# Estimation of $CO_2$ Sequestration Rate by Mangrove Ecosystem

## Background

In the framework of the Kyoto mechanism, mangrove plantation is expected to be one of the options of the forestation CDM project. For the verification of a CDM sink project, it is necessary to present the land use history of project area at the end of 1989 and predict the $CO_2$ stock amount by the project activity. Compared to other land forest, mangrove ecosystem accumulates sequestered carbon in the sediment, thus the development of the determination and estimation methodology of $CO_2$ sequestration rate in mangrove sediment layer is expected.

## Objectives

To develop determination techniques of a $CO_2$ sequestration rate in mangrove forest, carbon stock, $CO_2$ sequestration rate in mangrove sediment, and $N_2O$ emission flux from mangrove ecosystem.

## Principal Results

1. The applicability of the large area estimation method of Leaf Area Index (LAI) in the mangrove plantation area was verified, and the carbon sequestration was estimated. For the mangrove plantation area in Thailand, the leaf area index was measured by 3 kinds of techniques of direct method, indirect method and estimation method using satellite data. Direct method is very accurate, but cost is high. The estimation method using satellite data can measure LAI in large area, but it is not as accurate as the direct method. By supplementing satellite data with indirect method, LAI can has practical accuracy, and the cost is low. Using estimated leaf area index and photosynthetic data measured in the field, the carbon sequestration of the mangrove forest was estimated. This estimated value agreed almost with measured data by gas balance method at the tower site.
2. The practical utilization of multi-temporal satellite data and field survey data was investigated in order to obtain the useful information for the mangrove plantation as CDM project. Satellite data obtained by six sensors of four satellites with different resolution and sensitivity were converted in the normalized difference vegetation index (NDVI) in order to detect long-term land use change. Using this method, it could be directly compared in the long term (about 30 years) with the uniform accuracy. It is effective for the selection of planting site and the confirmation of land use in 1989 year-end. The relationship between stand age and biomass was investigated based on field survey (tree height, diameter, etc.) at near mangrove forest, in order to calculate carbon stock after plantation by the internationally recognized method. Combining the above relationship curve with estimation method of stand age using annual change of NDVI, carbon stock was estimated in the whole mangrove plantation area.
3. The result demonstrated that Pb-210 attached to fine organic carbon particle in sediment, is an effective time tracer to calculate organic carbon accumulation rate in mangrove sediment. Using $^{210}Pb$ vertical profile in sediment core and cumulative organic carbon amount in mangrove sediment, $CO_2$ sequestration fluxes in mangrove study sites of Japan, Vietnam, Thailand and Indonesia were estimated to be 1.9, 2.0, 4.9, 2.4 ton-C $ha^{-1}$ $year^{-1}$, respectively.
4. To evaluate the nitrous oxide emission from the mangrove forest, we investigated a method that considers the feature of the mangrove ecosystem. The method was applied at two mangrove forest fields. The total amount of $N_2O$ emission from the mangrove ecosystem can be estimated in two main routes; the exchange from seawater contacted with sediments in the forest, and direct emission from sediments to atmosphere at ebb tide. The amount of the $N_2O$ emission from the mangrove ecosystem is lower than the amount of the carbon fixation of the mangrove. However, it was clarified that concentration of $N_2O$ in seawater in the rainy season and contents of $N_2O$ in subsurface sediments were high amount. The present method is effective for evaluation of emission and absorption of greenhouse gases in mangrove plantation project.

## Future Developments

The developed methodology will be tested by real plantation area, and evaluated its performance.

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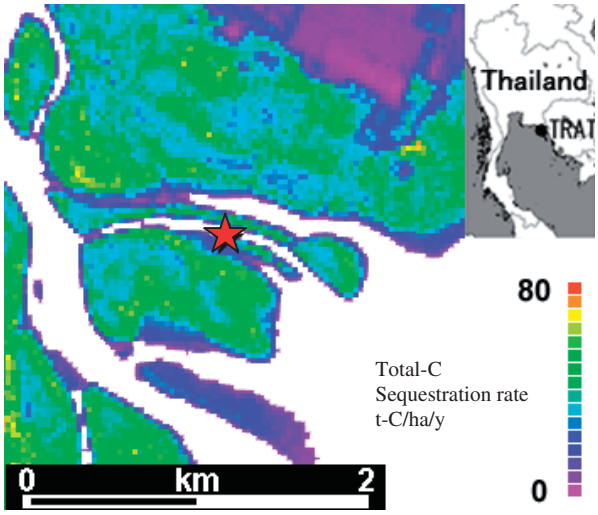



**Fig.1** Total carbon sequestration rate (Thailand, Trat)

Using relation between measured leaf area index (LAI) on the ground and NDVI derived from satellite, large area LAI was estimated. Comparing with measured $CO_2$ flux at sample area (★), total carbon sequestration was calculated in whole project area.

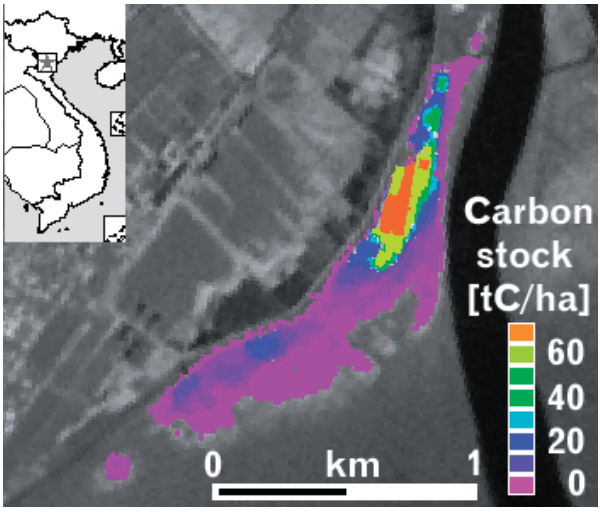
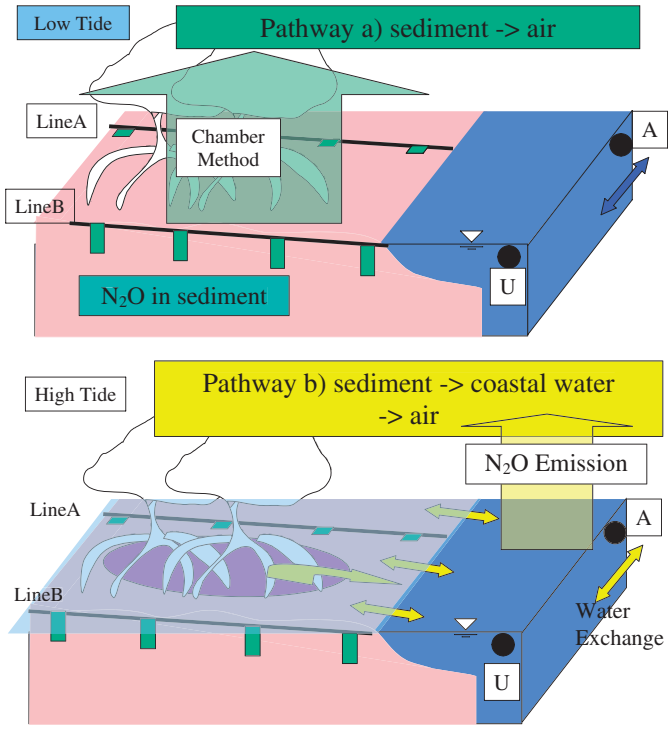



**Fig.2** Total carbon stock (Vietnam, Thanhoa)

By normalizing NDVI obtained by satellite data during last decade, forest age was estimated at the area. Using its relation with carbon stock at sample area, total carbon stock in whole project area was calculated.

NDVI: Plant has low refection in the visible red color wave band while high reflection in the near infrared band by its chlorophyll. Using this specific reflection by vegetation, NDVI is derived by satellite data of light wavelength bandinformation.

LAI: Total sum up of leaf area at each ground area unit. We use general definition which has one side area assuming flat distribution of leaf to unit area. Direct method derives LAI by measuring the total leaf numbers of representative treefollowed by scanning the all leaf area of sample tree. Indirect method derives LAI by using plan canopy analyzer.




$N_2O$ emission flux was estimated by 1) calculating pressure imbalance between air and measure $N_2O$ concentrations in sediment, seawater, 2) direct measurement of $N_2O$ flux by chamber method. The result shows some $N_2O$ was emitted from mangrove sediment and coastal water, while even by multiplying greenhouse coefficient, the estimated greenhouse effect (pathway a: -0.5～1.9tC/ha/y; pathway b: -0.03～0.3tC/ha/y) was relatively small compared to preventing effect by $CO_2$ sequestration by mangrove ecosystem (5～10tC/ha/y).

**Fig.3** $N_2O$ emission pathways from mangrove