Development of New Vegetation Indices and Algorithms for Detecting Vegetation Changes

-Evaluation of Global Net Primary Production of Vegetation -

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L. Zhang
Wuhan University

Our goal is to get NPP in the world

from a new vegetation index

using GLI data.

↓

What's the new vegetation index?

↓

The new vegetation index

is

VIPD (Vegetation Index based on Pattern Decomposition Method).

Why do we use VIPD instead of NDVI?

↓

Because, NDVI is calculated from only two bands, but VIPD is calculated from all bands of multi-spectral satellite data.

What's Pattern Decomposition Method (PDM)?

↓

> The PDM is an analytic method based on
> spectral shape patterns
> and
> linear spectral mixing of ground objects
> for n-dimensional satellite data.

Pattern Decomposition Method

N. Fujiwara, K. Muramatsu, S. Awa T.Hazumi and F. Ochiai.
「Pattern expand method for satellite data analysis」 (in Japanese)
Journal of The Remote Sensing Society of Japan, Vol. 17, No. 3, pp. 17-34, 1996.

K. Muramatsu, S. Furumi, A. Hayashi, N. Fujiwara, M. Daigo, and F. Ochiai.
「Pattern decomposition method in the albedo space for Landsat/TM and MSS data analysis」
International Journal of Remote Sensing, Vol. 21, No. 1, 99-119, 2000.

VIPD

Hayashi, K. Muramatsu, S. Furumi, Y. Shiono, and N. Fujiwara.
「An algorithm and a new vegetation index for ADEOS-II/GLI data analysis」
Journal of The Remote Sensing Society of Japan, Vol. 18, No. 2, pp. 28-50, 1998.

S. Furumi, A. Hayashi, K. Muramatsu, and N. Fujiwara.
「Relation between vegetation vigor and a new vegetation index based on pattern decomposition method」
Journal of The Remote Sensing Society of Japan, Vol. 18, No. 3, pp.17-34, 1998.

K. Muramatsu, S. Furumi, A. Hayashi, Y. Shiono, A. Ono, N. Fujiwara, M. Daigo, and F. Ochiai.
「Pattern decomposition method and a new vegetation index for hyper-multispectral satellite data analysis」
Adv. Space Res., Vol. 26, No. 7, pp.1137-1140, 2000.

Pattern Decomposition Method

Multispectral Satellite data : Ai (i=1,,,n) n-dimensional data

①

Three standard patterns

water pattern (Piw, i=1,,,n)

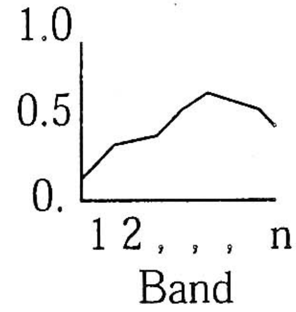
vegetation pattern (Piv, i=1,,,n)

soil pattern (Pis, i=1,,,n)

(shape of the spectral response pattern)

$1 = \sum_{i=1}^{n} Pij$ (i:band# , j=w,v,s)

spectral response pattern



② For each pixel

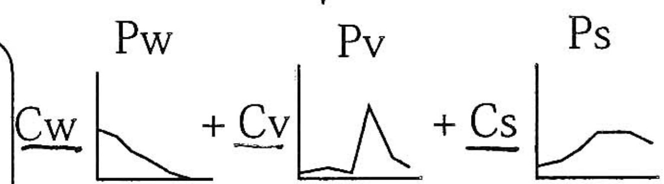
Pattern Decomposition

Ai → CwPiw+CvPiv+CsPis

(Cw,Cv,Cs) : least square method , Cw≥0, Cv≥0, Cs≥0

Band i's Remainder : Ri = Ai - (CwPiw+CvPiv+CsPis)

Relative error : $\Delta A = (\sum_{i=1}^{n} Ri^2)^{1/2} / \sum_{i=1}^{n} Ai$



Cw: water coefficient

Cv: vegetation coefficient

Cs: soil coefficient

The same standard patterns are used for analysis.

③ three

Pattern Decomposition Coefficients: (Cw, Cv, Cs)

3-dimensional data → VIPD

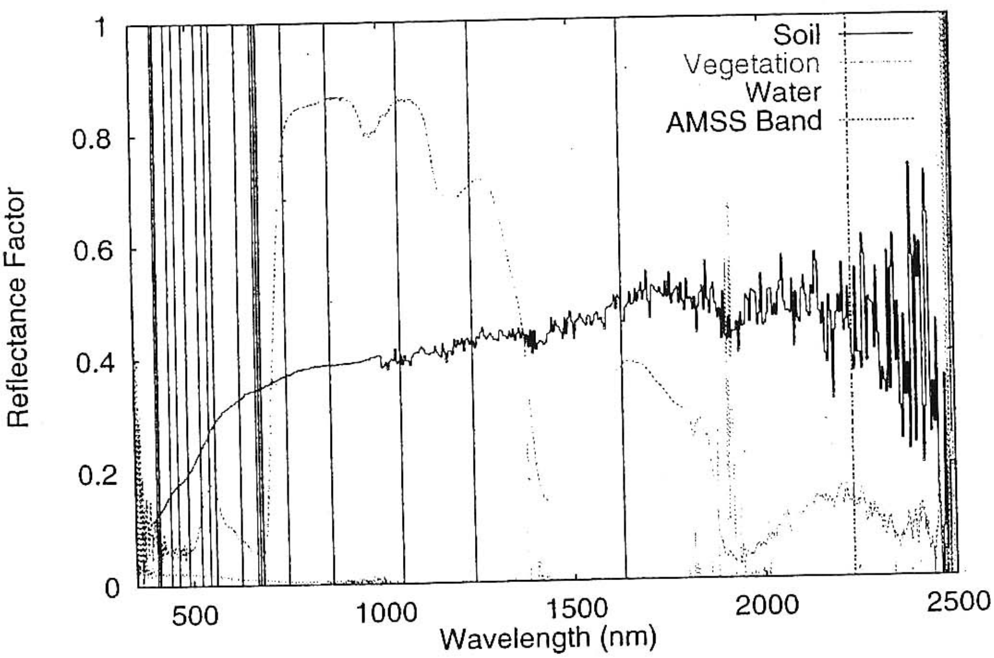
To check GLI data

2.2 i) AMSS (Airborne Multi spectral Scanner) Data Analysis

- AMSS has the same spectral bands as GLI
- Ground resolution is 5m

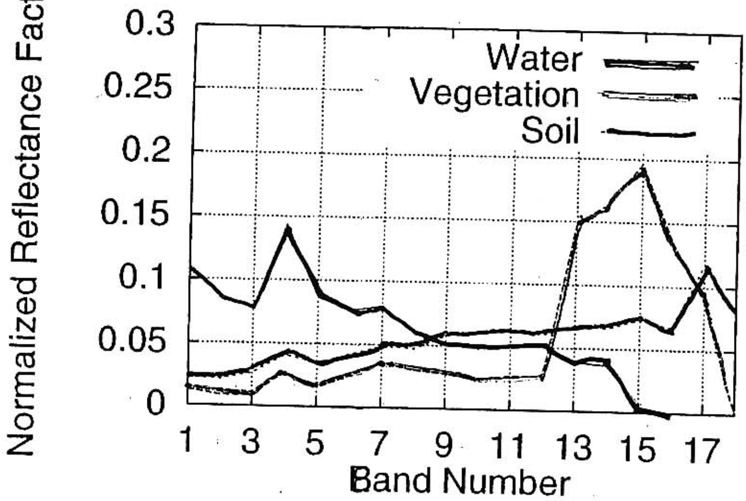
False color image of Sakata city, Akita prefecture, Japan, June 13, 1996

AMSS spectral bands

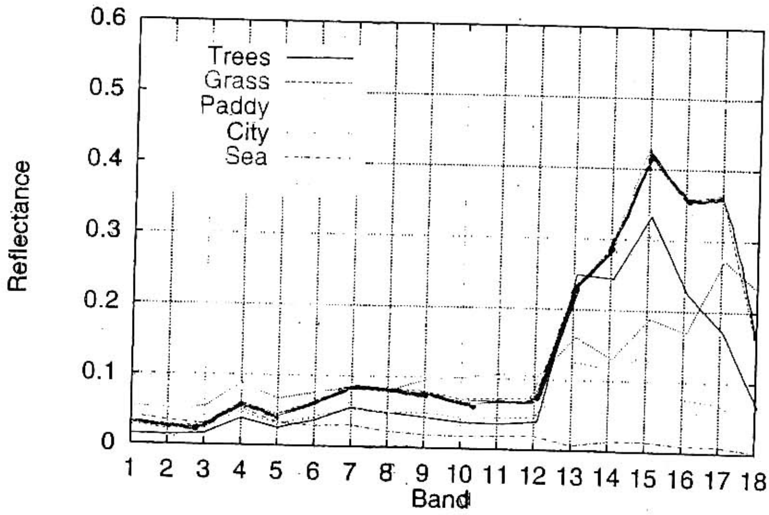


AMSS

Three Standard Patterns

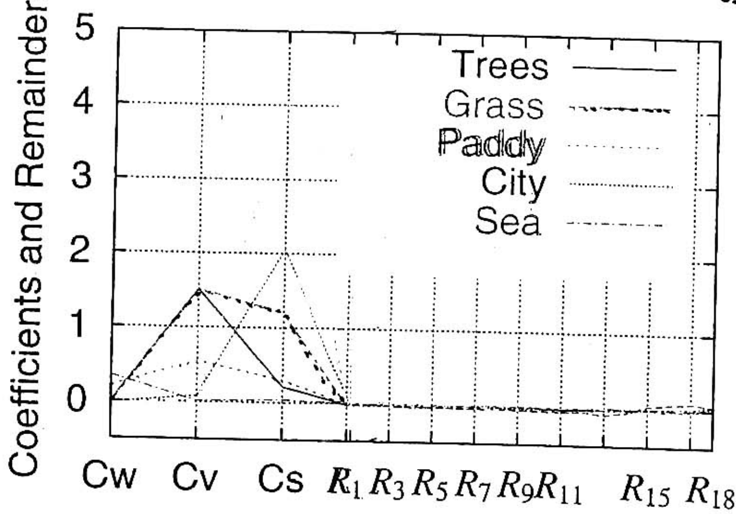


Spectral response patterns



Pattern decomposition Coefficients

Ground Covers



VIPD (Vegetation Index based on Pattern Decomposition Method)

The new vegetation index should be defined as the linear combination of three pattern decomposition coefficients.

$$VIPD = aC_w + bC_v + cC_s + d$$

Pure water area	$C_w \rightarrow S_w$	$VIPD = aS_w + d = 0$
Pure vegetation area	$C_v \rightarrow S_v$	$VIPD = bS_v + d = 1$
Pure soil area	$C_s \rightarrow S_s$	$VIPD = cS_s + d = 0$

S_w: the sum of the albedo values of six bands for the standard sample of water

S_v: for the standard sample of vegetation

S_s: for the standard sample of soil

$|c| = |b|$

$$VIPD = \frac{C_v - \frac{S_s}{\sum A_i} C_w - C_s + S_s}{S_s + S_v}$$

ΣAi: the sum of the albedo values of six bands for the pixel

Ground Truth

To get the relationship between VIPD and NPP,

we have done the following ground measurements.

(1) Measurement of spectral reflectance

for many objects

(2) Measurement of canopy spectral reflectance

for a tree

(3) Measurement of photosynthesis for a leaf

(4) Measurement of canopy photosynthesis for a tree

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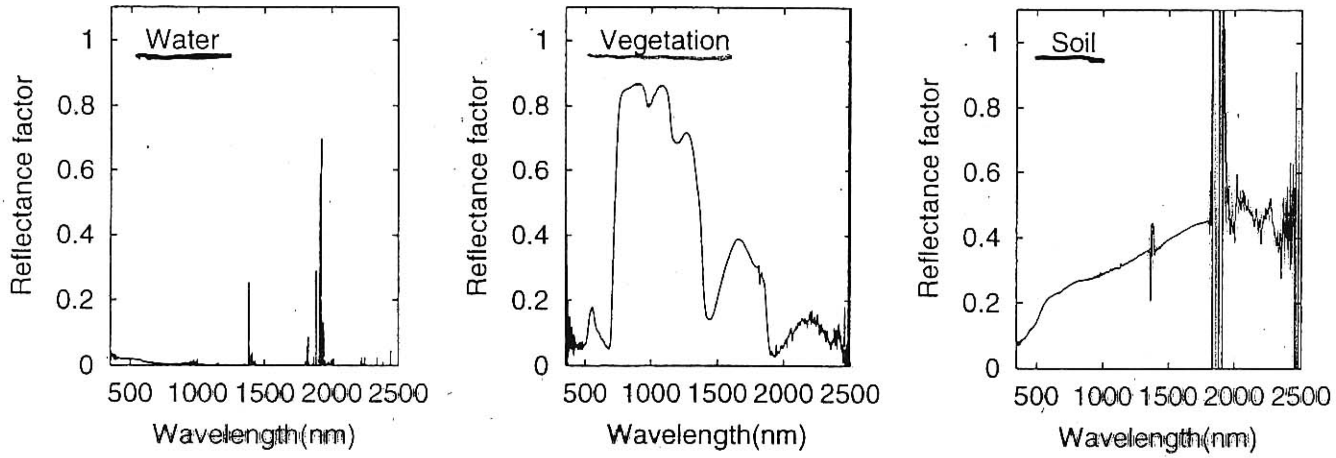
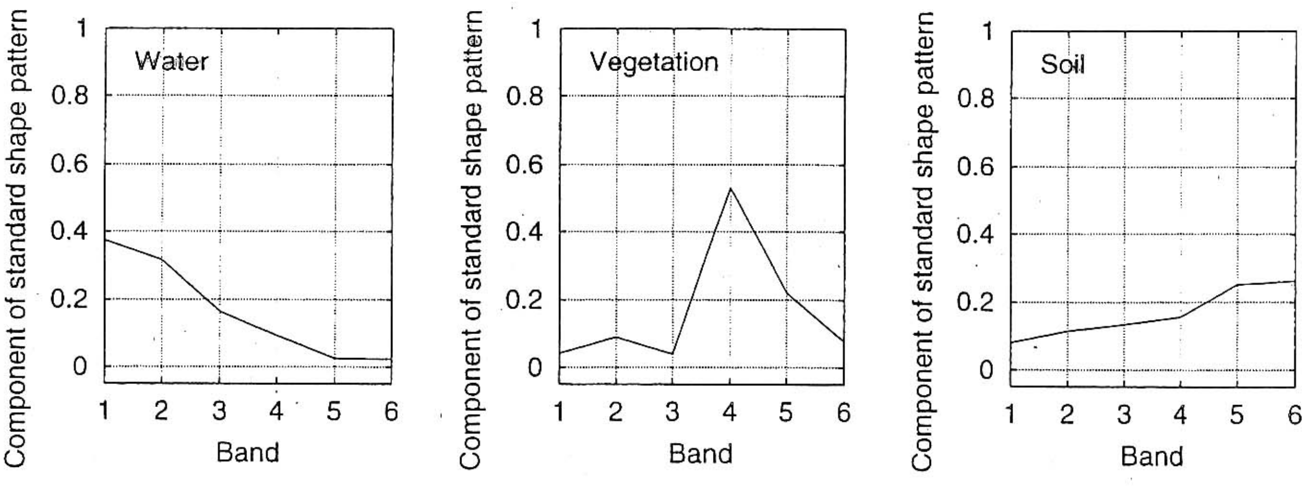
(5) Measurement of bi-directional reflectance factor

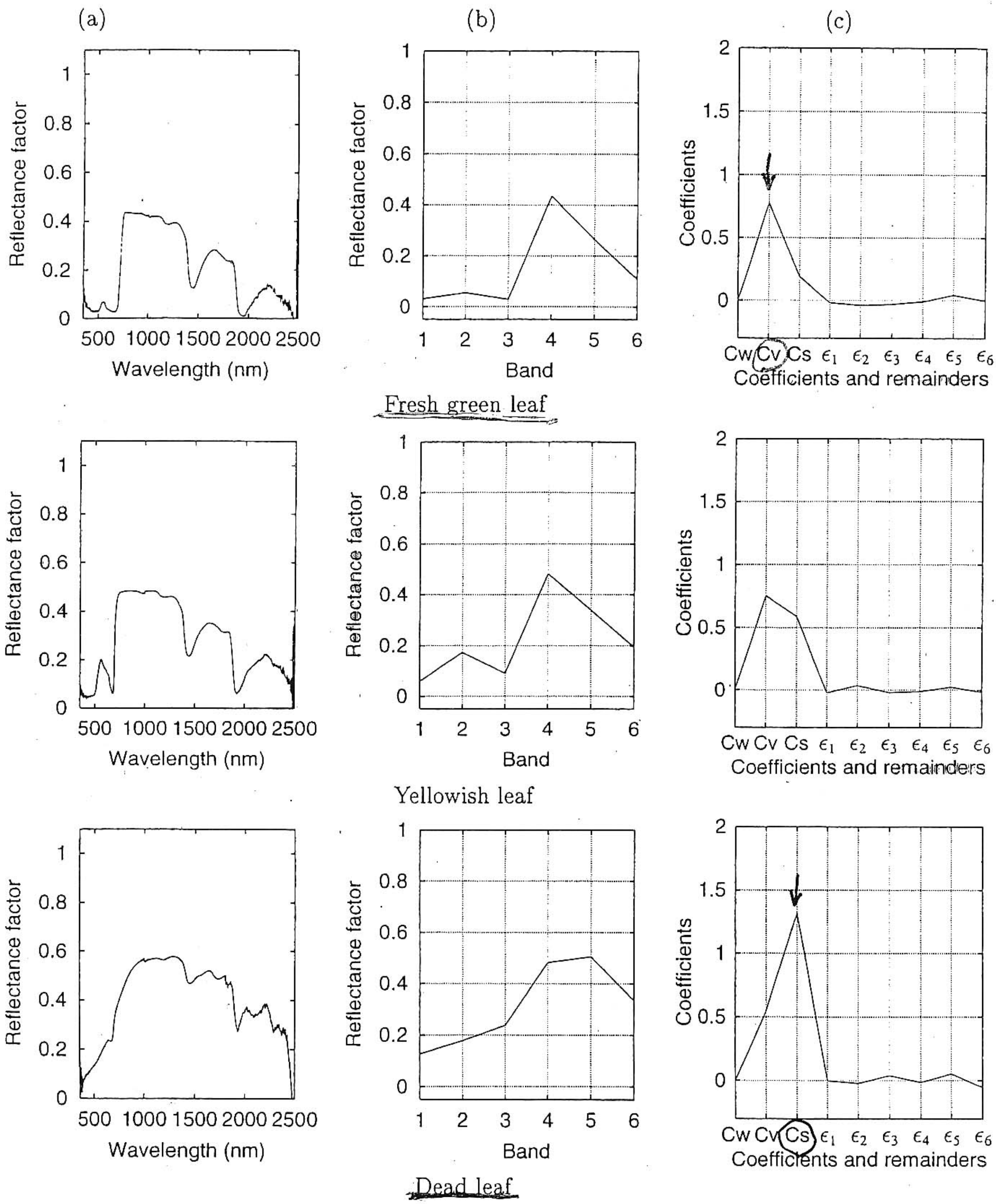
(1) Spectral reflectance is measured between 350 and 2500 nm using a Field Spec FR spectrometer.

(MSR-7000)



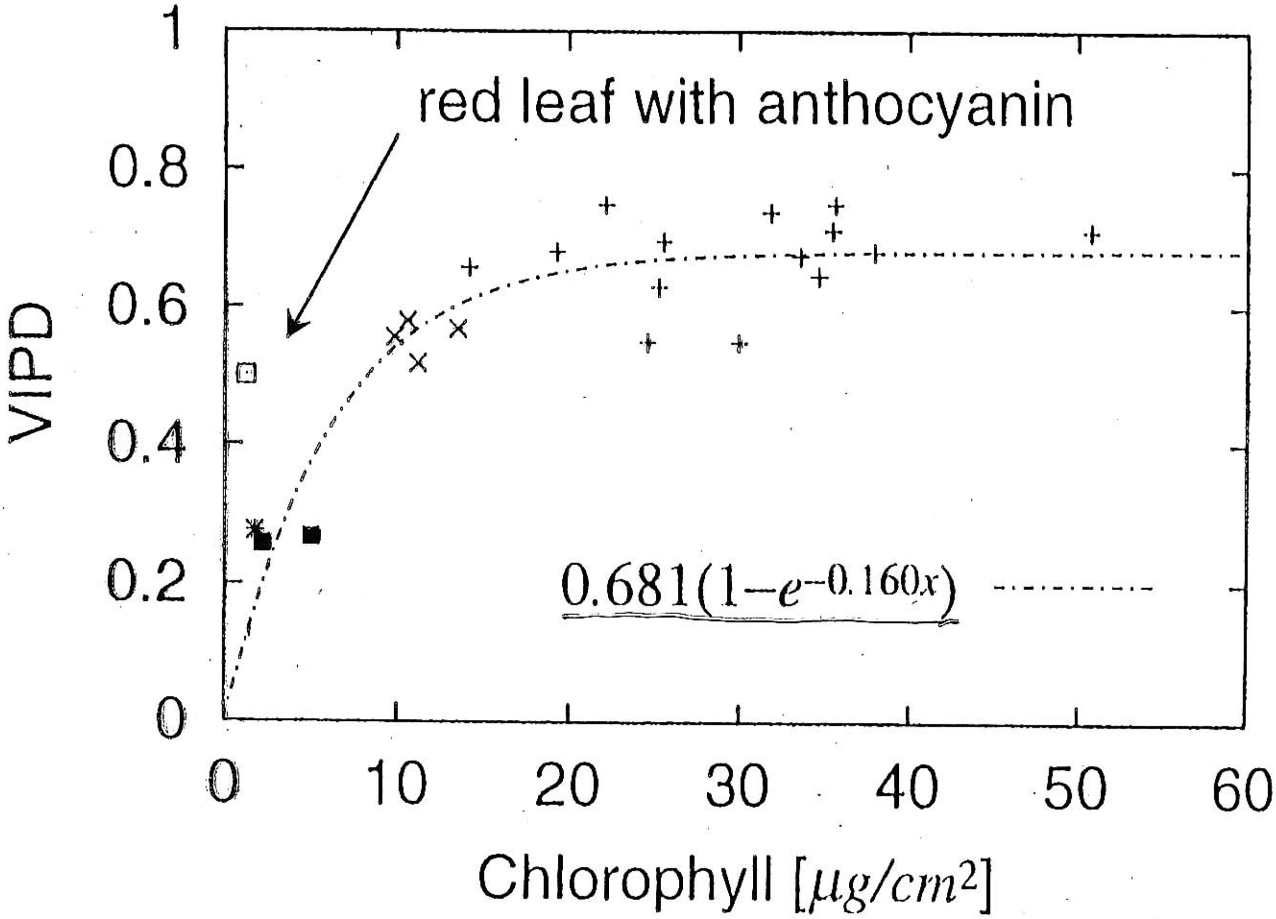
(a) Spectral reflectance curve





(a)
(b)
(c)
Reflectance factor
Wavelength (nm)
Band
Coefficients
Cw Cv Cs ϵ_1 ϵ_2 ϵ_3 ϵ_4 ϵ_5 ϵ_6
Coefficients and remainders
Fresh green leaf
Yellowish leaf
Dead leaf

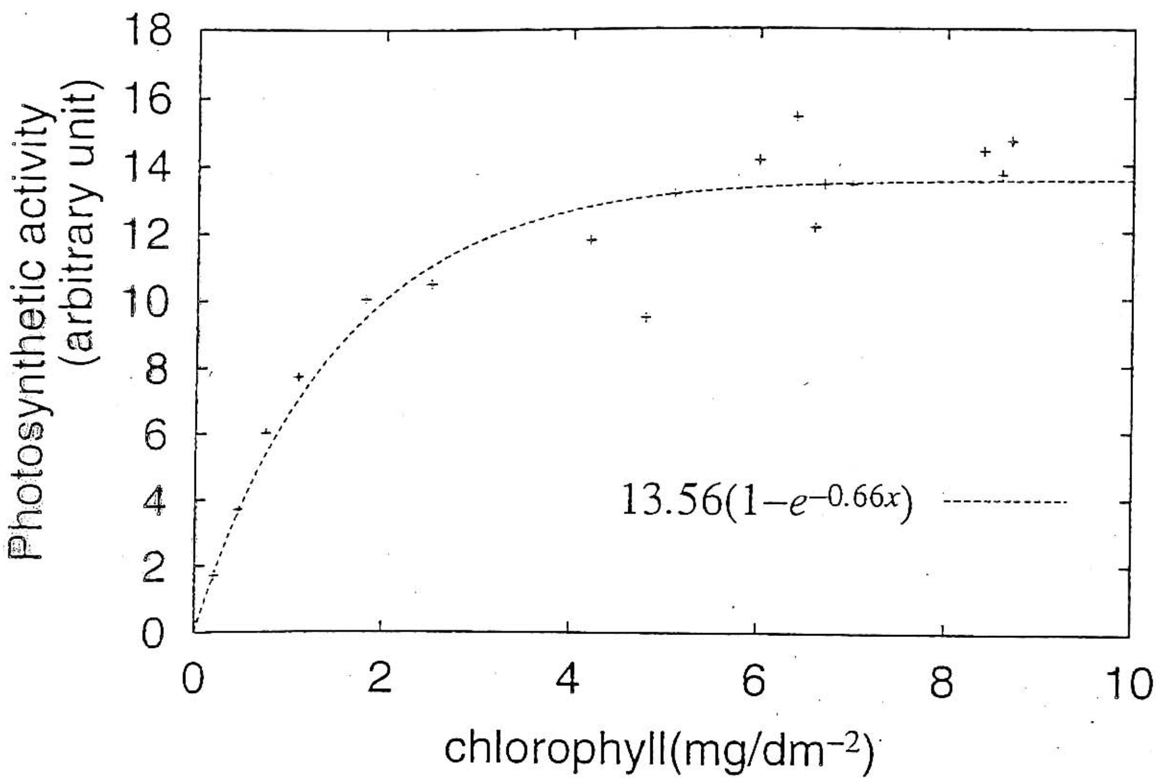
Relationship between Chlorophyll and VIPD



The broken line is the least regression line as a function $a(1-e^{-bx})$ of chlorophyll content.

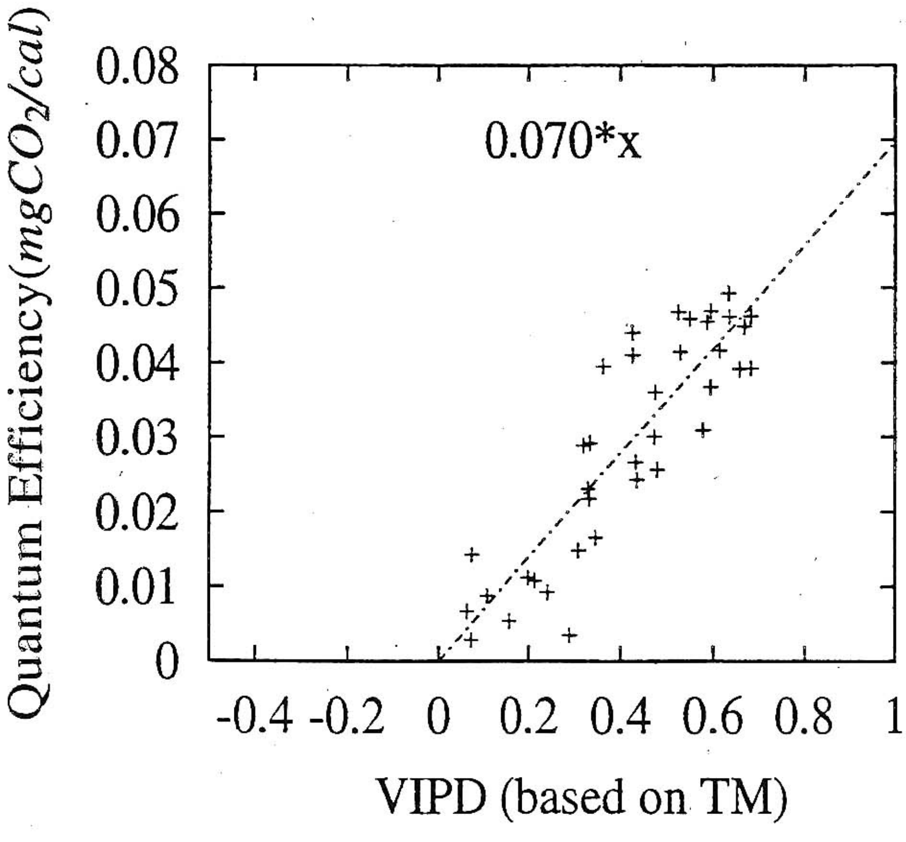
Relationship between chlorophyll content per leaf area and photosynthetic activity.

is referred



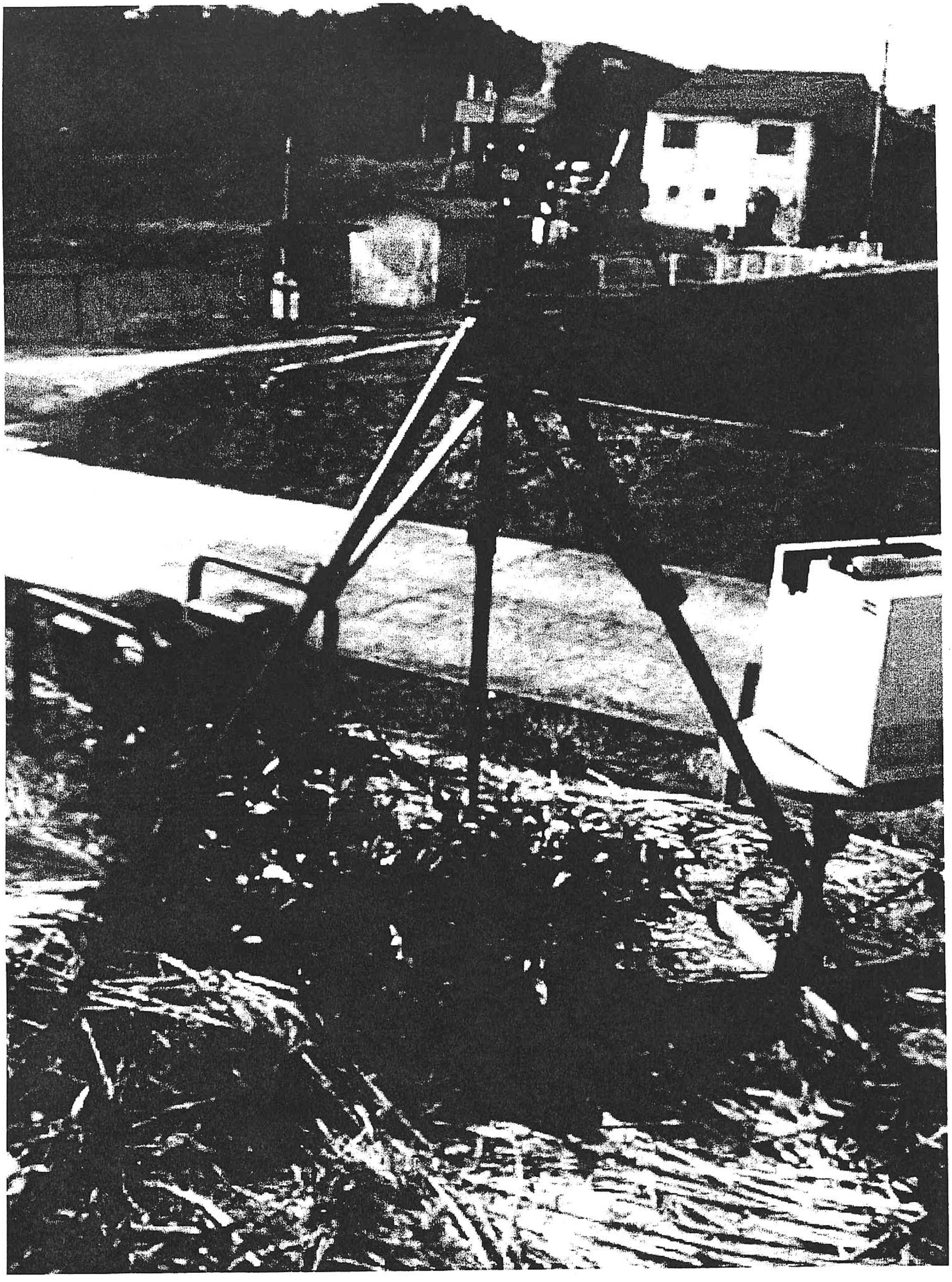
E.K. Gabrielsen Physiol. Plant., Vol1,5-13 (1948)

Relationship between VIPD and photosynthetic activity



$$QE = 0.070 \times VIPD$$

Measurement of canopy spectral reflectance



tea straw

(2) Canopy spectral reflectance is measured.

We estimated the canopy reflectance

by using Two-Stream Approximation Model.

B.J. Choudhury
Remote Sensing of Environment 22:209-233(1987)

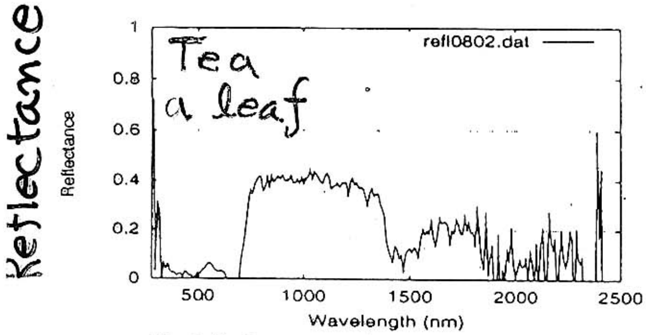


Fig.1 Reflectance of a leaf

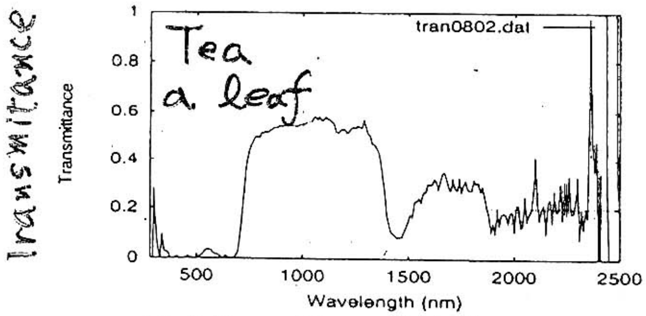


Fig.2 Transmittance of a leaf

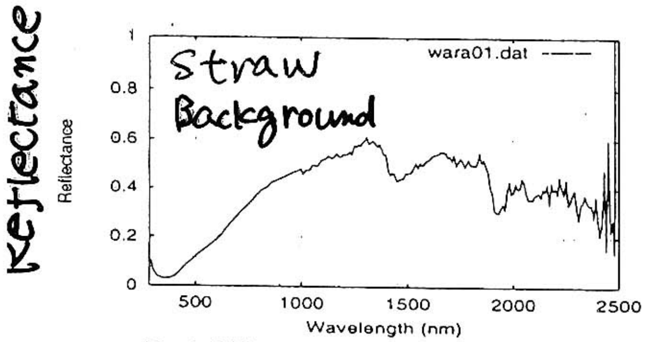


Fig.3 Reflectance of the straw

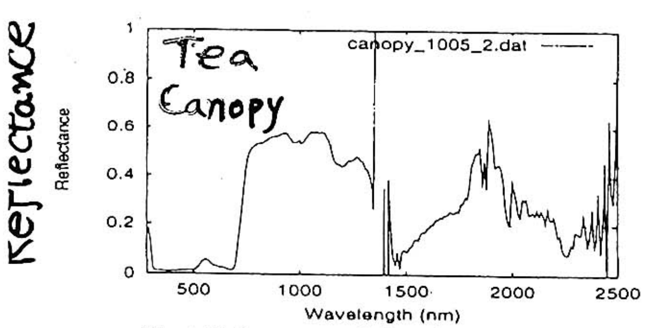
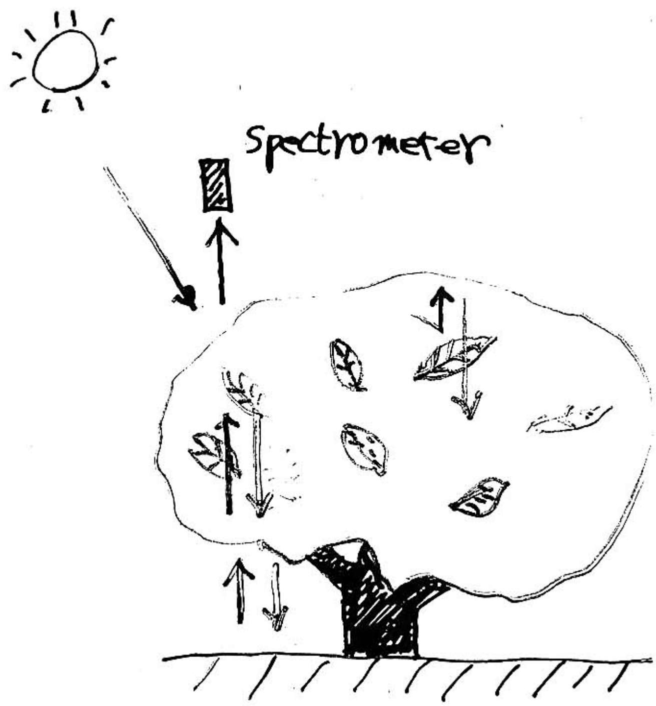


Fig.4 Reflectance of the whole tea canopy



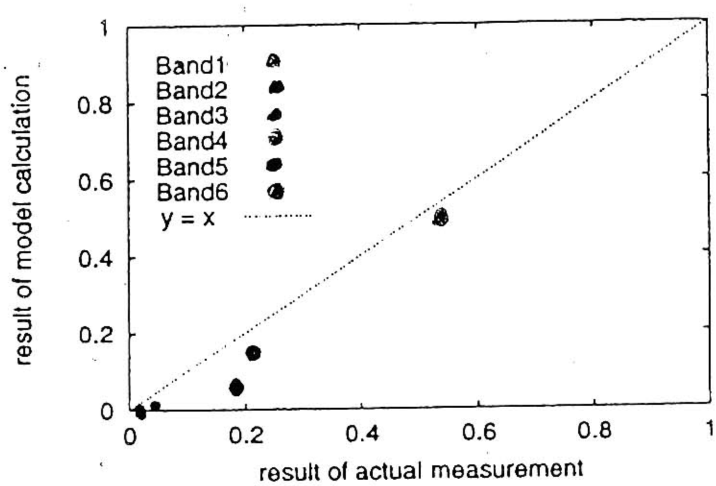
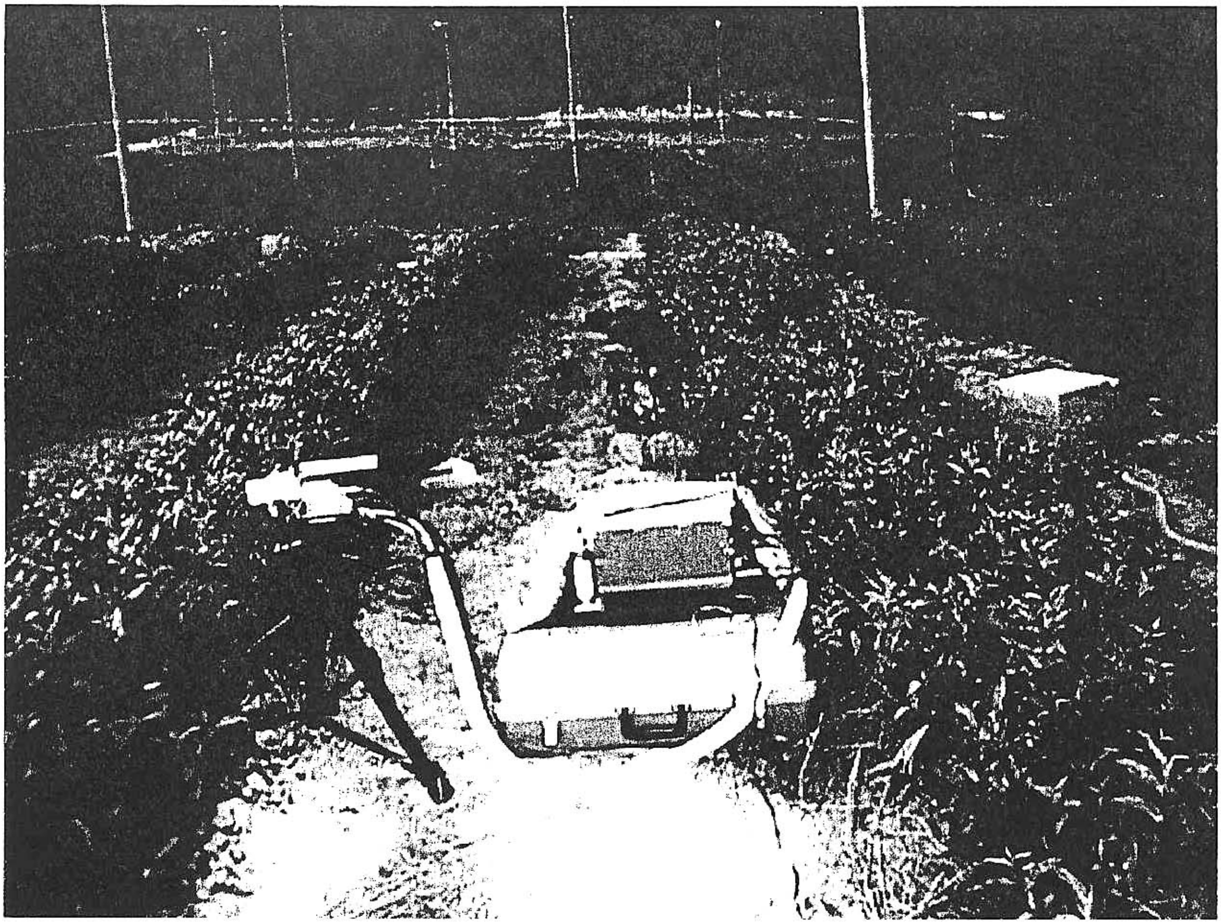


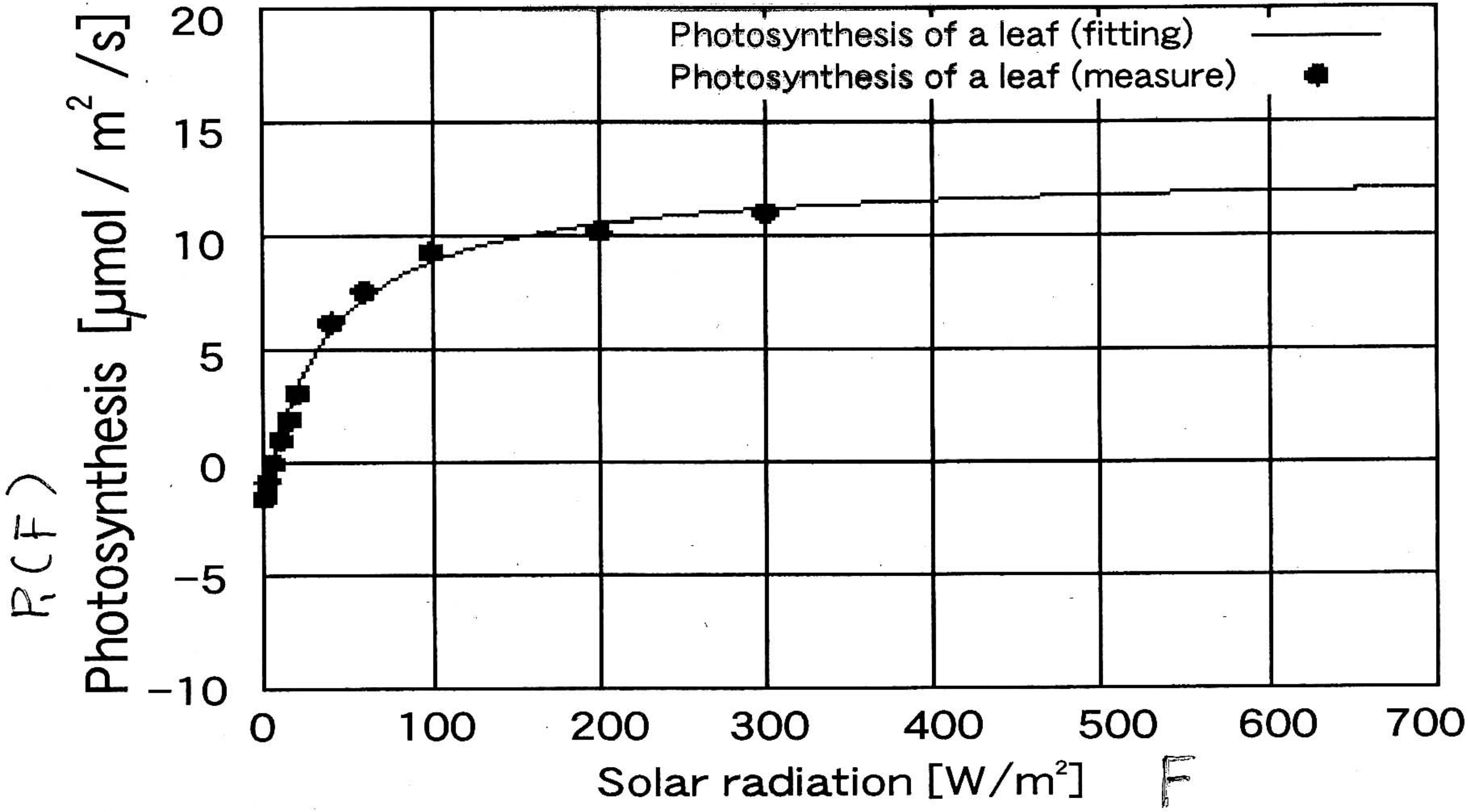
Fig.5 Comparison with actual measurement and simulation result

Measurement of photosynthesis for a leaf



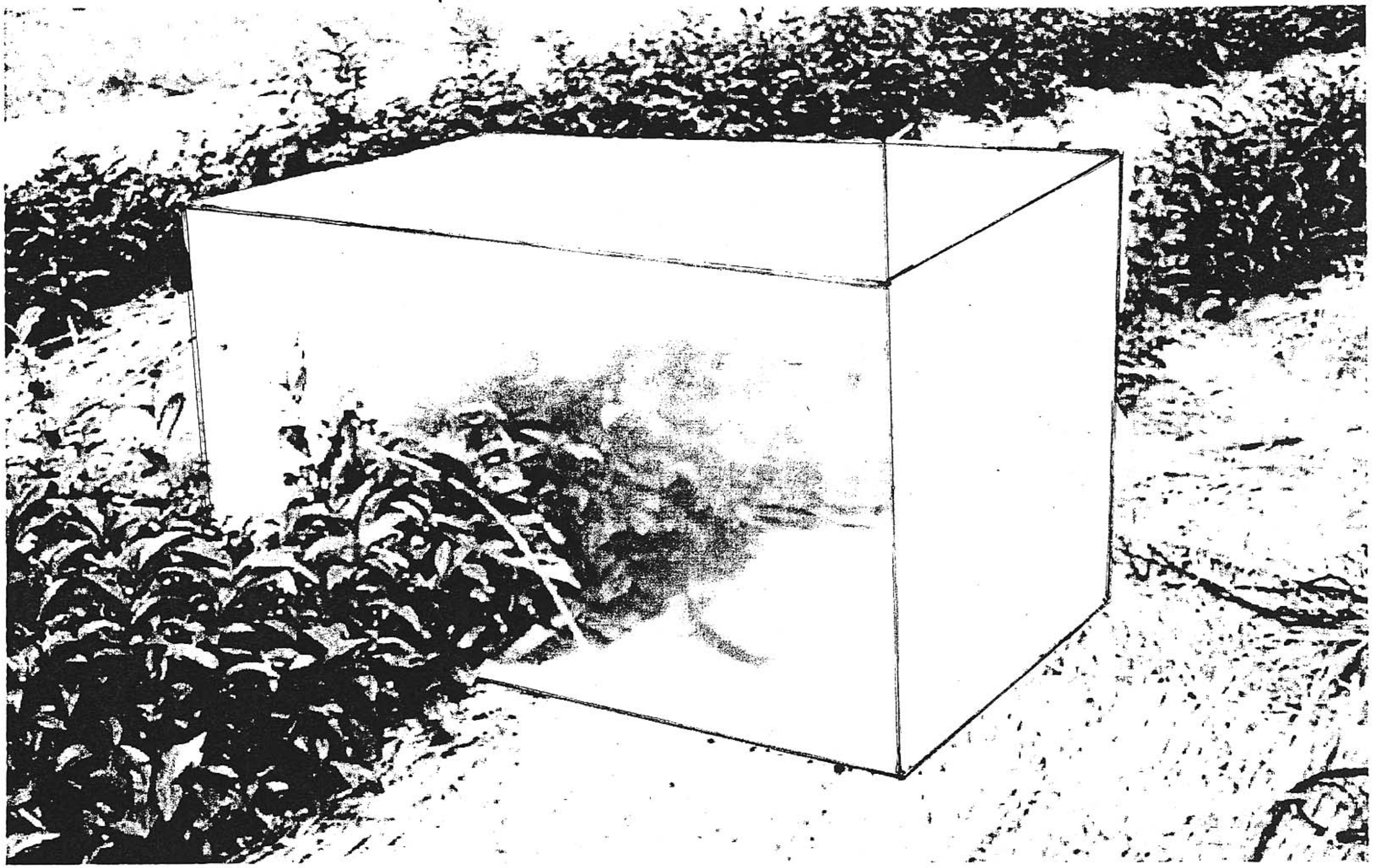
$$P_1(F) = \frac{P_{max}\, b'(F - F_0)}{1 + b''(F - F_0)}$$

$P_{max} = 0.5502$
$b' = 0.5502$
$b'' = 0.0236$
$F^0 = 5.1558$



Photosynthesis of a leaf

transparent vinyl



CO_2

air temparatur

solar radiation

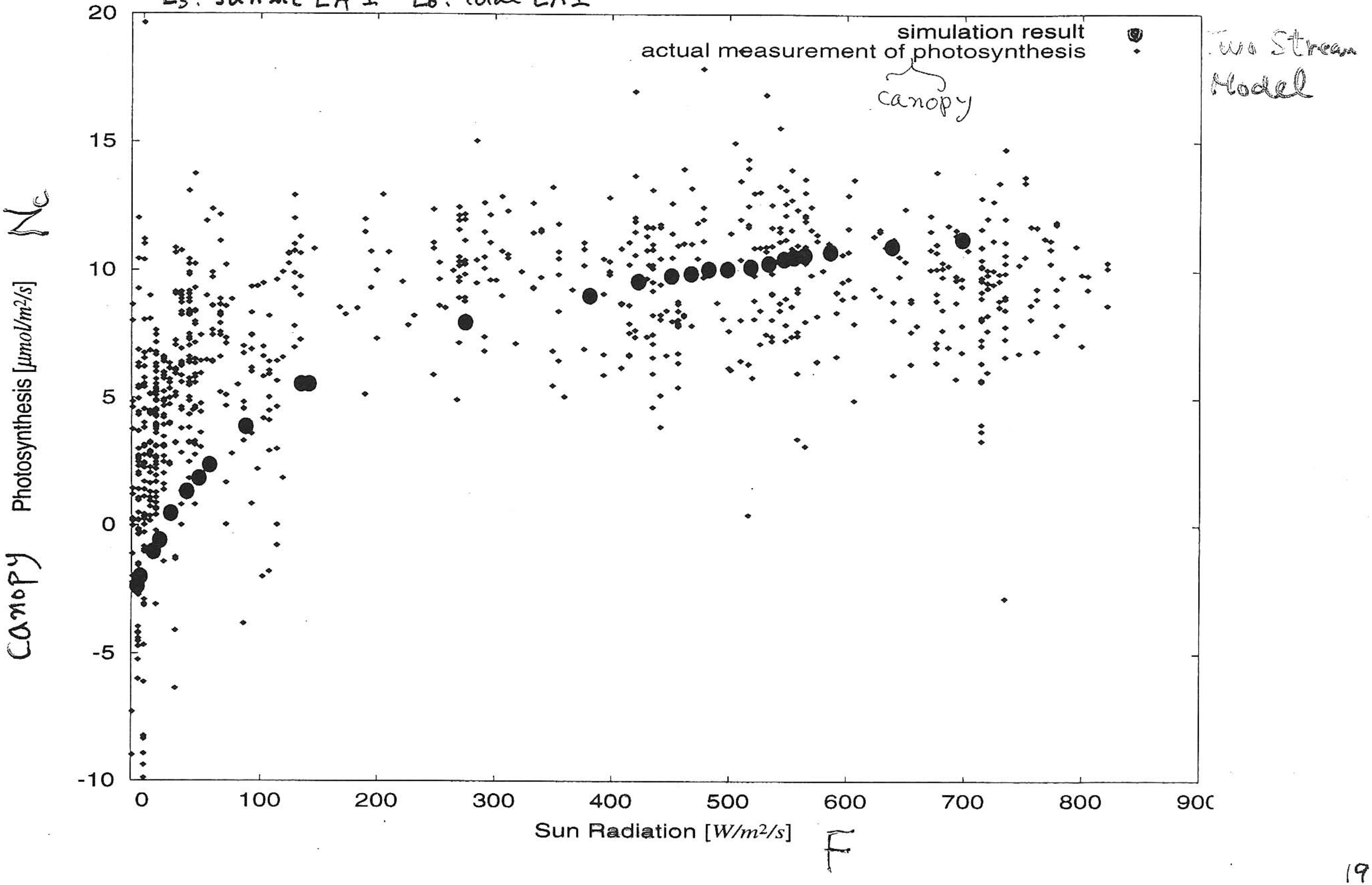
Measurement of canopy photosynthesis
2000.9.29 5:30～18:00

$N_C = L_S P_1(F_S) + (L_0 - L_S) P_1(F_d)$

L_S: sunlit LAI L_0: total LAI

F_S : irradiance on the sunlit leaves

F_d : irradiance on the shaded leaves



NPP(Net Primary Production)

$$NPP = \varepsilon \times \int (APAR)(1 - r_d(t))dt = \varepsilon \times \int (FPAR \times PAR)(1 - r_d(t))dt$$

APAR: Absorbed Photosynthetically Active Radiation

ε : Light Use Efficiency

$r_d(t)$: Respiratory Loss Factor $r_d(t) = \dfrac{7.825 + 1.145T}{100}$

T: Air Temperature

FPAR: Fraction of Photosynthetetically Active Radiation

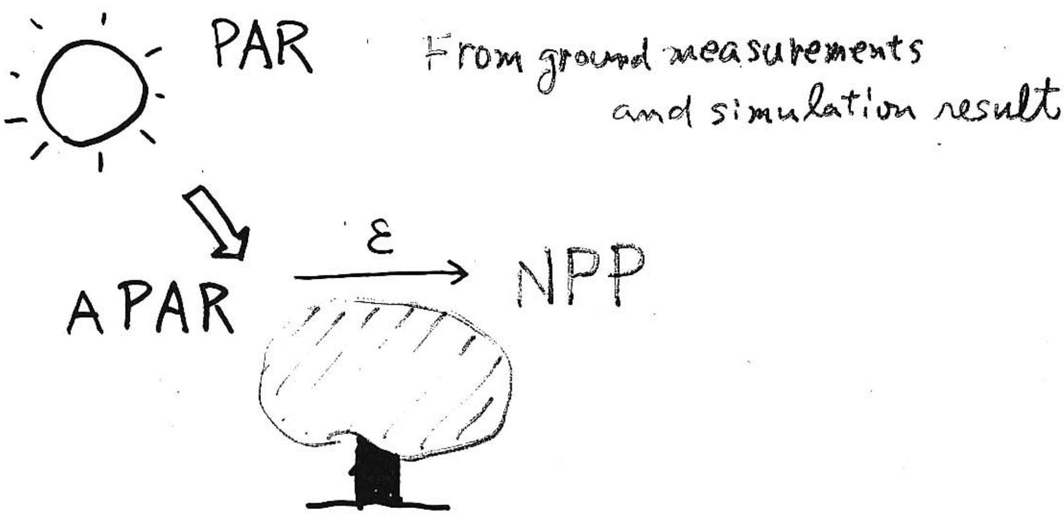
PAR: Photosyntheticlly Active Radiation (Solar Radiation)

From ground measurements

$$\varepsilon \times FPAR = f_s \times 0.070 \times VIPD$$

fs: Factor for the saturation of photosynthetic curve and canopy effects

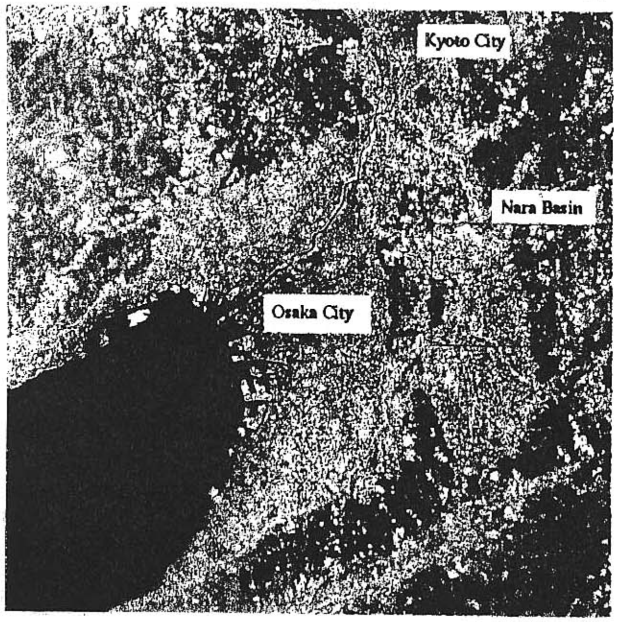
$$f_s = 0.25$$



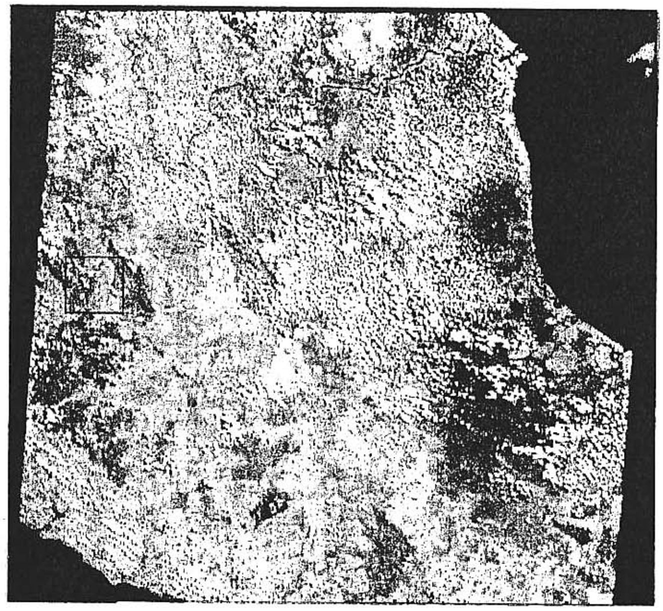
NPP estimation using Landsat/TM satellite data

Analysis Area

1. Nara basin in Japan

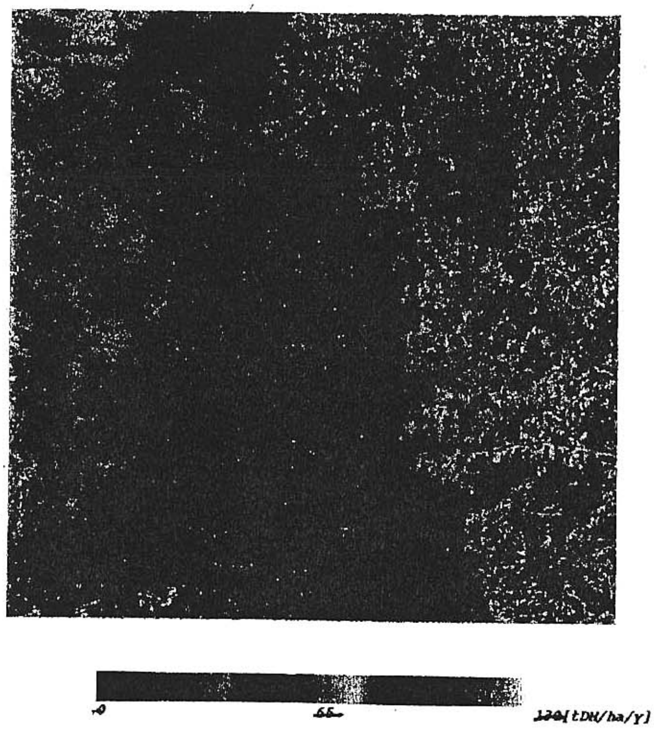


2. Negeri Sembilan in Malaysia

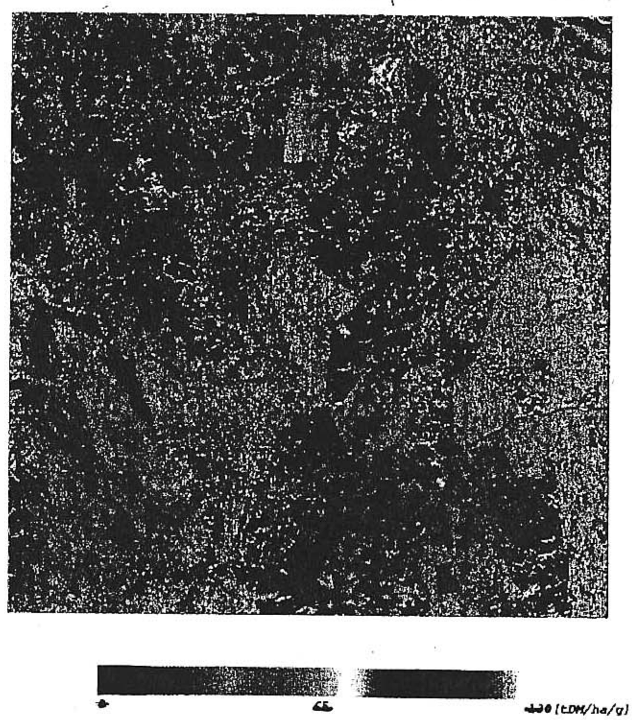


annual NPP map estimated from Landsat/TM data

tropical rain forest

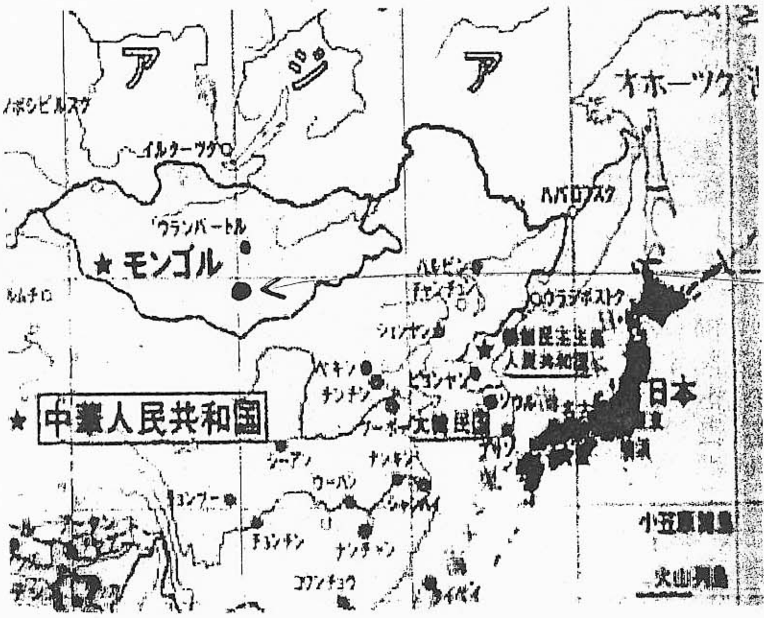


0 32.5 [tDM/ha/year]

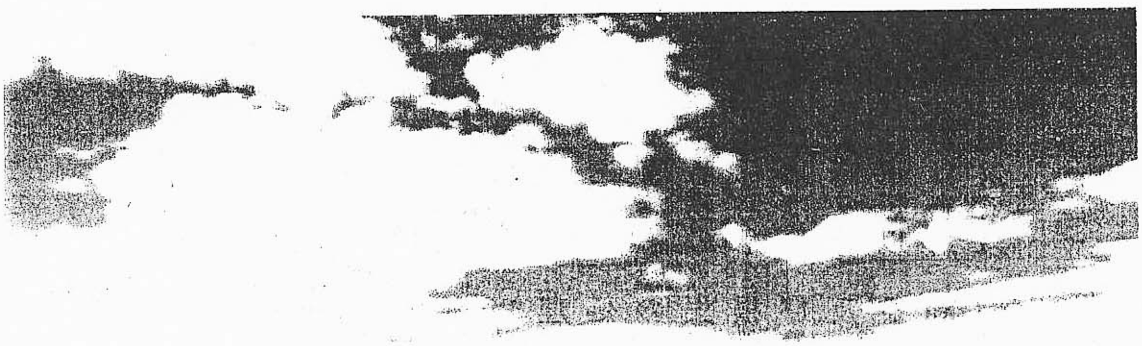


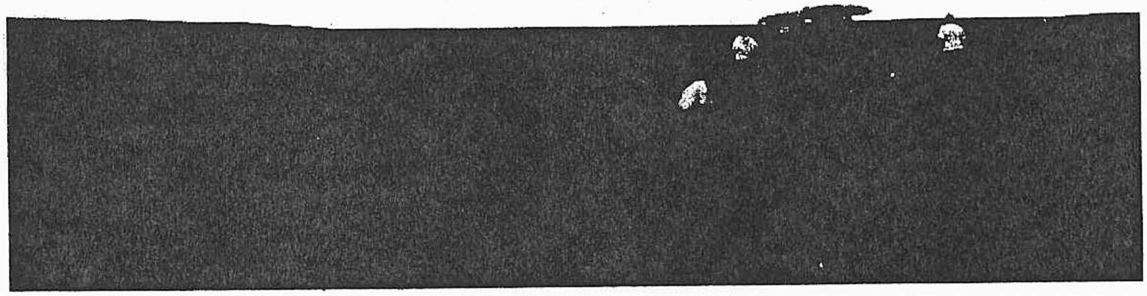
0 32.5 [tDM/ha/year]

Ground Truth in MONGOLIA (2001-8)



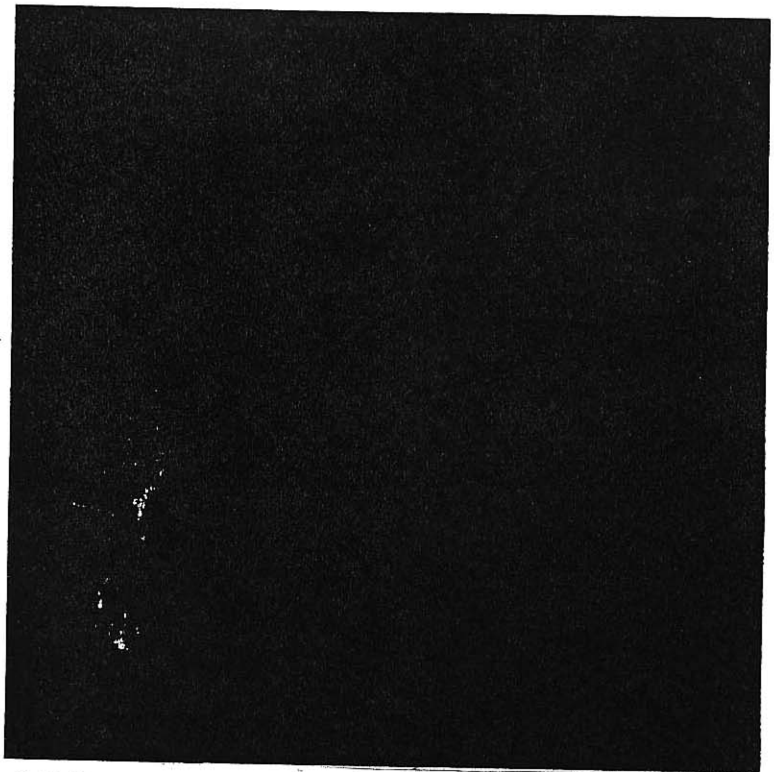
Mandalgobi





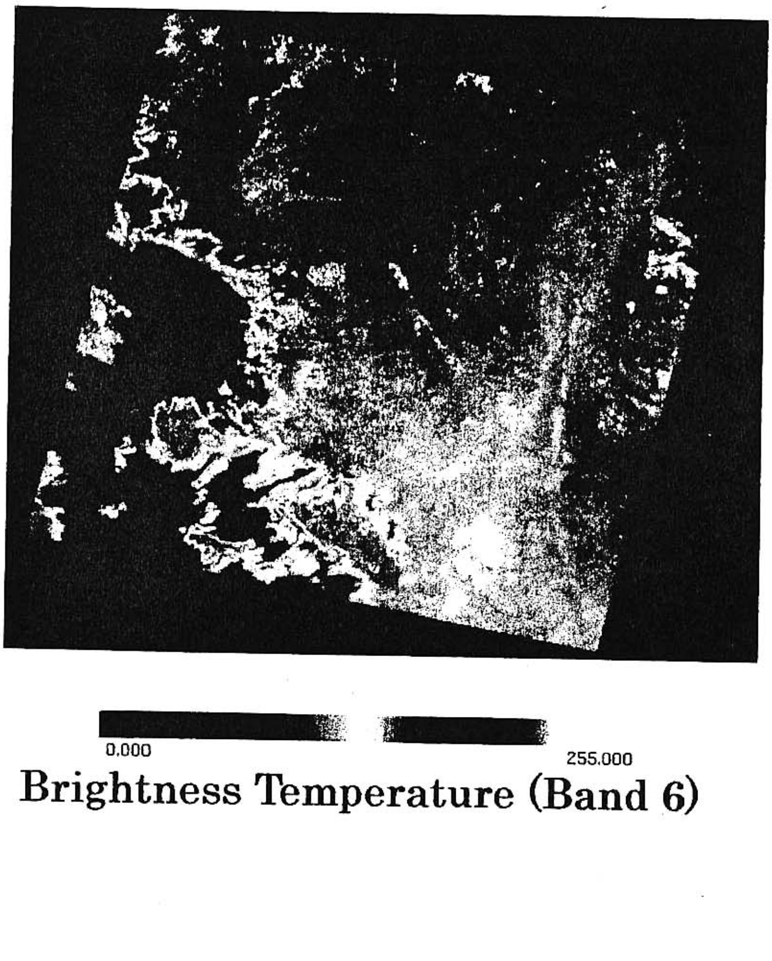
MONGOLIA (12.June.2001)

— *LANDSAT7/ETM+* —



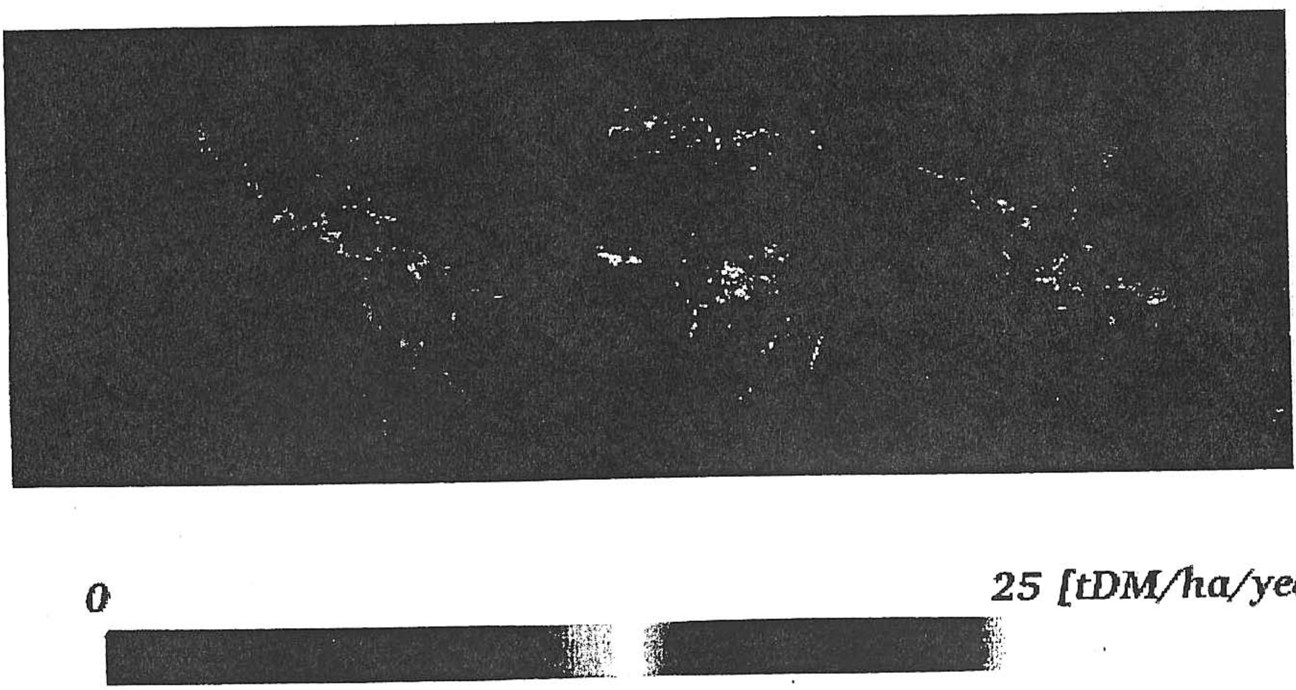
R 5
G 4
B 3

Ground Measurement Sites near Mandalgobi



Brightness Temperature (Band 6)

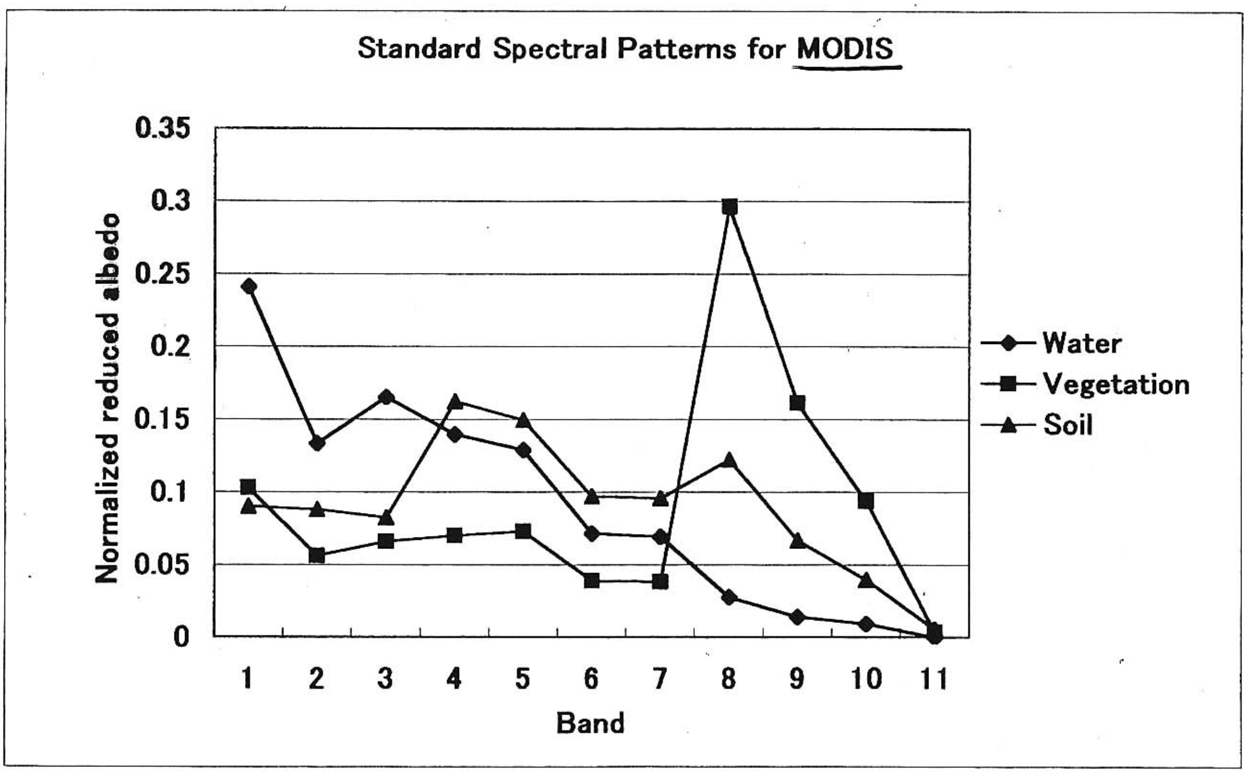
Annual NPP map (1995) using NOAA/AVHRR data based on estimation model



MODIS(1km) Level-1b

MODIS Band	Wave-length (μ m)	Wave Width (μ m)	Analysis Band
8	0.405-0.420	0.015	1
9	0.438-0.448	0.010	2
10	0.483-0.493	0.010	3
11	0.526-0.536	0.010	4
12	0.546-0.556	0.010	5
13-low	0.662-0.672	0.010	6
14-low	0.673-0.683	0.010	7
17	0.890-0.920	0.030	8
19	0.915-0.965	0.050	9
18	0.931-0.941	0.010	10
26	1.360-1.390	0.030	11

The standard spectral patterns of water, vegetation and soil for MODIS data using 11 bands.



VIPD in Kii-peninsula 2001.7.4

Conclusion

1) Pattern Decomposition Method to Hyper-spectral Satellite Data has been established.

   Ground measurement data using spectrometers

   AMSS (GLI) data

   MODIS data in progress

2) Ground measurements for NPP have been done.

   Measurement of reflectance for many objects

   Measurement of canopy reflectance

   Measurement of photosynthesis for a leaf

   Measurement of canopy photosynthesis

3) NPP can be estimated from VIPD(Vegetation Index based on Pattern Decomposition Method). We checked it.

   Rice field in Nara basin (Kii-peninsula)

   Tropical rain forest in Malaysia

   Grass field in Mongolia in progress

Our next plans are as follows:

1) Global NPP using MODIS data will be estimated and the validation will be done on Kii-peninsula and Mongolia plateau.
2) After getting GLI data, we will decide the standard patterns in PDM and calculate VIPD and NPP. The validation of them will be checked on the above areas.

● It is important for getting NPP to estimate canopy effects. Ground measurements will be continued.

● It is important for getting NPP to estimate atmospheric effects.

We expect good data after atmospheric correction.