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Automated DEM Extraction of a Tropical Peat Swamp Forest from Balloon Stereo Photographs*

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1. INTRODUCTION

Digital Elevation Models (DEM) and digital mapping of topography are powerful database to understand, model, and analyze terrestrial environments, fluxes of substances, and landscape. DEMs usually used to be extracted by digitalizing analogue data reduced from analytical photogrammetry until nowadays, when the more and more roles of analytical photogrammetry are replaced by newly developed techniques of photogrammetric automated DEM extraction from satellite and airborne imagery in cooperation with advances in computer abilities.

The dominant process to decide the precision in the automated DEM extraction is stereo matching, that is to decide conjugate points of a stereo pair. To get precise DEMs for topography, many studies on stereo matching have been done since Hobrough developed the first auto-correlator, Stereomat I in 1959. Some of these algorithms are adopted in packaged photogrammetric modules, however, only a small number of studies have been done for automated DEM extraction of the forest itself in the level of structure of individual trees, in spite that DEM of forests have the ability to understand, model, and analyze forest environment and fluxes from and to the forest in addition to the forest biomass estimation. This ability is supported by the fact that geometrical structures of a forest are measured in a laborious way and depicted as a " projection chart of canopy." Most of the studies for automated forest DEM extraction is objected to test a laser scanner, developed recently and still too expensive to be handled by scientists, engineers, and officials planning to apply the technique to their own fields. A photogrammetric automated DEM extraction technique is, meanwhile, easy to apply, providing a camera, a platform (say a balloon or an airplane), a standard personal computer, and an algorithm for the technique.

The objective of this study is to test an automated DEM extraction of a tropical peat

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swamp forest from balloon stereo images in Narathiwat, Thailand and develop an automated method for forest DEM extraction.

2. SITE SPECIFICATIONS

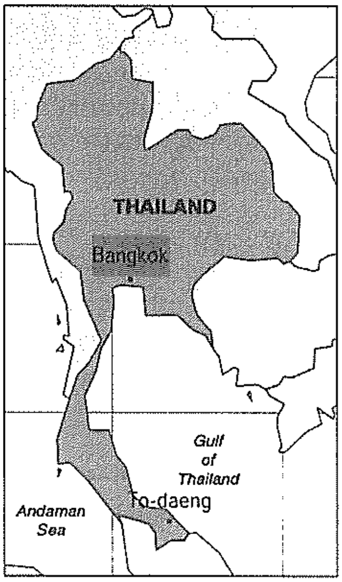
Our research site is designated as a tropical peat swamp forest situated in To-daeng, Narathiwat Province, Thailand and its latitude and longitude are N6° 4'30" and E101° 58'20" (Figure 1). Tropical peat swamp forest in Thailand is located in tropical peat swamp soil and originally formed in freshwater when the sea level was reduced and the mangrove forest at that place was taken into land in 6000 years ago. Tropical peat swamp soil covers 30-46 million ha (variable for estimation methods) in the world, 0.9% of the world's forests area, 3,454 million ha in 1995 (FAO, 1997). Forest in our research site is natural, which means height is about 25 and is almost flat for the environment of its formation and the solar beam reaches the ground from near nadir direction. These facts suit for neglecting the mentioned problems in digital matching : 1) steep slopes of the ground make image correlation between conjugate points lower ; 2) shadows of tree crowns make the texture for matching less.

3. STEREO PHOTOGRAPHS AND GCP

We took stereo (two) photographs with a camera (Nikon F801 with 35mm color film and 28 mm principal distance) mounted on a balloon fixed by a rope at the ground in To-daeng site on 8 September, 1996. The camera was suspended at the balloon so that it was kept horizontally. The shutter was released on the ground by a wireless device.

The slops of the forest surface were mostly larger than that of topography. In general, a pair of stereo photographs abandoned with steep slops has large parallax at the slops and should be taken in a smaller base-height ratio to avoid lower image correlation at conjugate points. We set the base-height ratio about 0.24-0.25, smaller than 0.5-1.0, that of SPOT stereo images mainly for topography. There were differences in projection center heights and rotation angles between the left and right photographs, caused by the difference in winds in the upper air when the photographs were taken. The projection centers were 438m and 451m heights, and the distance between them was 108m. Each of the photographs covers a 600m X 400m forest area with 70-80% overlap.

Figure1. Research site (To-daenq)



We provided four ground control points (GCPs) made of 0.5m X 0.5m white plastic boards supported by 2m steal sticks. Terrestrial coordinates of the GCPs were surveyed by a theodolite set at the top of a 36 m tall research tower. The left and right photographs were developed and digitized at the resolution of 5.0 μm per pixel on the film, that is of 80 mm on the terrestrial coordinate. The digitized images were transformed into images and the digital numbers were normalized to obey the similar distribution that have the same mean and standard deviation.

4. COMPUTER ALGORITHMS

4.1 Orientation and Rectification

The six exterior orientation parameters of the left and right photographs were determined with five GCPs by minimizing the summation of the residuals for the collinear condition equations with each GCP. The root mean square errors (RMSEs) of GCPs are 0.42m and 1.62m in the horizontal and vertical directions, respectively.

Using the orientation parameters, the images obtained by the mentioned preprocessing were rectified for the line with the projection centers of the left and right images. Rectification is an image resampling to arrange conjugate points on the same epipole line for fast and correct search for conjugate points (Figure 2). The algorithm for differential rectification (Novak, 1992) was mainly applied, but two additional points should be remarked as rectification algorithm for balloon stereo images. One is to decide the image coordinate boundary of rectified images before rectification. Airborne or close range stereo photographs are taken in a way that left and right images are parallel situations. Coordinates of points before and after rectification are almost the same, so that the image coordinate boundary of the rectified images is the same as that of before rectification or a little larger. On the other hand, balloon image coordinates are much different from that of after rectification since left and right images have different heights of projection center and rotation angles. The other is to separate memories assigned for rectified images into parts to optimize shared memory for calculation speed. The images before rectification do not separate since it takes time to calculate and read a boundary of the rectified images corresponding to each of the separated original images for difference of the exterior orientation parameters between left and right images. Images obtained by the rectification are shown in Figure 3.

4.2 Image correlation matching

The rectified images were degraded at 10:1 scale and two stereo pairs (0.8m and 0.08m horizontal resolutions) were generated. In forest image, height should be calculated in the image with more priority than that of topographic image, since the variation of elevation is larger. For this reason, the matching has been operated for each pixel on the coarser left image. The proposed algorithm for image correlation matching is shown in Figure 4 . First, the coarser image is used for matching. A conjugate

Figure 3. Rectified stereo images of To Daeng (8 September, 1996)

Left image Right image

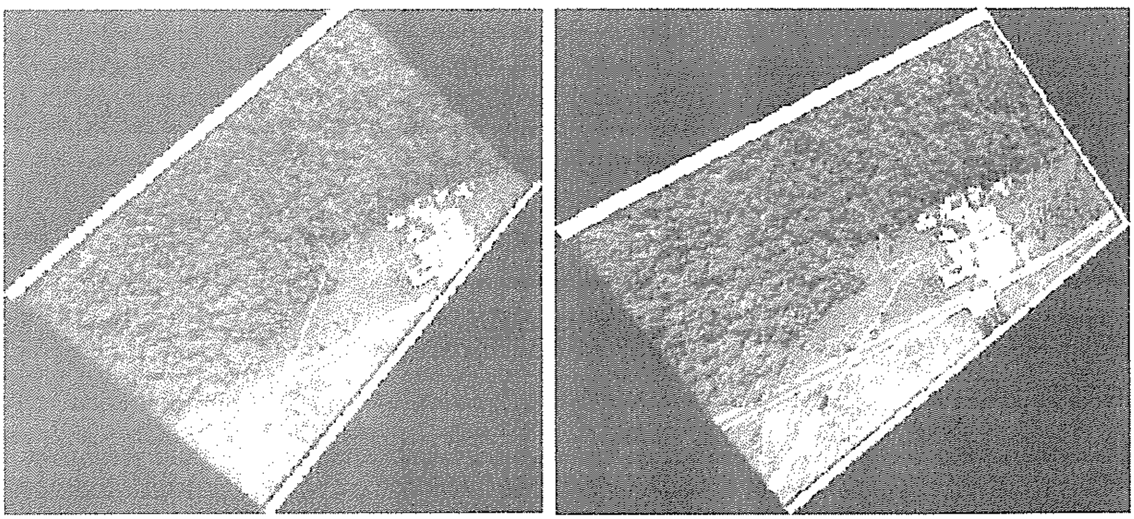
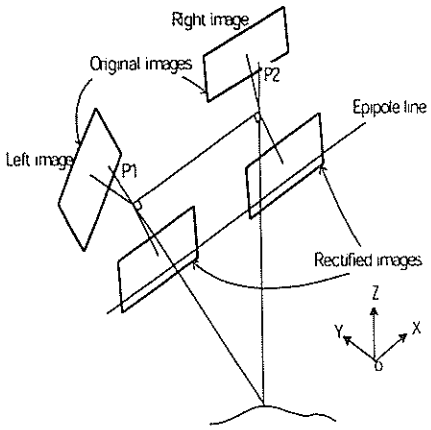


Figure 2. Rectification of balloon image



pixel for each pixel on the left image is decided by searching pixels giving a correlation function maximum value in the candidate pixels on the corresponding epipole line on the right image. As for candidate pixel we mean pixels that gives a possible height with exterior orientation parameters and the corresponding left pixel coordinates. Second, the finest image is used for matching. A conjugate pixel for each point on the coarser left image is decided by searching in a rectangle cornered at (i-20, j-10) and (i+20, j+10) on the finer right image, where (i, j) denotes coordinate of the conjugate pixel decided in the first process on the finer right image, i and j being the coordinates to the parallel and perpendicular direction of the epipole line, respectively. In this way, a conjugate pixel on the finer right image is decided for each pixel on the coarser left image. This algorithm is based on the coarse-to-fine matching algorithm, but coordinates of conjugate pixels decided in the first process are almost confirmed and one or two pixels (on the coarser image) adjustment is operated on the finer image since in the first process, as described in the section of "results and evaluation," there were no wanderings in search of inspected pixels providing proper correlation window sizes.

4.3 Ortho

Three dimensional coordinates including height of a terrestrial point corresponding to each pixel on the coarser left image are calculated from exterior orientation parameters and coordinates of the conjugate left and right pixels. The obtained DEM data is converted to ortho image based on an algorithm for making digital orthophotos (Hohle, 1996). In addition to the basic algorithm, height model in the terrestrial coordinate space is formed by connecting points corresponding to each pixel on the coarser left image. Ortho DEM is formed by projecting the height model to the horizontal plain in a sampling interval.

5. RESULTS AND EVALUATION

The image correlation matching algorithm was operated with some correlation window sizes and two correlation functions and results of the matching was tested with inspected points and results of ground survey.

5.1 Evaluation of matching with human eyes

Fifty pixels on the coarser left image were pseudorandomly chosen and matched by human eyes to inspect the automated matching result. Image correlation coefficient and reciprocal of image absolute disparity were used for correlation functions. As a result, Root Mean Square Errors (RMSEs) of the matching were 0.7-1.0 pixels for 11X11 - 41X41 sized correlation windows after the first process (Table 1). Method A, B are equivalent to usage of correlation func-

Table 1. Evaluation of matching
(first process, n=50)

Correlation window size	RMS Error (pixel), Percent of correct points	
	Method A	Method B
7×7	(1.06, 0.62), 96%	(2.52, 2.26), 92%
11×11	(0.84, 0.39), 100%	(1.05, 0.63), 98%
21×21	(0.74, 0.38), 100%	(0.78, 0.39), 100%
31×31	(0.87, 0.41), 100%	(1.00, 0.38), 96%
41×41	(0.92, 0.38), 100%	(0.98, 0.38), 100%
51×51	(0.96, 0.38), 98%	(1.00, 0.38), 98%
61×61	(1.00, 0.40), 98%	(1.07, 0.38), 98%

Table 2. Evaluation of matching (second process, n=50)

correlation window size (2^{nd} step)	RMS Error (pixel), Percent of correct points					
	Method A			Method B		
	13×13 (1^{st})	21×21 (1^{st})	41×41 (1^{st})	13×13 (1^{st})	21×21 (1^{st})	41×41 (1^{st})
49×49	(0.64, 0.38)	(0.64, 0.38)	(0.87, 0.42)	(0.85, 0.43)	(0.82, 0.42)	(0.89, 0.43)
59×59	(0.54, 0.36)	(0.54, 0.36)	(0.52, 0.36)	(0.66, 0.43)	(0.59, 0.42)	(0.58, 0.43)
69×69	(0.49, 0.37)	(0.49, 0.37)	(0.46, 0.37)	(0.59, 0.41)	(0.59, 0.41)	(0.57, 0.41)
79×79	(0.53, 0.35)	(0.53, 0.35)	(0.49, 0.36)	(0.51, 0.34)	(0.51, 0.34)	(0.49, 0.34)
89×89	(0.57, 0.34)	(0.57, 0.34)	(0.57, 0.35)	(0.56, 0.34)	(0.56, 0.34)	(0.54, 0.34)
109×109	(0.55, 0.35)	(0.55, 0.35)	(0.55, 0.35)	(0.58, 0.33)	(0.58, 0.33)	(0.56, 0.33)
129×129	(0.60, 0.34)	(0.60, 0.34)	(0.60, 0.34)	(0.63, 0.34)	(0.63, 0.34)	(0.63, 0.34)
169×169	–	(0.68, 0.33)	(0.68, 0.33)	–	(0.71, 0.34)	(0.71, 0.34)

[ ] : suitable error value

Figure 5. DEM of a sample area in To-daeng, Narathiwat

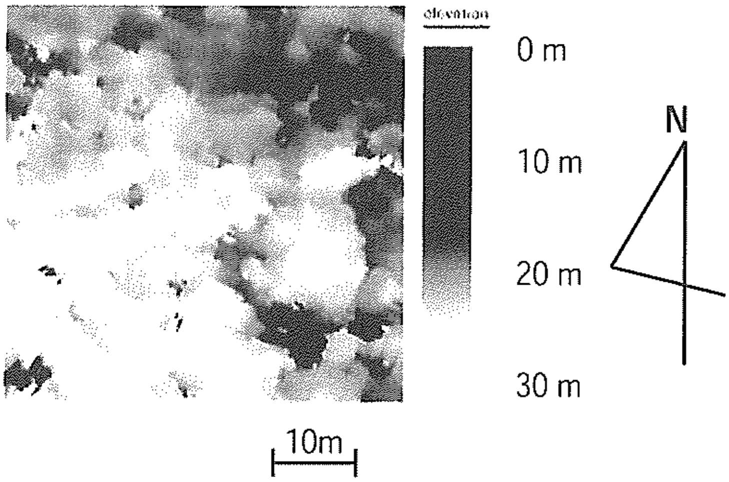
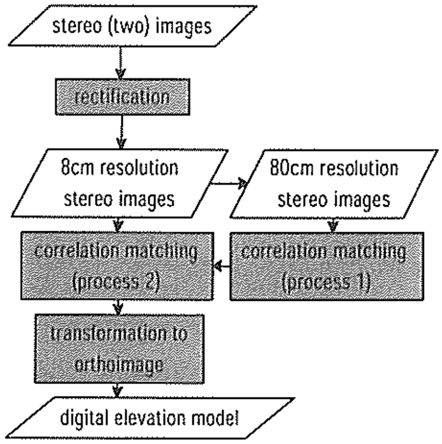


Figure 4. Flow of matching after



tions for image correlation coefficient and reciprocal of image absolute disparity, respectively. Percent of correct points means the rate of the inspected pixel whose error is within two pixels. The RMSEs were improved as 0.5-0.6 pixels after the second process with 6X6 - 13X13 (on the coarser image) sized correlation windows (Table 2). 0.9 pixels and 0.6 pixels are equivalent to 2.88 m and 1.92 m heights, respectively, considering the 0.8 m resolution and the 0.25 base-height ratio. Combining the errors with the orientation calculation, the errors are 3.3 and 2.5, respectively. Here, the error function is assumed to obey normal distribution function and the errors are estimated by an equation,

$$e = \sigma = \sqrt{\sigma_1^2 + \sigma_2^2} = \sqrt{e_m^2 + e_o^2}, \qquad (1)$$

where e is the estimated RMSE, e_m, and e_o denote RMSE for matching and orientation, respectively, and σ, σ_1, and σ_2 denote corresponding standard deviations of independent normal

distributions. In a similar way, errors to horizontal direction were estimated as 0.94 after the first process and 0.77 after the second process.

5.2 Forest DEM and Processing speed

Forest ortho DEM was formed in 0.2m interval. An example for the obtained DEM is shown in figure 5. Continuity of the forest surface structure and crown structure appear in the DEM. The processing speed for the digital analysis was about 5,000m^2/day under the Windows NT operating system on a PC equipped with a 200-MHz Pentium Pro processor, 128Mbytes of RAM, and 3.6 Gbytes of hard disk. The speed for manually operated work is estimated at about three hours per stereo pair, that is 1,340,000m^2/day and much higher than that of digital analysis, if there is no mistake in data input.

6. CONCLUSION

In this research, we tested a DEM extraction of a tropical peat swamp forest from balloon stereo images in Narathiwat, Thailand. The site has advantages in digital matching of forest: the ground is almost flat and tree shadow area is small. As a result of evaluation of the digital matching with that of by human eyes, RMSEs of the matching were 0.7-1.0 pixels for 13X13-41X41 sized correlation windows. The RMSEs were improved as 0.5-0.6 pixels with a newly developed time-saving coarse-to-fine matching algorithm. Considering errors in orientation calculation, the error with the new algorithm is estimated at 0.8m in the horizontal direction and 2.5m in the vertical direction.

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Influences of deforestation on heat and carbon balances in a tropical peat swamp forest in Thailand

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Introduction

There are approximately 0.4 million km² of tropical peatlands in the Southeast Asia, which account for approximately 70% of worldwide tropical peatlands. Most of the peatlands were covered with natural peat swamp forest in the Southeast Asia. However, natural forest has been developed for agricultural use or lumber production and converted to fields for cultivation, wastelands and/or secondary forests. We evaluated the effects of deforestation on both heat and carbon balances by micrometeorological monitoring.

Research sites and method

The experiments were carried out at two sites of different vegetation covers at a tropical peat swamp area, namely (1) To-Daeng (6° 4' 30" N ,101° 58' 20"E) for a primary forest, (2) Bacho (6° 30' 22" N ,101° 44' 42"E) for a secondary forest (Fig.1).

The primary forest was composed 31 tree species, belonging to 17 families and 26 genera. The uppermost story was mainly composed of *Ganua Motoreyana* and the under story was mainly composed of *Eugenia Tumida*. The mean canopy height was approximately 25m and above ground biomass was estimated at 245ton ha^{-1} of dry weight (described as tDW ha^{-1}). The peat was the uppermost layer of forest soil and accumulated less than 3m on the clay layer. The forest was water-logged through a year and the water depth was around 0.05m to 0.9m.

The primary forest had been clearly cut at the secondary forest and the ponding water had been drained to utilize for agriculture since the 1970's. However, the land could not be used for agriculture because of the strong acidity of the soil. The peat accumulated to less than 3m. There is no ponding water above the soil surface except in the rainy season because of drainage. The water level was observed at 60cm under the surface at its lowest in the dry season and 60cm ponding water at its highest above the surface in the rainy season. The stand was mainly composed of *Melaleuca cajuputi* and several kind of grasses. This region had been repeatedly burned and the average height of the stand had recovered to 2.5m through 4 years in April 1996. Above- and under-ground biomass was estimated at 12.0 $tDW\,ha^{-1}$ and 17.6 $tDW\,ha^{-1}$ respectively in April 1996.

Monitoring towers in both sites were used for micro-meteorological measurements (Fig. 2). The Bowen's method and the relaxed eddy accumulation method (REA) were used to estimate heat and CO_2 fluxes above the canopies, respectively.

Heat balance

Annual courses of monthly averaged heat balance components in both sites are shown in Fig.3. The deforestation of peat swamp forest

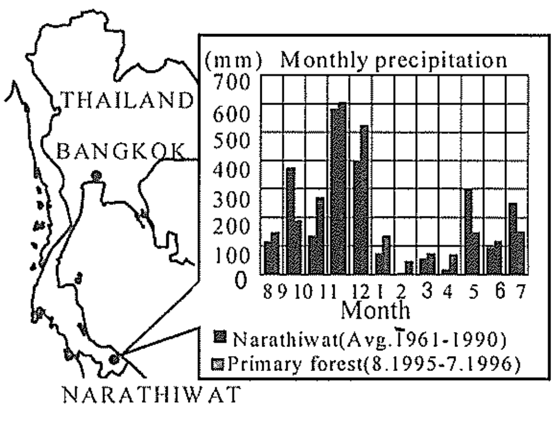

Fig.1 Research site and precipitation at the site.

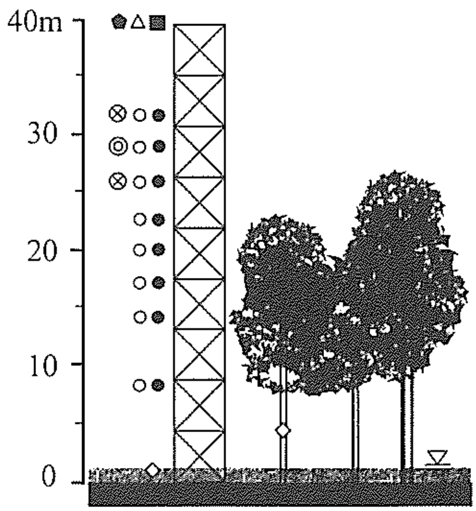

Fig.2 Arrangement of instruments for environmental monitoring at the primary forest. △ : Pyranometer, ⬟ : Net radiometer, ■ : Tipping bucket rain gauge, ◇: Thermocouple, ○: Dry bulb, ●: Wet bulb, ⊗: Air sample inlet for CO_2 measurement, ◎: Sonic anemometer.

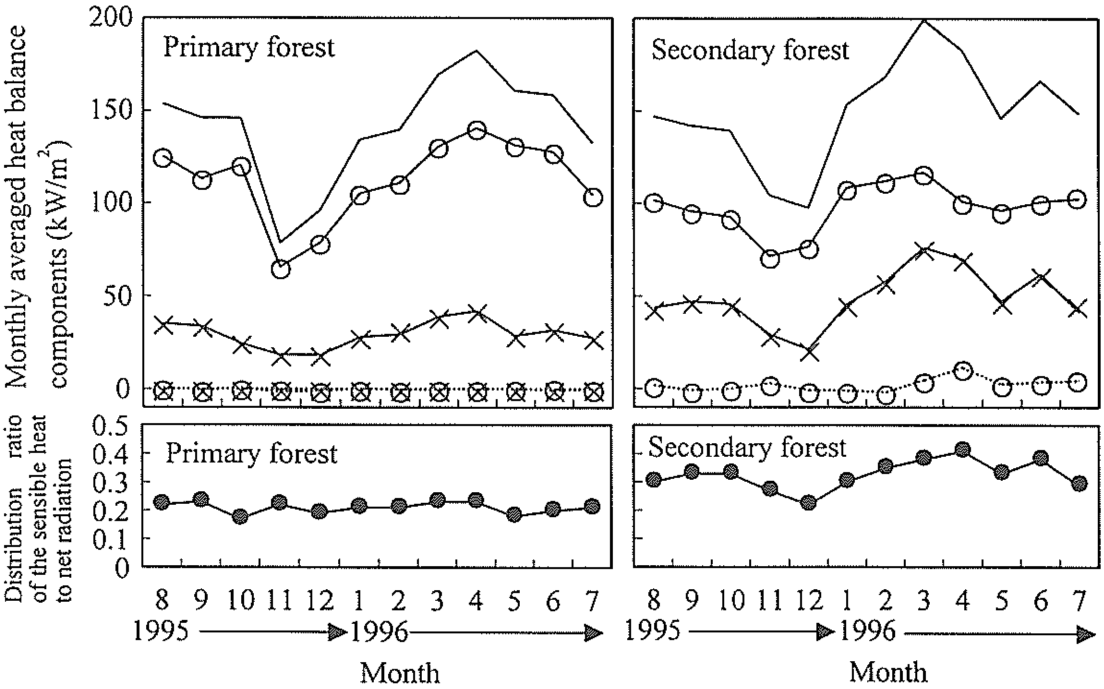

Fig.3 Annual courses of heat balance components and ratios of sensible heat to net radiation. (Rn) : Net radiatin, (lE) : Latent heat flux, (H) : Sensible heat flux, (G) : Heat flux into soil or heat storage in water, (Q) : Heat storage in stem.

Table 1 Yearly average ratios of the fluxes to the net radiation and total evapotranspirations

	Ratio to net radiation (%)		Evapotranspiration (mm)
	Latent heat	Sensible heat	
Primary forest	89	21	1553
Secondary forest	77	33	1312

leaded to an increase in the sensible heat flux in the secondary forest and a decrease in the latent heat flux. Especially, the sensible heat flux in the secondary forest increased in dry season because of decreasing in the latent heat flux by soil water shortage. The yearly average ratios of both fluxes to the net radiation are shown in Table 1 together with total evapotranspirations at both sites. These results suggested that the deforestation of peat swamp forest resulted in increase in ambient air temperature and decrease in evapotranspiration.

Table1 Yearly average ratios of the fluxes to the net radiation and total evapotranspirations

Net carbon absorption

Fig. 4 shows the courses of monthly amount of carbon absorption for both observation sites. Also, the simulated values in the secondary forest for two scenario, which are (1) in the case of keeping the soil under the dry condition through a year and (2) in the case of keeping ponding water without drainage through a year, are shown in the figure.

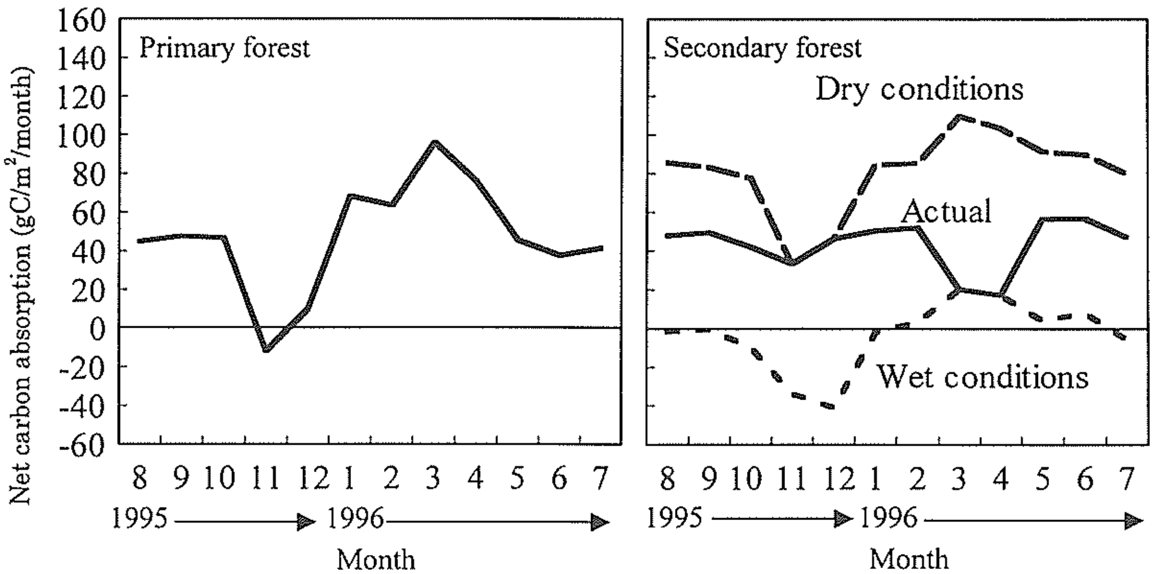

Fig.4 Courses of monthly amount of net carbon absorption

In the primary forest, net carbon absorption continued through a year, while low amount in rainy season because of low solar radiation. The total amount of net carbon absorption in a year was estimated to be 5.3 tC ha^{-1} yr^{-1} (Table 2). To-Daeng peat swamp forest could be considered to be matured and under climax stage because the forest have never been artificially disturbed. Usually the net absorption of carbon by the climax forest is expected to be zero because carbon absorption by photosynthesis is balanced by the carbon release from respiration processes. It is remarkable that the primary forest had net carbon absorption even if the forest was considered to be under climax stage. This is mainly because that the litter fall and fallen trees in the primary forest was stored under water as peat. Thus, the amount of release by the decomposition process was smaller and the net amount of carbon absorption continued. Authors have clarified the carbon balance at the site estimated by the accumulation method. The results support the above discussion. The continuous carbon absorption is a special feature of peat swamp forest and could be a quite important considering the global warming.

The secondary forest had low amount of net carbon absorption in dry season and high amount of net absorption in rainy season because the CO_2 flux against solar radiation was relatively high and the quantity of nocturnal CO_2 flux was low in the season. The total amount of actual net carbon absorption in a year was 5.2 tC ha^{-1} yr^{-1}. The difference of the total amounts between two sites was comparatively small. The reason for this was the large quantity of nocturnal CO_2 emission in the primary forest.

The annual amount of expected net carbon absorption in the secondary forest with ponded ground surface through a year were evaluated to be 9.7 tC ha^{-1} yr^{-1}, which equaled to 1.8 times of actual net carbon absorption. The expected net carbon absorption with complete drainage through a year were evaluated to be

Table 2 Annual net carbon absorption (tC ha^{-1} yr^{-1})

Primary forest	Secondary forest		
	Actual	Dry conditions through a year	Wet conditions through a year
5.32	5.22	−0.4	9.69

-0.4 tC ha^{-1} yr^{-1}, which means net carbon emission. These two scenarios show that water management is quite important for the secondary forest to restrict the peat decomposition and keep the forest as a carbon sink.

Conclusion

Deforestation of the primary peat swamp forest and development for agricultural field resulted in increase of sensible heat flux and decrease in evapotranspiration, which may change ambient air to higher temperature and drier. The peat swamp forest had a special feature as a continuous carbon sink. Deforestation and inadequate water management could change the area as a carbon source because of peat decomposition.

DIWPA Activities for Biodiversity Research at Western Pacific and Asia

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What is DIWPA ?

DIWPA, Diversitas Western Pacific and Asia, is an international network for promoting cooperative researches on biodiversity and, based on it, to promote action plans for conservation and sustainable use of biodiversity in the region of Western Pacific and Asia, under a close cooperation with its mother program, Diversitas organized by IUBS, SCOPE, UNESCO, ICSU, IGBP-GCTE and IUMS.

It proposed nine major theme concerning biodiversity research: 1) origin, maintenance and loss, 2) ecosystem functioning, 3) inventorying, classification and relationships, 4) assessment and monitoring, 5) conservation, restoration, and sustainable use, 6) human dimensions of biodiversity, 7) soil and sediment biodiversity, 8) marine biodiversity, 9) microbial biodiversity (Younès 1996). DIWPA was established in December 1993 as one of regional program of Diversitas and covered "Western Pacific and Asia", that is East Asia, South Asia, Southeast Asia, Micronesia, Australia and New Zealand.

DIWPA has the four main purposes: (1) Networking of field stations for biodiversity researches, (2) Promotion of international research projects, (3) Civilian interchange of biodiversity information, and (4) Encourage voluntary conservation activities (Inoue 1996).

At moment on July 1997, DIWPA has about 367 members from 37 areas (Table 1). DIWPA membership is open to not only to scientists, but also to citizens interested in research, conservation and sustainable use of biodiversity.

International Biodiversity Observation Year (IBOY)

In the first phase of DIWPA activities, International Biodiversity Observation Year (IBOY) is the one of most important event. In this program, DIWPA is conducting "Global monitoring on Biodiversity" using a standardized manual at DIWPA sites in 2001 (-2003). The aims of IBOY is (1) establish an international network for preservation and identification of biological specimen and (2) elucidate the effects of biodiversity on ecosystem functioning by inventorying and monitoring biodiversity simultaneously with a standardized manual in three ecosystems, forest ecosystem, lake ecosystem and coastal ecosystem. We are requested to prepare a research strategy for organizing various activities from field to laboratory, statistics and methodology for efficient sampling and comparison, and a logic of research that is understandable not only scientists in other regions, but also politicians, decision makers and citizens.

In order to accomplish the IBOY, a DIWPA Workshop "Developing Standards for Global Monitoring on Biodiversity" was held on November 1998, at Kyoto, Japan. In this workshop, specialized working groups for the three ecosystem (forest, lake and coastal ecosystems) discussed about research sites and methods on respective ecosystems. In addition, designs and strategies of IBOY, taxonomy and information system of IBOY, and the present organization for IBOY in each region and country were discussed. Protocols and inventory methodology and criteria for IBOY sites were also discussed at two parallel sessions. As a result, nominated respective research site for forest ecosystem is shown in Table 2. Preliminal result on the discussion: respective study sites and standardized manual will be published until June 1999, and pilot study will be done within next year.

International Field Biology Course (IFBC)

Another DIWPA activity under progress is International Field Biology Course (IFBC). IFBC was started in 1995 as one of activities of DIWPA. The purpose of the course is to exchange information on biodiversity at student level, and to initiate mainly undergraduate student for biodiversity science. First course was held at Lambir National Park, Borneo, Malaysia, second at Lake Baikal, Siberia, Russia, the third at four different tropical forest area in Thailand, and the fourth at Yakushima, Japan, one of the world heritage, in 1998 (Table 2). In the fourth course DIWPA accepted a request from JICA office to use this course as one of training program for JICA trainee and four trainee from Zambia participated the course. The course will be held annually in various biodiversity field stations. Especially from next year, IFBC will be held as not only training course for students, but also pilot study for IBOY. We hope many students will be interested in this program and also in IBOY through IFBC.

Future Activities of DIWPA

DIWPA office hope any people who are interested in biodiversity research to join us and exchange information on current activities concerning their biodiversity research. After 2001, from 2002-2004, data collected in BOY will be compiled and analyzed. The results will be published in a series of DIWPA reports. Throughout these activities, we could clarify the origins of species diversity from the biogeographical perspective and could discuss speciation and evolution as a process of increase of diversity. In 2005, DIWPA will organize the Biodiversity Summit in Western Pacific and Asia to synthesize information of the first phase of DIWPA activities, and to make the action plan for the next decade from year 2006.

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Table 1. Membership of DIWPA (until May 1997)

Area	Number of member	Area	Number of member
Australia	10	Mongolia	4
Bangladesh	1	Myanmer	1
Brunei	1	New Caledonia	2
Canada	1	New Zealand	2
China	38	Palau	1
Cook Islands	1	Papua New Guinea	1
DPR Korea	1	Philippines	6
Fiji	14	Russia	30
Finland	1	Singapore	18
France	9	Sri Lanka	2
French Polynesia	7	Taiwan, ROC	15
Germany	1	Thailand	11
Guam	3	The Netherlands	1
India	5	U. K.	4
Indonesia	12	U. S. A.	18
Japan	81	Vietnam	8
Korea	13	Western Samoa	5
Laos	1		
Malaysia	32		
Micronesia	2	Total	363

Table 2. Proposed Research Sites for BOY

Area	Site name	Forest type*	
Australia	Cape Tribulation	Tropical rain forest	C
Australia	Cououdale Ranges	Tropical rain forest	S
Australia	Eungella	Tropical rain forest	S
Australia	Lawington N.P.	Tropical rain forest	C
Australia	Paluma	Tropical rain forest	S
Australia	Robson Creek	Tropical rain forest	S
Brunei	Kuara Buruong	Tropical rain forest	S
China	Beiling Forest Ecosystem Res. Sta.	Warm-temperate deciduous forest	C
China	Changbaishan Forest	Temperate deciduous forest	C
China	Dinghushan Forest	Subtropical evergreen forest	C
China	Foping Sta.	Subtropical evergreen forest	C
China	Gonggashan Forest	Subtropical evergreen forest	C
China	Heshan Forest	Subtropical evergreen forest	C
China	Huitong Forest	Subtropical evergreen forest	C
China	Jiuliaanshan Sta.	Subtropical evergreen forest	C
China	Shengnongjia Sta.	Tropical evergreen forest	C
China	Xishuangbanna Forest	Tropical rain forest C	
China-Taipei	Fushan Forest	Subtropical evergreen forest	C
China-Taipei	Guandaushi Forest	Subtropical evergreen forest	C
China-Taipei	Nanjenshan Forest	Subtropical evergreen forest	C
China-Taipei	Tatachia Forest	Montane evergreen forest	C
China-Taipei	Yuanyang Forest	Temperate mixed forest	C
Indonesia	Bukit Soeharto Education Forest	Tropical rain forest S	
Indonesia	Gunung Halimun N.P.	Montane evergreen forest	C?
Japan	Ashiu Res. Sta.	Temperate deciduous forest	S
Japan	Ogawa Forest Reserve	Temperate deciduous forest	S
Japan	Tomakomai Res. Sta.	Temperate deciduous forest	C
Japan	Yakushima	Subtropical evergreen forest	S
Korea	Keumsan Forest	Temperate deciduous forest	C
Korea	Kwangung Experimental Forest	Temperate deciduous forest	C
Korea	Kyebangsan Forest	Temperate deciduous forest	C
Malaysia	Dannan Valley	Tropical raine forest	C?
Malaysia	Kinabaru	Montane evergreen forest	C?
Malaysia	Kubah N.P.	Tropical raine forest	S
Malaysia	Lambir N.P.	Tropical raine forest	C
Malaysia	Pasho	Tropical raine forest	C?
New Zealand	Maruia	Temperate deciduous forest	C?
Russia	Tura	Boreal forest	S

Russia	Vladiovstok	Temperate mixed forest	C
Thailand	Huei Kah Kchaeng	Tropical dry evergreen forest	C?
Thailand	Mae Klong Watershed Res. Sta.	Tropical deciduous forest	S
Thailand	Narathiwat	Swamp forest	S
Thailand	Sakaerat Environmental Res. Sta.	Tropical dry evergreen forest	C

* : C means "core site" and S means "sattelite site".

Table 3. Fields and participants of International Field Biology Course (IFBC)

Place	Country		number of students and Nationality	
Lambir National Park	Malaysia	1995	6	Japan
			2	Korea
			5	R. China
			5	Malaysia
Lake Baikal	Russia	1996	8	Japan
			1	Korea
			2	Russia
			1	Singapore
Tropical forest	Thailand	1997	5	China Taipei
			5	Japan
			5	Thailand
			1	U.S.A
Yakushima Island,	Japan	1998	5	China Taipei
			8	Japan
			1	Malaysia
			1	Russia
			2	Thailand
			4	Zambia (Trainee of JICA)