# FIELD WORKS IN MANGROVE FOREST ON STAND PARAMETERS AND CARBON AMOUNT FIXED AS CARBON DIOXIDE FOR COMBINING TO REMOTE SENSING DATA

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**ABSTRACT:**

On mangrove forest as a coastal ecosystem, evaluation of the environmental function has been tried multilaterally. It should be non-contentious that remote sensing is convenient to evaluate broad area of mangrove forest, and not only extraction of qualitative information but also quantitative information is expected.

One new method was developed to measure tree height and calculate trunk volume without climbing up or cutting down a stem. It was composed of a digital camera operated remotely, some laser pointers parallelized and a pole consisted of drawtubes to support them. An improved form was shown with measurements by the method.

Carbon amounts fixed as carbon dioxide had been calculated for combining with remote sensing data. Fresh weight of leaves, branches, trunk and roots was separately measured in mangrove forest, and samples of them also were collected to measure water content and carbon ratio. Carbon amount of each part of a tree was calculated by its dry weight and carbon ratio, furthermore the total carbon amount of a tree was summed up. Regression equations between DBH (diameter at breast height) and carbon amount were shown as the whole root, the other part of roots and the whole tree comprised leaves, branches, roots and the trunk for seventeen trees of *Rhizophora stylosa* (Yaeyamahirugi in Japanese).

## 1. INTRODUCTION

It is recognized widely that mangrove forest has a manifold function as an important coastal ecosystem. Remote sensing has been expected as a useful way to grasp the actualities of it. Although relationships between stand parameters of mangrove forest and remote sensing data must be made clear to utilize remote sensing, it is more difficult to measure them than ordinary land forest. And this matter is also a motivation to apply remote sensing against mangrove forest. Measurement on stand parameters under deep muddy condition is hard and conditioned with the tide. Furthermore, it is not permitted to cut down trees in some kinds of limited forest.

Sato K. and Tateishi R. of two authors of this paper have developed a new method to measure tree height and calculated trunk volume without climbing up or cutting down a stem. A basic components and form of the method was reported at the 22nd Asian Conference on Remote Sensing (Sato K. & Tateishi R., 2001). Although it was a basal condition to be held both poles for pulling up drawtubes for the fundament of this method, the expedient had been not enough to hold them upright. In this paper, a prototype to fulfill prerequisites was shown with measurements by itself. It is possible to adjust the camera unit for required level remotely. But it was avoided here, because the weight of top part increased.

Recently forest has been expected and recognized as an immense sink of carbon dioxide. Sato K. and Kanetomi M. (2000), and Sato K. *et al.* (2001) reported multiplex express of distribution of mangrove species and growing stock as trunk volume using remote sensing. Although it is possible to apply this technique for evaluation of fixed carbon amount in mangrove forest and expression of the distribution, the carbon amount not only in trunk but also in other parts must be measured. In this paper, the way of thinking was assembled to apply remote sensing for evaluation of amount of fixed carbon in mangrove forest. And field works for *Rhizophora stylosa* of a kind of mangrove was described with a figure as the result.

## 2. FIELD WORKS

To apply remote sensing for making distribution map or aggregate of forest resources, it is necessarily needed to collect data in the field. Relationships between Landsat TM data and stand parameters of mangrove forests in Okinawa had been investigated (Dwi S. *et. al*., 1997a & 1997b). Highly significant correlation coefficients were recognized between them. A regression equation in such relationships was used to make distribution map on growing stock. Mangrove forests in Okinawa were classified almost into the limited use forest, so it is difficult to cut down trees. When we want to know trunk volume of a mangrove tree without cutting down, it must be measured some diameters at some heights and a tree height for scaling by sections. There are two problems. One is the risk of fall and another is the hardness of field works, because this way needs climbing up a ladder or trunk and moving the ladder many times in a sample plot. We have tried to avoid the problems for accelerate the utilization of remote sensing.

### 2.1 Measurement of tree height and diameter of trunk

When we measure tree height, a measuring rod and a height meter were used to measure tree high of low and high trees respectively. The top of a tree must be seen clearly for using them, and the distance between a target tree and the instrument must be measured. But it is more difficult to satisfy these requirements in mangrove forest than the land forest, because deep muddy sediment and such intricate aerial root, pneumatophore as prop root, knee root, erect root, obstruct to move to suitable point for penetrating the treetop or to measure the distance.

We had suggested a new method to avoid the problems (Sato K. & Tateishi R., 2001). One fundamental device was a unit of parallelized laser pointers to project some laser points as scales on the target trunk. Other important devices were to introduce a digital camera, a panning unit, a pole consisted of drawtubes to support and elevate the former units and control unit of them. It became possible to see and certain taken imageries of trunks with scales in the field, and to process the imageries on a note personal computer at a base camp. Diameter of trunk can be calculated in proportion to the scales of distances between some laser points on the target trunk. Height of the camera can be measured with a fine tape measure fixed zero to the side of the camera, so tree height is measured when the camera catches the treetop in the center of the finder.

The fundamental form of this method had been completed with the addition of several improvements. Main improvements were to provide level sensors for x and y directions on the unit of laser pointers, two poles for pulling up the drawtubes, a metal tetragon for connecting the two poles, a handle reel to roll-up a line and a hook for pulling up the drawtubes and lines fixed to the bottom of panning unit for level adjustment of the camera. The level indicators were set in the control unit on the ground. The primary and simple form and the completed form of this method were shown in Fig. 1. The aspect to stet the new pole system and taken imageries with this method were shown in Fig. 2. Two lines in the photo of handle reel were for operation of the hook set to fly block. Small rings were attached at the top of each drawtube. When one tube was pulled up, this hook was hooked to the ring and rolled up almost one tube length. Then the bottom end of the tube connected to the top ofnext tube with a bolt and

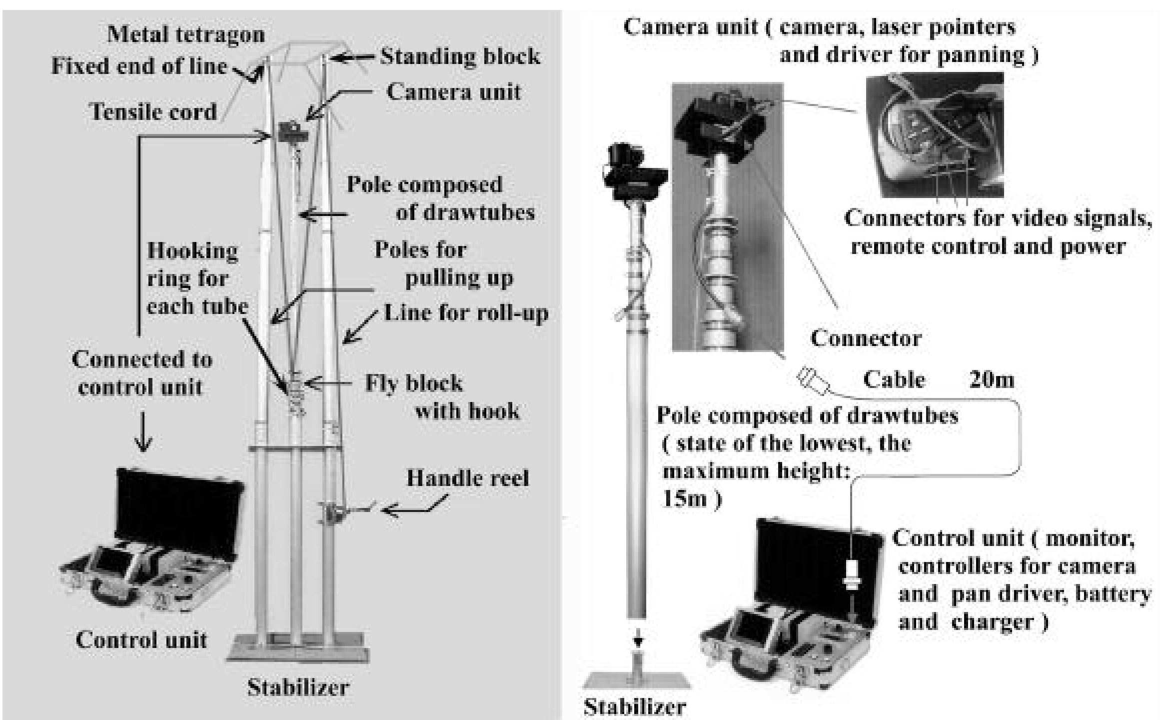


**Fig. 1 The first prototype of this method (right) and improved prototype (left)**

Fig. 2 Setting of new pole system in a mangrove stand (left), operation of the handle reel (below right),

a taken imagery of a trunk and drawn scales on an imagery of a trunk with an image processing

software (above right)

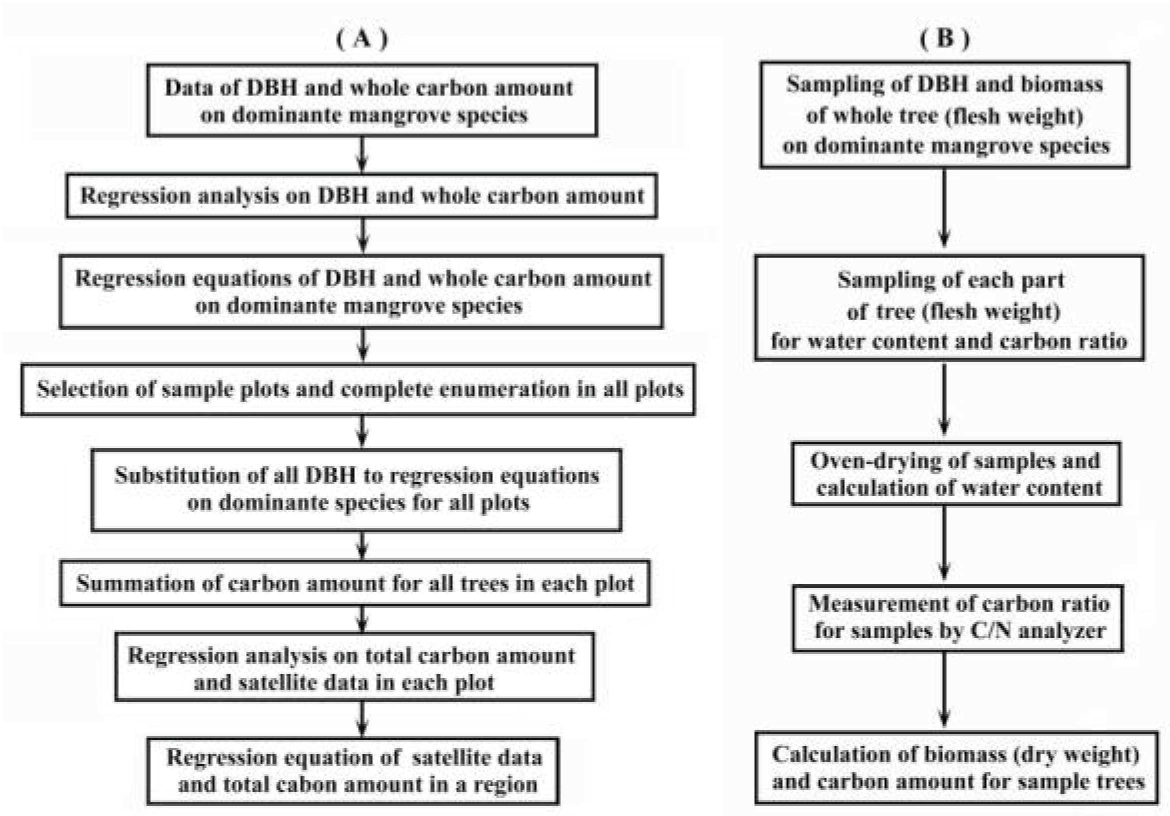


**Fig. 3 Procedure to estimate carbon amount fixed in mangrove forest using remote sensing (A) and to obtain carbon amount of sample trees (B)**

nut. After the hook was taken off from the ring with the operation of the lines, the hook and fly block were pulled down to the next ring with the lines. This operation was repeated for pulling up the drawtubes and contrary to this for reducing the height. Imageries of all target trunks could be taken at objective height using the panning unit. The camera could be held at any height to take imageries of target trunks with stopping and fixing the reel.

**2.2 Measurement of carbon amount of a tree**

We thought to follow the above steps to produce a distribution map of carbon amount fixed in mangrove forest using remote sensing. At first, we constructed the way of thinking of application of remote sensing for estimation of carbon amount fixed in mangrove forest following the estimation of growing stock with TM data of Landsat 5 (Sato K. & Kanetomi M., 2000, Sato K. *et. al*., 2001). The flow chart was shown as (A) in Fig. 3. Before the process of (A), we must collect the data on DBH and biomass of the whole mangrove tree to comprise leaves, branches, trunk and roots in the field. The flow chart from field works to laboratory works was shown as (B) in Fig. 3.

Although we had clarified the relationships between TM data of Landsat 5 and stand parameters of mangrove forest in Okinawa (Dwi S. *et. al*., 1997a & 1997b), biomass of the other parts of trunk was not included because it had been done from the point of forestry view. We already know the estimation equations between DBH and tree height or trunk volume on *R. stylosa* and *Bruguiera bymnorhiza*, but we have few measurements of biomass on mangrove leaves, branches and roots. Therefore we got the permit to cut down sample trees, because there was no reliable way besides what we cut down trees and measured the weight of each part of them.

There was not a serious problem to cut down trunk and measure the flesh weight of each part above the sediment, but it was hard to dig out roots under the sediment. Furthermore, it influenced surroundings significantly. Accordingly we selected the way to pull out roots. Although it was effective for prop roots of *R. stylosa*, it could not be used for *B. gymnorhiza.* Knee roots of *B. gymnorhiza* could not be identified on the trunks, because the knee roots linked to each trunk through horizontal roots under the sediment. From many knee roots we had to select the

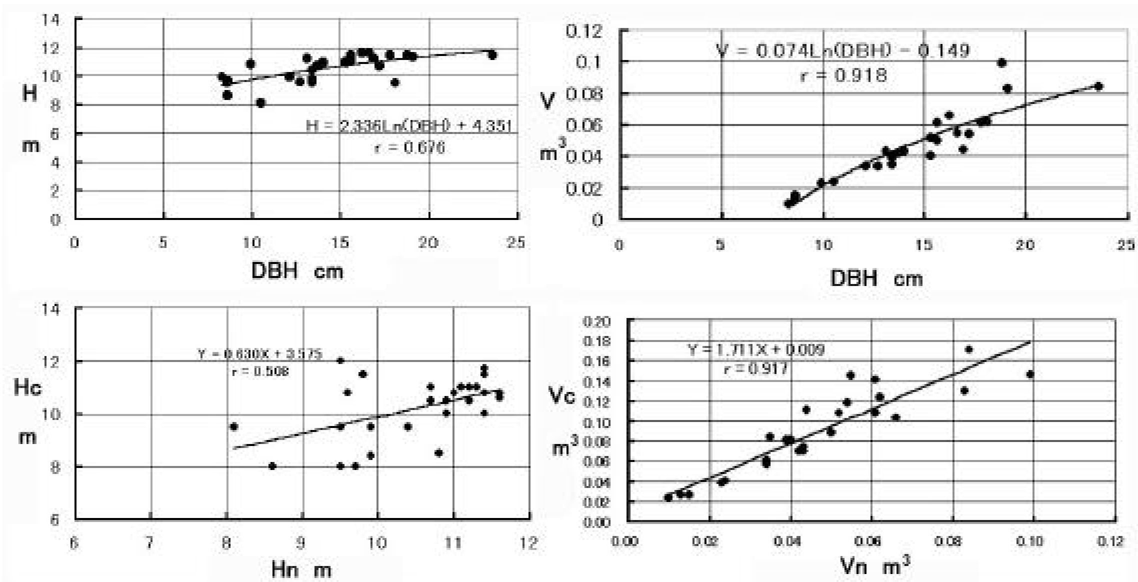


**Fig. 4 Two relationships between DBH and tree height (H), trunk volume (V) of measurements and calculated values by this method (above), and comparison of tree height and trunk volume by this method (Hn, Vn) and conventional way (Hc, Vc) (below)**

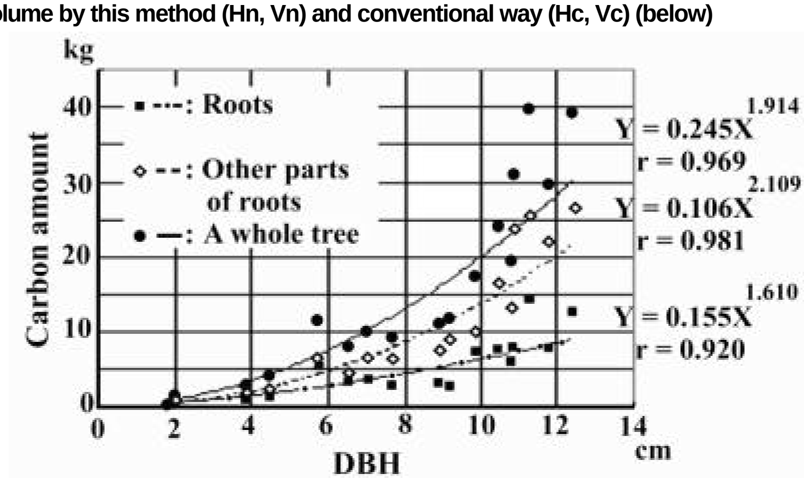


**Fig. 5 Relationships between DBH and carbon amount of each part and a whole tree**

knee roots that linked to a sample tree, but we could not obtain any suitable thoughts for identification of knee roots linked with a sample trunk. This problem will be remained in the future.

We collected seventeen data in the field for calculation of dry biomass and carbon amount on *Rhizophora stylosa*. A chain block was used to pull out prop roots, and it was simple and effective for the purpose. The procedure to handle the samples was done following (B) in Fig. 3.

## 3. RESULTS AND DISCUSSION

### 3.1 Pole and camera system

The difference between actual diameter of trunk and apparent it in an imagery was investigated in relation with the distance from the camera to the target trunk and the diameter of trunk. This difference did not matter in practical application because we knew the range of less than 0.5cm with the distance and diameter in the Figure. The results of measurements by this method were shown in Fig. 4. Measurements of tree height scattered in wide range and calculated values of trunk volume by conventional way when compared those of with this method were too much. The reasons were probably looking up treetop and tying a tape measure diagonally against trunk for measurement of the trunk perimeter with insecure attitude on a ladder or trunk, and the works was an unaccustomed works for students. It could be evaluated that accuracy of measurement was improved by this method. Time required for measurement per a tree was 4 minutes 38 seconds with conventional way and 4 minutes 26 seconds with this method. It is considered that the former is almost the limit but the latter can be reduced by experience.

By these improvements, operational safety and stability were advanced. And the accuracy of measurement also was raised because of the advancement in preserving the pole to support the camera upright. Although this method has a demerit that the number and weight of equipments increase, it is realized that cutting down trees and climbing up trunks are avoided. The matters are the most important merits from the points of view of the safety and minimizing the hardness of field works. It can be suggested that this method explains the possibilities to develop small scale remote sensing in the forest.

### 3.2 Carbon amount and DBH

Carbon amount of each parts of a *R. stylosa* tree was calculated with the flesh weight, water content and carbon ratio of each part. Total carbon amount of a whole tree was obtained as the sum of each part carbon amount. Relationships between DBH and carbon amount of roots, the other parts and whole a tree for seventeen samples were shown in Fig. 5. Carbon amount of a whole a tree (kg) can be estimated as Y by substituting DBH (cm) of a tree as X into the equation of $Y = 0.245X^{1.914}$. Total amount of carbon in a plot can be obtained as the sum of values estimated by substituting all DBH in a plot into the equation.

The dominant species of mangrove in Okinawa are *R. stylosa* and *B. gymnorhiza*. For *B. gymnorhiza* regression equation must be obtained, but it is not done yet. Because the problem of knee root identification has been left unsolved. We intend to solve the problem and obtain the regression equation for *B. gymnorhiza*. Thereby it becomes possible to go forward to the procedure of regression analysis between satellite data and carbon amount in a plot shown in flow (A) in Fig. 3.

Molecular weight of C is 12 and it of O is 16, so it of $CO_2$ becomes 44. Amount fixed as carbon dioxide (kg) in a tree or in a plot becomes 3.67 times of the weight of carbon.

## 4. CONCLUSION

Developed method is effectively useful to avoid the danger to fall from a ladder set against the trunk or a tree, and the hardness in field works. It should be also useful for ordinary land forest. Although the maximum height of this prototype is 15m, we wish to extend it finding suitable pipe for the tropical mangrove forest.

A big problem is remained for combining satellite data to carbon amount fixed in mangrove forest, but we considered that it should be solved in the near future. And remote sensing might be applied to a new aspect.

## REFERENCES

**Dwi S., Sato K. & Kohda Y.: 1997a,** Relationships Between TM Data of Landsat 5 and Stand Parameters on Mangrove Forest in Okinawa, Journal of Japan Society of Photogrammetry and Remote Sensing, 36 (2), pp. 4-12

**Dwi S., Sato K. & Kohda Y.: 1997b,** Relationships Between Calculated Indexes from TM Data of

Landsat 5 and Stand Parameters on Mangrove Forest in Okinawa, Journal of Japan Society of Photogrammetry and Remote Sensing, 36 (3), pp. 6-12

**Sato K. & Kanatomi M.: 2000,** Application of Remote Sensing with LANDSAT TM Data for Management and Control of Mangrove Forest – A Case Study in Okinawa –, Proceedings of the 21st Asian Conference on Remote Sensing, pp. 83-88

**Sato K., Anatomy M. & Dui S.: 2001,** Extraction of Stand Parameters on Mangrove Forest using Land sat 5 TM Data, Asian Journal of Geoinformatics, Vol. 1, No. 4, pp. 23-31.

**Sato K. & Tateishi R.: 2001,** Development of New Method for Field Survey of Stand Parameters on Mangrove Forest – A Prototype and Application Test –, Proceedings of the 22nd Asian Conference on Remote Sensing, pp. 1344-1349