site map - DBH, Height, BA - No. of trees - Tree species - Geographical data

Research Methodology (cont.)

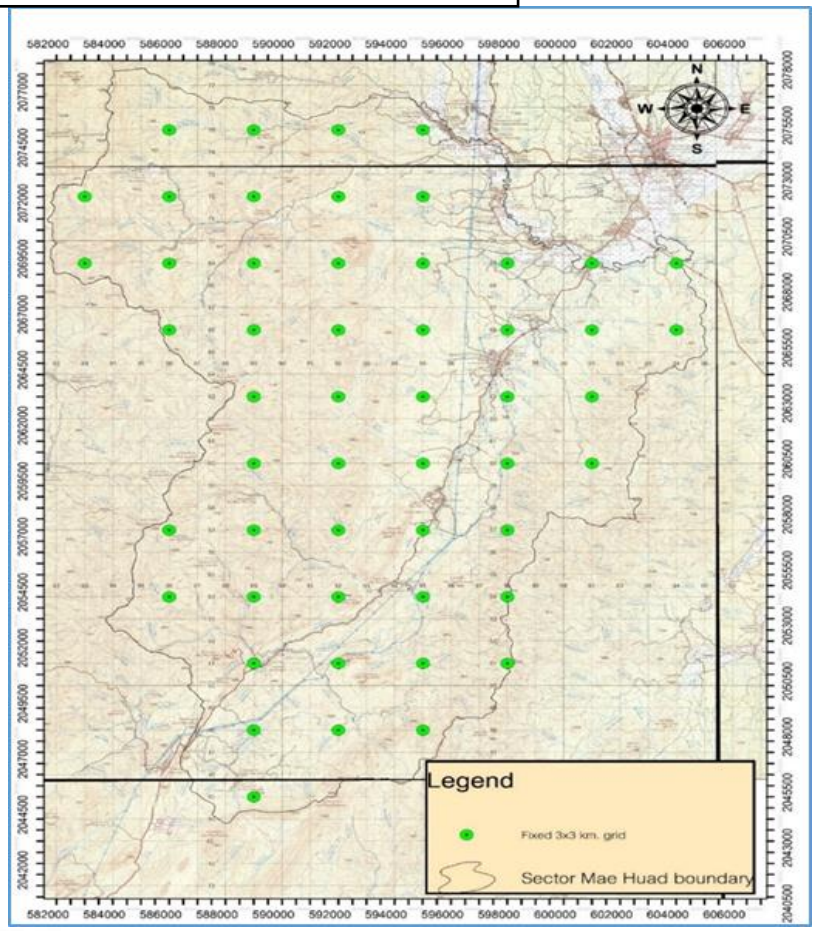
	Activities	Techniques	Outputs
3	Tree species classification	Classification using - Wood density - IVI	Species selection by wood density and IVI in each forest type
4	Sample Tree Collection for tree volume and wood carbon fraction analysis	- Forest Inventory - Forest Mensuration - Dendrochronology	- Tree Volume - Wood sample core for carbon fraction analysis
5	Wood Carbon fraction analysis	- Combustion Technique	- Wood carbon fraction

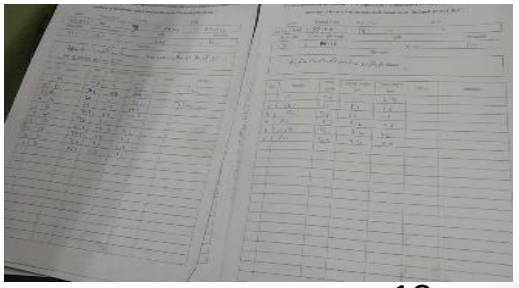
Research Methodology (cont.)

Activities	Techniques	Outputs
6 Construct Standing Tree Bole Carbon Equation	- Regression Analysis	- Standing Tree Bole Carbon Equations
7 Estimation of carbon sequestration in study area	- Statistical analysis	- Carbon Sequestration in study area

Field Forest Inventory for Species List Collection

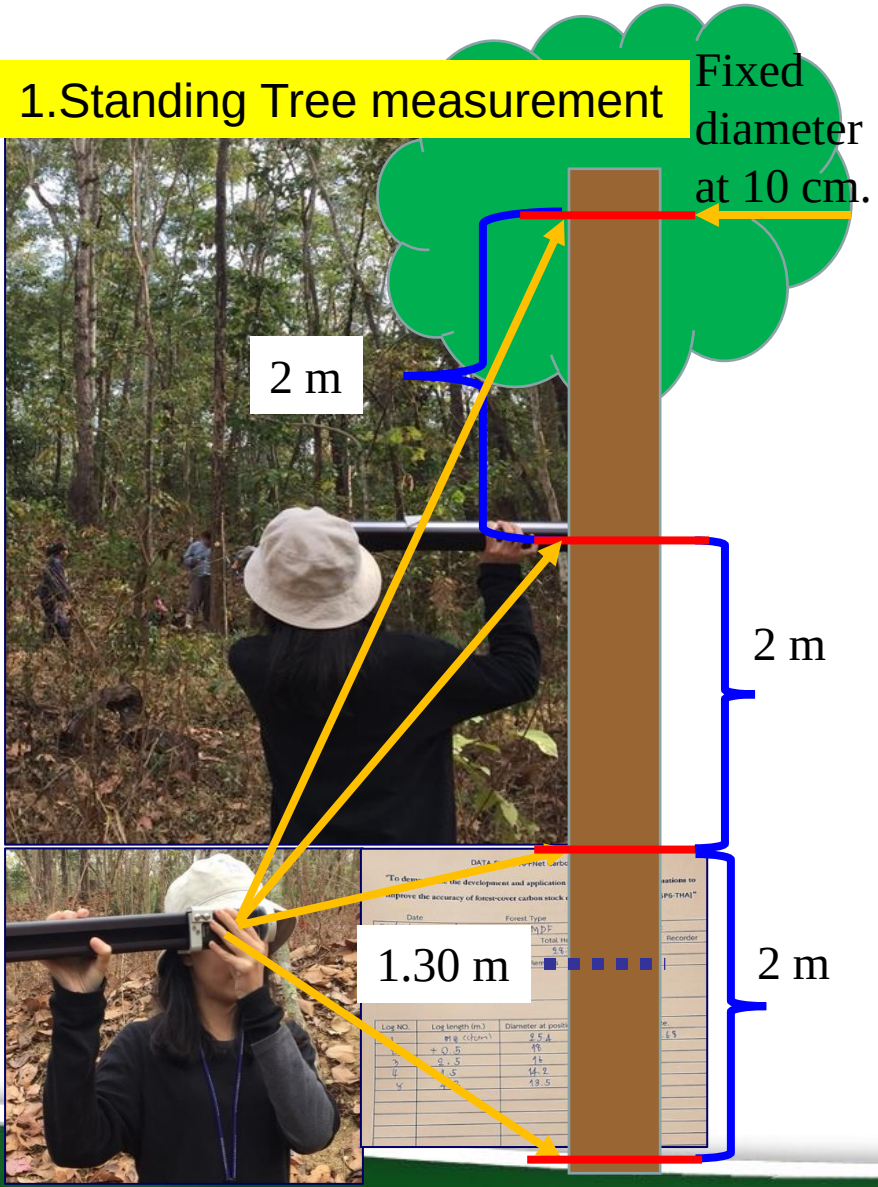
-3 x 3 km fixed point
-54 sampling points





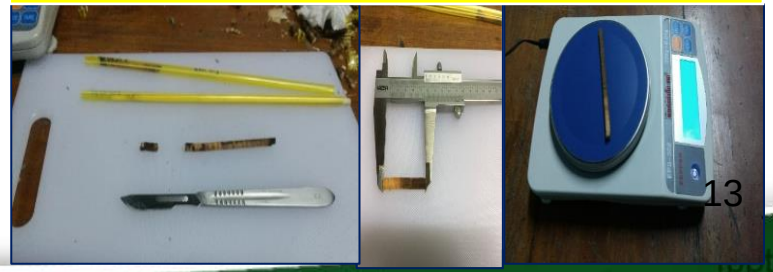
Field Forest Inventory for Sample Tree Collection

1.Standing Tree measurement



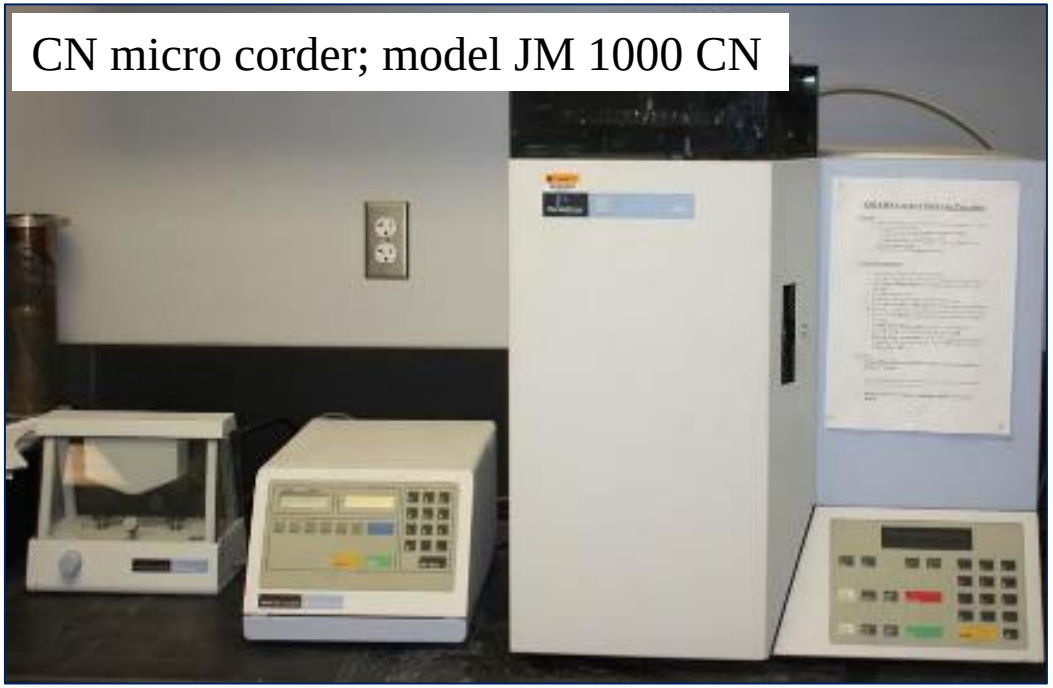
2. Sample wood collection

3.Sample wood measurement



Wood Carbon Fraction Analysis

CN micro corder; model JM 1000 CN



Construct Standing Tree Bole Carbon Equation

The standing tree bole carbon

$$C_c = W_d \times C_w$$

Where :
- C_t = Weight of carbon in a standing tree bole (kg)
- C_c = Weight of carbon in a wood sample core (kg)
- W_d = Dry weight of a wood sample core (kg)
- C_w = Percent carbon fraction in a sample wood
- V_w = Volume of wood sample core (m^3)
- V_t = Volume of standing tree bole (m^3)

$$C_t = \frac{C_c}{V_w} \times V_t$$

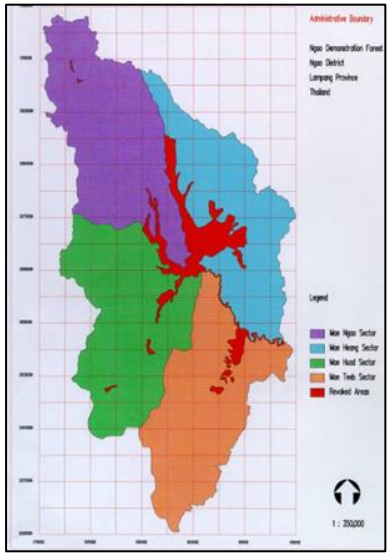
$$C_t \approx f(Height, DBH)$$

*C_t was calculated following the studies of Duangsathaporn et al. (2011) and Kanthawan et al. (2019)

RESULT

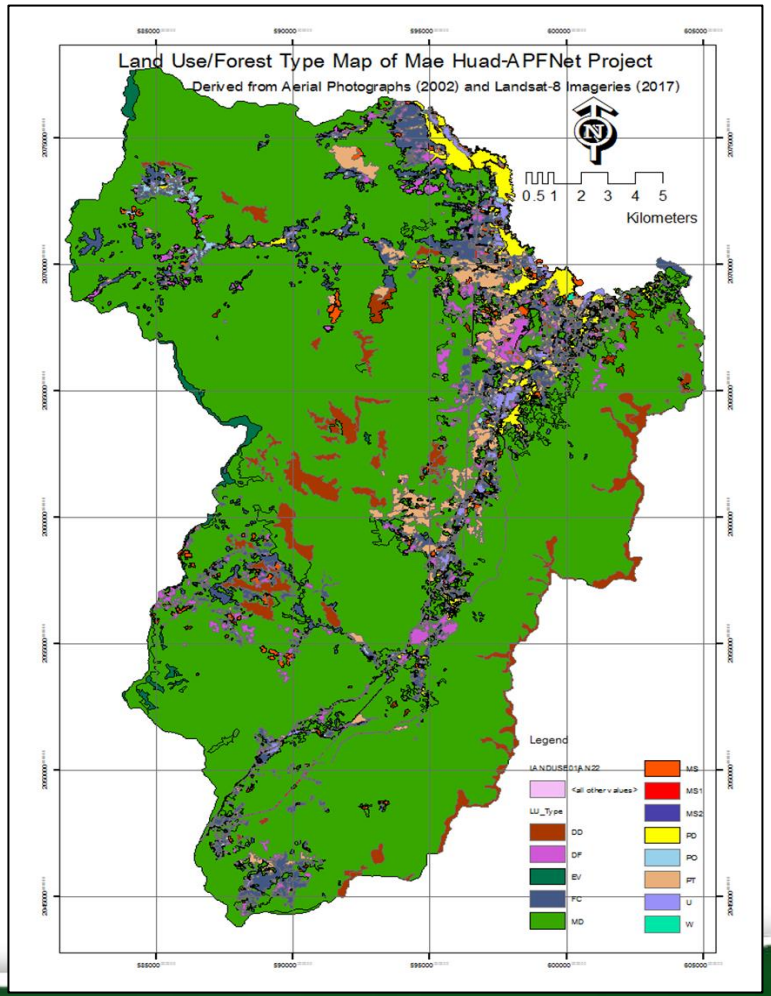
1. General data of Project area

- **Ngao Demonstration Forest**



- **Forest Area 66.28%**
  - EF 2.38%
  - MDF 44.58%
  - DDF13.83%
  - Plantation 5.49%
- **Non-Forest Area 33.72%**
  - Settlement 0.98%
  - Agriculture 4.62%
  - Old clearing 27.9%
  - Deforested area 0.12%
  - Water Bodies 0.03%
  - Mining 0.07%

Sector	Area	
	ha	%
Mae Ngao	44,140.38	25.2
Mae Huad	43,431.75	24.8
Mae Teeb	39,778.56	22.7
Mae Heang	35,624.13	20.3
Non-Model Forest area	12,181.19	7.0
Total	175,156.00	100.0



Notation: DD = Dry Deciduous
DF = Disturbed Forest
EV = Evergreen Forest
FC = Field Crops
MD = Mixed Deciduous
MS = Miscellaneous
MS1= Transmission Line
MS2 = Pave Road
PD = Paddy Land
PO = Fruit Orchard
PT = Teak Plantation
U = Urban Land
W = Water Bodies

RESULT

2. The Field inventory for Species list collection

- Data from filed forest inventory for species list collection

Average BA of 18.39 m^2/ha and 549 tree/ha.

46, 18 and 32 tree species in mixed deciduous forest (MDF) , Dry dipterocarp forest (DDF) and Dry evergreen forest (DEF), respectively.

Tree species with the highest IVI in MDF are *Xylia xylocarpa*, *Tectona grandis* and *Pterocarpus macrocarpus*

Tree species with the highest IVI in DDF are *Shorea siamensis*, *S. obtusa* and *Pterocarpus macrocarpus*

Tree species with the highest IVI in DEF are *Croton Roxburghii*, *Hopea odorata* and *Duabanga grandiflora*

RESULT

4. Wood Carbon fraction analysis

- The wood carbon content of selected species in each wood density class in each forest type

MDF

Range of wood density (kg/m³)	Major Species (Scientific name)	No. of sample trees	Cabon content (%)
282-385	*Cananga latifolia.* Finet & Gagnep.	15	47.75
386-488	*Litsea glutinosa* C.B. Robinson	15	46.86
489-591	*Lannea coromandelica* Merr.	16	45.75
592-694	*Tectona grandis* Linn. f.	16	49.66
695-797	*Albizia odoratissima* Benth.	15	46.84
798-900	*Terminalia nigrovenulosa* Pierre ex Laness.	16	47.13
901-1003	*Pterocarpus macrocarpus* Kurz	15	48.41
1004-1106	*Xylia xylocarpa* Taub.	15	48.03
1107-1209	*Dalbergia oliveri* Gamble.	17	47.13
1210-1312	*Terminalia corticosa* Pierre ex Laness.	15	48.55

DDF

Range of wood density (kg/m³)	Major Species (Scientific name)	No. of sample trees	Cabon content (%)
400-485	*Mitragyna brunonis* Craib	15	47.57
486-570	*Bridelia pierrei* Gagnep.	12	47.16
571-655	*Gardenia sootepensis* Hutch.	15	46.06
656-740	*Haldina cordifolia* (Roxb.) Ridsdale.	15	48.262
741-825	*Dipterocarpus obtusifolius* Teijsm. ex Miq.	15	47.62
826-910	NA		
911-995	*Pterocarpus macrocarpus* Kurz	15	48.41
996-1080	*Shorea siamensis* Miq.	15	46.76
1081-1165	*Dalbergia oliveri* Gamble ex Prain.	17	47.13
1166-1250	*Terminalia corticosa* Pierre ex Laness.	15	48.55

DEF

Range of wood density (kg/m³)	Major Species (Scientific name)	No. of sample trees	Cabon content (%)
387-474	*Duabanga grandiflora* Walp.	15	46.92
475-561	*Croton roxburghii* N.P.Balakr.	15	47.77
562-648	*Careya sphaerica* Roxb.	15	47.47
649-735	*Artocarpus lakoocha* Roxb.	15	48.31
736-822	*Cratoxylum formosum* (Jack) Dyer.	15	46.83
823-909	*Anogeissus acuminata* Wall.	15	46.81
910-996	*Pterocarpus macrocarpus* Kurz	15	48.41
997-1083	*Terminalia nigrovenulosa* Pierre ex Laness.	15	45.75
1084-1170	*Xylia xylocarpa* Taub.	15	48.03
1171-1257	*Quercus kerrii* Craib	15	45.43

RESULT

4. Wood Carbon fraction analysis

- The wood carbon content of selected species in each forest type

Forest Type	Carbon Content (%)	Number of Selected Species	
		$C_w > 47\%$	$C_w < 47\%$
MDF	47.61	7 (70.0%)	3 (30.0%)
DDF	47.50	7 (77.8%)	2 (22.2%)
DEF	47.17	5 (50.0%)	5 (50.0%)
Average	47.43	65.5%	34.5%

Remark: C_w is carbon content in a wood sample (%)

RESULT

5. Construct Standing Tree Bole Carbon Equation

- The carbon equations of selected species in each wood density class by forest types

MDF

No.	Range of Wood Density (kg/m^3)	Carbon Equation	Sample Tree No.
1	282-385	$C = 0.008730\ D^{2.335}\ H^{0.570}$	15
2	386-488	$C = 0.019454\ D^{2.335}\ H^{0.338}$	15
3	489-591	$C = 0.001538\ D^{3.014}\ H^{0.475}$	16
4	592-694	$C = 0.018836\ D^{1.833}\ H^{0.848}$	16
5	695-797	$C = 0.011350\ D^{2.043}\ H^{0.853}$	15
6	798-900	$C = 0.067764\ D^{2.011}\ H^{0.277}$	16
7	901-1003	$C = 0.014093\ D^{2.068}\ H^{0.723}$	15
8	1004-1106	$C = 0.011967\ D^{2.067}\ H^{0.791}$	15
9	1107-1209	$C = 0.017539\ D^{2.276}\ H^{0.547}$	17
10	1210-1312	$C = 0.005957\ D^{2.206}\ H^{0.819}$	15
General equation for all species , MDF		$C = 0.018155\ D^{2.2204}\ H^{0.490}$	155

DEF

No.	Range of Wood density (kg/m^3)	Carbon equation	Sample Tree No.
1	387-474	$C = 0.049317\ D^{1.997}\ H^{0.357}$	15
2	475-561	$C = 0.019498\ D^{2.300}\ H^{0.300}$	15
3	562-648	$C = 0.012134\ D^{2.056}\ H^{0.668}$	15
4	649-735	$C = 0.001549\ D^{2.608}\ H^{0.854}$	15
5	736-822	$C = 0.003192\ D^{2.374}\ H^{0.876}$	15
6	823-909	$C = 0.015560\ D^{2.109}\ H^{0.625}$	15
7	910-996	$C = 0.014093\ D^{2.068}\ H^{0.723}$	15
8	997-1083	$C = 0.002624\ D^{2.263}\ H^{1.086}$	15
9	1084-1170	$C = 0.049317\ D^{1.997}\ H^{0.357}$	15
10	1171-1257	$C = 0.006353\ D^{2.482}\ H^{0.609}$	15
General equation for all species , DEF		$C = 0.011803\ D^{2.1844}\ H^{0.417}$	150

DDF

No.	Range of Wood Density (kg/m^3)	Carbon Equation	Sample Tree No.
1	400-485	$C = 0.006353\ D^{2.227}\ H^{0.802}$	15
2	486-570	$C = 0.004887\ D^{2.618}\ H^{0.438}$	12
3	571-655	$C = 0.020417\ D^{2.237}\ H^{0.696}$	15
4	656-740	$C = 0.001928\ D^{2.664}\ H^{0.679}$	15
5	741-825	$C = 0.000975\ D^{2.389}\ H^{1.277}$	15
6	826-910	NA	
7	911-995	$C = 0.014093\ D^{2.068}\ H^{0.723}$	15
8	996-1080	$C = 0.022751\ D^{2.209}\ H^{0.458}$	15
9	1081-1165	$C = 0.017539\ D^{2.276}\ H^{0.547}$	17
10	116-1250	$C = 0.005957\ D^{2.206}\ H^{0.819}$	15
General equation for all species , DDF		$C = 0.009462\ D^{2.328}\ H^{0.602}$	134

The general tree carbon equation is as follows:

$$C = 0.012348\ D^{2.1676}\ H^{0.6539}$$

Where:

C = Carbon sequestration in stem bole, kg

D = Diameter at breath height of the tree, cm

H = Total height of the tree, m

RESULT

6. Estimation of carbon sequestration in Mae huad sector, Ngao demonstration forest.

DDF

- Basal Area = 36.0 m^2/ha
- No. of Trees = 740 tree/ha
- Carbon sequestration = 77.21 ton/ha

MDF

- Basal Area = 20.9 m^2/ha
- No. of Trees = 783 tree/ha
- Carbon sequestration = 39.88 ton/ha

DEF

- Basal Area = 15.0 m^2/ha
- No. of Trees = 87 tree/ha
- Carbon sequestration = 8.54 ton/ha

TOTAL AREA

- Basal Area = 22.7 m^2/ha
- No. of Trees = 662 tree/ha
- C Sequestration = 40.97 ton/ha

RESULT

- The total carbon stock in Ngao Demonstration Forest is ranged from 0.88 – 1.28 million tons

DDF carbon stock ranged for 0.19 – 0.29 million tons

MDF carbon stock ranged from 0.64 – 0.94 million tons

DEF carbon stock ranged from 0.03 – 0.05 million tons

Action plan to construct and promote national tree carbon equations prepared

Focus Group Meeting : 7 November 2018 At Meeting Room 303, 60 Years Anniversary Building, Faculty of Forestry, Kasetsart University, BKK

15 Experts from:

- RFD
- DNP
- DMCR
- FIO
- RECOFT
- TGO
- Universities

Action plan to construct and promote national tree carbon equations prepared

The Way Forward the National Plan

1. The participants of Focus Group meeting agreed to continue the project in order to apply these techniques and carbon equations for calculating carbon sequestration in national forests.

2. The participants also suggested to expand the study sites into all regions and all forest types of Thailand.

3. In order to succeed at the national scale, the participants suggested close cooperation among the relevant organizations and experts to apply and upscale this research methodology to develop national carbon equations and carbon map to support the national plan on forest management.

Action plan to construct and promote national tree carbon equations prepared

PROJECT STRATEGY AND ACTIVITIES OF THE NATIONAL WORK PLAN

There are 3 steps to scaling-up the project to the national level. These are:

1. Divide the country into five geographic regions (north, north-east, east, west & central, and south), and consider the forest types within each region.
2. Apply the 2015P6-THA project methodology to obtain new tree carbon equations and maps for each forest type within each region. Refer to 2015P6-THA project Technical Reports No. 1 and No. 2.
3. Promote the new national carbon equations (2015P6-THA project), and get the new tree carbon equations and maps formally approved on the national level and incorporated into the IPCC reporting process.

Information and knowledge from the project disseminated among stakeholders

- The Workshop
- The Project Website
- The Project Brochure
- The Training Course

Information and knowledge from the project disseminated among stakeholders

- The Workshop **18 December 2018,** Kasetsart University, BKK

The Workshop aim to:

1. Provide a better understanding and transfer of knowledge of carbon estimation in a standing tree and forest stand by using novel carbon equations and remote sensing techniques.

2. Discuss a national work plan on the development of national standing-tree carbon equations and forest carbon stock map to improve the accuracy of tree-bole carbon stock estimates in Thailand.

Information and knowledge from the project disseminated among stakeholders

- The Workshop **18 December 2018,** Kasetsart University, BKK



42 Participants from

- RFD
- DMCR
- GISDA
- FIO
- TEI
- TGO
- BEDO
- DNP
- Universities
- ONEP
- FAO





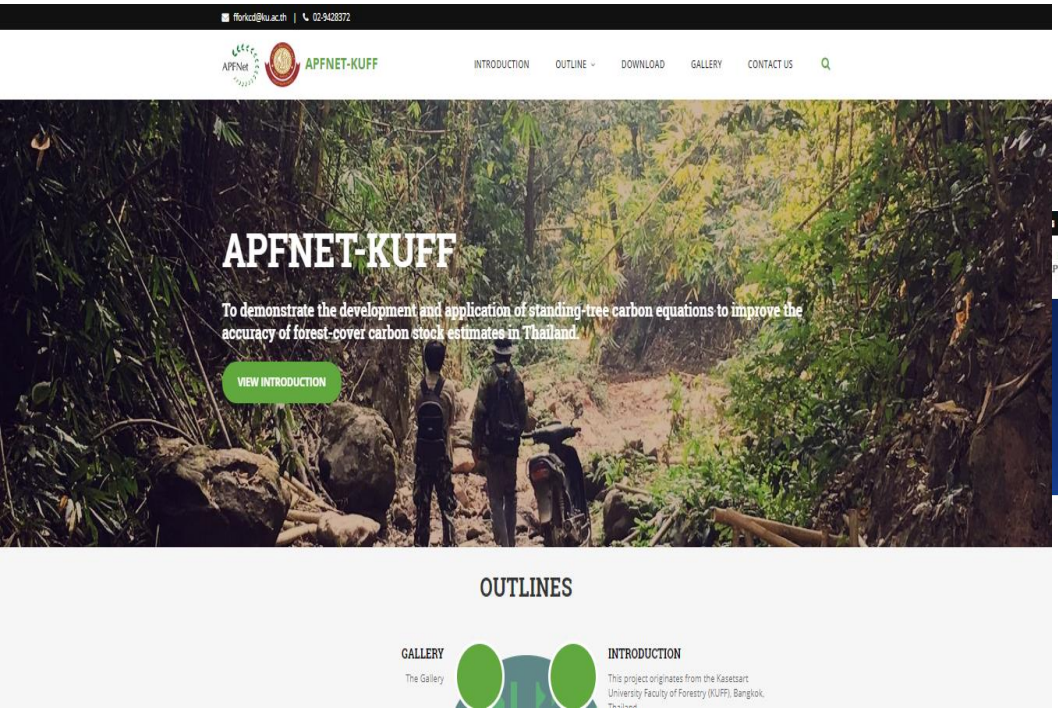


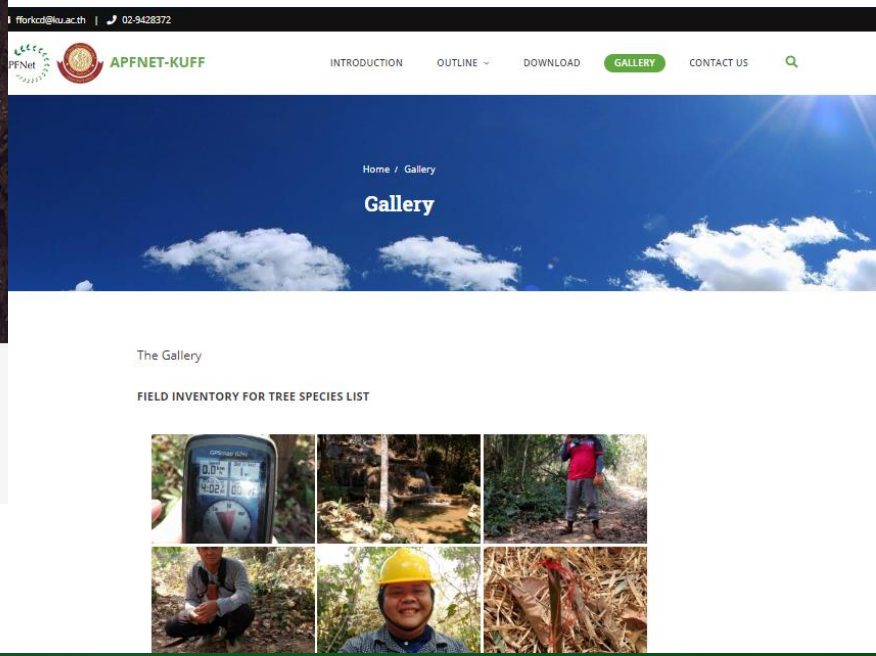




Information and knowledge from the project disseminated among stakeholders

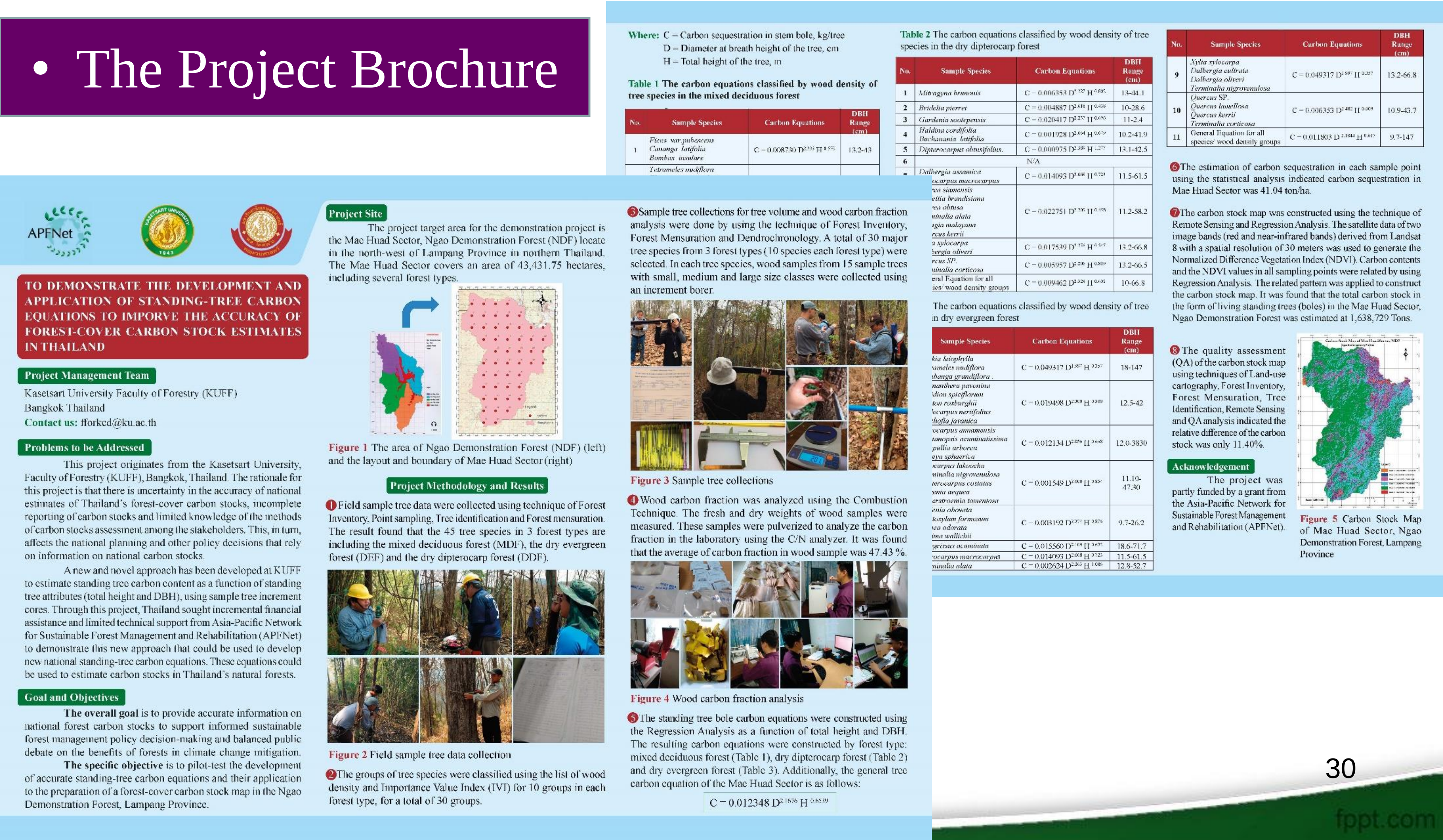
- The Project Website url: http:www.apfnet-kuff.com





Information and knowledge from the project disseminated among stakeholders

- The Project Brochure



Where: C – Carbon sequestration in stem bole, kg/tree
D – Diameter at breath height of the tree, cm
H – Total height of the tree, m

Table 1 The carbon equations classified by wood density of tree species in the mixed deciduous forest

No.	Sample Species	Carbon Equations	DBH Range (cm)
1	*Ficus var.pubescens* *Cananga latifolia* *Bombax insulare*	$C = 0.008730 D^{2.335} H^{0.570}$	13.2-43
	Tetrameles nudiflora		

Table 2 The carbon equations classified by wood density of tree species in the dry dipterocarp forest

No.	Sample Species	Carbon Equations	DBH Range (cm)
1	*Mitragyna brunonis*	$C = 0.006353 D^{2.327} H^{0.836}$	13-44.1
2	*Bridelia pierrei*	$C = 0.004887 D^{2.618} H^{0.438}$	10-28.6
3	*Gardenia sootepensis*	$C = 0.020417 D^{2.237} H^{0.696}$	11-2.4
4	*Haldina cordifolia* *Buchanania latifolia*	$C = 0.001928 D^{2.664} H^{0.679}$	10.2-41.9
5	*Dipterocarpus obtusifolius.*	$C = 0.000975 D^{2.308} H^{1.277}$	13.1-42.5
6	N/A		
	Dalbergia assamica *...ocarpus macrocarpus*	$C = 0.014093 D^{2.068} H^{0.723}$	11.5-61.5
	...rea siamensis *...ettia brandisiana* *...rea obtusa* *...minalia alata* *...gia malayana* *...rcus kerrii*	$C = 0.022751 D^{2.206} H^{0.158}$	11.2-58.2
	...a xylocarpa *...bergia oliveri*	$C = 0.017539 D^{2.276} H^{0.547}$	13.2-66.8
	...rcus SP. *...inalia corticosa*	$C = 0.005957 D^{2.206} H^{0.819}$	13.2-66.5
	...eral Equation for all ...ies/ wood density groups	$C = 0.009462 D^{2.328} H^{0.602}$	10-66.8

The carbon equations classified by wood density of tree ... in dry evergreen forest

Sample Species	Carbon Equations	DBH Range (cm)
...kia leiophylla *...ameles nudiflora* *...banga grandiflora .*	$C = 0.049317 D^{1.997} H^{0.257}$	18-147
...nanthera pavonina *...idion spicflorum* *...ton roxburghii* *...locarpus neriifolius* *...hofia javanica*	$C = 0.019498 D^{2.309} H^{0.309}$	12.5-42
...ocarpus annamensis *...tanopsis acuminatissima* *...pallia arborea* *...eya sphaerica*	$C = 0.012134 D^{2.056} H^{0.668}$	12.0-3830
...ocarpus lakoocha *...minalia nigrovenulosa* *...terocarpus costatus* *...enia aequea* *...erstroemia tomentosa*	$C = 0.001549 D^{2.609} H^{0.854}$	11.10-47.30
...enia obovata *...toxylum formosum* *...ea odorata* *...ima wallichii*	$C = 0.003192 D^{2.271} H^{0.876}$	9.7-26.2
...geissus acuminata	$C = 0.015560 D^{2.169} H^{0.625}$	18.6-71.7
...ocarpus macrocarpus	$C = 0.014093 D^{2.068} H^{0.723}$	11.5-61.5
...minalia alata	$C = 0.002624 D^{2.263} H^{1.086}$	12.8-52.7

No.	Sample Species	Carbon Equations	DBH Range (cm)
9	*Xylia xylocarpa* *Dalbergia cultrata* *Dalbergia oliveri* *Terminalia nigrovenulosa*	$C = 0.049317 D^{1.997} H^{0.257}$	13.2-66.8
10	*Quercus SP.* *Quercus lamellosa* *Quercus kerrii* *Terminalia corticosa*	$C = 0.006353 D^{2.482} H^{0.609}$	10.9-43.7
11	General Equation for all species/ wood density groups	$C = 0.011803 D^{2.1844} H^{0.617}$	9.7-147

❻ The estimation of carbon sequestration in each sample point using the statistical analysis indicated carbon sequestration in Mae Huad Sector was 41.04 ton/ha.

❼ The carbon stock map was constructed using the technique of Remote Sensing and Regression Analysis. The satellite data of two image bands (red and near-infrared bands) derived from Landsat 8 with a spatial resolution of 30 meters was used to generate the Normalized Difference Vegetation Index (NDVI). Carbon contents and the NDVI values in all sampling points were related by using Regression Analysis. The related pattern was applied to construct the carbon stock map. It was found that the total carbon stock in the form of living standing trees (boles) in the Mae Huad Sector, Ngao Demonstration Forest was estimated at 1,638,729 Tons.

❽ The quality assessment (QA) of the carbon stock map using techniques of Land-use cartography, Forest Inventory, Forest Mensuration, Tree Identification, Remote Sensing and QA analysis indicated the relative difference of the carbon stock was only 11.40%.

Acknowledgement

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Figure 5 Carbon Stock Map of Mae Huad Sector, Ngao Demonstration Forest, Lampang Province

APFNet

TO DEMONSTRATE THE DEVELOPMENT AND APPLICATION OF STANDING-TREE CARBON EQUATIONS TO IMPORVE THE ACCURACY OF FOREST-COVER CARBON STOCK ESTIMATES IN THAILAND

Project Management Team

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Problems to be Addressed

This project originates from the Kasetsart University, Faculty of Forestry (KUFF), Bangkok, Thailand. The rationale for this project is that there is uncertainty in the accuracy of national estimates of Thailand's forest-cover carbon stocks, incomplete reporting of carbon stocks and limited knowledge of the methods of carbon stocks assessment among the stakeholders. This, in turn, affects the national planning and other policy decisions that rely on information on national carbon stocks.

A new and novel approach has been developed at KUFF to estimate standing tree carbon content as a function of standing tree attributes (total height and DBH), using sample tree increment cores. Through this project, Thailand sought incremental financial assistance and limited technical support from Asia-Pacific Network for Sustainable Forest Management and Rehabilitation (APFNet) to demonstrate this new approach that could be used to develop new national standing-tree carbon equations. These equations could be used to estimate carbon stocks in Thailand's natural forests.

Goal and Objectives

The overall goal is to provide accurate information on national forest carbon stocks to support informed sustainable forest management policy decision-making and balanced public debate on the benefits of forests in climate change mitigation.

The specific objective is to pilot-test the development of accurate standing-tree carbon equations and their application to the preparation of a forest-cover carbon stock map in the Ngao Demonstration Forest, Lampang Province.

Project Site

The project target area for the demonstration project is the Mae Huad Sector, Ngao Demonstration Forest (NDF) locate in the north-west of Lampang Province in northern Thailand. The Mae Huad Sector covers an area of 43,431.75 hectares, including several forest types.

Figure 1 The area of Ngao Demonstration Forest (NDF) (left) and the layout and boundary of Mae Huad Sector (right)

Project Methodology and Results

❶ Field sample tree data were collected using technique of Forest Inventory, Point sampling, Tree identification and Forest mensuration. The result found that the 45 tree species in 3 forest types are including the mixed deciduous forest (MDF), the dry evergreen forest (DEF) and the dry dipterocarp forest (DDF).

Figure 2 Field sample tree data collection

❷ The groups of tree species were classified using the list of wood density and Importance Value Index (IVI) for 10 groups in each forest type, for a total of 30 groups.

❸ Sample tree collections for tree volume and wood carbon fraction analysis were done by using the technique of Forest Inventory, Forest Mensuration and Dendrochronology. A total of 30 major tree species from 3 forest types (10 species each forest type) were selected. In each tree species, wood samples from 15 sample trees with small, medium and large size classes were collected using an increment borer.

Figure 3 Sample tree collections

❹ Wood carbon fraction was analyzed using the Combustion Technique. The fresh and dry weights of wood samples were measured. These samples were pulverized to analyze the carbon fraction in the laboratory using the C/N analyzer. It was found that the average of carbon fraction in wood sample was 47.43 %.

Figure 4 Wood carbon fraction analysis

❺ The standing tree bole carbon equations were constructed using the Regression Analysis as a function of total height and DBH. The resulting carbon equations were constructed by forest type: mixed deciduous forest (Table 1), dry dipterocarp forest (Table 2) and dry evergreen forest (Table 3). Additionally, the general tree carbon equation of the Mae Huad Sector is as follows:

$$C = 0.012348 D^{2.1676} H^{0.6589}$$

Information and knowledge from the project disseminated among stakeholders

- Training Course

18-22 March 2019 at Hat Wanakorn National Park, Prachuap Khiri Khan, Thailand

"Forest inventory for estimation of carbon sequestration" to 60 DNP Staffs






Under the project: **To demonstrate the development and application of standing-tree carbon equations to improve the accuracy of forest-cover carbon stock estimates in Thailand**

Information and knowledge from the project disseminated among stakeholders

- Training Course

- Planning for further knowledge transferring to other relevant organizations

- ROYAL FOREST DEPARTMENT

- THAILAND GREENHOUSE GAS MANAGEMENT ORGANIZATION (PUBLIC ORGANIZATION)

- DEPARTMENT OF MARINE AND COASTAL RESOURCES

- FOREST INDUSTRTY ORGANISATION

Conclusions

- **The standing tree bole carbon equation**

Twenty-four carbon equations classified by wood density class in each forest type

Three carbon equation classified by forest types of MDF, DDF, DEF.

A general tree carbon equation in the Mae Huad Sector is as follows: $C = 0.012348D^{2.1676}H^{0.6539}$

- **The total carbon stock in Ngao Demonstration Forest is ranged for 0.88 – 1.28 million tons**

DDF carbon stock is ranged for 0.19 – 0.29 million tons

MDF carbon stock is ranged for 0.64 – 0.94 million tons

DEF carbon stock is ranged for 0.03 – 0.05 million tons

- **Promote the new national carbon equations (2015P6-THA project) and get the new tree carbon equations and maps formally approved on the national level and incorporated into the IPCC reporting process.**

Thank you