Evaluation of The Forest Damage by Typhoon Using Remote Sensing Technique

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Abstract— **The forest damage (fallen trees) by a typhoon or a strong wind is frequently generated in recent years. For example, Typhoon SONGDA (2004.09) brought about destructive strong winds to almost western half of Hokkaido. According to a temporary report issued by Japan Meteorological Agency, in Sapporo, 50.2 m/s was recorded as a maximum instantaneous wind speed in the history of observation. This typhoon also caused serious damage to the forest of Hokkaido. ASTER (Advanced Spaceborne Thermal Emission and Reflection Radiometer) aboard NASA's satellite Terra is a high resolution multispectral radiometer of 14 bands. The spatial resolution is 15 m in visible and near infrared, 30 m in short wave infrared and 90 m in thermal infrared spectra respectively. Data from ASTER were used to produce the along of fallen trees extraction for the south western coastal area of Hokkaido. We evaluated the damage of forestry based on the spectrum characteristics of fallen trees. As a result the extraction of almost all fallen trees data has been succeeded.**

Keywords: Fallen tree, NDVI, NDWI, LAI, Typhoon SONGDA

I. INTRODUCTION

Typhoon SONGDA brought about destructive strong winds. According to a temporary report issued by Japan Meteorological Agency, five observation points in Hokkaido were ranked in the list of 20 points that marked the maximum gust, such as 51.5m/s at Omu and 50.2m/s at Sapporo. The strong wind collapsed the symbol of Sapporo, a row of poplar trees Hokkaido University. The damages of agriculture, forestry and other infrastructure is so extensive that the strong winds of this typhoon will be kept in memory (©Digital Typhoon, 2004) [1].

In order to evaluate the forest windfall damage by this typhoon, we performed a field survey, aerial photography, using Global Positioning System (GPS) and investigated forest damage in a wide area using remote sensing technique. Remote Sensing technique is the science and art of acquiring (spectral, spatial and temporal) information about material objects, area, or phenomenon, without coming into physical contact with the objects, or area, or phenomenon under investigation. Without direct contact, some means of transferring information through space must be utilized. In remote sensing, information transfer is accomplished by use of electromagnetic radiation (EMR). EMR is a form of energy that reveals its presence by the observable effects which strike the matter. The earth observation satellite, which has the spectral wavelength distribution between visible bands (0.30-0.70 micro-meter), NIR (Near Infrared: 0.80-1.10 micro-meter) bands, and SWIR ((Short Wave Infrared: 1.6-2.5 micro-meter) bands and TIR (Thermal Infrared: 8.0-12.0 micro-meter) bands, is available to monitor the earth surface water bodies, barren soil and green vegetation. Although the remote sensing technique may be not suitable to find forest damage in a small range, is infallible and

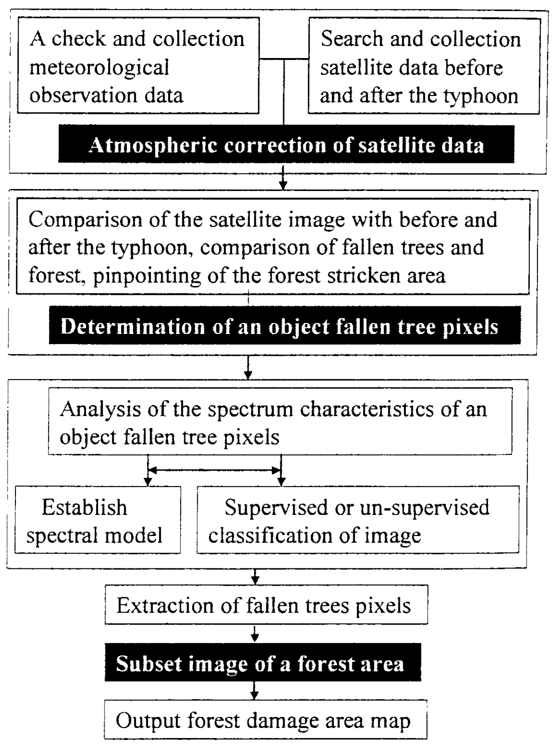

Fig. 1 The extraction method of fallen tree pixels using remote sensing technique.

a very effective method to evaluation of the forest damage in a large range like this case [2] [3] [4].

A. Objectives

Our objective was to evaluating the forest damage by the typhoon No. 18 (2004: Songda) in Hokkaido Japan. We intended examine how to evaluate the forest damage by the typhoon in wide scales using remote sensing technique.

II. METHODOLOGY

Acquisition of non-cloud good satellite data is very difficult because of a bad weather condition at the time of a typhoon. Therefore, it is necessary to search the suitable data before and after the typhoon in the stricken area.

A. The Data analysis in this study

First of all, the pixel appropriate for fallen tree was determined to analyses the spectrum feature of a fallen tree pixels. Fig.1 shows the extraction method of fallen tree pixels using remote sensing technique.

We used ATCOR software method for the correction of the atmospheric effect about path radiance, adjacency radiation and terrain radiation reflected to the pixel in order to calculate the reflected radiation from the viewed pixel. In passive remote sensing the measured signal is due either to solar radiation reflected by the earth-atmosphere system or else emitted by the earth's surface and the atmosphere. Proper interpretation of the measured signal requires knowledge of the interaction of the radiation with the atmosphere and the underlying surface. Thus, in the remote sensing community there is a need to know how the radiance at the top-of-the-atmosphere (TOA) or at aircraft altitude depends on atmospheric and surface parameters. The ATCOR model algorithm considerate the total signals at the sensor that consists of four components: path radiance, reflected radiation from the viewed pixel, scattered radiation from the neighborhood, and terrain radiation reflected to the pixel (topographic correction). The atmospheric conditions (water vapor content, aerosol type and visibility) for a scene can be estimated with the SPECTRA module. The surface reflectance spectrum of a target in the scene can then be viewed as a function of the selected atmospheric parameters. It can be compared to typical library spectra. Data used from Terra/ASTER original Level 1B Visible-Near Infrared / Shortwave-Infrared Thermal Infrared (VNIR/SWIR/TIR) Data (Before Typhoon: 10:25 AM, October 17, 2001, and After Typhoon: 10:25 AM, September 23, 2004, Path-108/Row-886, the coordinate of the UL Geo N42°50'15.62", E141° 2' 15.96") and supplied by the ©ERSDAC, Japan, shown in Table 1)[4] [5] [6].

The preprocessing of data include resampling the 3-layers different resolution ASTER VNIR (15 m), SWIR (30 m) and TIR (90 m) data to one layer same spatial resolution (15 m) dataset; and statistical calculation of correlation coefficient between band by band.

B. Normalized Difference Vegetation Indices

Normalized Difference Vegetation Index (NDVI), Leaf Area Index (LAI) and Vegetation Leaf Water Index (VLWI) are often used as indices expressing the state of healthy vegetation, either green non-vegetated areas or unhealthy green vegetation. To determine the density of green on a patch of land, we must observe the distinct colors (wavelengths) of visible and near-infrared (NIR) sunlight reflected by plants. As can be seen through a prism, many different wavelengths make up the spectrum of sunlight. When sunlight strikes objects, certain wavelengths of this spectrum are absorbed and other wavelengths are reflected. The pigment in plant leaves, chlorophyll, strongly absorbs visible light (from 0.4 to 0.7 micro m) for use in photosynthesis. The cell structure of leaves, on the other hand, strongly reflects near-infrared light (from 0.7 to 1.1 micro m). The more leaves a plant has, the more these wavelengths of light are affected, respectively. NDVI can be calculated by equation (1).

$$NDVI = \frac{NIR - RED}{NIR + RED} \qquad (1)$$

LAI can be calculated by equation (2).

$$LAI = -\frac{1}{a_2} \times \ln(\frac{a_0 - NDVI}{a_1}) \qquad (2)$$

Table 1. Specification of Advanced Spaceborne Thermal Emission and Reflectance Radiometer

VNIR(Visible & Near Infrared) wavelength (micro-meter)	Band 1 (Green): 0.52～0.60
	Band 2 (Red): 0.63～0.69
	Band 3N(NIR): 0.76～0.86
Spatial Resolution	15 m
SWIR(Short Wave Infrared) wavelength (micro-meter)	Band 4: 1.600～1.700
	Band 5: 2.145～2.185
	Band 6: 2.185～2.225
	Band 7: 2.235～2.285
	Band 8: 2.295～2.365
	Band 9: 2.360～2.430
Spatial Resolution	30 m
TIR (Thermal Infrared) wavelength (micro-meter)	Band 10: 8.125～8.475
	Band 11: 8.475～8.825
	Band 12: 8.925～9.275
	Band 13: 10.25～10.95
	Band 14: 10.95～11.65
Spatial Resolution	90 m

Where a_0, a_1 and a_2 is parameters of vegetation with varied vegetation (or soil) types. For example, $a_0 = 0.82$,

$a_1 = 0.78$ and $a_2 = 0.60$ is cotton; or $a_0 = 0.68$, $a_1 = 0.50$ and $a_2 = 0.55$ is corn (Asrar et al. 1984 and Guyot, 1991). VLWI can be calculated by equation (3).

$$VLWI = K_0 + \left[\frac{NIR - SWIR}{NIR + SWIR} \right] \quad (3)$$

In the above equations, NIR and SWIR are reflectance in visible Near Infrared and Short Wave Infrared bands and K0 is an adjusting factor for the influence of the background soil reflectance (in this case, we input K0=0.25)[2].

The fallen tree should have the low values of NDVI, LAI and VLWI compared with an ordinary healthy forest [5] [6].

III. RESULT

A. The sstudy area

The study areas were located in the Nopporo Forest Park P1 (N43°2'47.88", E141° 31' 19.57") and forest near Lake Shikotsu P2 (N42° 45' 37.44", E141° 29' 30.58") of Hokkaido Japan (shows Fig. 2). These areas include the forest which is suffered serious damage most from this typhoon-18 (Songda). Fig. 3 shows the aerial photo of fallen trees of forest near Lake Shikotsu. The main trees which suffered damage of windfall are Sakhalin fir, Sakhalin spruce and Picea jezoensis (Ezo spurce) artificial plantation and soma natural forest.

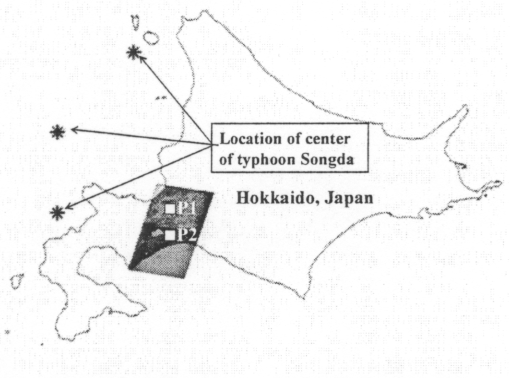

Fig. 2 Location of study area in Hokkaido Japan (P1: Nopporo forest park; P2: forest near Lake Shikotsu).

B. The spectrum characteristics of fallen trees

Plant characteristically absorb light in the red visible regions of the spectrum and tend to reflect strongly in NIR. As the leaves senesce, starch, chlorophyll, protein and nucleic acid components degrade. The loss of green chlorophyll was represented by a decreased infra red reflectance and the considerable reduction of infrared plateau (at about 0.75

Fig. 3 The aerial photo of the fallen trees in study area (by ©Shin Engineering Consultants Co., Ltd, Japan). The center portion of the photograph is fallen trees arrowed in the circle.

microns) is. The same reductions also occur when leaves lack their normal functionality by insect or disease strike. Simply put, spectral reflectance differs between healthy and stressed vegetation making satellite imagery a powerful tool for reporting plant vigor. The change in reflectance in the NIR wavelengths can be quite considerable and has proven very useful in monitoring of fallen trees. NDVI measures vegetation "greenness" or plant health based on the principle that plants prefer to use (absorb) visible red colors (wavelengths) of sunlight for photosynthesis during growth. For example, a healthy plant absorbs more visible red sunlight for photosynthesis and reflects less back to space. A plant stressed by drought photosynthesizes less and reflect more sunlight back to space. A satellite can measure the amount of sunlight reflected in the red and NIR spectrum and the NDVI which can be computed to provide a relative measure of greenness or plant health that can be displayed as an image. Fig.4 shows the comparison of fallen tree and a healthy forest. The reflectance of fallen trees shows suite higher value in ASTER band-2 (red: chlorophyll absorption) and shows the suite lower value in the ASTER band-3 (NIR: chlorophyll reflection), that mean the fallen tree has lost the function as a healthy tree [4] [5].

The fallen tree can be specified by comparison of the value of NDVI calculated from the same satellite data before and after a typhoon per pixel. Fig. 5 shows the compared result of NDVI of before and after the typhoon in same pixels. In Northern Japan, leaves will begin to wither in September and the values of NDVI become lower. Usually, in October leaves wither more than in further from September. However, in Fig. 5, conversely, the way of NDVI of October showed higher value than NDVI of September. Consequently we determined the pixels of September were fallen tree pixels [1] [3].

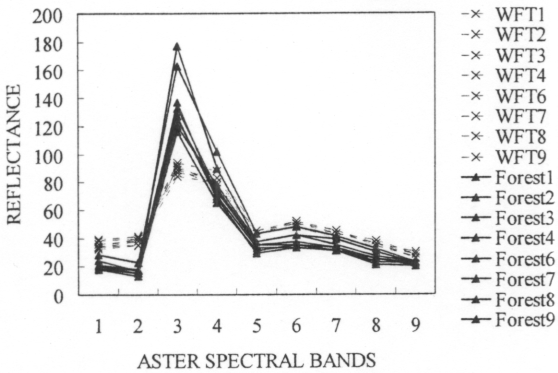

Fig.4. Comparison of the spectral reflectance of fallen tree pixels and forest pixels using ASTER VNIR/SWIR data after the typhoon (Sep. 23, 2004). In the map, *WFT shows fallen trees pixel and *Forest shows forest pixel.

If there is no picture before and after a typhoon, specification of fallen tree can be performed also by a comparison of NDVI of damaged and healthy forests. Fig. 6 shows nine points which we investigated while NDVI of a healthy forest is 0.778, NDVI of the fallen trees is only 0.403. Similarly, the fallen tree loses the water content of leaves gradually and green leaf photosynthesis function of chlorophyll falls. VLWI of a healthy forest is 0.797, VLWI of the fallen trees is only 0.537 (shown in Fig. 6).

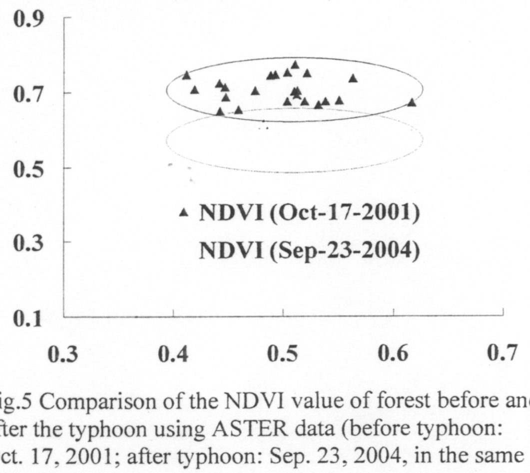

Fig.5 Comparison of the NDVI value of forest before and after the typhoon using ASTER data (before typhoon: Oct. 17, 2001; after typhoon: Sep. 23, 2004, in the same pixel)

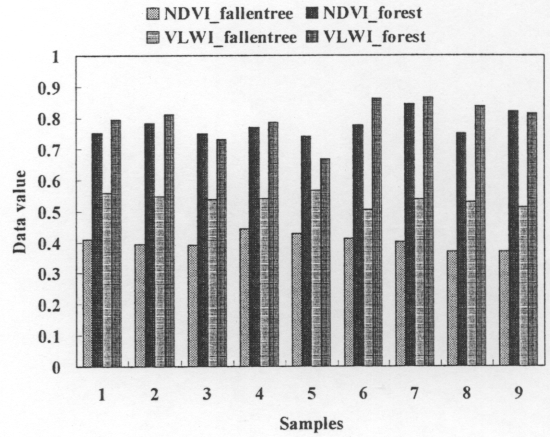

Fig.6 Comparison of the NDVI (and VLWI) value of a healthy forest and the fallen trees at investigated points using ASTER data after the typhoon (Sep. 23, 2004).

The LAI is also important index for extraction of the fallen trees. The LAI of the fallen trees is very small compared with the whole forest. Furthermore, it becomes smaller as time is passed. 15-days after the typhoon, the value of 0.8<LAI=<1.5 shows fallen trees pixel. Average LAI value of forest is 2.0 while average LAI value of fallen trees is 1.0 in all over the monitoring area (shown Fig. 7).

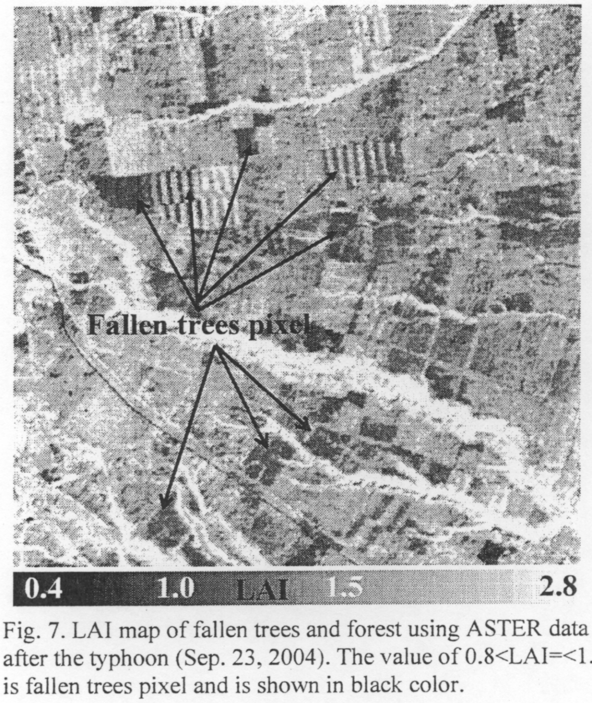

Fig. 7. LAI map of fallen trees and forest using ASTER data after the typhoon (Sep. 23, 2004). The value of 0.8<LAI=<1.5 is fallen trees pixel and is shown in black color.

IV. CONCLUSION

In this research, we succeeded in evaluation of the forest damage by the typhoon based on comparison of the satellite data (NDVI, VLWI and LAI) before and after the typhoon. By the comparison of NDVI and VLWI in nine investigated points, we found that the average value of NDVI range of healthy forest and fallen trees ($\Delta NDVI_{(forest)-(fallentree)} = 0.375$) was larger than the range of VLWI ($\Delta VLWI_{(forest)-(fallentree)} = 0.259$). Also we found, that 15-days after the tree falling down the LAI withered to half.

Acknowledgment

This study was supported by the Academic Frontier Joint Research Project of Tokyo University of Information Sciences (supported by the Ministry of Education, Sciences and Culture, Japan). The authors' deep appreciation is expressed to Professor Naoki Seki, from the Hokkaido Institute of Environmental Sciences, Japan for the valuable comments on the manuscript.

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