ELUCIDATIVE MECHANISM OF THE RECESSION OF ALPINE PLANTS AND THE INVASION OF DWARF BAMBOO KURILENSIS IN THE TAISETSU MOUNTAINS

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Abstract — Global warming's influence over the last 30 years, along with soil dehydration in the Taisetsu mountains has resulted in shrubbery such as Dwarf bamboo (*Dwarf bamboo kurilensis*), a species of dwarf bamboo, and Japanese Stone pine (*Pinus pumila*) (an indicator of soil dehydration), increase in area of distribution while many herbaceous species of alpine plants have reduced in distribution area to the extent where some extinction has occurred. This study, using multipolarization of ALOS satellite PALSAR L-band microwave (HH/HV) data, has developed a model to estimate soil moisture in densely vegetated areas to clarify factors in the seasonal variation of soil moisture in an area with fluctuating vegetation and so clarify factors in the casual relationship between soil dehydration and vegetation fluctuation in a wide area. Moreover, conducting this research will enable identification of potential areas where Dwarf bamboo may easily invade, and thus contribute to environmental measures.

Keywords —alpine environment, a new method of soil-moisture estimation, The influence of global warming.

I. INTRODUCTION

The impact of global warming, caused by climate change, on terrestrial ecosystems will be particularly prominent in the Polar Regions (the North and South poles and the alpine belt) [1].

Recently the snowmelt period has been starting earlier from year to year in the Taisetsu Mountains [2]. The cold location (low temperature and high snowfall) of the Taisetsu Mountains and the varying snowfall resulting from the geographical features, create two totally different kinds of environment, wind swept areas and snowfields. There are many differences in the thaw period due to these two special environments and the characteristics of alpine plants include many peculiar and or rare species in this ecosystem [2][3]. Due to this, the mountain ecosystem consists of a specific and stringent environment, which is extremely sensitive to global warming and dehydration. An early thaw period accelerates soil dehydration and temperature increase that changes vegetation distribution through the competitive relationships of plant species and so changes the flowering period. Also of concern is the affect on fauna utilizing the vegetation.

It is documented that the early snowmelt from global warming is leading to progressive soil dehydration and that dwarf bamboo kurilensis has invaded the alpine wilderness area changing the alpine vegetation community. An earlier study of a basic spatial unit of the Goshikigahara area of the Taisetsu Mountains to quantify vegetation change by areal photographs (Fig.1), identified the expansion rate of Dwarf bamboo to be up to 57% and on average 25% from 1977 to 2009 [2].

Also, in August, September and October, there was a clear soil moisture content decrease in most areas under dense dwarf bamboo while at the edges of some expanding areas of dwarf bamboo an increase in soil moisture was observed. There were no major fluctuations in areas where alpine plants occupied a wide area from August to October but the areas did show slight dehydration [4][5].

However, individual ground surface or soil dehydration in the vegetation change area and the seasonal changes in soil moisture and vegetation change were not studied enough to identify a primary factors. Now, this study in the model Goshikigahara area of the Taisetsu Mountains, seeks to clarify seasonal change in the soil moisture of the vegetation change area, clarify the relationship between soil dehydration and seasonal fluctuation in the vegetation changing area and also conduct research to identify potential areas where dwarf bamboo may easily invade.

II. THE STUDY OBJECTIVES

About 98 *ha* of land in the central part of the Goshikigahara area (altitude: 1,700 - 1,800 meters, $43^0$33'N, $142^0$54'E) on the Taisetsu Mountains, in Hokkaido Japan was selected as the multitemporal ALOS PALSAR HH/HV polarization data in June 19, Jull 7, August 4, August 21, September 19 and October 6, 2010. The field measurement of plants species and soil moisture (using ©Hydrosense, Campbell Scientific Inc. with a 12 cm probe) of study area was taken in July, August and September four years of 2008, 2009, 2010 and 2011.

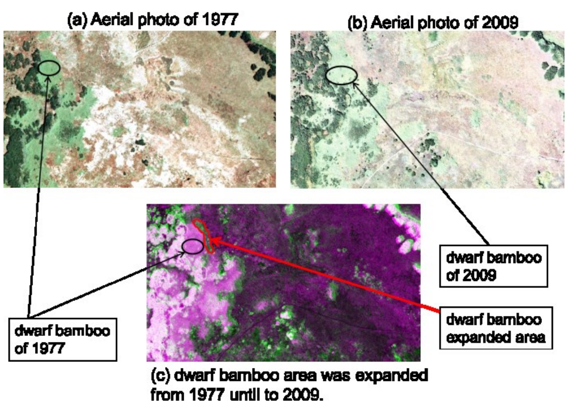

Fig. 1 Distinct result of visual vegetation using areal photography of the Goshikigahara area of Mt Taisetsu (Where, the magenta colors shows dwarf bamboo in 1977 and green colors shows expansion area of dwarf bamboo from 1977 until to 2009)

The objective of the study is to establish the remote sensing method for the estimation of soil moisture in a large scale, which is covered with dense vegetation. It is necessary to take into account the impact of the vegetation (roughness height). Therefore, the method for identifying seasonal fluctuations of soil moisture content over large areas was developed using the multitemporal and the multipolarization microwave backscattering coefficients (σ^0) for densely vegetated areas.

III. METHODOLOGY AND RESULT

For modeling backscatter from vegetation canopies using radar data, a common approach is to first develop direct models simulating the backscattering coefficient of a canopy with known characteristics. These models include the following types: empirical model, theoretical model, and semiempirical model [6]. In semiempirical water-cloud models, the canopy is represented by ``bulk" variables such as leaf area index (LAI) or total water content, and because of the parsimonious use of parameters, these models can be easily inverted; they are, therefore, good candidates for use in retrieval algorithms [7] [8]. In this context, radar backscattering from a canopy can be expressed as the sum of contributions due to (i) volume scattering in the canopy itself, (ii) surface scattering by the underlying ground surface, and (iii) multiple interactions involving both the canopy and the ground surface. The water-cloud models represent the power backscattered by the whole canopy (σ^0) as the incoherent sum of the contribution of the vegetation (σ^0_{veg}) and the contribution of the underlying soil (σ^0_{soil}), which is attenuated by the vegetation layer. For a given incidence angle q, the backscatter coefficient is represented in water-cloud models by the general form [6] [7][9]:

$$\sigma^0 = \sigma^0_{canopy} + \sigma^0_{canopy+soil} + \tau^2 \sigma^0_{soil} \qquad (1)$$

Where, τ^2 are the two-way vegetation transmissivity. The first term represents the scattering due to the vegetation canopy, the second term represents the interaction between the vegetation canopy and the soil underneath and accounts for multiple scattering effects, and the third term represents the scattering from the soil layer. With the canopy (roughness) effect, the study assumed that the seasonal changes (growth) of the roughness height of dwarf bamboo and stone pine over one month does not affect the backscattering signal, based on the penetration properties of the L-band microwave through the plant layer and the phenological characteristics of dwarf bamboo and stone pineBased on this assumption, the following equation was created [5]:

$$\Delta VSM = \Delta f(R, m_s) \approx \Delta\sigma_t^0 = (\sigma_{t2}^0 - \sigma_{t1}^0) \quad (2)$$

Where, R is roughness; m_s is the volumetric soil moisture (*VSM*) surveyed; ΔVSM is seasonal changes in the soil moisture; $\Delta\sigma^0_t$ is the difference between backscattering coefficients; σ^0_{t1} and σ^0_{t2} are backscattering coefficients from soil in season t2 and season t1, respectively.

In the development of the algorithm, the fact that the seasonal changes in dwarf bamboo and stone pine were much smaller than the seasonal changes in other alpine plants and soil moisture content was used to develop a model which used differences in microwave backscattering coefficients while taking into consideration the phenology. The moisture contents in the soil under specific vegetation in the Goshikigahara area were then identified. When looking at the seasonal fluctuations of soil moisture in 2010 in areas under stone pine, dwarf bamboo and alpine plants, the soil moisture content in the Goshikigahara increased in general from mid-June to early July, except for a decrease in some areas covered by dense dwarf bamboo. In August, September and October, there was a clear soil moisture content decrease (dehydration) in most areas under dense dwarf bamboo. At the edges of some expanding area of dwarf bamboo (where dwarf bamboo was invading alpine vegetation areas), the increases in soil moisture content were observed. There were no major fluctuations in areas where alpine plants occupied a wide area from August to October, but the areas showed slight dehydration.

The field measurements revealed that soil moisture contents in the Goshikigahara ranged between 65% and 80%. The moisture contents on steep slopes of the southeast side were relatively low. Dwarf bamboo has expanded into this area.

Fig. 2 shows the seasonal changes in soil moisture conditions extract from the backscattering coefficients in the Goshikigahara area calculated from equation 2 and field measurement of soil moisture in test sites. The positive values a (blue color) indicate an increase in soil moisture, the negative values (light color) indicate a decrease in soil moisture, and the values close to zero indicate that the changes were small. It was confirmed that soil moistures decreased in areas where dwarf bamboo grew densely in mid-June to early July and that soil moistures increased in many areas as the snow melted. However, from early to late August and from September to October, soil moistures clearly decreased (dehydration) in areas under dense dwarf bamboo over wide area. There was an exception: soil moistures increased at the edges of dwarf bamboo expanding areas. It was confirmed that soil moistures were relatively constant from August to October in areas where alpine plants covered a wide area, but the areas showed slight dehydration.

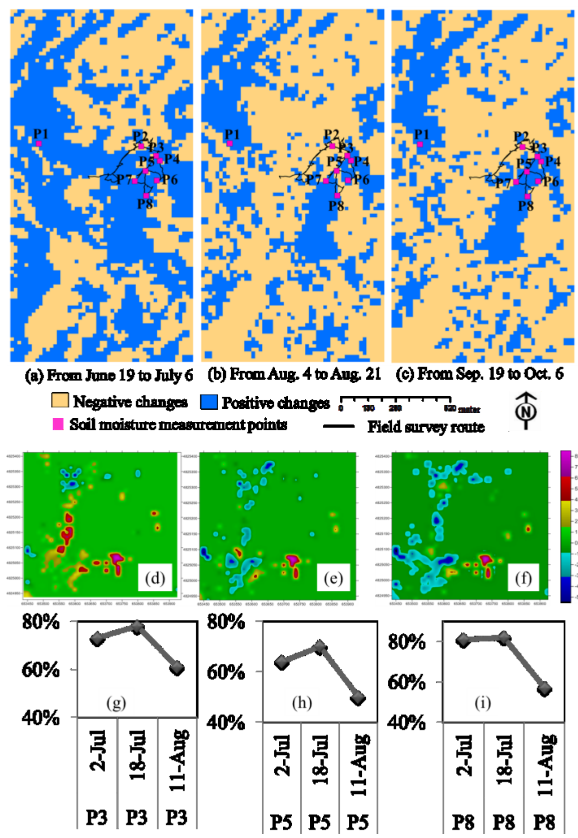

Fig. 2 (a, b, c). Seasonal change in soil moisture condition extracted from L-band PALSAR multipolarization backscattering coefficients. (Where, the light color shows negative change and the blue color shows the positive change. The Fig. 2 (d, e, f) shows the subtraction results of backscattering coefficients difference between (d): July 6 and June 19, 2010 (the positive change area is 64%); (e): August 21 and August 4, 2010 (the positive change area is 47%); and (f): October 6 and September 19, 2010 (the positive change area is 44%) in the dwarf bamboo area. The points and lines show the location of field survey; and the Fig. 2 (g,h,i) shows the field measurement of soil moisture (depth: 0 - -12 cm) using hydrosense© in test sites.)

IV. DISCUSSION

Estimation of soil moisture in densely vegetated area is very difficult, because the microwave backscatter is influenced by the roughness surface height. Based on the accurate scattering model, both the soil moisture and surface roughness can be retrieved from the polarimetric backscatter measurements with a good accuracy for bare-soil surfaces. In the present study, we provide a new method to estimate the surface soil moisture in dense vegetation area in the Taisetsu Mountains with an L-band dual-polarization (HH and HV) radiometer measurement considering vegetation phenology. For high dense vegetated surfaces, we used the multitemporal and multipolarization backscatter coefficient data and the subtraction methods to provide the estimation of the vegetation effects. After the soil moistures corrected based on vegetation phenology, the surface soil moistures can be inferred by the estimated surface backscatter signals. Estimation of potential dwarf bamboo magnification area is very important. From the microwave backscattering from late June to early July, early August to late August and September to October, we extracted high dehydration trends and high hydration trends in each of the periods observed resulting from seasonal changes in the soil moisture and preferences of microtopography. Dwarf bamboo preference for dry areas is proven by this study and as dwarf bamboo basically spread by root systems underground to form a community, future dwarf bamboo expansion is highly possible on the edges of present areas of Dwarf bamboo growth. This area warrants a long term monitoring survey.

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