Long-term Monitoring of Forest Carbon Dynamics in the East Asia Forest Dynamics Plots Network（Abstract of the Final Report）

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1. Introduction

Recent evidence of global warming has raised awareness of the importance of mitigation practices to reduce or avoid the threats of climate change. The REDD+ mechanism (Reducing Emissions from Deforestation and forest Degradation and the role of conservation, sustainable management of forests and enhancement of forest carbon stocks in developing countries) is a cost-effective way of reducing greenhouse gas emissions [1)]. The measurement, reporting, and verification (MRV) of forest carbon change are indispensable for REDD+ implementation. Robust, cost-efficient and transparent MRV system is needed to generate of benefits from REDD+ [3)].

Long-term monitoring of forest dynamics can help us to estimate changes in forest carbon stocks more accurately. Networking of monitoring plots provides opportunities for global comparisons and the synthesis of researches that could not be accomplished with individual plots [2)]. In FY2009, Japan's Forestry and Forest Products Research Institute (FFPRI) established a new network of forest dynamics plots, the East Asia Forest Dynamics Plots Network (EA-FDPN), with funding from the Japanese Ministry of the Environment. The EA-FDPN covers forests from Siberia to the Equator to conduct monitoring forest carbon dynamics. There is more information available elsewhere on the project website about our activities (http://www.ffpri.affrc.go.jp/labs/EA-FDPN/). In 2014, FFPRI received new funding again from the Japanese Ministry of the Environments, and start Phase II of the project collaboration with the Japan International Research Center for Agricultural Science (JIRCAS). We expand our network to new countries and new forest type. With long-term monitoring of forest dynamics, the EA-FDPN data will enable a more precise estimation of carbon pools including development of measuring methods in the East Asian forest ecosystems.

2.Research Objective

The aims of the project are:

- to collect forest carbon stocks data with high accuracy in East Asia
- to compare with annual fluctuations in forest carbon stocks using monitoring data
- to develop measuring methods for carbon stocks with low uncertainties.

The project is expected to supply:

- annual NPP and carbon stock data from a broad range of East Asian forest sites
- knowledge of how climate and soil moisture status control carbon cycling
- information on the long-term behavior of forest productivity and carbon fixation
- improved knowledge of the implications of carbon sinks for climate change mitigation

and adaptation policies in East Asia

- measuring method for national forest carbon monitoring under REDD+ implementation
- vital insights into the mechanisms underlying the current responses of ecosystems to climate and the possible future of East Asia under global change scenarios
- scientifically robust data to support sophisticated analysis of global climate change.

3. Research Methods

(1) Monitoring sites

In last few decades, FFPRI has set up large-scale and long-term research sites for monitoring forest dynamics in Japan and East Asia in collaboration with many foreign research institutes and universities. In 2009, FFPRI created the EA-FDPN, which covers forests from Siberia to the Equator. The EA-FDPN encompasses four forest types: boreal forest (Tura), tropical dry forest (Mae Klong), tropical rain forests (Semangkok, Pasoh, and Bukit Soeharto), and tropical swamp forests (Lam Se Buy and Ranong) (Fig. 1).

In 2014, FFPRI and JIRCAS expand our network to new countries (e.g. Cambodia and Mongolia) and new forest type (e.g. selective logging forest and plantation). New long-term research sites are as follows:

- Udleg [Boreal forest; Mongolia]
- Chiang Mai [Tropical dry forest; Thailand]
- Kratie [Tropical dry forest; Cambodia]
- Sakaerat [Plantations in tropical dry forest zone; Thailand]
- Semangkok (selective logged forest) [Tropical rain forest; Malaysia]
- Perak [Plantations in tropical rain forest zone; Malaysia]
- Trat [Tropical swamp forest; Thailand]

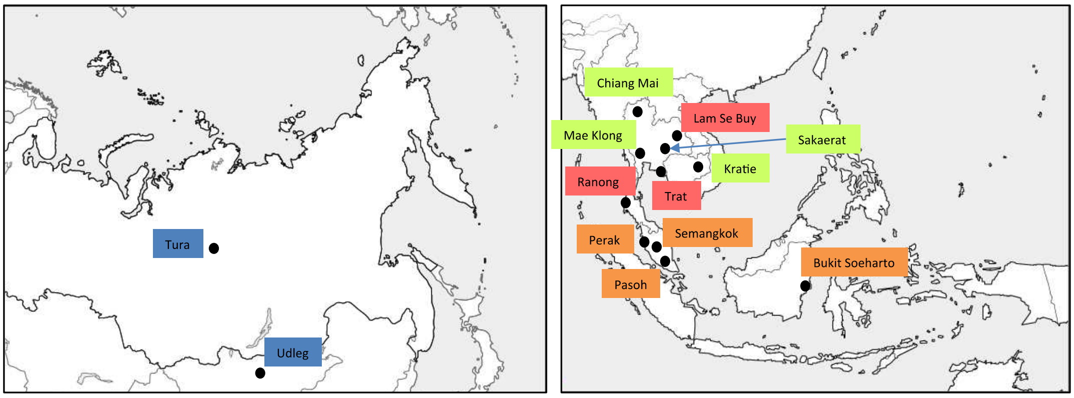

Fig.1 Research sites in the EA-FDPN

(2) Monitoring of carbon dynamics

The EA-FDPN data will allow us to estimate carbon pools in East Asian forest ecosystems more precisely. Analysis of data on five carbon pools within a broad range of forest types will give us new insights into both spatial and temporal variations in carbon pools under different climatic and site conditions.

Since FY2014, we had estimated carbon stock in tree biomass (aboveground and belowground) and aboveground net primary production (ANPP) in the monitoring plots. We had also measured another carbon pool such as herb layer and bamboo biomass in tropical dry forests.

Community-wide general flowering and mast seeding phenomena at irregular intervals is a unique reproductive trait in tropical rain forests in Southeast Asia. To detect a pattern of reproductive phenology containing mast years, we had analyzed relationship between masting and environmental conditions (e.g. temperature and soil drought) in a primary lowland dipterocarp forest in Pasoh Forest Reserve, Peninsular Malaysia.

(3) Development of measuring method for carbon stocks

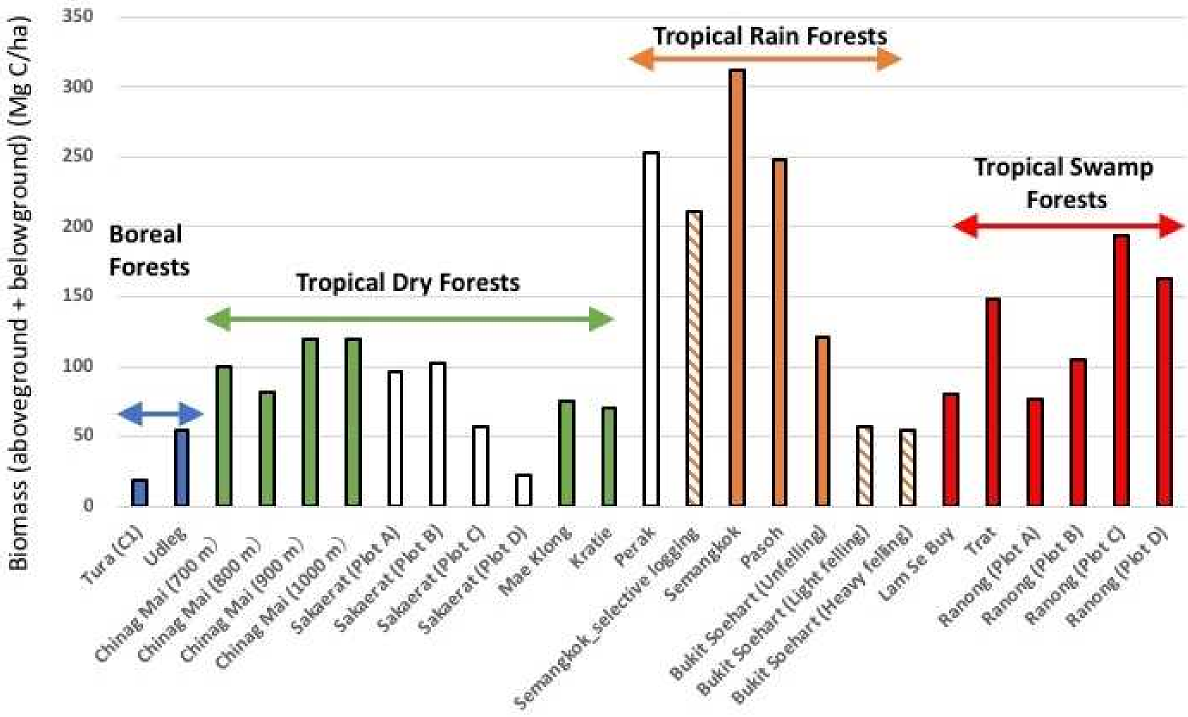

Fig. 2 Comparison of carbon stocks in aboveground and belowground biomass among the monitoring plots in the EA-FDPN

Open bar shows plantation site. Hatching bar shows site with selective logging histories.
In Bukit Soeharto, three monitoring plots were set up based on disturbance intensities: lightly disturbed (UF), moderately disturbed (LF), and heavily disturbed (HF).

Surveys of live biomass alone are insufficient to determine carbon budgets [4)] because coarse woody debris (CWD) is a large carbon pool in forest ecosystems. We focused on methodology that saves labor power to estimate of CWD stocks. In three different plots (Bukit Soeharto, Pasoh, and Semangkok), we had conducted comparative studies in CWD stocks estimation using two different measured thresholds: 10 cm and 20 cm of end diameter of dead log.

4. Results and Discussion

(1) Monitoring of carbon dynamics

Carbon stocks in tree biomass varied among the monitoring sites and showed general tendency of decrease in their values toward high latitudes (Fig. 2). Boreal forest sites showed relatively low carbon stock such as 20 Mg C/ha in Tura, Russia and 60 Mg C/ha in Udleg, Mongolia. On the other hand, igh carbon stock values, ranging from 250 to 300 Mg C/ha, were estimated in tropical rain forest ecosystems (e.g. Pasoh and Semangkok). The monitoring sites without severe disturbances (e.g. Pasoh and Semangkok) showed less fluctuations in biomass (Fig. 3) and ANPP during the monitoring period. In Bukit Soeharto, there were no clear differences in AGB and ANPP between non-selective logging site (UF) and selective logging sites (HF and LF) since 2015 (Fig. 3). This might be due to tree mortality caused by drought associated with ENSO (El Niño Southern Oscillation) event in 2014-2015.

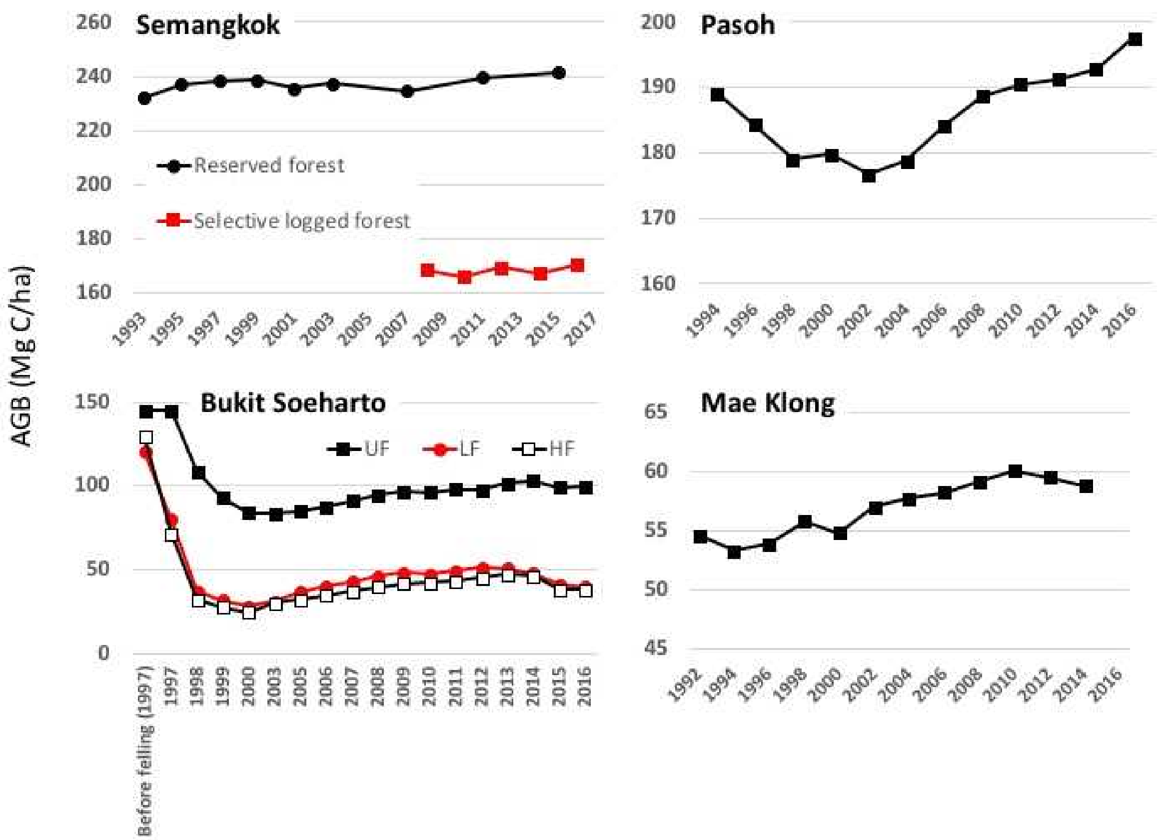

Fig. 3 Annual fluctuations in aboveground biomass (AGB) among the monitoring plots in the EA-FDPN

In Bukit Soeharto, three monitoring plots were set up based on disturbance intensities: lightly disturbed (UF), moderately disturbed (LF), and heavily disturbed (HF).

In Mae Klong, aboveground biomass of bamboo, comprised about one third of tree aboveground biomass, has increased continuously since 1992. Although three of four bamboo species showed mass flowering and subsequent mortality, bamboo biomass did not fluctuate widely throughout the measurement period. Kratie, same forest type as Mae Klong, has a dense cover of herb layer owing to sparse stem densities. Aboveground biomass (AGB) of herb layer accounted for 10% of tree AGB in the site. However, belowground biomass in herb layer reached 35 Mg/ha in lower slope area. Herb layer biomass varied among slope positions and might be comprised of about 30-40% of total biomass in lower slope area.

We found five masting events (1996, 2002, 2005, 2009 and 2014) that had occurred cyclically at 3-6 years interval relating to supra-annual fluctuation of soil moisture based on 25-years seed production data (1992 -2017) of Pasoh Forest Reserve. Estimation of soil water contents from daily rainfall revealed that number of water stress days in the first quarter (January to March) changes cyclically and trigger general flowering. This masting cycle start with the wet year with no water stress in the first quarter. Severe drought and low temperature triggered the largest masting in 1996, but masting in 2002, 2005 and 2014 had not low temperature signal.

(2) Development of measuring method for carbon stocks

Sampling time by line intersect sampling for assessment of CWD was 20 minutes on average in the Kratie site, and required time was one third amount time compared to plot inventory survey. Although line transect sampling gave relatively high estimate of CWD, estimated CWD mass showed relatively small and ranged between 1.2 to 1.5 Mg/ha obtained from the both measuring methods.

From our data set among three monitoring sites (Bukit Soeharto, Pasoh and Semangkok), most of fallen dead woods were smaller than 20 cm in end diameter (i.e. 40 to 70% of total dead woods). On the other hand, the proportion of these small dead woods only accounted for some 5-17% of total dead woods mass. There was a liner relationship between amount of fallen logs greater than 20 cm in diameter and total amount of fallen logs (i.e. all fallen logs greater than 10 cm in diameter) in each sampling site. After combining all CWD data among different forest types (e.g. tropical rain forest and tropical dry forest), we found following equation:

$$\mathit{All\ CWD} = 0.998 * \mathit{CWD}_{20cm} + 4.1599 \quad (r^2 = 0.9957;\ n = 178)$$

where *All CWD* (Mg/ha) is total amount of fallen logs greater than 10 cm in diameter, CWD_{20cm} (Mg/ha) is amount of fallen logs greater than 20 cm in diameter, respectively.

We found no significant differences between measured CWD mass and predicted CWD mass using this relationship (Mann-Whitney test, $p > 0.05$).

CWD measurement in mangrove is difficult for the reason that obstacle of dense prop roots and dead wood removal by tidal fluctuation occur in mangrove forest. The CWD mass derived the line intersect method showed a good correlation with estimated necromass due to mortality from tree census data in Ranong site. This result implies the line intersect method is the first choice for CWD measurement in mangrove forest.

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