

リモートセンシングデータによる森林資源の評価*
—山火事跡地と松枯れ状況の事例研究を通して—

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Assessment of Forest Resources Using Remote
Sensing Data
-Case studies on forest fire and pine forest blight-

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Summary

There is a huge quantity of forest resources on the earth. Vast forest regions, however, exist only in specific areas. Many small scale forests are distributed broadly in various places. Topographically steep remote areas make a quantitative forest resources evaluation quite difficult. Without remote sensing methods, it takes tremendous amount of cost, labor, and time to obtain an adequate evaluation of forest resources.

Thanks to the contemporary remote sensing technology, we can make an access to necessary objective information needed for a forest resources assessment: the changes of damaged lands, the extent of forest destruction, and the quantity of resources. Remote sensing techniques for forest investigation using satellite data are in practical use nowadays. One of the major advantages of remote sensing technique is an easy access to periodical monitoring, extensive data and simultaneous observation.

Among many forest fires occurred in Daxinganling, China, the one took place on May 6, 1987 (hereafter 5.6 Large Forest Fire) caused the largest damage in the area of 13.2×10^5 ha. It has been pointed out by Tans et al. (1990), Houghton et al. (1995), and Nakane & Lee (1995), that not only tropical forests but also forests in the Temperate Zone, the Subarctic and Subantarctic Zone are contributing greatly to the preservation of global environment. Therefore, 5.6 Large Forest Fire should not be overlooked. Data with respect to the extent of damaged area, lost biomass and vegetation recovery are of great ecological importance. Moreover the data bear sociological significance since they relate deeply to the problems of global environment.

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The 5.6 Large Forest Fire was studied under GPS (Global Positioning System) on the basis of field survey data, in which the damage extent for each type of vegetation was estimated with reference to NOAA/AVHRR data. The recovery of vegetation in extensive forest fire sites was measured quantitatively basing on the observation of vegetation cover changes over time. The changes in vegetation quantity were estimated by analyzing regularized vegetation indexed NOAA data.

The large forest fire occurred in Daxinganling, China on May 6, 1987, which lasted for over one month. It caused a great damage to the forest (c.a. 1,330,000ha; 121° 53' ~125° 00' E, 52° 32' ~53° 32' N). Images of the entire burnt area were extracted from NOAA/AVHRR data obtained in 1988 and 1996, respectively. When performing spot investigation on ground was conducted 2 times in 1988 and 1996. A topographic correction was made in forest fire region's data of Daxinganling based on a topographical map of 1:1,000,000. The vegetation in the forest fire regions was classified into twelve categories: *Larix* sp., *Larix gmelinii*, *Pinus sylvestris*, *Betula eramanii*, *Pinus sylvestris* var. *mongolica*, *Populus Davidiana*, *Betula plaryphylla*, Grass, Shrub, Urban and others, Cloud and recovery area. In terms of the maximum likelihood method, the vegetation types in the burnt area called Tahe were classified with an accuracy of over 94% and 100% in 1988 and 1996, respectively. Based on the satellite information and ground survey data, the pixels of the study area (13.3×10^5 ha) in 1996 were classified into the following six types: conifers (6.0×10^6 ha), hardwood (1.3×10^5 ha), shrubs (1.9×10^5 ha), mixture forest (1.8×10^5 ha), grass (1.1×10^5 ha), others (1.2×10^5 ha). Correlating the volume of timber to the vegetation index (NDVI) calculated using the NOAA/AVHRR data, the volume of timber in each pixel was estimated and mapped for each forest type (conifer and hardwood) together with the degree of damage. The average timber volume of conifers and hardwood in the burnt areas were $166 \text{ m}^3 \text{ ha}^{-1}$, $37 \text{ m}^3 \text{ ha}^{-1}$ in 1988; and $469 \text{ m}^3 \text{ ha}^{-1}$, $179 \text{ m}^3 \text{ ha}^{-1}$ in 1996. The satellite data and ground survey data suggested that the vegetation was almost fully recovered. Therefore we see here that a healthy forest ecosystem can be restored even after an extensive fire.

In Japan, pine forest blight has increased markedly since 1970 especially in the Seto Inland Sea area and San-in district, west Japan. According to the Prefectural Forest Division (1989) study, about 512×400 pixels of forests, that is nearly 20% of the total pine forests of Hiroshima Prefecture has been damaged by pine blight. Such extensive forest damage may result from malfunction in the forest preservation system such as poor water regulation, damaged nutrient cycle, land slides, and loss of biological resources (timber and mushrooms). It is absolutely necessary therefore to identify the causes of pine blight and develop effective countermeasures.

One of the most effective techniques for surveying extensive forest damage is the use of remote sensing data from satellites such as Landsat. A few attempts have been made to roughly assess the degree of blight damage. For examples, Mukai et al. (1984) conducted an assessment based on Landsat MSS (Multi-Spectral Scanner, $80\text{m} \times 80\text{m}$ mesh); Higashi (1990), and Nakane & Kimura (1992) offered an assessment by using Landsat TM (Thematic Mapper $30\text{m} \times 30\text{m}$ mesh). However, only a few studies have attempted to estimate periodical and topographical changes in the degree of blight damage quantitatively.

Since 1970, Japanese pine forest blight has increased markedly, especially in the Seto Inland Sea area and San-in district, west Japan. In order to collect blight information, TM images were obtained to evaluate Japanese red pine blight in the western part of Hiroshima Prefecture. Topographic corrections on Landsat TM (Bands 2~5, Path 112, Row 36) data of Mt. Gokurakuji area were made based on a topographical map of 1:200,000. Using the multi-level slice classification method, the research areas were classified into twelve categories: Water, Urban-1, Urban-2, Residential area-1, Residential area-2, Bare land-1, Bare land-2, Cultivated land, Grass land-1, Grass land-2, Forest-1, and Forest-2. The corrected Landsat TM data were employed for the detection and assessment of the pine forest damage degree with a spectral vegetation index. The ratio of the digital number (relative reflectance on the ground surface) of TM Band 4 to Band 3 (SR) was observed on four days: May 8, 1987; May 16, 1990; May 16, 1992 and May 16, 1996. The data of the 184km² area were divided into 512 pixels×400 lines and converted into the configuration map (1/200 000 scale) based on the coordinate system. The vegetation index study produced the following result with respect to the damage degree: 0% for (0); 0~20% for (I); 20~40% for (II); 40~60% for (III); and 60~100% for (IV). The relationship between SR and D (the damage degree of pine forest observed on the ground, %) was $SR = aD + b$ (a and b are coefficients). The value of SR decreased with the increase of D, and coefficients a and b were relatively stable during the four years. The range of vegetation index calculated from the same season data was 1.50~3.00 in 1987, 1.32~2.31 in 1990, 1.22~2.34 in 1992, and 1.78~3.26 in 1996. The mean classification accuracy of the grades (0-IV) of pine forest damage was 61.8%, 68.8%, 81.2%, and 79.1% in the training data of 1987, 1990, 1992 and 1996, respectively. The result suggested that the damaged forest areas were concentrated in or near cities, industrial areas and expressways in the Seto Inland Sea coast area. The pine damage remarkably spread along Mt. Gokurakuji's south slope (that is, the Inland Sea side) from 1987 to 1996. The study of the damage degree in various altitudes showed that the speed of the damage was 6 times greater in the Inland Sea side area than in the inland. This suggests that air pollution might be blamed for the pine damage (Nakane & Kimura 1992, Kume et. al. 1999).

The remote sensing is extremely effective in assessing forest resources. Furthermore the performance of satellite remote sensors will improve with the development in technology. The satellite remote sensing is now an indispensable means of data collection and data analysis since it provides accurate and update information. The meaning of the present research is consequential because it has made the best use of satellite remote sensing data. The research has produced satisfactory results with wide applicability in relevant study areas. Using NOAA/AVHRR and Landsat TM data, and a topographically corrected configuration map (1/1,000,000 scale and 1/200,000 scale) of 5.6 Large Forest Fire in Daxinganling region of China, and the heavily damaged pine forest of the Seto Inland Sea areas of Japan, the recovery of forest vegetation and the assessment of pine damage degree were evaluated and mapped. A large scale vegetation recovery was observed in the site of 5.6 Forest Fire eight years after the fire. Above-ground timber volume was also estimated and mapped based on the relationship between vegetation indices (NDVI) and timber volume data obtained on the

ground of Daxinganling. The degree of pine damage in the Inland Sea area was estimated and mapped based on the relationship between SR and D. The changes in the Seto Inland Sea area and the pine damage degree were also quantitatively estimated and mapped in due consideration of time and altitude.

As discussed above, forest vegetation was classified and mapped based on the relationship between the combination of spectral reflectances obtained by either NOAA/AVHRR or Landsat TM, and forest vegetation data obtained on the ground. The relationship between NOAA/AVHRR or Landsat TM data and forest vegetation data was also examined in order to correlatively assess the timber volume of forest and pine forest blight. Therefore the structural and functional characteristics of forest vegetation were estimated and mapped quantitatively and periodically based on the NOAA/AVHRR and Landsat TM data. Therefore, using remote sensing data not only we can estimate forest resources but we can also diagnose vegetation recovery and pine forest blight taking time and geographical conditions into consideration.

Remote sensing has become one of the most effective forest resources assessment tools. By making a precise diagnosis of forest's recovering process, we can assess forest resources. The diagnosis of vegetation recovery and pine damage can be made based on satellite data, ground verification data, topographical information, and geographical information. A data base can be constructed by integrating geographical, topographical, and surface cover data into periodically overlaid satellite data. The present study offers with accuracy an assessment of forest resources in two cases: 5.6 Large Forest Fire in China, and pine plight damage of the Inland Sea areas in Japan. The study shows that the satellite monitoring system is indeed one of the promising tools for the assessment of forest resources in both regional and global scales.