VEGETATION MONITORING STUDY USING LEAF WATER CONTENT INDEX (LWCI) AND NDVI

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ABSTRACT：Leaf Water Content Index (LWCI) was proposed by Hunt, E. R. Jr., and et al (1987). At the beginning we tried and succeeded to develop this index for the practical application to the satellite remote sensing data such as Landsat TM. Next we performed vegetation monitoring using LWCI by SPOT Vegetation and we got same results. LWCI is not susceptible to influences from the atmospheric noise such as the haze and smoke, which are caused very often by fires or climatic conditions in the tropics, because it utilizes longer wavelength bands, SWIR (1.58-1.75μm) and NIR (0.79-0.89μm) than NDVI.

This time we applied LWCI to the one-year time series of SPOT Vegetation 10 days composite data that were processed in advance to exclude the influences of clouds (Sawada, 2001). We tried to compare the seasonal change profiles of LWCI between the tropical agricultural lands (Thailand) and the temperate agricultural lands (Japan) in addition to the forest zone. The seasonal change profile of NDVI was created simultaneously and was compared, too.

As a result, although it must be consider the influence of the snow in the case of Japanese winter season, both tropical and temperate evergreen forests in non-winter season showed the relatively same trend. As for the temperate deciduous forest, such evident time lag that is seen in the tropical deciduous forest was not observed. It was found for the first time that the seasonal change of LWCI could be observed even in the agricultural areas (paddy fields, upland farming fields, grassland), however, in both tropical and temperate zones the time lag between LWCI and NDVI profile was hardly observed. This fact seems to indicate that in the plant phenology of the temperate zone like Japan the moisture condition does not play more important role than that of the tropical zone, rather the cumulative temperature or photoperiod effect the plant phenology.

1. INTRODUCTION

LWCI has been found useful for detecting the leaf water content in forest canopy or monitoring the dry condition of forest in the tropical region. In the tropics the seasonal change of the leaf water condition within forest (water stress: wet and dry) seems to play important role in phenological dynamics of forest such as foliation and defoliation (Lips and Duivenvoord, 1996), especially in deciduous forest like teak. Therefore, as for the monitoring of forest phenology and vegetation activities in this area, it is effective to measure the leaf water content by using satellite data.

It was previously reported that LWCI has good correlation with the ground truth data like LAI (leaf area index), LLP (leaf litter production), rainfall and NDVI, moreover it has also about two months preceding time lag of the seasonal fluctuation from NDVI in the tropical seasonal forest zone (Anazawa et al., 2000). As for rainfall, we acquired the monthly accumulated precipitation data derived from TRMM (PR level3 3A25), and we could confirm the correlation between rainfall and LWCI at the several points in Southeast Asia.

In the last ACRS, we have showed that regional water condition map could be created using multi-temporal LWCI images, and also that the environmental gradient analysis was conducted to the water availability map for watersheds, integrating the DEM data as GIS.

2. STUDY AREA AND DATA USED

(1) Study area

We selected the following 3 places as Japanese agricultural areas which were checked the details with Landsat TM image, 1) Ishikari Plains as the paddy fields, 2) Shari as upland farming fields, 3) Konsen plain as the grassland (Fig. 1).

As for the evergreen forest and deciduous forest, 1) the evergreen forest area; Yanase region in Kouchi Prefecture, 2) the deciduous forest area; Shirakami Mountainous region were selected as the study areas (Fig. 2).

As for the tropical evergreen forest, the deciduous forest (seasonal forest) and the cultivated field, we selected study area at Phukhieo region in Thailand, referring to the vegetation, land cover information of Global Map data and Phukhieo water condition map based on LWCI which we had created (Fig. 3).

(2) Data used

(a) The acquisition dates of Landsat TM and SPOT Vegetation, which we utilized in this analysis, were shown in the following Table 1.

Table 1 List of acquired Satellite data.

Area	Sensor	Path Row	Date
Japan	SPOT Vegetation	—	1999/11/1-2000/10/21 (36scenes)
PhuKhieo	SPOT Vegetation	—	1998/4/1-2000/3/21 (72scenes)
Ishikari Plain	Landsat TM	107/30	1995/6/12
Shari	Landsat TM	106/29	1995/8/17
Konsen Plain	Landsat TM	105/30	1996/6/7
Shirakami	Landsat TM	108/32	1992/9/14
Yanase	Landsat TM	110/37	1984/5/8

(b) Global Map Ver.1 by International Steering Committee for Global Mapping (ISCGM)which was released on the web (http://www.iscgm.org/index.html).

3. METHODOLOGY AND ANALYSIS

(1) Appication of LWCI to SPOT Vegetation data

On the basis of LWCI proposed by Raymond Hunt (1987), we already succeeded practical utilization of LWCI in remote sensing data, especially in Landsat TM data by using the energy value of TM4 and TM5 spectral bands instead of reflectance. As SPOT Vegetation has similar observation bands to Landsat TM in SWIR (1.58-1.75μm) and NIR (0.79-0.89μm) range, in SPOT Vegetation data it was found that we could directly utilize the reflectance value (SPOT3 and SPOT4) in the LWCI formula without conversion into the energy value (the formula shown below). We could get the cloud free SPOT Vegetation 10 days composite data in time series after removing cloud influence by the algorithm which our collaborator had developed. The formula of normalized LWCI is as follows,

$$LWCI = \frac{-\log[1-(SPOT3/A - \alpha \times SPOT4/B)]}{-\log[1-(SPOT3ft/A - \alpha \times SPOT4ft/B)]}$$

SPOT3 and **SPOT4** show the normalized reflectance value as the following:

$$\mathbf{SPOT3} = \frac{\mathbf{Band3} - \mathbf{Band3_{min}}}{\mathbf{Band3_{max}} - \mathbf{Band3_{min}}}$$

$$\mathbf{SPOT4} = \frac{\mathbf{Band4} - \mathbf{Band4}_{min}}{\mathbf{Band4}_{max} - \mathbf{Band4}_{min}}$$

Band3$_{max}$: Maximum value of **Band3** through whole images
Band4$_{max}$: Maximum value of **Band4** through whole images
Band3$_{min}$: Minimum value of **Band3** through whole images
Band4$_{min}$: Minimum value of **Band4** through whole images

α: the ratio of **SPOT4** to **SPOT3** in the theoretical solar radiation spectrum curve (constant)
SPOT3ft and **SPOT4ft**: **SPOT3** and **SPOT4** at the season of the minimum water stress (the highest moisture) and maximum water stress(the lowest moisture), that is, these are the maximum value composite image of **SPOT3** derived from all images and the minimum value composite image of **SPOT4** derived from all images.

(2) Creation of LWCI and NDVI Images

As for Japan (Latitude; N 30° —46°, Longitude; E 129° —146°), LWCI images were calculated using SPOT Vegetation 10 days composite data from 1999/11/1 to 2000/10/21. As for Phukhieo (Latitude; N 16° — 17°, Longitude; E 101° —102°), LWCI Images were calculated using SPOT Vegetation 10 days composite data from 1998/04/1 to 2000/03/21.

4. RESULTS AND DISCUSSIONS

(1) Agricultural areas

According to Fig.4, it was found for the first time that the seasonal change of LWCI could be observed even in the agricultural areas (paddy fields, upland farming fields, grassland), and also found that LWCI and NDVI behaved similarly in their seasonal changes. From the comparison of Fig4 with Fig.6, the time lag between LWCI and NDVI was seen a little in tropical zone (about one month), however, it was hardly observed in the temperate zone.

(2) Forest areas

As a result, although it must be consider the influence of the snow in the case of Japanese winter season, both tropical and temperate evergreen forests in non-winter season showed the relatively similar trend(Fig.5 and Fig.7). As for temperate deciduous forest, such evident time lag that is seen in tropical deciduous forest was not observed. Paying attention to this graph in detail, the tropical evergreen forest has two peaks (a big and small peaks), this might be the influence of the rest in the rainy season, however, in both tropical and temperate zones the time lag between LWCI and NDVI profile was hardly observed. This fact seems to indicate that in the plant phenology of temperate zone like Japan the moisture condition does not play more important role than in tropical zone, rather the cumulative temperature or the photoperiod has more effect upon the plant phenology.

5. CONCLUSIONS AND RECOMMENDATIONS

1) This time we succeeded to apply LWCI to SPOT Vegetation directly using reflectance value (SPOT3 and SPOT4) data without utilizing the energy value. We could get time series (1-2 years) of LWCI images in good reliability by utilizing cloud free SPOT Vegetation data.
2) It was found that LWCI could apply not only to forest area, but also to agricultural area. As for the agricultural area, the time lag between LWCI and NDVI was seen a little in tropical zone (about one month), however, it was hardly observed in the temperate zone.
3) Although the time lag of several months between LWCI and NDVI was evidently observed in the tropical forest, it was not observed in the deciduous forest of Japan. This is considered because the role which moisture condition plays in growth and phenology of a plant is smaller than other temperature and daylight condition in the temperate zone such as Japan in comparison with the tropical zone.

It is recommended and expected that future research on LWCI should apply to the agriculture field (the harvest estimation, the monitoring of drought/water scarcity) and the forestry field (the prediction of forest fire risk, the climate mitigation mechanism/the estimation of the water balance and evapotranspiration in forest, the estimation of carbon flux).

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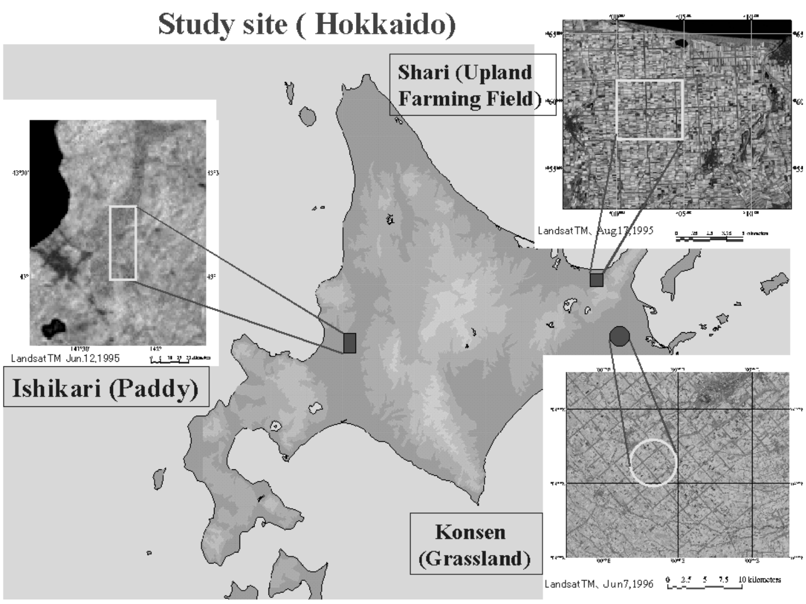

Fig. 1 Study sites (agricultural lands) in Hokkaido

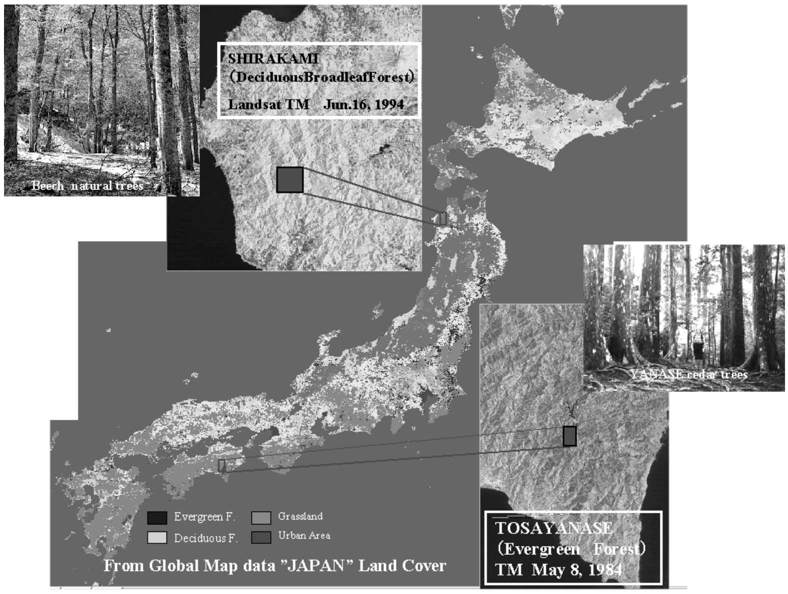

Fig. 2 Study sites (evergreen forest and deciduous forest) in Japan

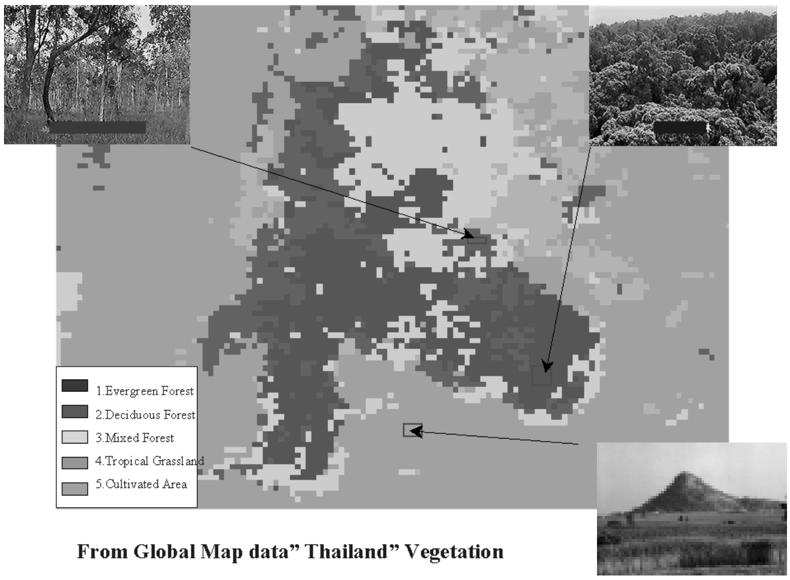

Fig. 3 Study sites (evergreen forest,deciduous forest and cultivated field) in Phukhieo area

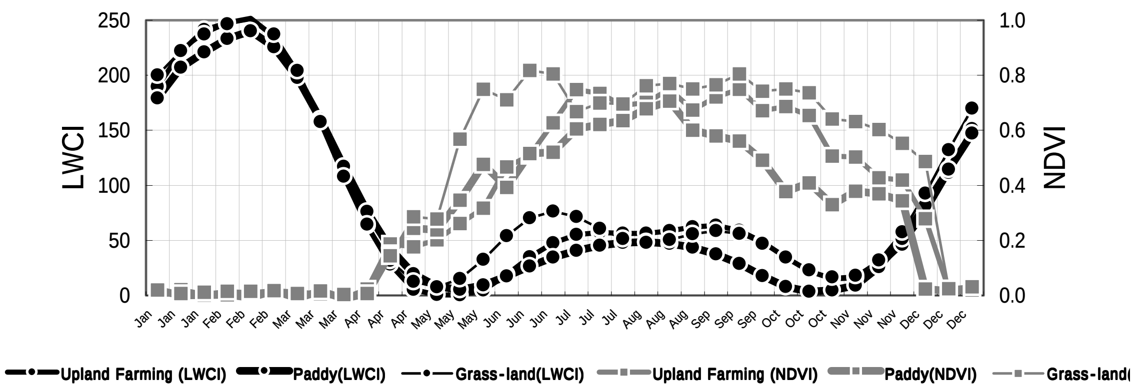

Fig. 4 LWCI and NDVI Profiles in 3 Agricultural Types (Paddy Field, Upland Farming Field, Grassland) (The influence of snow cover was observed during winter,from Dec.to Mar.in Hokkaido)

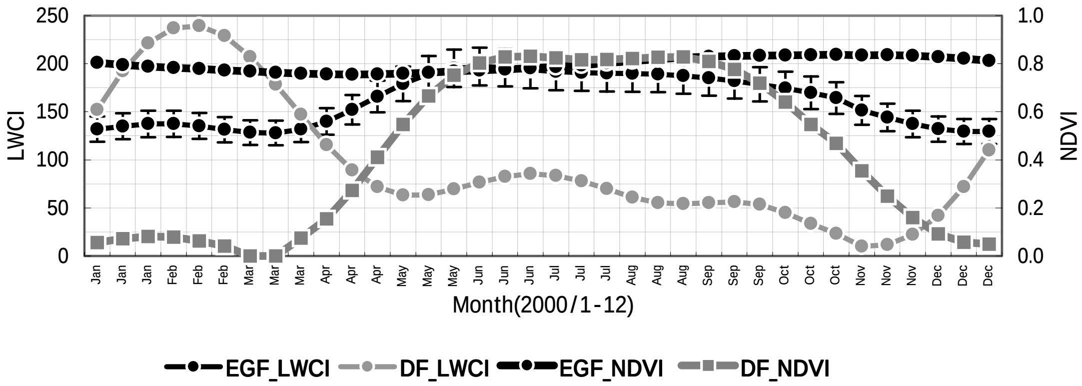

Fig. 5 LWCI and NDVI Profiles in Japanese Evergreen Forest and Deciduous Forest

(The influence of snow cover was observed during winter,from Dec.to Mar.in Shirakami)

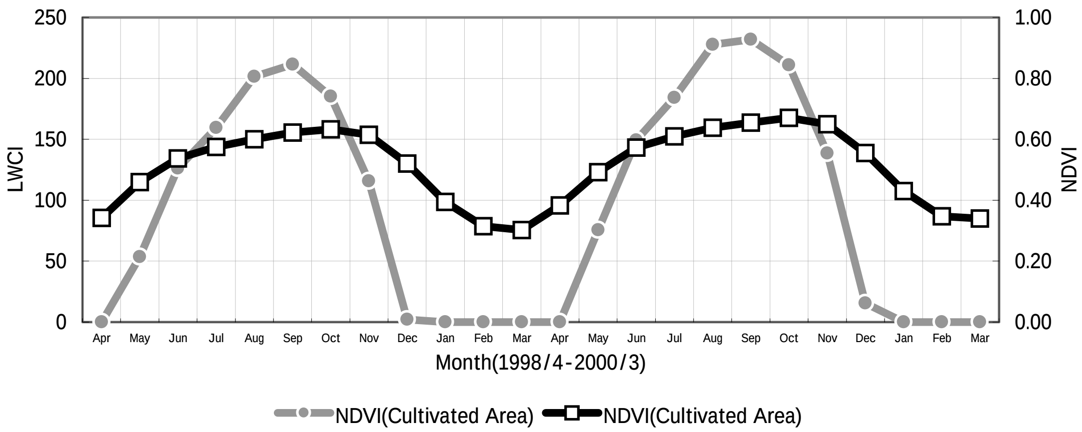

Fig. 6 LWCI and NDVI Profiles in Tropical Agricultural Area (PhuKhieo Cultivated Field)

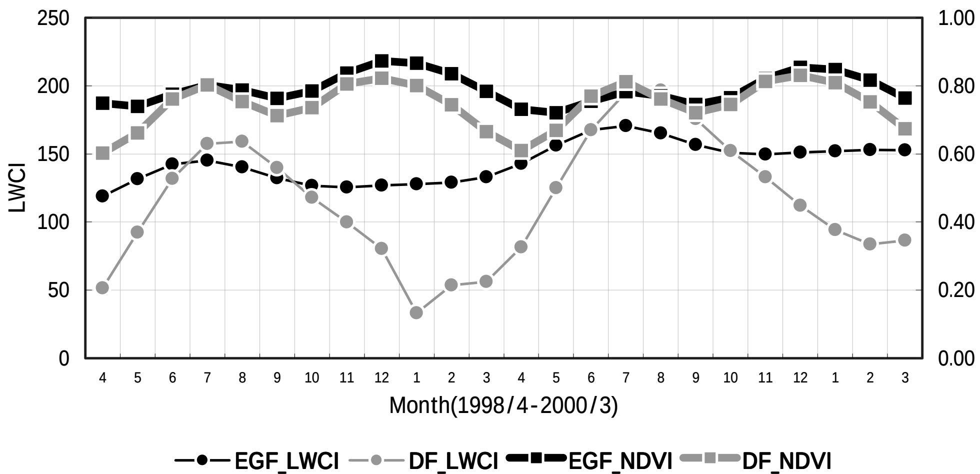

Fig. 7 LWCI and NDVI Profiles in Tropical Evergreen Forest and Deciduous Forest