Development of Forest Biomass Estimation Model to Monitor Carbon Stocks Change in Thailand

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Geo-informatics and Space Technology Development Agency; GISTDA

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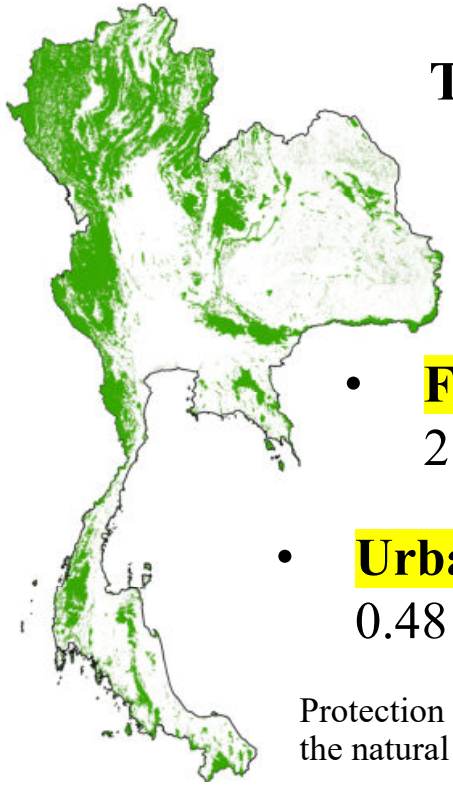
1. Introduction

Carbon neutrality and net-zero -- the 26th Conference of the Parties – COP26, Thailand has set goals for becoming carbon neutrality and net-zero by 2050 and 2065 respectively.

Thailand government has assigned various sectors to establish the activities for accomplishing the goal of reducing greenhouse gases emission into the atmosphere.

Thailand has set up the commitment to increase forest cover of the country to achieve 55% of the total country area under the 20-Year National Strategic Plan (2018-2037)



The 20-year National Strategy (2018-2037)

- **Natural forest** (conservation, national forest, mangrove forest, community forest etc.)
  1.8 million hectare
- **Forest plantation** (economic crop)
  2.56 million hectare
- **Urban/rural** (green area)
  0.48 million hectare

4.85 million hectare

Protection of forest encroachment in the natural forest and wildfire.

2. Aims of the project

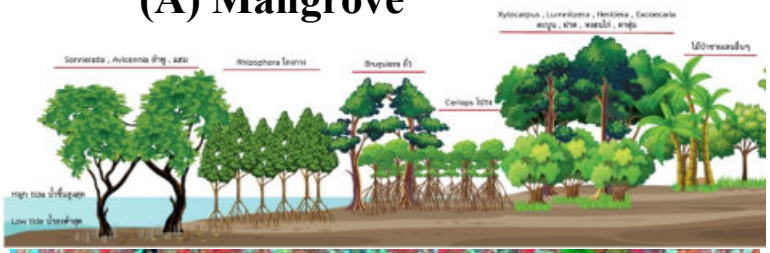
2.1 To perform the estimation of Aboveground biomass; *AGB* (carbon) model for Thailand.

2.2 To develop the system to investigate the potential areas for enhancing carbon stocks in forested areas.

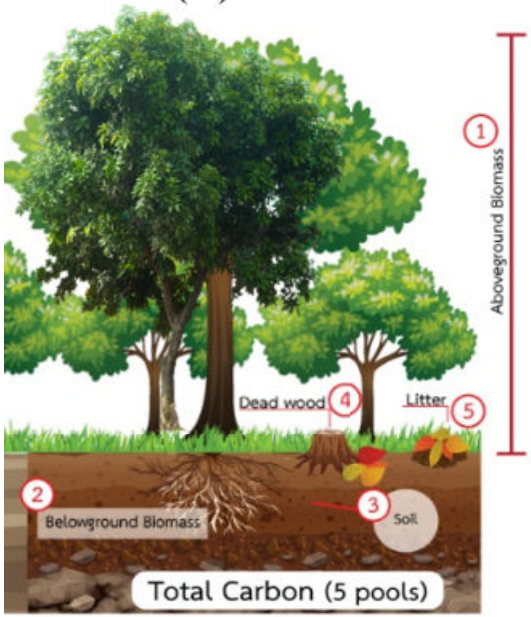
2.3 To support information to government for achieving the goal to reduce greenhouse gases emission in LULC change and forest sector.

Carbon pool (five pools)

(A) Mangrove



(B) Forest



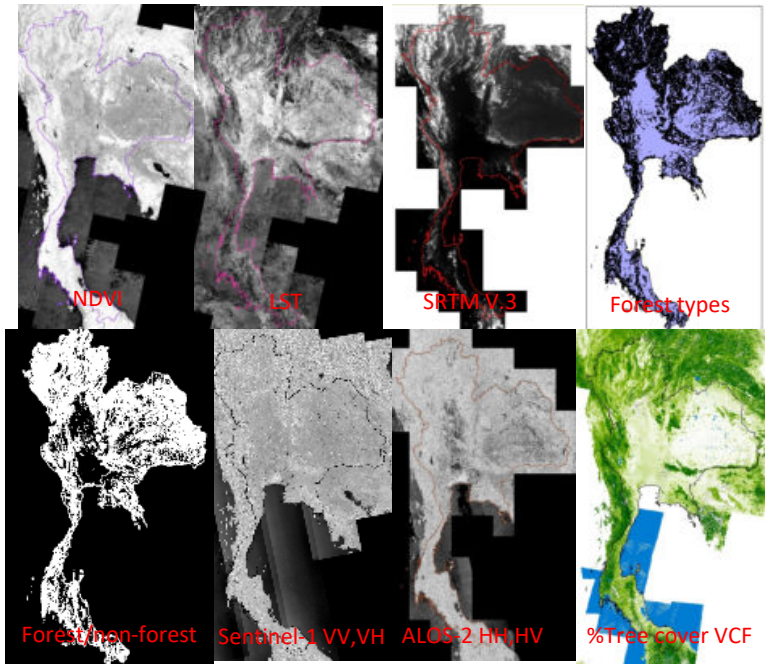
Pool		Description
Living Biomass	**Above-ground Biomass (AGB)**	All living biomass above the ground including stems, stumps, braches, bark, seeds and foliage
	Below-ground Biomass (BGB)	All living biomass comprising of live roots. fine roots of less than 2mm diameter are often excluded in the BGB.
Dead Organic Matter (DOM)	**Dead Wood**	Dead wood includes all non-living woody biomass not contained in the litter (standing, lying or in the soil) and is comprised of dead root and stump larger than 10 cm in diameter.
	Litter	Litter comprises all non-living biomass with a diameter of less than a minimum diameter chosen by the country in question (for example 10 cm), lying dead in various states of decomposition above the mineral or organic soil and litter, fumic and humic Layers.
Soils organic matter (SOM)	**Soil Organic Matter**	Soil organic matter consists of organic carbon in mineral, organic soil or peat soil, with the specified depth chosen by the country in question and applied consistently through the time series.

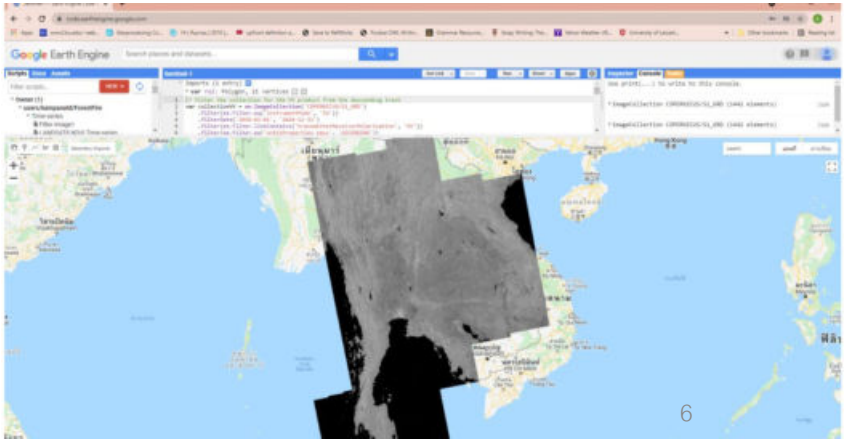
"AGB" can mean the dry mass of living biomass above the ground or carbon per unit ($t\ ha^{-1}$ or $t\ C\ ha^{-1}$).

3. Development model/ Dataset/ Methodology

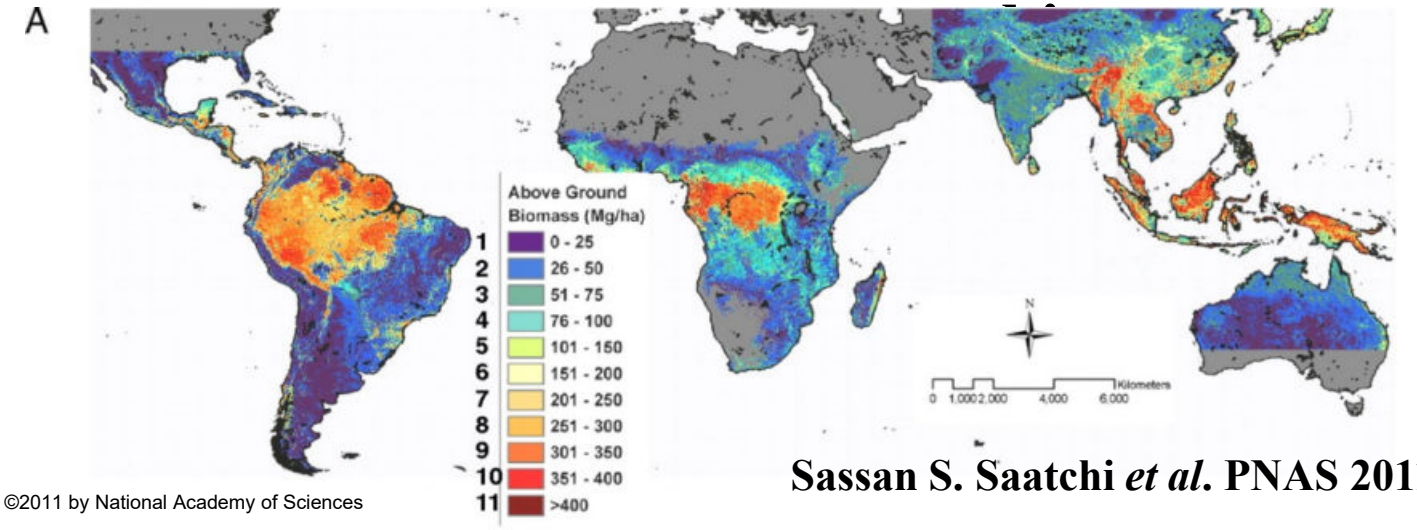
List of spatial datasets used in this project

Variable factors	
SAR L-band Backscatter intensity	ALOS-2
SAR C-band backscatter intensity	Sentinel-1
SAR C-band Coherence	Sentinel-1
Biophysical parameter	Sentinel-2 (LAI, fapar, fcover)
SRTM (Elevation, Slope, Aspect)	SRTM V.3
%Tree cover Landsat VCF	LANDSAT-7
Forest height	GEDI
Land surface temperature	LANDSAT-8
NDVI	LANDSAT-8
Forest types	RFD
Forest inventory plots	DNP



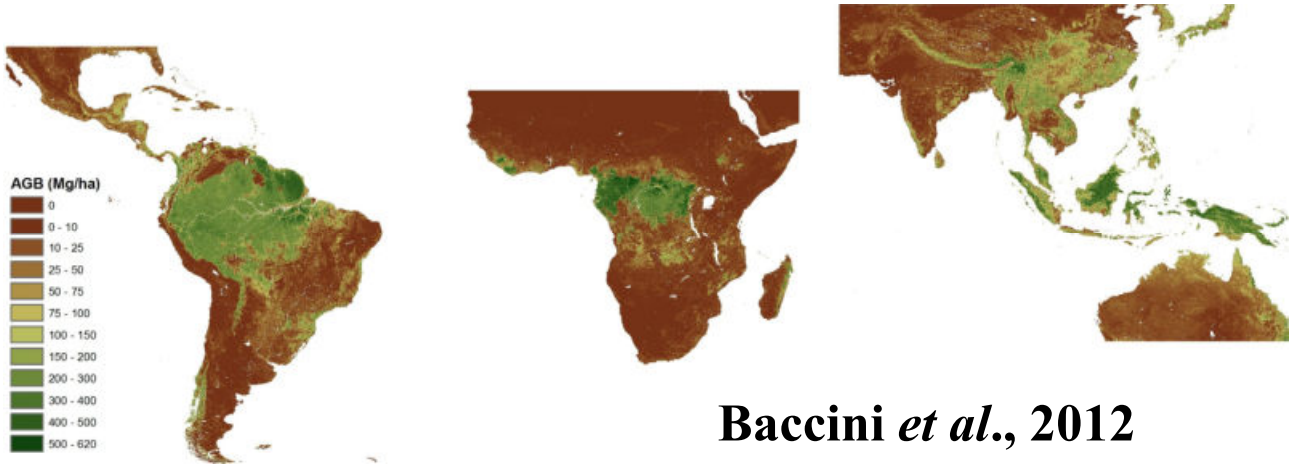


Distribution of forest aboveground



MaxEnt approach

Sassan S. Saatchi *et al.* PNAS 2011;108:9899-9904



Random forest

Baccini *et al.*, 2012

MaxEnt approach

Benchmark map of **forest** carbon stocks in tropical regions across three continents

SS Saatchi, NL Harris, S Brown… - Proceedings of the …, 2011 - National Acad Sciences

… to produce robust estimates of **forest** carbon stocks for … a "**benchmark**" **map** of biomass carbon stocks over 2.5 billion ha of **forests** on three continents, encompassing all tropical **forests**, …

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Estimated carbon dioxide emissions from tropical deforestation improved by **carbon**-density maps

A Baccini, SJ Goetz, WS Walker, NT Laporte… - Nature climate …, 2012 - nature.com

… **estimates** of aboveground **carbon** stocks with regional deforestation rates 4 we **estimate** the total net **emission** of **carbon** … –2010—based on the **carbon** bookkeeping model. These new …

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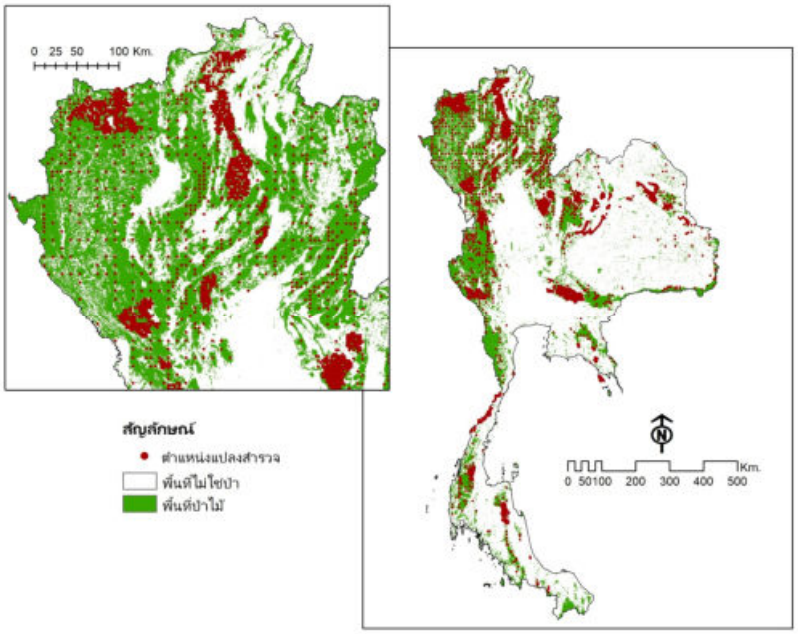
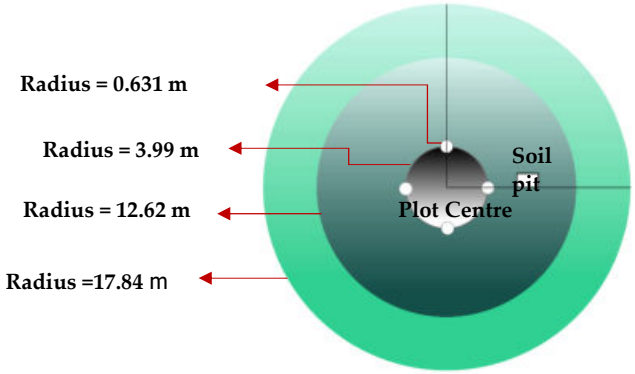
Random forest model



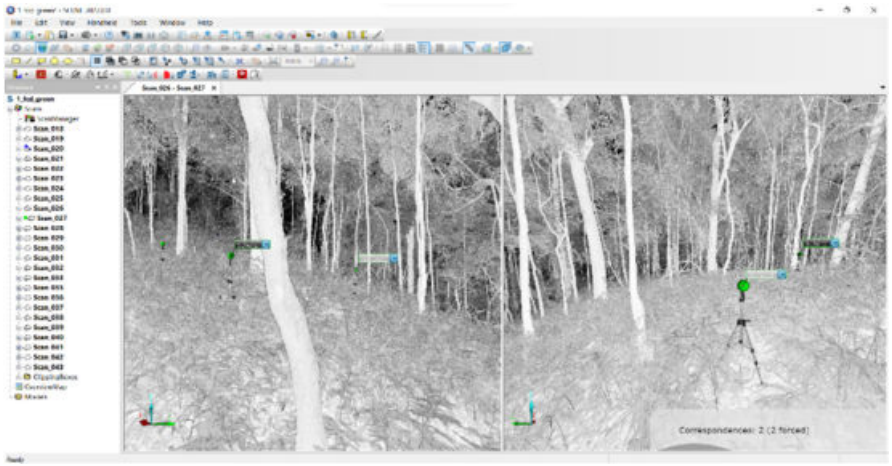
Forest plots 2010-2016 (DNP)

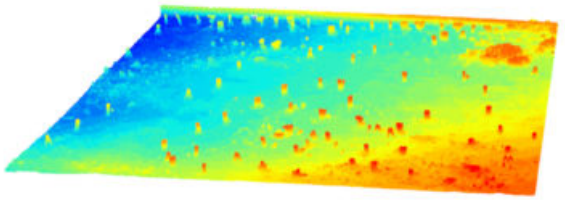
Forest inventory plots data were obtained from the forest resources inventory group DNP. Each of forest plots representing an area of 0.1 hectare or 1000 m^2. **(3,649 plots)**

- training model **3,044 plots**
- testing model **605 plots**

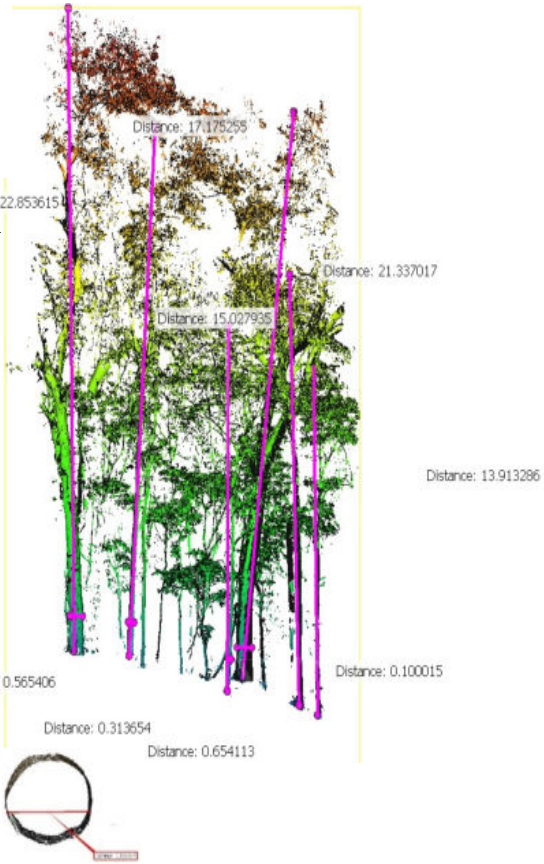


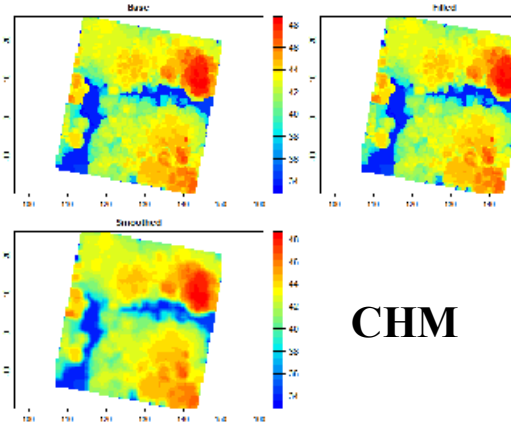
Terrestrial Laser Scanner; TLS (3D Scanner)



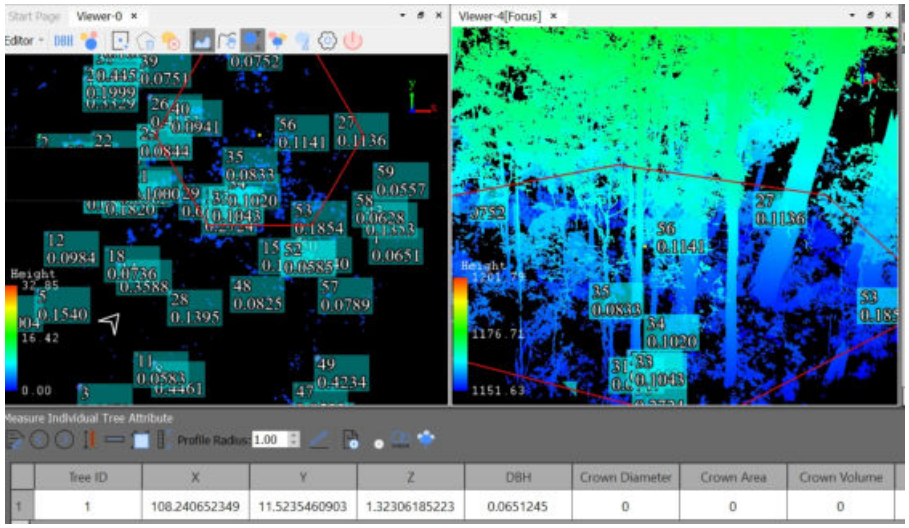


Ground Surface Classification

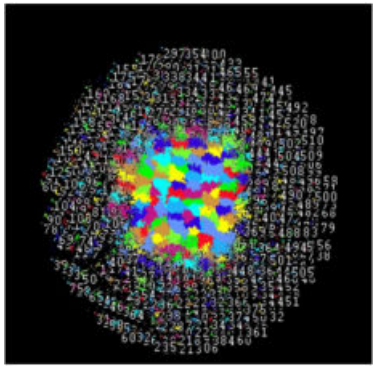


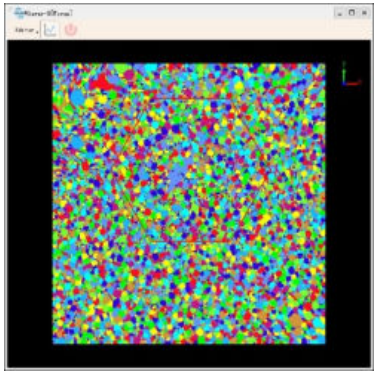


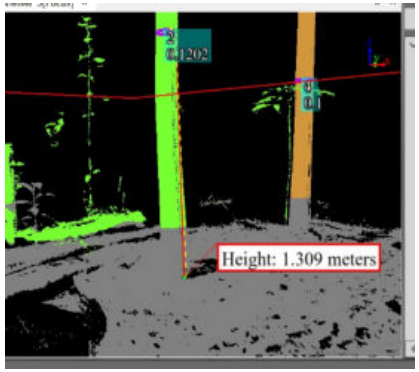
CHM

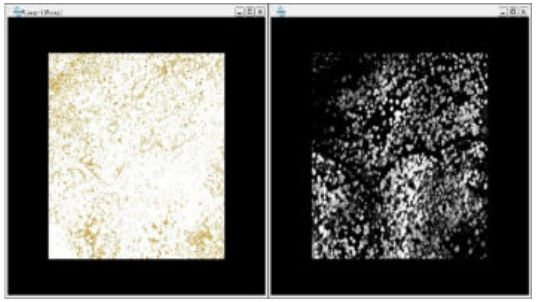


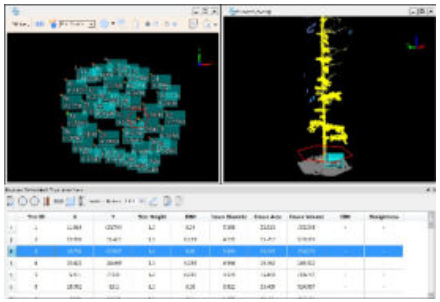
Tree ID	X	Y	Z	DBH	Crown Diameter	Crown Area	Crown Volume
1	108.240652349	11.5235460903	1.32306185223	0.0651245	0	0	0

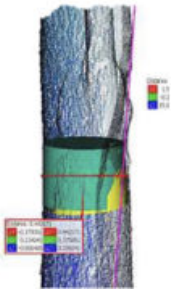


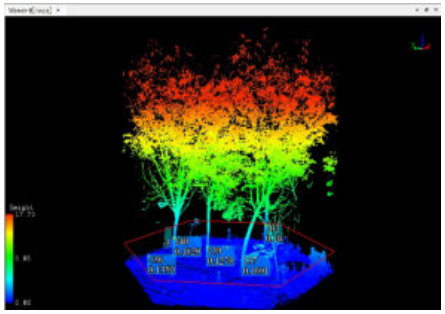


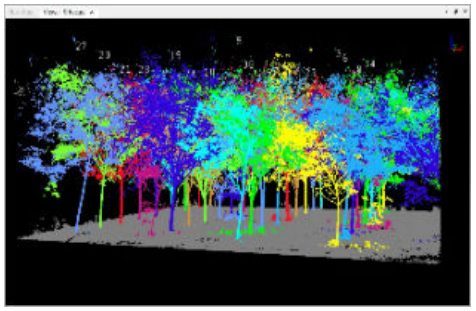












ภาพที่ 1 ตัวอย่างการวางแปลงสำรวจขนาด 20x20 เมตร เพื่อเก็บข้อมูลความโต ความสูงของต้นไม้ด้วยเครื่อง TLS

ภาพที่ 3 การเก็บข้อมูลในพื้นที่ป่าธรรมชาติ และสวนยางพาราด้วยเครื่อง TLS ซึ่งต้องคำนึงถึงตำแหน่งของ sphere น้อย 3 ตำแหน่ง ให้สามารถครอบคลุมในแต่ละตั้งของการสแกน

The development of *AGB* model using machine learning

Total carbon storage over forested areas and rubber plantation **1,103.6** m tCO_2e

Natural forest
889.2 m tCO_2e

Rubber plantation
214.4 m tCO_2e

Evergreen forest
460.9 m tCO_2e

Deciduous forest
428.3 m tCO_2e

หมายเหตุ ปริมาณการสะสมคาร์บอนที่ได้จากแบบจำลองยังเป็นตัวเลขประมาณการ เนื่องจากยังอยู่ในระหว่างการพัฒนา

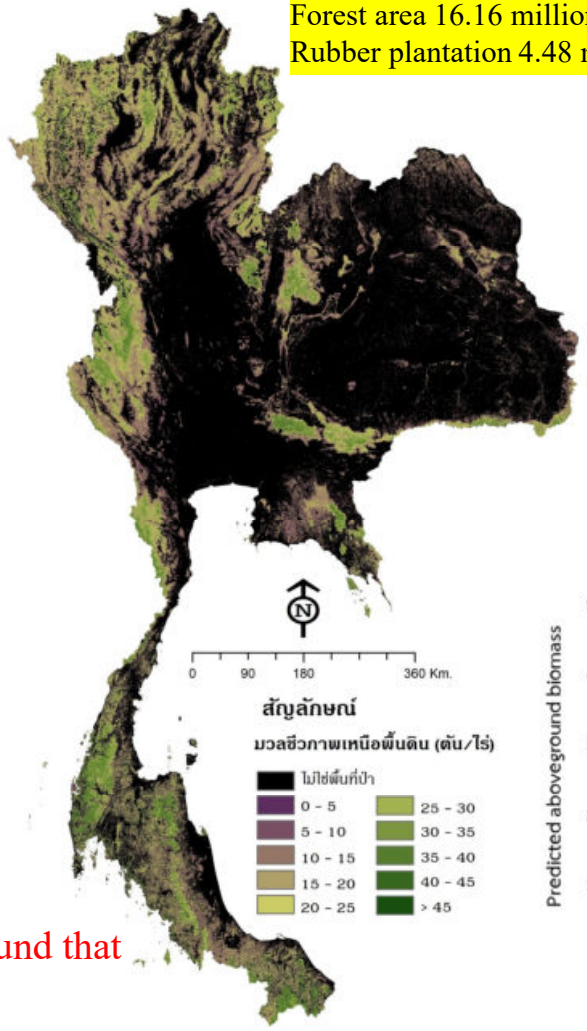
เพื่อให้ได้ความถูกต้องสูงสุด เช่น การเพิ่มหรือลดปัจจัยที่นำมาใช้ รวมถึงการเพิ่มแปลงสำรวจป่าไม้ เป็นต้น

FAO'S definition of forest

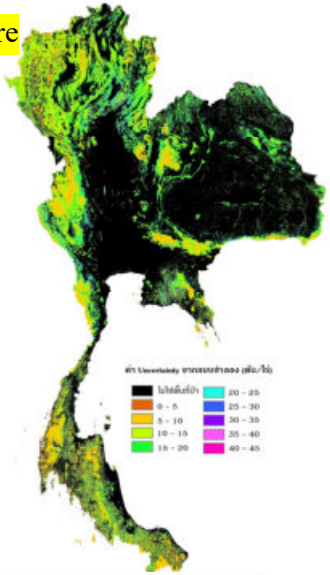
The accuracy assessment of individual forest plots dataset found that

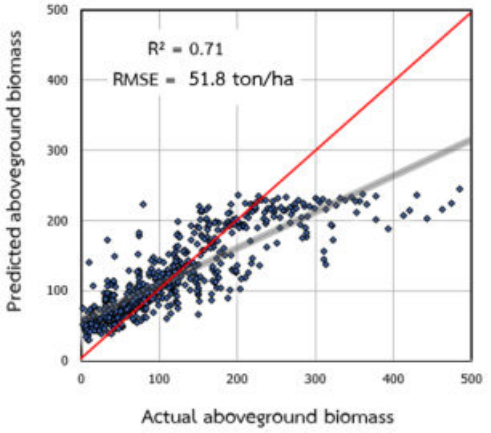
Aboveground biomass map

Forest area 16.16 million hectare
Rubber plantation 4.48 million hectare



Uncertainty map

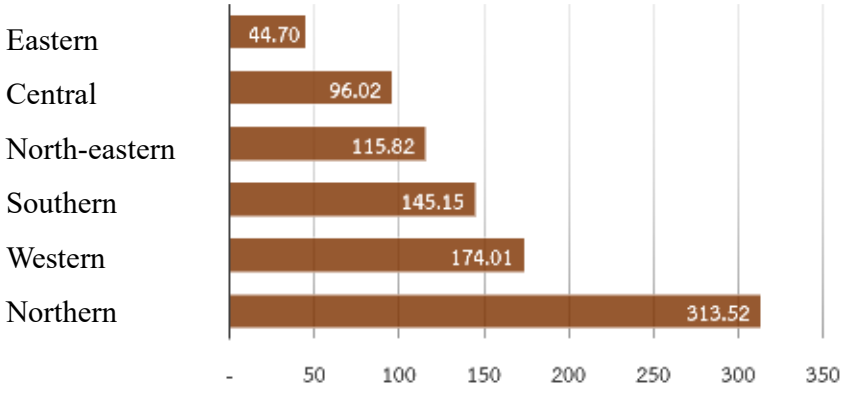




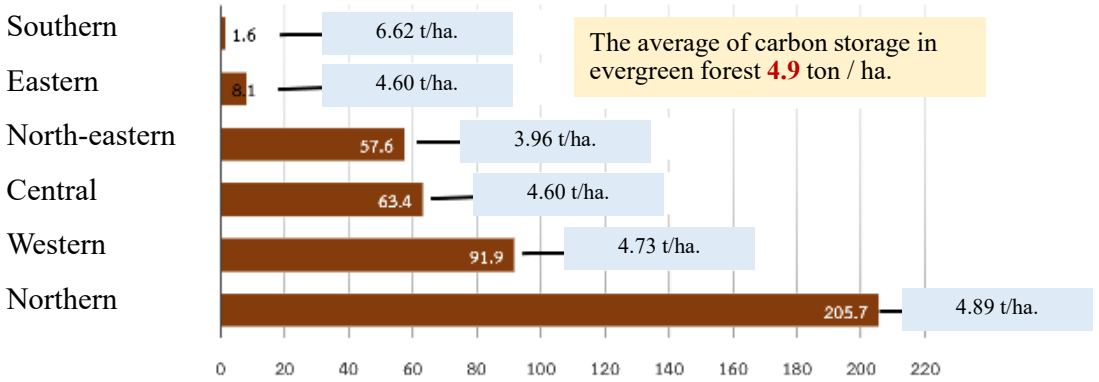
Pixel size 20 m.

The amount of Carbon stocks in each of regions in Thailand

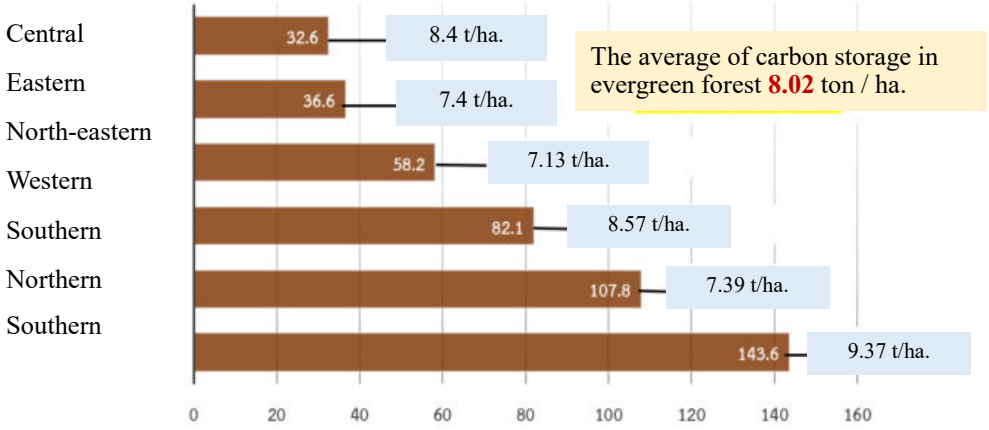
Carbon storage in natural forest



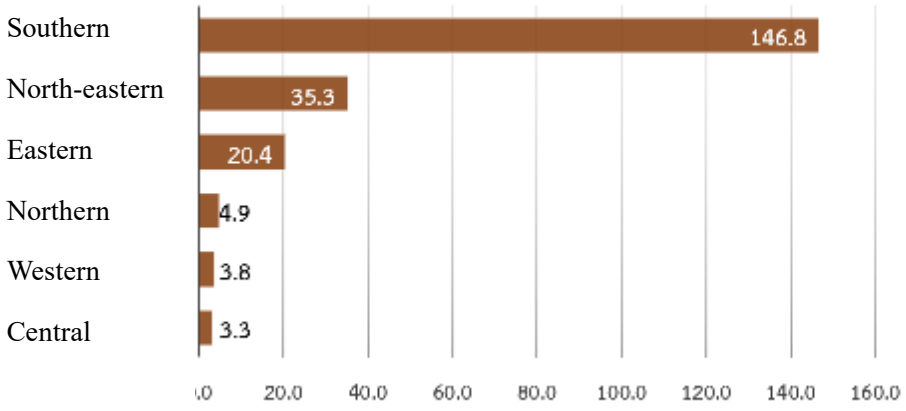
Carbon storage in deciduous forest



Carbon storage in evergreen forest



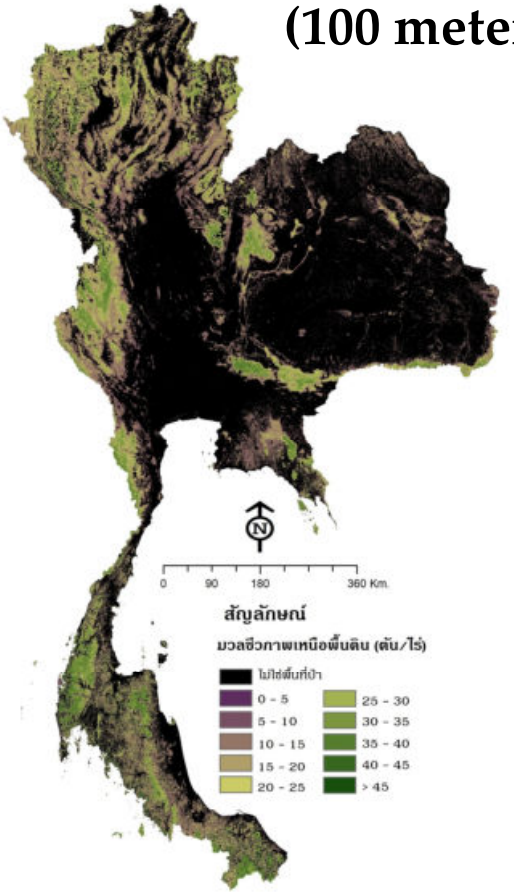
Carbon storage in rubber plantation

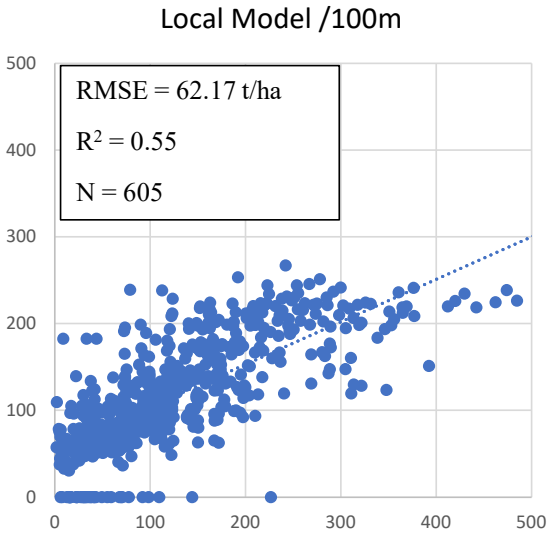


The accuracy assessment of individual forest plots dataset between Globbiomass and Local model at the same spatial resolution (100m).

testing model 605 plots

Local model (100 meter)



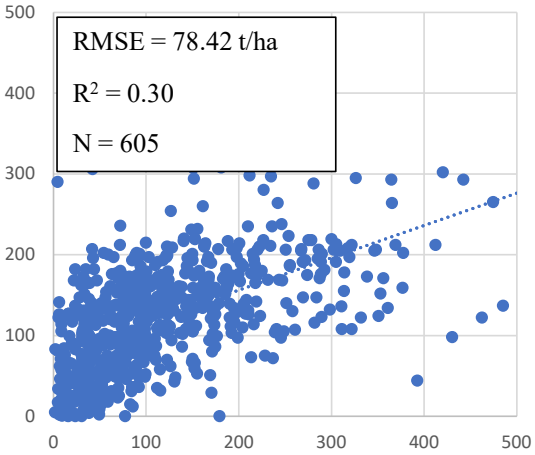


Local model

RMSE = 62.17 t·ha^{-1}

R^2 = 0.55

The global map has less accuracy than the local map.



Global model

RMSE = 78.42 t·ha^{-1}

R^2 = 0.30

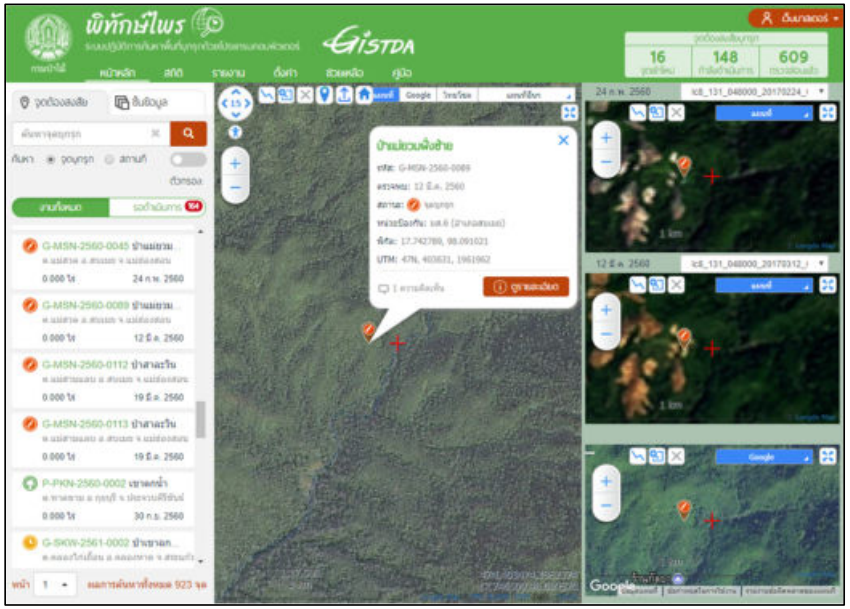
Forest losses

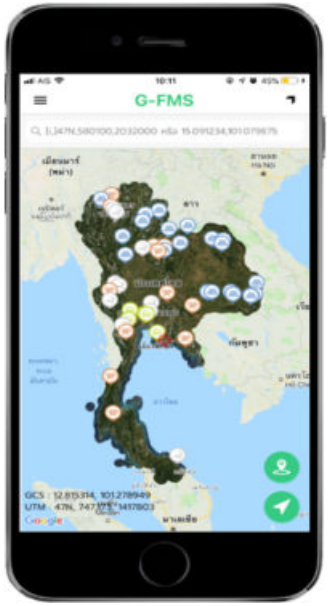
Forest change derived from GISTDA Forest Monitoring System (G-FMS)

The Royal Thai Forest Department (RFD)

ระบบพิทักษ์ไพร

GISTDA Forest Monitoring System (G-FMS)





Year	Forest change (ha)
2017	838.0
2018	770.0
2019	1,445.6
2020	1,580.3
2021	404.3
Total	5,038.2

https://gfms.gistda.or.th

The average carbon stock in natural forest is **68.2** tCO_2e.

Carbon emission into the atmosphere is **343,605** tCO_2e.

Carbon stock change mapping

Forest 2005
13,134 ha.

Forest 2022
14,482 ha.

Forest
Non-forest

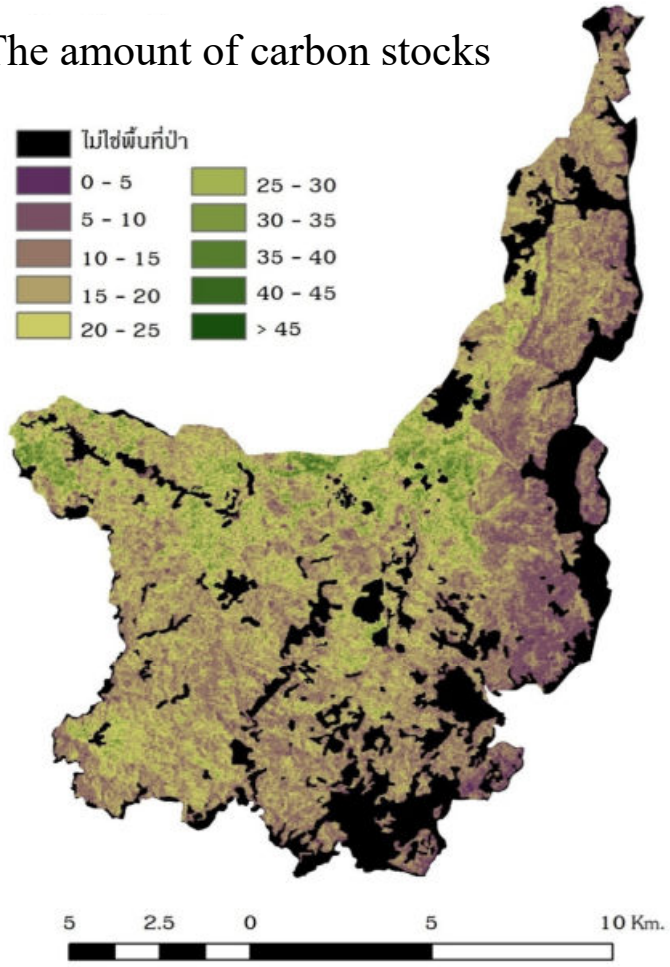
Carbon stocks
4,337,265 (tCO_2e)

Carbon stocks
4,923,618 (tCO2e)

Mean annual increment of carbon stock per year

34,491 ($tCO_2e\ y^{-1}$) → **Carbon credit**

The amount of carbon stocks



4. The utilization of Aboveground biomass (carbon) map

- Carbon map can improve performance to increase carbon stock in the forested areas such as reforestation/afforestation and wildfire protection *etc*.
- It is crucial information to plan and allocate budget into the local government office
- The carbon map is one of the scientific information that supports the carbon market (carbon credit) and it is one of the variable factors in the global carbon model.
- Carbon map can evaluate the emission and absorption of the carbon dioxide by using time-series dataset.

Geo-Informatics and Space Technology Development Agency (Public organization)
Ministry of Higher Education, Science, Research and Innovation

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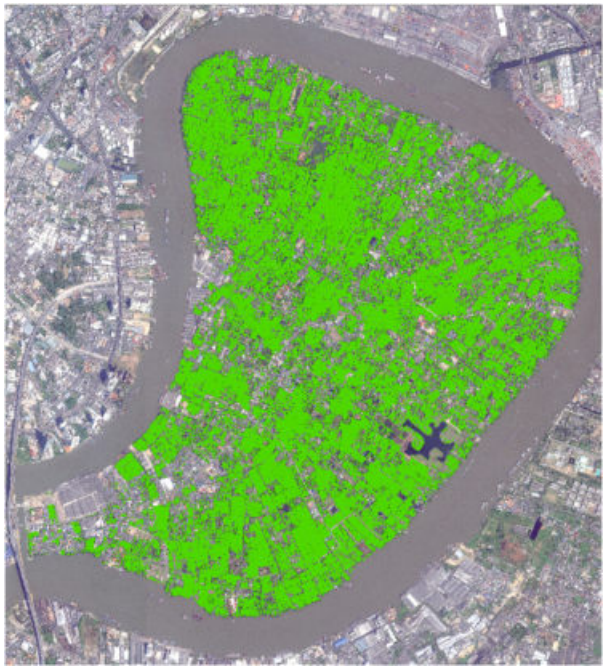
Chaengwattana Rd. Thung Song Hong Subdistrict, Lak Si District, Lak Si District,
Tel 0 2141-4548 Fax 0 2143-9586



GISTDA gistda_space
gistda_space gistdaspace