ECOLOGICAL APPLICATIONS OF DIGITAL CANOPY HEIGHT MODEL DERIVED FROM STEREO PAIR AERIAL PHOTO IMAGERIES

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ABSTRACT: One of the advantages of aerial photos, both analog and digital, is the extraction of height information from their stereo pair image dataset. Digital canopy height model (DCHM) derived from digital surface model (DSM) and digital elevation model (DEM) is significant ecological information. DCHM is very meaningful to monitor a stand development or to detect a mature stand. In Japan, there is the archive of the numerous aerial photos from one taken by the U.S. Forces in the 1940s to the latest digital airborne system, for instance, the monitoring of temporal change of forest can be achieved using them. Moreover, recently, the opportunity of the image data acquisition using an airborne digital camera system is increasing, and digital stereo pair data has been also analyzed more often. I would like to introduce a forestry research using temporal aerial photos and the research project for a coastal pine forest management using digital aerial photos, and to discuss about the ecological application of digital canopy height model derived from aerial photos.

1. INTRODUCTION

Acquisition of the ecological height information in remote sensing is measuring the height of stand, that means the height of a canopy. Remote sensing technology has great advantage to acquire digital surface model (DSM) in broad scale since that technology is able to collect the height information of canopy. Usually, if we would monitor the height of canopy, there is only periodical field survey, but the limitations of field survey are its difficulties of broad scale measurement and impossibility of tracing back in the past.

Now, the procedure of measuring the height of earth surface has the photogrammetry method in which the stereo pair image (Gong *et al.*, 2002) and a direct method by Light Detection and Ranging (LiDAR) (Patenaude *et al.*, 2004) were used. Although LiDAR is a direct measurement of the height of ground surface, there is an issue of a high production costs. Moreover, in LiDAR, it cannot trace back in the past from the present. The past aerial photos are not only useful as an image data, but have the advantage that the past DSM can be created. In Japan, there is the archive of the numerous aerial photos from one taken by the U.S. Forces in the 1940s to the latest digital airborne system, for instance, the monitoring of temporal change of forest can be achieved using them.

Comparing aerial photo with satellite data, the spatial resolution of 10 cm is realizable. Although satellite data have an advantage in wider coverage of data and less distortion of the image accompanying topographical feature, aerial photo imageries can obtain the height of ground surface through stereo pair data. Aerial photo has more flexibility in control of observation timing. Comparing with an analog aerial photo, satellite data has some advantages, like that it is digital, observing the invisible wavelength band, and its higher radiometric resolution. However, airborne digital sensor has become widespread recently; it is easy to collect the near-infrared information with high radiometric resolution.

This paper takes notice of the applications of the aerial photo imageries in the ecological field and introduces two case studies. Particularly, the advantage of the aerial photo which could create DSM from stereo pair data was focused on. One of the two case studies employed digital aerial photo. In the ecological field of witch main target of vegetation, it is thought that the use of the digital aerial photo will advance in future including the DSM application. In this paper, I would like to emphasize about the advantage of modern aerial photo application.

2. DSM APPLICATION FOR COASTAL FOREST USING DIGITAL AERIAL PHOTO

2.1 Aim

In the coastal area in Japan, in order to mitigate the damage to behind area caused by serious blowing sand or salt breeze, coastal forest has been usually developed at many places. The history of development of coastal forest extends more than 300 years. Moreover, it is confirmed that coastal forest has also an effect in mitigation of tsunami damage. In Japan, the scenery of white sandy beach and full of green pine along seashore is recognized as a traditional landscape. Many pine trees in Japan, however, have suffered pine wilt disease (PWD) carried by long-horned beetle (*Monochamus alternatus* Hope). This damage is in progress now and PWD does not show a sign to the end in the Niigata city where the study area of this analysis. This paper reports how digital aerial photo imageries can contribute to the monitoring of coastal pine forest. It is emphasized about the significance of DSM acquisition from stereo pair data especially here.

2.2 Study area

Study area was the coastal forest developed along the coastline in Niigata city. There is 59-km long coastline in Niigata city. The forest reserve stands in a narrow belt along this coastline, and that total area is 1,093ha. 690ha is specified for 63% of them as the blowing sand defense forest reserve. Now, the coastal forest is considered as important not only as for the function as a blowing sand defense forest reserve but the one as a place of citizens' recreation. The main tree species which compose a coastal forest is Japanese Black Pine (*Pinus thunbergii*), but they have died caused by pine wilt disease. On the other hand, many broadleaved trees have encroached upon the coastal forest. Yamaguchi and Nakata (2008) pointed out since the coastal forest in Niigata city was close to city area and there are many encroach of broadleaved trees of which seed spread by bird, the seed of the garden tree of a residential area or the planting tree of a park is supplied by birds in the coastal forest.

2.3 Aerial Photo Imagery data

Digital aerial photos were taken by digital aerial camera DMC of the Aero Asahi Corporation, spatial resolution is 0.1 m and radiometric resolution is 12 bits. Table 1 represents the specification of this airborne digital camera. Data acquisition years are 2005 (17 and 18 April) and 2011 (18 April, and 3 and 16 May).

2.4 Image Analysis

In this research, in order to express the vertical interval as the canopy height of a pine stand, DSM was created. DSM was determined after the aerial triangulation by Leica Photogrammetry Suite (LPS; ERDAS Inc.). The cell size of DSM was determined to 1 m which is 10 times the spatial resolution of a digital aerial photo. Triangulated Irregular Network (TIN) was created by mass point which its three-dimensional coordinate was determined by image matching. TIN was converted to DSM with raster style with 1-m spatial resolution. Digital Canopy Height Model (DCHM) was determined as tree height data. In this research, DCHM was determined by subtracting DEM from the DSM. Since the spatial resolution of DEM was 5 m, one of DCHM was also set to same size, 5 m. The result of created DCHM and a field survey (height of a building and tree height) was compared. Change of canopy height was extracted from the difference of DSM of two stages.

2.5 Results

A tree-species classification map, a canopy height map, a vegetation change map derived from NDVI composite image, and a canopy height change map were created in this analysis. About DSM, some area created well and another area did not well.

2.6 Discussion

As use of the three-dimensional information in a coastal forest, Kudo *et al.* (2009) is performing the trial in which the landscape of a coastal forest is evaluated, using DSM created from the airborne laser profiler. Fig. 1 was created by combination of the classification map and DCHM which were obtained in this paper. To present the height distribution of the coastal forest which exists along the coastline displays visually the location and height of wall which prevents salt breeze and blowing sand exists. This might be important information for management of the various functions of a coastal forest. Since existence of height information is very useful for management of a coastal forest, application of the digital aerial photo which can create it is effective. Development of monitoring system based on digital aerial photo and creation of forest type map or canopy height map might become important for management of coastal forest. In order to make sustainable the functions of coastal forest, it is expected for remote sensing technology that the information supplement which can contribute to planning of the management of a future coastal forest should be attainable.

3. DSM APPLICATION USING PAST AERIAL PHOTO

3.1 Aim

In order to manage forest efficiently, the database which recorded the information about forest is indispensable. In Japan, globally unusual nationally developed database called “sinrinbo” (forest database) exists. This forest database is prepared for all the stands to be planned with polygon-based data. However, it has been pointed out that the precision of this data is insufficient. This problem is related with the accuracy of its spatial position and attributes data. Specifically, it means that the position or boundary of a plantation has an error, or stand age information is not exact. This research attempted to address this issue using past aerial photos. The objective of this research is to examine the method of extracting stand age information and boundary of plantation through change detection using temporal aerial photo imageries.

3.2 Study area

A study area is the Katsuki area, Murakami city, Niigata Prefecture, Japan. The proportion of forests in this area is 93%, and the artificial plantation occupies 39% of forest. In this region, forestry has been held actively. The main tree species for the plantation of this region is Japanese cedar, and 98% of plantations consist of Japanese cedar within the study area.

3.3 Aerial Photo Imageries data

The basic information on the aerial photos used in this analysis is indicated in table 1. The employed aerial photos were 21 sheets in total (seven stages and three photos per stage) and each taken by the Forestry Agency, Japan. All the photographs were taken with a monochrome film. Photos which processed by adhesion size were obtained. These were scanned and digitized by 600dpi.

3.4 Image Analysis

DSM was created from the stereo pair data of each stage (year). DCHM was calculated by subtracting DEM from this DSM. Discrimination of each stand which showed different canopy height was tried by using not only the brightness of the image but canopy height information this time. DCHM was expected especially to separate young stand from mature stand because both gray levels are similar. In this analysis, the two adjacent stages were combined and the image classification of that two stage composite data was carried out. The Classification And Regression Trees method (CART; Breiman *et al.*, 1984) was employed for the classification. The image applied for the classification is derived from the second principal component of the principal component analysis of two-stage composite image of brightness or DSM data (the following, Brightness-PC2, DSM-PC2). The decision tree of CART was obtained by Brightness-PC2 and DSM-PC2. Finally, a map showing the boundary of stand and estimated stand age was created.

3.5 Results

Fig. 2 shows an original photograph and DCHM image. These figures are the typical example which indicated the effectiveness of DCHM. Bare land like a cutting area looks white, because the vegetation is lost after clear cutting and soil is exposed. Moreover, since a cutting area does not have height compared with the surrounding forest, DCHM indicates a low value. On the other hand, if a younger stand about ten years old, the crown will close each other and then the brightness of such stand will become darker. Such condition, it is difficult to distinguish young stand from surrounding mature stand. In the meantime, since the DCHM of young stand smaller value, comparing with surrounding stands, it is clear that its height is obviously low like this image.

Decision trees were determined in each period. The count number of features applied, the Brightness-PC2 was 10 times, DSM-PC2 was just 2 times. The results indicated that brightness based feature was mainly employed. At the first branching of CART, in the change extraction for the combination of 1965 and 1981, DSM-PC2 was selected, whereas Brightness-PC2 was selected in most other change extraction. It is understood that DSM worked well in the long interval.

3.6 Discussion

The estimated stand age and its boundary of plantation were able to be specified using the decision tree created by the CART method of temporal composite aerial photo imagery. Since a brightness value rose mainly with the appearance of clear cut, Brightness-PC2 which used the brightness value as the base was chosen as the classification. On the other hand, in the long interval of taking photos, employment of DSM worked effectively. If time passes since renewal of plantation, planted trees will grow up, its crown will close, soil will disappear and brightness value of canopy will decline because dense vegetated area indicate less reflectance in visible band. It is difficult to discriminate between younger stand and older one when the brightness values of younger stand become darker. This analysis showed that DSM data compensated for this disadvantage. The younger plantation area which cannot be well discriminated only with a brightness value was able to be extracted by employment of DSM. Although there is no multispectral information in a past aerial photo, image acquisition by stereo pair style would be more advantage to use canopy height information and extract newly appeared planted area effectively. This advantage would contribute to delineate the boundary of planation and estimate its stand age.

4. CONCLUSIONS

Two ecological (forestry) case studies using the aerial photo imagery data were introduced in this paper. Especially, paying attention to the advantage that DSM can be obtained from stereo pair data, this paper showed what kind of applicative value would be caused. Mostly the airborne camera will be digital sensor. By use of a digital sensor, application of the near-infrared region data which was not able to be acquired with a normal film is attained. This is very advantageous to vegetation analysis. Moreover, stereo pair data provide height information. In the case of a digital camera, if even the capacity of HDD is allowed, it is also possible to improve an overlap rate. When this creates an ortho image with less distortion, it is very advantageous. Thus, in ecological application, the presence of aerial photo imagery will increase certainly hereafter. It will be very important to contribute to natural resource management, making full use of photogrammetry technology.

5. REFERENCES

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Table 1 Specification of airborne digital camera.

Sensor	DMC
Number of pixels	8,000 x 14,000
Focal length	120 mm
Number of Bands	4
Radiometric resolution	12 bits
Altitude	970 – 1,460 m
Scale	1:8,000
Spatial resolution	0.1 m

Table 2 List of temporal aerial photos.

Data Acquisition Date	Altitude (m)	Scale	Number
1963/10/8	4,198	1:20,000	3
1965/8/27	4,183	1:20,000	3
1981/7/30	3,421	1:16,000	3
1986/7/30	3,421	1:16,000	3
199310/15	3,419	1:16,000	3
1997/6/13	3,417	1:16,000	3
2002/10/12	3,417	1:16,000	3

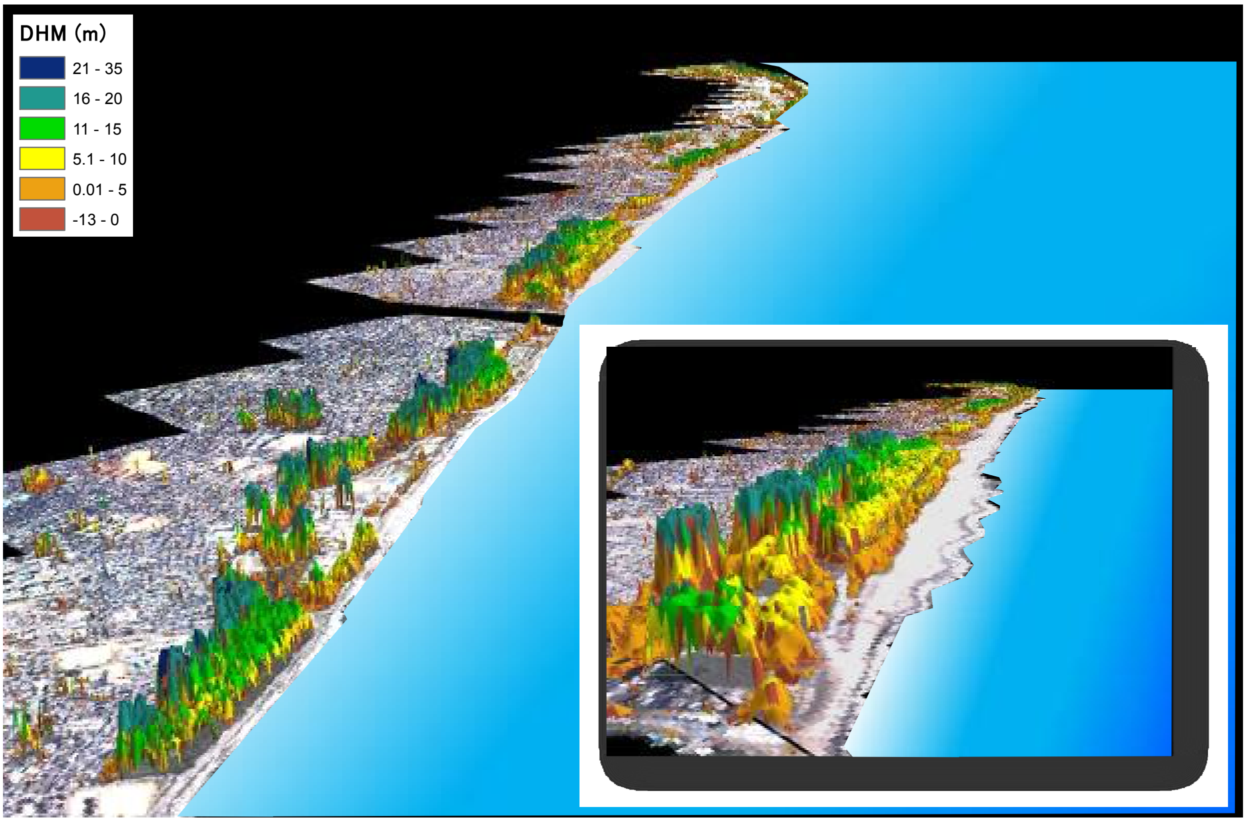

Fig.1 3D view of coastal forest. Only pine stands were extracted based on classification map and canopy height information was used for three-dimensional expression.

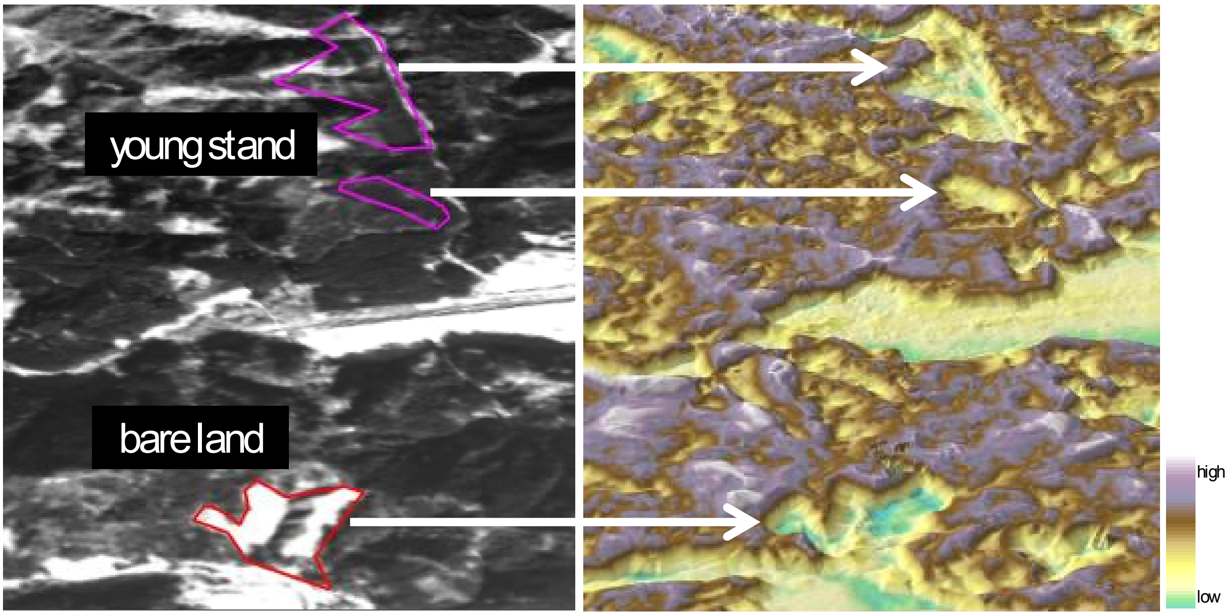

Fig.2 3D view of aerial photo (left) and DCHM (right). Bare land includes clear cutting area. Bare land represents lower height due to no tree. Although young stand of which reflectance is similar to mature stand shows similar color surrounding stand, it is possible to distinguish young stand from other older stand using canopy height information.