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Satellite Ecology, an Attempt to Link Remote Sensing with Ecology for River Basin Studies

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Abstract

The Satellite Ecology Program has been launched since 2004 at Gifu University. The goal of this Program is to find the links between remote sensing, ecosystem ecology and micrometeorology for studying ecosystem structures and functions in the mountainous landscape of central Japan. It aims at making "Satellite Ecology" into a comprehensive yet practical science by making regional carbon and water monitoring via satellite remote sensing technology which has advanced drastically. It enrolls the Ecological Process Research Group, the Remote Sensing Analysis Group, and the Meteorological Observation and Modeling Group. The characteristics of this Program are, meso-scale regional study, carried out on mountainous landscapes consisting of a complex of various ecosystems, and interdisciplinary collaboration. In this review paper, we introduce the background, concepts, and some findings by the Remote Sensing Group. Our group contributed for the evaluation of horizontal accuracy of high resolution images, the creation of multi-stage landcover classification maps, the development of ground validation methods using digital imagery, and forest phenology analysis using seasonal MODIS/NDVI.

1. Background

Moving into the 21st century, the surrounding environment of remote sensing has changed drastically. First and foremost, sensors onboard earth observation satellites have improved in spatial, spectral and temporal resolutions (Akiyama et al., 2004). That is, super high resolution satellites like QuickBird and IKONOS possess 2.4 or 4 m of spatial resolution, Terra/MODIS and EO-1/Hyperion can take hyperspectral images, and Terra and Aqua/MODIS acquire daily data with 250 m of resolution. In addition, user friendly software and programs have prevailed for image analysis, and the Geographic Information System (GIS) became widespread as a necessary and reliable tool. The Global Positioning System (GPS) with high precision accuracy has also become an imperative tool for field survey and ground truth. Table 1 shows noteworthy progressions of satellite sensors between 1990's and 2000's.

Frequent observation with low spatial resolution satellites such as NOAA/AVHRR, and Terra and Aqua/MODIS has clarified various global environmental issues (eg. Myneni, 1997). However, there are few methods to verify the accuracy of actual events happening on the ground. Because of the remarkable progress of remote sensing technology, it has become possible to validate ground-based ecological processes using finer resolution satellites at a regional scale. Figure 1 shows overlapping of scale in a process ecology experiment and satellite remote sensing analysis in the spatial and temporal domains (Akiyama, 2006).

2. The Satellite Ecology Program

In the 21st Century the COE (Center Of Excellence) Program of the Japan Society for the Promotion of Science, "Satellite Ecology" has been launched in 2004 at Gifu University. The goal of this Program

Table 1. Improvement of spatial, spectral and temporal resolutions of satellite sensor between 1990's and 2000's

Resolution	1990's	2000's
Spatial	20m (SPOT/HRV)	2.4m, 4m (QuickBird, IKONOS)
Spectral	7bands (Landsat/ETM+)	36bands, 220bands (MODIS, Hyperion)
Temporal	Daily (NOAA/AVHRR)	2times/day (AM/PM) (Terra/Aqua MODIS)

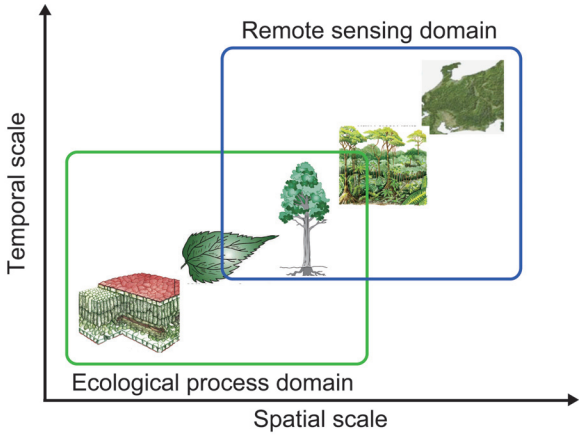

Fig. 1. Overlapping of Remote sensing analysis domain and Ecological process research domain on spatio-temporal scales.

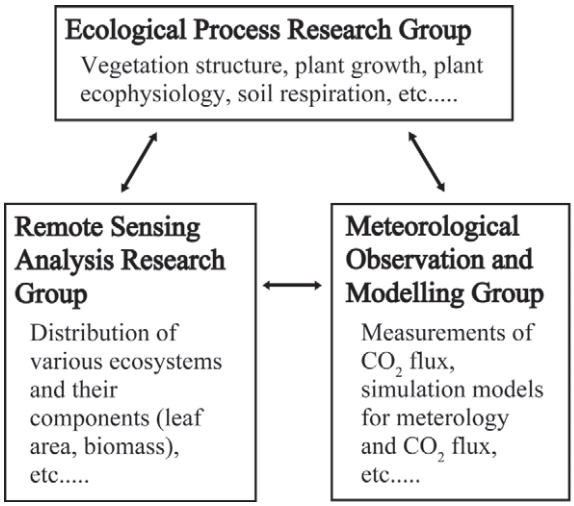

Fig 2. Configuration of supporting research groups for Satellite Ecology Program and its roles

is to find the linkage between remote sensing, ecosystem ecology and micrometeorology for studying ecosystem structure and function in the mountainous landscape of central Japan. Figure 2 shows schematic roles of three research groups including the Ecological Process Research Group, the Remote Sensing Analysis Group, and the Meteorological Observation and Modeling Group (Koizumi and Muraoka, 2005). It has been carried out with 9 permanent researchers and 4 degree recipients. This Program aims at making "Satellite Ecology" into a comprehensive yet practical science by making regional carbon and water monitoring via satellite remote sensing technology which has advanced drastically.

Specific themes for the Remote Sensing Group include forest and landcover type classification at multiple scales, the creation of a distribution map of biomass and carbon storage, and spatio-temporal changes of leaf area in the study area. These will be combined with CO_2, water and heat flux of the forest, and soil respiration and photosynthesis measurement by the Ecological Process Research Group and the Meteorological Observation and Modeling Group. The framework of the ecology- meteorology model (by the name of SATECO model) was established in 2006 with a 1km mesh, which was improved to a 100m mesh in 2008 (Yoshino et al., 2008, Tamagawa et al., 2008).

The characteristics of this Program are, meso-scale regional study, carried on mountainous landscapes consisting of a complex of various ecosystems, and interdisciplinary collaboration.

This Program also aims at the creation of a worldwide research post in this new scientific field. For this reason, we are expanding the wave of research exchanges between Asian and European Institutes. The cultivation of young scientists is also an important issue here.

Out of these Programs, the authors will try to introduce research activities done by the Remote Sensing Group in Section 4.

3. Study area and super site

3.1. Study area

The study area, the Daihachiga River basin, is located in the northern part of the Gifu Prefecture, in central Japan (Figure 3). It covers 60 km^2 of catchment area, 1000 m of altitude gap between headstream (1,595m above sea level, asl) and confluence

point to Miya River (600 m asl). The study area is dominated by rigid forest land including vast deciduous broadleaved (DB) forests and evergreen coniferous (EC) forests, a small area for agricultural land, and some residential and commercial areas near the central Takayama city.

We investigated 28 forest plots inside the study area in 2005 and estimated aboveground biomass from allometry formula using Diameter at Breast Height (DBH) reported by Komiyama et al. (2002).

For agriculture lands, seasonal biomass and leaf area index (LAI) changes were examined for 3 years in rice paddy fields, corn fields, pastures, and abandoned crop fields.

Data of air temperature is being collected at 10 sites distributing portable microclimate recorders (HOBO, USA) from 600 m to 1,570 m asl. at 20 minute intervals since January in 2006.

3.2. Super site

The super site was established in the early 1990's in the cool-temperate DB forest at around 1,400 m asl. This site is located in the upper stream zone inside the study area (Figure 3), and occupies 1 hectare (100m by 100m) of land. The original vegetation was Japanese beech (*Fagus crenata*), but it is now covered by

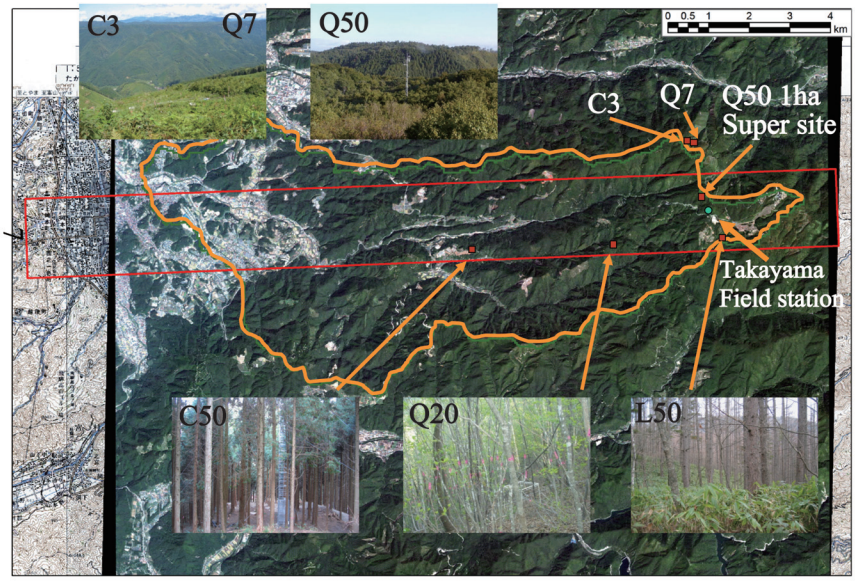

Fig. 3. Satellite image of the study area (Daihachiga river basin, inside yellow line) and photographs showing several forest sites with different species and ages
One hectare super site is appearing on the right end of the study area.
C:Cider forest, Q:Quercus dominant DB forest, L:Larch forest. Numbers following alphabet mean forest age.

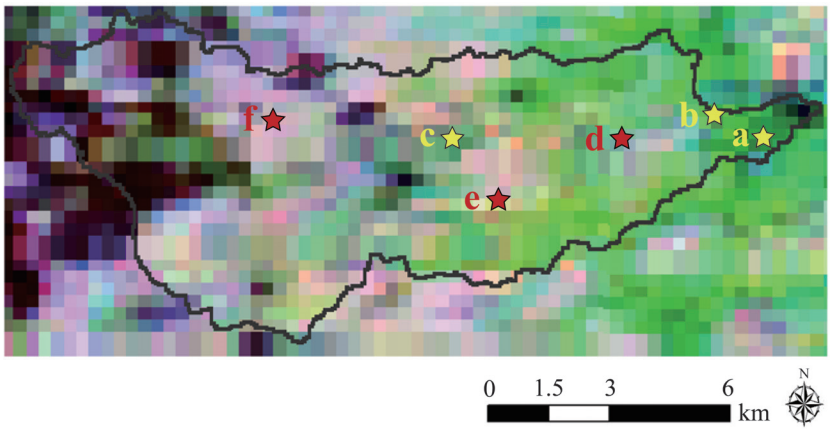

Fig. 4. Forest type classification using MODIS/NDVI acquired in different seasons a, b and c (greenish color) are deciduous forest, d, e, and f (whitish color) are evergreen forest. Dark color on the left side shows construction in Takayama city. Assigned March on red, July on green, and November on blue.

Table 2. Concept of multi-stage classification of forest class according to the spatial resolution of satellite Low resolution corresponds to Terra and Aqua MODIS, Middle resolution for Landsat/ETM+, SPOT/HRV and Terra/ASTER, High resolution for ALOS/AVNIR-2, IKONOS and QuickBird, respectively.

Class	Low Resolution 250 - 500 m	Middle Resolution 15 - 30 m	High Resolution 2 - 10 m
Forest	Deciduous (D)	D Broadleaved (DB)	DB with Sasa (DBs)
			DB without Sasa (DB-)
		D Coniferous (DC)	DC with Sasa (DCs)
			DC without Sasa (DC-)
	Evergreen (E)	E C (EC)	EC of Cedar (ECe)
			EC of Cypress (ECy)
			EC of Pine (ECp)
	Mixed (M)	B C (MM)	Mixed, DB dominant, B>50% (MMb)
			Mixed, EC and DC dominant, C>50% (MMc)
	Fallen (F)	Fallen (FF)	Fallen, old (FFo)
			Fallen, young (FFy)

a secondary DB forest including *Quercus crispula, Betura ermanii, Betura platyphylla* var. *japonica*. The forest floor is covered by a dense dwarf bamboo, *Sasa sinanensis* (Sakai et al., 2001). Tree census has been carried out every year since 1999, and has found 44 tree species, 1,907 stem numbers higher than 1.3m. Net primary production (NPP) of this site using stem growth by yearly tree census was 2.38 Mg ha^{-1} (Ohtsuka et al., 2005). Jia and Akiyama (2005) estimated 440.6 tC ha^{-1} of total carbon is stored in this ecosystem, 107.0 tC ha^{-1} of it is in vegetation, and 333.6 tC ha^{-1} in soil.

Two carbon flux towers were set up in the study area. One was built by the National Institute of Advanced Industrial Science and Technology (AIST) at 1400 m asl. in the super site, and it measures carbon dynamics between atmospheric and terrestrial layers in the DB forest. CO_2 flux at the DB forest has been measured since 1993, now it was certified as one of the AsiaFlux forest sites. The results of CO_2 flux measurement clarified that atmospheric CO_2 concentration increased 1.8% per year during these 10 years. The annual NEP (net ecosystem production) values for 1999, 2000 and 2001 were estimated to be 198, 309 and 290 gC m^{-2} $year^{-1}$ (Saigusa et al., 2005). A second tower was built in 2005 by Gifu University in a Japanese cedar (*Cryptomeria japonica*) forest which was artificially planted in the 1960's at the mid-stream of the study area (800 m asl.).

An ecological observation tower was built in 2002 in the DB forest at 1,430 m asl. The corridors were set at 18 m, 10 m and 4 m of height. Here we can directly measure several physiological phenomena of the canopy. Muraoka and Koizumi (2005) reported photosynthesis and structural characteristics of the canopy using this tower.

4. Some findings by the Remote Sensing Group

4.1.The evaluation of horizontal accuracy of high resolution image

One of the fundamental and specific problems of high resolution satellite imag to apply on mountainous rigid landform area is accurate registration and geometric correction. Kojima et al. (2007) described the quantitative evaluation of the horizontal accuracy of ortho-QuickBird images using DEM (Digital Elevation Model), DSM (Digital Surface Model) and the control points over the top of the tree canopy. Tree height also affected the horizontal errors as well as topographical elevation. They estimated the accuracy of several images of high resolution satellite.

4.2. Multi-stage landcover classification

Multi-scale and multi-stage landcover classification was carried out using various remote sensors such as aerial hyperspectral imagery by CASI, satellite im-

ages by QuickBird, ALOS/AVNIR-2, Terra/ASTER, Landsat/ETM+, and Terra/MODIS. Table 2 shows the concept of multi-stage classification for part of the forest class. Coarse resolution satellite imagery like MODIS can identify 3 or 4 forest classes, but images from mid- and fine-resolution can detect 5 to 11 classes according to the spatial resolution.

Wahid and Akiyama (2007) analyzed the ALOS/AVNIR-2 which was launched January 2006 with 10m spatial resolution. They could identify 13 classes including 10 vegetation classes (6 forest and 4 crop and grassland classes), 2 construction classes, and 1 water class. Kojima et al. (2008) analyzed the data from several satellites for comparison, and concluded that one-meter to several tens of meters of spatial resolutions, and daily to weekly temporal resolutions, are suitable to understand the structures and functions of a basin ecosystem. Maki et al. (2008) mapped the potential distribution of dwarf bamboo under the DB forest using DEM and the differences in ASTER/NDVI between pre- and post-leaf fall period. As the result, the logistic regression model indicated an overall accuracy of 86.11%. Isolation of a DB forest and an EC forest can be done using MODIS/NDVI images acquired on 3 different seasons. Figure 4 shows an NDVI composite image with the March, July and November data assigned to R/G/B, respectively. Here, a, b, c (greenish color) are the DB forests, and d, e, f (whitish color) are the EC forests (Maki, unpublished).

4.3. Ground validation methods using digital image

The development of a proper method for ground validation is important for knowing the actual situation of plant phenology happening on the ground.

Kawamura et al.(2001) examined spatial and temporal variations of light regime and leaf phenology of the DB forest in the super site, by taking photographs and using the shoot sampling method for 9 representative tree species from the leaf development stage in spring to leaf fall in autumn. As a result, development and falling of leaves in *Betula ermanii* and *Betula platphylla* var. *japonica* were several days earlier than those of *Quercus crispula*.

Tsuchida et al. (2005) developed the PEN (Phonological Eyes Network) system for phenology monitoring. One of them was applied at the Takayama super site of DB forest beneath the ecological observation tower. It consisted of an automatic-capturing digital fisheye camera (ADFC) and a hemispherical spectroradiometer (HSSR) system. They reported that when PEN observation is combined with flux or ecosystem research, the validation study of ecosystem remote sensing will be enhanced. This kind of stationary measurement can take accurate data, but it gives a limited spot of information.

Ishihara et al. (2008) proposed a ground observation method to acquire data on detailed phenology changes of various vegetation types. They took digital images using a digital camera and movie camera between spring and autumn from around 600m asl. to 1,340m asl. points along the mountain road. It was confirmed that changing patterns of calculated Normalized Channel DN (Maeda et al., 2005) reflected the forest phenology change. Especially, the pattern of Normalized Green coincided with the leaf development stage and the yellowing stage, and the change of Normalized Red fit to the defoliation stage (Figure 5).

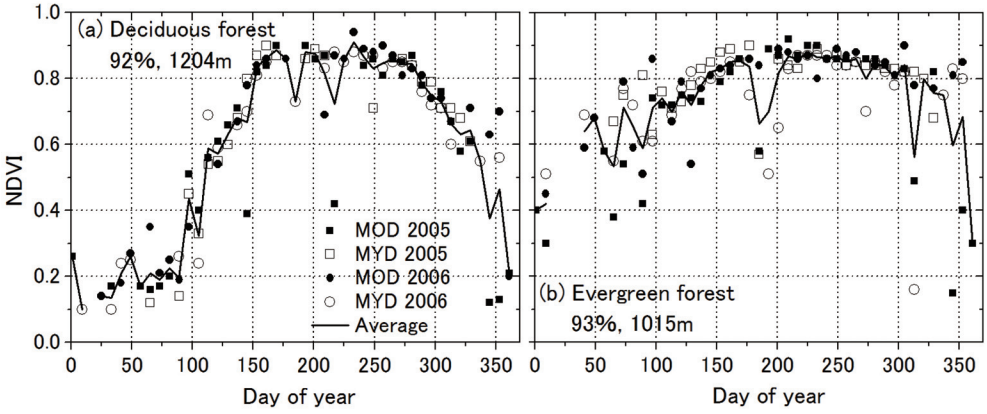

Fig. 5. Seasonal variation patterns of MODIS/NDVI by Terra (MOD) and Aqua (MID) in 2005 and 2006
(a) Deciduous dominant (92%) forest at 1204m asl. (b) Evergreen dominant forest (93%) forest at 1015m asl.

Akiyama et al. (2007) tried to use walnut (*Juglans mandshurica* Maxim) as an indicator plant of DB species. They selected 13 walnut trees growing at different altitudes along a mountain road in the study area, and visually recorded 6 phenological events from bud start-up to complete defoliation. They also measured chlorophyll concentration in leafs using a SPAD meter. According to the results, it was found that walnut phenology was affected by air temperature in spring. But it did not synchronize with MODIS/NDVI changes. Existence of floor vegetation and snow-melting might be the main causes for the inconsistency.

4.4.Forest phenology analysis using seasonal MODIS/NDVI

A forest fluctuates its photosynthetic capacity according to the seasonal changes of leaf amounts and leaf assimilation rates (Sakai et al., 2006). Especially in DB forest, status of leaf changes from development, maturing, yellowing, and shedding in a yearly cycle. Nagai et al. (2008) estimated the dates of budburst (BB) and leaf defoliation (LD) from 2004 to 2006 in the super site using the PEN (Tsuchida et al., 2005) system, which observes by a spectroradiometer situated above the DB forest canopy, and the satellite-based NDVI, which was obtained by the MODIS sensors onboard Terra and Aqua satellites. The ground- and the satellite-based NDVIs increased in the BB and decreased in the LD periods. However, when they estimated the dates of BB and LD by using the threshold value, which was the midpoint between the annual maximum NDVI and the annual minimum NDVI, the estimated date of BB was 20 days earlier than the ground observation and the estimated date of LD was 32 days later than the ground observation.

Spatial resolution and temporal resolution is a setoff relation under the present satellite systems. Frequent observing sensor is inevitable for the forest phenology monitoring, but it has a coarse spatial resolution (250m, in the case of MODIS). Therefore, we must consider about mixel in the mountainous area.

Ishihara et al. (2008) calculated the vegetation ratio (DB and EC) in 250m grid by using detailed landcover map derived from QuickBird image to verify the characteristics of MODIS/NDVI seasonal variation. As the result, EC kept longer peak season of NDVI compared with DB forests in the study area. In addition, the seasonal variation pattern of NDVI changed according to the mixing ratio of DB and EC forest.

5. Conclusions

Recent progress in remote sensing allows analysis of ecosystem function and structure using satellite imaging. Several scales of landcover maps from precise to brief were created in response to the purposes. Moreover, if remote sensing technology is combined with several methods like flux measurement, PEN observation for ecosystem research, validation study of ecosystem will be enhanced.

As spatial resolution and temporal resolution is a setoff relation under the present satellite systems, the Remote Sensing Group applied several satellite data possessing different resolutions to fill any gaps. Development of a scaling method is still important.

Leaf phenology is one of the key parameters for the estimation of carbon budget in the forest. But we could not find the best fitting method from high temporal satellite imagery because of course, of spatial resolutions. New technology for the mixel analysis is needed.

Research shown in this paper and our activity in Takayama site have been financially supported by JSPS/MEXT 21st Century COE Program.

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Estimation of Carbon Stock in Even-aged Sugi Forests Using Satellite Image Data

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Abstract

A Japanese cedar occupies 40% of an artificial plantation of Japan, and is most artificial plantation resources. The amount of biomass of sugi plantation was presumed using satellite data. The biomass can be easily presumed from volume. Therefore, volume presumption is important. From a result of analyzing the relationship between volume and digital number of the band according to wavelength in the amount of biomasses of LandsatTM Images, the band five showed the highest correlation between volume and digital number. And, high resolution satellite image data (IKONOS) were visually excellent and its position of an investigation plot is also clear. Then, the relationship between a plot volume and the digital number classified by band was analyzed. Regression was obtained between digital number of band3 and volume from IKONOS data. Every subcompartment volume was presumed using these regressions and the map of biomass estimated from volume was showed. On the other hand, in forest register of Japan, volume for every subcompartment has added up only one value. We analyzed volume from plot, volume from forest register and volume from satellite data and investigated whether estimated volume accuracy of which was the highest. As a result, the estimated volume from satellite data was the best.

Introduction

With Kyoto Protocol coming into effect, reduction of CO_2 emission is an urgent subject. The report of IPCC was performed last year (2007). The report predicts future global warming. According to this, it predicts that the earth environment of 50 years after will be in a very severe state. As prescribed in Kyoto Protocol Article 3, paragraphs 3 and 4, plantations and forests under management are regarded as carbon stock, and we need to estimate carbon stock fixed by forests in Japan. Usually, the carbon stock fixed by forests is estimated from the timber volume, which is obtained by summing up the values listed in forest registers managed by each prefecture.

However, the volume listed in the forest register often differs greatly from the real volume. The timber volumes listed in the forest registers are calculated using a growth equation for each tree species inputted in a computer. The difference between the timber volumes listed in the forest register and real timber volume in the forests is uncertain until survey. From a result of analyzing the relationship between volume and digital number of the band according to wavelength in the amount of biomasses of LandsatTM Images, the several bands showed the correlation between volume and digital number. On the other hand, the use of high resolution image data is effective for small sized private forest. But, swath wide is 11km. It is difficult to estimate biomasses for wide area .

In this study, therefore, we established a method of estimating timber volume in sugi plantations in Aga-cho using LandsatTM data, and IKONOS images for even-aged area, and estimated the carbon stock in the sugi plantations from the distribution pattern of the timber volume.

Investigation Area and Study Methods

Outline of investigation plots

First, we set up 73 investigation plots within whole Aga-cho area. Second, we set up 45 plots within Torii and Toyomi even-aged forest stand consolidation in Aga-cyo. The Torii forest stand consolidation planted

the Japan cedar of 10ha in 1977 and Toyomi forest in 1976 to 1978 of same Japan cedar stand of 10ha in Aga-cho. Volume's range was from 213m^3/ha to 1372m^3/ha and age's range was from 36 to 81 in case of whole Aga-cho area. In case of Torii and Toyomo, volume's range was from 88m^3/ha to 313m^3/ha. The timber volume was estimated from the measured values, and it was converted to timber volume per ha. For the analysis, timber volume(m^3/ha), sum of section areas at breast height (basal area, m^2/ha), average tree height(m), number of standing trees(number/ha) and tree age(year) were used.

Used image data.

LandsatTM image taken on June 3, 2001 was used. And, IKONOS image taken on May 29, 2002. LandsatTM image resolution was 30m×30m and IKONOS was 4m(color) and 1m(pan).

Correction of position on image and determination of digital number(DN) in each plot.

Easily detectable plots(co-ordinate) on the image were surveyed in the field using the Differential Global Positioning System(DGPS), (Trimble Co., Pathfinder Pro XR) and the position of each plot on the image was corrected. Especially, this method was effect in case of IKONOS. Then the average of DN corresponding to the position of each plot was obtained.

Estimation of timber volume from forest register in Aga-cho

Relationship between timber volume(m^3/ha) and each image of digital number(DN) in each plot was analyzed. We used LandsatTM, and IKONOS images. LandsatTM images are effective for wide area, like whole Niigata Prefecture. On the other, high resolution images are effective to obtain more detailed information for small area. Most of the sugi plantations are smaller than 1 ha. This is the characteristic of private forests in Niigata Prefecture not only in Aga-cho but also in other areas. Timber volume in such a small compartment can not be estimated well using the image with a low resolution. We used average DN with plots. Plot size is 20 m multiplied by 20 m.

Determination of digital number(DN) in the subcompartments corresponding to different plot sizes

Hitherto, timber volume in a district has been estimated from the regression formula between DN on the satellite image and timber volume in the corresponding plot (Ahern et al.1991, Ardo 1992, Gemmell 1995), DN in the plot is the sum of the DN of each pixel included in the subcompartment. We analyzed the relationship between the average DN in the plot and the timber volume in the plot, because the average DN in the plot is considered to reflect the average of tree densities and growth stages of the trees in the plot.

Expression of error

Average errors of timber volume estimated from forest registers and IKONOS, LandsatTM image against the real timber volume in the plot(real value) are shown by root mean square error(RMSE).

$$RMSE=\sqrt{\frac{(real\ value\text{-}estimated\ volume)^2}{N}}$$

Where, N is sample number (number of plots).

In case of even-aged stand in Torii and Toyomi, we showed total volume and volume/ha in forest register, real volume and estimated volume from IKONOS image.

Results of Analysis

Relationship between average DN and timber volume in each plot

Relationship between timber volume and DN band 5 of Landsat in Aga-cho (Kimura 2003). It is shown R^2= -0.58. Relationship between average DN at band 3 of IKONOS and timber volume in Aga-cho area is shown R^2=-0.50 (Abe and Ishida 2004). Relationship between average DN at pan and timber volume in even-aged stand in Torii and Toyomi is shown R^2=0.7(Fig.1). Pan is showed in significant at the 5% level relation between DN and timber volume.

Accuracy of estimation of timber volume RMSE in case of Aga-cho.

The RMSE was calculated for the timber volume estimated from forest registers and LandsatTM, IKONOS images. The result of the RMSE of timber volume estimated from forest registers and each images were shown on table1.

Results from images are a little accurate than forest registers. Thus, it is possible to reduce the estimation error of timber volume by using high resolution im-

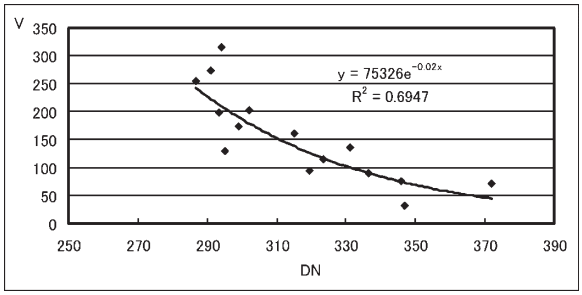

Fig. 1. Relationship between average DN(IKONOS PAN) and Volume

Table 1. RMSE

		RMSE
LANDSAT	219	Forest register 222
IKONOS	220	Forest register 239

ages. On the other hand, total and /ha volume in Torii and Toyomi area were calculated. In this case, forest register is presumed more nearly excessively than an actual value.

Estimation of carbon stock in Aga-cho District

Carbon stock can be estimated by multiplying timber volume by a coefficient(Matsumoto 2001).

Carbon stock =timber volume ×expansion coefficient ×bulk density×rate of carbon

expansion coefficient (1)

; bulk density0.32t/m^3 rate of carbon;0.5

In this study, the volumes of branches, leaves and underground part were not examined. Since we examined the correlation between estimated timber volume and carbon stock, here, we did not multiply the timber volume by expansion coefficient, and calculated carbon stock in timber volume from timber volume × bulk density×rate of carbon.

The average error of timber volume estimated from images were smaller than that estimated from the forest register. Then, the distribution of timber volume in sugi plantations of Aga-cho area were estimated from the DN by equation of each subcompartment. Even-aged carbon stock shows per 20mx20m in Torii and Toyomi(Fig.2.).

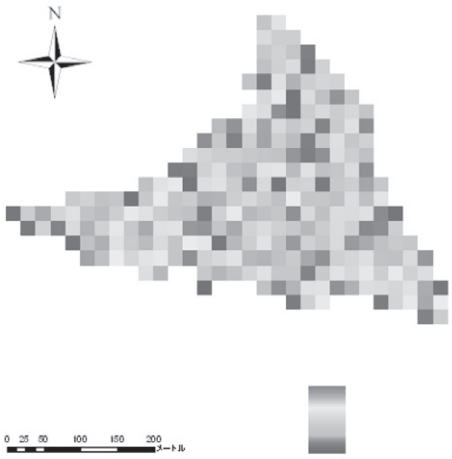

Fig. 2. Carbon stock in even-aged stand in Torii and Toyomi
Dark shows high biomass and light shows small biomass

Discussion

There are many reports on the relationship between DN at various wavelengths of the subcompartment of LandsatTM image and timber volume in the plot, and on what kind of regression formula is applicable to the relationship. Ahern et al. (1991) obtained R^2= 0.808 between DN at band 4 and timber volume in the stands of Picea and Abies in Canada. Ripple et al. (1991) examined the correlation between the timber volume of 25- to 148-year old Douglas fir and DN at band 4(wavelength) and expressed the correlation by exponential equation with R^2=0.704. The maximum timber volume of Ahern et al. (1991) was as low as 250m^3 and that of Ripple et al. (1991) was 800m^3. Gemmel(1995) examined conifer forests mainly composed of Douglas fir(average timber volume 300m^3/ha,maximum 500m^3/ha), and obtained R^2=0.97 for the quadratic equation between DN of LandsatTM image and the timber volume.

For the data of LandsatTM, exponential expression tends to be applied when the timber volume is large. Ardo (1992) reported R=-0.80 between logarithmic function of DN at band 5 and timber volume. Ito (2004) obtained R^2=0.40 between exponential function of DN at band5 and timber volume. Numbers of data are 73, and Ito(2004) divided data into the area and investigated relationship between digital number and timber volume for every area in sugi plantation. These value R^2= 0.37 ~ 0.79 between power function of DN at band 5 by area. Kimura (2003) obtained R^2=0.69,at the maximum, between power function of the timber volume of sugi plantations in Niigata

Prefecture and DN at band 5 of Landsat image. Until now, mentioned above report was the case that the relation between DN at a certain time and a timber volume part factor or the region was narrow.

However, Ito's report (2004) is the example of analysis of change of the data from the Niigata whole region, and a timber volume part factor with Kimura' s report (2003) with time, and the past scene. It means that both relations are significant that regression was materialized between a digital number of band5 and timber volume in the report of both Kimura and Ito. On the other hand, Trotter et al. (1997) obtained only R^2<0.3 between the DN at band 3.4 and timber volume in radiate pine stand. In that stand, the range of tree age was only 21 to 29 years old. In the stand with similar tree age, correlation between DN and timber volume may be low.

The correlation between timber volume and DN at band3(visible spectrum) of high resolution satellite images were expressed by exponential equation, which was different from the correlation between the timber volume and DN in the infrared region of the LandsatTM image. The IKONOS image provides 11-bit information and DN varies from 0 to 2047. Although Puhr and Donoghue (2000) argued that the range of DN is too narrow for the maximum timber volume, it may not be applicable to the estimation in this study. However, DN in this study varied only from 88 to 134, although timber volume in the investigated plots varied from 324 to 913m^3/ha in Aga-cho. In the future, we need to examine what kind of forest factors is effectively examined by 11-bit information, for instance, by examining the stands at different growth stages.

On the other hand, there are no reports on the estimation of timber volume using high-resolution satellite images. Wulder et al.(2000) estimated the basal area using optical sensor loaded on airplane. In that report, however, timber volume was not estimated from the sum of the basal area.

The difference in average DN between the plots with large and small timber volumes may be caused by the difference in crown size and the size of gap among individuals. In the average DN in each plot, information on the individual size and stand densities may be included. Because the aim of this study is to estimate the carbon stock fixed by forests, we analyzed only the relationship between the DN and timber volume.

As prescribed in Kyoto Protocol Article 3, paragraph 4, a forest under sustainable management is evaluated as a carbon stock. The area investigated in this study is a forestry region from old times, and the plantations are pruned and thinned using forest technology. Expression of the forest condition from the size of carbon stock as shown in Fig.2. is expected to be useful and accumulation of such information should justify further the estimation of carbon stock fixed by forests.

Conclusions

LandsatTM images are effective for wide area, like whole Niigata Prefecture. On the other hand, high resolution images are effective to obtain more detailed information for small area. The correlation between timber volume and DN at band 5 of LandsatTM satellite images was expressed by power function from data in Aga-cho area.

On the other hand, high resolution images are effective to obtain more detailed information for small area. Most of the sugi plantations are smaller than 1 ha. This is the characteristic of private forests in Niigata Prefecture not only in Aga-cho area but also in other areas. But, image price is very expensive and swath wide is narrow. The first high-resolution satellite ALOS of Japan was launched in 2006, and, the ALOS Data is cheap and swath wide is 70km. It is expected to provide data for application to forestry.

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Comparison of Wind and Wave Fields between High-Resolution Simulations and Operational Forecast Products: A Case of Wave Development under Easterly Wind Jets in the West of the Tsugaru Strait

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Abstract

We compare high-resolution simulated wave fields with operational wave forecasts under easterly coastal wind jets in the west of the Tsugaru Strait from a case study on 5-9 June 2003. We use a series of numerical simulations by one-way coupling between a mesoscale meteorological model and a shallow-water wave model with high spatiotemporal resolutions of 2 km and 1 hour. The simulated wind fields represent pairs of small-scale wind jets blowing from the coast and their confluence to form a large wind jet. These features are consistent with those revealed by a high-resolution wind field derived from RADARSAT. The wave simulations reflect the features of the wind fields and show localized higher wave regions under the wind jets. At the same time, the simulations show peaks of significant wave height corresponding to each small-scale wind jet. The wave energy spreading from the higher wave region reaches the surrounding coast. On the other hand, the operational forecast products of wind and wave with 10-km resolution reproduce the only main wind jet blowing through the strait and a corresponding high wave region. Wave energy spreading toward the coast and time evolutions of wave development are not represented. This study shows the limitation of the operational forecasts and proposes a required resolution for accurate forecasts of coastal wind and wave.

1. Introduction

Wave simulations with higher spatiotemporal resolution are indispensable for better forecast and hindcast of coastal waves. High spatial resolution simulations can improve the geometry of the coastline and topographical features and reflect detailed features of wind fields (Cavaleri and Bertotti, 2004). Simulations with high temporal resolutions allow us to investigate evolution of wave. Due to the technical improvements and sophisticated algorithm developments, it has been verified that recent wave models have applicability to high-resolution simulations of coastal waves (e.g., Gorman and Neilson, 1999; Wornon et al., 2001; Rogers et al., 2003; Signell et al., 2005; Shimada and Kawamura, 2006; Isoguchi and Kawamura 2007; and Shimada et al. 2008). However, it is still a crucial challenge to obtain wind input whose resolution is comparable to the wave model performance and is high enough to capture the coastal wind variations. In fact, the above-mentioned studies have shown the limit of application of general operational wave products to coastal wave forecasts and hindcasts. Global/regional weather products provided by operational service still generally do not have a spatiotemporal resolution of the models required to accurately forecast coastal wind and wave. At the same time, evaluation of the operational wave forecasts to discuss the limit of their application has not been available yet near the Japanese coast.

Wave development under gap exiting winds is one

of the cases in which high-resolution capability is strongly required for both wind and wave simulations. Thus, we focus on the wave development under the gap exiting winds. We choose an area in the west of the Tsugaru Strait during the warm half-year as a case study (Fig. 1). In June-August, the wind often blows from the Pacific Ocean toward the Tohoku District and Hokkaido, associated with the high-pressure system over the Sea of Okhotsk. This northeasterly/easterly wind usually persists for several days and accompanies cool and wet air, low-level clouds and fogs due to a thin mixed layer and an upper stable layer (e.g., Ninomiya and Mizuno, 1985). The wind is known as Yamase (e.g., Takai et al., 2006). These characteristics of Yamase promote the formation of locally intensified winds (i.e. wind jets) in the terrestrial gaps. Shimada and Kawamura (2007) have mentioned several pairs of strong and weak wind regions in the west of the Tsugaru Strait along the coast of the Japan Sea. However, it is the only study on localized strong winds in this area and detailed distributions of wind and wave have not been described.

This study investigates wind and wave distributions under the easterly wind jets in the west of the Tsugaru Strait from a case study on 5-9 June 2003 and compares wind and wave fields represented by high-resolution simulations and operational mesoscale forecast products. We make use of one-way coupling of a mesoscale meteorological model and a shallow-water wave model with 2-km and 1-hour resolutions in space and time. The case is selected because the easterly winds are persistent during the case study period. Specific questions we would like to address are: 1) What are the structural properties of the strong winds and high waves in the west of the Tsugaru Strait? 2) How much does the resolution difference have an impact of the wind and wave distributions?

This study has the following significances. First, the present study can specify the limit of application of the operational wave product, which is used for public coastal wave forecast. In fact, we point out possible localized high wind and wave for practical use. Enhanced services relevant to sea conditions are required for various field activities over the ocean such as ocean shipping, marine security, and marine disaster prevention. Then, understanding of localized winds leads to the study of coastal ecosystems because wind variations are significantly important for ocean circulation especially in the coastal seas. It

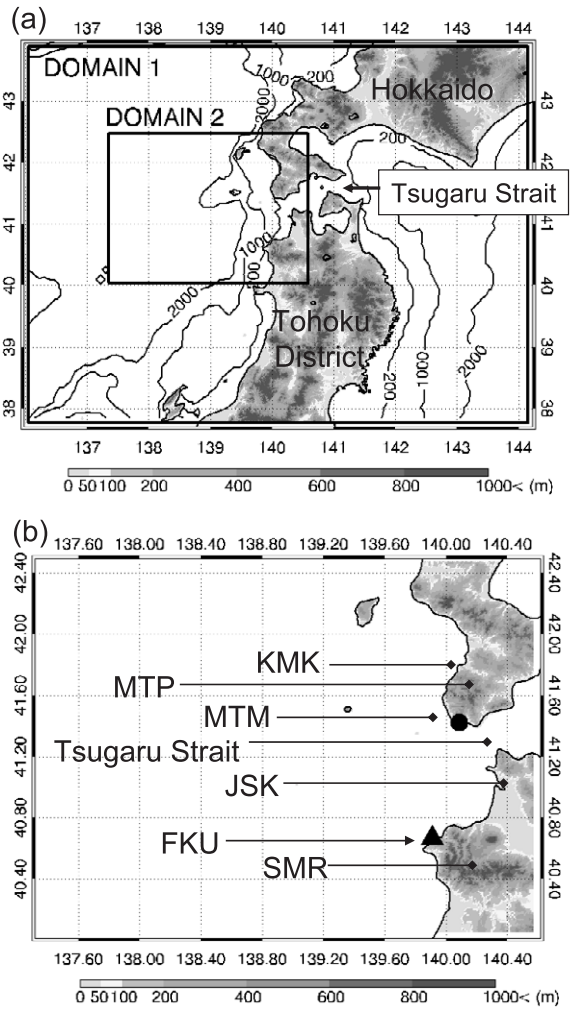

Fig. 1. (a) Map of the topography and geographical locations referred to in this paper. The two MM5 model domains are indicated by the rectangles. The color scale overland, in these figures and others to follow, indicates the terrain elevation. The contours are isobaths of 200, 1000, and 2000 m. The inner domain (Domain 2) of MM5 is also the domain of the SWAN simulation. (b) A closeup of Domain 2. The solid circle indicates an AMeDAS station. The triangle indicates a NOWPHAS wave observation station. Abbreviations are geographical and station names: KMK Kaminokuni; MTP: Matsumae Peninsula; MTM Matsumae; JSK Jyusanko; FKU Fukaura; and SMR Shirakami mountain range.

is verified by satellite observations that the localized strong wind can activate oceanic ecosystems due to the resulting upwelling and mixing (e.g., Hu and Liu, 2003; Samuelsen and O'Brien, 2008). Finally, this study deals with the final stage of the air-sea-land interaction induced by Yamase. A great number of stud-

ies have been made on Yamase because agriculture in the Tohoku District is subject to cool summer damage induced by Yamase and because accompanying cloud and fog influence aviation and marine navigation. However, little attention has been given to the wind after passing through the strait and the resulting wave field.

We give brief data descriptions and model simulation frameworks in the following section. In section 3, we illustrate simulated wind and wave fields to compare with observations and operational products. Section 4 is devoted to summary and concluding remarks.

2. Data and Model

We use two types of Grid Point Value (GPV) data provided by the Japan Meteorological Agency (JMA). One is the 6-hourly objectively analyzed data at a 10-km grid interval produced by Meso-scale Non-hydrostatic Model (MSM) in order to give initial and boundary conditions for meteorological simulations. The other is GPV wave forecast data at a 10-km grid interval in order to compare with the simulated wave field. The GPV wave forecast data are produced by JMA using the GPV MSM wind data, and contain analyzed fields every 12 hours (0000 and 1200 UTC) and forecasts every 6 hours (0600 and 1800 UTC). For meteorological simulation, the daily merged SST maps (Guan and Kawamura, 2004) are averaged to make a constant ocean surface boundary condition. We use the following four datasets to verify the model simulation results. 1) Ocean surface wind vectors observed by SeaWinds/QuikSCAT at 12.5-km resolution. 2) The RADARSAT-derived wind field with a resampled grid interval of 500 m using a scatterometer model function and the polarization ratio conversion factor (Thomson and Beal, 2000) with wind direction from the GPV MSM data. 3) Hourly wind observations at a station overland acquired by automatic observation facilities, called AMeDAS (Automated Meteorological Data Acquisition System) operated by JMA (Fig.1b). 4) Significant wave height (SWH) data recorded every two hours by a wave observation station called NOWPHAS (Fig.1b).

Model simulation efforts in this study are made with the Pennsylvania State University-NCAR (PSU-NCAR) fifth-generation Mesoscale Model MM5 [Grell et al., 1995] and a third generation wave model SWAN (Simulating WAves Nearshore) [Booij et al. 1999; Ris et al. 1999]. Hourly surface wind fields simulated by MM5 are used to drive the SWAN simulation. For MM5 simulation, we define two model domains with grid size of 6- and 2-km as shown in Fig.1a. The inner domain of MM5 is the same with the SWAN model domain. They have a grid spacing of 2 km and an hourly temporal resolution in common. Because this case study satisfies the fetch-limited condition and we focus on only wind-generated waves, incoming waves at the open boundaries of the model domain are assumed to be zero. The SWAN model is run in non-stationary mode. According to the method of Shimada and Kawamura (2008), the result in stationary mode at 0900 UTC 6 June 2003 is used as an initial condition. The MM5 simulation is initialized at 0000 UTC 5 June 2003 and integrated to 0000 UTC 10 June 2003 during 120 hours. The SWAN simulation is initialized at 0900 UTC 6 June 2003 and integrated to 0000 UTC 10 June 2003 during 87 hours. The detail model setups and one-way coupling methodology follow Shimada and Kawamura [2008].

3. Results and Discussion

3.1. Observations of wind jets in the west of the Tsugaru Strait

Between 5 and 9 June 2003, the easterly wind blows persistently toward the Tohoku District and Hokkaido. The MM5 simulation begins on 5 June, when a high-pressure system over the Sea of Okhotsk started to develop and a low-pressure system moved eastward on the southern coast of Japan according to the weather charts (not shown). Then, the center of the high-pressure system moved southward from the Sea of Okhotsk to the southeast side off Hokkaido, accompanying the easterly wind. With the southward movement of the high-pressure system, the easterly wind gradually shifted to the south over the study area (Fig.1a). The end of the MM5 simulation corresponds to this timing. The persistent easterly wind is one of the characteristics of Yamase. The series of wind fields from SeaWinds measurements and their descriptions during the study period are given in Shimada and Kawamura [2007].

We first show that wind jet is captured in wind speed time series of a meteorological station data (Fig. 2), and pinpoint the timing of the focus of this study. Because an AMeDAS station MTM is located at the western exit of the Tsugaru Strait, it is an appropri-

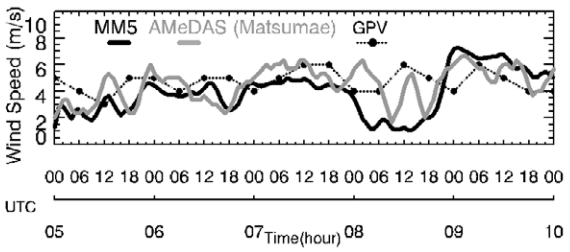

Fig. 2. Hourly time series of wind speeds at station Matsumae (gray) and derived from MM5 (black) at the corresponding grid during 5-9 June 2003. Wind speeds from six hourly GPV data are also plotted (dotted black line with black circles).

ately positioned meteorological station to capture the wind jet event among available stations. While wind speeds are 3-6 m/s before 1800 UTC 8 June, wind speed increases rapidly after that time. The satellite wind observations in Fig. 3 are obtained during the intensification of the wind jet. Hereafter we focus on the wind and wave fields at 1800 UTC 8 June. This is because the wind distributions do not change so much after the onset of the wind jet at 1800 UTC 8 June, and because GPV data available at 1800 UTC 8 June is closest to the observations. The simulated wind speeds by MM5 are also shown in Fig. 2. While the simulated time series underestimate the wind variations during 0000-1800 UTC 8 June, the wind speeds and their variations are generally consistent with the observations. The average difference between the simulated and observed wind speed is -0.61 m/s and the correlation coefficient is 0.62. This supports the validity of the MM5 simulations. Six-hourly wind speeds from the GPV data are also plotted at the corresponding grid. The GPV wind speeds apparently seem to be close to the observations and simulations because of the fluctuations between 4 and 6 m/s. However, it is difficult to say that the GPV wind can well represent the wind variations during the term.

Fig. 3 shows wind fields observed by SeaWinds/QuikSCAT at 12.5-km resolution and derived from RADARSAT at a resampled resolution of 500 m. In the 12.5-km wind field (Fig.3a), we can identify a major wind jet blowing from the western exit of the Tsugaru Strait and a part of a minor wind jet at 42.0 °N/139.2°E. The SeaWinds observations within 20 km of coastlines are not available because of possible land contamination. On the other hand, the wind field

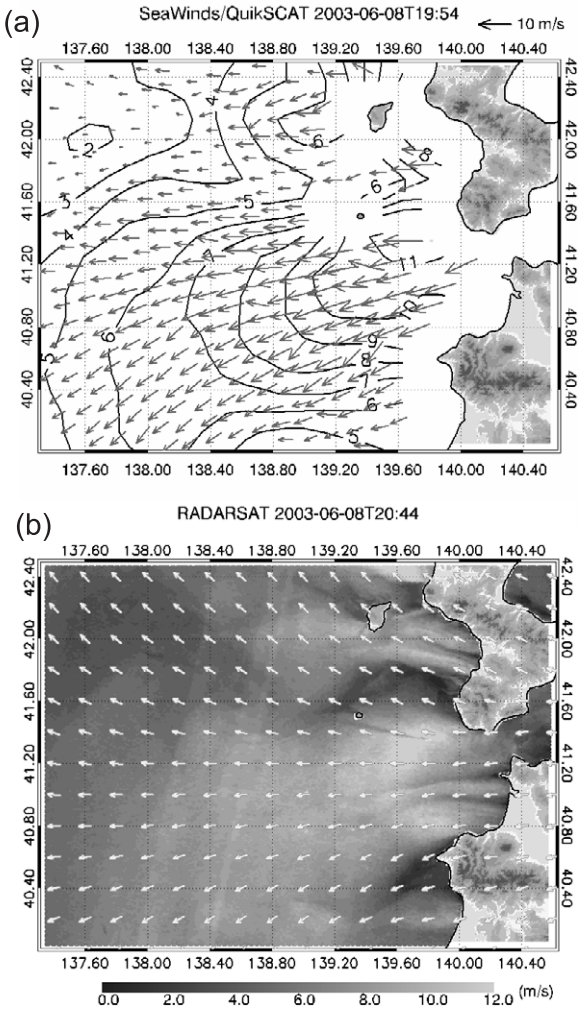

Fig. 3. (a) Ocean surface wind vectors measured by SeaWinds/QuikSCAT at 1954 UTC June 8 2003. The contours indicate wind speed. (b) Wind field derived from RADARSAT at 2044 UTC June 8 2003. The arrows of equal length indicate wind direction extracted from the GPV MSM data.

derived from RADARSAT reveals the detailed structure of winds near the coast. We can see several pairs of strong and adjacent weak wind regions along the coast. It is clearly confirmed that the two wind jets inferred from the SeaWinds observations are composed of a few of small-scale wind jets with several-kilometer width. It is possible to trace weak wind regions between the strong wind jets over the 50-km at least from the coast. The wind maxima are located just after passing through the coastal tips at 41.4° N/139.8°E and 40.8°N/139.8°E. Wind is blocked by the mountainous areas (MTP and SMR) and weak winds are observed in the lee. The wind speeds are much smaller than inferred from the SeaWinds ob-

servations. Comparison of these wind fields makes us to recognize anew that high-resolution capability is indispensable for accurately illustrating wind fields near the coastline. Thus, this RADARSAT-derived wind field serves to evaluate the performance of the wind simulations.

3.2. High-resolution simulated fields of wind and wave

Fig. 4 shows wind and wave fields simulated by MM5 and SWAN at 1800 UTC 8 June 2003. The simulated wind field (Fig. 4a) with a grid interval of 2 km well reproduces the detail structures revealed by the RADARSAT-derived wind field (Fig. 3b). The time difference between them is not important here. This is because the simulated wind distributions change little over the sea surface for the next six hours though the overland wind speed increases rapidly at station MTM (Fig.2) after 1800 UTC 8 June 2003. It is confirmed in Fig. 4a that the small-scale wind jets blowing from the coast merge to form one large wind jet with keeping the weaker wind region between them. While the wind speeds in the lee of the mountainous area (MTP and SMR) are a little smaller than the observations in Fig.3b, the shapes of the distributions of weak winds are quite similar.

The simulated SWH field by SWAN at 1800 UTC 8 June 2003 is shown in Fig.4b. The SWH field reflects the features of the wind field in Fig.4a. We first should note the two peaks of SWH greater than 0.85 m at 40.9°N/139.6°E and 41.2°N/139.6°E. They result from wind jets blowing from the west exit of the Tsugaru Strait and a small terrestrial gap upwind of JSK. While the lower SWH region is can be traced along the weak wind region between the wind jets, the two peaks of SWH merge to form a large high SWH region. The high SWH region extends toward the southwest along the wind direction. Higher waves from the main high wave region reaches the coast near SMR due to wave directional spreading. In the lee of MTP, lower SWH region extends downwind toward the northwest. On the north of it, higher SWH region extend toward the northwest, being partly blocked by the island. We can confirm two peaks of SWH greater than 0.40 m at 41.9°N/139.7°E and 42.0° N/139.7°E, whose locations correspond to the wind jets.

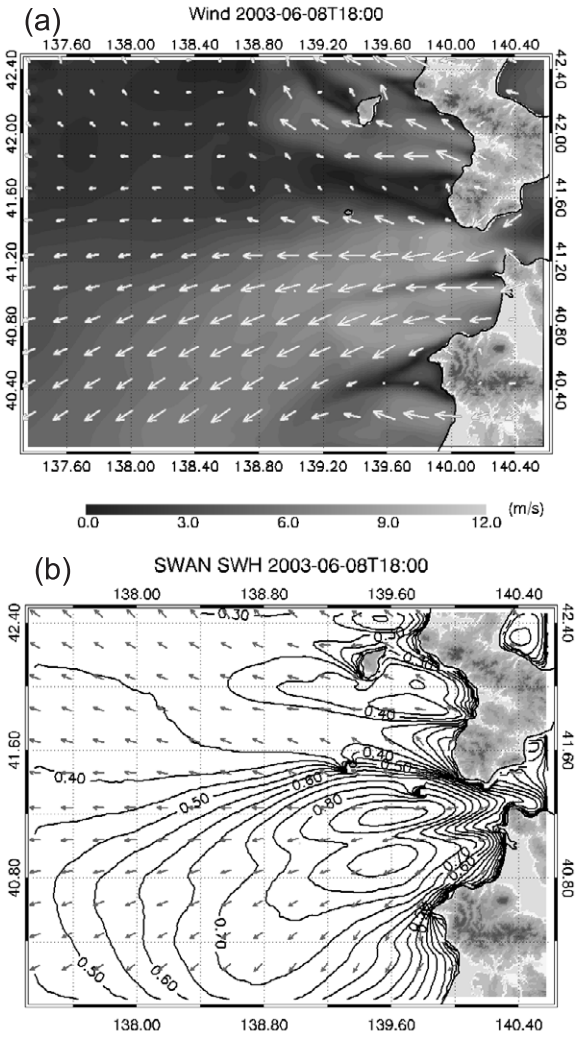

Fig. 4. (a) Simulated wind field by MM5 at 1800 UTC June 8 2003. Grayscale shade indicates wind speed. (b) Simulated significant wave height field by SWAN at 1800 UTC June 8 2003. The arrows of equal length indicate mean wave direction.

3.3. Operational wave forecast field

Fig. 5 shows wind and wave fields from the GPV data at 1800 UTC 8 June 2003. These 10-km fields are the finest-resolution products operated by JMA for daily weather forecast. In the wind field (Fig. 5a), only one wind jet is reproduced in the west of the Tsugaru Strait. While the maximum wind speed is close to that of the observation, the structures of the wind jets are totally different. The location of the wind maximum shifts westward. The wind jets extending from JSK and KMK are not reproduced, and there are no indications of the lower wind regions in the lee of MTP and SMR.

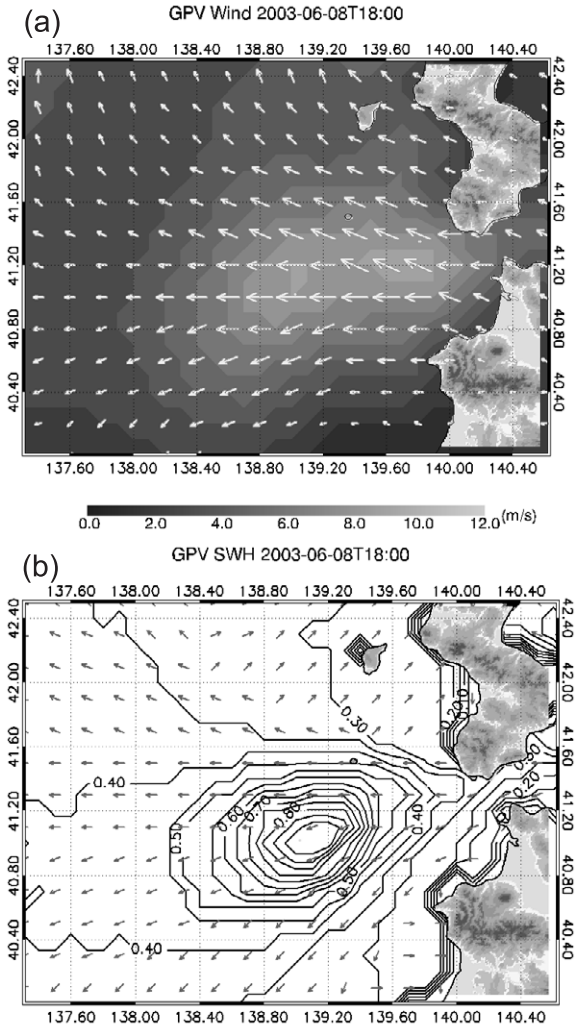

Fig. 5. (a) Wind vector field by GPV MSM at 1800 UTC June 8 2003. Grayscale shade indicates wind speed. (b) Significant wave height field by GPV data at 1800 UTC June 8 2003. The arrows indicate mean wave direction.

Such wind distribution is reflected in the wave field (Fig.5b). While the highest SWH is almost the same with that of the SWAN simulation, the higher wave region is located westward at 41.0°N/139.2°E. Contrary to the SWAN simulation, the two peaks of SWH are not reproduced. The high wave region is localized concentrically and its broadening is too small to reach the coast near station FKU. Consequently, wave development within 30 km of the coastlines is underestimated.

Finally we show in Fig. 6 SWH time series of the observation, the SWAN simulation, and the GPV data. SWH is sampled at a grid corresponding to wave station FKU. While the station is not located downwind on the main axis of the wind jets from

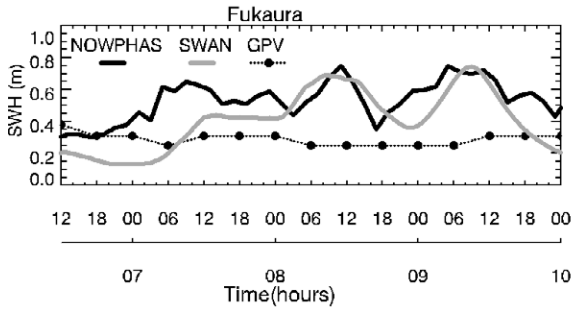

Fig. 6. Two-hourly significant wave height recorded at stations FKU (solid black line) from 1200 UTC June 6 2003 to 0000 UTC June 10 2003. Hourly simulated significant wave heights by SWAN (solid gray line) and GPV data (dotted black line with black circles) at the corresponding point are also shown.

the Tsugaru Strait, the station is expected to observe the waves spreading from the high wave region. The observed SWH generally ranges from 0.5 to 0.7 m during 7-9 June, and shows two peaks at 1100 UTC 8 June and at around 0900 UTC 9 June. While the SWAN simulation underestimates the SWH by 0.1-0.2 m before 0000 UTC 8 June, the simulation result is generally consistent with the observations. Particularly, the simulation is capable of predicting the two SWH peaks. On the other hand, the SWH from the GPV data is almost constant at 0.3 m during the study period. This means that waves near the shore are hardly predicted. In fact, the spreading effect of high waves is not taken into account because the wind jets are not reproduced well (Fig. 5a).

4. Summary and Concluding Remarks

We have compared high-resolution wave simulations and operational wave forecasts under coastal wind jets in the west of the Tsugaru Strait from a case study on 5-9 June 2003. The simulated fields of wind and wave with 2-km and 1-hour spatiotemporal resolutions are compared with operational wave forecasts with 10-km and 6-hourly spatiotemporal resolutions. The following conclusions are obtained.

1) The high-resolution wind field derived from RADARSAT with a 500-m grid interval reveals wind jets blowing from terrestrial gaps. The major wind jet blowing from the Tsugaru Strait merges with small wind jets to form a large wind jet. Merging of wind jets is also observed along the coast of Hokkaido. Wind blocking is seen in the lee of the mountainous areas. Maximum

wind speed differences are up to 8 m/s between the neighboring strong and weak wind regions. These features are well reproduced by the MM5 simulations.

2) The simulated wave fields by SWAN with a grid interval of 2-km well reflect the features of the wind fields. The simulated SWH field represents SWH peaks corresponding to each wind jet and wave blocking in the lee of the islands. The variation of SWH is consistent with observations.

3)Wind forecasts with a 10-km grid interval from the GPV data represent only one localized strong winds in the west of the Tsugaru Strait. While the maximum wind speeds are close to the observations, the distributional shapes of the strong winds are different from those of high-resolution observations and simulations. No other small wind jets can be reproduced. While 10-km wave forecasts represent the localized high wave region, the forecasts do not show two SWH peaks corresponding to the wind jets and wave blocking due to the islands. The GPV wave forecasts have difficulty replicating coastal SWH variation due to the spatiotemporal resolution.

Looking back the results above, we can draw the following conclusions. First, consideration of high-resolution wind fields is an important starting point for accurate wave forecasts. Though we have taken this fact for granted, unpredictable distributions of coastal wind can be revealed by high-resolution observations in some cases. Wave development under a gap exiting wind is one of the cases in which high-resolution capability is strongly required for both wind and wave simulations. For example, alternating strong and weak wind region affect the directional properties of waves [Shimada and Kawamura, 2006]. Then, we have proposed a resolution required to describe winds and wind waves in this study area. Terrestrial gaps with width of 5-15 km can form a wind jet extending over 100 km. A small island can block the wave and leave a long tail of lower wave height. These topographic features must be resolved adequately in the simulations. Finally we should note that monitoring of the wind jet development and high waves is only possible at limited locations. Examination of high-resolution observations and simulations can provide us with a chance to reconsider and improve the configuration and network of observation systems. Understanding of strong winds and severe waves in coastal seas are important not only for studying intense air-sea interaction but also for practical use such as shipping, marine security, and marine disaster prevention. The transmission of such information is becoming more important for the appropriate agencies or communities. Regional forecast is also expected to satisfy the above demands.

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Possibility of Monitoring of Waste Disposal Site Using Satellite Imagery

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Abstract

Waste management is one of the expected applications for satellite imagery. This study investigated the usefulness of monitoring waste on land areas using data from the currently operated earth observation satellites ALOS (Advanced Land Observing Satellite) and Quickbird. The Japanese ALOS has two optical imagers, PRISM and AVNIR-2, and an L-band synthetic aperture radar (PALSAR). Quickbird is a commercial high-resolution satellite that provides submeter-resolution imagery. Surface changes associated with legal and illegal waste disposal were examined using ALOS imagery in Miyagi prefecture, Japan. The results indicate that a landfill site can be identified and temporal changes in the disposal site are clearly evident on PRISM imagery. Pan-sharpend PRISM and AVNIR-2 images are useful for image interpretation. Quickbird has a nominal ground resolution of 0.6 m for panchromatic imagery and 2.4 m for multispectral imagery. The ability to use Quickbird data to identify garbage of different size and material was examined. A junkyard with a size of approximately 6 x 4 m was clearly evident on pan-sharpened images obtained on June 2003. The same junkyard was identified in the image obtained on September 2006, and it had expanded to approximately 10 x 4 m. A target within an area with vegetation was identifiable, but another target of almost the same size in an area with bare soil was difficult to see. A waste-tire dumping site was also used to assess what could be identified from Quickbird data. Spatial resolution improvements, shorter observation intervals, and data-cost reductions could make satellite imagery practically useful in waste monitoring.

1. Introduction

The importance of waste management in environmental control is increasing. Remote sensing is anticipated to be useful in ameliorating this problem, especially in the monitoring of waste disposal sites. Garofalo and Wobber (1974) suggested the usefulness of aerial photographs for solid-waste management and planning. Many studies have demonstrated the effectiveness of applying visual interpretation techniques to airborne data (Ottavianelli *et al* , 2005). For example, Barnaba *et al*. (1991) described a procedure for performing comprehensive inventories of waste disposal sites over country-sized areas on Suffolk county (New York, United States) based on historical aerial photographs. Folkard and Cummins (1998) used airborne hyperspectral data to monitor soil contamination, particularly around landfill sites. The usefulness of spaceborne data has also been evaluated. Phillipson *et al*. (1988) tested the suitability of SPOT satellite images for monitoring land-cover changes that could be significant in investigations of landfills. Brivio *et al*. (1993) applied the spatial autocorrelation method to Landsat TM data, and concluded that it appears to be an effective tool for producing an inventory and assessment of waste-disposal sites. The potential of spaceborne synthetic aperture radar (SAR) remote sensing and SAR interferometric processing for detecting landfill sites was evaluated by Ottavianelli *et al*. (2006). These studies have shown that the usefulness of remote sensing data in waste management depends on sensor parameters, including the spectral, spatial, and temporal resolutions. However, ambiguity in the results by image spatial and spectral dimensions has been pointed out.

The possibility of using remote sensing data to de-

tect illegal dumping has also been discussed. Tomiyama *et al*. (2005) assessed the capability of detecting illegal waste dumping sites using airborne SAR data. A method that uses IKONOS satellite data and GIS (Geographic Information System) data to identify unknown landfills over large areas was validated by Silvestri and Omri (2008).

The present study investigated the applicability of recently launched satellite sensors to waste management. ALOS (Advanced Land Observing Satellite) is a Japanese satellite launched in 2006 that has three sensors: PRISM (Panchromatic Remote-sensing Instrument for Stereo Mapping), AVNIR-2 (Advanced Visible and Near Infrared Radiometer type 2), and PALSAR (Phased Array type L-band Synthetic Aperture Radar). PRISM is a panchromatic sensor that can observe the earth surface from three directions to generate a digital surface model. Its spatial resolution is 2.5 m on nadir viewing. AVNIR-2 is a multispectral optical sensor with a spatial resolution of 10m. PALSAR is a SAR with a range resolution of about 10 m on fine-mode imagery. Quickbird is an American commercial high-resolution satellite launched in 2001 that has sensors that acquire 0.61m panchromatic and 2.44m four-band multispectral images. The usefulness of using ALOS imagery to monitor known waste disposal sites and Quickbird imagery to identity illegal dumping were examined. The goal of this research was to clarify the usefulness and limitations of detecting surface changes in Japanese waste disposal sites by visual interpretation of images obtained by currently operated satellites.

2. ALOS Data Sets

2.1. Study Area and Test Sites

Public and private waste disposal sites in Miyagi prefecture, Japan, were the focus of this study. Thirty public waste disposal sites were managed by the local government of Miyagi prefecture as at 1 October 2007 (Miyagi prefecture, 2008). The Ishidumori landfill site was selected as a target site. This is the largest public waste disposal site in Miyagi prefecture, and is located in Tomiya-cho (north of Sendai city) and has a total landfill capacity of 6,412,000 cubic m. The site has a total area of 800,000 sq m and a landfill area of 348,400 sq m. The landfill operation started in 1986 and will finish in 2011. The main landfill material is ash from incineration factories. Other disposal sites, such as the Morisato landfill site and Otsurusawa waste disposal site, were also examined. The Morisato landfill site (whose landfill operations have ended) is located in Rifu-cho, north of Sendai city. The Otsurusawa waste disposal site is located in Taiwa-cho and is managed by Miyagi Environment Public Corporation. The Morisato landfill site is about 1 km from the Otsurusawa waste disposal site. The local government monitors private disposal sites, and the sites of interest in this research included several private disposal sites with known locations.

2.2. Data and Analysis

ALOS PRISM, AVNIR-2 and PALSAR data were analyzed in this study. The observation dates were 28 December 2006, 1 March 2007, 15 November 2007, and 2 July 2008 for PRISM data, and 26 November 2006, 25 December 2006 and 1 March 2007, 15 November 2007, 17 May 2008, and 2 July 2008 for AVNIR-2 data. Pan-sharpend images of the target area were generated from PRISM and AVNIR-2 data. Assuming that the surface of the target area was almost the same over a 3-days period, PRISM and AVNIR-2 data sets with an observation interval of three days were pan-sharpened. Targets in the obtained images were identified.

PALSAR fine-mode intensity images acquired between June 2006 and August 2007 were also examined. Their polarization was HH, and the observation off-nadir angles were 21.5°, 34.3°, 41.5°, and 50.8°. Both ascending and descending data were examined.

2.3. Results and Discussion

Obvious changes in land surface were identified at the Ishidumori landfill site and interpreted from obtained PRISM images (Fig.1). For example, progressing landfill was evident in the south part of landfill sites within circle A in the figure. Objects were evident on the ground in December 2006 within circle B, and this had disappeared in November 2007. The area within circle C was covered by vegetation in November 2007 but appeared to be open ground with a supply road appearing in the image obtained in July 2008. These surface changes could be identified on PRISM imagery; however, pan-sharpend imagery is much more helpful for extracting surface changes by visual interpretation, especially in areas with vegetation. It is necessary to consider how the radiance differs with time and season in each observation, be-

cause the radiance is affected by the transmittance and the solar zenith angle (Iikura and Yokoyama, 1999). Only seasonal vegetation changes were identified at the Morisato landfill site. Several surface changes were found at the Otsurusawa waste disposal site, but none were obvious at the Ishidumori landfill site.

It was impossible to identify land-surface changes at waste disposal sites from the visual interpretation of PALSAR intensity images. Features of the landfill sites were hidden by speckle pattern, with only containers on private waste disposal site being distinguishable because they cause double-bounce.

3. Quickbird Data Sets

3.1. Test Site and Data

The usefulness of Quickbird imagery for detecting illegal dumping was examined on the Taihaku campus of Miyagi University, Sendai city. Panchromatic and multispectral Quickbird data acquired on 21 September 2006 with an off-nadir angle of 19° and on 5 June 2003 with an off-nadir angle of 23° were analyzed. Several buildings had been reconstructed between 2005 and 2007 in the study area. Garbage on the campus represented targets for verifying whether identification was possible. Ground-based

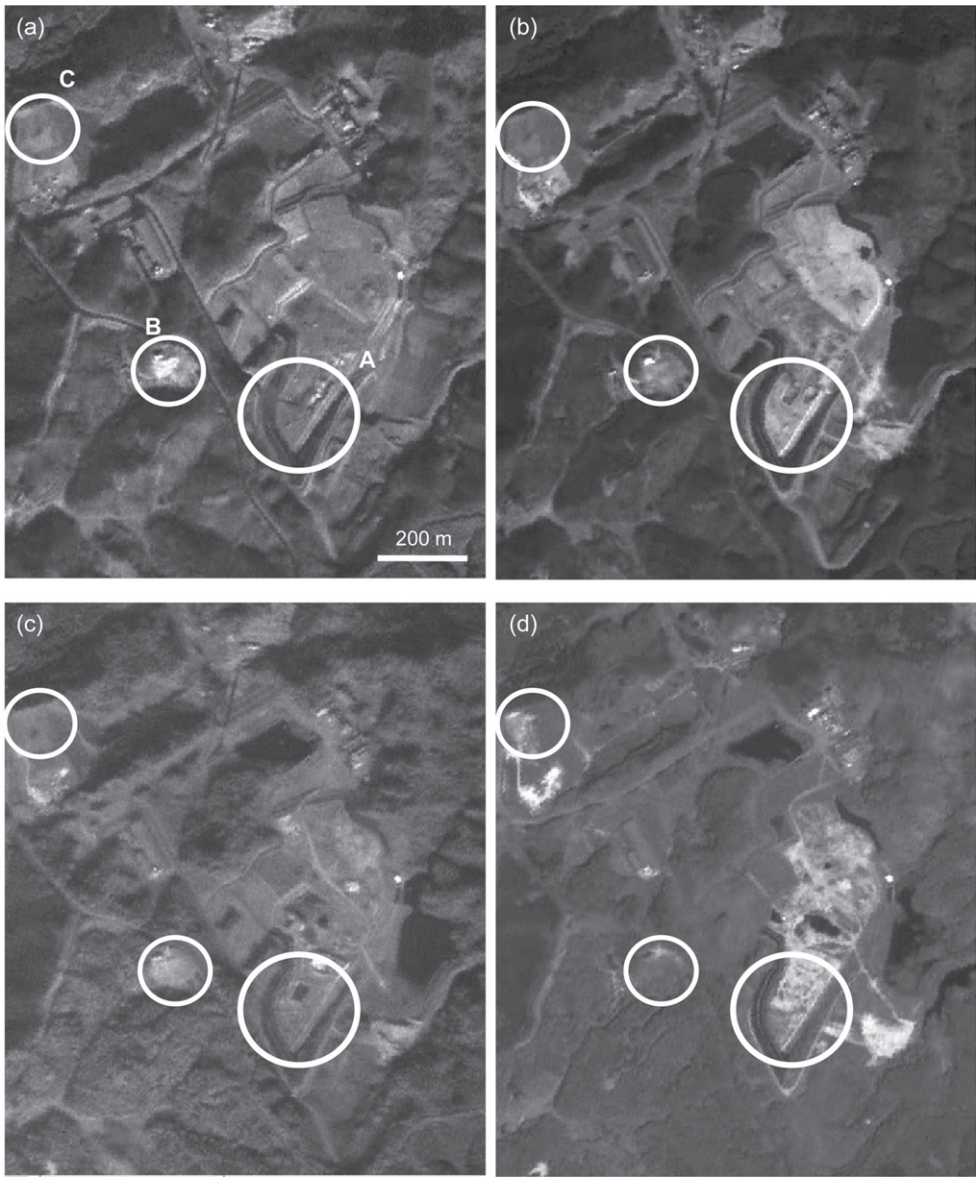

Fig. 1. ALOS PRISM imagery acquired with nadir viewing of the Ishidumori landfill, Miyagi prefecture on 28 December 2006 (a), 1 March 2007 (b), 15 November 2007 (c), and 2 July 2008 (d). Circles show the areas where temporal change were identified. (PRISM images are shown here due to the journal not including color pages.)

observations were carried out on 25 September 2006, which confirmed the presence of derelict concrete, iron, paper, plastic objects, and a junkyard with a size of approximately 10 x 4 m (Fig.2).

The Nakaniida area of Kami-cho, Miyagi prefecture, was also investigated, which contained a private waste-tire dumping site occupying about 1,200 sq m. This was used to assess what could be identified from Quickbird data obtained on 5 August 2005. Pan-sharpened images were generated from panchromatic and multispectral data.

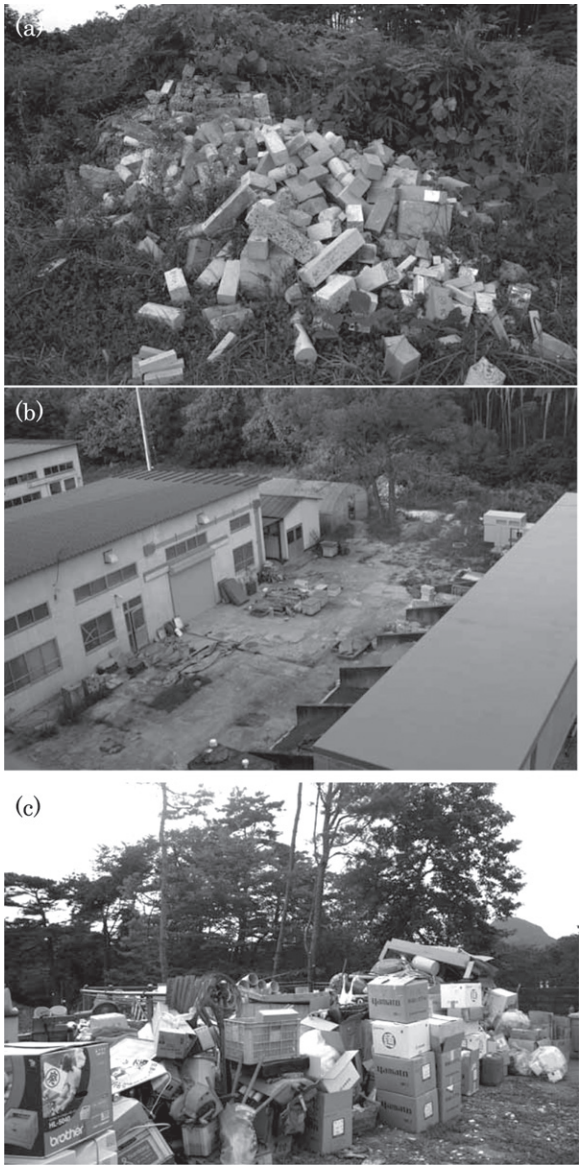

Fig. 2. Garbage on Taihaku campus, Miyagi University, observed on 25 September 2006 by ground based observations. Scrap concrete (a), iron and plastic lying on bare soil (b), and a junkyard (c).

3.2. Results and Discussion

3.2.1. Garbage on Taihaku Campus

Scrap concrete larger than approximately 2 x 2 m could be identified in the area with vegetation on Quickbird pan-sharpend images, as shown in Fig.2 (a). This target could also be identified on panchromatic images (Fig.3 (a)), but multispectral information greatly helped to distinguish between concrete and vegetation due to their differing spectral characteristics. It was difficult to identify scrap iron and plastic with a size of approximately 2 x 2 m lying on bare soil (Fig.2 (b)) in either panchromatic or pan-sharpend images. Plastic, concrete, and bare soil generally exhibit high reflectance. A junkyard with a size of approximately 4 x 10 m was identifiable

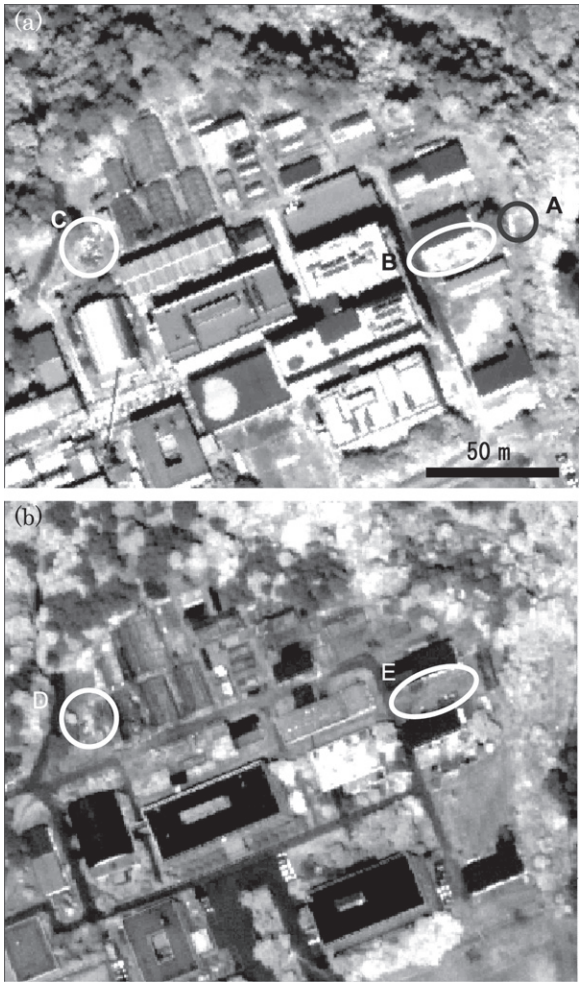

Fig. 3. Quickbird panchromatic images of Taihaku campus, Miyagi University obtained on 21 September 2006 (a) and 5 June 2003 (b). Areas labeled “A”, “B” and “C” correspond to Fig.2 (a), (b) and (c), respectively. Areas labeled “D” and “E” are described in the main text.

on both panchromatic and pan-sharpened images, as shown in Fig.2 (c). This junkyard was surrounded by vegetation, and it appeared as an area with a high reflectance and inhomogeneous texture in panchromatic images. Multispectral information facilitates discrimination between garbage (paper, plastic, and iron) and vegetation. This area was identifiable as a junkyard on images acquired on 5 June 2003, as shown by circle D in Fig.3 (b), and had an estimated size of approximately 4 x 6 m. Garbage or other subjects were thought to be present on the ground within ellipse E in Fig.3 (b).

Quickbird is the currently operated civilian satellite that provides the highest resolution ground imagery, and allows approximately 2 x 2 m of garbage surrounded by vegetation to be identified. Although actual field information is necessary for detailed image interpretation, it is possible to assume the presence of garbage and its extent if the underlying circumstances are known.

3.2.2. Waste-Tire Dumping Site in Kami-cho

The private waste-tire dumping site in Kami-cho was large enough to identify from Quickbird panchromatic and multi-spectral imagery (Fig.4). It appeared as a dark and smooth area on panchromatic images, and with a relatively low reflectance area on bands 1 to 4 in multispectral images. The mean values for extracted typical area on land representing waste tires, water, forest, agricultural field, buildings, and soil in each band are plotted in Fig.5. The waste-tire area looks similar to water except in the near-infrared area (band 4), where its value is higher than that of water.

Fig. 4. Quickbird panchromatic imagery on a part of Kami-cho, Miyagi prefecture. The circle shows a private waste-tire dumping site.

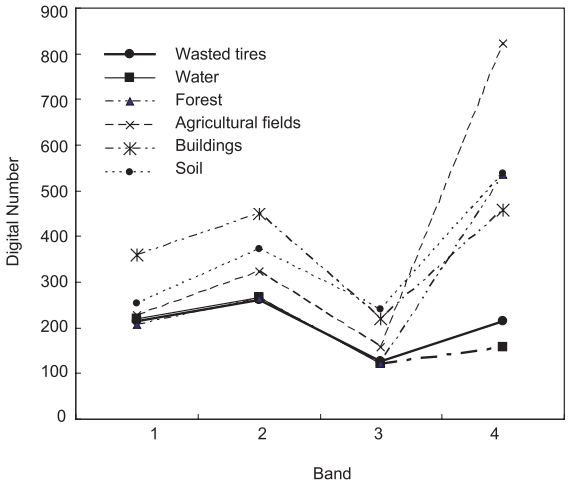

Fig. 5. Plots of mean digital numbers in extracted area from representing waste tires, water (pond), forest, agricultural fields, buildings, and soil for band 1, 2, 3 and 4 of multispectral Quickbird imagery.

4. Conclusion

Waste management is an important task for local governments in Japan, which administer waste disposal sites and landfills to ensure that they operate appropriately, and also monitors illegal dumping. Satellite imagery can be used to monitor the usage and extent of private and illegal dumping sites that have already been identified. Visual interpretation of satellite data is a practical method for local governments to manage waste disposal sites, with spectral characteristics of satellite data being useful for identifying the illegal dumping of waste. One of the problems is discriminating between materials with similar spectral characteristics. The practical application of satellite imagery to waste monitoring requires improvements to sensor spatial resolutions, shorter observation intervals, and reductions in the cost of data.

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Investigation of Possibility Using PALSAR to Monitor Changes in Rice Paddy Fields

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Abstract

Rice is a staple food in Asia, and production may vary within and among countries or regions. Therefore, monitoring of rice planted areas is important and an unfailing and timely method is needed. Synthetic Aperture Radar (SAR) is expected for paddy fields observation because SAR can observe all weather conditions. In 2006, the JAXA launched the ALOS/PALSAR that is the world's first L-band multi polarimetric satellite based SAR. The purpose of the research is to clarify the problem and effectiveness of ALOS/PALSAR when used to observe rice paddy fields over a large area. The study was carried out in Tsukuba and surrounding areas, Ibaraki Prefecture, Japan. PALSAR data were collected for 11 different periods in 2007 from before transplanting until harvesting all the paddy fields. In this study, ALOS/PALSAR images were compared with ground truth data. As results, in this time, it is difficult to easily distinguish water-filled paddy fields from non-water-filled paddy or other fields based on the differences in backscatter coefficient values in ALOS/PALSAR images. Therefore ALOS/PALSAR data are difficult to use determination of the rice planted area. In addition, the data show that it is difficult to evaluate growth of rice from ALOS/PALSAR backscatter coefficients. At the same time, the data indicate the importance of selecting uniform data sources when performing time series analysis using ALOS/PALSAR data.

1. Introduction

In agricultural areas, changes on the ground surface may be rapid and more dynamic than those in forests. Farm products may be harvested within a few months or less than a year. Therefore, it is important that timely and periodic observations be carried out in agricultural areas. When using optical sensors, because they are influenced by weather, the availability of timely observations may be difficult. On the other hand, Synthetic Aperture Radar (SAR) can observe rainy and cloudy weather, and is capable of producing timely observations of agricultural land. Thus, both periodic and timely observations can be obtained through satellites SAR remote sensing.

Rice is a staple food in Asia, and production may vary within and among countries or regions. Therefore, monitoring of rice planted areas is important and an unfailing and timely method is needed. Satellite based SAR is useful for monitoring rice production because it can provide timely and periodic observations, even during the Asian monsoon season.

Until date, there have been many studies carried out using SAR to monitor rice paddy fields (Kurosu *et al*., 1995; Le Toan *et al*., 1997; Ogawa *et al*., 1998; Okamoto and Kawashima, 1999; Ribbes and Le Toan, 1999; Ishitsuka *et al*., 2001; Shao *et al*., 2001; Li *et al*., 2003; Ishitsuka *et al*, 2003). Most of the research has used C-band SAR, for example the Canadian RADARSAT Earth observation satellite project or the European Space Agency's ERS system. In addition, a small amount of research has been carried out using L-band SAR, provided by aircraft based AIRSAR, Japan's JERS-1, and Pi-SAR systems, as well as NASA's shuttle based SIR system (Miranda et al., 1996; Ferrazzoli *et al*., 1997; Rosenqvist, 1999; Lee *et al*., 2001; Ishitsuka *et al*, 2002, Ishitsuka *et al*, 2004). In 2006, the Japan Aerospace Exploration Agency (JAXA) launched the Advanced Land Observing Satellite (ALOS). ALOS has a Phased Array type L-band Synthetic Aperture Radar (PALSAR)

that can observe using multiple polarizations. ALOS/PALSAR is the world's first L-band multipolarimetric satellite based SAR system. Here, I report on the problem and effectiveness of ALOS/PALSAR when used to observe rice paddy fields over a large area.

2. Materials and Method

2. 1. Study Area

The study was carried out in Tsukuba (36° 01' 57" North, 140° 04' 38" East) and surrounding areas, Ibaraki Prefecture, Japan (Fig.1). This region has one of the major mountains of the Kanto region, Mt. Tsukuba, in the north, and the second largest lake in the country, Kasumigaura, in the east. The rivers are running through the area from north to south (such as Kokai River, Sakura River, East and West Yata Rivers). The area has a flat geographical feature called the Tsukuba-Inashiki Plateau, 20-30m above sea level, which is covered with Kanto Loam Layer. Land-use is combined with urban, woods, and fields including paddy fields. The annual average temperature is mild, 13.7 degree Celsius (1995). The annual average rainfall between 1992 and 1996 was 1342.1 mm. (Tsukuba city hall, 2006)

2. 2. Data used

PALSAR data were collected for 11 different periods from before transplanting until harvesting all the paddy fields (Table 1). The first image was taken before paddy field puddling and leveling, a time when paddy fields are not filled with water. In the last 2 images, most of the paddy fields had been harvested. Therefore, there were 8 ALOS/PALSAR images showing conditions when rice plants were present on the paddy fields. Unfortunately, 4 of those 8 images only provide single polarization data. Multipolarization data are available for the remaining 4 images, and moreover, full polarimetric data are only present in one of those four.

The satellite images were geometrically corrected using polynomial regression with ground control points (GCP) chosen from Digital Map 25000 (Geographical Survey Institute, Tsukuba, Japan). The study area was relatively flat; therefore no orthogonal corrections were applied.

σ^0 was calculated using equation (1) (Shimada *et al*., 2007)

$$\sigma^0 = 10 \bullet \log_{10}(DN^2) + CF \qquad (1)$$

where DN is a digital number and CF is a calibration factor. In these digital PALSAR images, CF is read from the header file, CF= -83

Digital image processing was carried out using the software IMAGINE (ESRI Corp., Redlands, CA, USA) and TNTmips (MicroImages Inc., Lincoln, NE, USA).

2. 3. Methods

ALOS/PALSAR images were compared with ground truth data. Field surveys were carried out periodically from May to September. Rice height was measured, and paddy field conditions were recorded with a GPS camera.

An initial question was whether ALOS/PALSAR

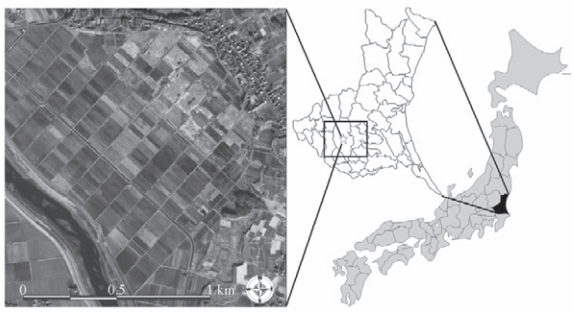

Fig. 1. Study Area
The painted part by black is Ibaraki Prefecture. Rectangle shows coverage of Fig. 3. ☆ located in field survey point. Left image is around field survey area observed by IKONOS on January 17th 2001

Table 1. Collected PALSAR data

	Orbit	Polarization
19-Apr-07	Ascending	Full
11-May-07	Ascending	Single
04-Jun-07	Ascending	Full
26-Jun-07	Ascending	Dual
14-Jul-07	Descending	Single
31-Jul-07	Descending	Single
11-Aug-07	Ascending	Dual
29-Aug-07	Descending	Single
15-Sep-07	Descending	Dual
26-Sep-07	Ascending	Dual
14-Oct-07	Descending	Dual

Full: VV+VH+HV+HH
Dual: HH+HV
Single: HH

could specifically detect only areas filled with water. Most studies of paddy fields using SAR, have incorporated specular reflection on water surfaces to detect water bodies and water-filled paddy fields. Fig. 2 shows an example of the basic principal from Ishitsuka *et al*. (2003). If ALOS/PALSAR is not possible to detect water, it is difficult to extract water-filled paddy fields. Thus, we tested whether ALOS/PALSAR detects water surfaces.

The second part of my investigation was to determine whether ALOS/PALSAR could detect rice growth. If ALOS/PALSAR could effectively detected rice growth, as well as water-filled paddy fields, it would be useful for monitoring rice production over large areas.

3. Results and Discussion

3. 1. Detection of water-filled paddy fields

Fig. 3 shows the ALOS/PALSAR image of the study area taken on May 11th, 2007. Most paddy fields had finished puddling and leveling, and transplanting of rice was underway on that date. Dark areas from the north to the south, in the image, appear like a stripe along the left of the figure, and similar dark areas are seen in the upper-central to right side of the image. These are locations of major paddy fields in this region, and the image suggests that specular reflection of water has been detected from these rice paddy fields. In the image taken on May 11th, 2007, the portions that appear like a thin dark stripe in a bright gray area are "yatsuda" agricultural area along a valley (Fig. 3 upper right).

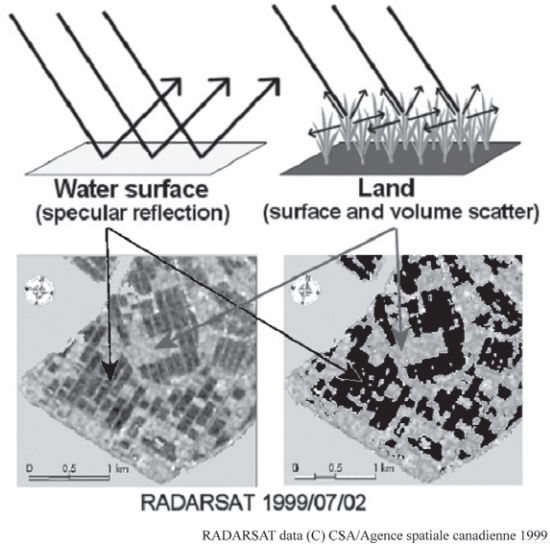

Fig. 2. Basic principal of detecting water-filled paddy fields

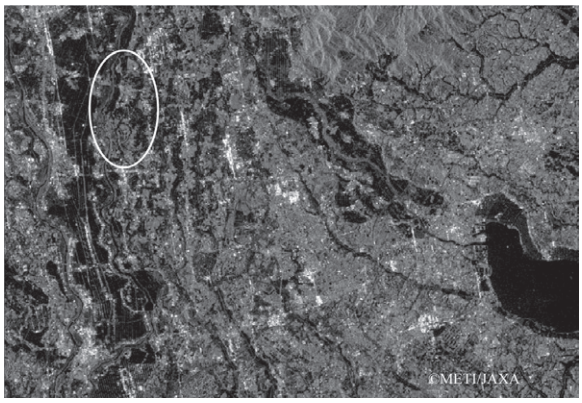

Fig. 3. PALSAR Image (May 11th 2007)

It is known that darkness in SAR images may indicate specular reflection from water surfaces (Iisaka, 1998; Ouchi, 2004). On the other hand, image portions that appear bright white or gray indicate urban or forest areas. However, all parts that appear dark are not rice paddy fields (areas circled in Fig. 3). This region has many turf fields and such waterless fields may appear dark. Thus, it is difficult to distinguish those turf fields from water-filled paddy fields. The reason for this difficulty is that L-band SAR may consider a surface to be smooth even if somewhat rough. This is because of the wavelength of the L-band, which is longer than that of the C-band. In concrete terms, the convexo-concave of turf field surfaces is typically small and is usually accepted as smooth using the Rayleigh criterion, equation (2), which may be used as an indicator of surface roughness.

$$\sigma_h << \lambda/(8\cos\theta) \qquad (2)$$

where σ_h is the surface roughness, defined as the root-mean-square height relative to a perfectly smooth surface, λ is the wavelength of the SAR and θ is the angle of incidence.

Therefore turf field roughness is not markedly different from water-filled paddy fields, both may appear dark.

Similar results have been obtained in another area. Ishitsuka and Saito (2007), reported that it was difficult to clearly distinguish paddy fields filled with water, from fields during puddling and leveling operations, or from wheat fields. These difficulties were related to similarities in ALOS/PALSAR backscatter coefficient values for those area types. Therefore, it appears that ALOS/PALSAR has difficulty, specifically distinguishing water-filled paddy fields.

Polarimetric observation is an important character of ALOS/PALSAR. I studied only using single HH

polarization until here, and I consider the other polarization images have possibility different from HH polarization. Images taken on April 19th, 2007 and June 4th, 2007 that observed full polarimetric data were compared. Figs. 4 and 5 show examples of enlarged image areas around rice paddy fields in VH, HH, and VV polarization. Images observed on April 19th, 2007 are shown on the left side, whereas those observed on June 4th, 2007 are seen on the right. Only VH polarization shows cross polarization because it is able to consider HV and VH polarization as the same. On April 19th, 2007, most paddy fields were not water-filled; however, there were a few paddy fields that had started water filling or were undergoing puddling and leveling. On June 4th, 2007, all paddy fields had already finished transplanting. Therefore ground surface of the paddy fields had changed from bare to water drastically.

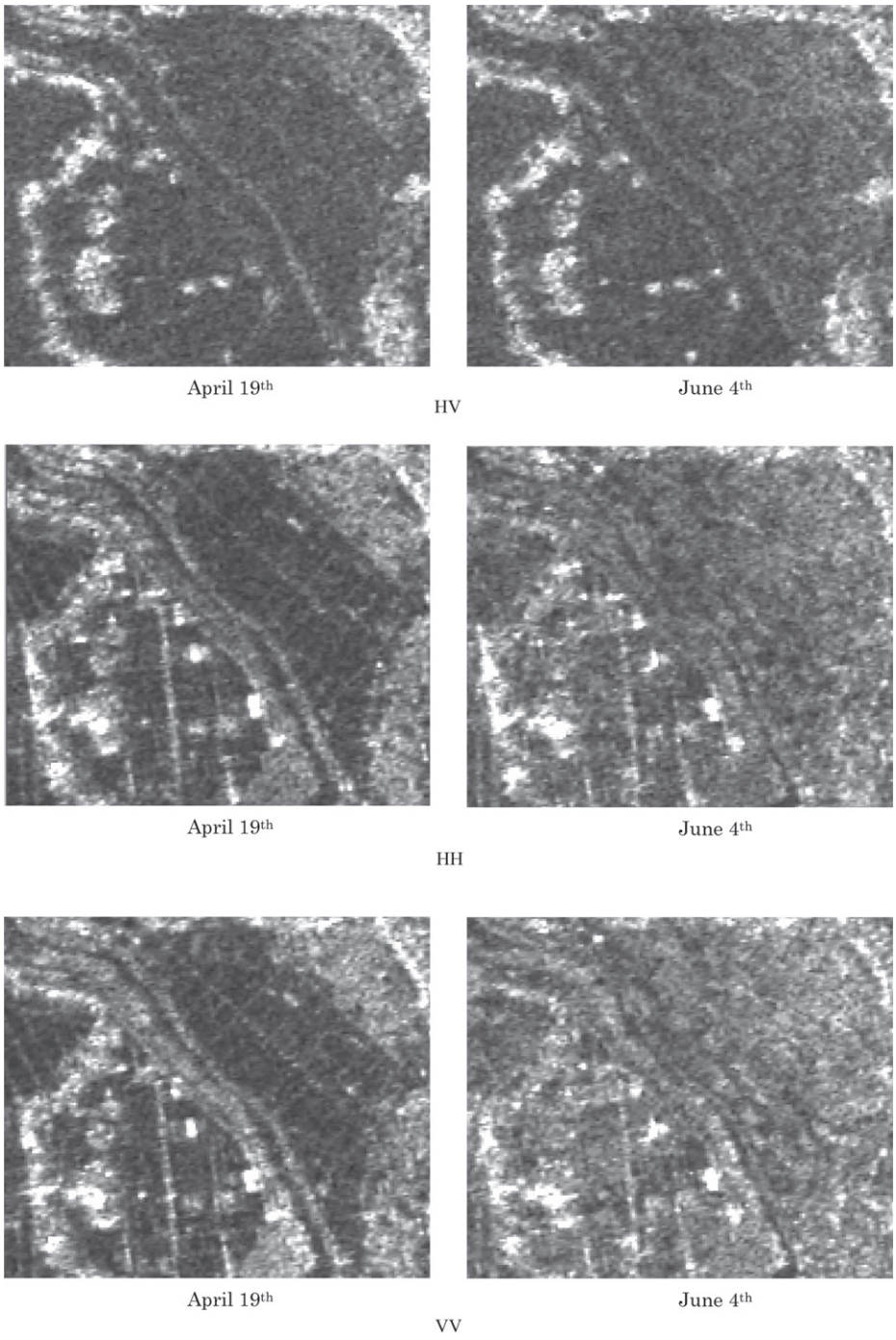

Fig. 4. Comparison of image observed on April19th 2007 with June 4th 2007
-Examples that the water-filled paddy fields can distinguish other fields comparatively-

Fig. 4 shows examples that water-filled paddy fields can be distinguished from other fields comparatively. In the HV images, there was no marked change between two periods. HV is a form of cross polarization that is appropriate for volume scattering (Iisaka, 1998; Ouchi, 2004). The data suggest that there was no substantial change in the volume of the plant body though the change in the surface was dramatic. In HH and VV images, the water-filled paddy fields can be identified because those fields changed to dark. However, some fields were not able to be detected the change because the fields already look dark in the April image. In addition, the change of the backscatter coefficient in VV polarization between two periods was greater than that in HH polarization.

Fig. 5 shows examples that it was difficult to distinguish between water-filled paddy fields and other fields. In HV images, there is hardly a difference in the two

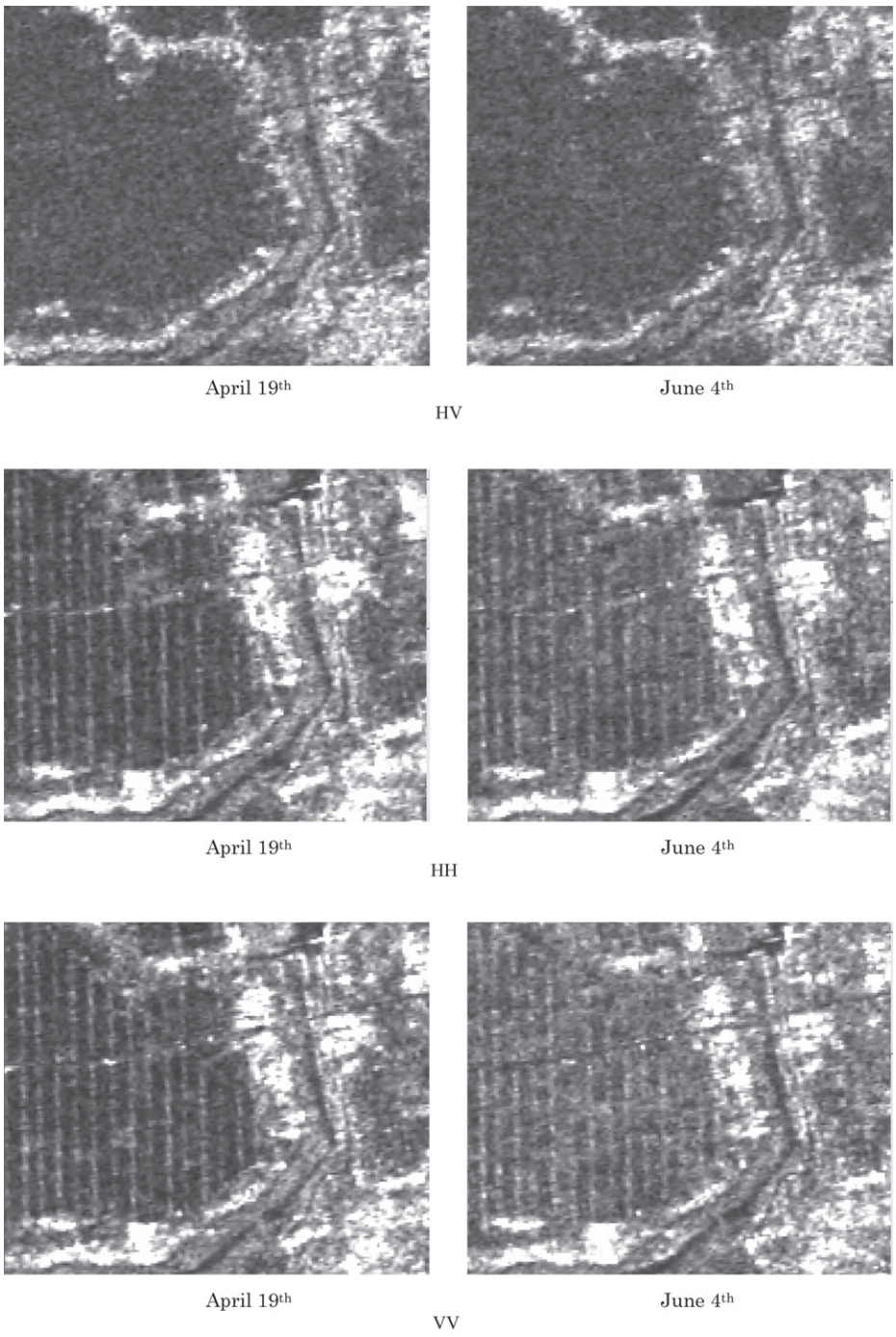

Fig. 5. Comparison of image observed on April19th 2007 with June 4th 2007
-Examples that the water-filled paddy fields can not distinguish other fields clearly-

periods images. In HH and VV images, the paddy fields are seen to change only slightly. However, there were many paddy fields with no or little change between two periods. Also in this comparison, the change in the VV polarization between the two periods was greater than that in the HH polarization. It is considered that there may be a difference of convexo-concave or soil moisture in paddy fields. The data also suggest that VV polarization may be more effective than HH in detecting water-filled paddy fields.

In summary, with conventional methods, ALOS/PALSAR data are difficult to use determination of the rice planted area because it is difficult to ensure accurate distinction of water-filled and non-filled paddy fields.

3. 2. Comparison of rice growth

Here, I compare the growth of rice with the backscatter coefficients values in a temporal series of ALOS/PALSAR images. Fig. 6 shows time series changes in backscatter coefficients (dB) in HH polarization images. These backscatter coefficients values represent averages from several paddy fields; in addition, maximum and minimum values are also presented.

On first glance, the pattern in Fig. 6 appears random and there is no obvious relationship with rice growth. However, in Fig. 6, indicated "A" is the ascending, "D" is descending, it seems to be related to satellite orbit. Therefore, I selected ascending data only and, because they were at a different resolution, excluded the full polarimetric data. Using those data restrictions, Fig. 7 was created. It shows a temporal change of backscatter coefficient in the ascending HH images that appears to be related to the height of rice as measured during ground truthing. The relationship' s initial appearance of randomness decreased and the fluctuations decreased. This indicates the importance of selecting uniform data sources when performing time series analysis using ALOS/PALSAR data.

In the Fig. 7, it seems both values increased, and that suggesting a good relationship between backscatter coefficients and rice growth. However, the backscatter coefficients increase was less than 3dB and the backscatter coefficients variance was larger than 3dB. Thus, it is difficult to evaluate growth of rice from ALOS/PALSAR backscatter coefficients.

When evaluating the biomass of rice from backscatter coefficients, HV polarization was considered suitable because cross polarization reflects volumetric

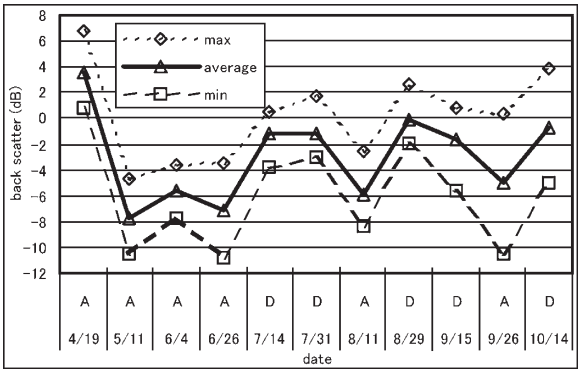

Fig. 6. Time series change of backscatter coefficient

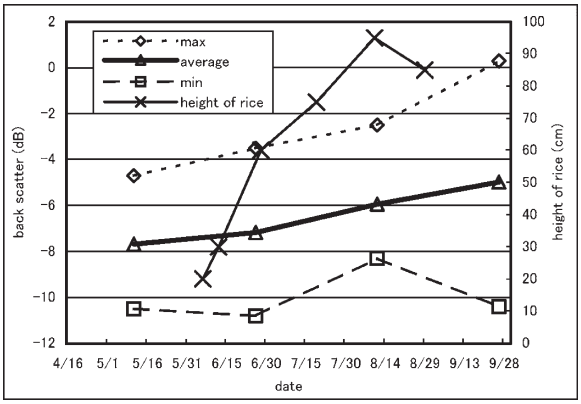

Fig. 7. Time series change of backscatter coefficient only in ascending HH images same spatial resolution and height of rice

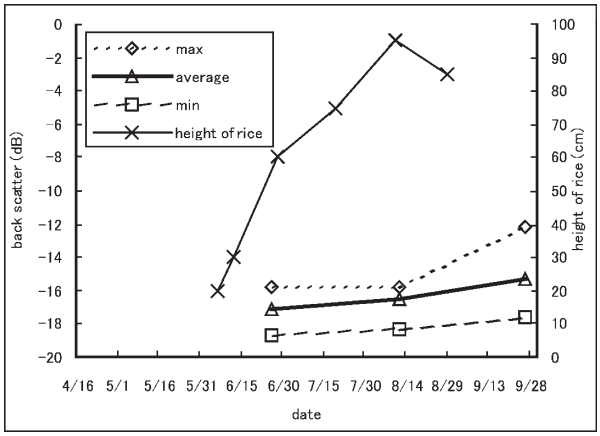

Fig. 8. Time series change of backscatter coefficient only in ascending HV images same spatial resolution and height of rice

scattering. Fig. 8 shows temporal change in backscatter coefficients only in the ascending data from the same resolution HV images and the ground truth data for rice height. It is difficult to detect relationship between rice growth and backscatter coefficients using HV polarization.

As results, it is difficult to evaluate rice growth

from differences in backscatter coefficients values in ALOS/PALSAR images. However, in this study, there were little data to conclude. Continuation of research is needed.

4. Conclusions

There are many studies of rice paddy fields using SAR, and they mostly use C-band SAR, such as RADARSAT. When using L-band SAR, conventional methods cannot be used to directly monitor rice paddy fields because the scattering of paddy fields is different from C-band SAR. In this study, I compared ALOS/PALSAR data with ground truth data to identify problems and determine effectiveness when estimating the planted area of rice paddy fields.

The data indicate that it is difficult to easily distinguish water-filled paddy fields from non-water-filled paddy or other fields based on the differences in backscatter coefficient values in ALOS/PALSAR images. However, I consider that it is possible to distinguish such fields if ALOS/PALSAR images are combined with a SAR image taken at different wavelengths or combined with an optical sensor derived image. In addition, the data set in this time indicates that it is difficult to evaluate growth of rice from ALOS/PALSAR backscatter coefficients, at the same time, the data set indicates the importance of selecting uniform data sources when performing time series analysis using ALOS/PALSAR data.

Unfortunately, there were no full polarimetric mode data available during the 2007 rice-growing period in this region. Typically, vertical polarization microwave scatters well when observing plant bodies with a vertical structure, such as the rice plant. There is possibility that the change of the backscatter coefficient in VV polarization may have been greater than those in this study, if full polarimetric data exist in growing or earring or harvesting period. Further investigation into vertical polarization and full polarimetric data are needed. In addition, research into changes related to microwave incidence angle is needed.

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Spatial Model Approach on Deforestation of Java Island, Indonesia

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Abstract

Java is the most populated island in the world. In 2000, forest area in Java covered about 2.0 million hectares but in 2005 it decreased to 1.2 million ha. Regardless of the debate on the different methodology of forest inventory applied in 2005 that resulted in under estimation figure, the decrease of forest cover in Java is obvious and needs immediate response. Spatial modeling of the deforestation will assist the policy makers to understand the process and to take it into consideration when decisions are made. Moreover, the result can be used as data input to solve environmental problem resulted from deforestation. We modeled the deforestation in Java by using logistic regression. Percentage of deforested area was considered as the response variable, whilst biophysical and socioeconomic factors that explain the current spatial pattern in deforestation were assigned as explanatory variables. Furthermore, we predicted future deforestation process, and then it was validated with actual deforestation derived from MODIS satellite imagery between 2000-2008.

1. Introduction

Since 2000, population of Java has been growing by 2.08% per year compared to 1.31% in the 1980's. Java accounts for 70% of total population of Indonesia. The population concentrates in only 7 % of land area of Indonesia or 1,026 inhabitants per km^2 (BPS-Statistics Indonesia, 2008). If the rate is assumed to be steady, the population will reach about 212.8 million or 2,070 inhabitants per km^2 in 2050. There are many publications pointed out that population increase will affect land use changes (Ramankutty et al., 2002). In the process of land use changes, there are also activities such as forest clearing for agriculture, wood extraction, settlement and infrastructure expansion that are attributed to deforestation. Angelsen and Kaimowitz (1999) argued that increased population growth leads to increase of demand for forest land and resources, and furthermore, the high rates of deforestation will drive to poverty. Driving of the population growth to the rate of deforestation is also pointed out by Zhang et al. (2000). He stated that population growth in China is the main factor contributed to the loss of natural forest. Studies from Brazil (Andersen, 1996), Mexico (Barbier and Burgess, 1996), and Thailand (Cropper et al., 1997) also gave similar result. However, Sunderlin and Resosudarmo, 1996 pointed out that the impact of population on the deforestation in Indonesia is site-specific.

So far, analyses of deforestation were based on numerical statistical data and less consideration on spatial context, whilst, in fact, it is very important to assist policy makers to understand the process and take it into consideration when decisions are made. Important data on the rate and spatial distribution of deforestation have been provided by the analysis of remote sensing images (DeFries et al., 2000). Furthermore, Lambin (2001) and Angelsen and Kaimowitz (1999) summarized that other researchers had studied deforestation at detailed scales by identifying the causes and underlying driving factors of the processes leading to deforestation. These models make an important contribution to the integrated analysis of the different deforestation trajectories in their environmental and socio-economic context.

Land-use and land cover changes analysis in Java has been investigated by Verburg, Veldkamp, and Bouma (1999). They have predicted that land use

change will especially occur in the lowland areas, either directly through construction or indirectly through the demand for higher value crops. The upland areas will stay primarily rural. The models were developed based on rough grid spatial data equals to 40 km x 40 km (1,600 km^2) derived from agricultural surveys of the Central Bureau of Statistics and coupled with provincial forest cover.

The objective of this study is to illustrate possible application of spatial modeling for deforestation by using available forest cover data derived from remote sensing data and social economical data derived from village survey which were mapped on 10 km x 10 km grid spatial data.

2. Methodology

2. 1. An approach for analyzing deforestation

Angelsen and Kaimowitz (1999) explained that there were two types of variables causing the deforestation; first, the immediate causes, which causing the farmers and loggers decided to clear more forests; and second, the underlying causes. Agricultural prices, technological progress in agriculture, accessibility and roads, and timber prices are the immediate causes. Although it is difficult to establish a clear link between deforestation and its underlying causes, namely population growth, land use, forest policy, and cultural factors (Yengoh, 2008), the deforestation rates may increase since the population is growing, and it needs more land for food, fuel wood, timber or other forest products.

Many studies have attributed road infrastructure to one main cause of deforestation. Geist and Lambin (2001) and Krutilla, et al. (1996) argued that the construction of roads requires clearing of vegetation that leads to deforestation. Greater access to forests and markets will accelerate the deforestation. Forest fragments are more accessible than large compact forest, and forests in coastal countries and islands are more accessible than those in continental countries.

Thus, in this study, we have assumptions that farmers, landholders or other factors are most likely to convert forest to agricultural use where good access to markets and favourable conditions for farming makes agriculture more profitable. In addition, the spatial model incorporated population/agricultural census and spatial data into geographic information system framework, which allows modelers to take into account many additional variables.

One of the main components required to estimate deforestation in Java is an understanding of the correlation between forests cover change and other georeferenced variables, such as population density, road density and so on. Here, we focused on the conversion of forest cover to non-forest cover from 2000 to 2005 and predict the forest conversion in the future. Map of deforestation shows the historic cumulative change of areas where deforestation occurred from 2000 to 2005 (Fig. 1).

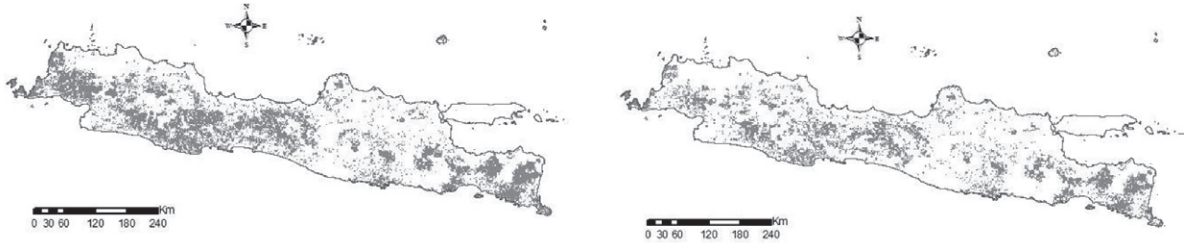
Generating a model of deforestation was based on forest presence-absence of deforestation data from both datasets, and considered the physical environment and socioeconomic data as explanatory variables. The model then can be used to obtain and identify the areas vulnerable to future forest changes.

2. 2. Datasets, data preparation and statistical analysis

2. 2. 1. Datasets and data preparation

In order to analyze spatial patterns of deforestation and make the prediction on deforested areas with a probability of conversion in the future, several datasets were used in the analysis (Table 1).

The information of forest cover in Java was obtained from datasets of land use map of Department of Forestry in 2000, and a land use map of Ministry



in 2000 in 2005

Fig. 1. Forest condition of Java Island in 2000 and 2005

of the Environment in 2005. First we synchronized the datasets with the same definition of forest cover, and then forested areas were separated from non-forested area. The pattern of forest cover represented in the deforested map was the result of the history of deforestation events from 2000 to 2005. Based on the deforestation map we developed binary grid map of deforestation, whereas value 1 represented deforested area and 0 represented non-deforested area. In similar way we developed grid binary maps for population density, percentage of population having agricultural sectors source of income, percentage of population having non-agricultural sectors source of income, road density, elevation and slope. Detailed criteria for defining value of grid whether 1 or 0 are presented in Table 1.

Each data parameter was re-sampled in 10 km grid as unit analysis in the model. Vector grid data of 10 km were made by creating fishnet command in ArcGIS, and further it was attributed by using input parameters such as forest area, road density, slope, elevation, population density, population having agricultural and non-agricultural sector source of income. Grid attributing process for vector data was conducted by Hawth Tools, free add-on extension in ArcGIS version 9.2 (http://www.spatialecology.com/htools) and raster data by ERDAS Imagine 9.1

As explained above the population growth is expected to be potentially the major driver of deforestation. A map of population density from 2000 to 2005 was generated at the village-level using national census data (PODES, *potensi desa*) (Table 1). The population growth is continuously changing in time and space; therefore, simulations were made in this

Table 1. Data used, assumption and criteria in the deforestation model

Data	Source	Assumption	Criteria
Deforestation	Analysis from Land use map by Department of Forestry (Land cover in 2000) and Ministry of Environment (Land cover in 2005)	Analyzed from forest cover change from 2000 to 2005, and the ideal threshold was a half of grid size (100km^2). But, since that threshold was not significant, 20 km^2 was used as a threshold for deforestation	Deforestation > 20 km^2= 1 Deforestation < 20 km^2 = 0
Slope	Generated from SRTM DEM USGS (2004), Shuttle Radar Topography Mission 90 x 90m, Global Land Cover Facility, University of Maryland, College Park, Maryland, February 2000.	Mean of slope threshold was 15%, with assumption: slope 15% above is unsuitable for agriculture and settlement	Slope > 15% = 0 Slope < 15% = 1
Elevation	Generated from SRTM DEM USGS (2004), Shuttle Radar Topography Mission 90 x 90m, Global Land Cover Facility, University of Maryland, College Park, Maryland, February 2000.	Mean of elevation threshold was 200 m.asl, with assumption that areas with elevation below 200 m.asl is very vulnerable	Elevation < 200 m = 1 Elevation > 200 m = 0
Population density	Analyzed from BPS-Statistics Indonesia, data PODES 2000 and 2005	Threshold was the mean of population, with assumption that since population density is increasing, deforestation rate also will be increasing	Population density > mean = 1 Population density < mean = 0
Road density	Extracted from Base and Topographic map Scale 1:25.000 by National Coordinating Agency for Surveys and Mapping, Indonesia (1999)	Threshold was the mean of road density, with assumption that the higher road density, the pressure to forest also is increasing	Road density > mean = 1 Road density < mean = 0
Population having agricultural sector source income	Analyzed from BPS-Statistics Indonesia, data PODES 2000 and 2005	Threshold was the mean of percentage of population having income from agricultural	Population having agricultural sector source income > mean = 1 Population having agricultural sector source income < mean = 0
Population having non-agricultural sector source income	Analyzed from BPS-Statistics Indonesia, data PODES 2000 and 2005	Threshold was a mean of percentage of population having income from non- agricultural sector	Population having non-agricultural sector source income < mean = 1 Population having non-agricultural sector source income > mean = 0

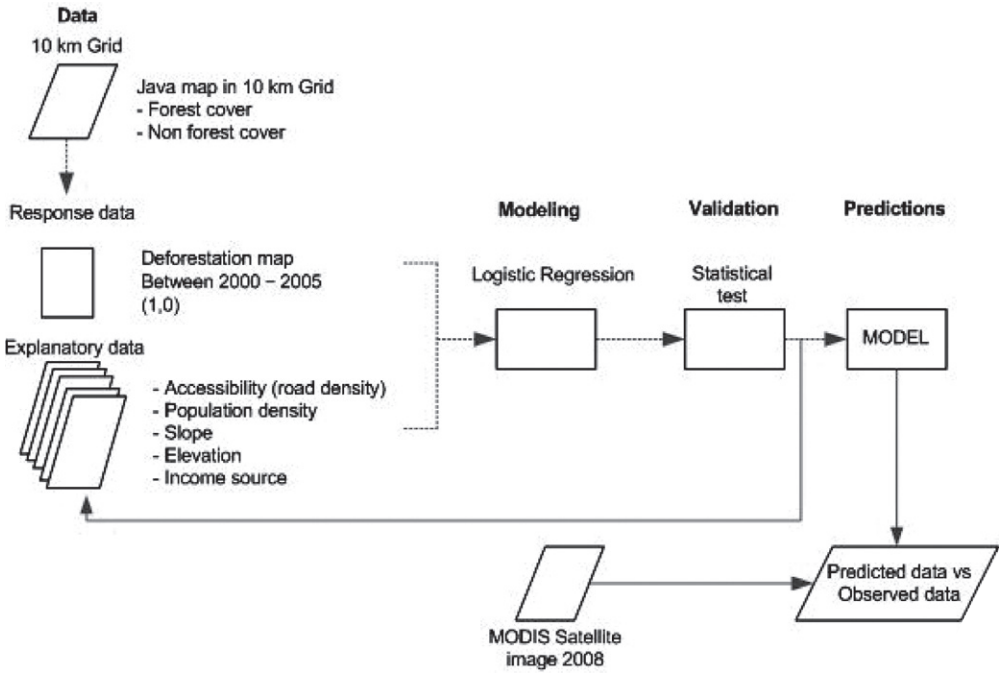


Fig. 2. Flowchart of the methodology in this study

study. Two scenarios were used, namely an increase of those independent variables as high as 2% for normal/moderate scenario and an increase of 6% of those variables for extreme scenario (Fig. 2).

In order to quantitatively validate our predictions of deforestation, we used MODIS satellite images in 250 m resolution with 16-day composite which were acquired in February 2000, February 2008, August 2000 and August 2008. The image MODIS was obtained from Land Processes Distributed Active Archive Center, U.S. Geological Survey, http://lpdaac.usgs.gov/datapool /datapool.asp.

Pixels forest value of MODIS was identified and classified from MODIS datasets in different season data in order to get annual forest and non-forest coverage. Then, a forest-non forest maps were resampled to 10 km grid size.

2. 2. 2. Statistical modeling

As explained in Table 1, the six independent variables were used as predictors in the analysis. Logistic regression as statistical modeling was employed for estimating event probabilities of the occurrence of the deforestation as a dichotomous dependent variable. The regression coefficients obtained were used for integrating the spatial layers and the result was aggregated using a logit transformation [$P = \{exp(a+BX..)/ 1+(exp(a+BX..)\}$] to obtain the probabilistic map of deforestation.

The initial specification of the model, based on theoretical considerations and data availability, was:

$$P=\left\{ \frac{\exp(a+\beta_1 c\_pop++\beta_1 c\_elev+\beta_1 c\_road+\beta_1 c\_ptdens+\beta_1 c\_nptdens)}{1+\exp(a+\beta_1 c\_pop++\beta_1 c\_elev+\beta_1 c\_road+\beta_1 c\_ptdens+\beta_1 c\_nptdens)} \right\}$$

Where:
P: probability of the occurrence of deforestation; a: intercept; c_popdens: population density; c_elev: elevation; c_road: road density; c_ptdens: percentage of population having agricultural sectors source of income; c_nptdens: percentage of population having non-agricultural sectors source of income

Spatial modeling was done using logistic regression to predict the future spatial location of forest conversion, whereby the predictions using two kinds of population growth rate were 2% (normal/moderate) and 6% (extreme).

Results of logistic regression models are often judged as successful if predicted probabilities, i.e. $P > 0.5$ correspond with the observed occurrence and value $P < 0.5$ with the absence of occurrence. Finally, we validated the deforestation map predicted in 2008 as a result of deforestation modeling with observed data of cleared forest/non-forest areas, which was interpreted from MODIS satellite imagery. Our aim was to validate only the approximate location of predicted forest conversion, and not to quantify the change. Then, the model was used to predict the occurrence of deforestation in 2020.

3. Results and Discussion

3. 1. Forest change detection

Most of the remaining forest areas in 2005 was situated in high elevation and steep slopes as stated by Verburg, Veldkamp, and Bouma (1999), since lowland forest in Java had been converted to other land cover type, such as agriculture, shrimp pond and plantation in 1990's (FWI/GFW, 2002). From 2000 to 2005, the deforested areas located in the quietly steep slope and steep volcanic slope were 31.5 % and 40.1%, respectively. Most of the forest conversion was due to agricultural expansion such as for paddy field, upland agriculture, cash crops plantation, and small area for settlement development (Fig. 3). With regard to the provincial distribution, the highest deforestation occurred in East Java, followed by West Java and Banten, Central Java and Jogyakarta.

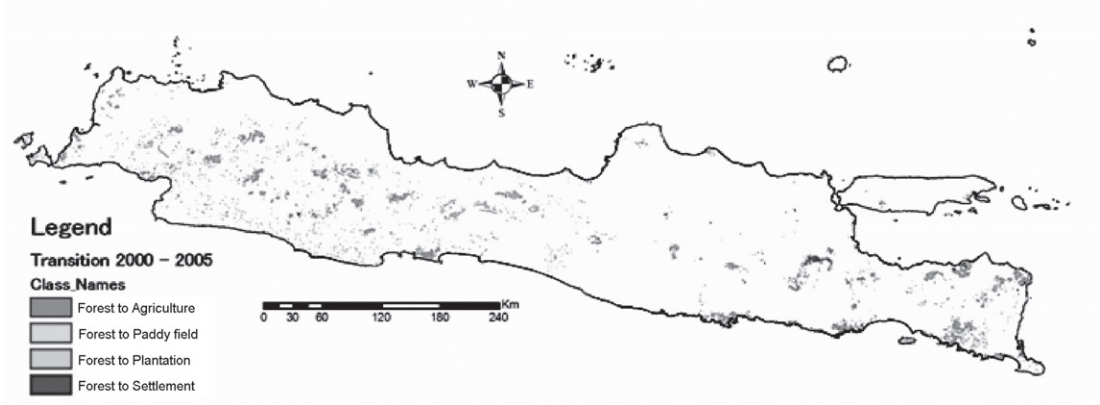


Fig. 3. Transition forest cover in Java from 2000 to 2005.

3. 2. Predictions of deforestation

The result of logistic regression is presented in the equation below and the result of goodness of fit of variables is presented in Table 2.

$$P = \frac{e^{(-18.74 - 16.681\ (c\_pop) + 0.967\ (c\_elev) - 0.683\ (c\_road) - 1.597\ (ptdens) + 15.445\ (c\_nptdens)}}{1 + e^{(-18.74 - 16.681\ (c\_pop) + 0.967\ (c\_elev) - 0.683\ (c\_road) - 1.597\ (ptdens) + 15.445\ (c\_nptdens)}}$$

where:
P: probability of the occurrence of deforestation; a: intercept; c_popdens: population density; c_elev: elevation; c_road: road density; c_ptdens: percentage of population having agricultural sectors source of income; c_nptdens: percentage of population having non-agricultural sectors source of income

Based on goodness fit test (Table 2) population density, road density, and percentage of population having agricultural sectors source of income were significant in predicting deforestation process. The equation above showed that those variables were having negative impact on forest cover areas.

Under the normal/moderate scenario, in 2020 only one district/municipality in Banten would face deforestation problem, meanwhile in West Java, Central Java, Yogyakarta and East Java there would be 7 districts, 22 districts, 4 districts and 6 districts, respectively. Under the extreme scenario, the number

Table 2. Goodness of fit test of variables

Factor	B	S.E.	Wald	df	Sig.	Exp(B)
c_slope	1.163	.319	13.309	1		
c_pop	-16.681	1685.371	.000	1	.992	.000
c_elev	.967	.279	11.982	1	.001	2.629
c_road	-.683	.621	1.211	1	.271	.505
c_ptdens	-1.597	.390	16.784	1	.000	.203
c_nptdens	15.445	1871.765	.000	1	.993	5102496.376

Where :
B: estimated logit coefficient, S.E : Standard Error of the coefficient, Wald = $[B/S.E]^2$, df : degree of freedom, Sig : significance level of the coefficient, Exp(B) : is the odds ratio of the individual coefficient

of deforested districts of Banten, West Java, Central Java, Yogyakarta and East Java would be 2 districts, 11 districts, 18 districts, 5 districts, 26 districts, respectively (Fig. 4). Regarding watershed boundary, in 2020 the number of watersheds that would be expected to face serious deforestation is 47 watersheds under the normal scenario, and almost three times as much (123 watersheds) under the extreme scenario (Fig. 5).

Policy implication of the result model prediction is that the government should take more attention to the population problem and have to create non-agricultural sectors jobs in order to reduce pressure on forest, especially at district which will face serious deforestation. Un-resolved conflict of forest border between community and the government as underlying factor of state forest (government forest area) encroachment (Prasetyo, et al. 2008) should be mediated.

3.3. Model Validation

The logistic regression model was also used to predict the deforestation in 2008, and was validated using observed deforestation data derived from MODIS satellite imagery taken in 2000 and 2008). The validation result showed that the overall accuracy of the model is 88.70%, and the producer accuracy and user accuracy for un-deforested area were 95.76% and 92.44% respectively. Meanwhile, the producer accuracy and user accuracy for deforested area were 2.97% and 13.64%, respectively. Therefore, the model could predict un-deforested area with high confidence, but it was still low and needed to be developed for deforested areas.

4. Conclusion

This study showed the utility of a combination of statistical modeling approach and spatial analysis in order to analyze and predict deforestation. Population density, road density and agricultural source of income were found to be the important variables in the model for explaining the pattern of deforestation observed in Java, however, the accuracy of prediction should be increased especially for deforested areas. The involvement of some variables such as land tenure status, forest distance from road, and other socio-economic data (level of income, level of education), which have contributed to deforestation might be incorporated in the model.

Acknowledgement

We would like to express our gratitude to the Co-ordinating Ministry for Economic Affair Republic of Indonesia for their support.

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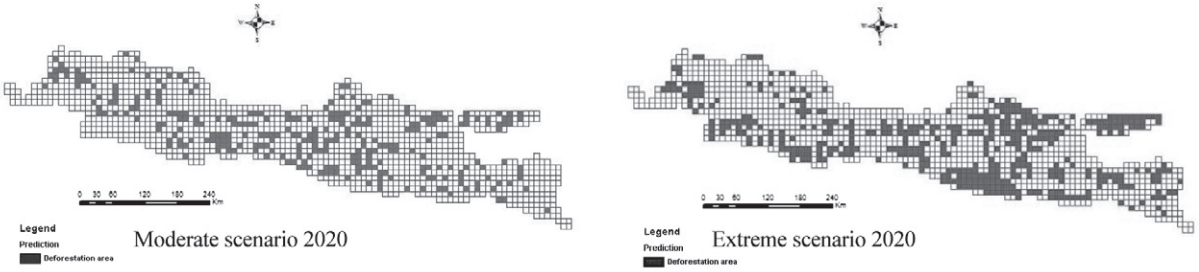

Fig. 4. Deforestation prediction in moderate and extreme scenarios in 2020

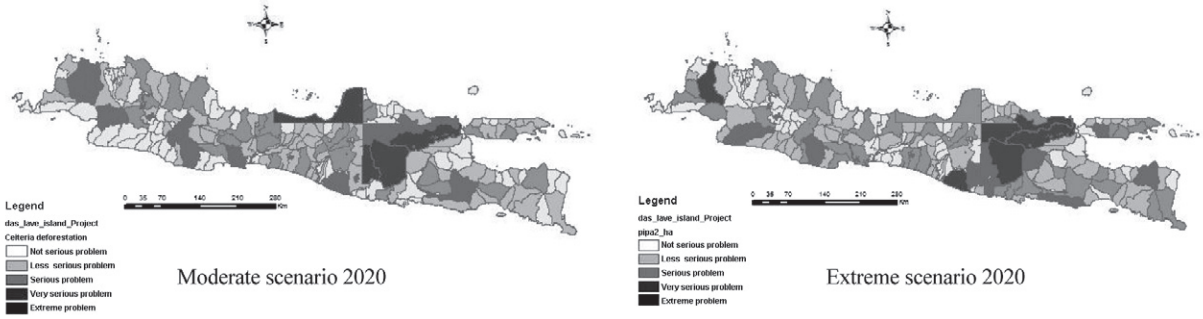

Fig. 5. Deforestation prediction with regard to watershed boundary.

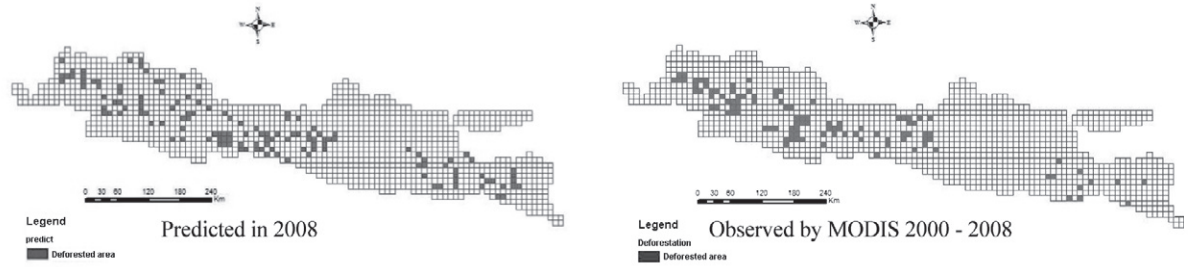

Fig. 6. Comparison of deforested and un-deforested areas predicted in 2008 and bserved deforestation by MODIS 2000-2008

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Grassland Degradation and Recovery Based on Remote Sensing and GIS in Inner Mongolia

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Abstract

Inner-Mongolia, used to be the fertile field, has been facing the grassland degradation since the past decades. This leads to the less production and impacts the environment of North China. The survey and management based on remote sensing and GIS help the people to recover the grassland and make the development sustainable.

1. Background of the research

Since the 20th century, mankind has been facing many environment problems including the grassland degradation. The grassland degradation causes worldwide environmental concerns, serious impact on the survival of mankind, and also on the environment, society and economy sustainable development. China has the vast territory and grassland area. But these resources have regional disparities, the complex type, grassland vegetation changes within the time and seasons. Human activities deeply affect the grassland with the imbalance between livestock and grassland productivity. Furthermore natural disasters have occurred often. The grassland degradation has become increasing and obvious. Grassland is generally on the recession.

It is clear that some powerful, reasonable and scientifical decisions and actions should be, or must be, taken for reserving and recovering grassland.2. Social and economical development and grassland.

2. Social and economical development and grassland

2.1. Grassland resources and animal products

Compared with some other countries, although the

Table-1-1 Grassland resources of China(2007)

Country	Population (million)	Total area (m.ha)	Grassland(%) -area per person (m.ha/ha)	Agri.land /area per person (m.ha/ha)
China	1276	960	(41.70%)-400/0.31	120 /0.094
Australia	20	769.2	(60%)-458/27	
New Zealand	3.7	26.9	(60%)-16.12/4.36	
Argentina	37.8	2.78	(72%)/200.34/5.3	

Table-1-2 Grassland degradation in China (2003)

Total area (country)	Natural rangeland	Grazing grassland	Degraded grassland	Badly degraded	Agr.land
960 m.ha	400 m.ha	330 m.ha	360 m.ha	180 m.ha	120 m.ha
100%	41.70%				12.50%
	100%		90%	55%	

grassland area per person is not very high, only 0.31 ha, but it is nearly 4 times than the agricultural land which a Chinese has. This ratio of grassland is about 41.70% in the total areas of the country. The whole grassland (400 million ha.) can match Australia's (458 million ha.). (ref. Table-1-1)

This vast grassland distributes in most part, especially the north and the northwest of the country. Inner Mongolia has rich grassland, highest rate of the region. (ref. Figure-2-1)

The Inner Mongolia lies in north China, accounts for about one eighth of the whole country area, across the northeast, north and northwest regions. The natural grass covers the land of 680,000 square kilometers which is an important component of the Euro-Asia grassland band.

2.2. Market requirement and the animal product development

With the fast social and economic development, the requirement for the beef, lamb and milk has been great increase. According to the statistics, only in 7 years (from 2000 to 2006), the production of beef and lamb has been doubled, while the milk production has been nearly 4 times. (ref. Figure-2-2)

2.3. Impact on the grassland and the results

Generally speaking, the grassland of Inner Mongolia has high productivity, 200~1,000kg/ha each year, from west to east. This production could support 0.2~0.5 sheep unit/ha. But, according to the survey, in some places of Inner Mongolia, this number had reached to 10 times or more in several years ago.

It is no doubt that the grassland has to be in recession with the impact of the requirement for the animal products. We have not got any surveying work result to show how the grassland proceeded in the whole areas in the past 30 years. But some alarms, natural disasters, had indicated that the human would face the more fearful environment problem if we wouldn't be thinking about what we should do.

According to the official report that, in north part of China, the sand storms have been more and more often in spring season every year in the past 50 years. There were 5 times every year in 1950's, but 8 times in 1960's, 13 times in 1970's, 14 times in 1980's, and in 1990's, it had reached to 23 times every year. The less and less grass and the other vegetations, the less and less rainfall, the more and more bare land, the sand flows from west to east with strong wind.

Because of grassland degradation, vegetation becomes sparse, the topsoil is exposed, wind diminish the fertility of the land seriously and rapidly. This will not only restrict the development of animal husbandry, but also compact the ecological environment. It is to be understood that, the accurate data should be

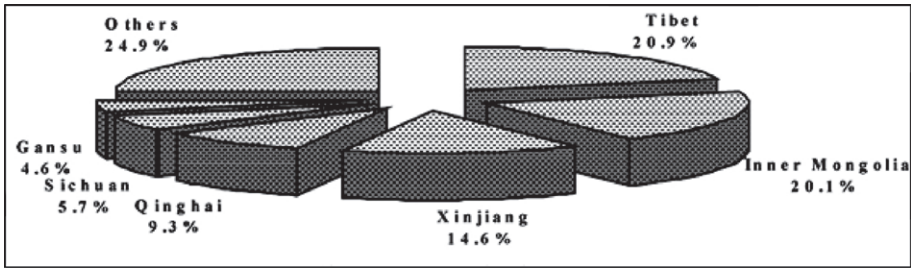

Figure-2-1 Area proportion of China grassland region

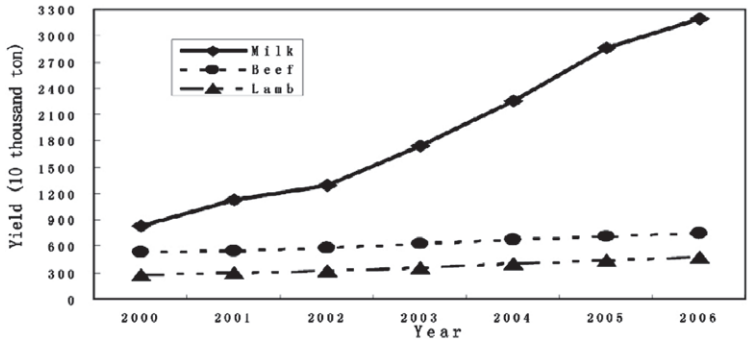

Figure-2-2 China Beef, Lamb and Milk Production

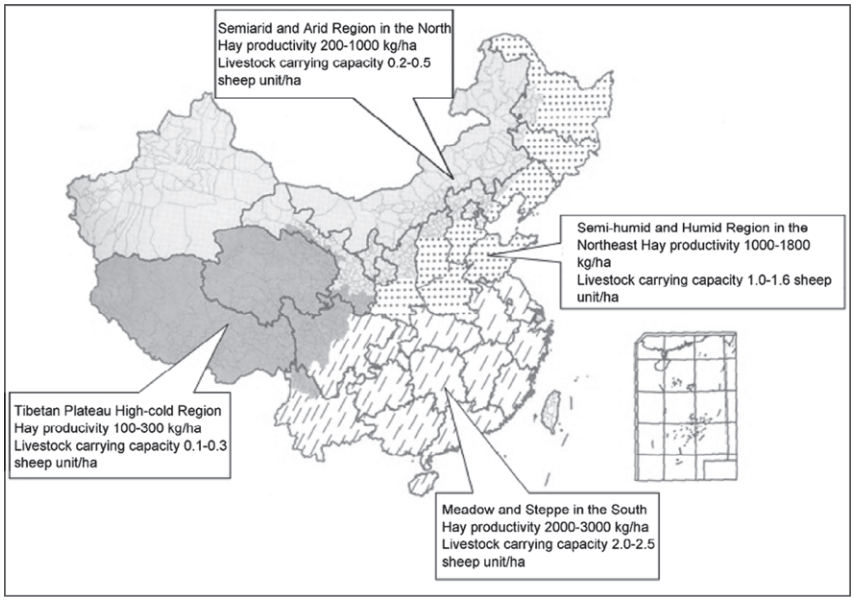

Figure-2-3 Carrying Capacity of different grassland in China

Figure-2-4 Sand Storm in north of China in past 50 years

collected based on the remote sensing and GIS. The degradation evaluation should be taken as a reference to the standards, so that we can understand the status of grassland resources and its development trends. In this case, socio-economic impact on the grassland can be analyzed. Then the grassland can be used reasonably and sustainably based on the good planning and management.

3. The grass growth status survey based on MODIS

3.1. The contents of study and aims

For the degradation survey, the most important is to investigate the biomass and biomass changes of the grass and the other vegetations based on MODIS in short term and long term. Supported by the MODOL, biomass production could be surveyed based on the remote sensing data reflectance, NDVI. With the time, the grass growth statues could be surveyed. The remote sensing system could help to finish this work in real time.

3.2. NDVI and method

EOS-MODIS is a powerful remote sensing system with 36 bands in the electric wave-length, 0.4~14μm, middle spacial resolution 250m~1,000m.

From Figure-3-1 we can see the advanced 7 bands of MODIS. Band-1, red, from 620~670nm; and Band-2, NIR from 841~867nm. From the spectrum characteristic curve, the difference between Band-2 and Band-1 strongly related to the biomass-vegetation growth status. The NDVI value could be calculated according to the following function:

NDVI = (ρNIR-ρR) / (ρNIR+ρR),

in which ρNIR is the reflectance of Band-2(near infrared) and ρR is the reflectance of Band 1(red).

The value range of NDVI is: -1<=NDVI<=1. Negative value is related to the cloud, water or snow. The positive value is strongly related (linear in some ranges) to the vegetation, its coverage and biomass. It means that we could get the biomass from the NDVI in pixel (match to the area on the ground) based on the "MODEL". Although this relationship is sometimes affected by soil background and atmosphere, but anyway, NDVI and EVI (enhancement vegetation index, just like NDVI but joint with atmosphere factor and soil background factor) can indicate the biomass in vast areas.

3.3. The model of sur vey

3.3.1. The flow chart of data processing

In the working flow chart, the core is the MODEL which related to NDVI value in certain pixel, to the relevant truth data of grass on the field as well (the biomass weight in unit, the grass coverage), and the other factors to evaluate the grassland and degradation (the soil moisture, etc.). The classified NDVI value map is very important to let some areas of NDVI value match to some grass production level in one unit.

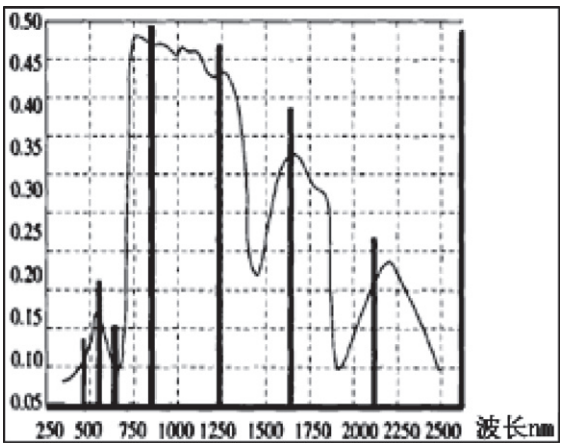

Figure-3-1 MODIS Band 1~7

3.3.2. The mapping of NDVI class

The experimental site located in Xilingole district of Inner Mongolia, the position is from E115°13′ ~117°06′, and N43°02′~44°52′, is a very typical grassland which is bigger than Switzerland in area. Since the NDVI value is about 0.3~0.47, it is divided into 5 different levels: <0.3, 0.3~0.4, 0.4~0.5, 0.5~0.6, >0.6. (ref. Figure-3-3)

3.3.3. Sampling for the truth ground data

On the field work, some vegetation samples (biomass in one unit) were collected in the areas with different NDVI values.

Based on the sample data accompanied with the other information, NDVI, vegetation coverage, biomass and soil moisture, the grassland degradation evaluation method could be used. Different level of the parameters represents the different grassland degradation level: A(less), B(some), C(worse), D(worst).

3.3.4. The SUM of NDVI in seasons of grass growth

The SUM of NDVI in grass growth seasons could more correctly relate to the grass status escaping from some temporal or randomization influence of atmosphere humidity, rainfall, sun shine, etc.

The working steps as follows:

- The MODIS mosaic imagery in ten days without clouds.
- Estimate NDVI for this mosaic imagery.
- Identify the grass growth seasons: 10th of May~10th of Sept.
- There are totally 12 NDVI maps of each 10 days of the grass growth seasons every year.

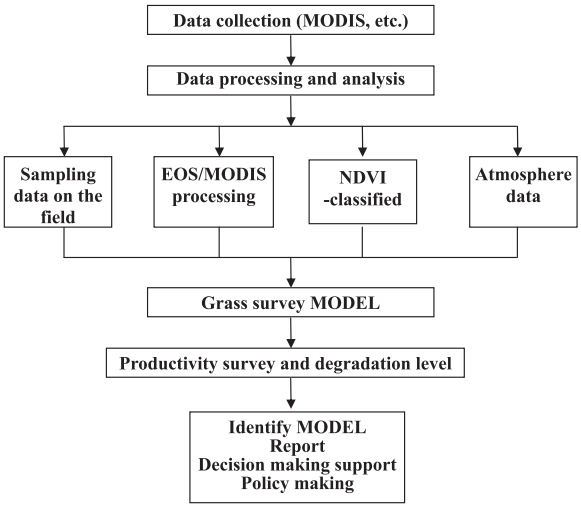

Figure-3-2 Flow chart of working for grass survey based on MODIS

Table-3-1 Grass sample data (2007)

No.	Fresh Mass (g/m^2)	Dry Mass (g/m^2)	Moisture (%)
01	310.00	108.49	71.28
	260.00	82.28	
02	221.00	63.23	68.20
	174.00	86.26	
03	255.00	86.34	71.47
04	205.00	86.34	64.14
05	209.00	82.04	66.47
06	255.00	100.22	65.58
07	160.00	103.63	39.70
08	141.00	95.84	36.72
09	103.00	51.55	61.25
10	74.00	43.40	54.64
11	196.00	83.53	63.19
12	46.00	28.49	62.54
13	95.00	39.88	71.58
14	83.00	40.69	65.09
15	74.00	37.33	65.48
16	84.00	42.12	63.45
17	216.00	83.34	67.00
18	195.00	65.18	73.34
19	74.00	46.79	49.47
20	62.00	39.85	50.34

Table-3-2 Grassland degradation evaluation based on NDVI, etc.

Factor	Grassland Degradation Level			
	A	B	C	D
NDVI	> 0.5	0.4~0.5	0.3~0.4	< 0.3
Coverage (%)	> 50	30~50	10~30	< 10
Biomass (g/m^2)	> 300	300~200	200~100	< 100
Soil moisture (%)	> 3.0	3.0~2.0	2.0~1.0	< 1.0

- SUM 12 NDVI of each 10 days mosaic imagery of every year.
- Establish the survey MODEL
- Study and analyze the results

From the SUM NDVI comparison between 2002 and 2004, it is more clear that the grassland trends to decline in productivity by two years.

3.4. Grassland survey in long term

Based on SUM NDVI some grassland survey could be taken in long term. The grassland changes information is very important in every month, every week in one year. More important thing is that the changes occur on a year by year basis. This long term survey could help the grassland management and environment management.

EOS-MODIS, the powerful remote sensing system for the earth observation, could provide 2 times global data in one day. This program started in 1998, and will be continued till 2013. After that, there will be many other systems. Before 1998, there was NOAA system which was launched in 1960's. The grassland survey in long term will continue in the project.

4. Grassland planning and management based on GIS

4.1. "Grassland Fence" and degraded grassland recovery

Overgrazing is becoming one of the main reasons for grassland degradation. "Grass Fence" could effectively protect the grassland and ecological environment. It is also the most basical, simple and economical way to protect grassland in ecological fragility area and against degradation, and desertification.

After grassland is fenced, the vegetation has a chance to rest and recover. This will give the grassland a good opportunity and fully play to the strong self-repair function of natural grassland. With the times, grassland could recover step by step.

The investigation results have shown that the productivity inside of "Grass Fence" is over two times compared with that of outside at the same landscape position, the same climate and rainfall, the same sunshine, etc. (ref. Table-4-1) It is indeed that the Fence had helped the grass to recover and there is better grass inside of Fence.

4.2. Information collection for "Fence" based on remote sensing

Since there is better grass inside of Fence, it is very easy to find the areas of Fenced grassland. Mapping for the grassland Fence information will help grassland planning and management.

From the working results, we have known that, in Xilinhaot, the capital of the district, the Fenced grassland is less than 20% of the total areas.

And also we have known that, the planning of grassland Fence is not good. A lot of fenced grassland area consumed more materials and investment be-

Table-4-1 "Grass Fence" affects the grass productivity

Grassland	Plant species	Fresh weight	Average(5 samples)
Inside fence (Siziwangqi)	5	29g	36.5g
	5	44g	
Outside fence (Siziwangqi)	3	25g	18.5g
	4	12g	
Inside fence (Ejinhuoluoqi)	6	145g	145g

cause of its independence and unconnected with others. In this case, we must think about how to develop the technology and to construct more Fenced grassland. We need a better plan, we should push this work forward. Remote sensing and GIS could contribute a lot to the planning and management work.

5. Discussion

5.1. Technology and policy making

Technology, remote sensing and GIS, give us a good chance to know the details of grassland and the others. The policy making has got a strong support from the technology. The correct and good policy and regulations affect human's activities. Based on the RS and GIS, the grassland could be used reasonably, the grassland degradation could be better and restored.

5.2. Research and applications

The research results are good and satisfactory. We need to put these case studies into the application in a vast area in the future.

5.3. Cooperation

Grassland reservation and environment protection are very important not only for the local people, but also for the others, nationally and internationally. Exchange of ideas and experiences, sharing of the data and technology, joint working and so on will give us more chances to resolve the environmental issues including grassland reservation.

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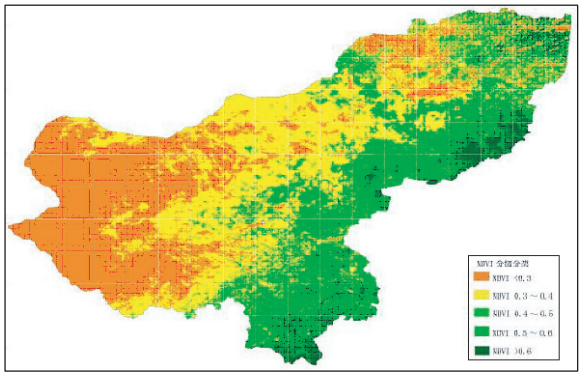

Figure-3-3 Map of NDVI class of Xilingole district, Inner Mongolia

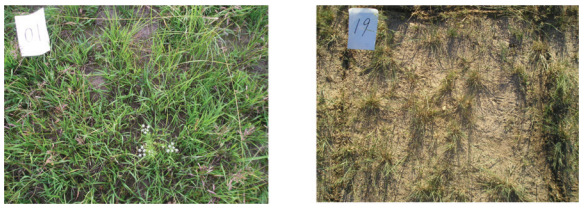

Figure-3-4 Sample No.01 and Sample No.19

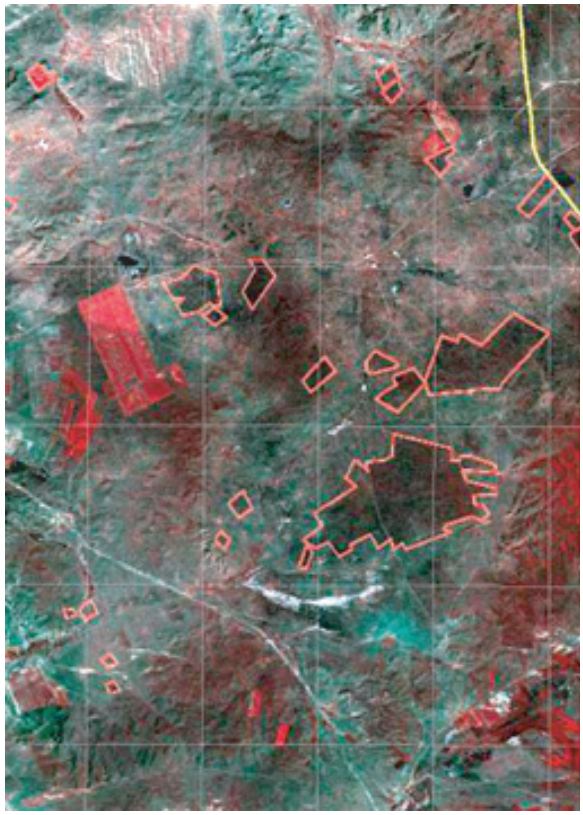

Figure-4-2 Mapping grassland Fence based on ETM

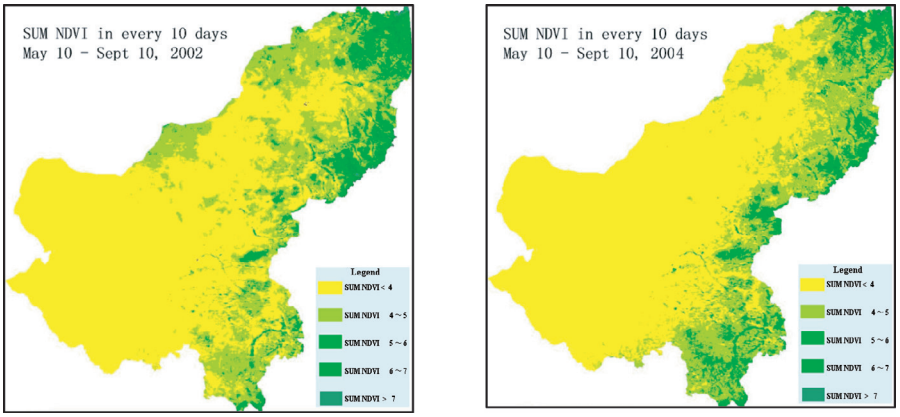

Figure-3-5 SUM NDVI of Xilinguole district 2002-2004

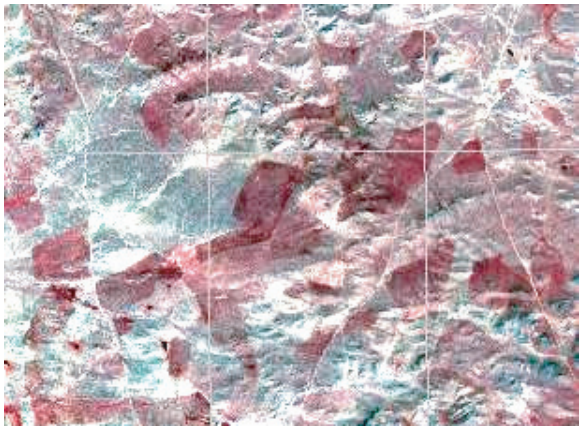

Figure-4-1 The ETM Image in Siziwangqi (the grassland fences)

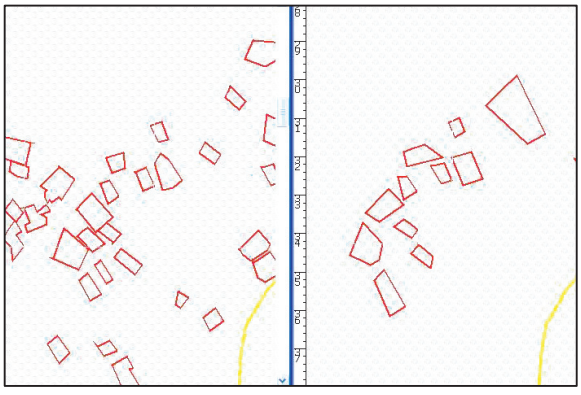

Figure-4-3 Grassland Fence management based on GIS

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Understanding of Planted Crops Using AVNIR-2 Data

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Abstract

Since the ALOS performs observations at a comparatively high frequency in Japan, it does not receive as much restriction during observation time. Multitemporal ALOS/AVNIR-2 data in the paddy field zone in Hokkaido were used to carry out the land-cover classification of farmland and the classification of crops. The classification accuracy was examined by performing a supervised classification of major crops in the study site, such as winter wheat, paddy, soybean, azuki bean, sugar beet and onion. This was done by using ALOS/AVNIR-2 data with three scenes that had been observed on the 27th of May, the 28th of July and the 26th of August in 2006. On each observation day, the classification accuracy was above 95% for winter wheat, paddy and sugar beet, but was below 95% for soybean, azuki bean and onion. The classification of land-cover for the whole study area was also carried out by using the data from the three observation days. Regarding the area of each crop classified, the classification accuracy for winter wheat, paddy and sugar beet was high at ±10% compared to that of the statistical data for soybean, azuki bean and onion, which was low. Even the ALOS/AVNIR-2 data, for which the short-wavelength infrared region was not observed, was able to classify the paddy field with high accuracy because of the use of multitemporal data.

1. Introduction

It has been found that, it is necessary to carry out timely observation of the land-cover classification of farmlands using satellite information based upon the status of the fields used as a result of tillage, flood water and the growth condition of crops. It is reported that the precise classification of wheat, sugar beet, maize, potato and soybean was able to be conducted, due to the availability of data from the LANDSAT/TM observed from spring to autumn in the Tokachi district of Hokkaido (Okano et al. 1993), which is one example of land-cover classification of farmland in Japan. Moreover, it is reported that the short-wavelength infrared ray data observed immediately after the transplantation of paddy was able to distinguish paddy fields with high accuracy (Okamoto et al. 1996). However, it is also assumed that observations can not be conducted in due time with a commonly used optical sensor based on weather conditions. On the other hand, although a stable observation is possible using the synthetic aperture radar (SAR), which is a weather resistant sensor and does not depend on the weather conditions, examples in Japan are mainly limited to the classification of paddy fields (Ishitsuka et al. 2003).

The Advanced Visible and Near Infrared Radiometer type 2 (AVNIR-2) sensors have also been loaded onto the Japanese Advanced Land Observing Satellite (ALOS) which was launched in 2006. Although it does not observe the short-wavelength infrared region, the whole country is being observed with a comparatively high frequency ground resolution of 10 m since the spring of 2006, and it can be expected to be used for classifying crops. In this context, an attempt was made to classify the land-cover of farmland by examining the classification accuracy of major staple crops and using ALOS/AVNIR-2 data observed during multiple times from spring to autumn in 2006 for the paddy field zone in Hokkaido.

2. Materials and Methods

1) Study site

The Naganuma Town was selected as the study site

which is the representative paddy zone of Hokkaido possessing low plain fields downstream from Ishikari River. Although most of the farmland in Naganuma Town is occupied by paddy fields,, a conversion into upland fields has been advancing in recent years and the rate of change in crops has reached 60%. The major crops cultivated are winter wheat, paddy, soybean, azuki bean, sugar beet and onion and others include vegetables and grass. The cultivated area and the proportion of main crops are given in Table 1. Since most of the grassland's areas are perennial, it was possible to efficiently understand the cultivation situation in the region by classifying the major crops that occupy almost 75% of the cultivated area.

2) Satellite data and analysis methods

Distinguishing crop types and classifying land-cover were both carried out for major crops such as winter wheat, paddy, soybean, azuki bean, sugar beet and onion by using the ALOS/AVNIR-2 data from three scenes of the targeted region that were acquired on the 27th of May, the 28th of July and the 26th of August in 2006, respectively. The average standard cultivation period of major crops and the observation days of the satellite that had been used for analysis are illustrated in Fig. 1.

A supervised classification was performed by selecting 20 plots each of winter wheat, paddy, soybean and sugar beet, 15 plots of azuki bean and 8 plots of onion from the study site and by acquiring the average digital number (DN) of each field according to the band from each satellite data.

Table 1. Composition of cropping area in Naganuma Town

Planted crops	Statistical area (2006) (ha)	Proportion (%)
Winter wheat	2,450	24
Paddy	3,190	32
Soybean	1,680	17
Adzuki bean	107	1
Sugar beet	187	2
Onion	110	1
other	1,170	12
Grass	1,130	11
Total	10,024	100

3. Results

1) Classification accuracy of each crop

The classification accuracy of each crop according to the satellite observation day is given in Table 2. The accuracy during the crop growing period was above 95% on 27th of May for winter wheat. The same results were also found on the 28th of July and the 26th of August for paddy and the 26th of August for sugar beet. However, it was always below 95% for soybean, azuki bean and onion.

2) Land-cover classification

(1) Classification of crops

According to supervised classification of satellite data, the whole study site was categorized into six

Table 2. Classification accuracy

Planted crops	Observation date		
	27th May	28th July	26th August
Winter wheat	100.0	(97.3)	(96.9)
Paddy	91.6	95.5	97.0
Soybean	48.5	64.1	85.3
Adzuki bean	52.2	79.5	72.3
Sugar beet	55.0	85.5	96.5
Onion	73.2	90.5	(93.9)

Note: Values in parentheses denote after harvesting

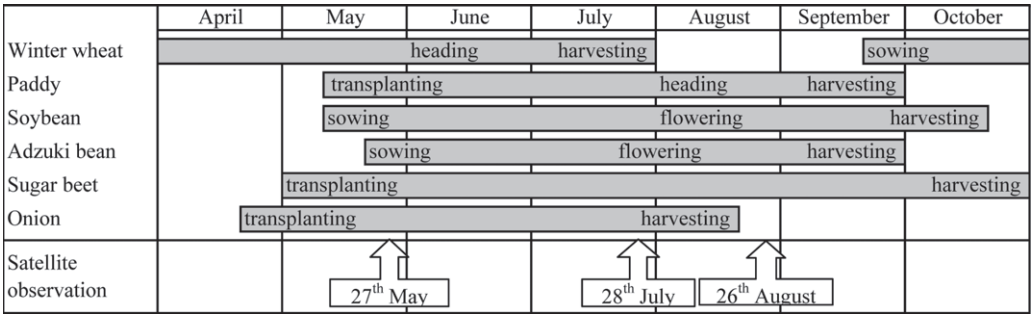

Fig. 1. Calendar of major crops in Naganuma Town and satellite observation

classes, made up of winter wheat, paddy, soybean, azuki bean, sugar beet and onion. Although forests, urban areas and rivers also existed in the study area, the cultivated crops were classified into six classes including them all. The classification of each result from satellite data was then compared and the respective crops were judged by each pixel, considering the classification accuracy of all satellite data. A brief description on the judgment of each crop is given below.

a) Winter wheat

Unlike other crops, winter wheat showed to be strong vegetation on the 27th of May, and the classification accuracy of winter wheat was high on all three observation dates. This is because wheat was harvested in late July and wheat plants had already disappeared completely before the observations on the 28th of July and the 26th of August. Therefore, only the pixels that were classified as "winter wheat" on all three scenes of 27th May, 28th July and 26th were judged as winter wheat. Moreover, both winter wheat and onion had already been harvested before the 26th of August. Therefore, the classified pixels of "winter wheat" on the 27th of May and the 28th of July and of "onion" on the 26th of August were also judged to be winter wheat.

b) Paddy

Similar to all other crops with the exception of winter wheat, paddy did not have vegetation on the 27th of May. Although, the classification accuracy on the 28th July and the 26th of August was high. Therefore, the pixels that were classified as "paddy" on the 28th of July and the 26th of August but not as "winter wheat" on the 27th of May were judged as paddy. However, among these, the pixels having been distinguished as "winter wheat" on the 28th of July and "winter wheat" and "onion" on the 26th of August were not distinguished as paddy.

c) Sugar beet

Sugar beet did not have vegetation on the 27th of May. This was similar to all the other crops with the exception of winter wheat. The classification accuracy on the 28th of July was low. Therefore, out of all pixels other than the ones judged as winter wheat and paddy, pixels that were classified as "sugar beet" on the 26th of August but not "winter wheat" on the 27th of May were judged as sugar beet. However, among these, the pixels that were distinguished as "onion" on the 28th of July were not distinguished as sugar beet.

d) Onion

Onion did not have vegetation on the 27th of May. This was similar to all other crops with the exception of winter wheat. The classification accuracy on all three observation days was not high, although the plants had withered before the 28th of July and the vegetation had disappeared due to the harvest before the 26th of August. Therefore, out of all pixels other than ones being judged as winter wheat, paddy and sugar beet, the pixels that were classified as "onion" on the 28th of July, and those classified as "winter wheat" and "onion" on the 26th of August but not "winter wheat" on the 27th of May were judged as onion.

e) Soybean

Soybean did not have vegetation on the 27th of May. This was similar to all other crops with the exception of winter wheat. Although vegetation was present on the 28th of July and the 26th of August, the classification accuracy of all three observation days was not high. Therefore, from the pixels other than ones being judged as winter wheat, paddy, sugar beet and onion, the pixels that were classified as "soybean" and "azuki bean" on the 26th of August amongst the pixels being judged as "soybean" on the 28th of July but not "winter wheat" on the 27th of May were all judged as soybean. This also applies to the pixels being classified as "soybean" on the 26th of August out of all the pixels classified as "azuki bean" and "sugar beet" on the 28th of July but not to those of "Winter wheat" on the 27th of May.

f) Azuki bean

Azuki bean did not have vegetation on the 27th of May. This was similar to all other crops with the exception of winter wheat. Although the vegetation was present on the 28th of July, it turned yellow on the 26th of August. However, the vegetation of azuki bean on the 28th of July is comparatively smaller than that of paddy, soybean and sugar beet. Since the classification accuracy was not high on all three observation days, out of all the pixels, other than the ones being judged as winter wheat, paddy, sugar beet,

onion and soybean, the pixels that were classified as "azuki bean" on both the 28th of July and the 26th of August, but not classified as "winter wheat" on the 27th of May were judged as azuki bean.

(2) Improvement in classification accuracy

The classification result was processed as follows and the accuracy improvement in the classification result was performed.

a) Deletion of isolation pixel

The isolated eight pixels that were surrounding the classified pixels and were not classified into any crop group were deleted from the classification results due to the possibility of misclassification.

b) Correction of minute division

Regarding the minute division of classified crops into other crops that was different from the major ones, these pixels were adjusted into similar crops surrounding the eight pixels.

c) Correction of boundary pixel

When there was a pixel classified into other items in the boundary region (for example, the outer parts of the division classified into certain items), a pixel was adjusted to the items that were regarded as the subject of the division, because it was thought that the pixel in the boundary part could be misclassified.

The result mentioned above and the obtained land-cover classification charts are given in Fig. 2.

(3) Summing up of the classification result

The estimated area of the respective crop was summed up from the acquired land-cover classification map, and the results of these, compared with the statistical information of cities, towns and villages are given in Table 3. The area of each crop classified by the satellite data corresponded well to the statistical area by an accuracy of ±10% for winter wheat, paddy and sugar beet. However, the classification accuracy decreased for soybean, azuki bean and onion.

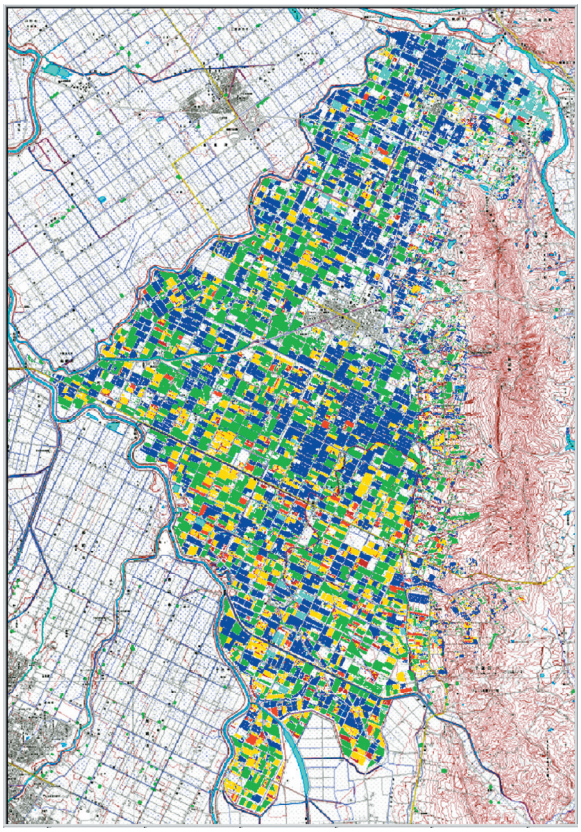

Fig. 2. Distribution map of planted crops in Naganuma Town prepared from the ALOS/AVNIR-2 data

Table 3. Comparison between the estimated areas and the statistical areas

Planted crops	Estimated area (ha)	Statistical area (2006)(ha)	Percentage
Winter wheat	2,524	2,450	103
Paddy	2,992	3,190	94
Soybean	1,201	1,680	71
Azuki bean	224	107	209
Sugar beet	170	187	91
Onion	347	110	315
Total	7,457	7,724	

4. Discussion

1) The comparison between the results of land-cover classification and the actual crop information showed that the classification results corresponded well to the actual crop information for winter wheat, paddy and sugar beet that had high classification accuracy. In the case of paddy fields, the pixels involving ridges were often distinguished as anything other than paddy fields. It was considered to be one of the factors causing the classified area to be smaller than the statistical area.

2) In several cases, soybean was either misclassified as azuki bean or was not classified into any of the six major crops. A large variation in the amount of

growth in the region could be considered a contributing factor, because two or more soybean types with different characters were cultivated in the study area.

3) The classification result of onion turned out to be three times above the statistical area. Although onion fields were classified almost exactly, there were a lot of cases in which other vegetables were misclassified as onion. Leafy vegetables were grown on the study site, and it is thought that the leafy vegetables during the growth period could have possibly been misclassified as onion crop due to their similarity.

4) Although crop items were judged by comparing their multitemporal classification results, the classification was not carried out on anything other than six target crops and there was almost no misclassification concerning forest and urban areas. The features showing that vegetation on farmlands change during the seasons demonstrate that farmland and non-farmland can be distinguished with good accuracy. However, since the barren land in the mountainous and urban areas were misclassified; it is thought that classification accuracy can be further improved by distinguishing the farmland pixels beforehand by combining and using techniques such as the Geographic Information System (GIS).

5) Although the flooding state immediately after the transplant of rice (during late May in Hokkaido) had been a proper time for classification till date, the classification accuracy on the 27th of May was not very high. The observation wavelength used for the classification ranged from visible wavelengths to nearly infrared wavelength regions. The short-wavelength infrared region, which is suitable for distinguishing water bodies, could possibly be a factor for not having been observed. Based on the satellite data of late May, Kusume et al. 2004 reported low classification accuracy in the paddy fields where wavelengths ranging from visible to nearly infrared were used for soil with especially a lot of humus content (i.e. peat soils). The major soil types used in the study site were Gleyic and Histic soils (Hokkaido Central Agricultural Experiment Station 2008). The result indicated a possibility of influences from soil conditions on classification accuracy. However, even the ALOS/AVNIR-2 data that do not observe the short-wavelength infrared region were able to classify paddy with high accuracy rates by using the multitemporal data in which the short-wavelength infrared region was not observed.

6) In addition, the improvement in accuracy is expected to be based upon classifying the items in each field by a combined use of GIS data (Takahashi et al. 2003, Kusume et al. 2004). This is because the summation of the classified area is carried out using the unit of pixels.

5. Conclusions

1) The supervised classification of the six major crops (winter wheat, paddy, soybean, azuki bean, sugar beet and onion) in the paddy field region in Hokkaido was carried out using the multitemporal ALOS/AVNIR-2 data, and the accuracy of classification was examined. The results showed that the accuracy of classification varied according to the observation day. The accuracy was above 95% for the winter wheat, paddy and sugar beet while was below 95% for soybean, azuki bean and onion on each observation day.

2) The land-cover classification of the whole study area using the data from the three observation days showed that the area of the classified crops of winter wheat, paddy and sugar beet was estimated with a ± 10% accuracy compared to that of the statistical area where the accuracy was lower for soybean, azuki bean and onion.

3) Even the ALOS/AVNIR-2 data, in which the short-wavelength infrared region was not observed, were able to classify the paddy field with high accuracy as a result of the use of multitemporal data.

4) Since the use of multitemporal satellite data to classify the land-cover could become a limiting factor at a certain point regarding observation costs and data acquisition, technology for distinguishing crop items with high accuracy using a low satellite observation frequency could be made possible by the combined uses of information and techniques such as GIS.

Acknowledgements

The ALOS/AVNIR-2 data used for the analysis were received from Japan Aerospace Exploration Agency (JAXA) as part of the activities of the Satellite Remote Sensing Promotion Committee and the crop information was received from the Naganuma

Agricultural Association. We wish to express our gratitude for this.

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JIFS, 6 : 59 − 70 (2009) Original Paper

Relationships between Land Use and River Nutrient in the River Basins of Kitakami River and Ishikari River Using Remote Sensing and GIS

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Abstract

Land uses of the Kitakami River and Ishikari River basins were determined using remote sensing and GIS, and the relationships between land uses and the nutrient concentrations of river water were investigated. The classes of land uses were as follows, coniferous forest (C-forest), broad-leaved forest (B-forest), paddy field (Paddy), cultivated field or grassland (Culti or Grass), low vegetation or bare soil (Low Vege or Soil), urban area (Urban Area) and water body (Water Body). There were positive correlations between the area rate of Paddy, Culti or Grass and Urban Area and, total nitrogen (T-N) and total phosphorus (T-P), and between Low Vege or Soil and T-N. There were negative correlations between B-forest and, T-N and T-P. The results suggested that N and P in the river water were mainly supplied from agricultural area and urban area more than forest. We compared the elemental ratio of the river nutrients with Redfield ratio, using existing report. The Si ratio was high in the both river comparing with Redfield ratio. Therefore, it was considered that the red tide of dinoflagellate was not caused easily in the coastal ocean near the mouth of the Kitakami River and the Ishikari River. It was suggested that the nutrients supplied from agricultural area and urban area were not cause of red tide and contributed to the growth of diatoms.

Introduction

Phytoplankton is a primary producer in the sea. The production is bigger in the coastal ocean than in the middle of ocean. Nitrogen (N), phosphorous (P) and silica (Si) are essential nutrients for phytoplankton, especially for diatom. In the coastal ocean, the main supply of these nutrients is considered river water. Such nutrients in the river water are influenced by the land use of the river basin. Therefore the relationships between land uses of river basin and the nutrients in the river water are important for the environment and fishery in the coastal ocean.

There are a lot of studies about relationships between land uses and river water or seawater as pollution at coastal ocean. For example these are urbanization (e.g. Yuan, 2008; Tang, 2005), soil erosion (e.g. Ning et al., 2006; Tanaka et al., 2003) and red tide caused by the excess supply of nutrients (e.g. Magnien et al., 1992; Cloern, 1996; Li et al., 2005; Livingston, 2007; Hayashi et al., 2008). However, it is said that the nutrients flowed out from broad-leaved forest are important for the phytoplankton in the coastal ocean. Therefore, it is necessary to study relationships between all land use of whole river basin and river nutrients as for the supply nutrients for phytoplankton from the land into the coastal ocean.

In this paper, we studied the relationships between land uses of whole river basin and the nutrients in the river water. The investigations of river water quality at the main river have been performed by the Ministry of Environment of Japan. We can use the results of those investigations. Therefore we use the concentrations data of T-N and T-P in the results. We analyzed land use of river basin using remote sensing and GIS.

Dinoflagellate is the main cause of the red tide that gives fishery damages. It is considered that diatom is dominant phytoplankton in the ocean when Si is rich, and the red tide that is the cause of dinoflagellate is not generated. However, when N or P is excess, dinoflagellate is dominant and causes red tide. The nutri-

ents balance is important in the ocean. Therefore, we discussed that the nutrient contributed to growth of diatom or whether it caused the red tide.

Target Area

The target areas of the study were the river basins of the Kitakami River and the Ishikari River (Fig.1). The Kitakami River passes through in Iwate and Miyagi Prefecture in the northeast of Japan, and the river has the biggest river basin in Tohoku district of Japan. The distance of north-south and east-west is about 190 km and 100 km, respectively, and the area of the river basin is about 10,200 km^2. Most part of the Kitakami River basin is included in Iwate Prefecture. The annual average temperature is 10.0 centigrade and the annual precipitation is 1,254 mm in Morioka city that is the prefectural capital of Iwate Prefecture (Morioka meteorological observatory HP, 2008). The Ishikari River passes through the west of Hokkaido, and the river has the biggest river basin in Hokkaido. The distance of north-south and east-west is about 170 km and 200 km, respectively, and the area of the rive basin is about 14,500 km^2. The annual average temperature is 8.5 centigrade and the annual precipitation is 1,100 mm in Sapporo that is the prefectural capital of Hokkaido (Sapporo city office HP, 2008).

Used Data

The used satellite data are listed in Table 1. Landsat/TM or Terra/ASTER images observed in two seasons were used to make land use maps. The 50 m resolutions digital elevation model (DEM) was used to calculate the whole river basin and the river basin at each sampling point of river nutrients. The DEM data were produced by Geographical Survey Institute. The DEM of the Kitakami River basin was edited by Dr. Yokoyama of Iwate University. The river basin polygons separated into some small river basin were used to modify the river basin made from the DEM.

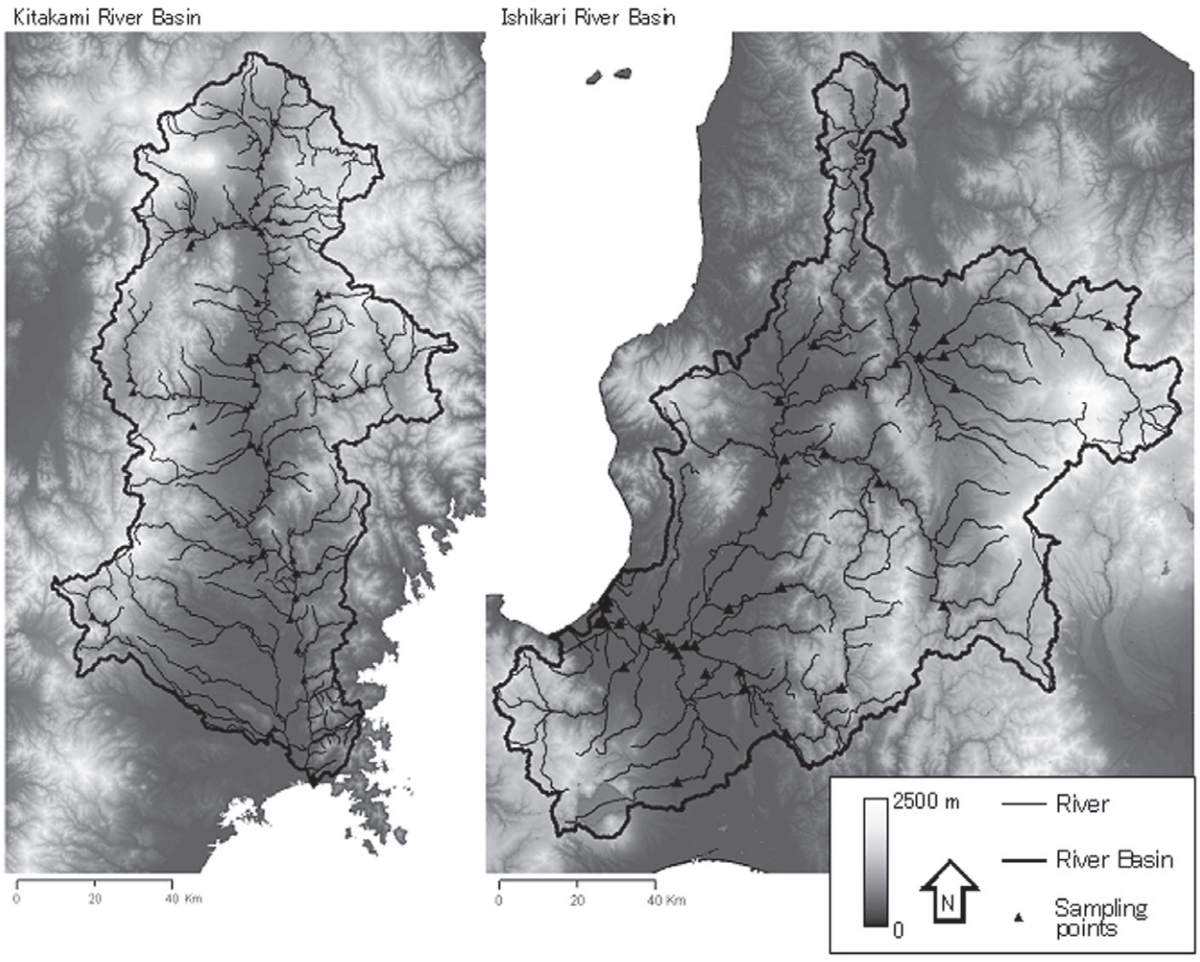

Fig.1. Location of the Kitakami River Basin and the Ishikari River Basin
The sampling points of river water were 55 points in the Kitakami River and 26 points in the Ishikari River.

Table 1. The used satellite data to make land use maps

	satellite/sensor	observed date	using band
Kitakami River Basin	LANDSAT/TM	11-Jul-00	1 - 4
	Terra/ASTER	21-Sep-00 24-Oct-00 7-Jun-02 2-May-03 7-Jul-04	1 - 9
Ishikari River Basin	LANDSAT/TM	12-Jun-95 11-Jul-00	1 - 4
	Terra/ASTER	18-Oct-04 2-Jul-06	1 - 9

That polygon data were downloaded from the website of Ministry of Land, Infrastructure, Transport and Truism in Japan (Ministry of Land, Infrastructure, Transport and Truism, 2007). The concentration data of total-nitrogen (T-N) and total-phosphorous (T-P) were downloaded from Ministry of Environment in Japan (Ministry of Environment in Japan, 2007). The river nutrients were investigated once in two months in the Kitakami River and once a month in the Ishikari River. There were 55 sampling points in the Kitakami River and 26 points in the Ishikari River. The points were listed in Fig.1.

Methods

Process of the methods was showed in Fig.2. First, Unsupervised classification was performed on the satellite images to make land cover maps. We interpreted the classes of land cover using spectral information. The land use maps were produced by the overlay method using the land cover maps of two seasons. We classed the land use map into 7 classes. They were coniferous forest (C-forest), broad-leaved forest (B-forest), Paddy field (Paddy), cultivated field or grassland (Culti or Grass), low vegetation or bare soil (Low Vege or Soil), urban area (Urban Area) and water body (Water Body). Culti or Grass included the vegetation area of riverside. Low Vege or Soil included the vegetation area around top of mountains. Second, river basins at each sampling point were produced using 50 m resolutions DEM and were modified using the polygon data of small river basins and a 1:25,000 topographic map. Third, the land use map was extracted by the basins of each sampling point and the area rate of land use of each river basin was calculated. Finally, the coefficients of correlation between the area rate of land use and the concentrations of T-N and T-P were calculated.

Results

The land use maps of the Kitakami River basin and the Ishikari River basin were showed in Fig.3 and Fig.4, respectively. The area rates of land use in the whole river basin of Kitakami River and Ishikari River were showed in Fig.5. In the Kitakami River basin, forest covered 68 %. C-forest was 30 % and

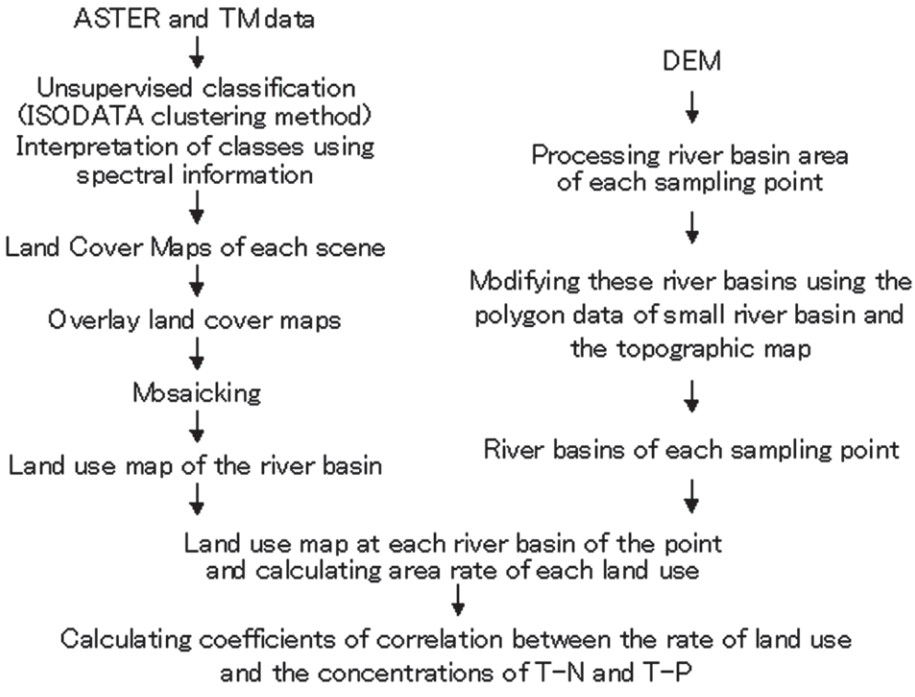

Fig.2. Flowchart of procedure

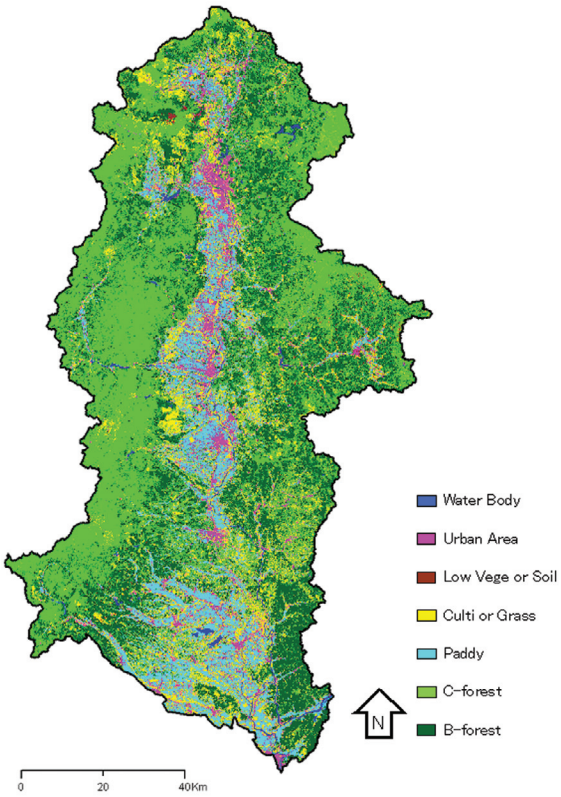

Fig.3. The land use map of Kitakami River Basin
The land use map was classed into 7 classes.

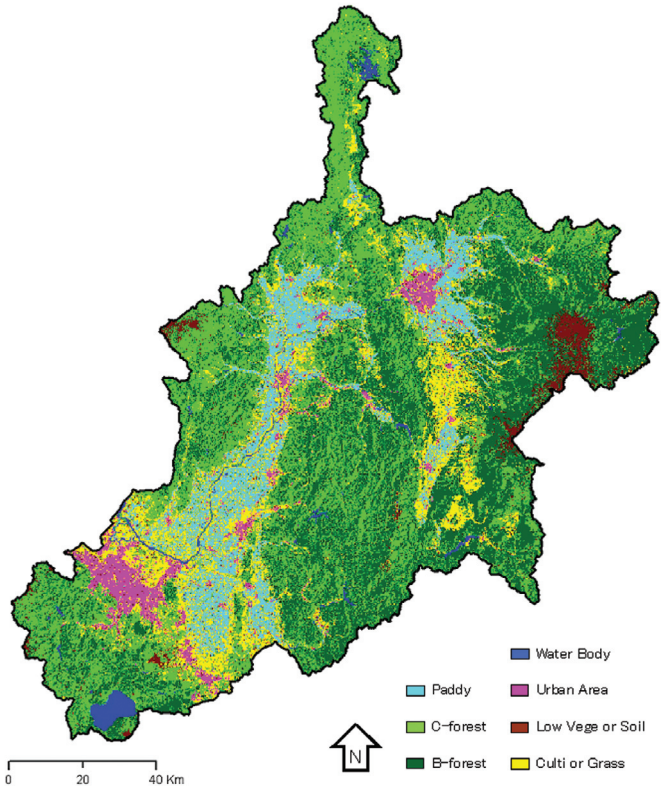

Fig.4. The land use map of Ishikari River Basin
The land use map was classed into 7 classes.

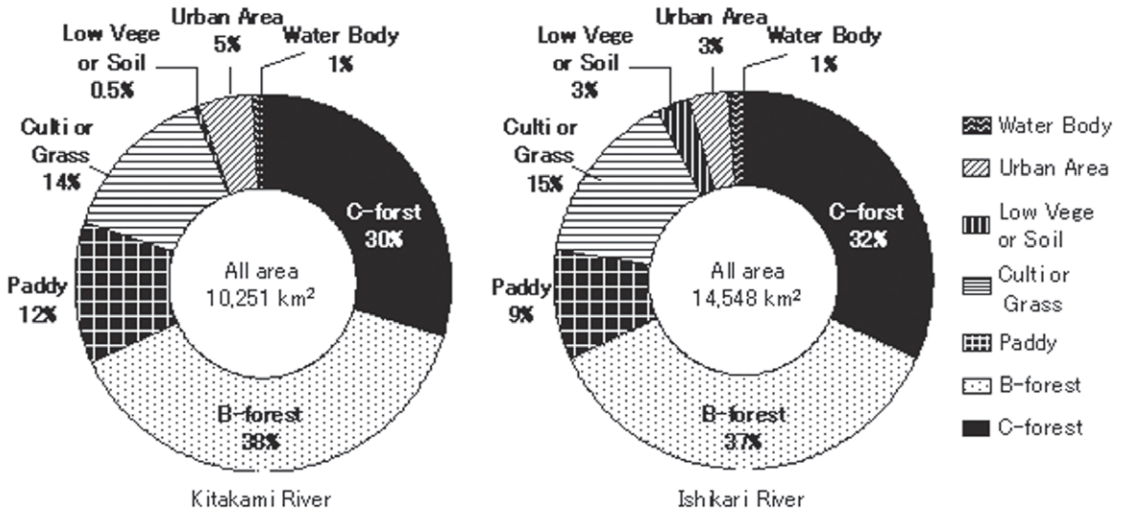

Fig.5. Area rate of land use in the Kitakami River basin and the Ishikari River basin

B-forest was 38 % in the river basin. Paddy, Culti or Grass, Low Vege or Soil, Urban Area and Water Body covered 12 %, 14 %, 0.5 %, 5 % and 1 %, respectively. Paddy and Urban Area are located in the middle part of river basin. Paddy and Urban Area were along the Kitakami River and were low and flat area. In the Ishikari River basin, the forest covered 69 %. C-forest was 32 % and B-forest was 37 %. Paddy, Culti or Grass, Low Vege or Soil, Urban Area and Water Body covered 9 %, 15 %, 3 %, 3 % and 1 %, respectively.

The relationships between the area rate of land use and, the elevation and slope were investigated (Fig.6). In the Kitakami River basin, most part of the Paddy and Urban Area distributed at 0-200 m of elevation and 0-5 degree of slope. The Culti or Grass distributed at 0-400 m of elevation and 0-10 degree of slope. The low elevation area was used to urban area and agricultural area, and the flat area more than 70 % in the low elevation was used as agricultural area. Culti or Grass of high elevation area was mostly used as pasture field. The area rate of B-forest increased with increasing of elevation and slope. However, the area rate of C-forest peaked at 201-400 m of elevation and 11-20 degree of slope. In the Ishikari River basin, most part of the Paddy and Urban Area also distributed at 0-200 m of elevation and 0-5 degree of slope. The Culti or Grass distributed at 0-400 m of elevation and 0-10 degree of slope. The Low Vege or Soil over 801 m of elevation and 21 degree of slope was considered the area around top of mountains. The B-forest distributed as same rate at 51-800 m of elevation and over 1 degree of slope. The area rate of C-forest increased with increasing of elevation and slope.

The coefficients of correlation between the area rate of land use and concentrations of T-N and T-P were showed in Table 2 and Table 3. The concentrations of T-N and T-P were the average concentrations of each period from 2001 to 2005 in Kitakami River and from 2003 to 2005 in Ishikari River. In the Kitakami River basin, there were positive significant correlations between the area rate of Paddy, Culti or Grass and Urban Area and, T-N and T-P. There were negative significant correlations between B-forest and, T-N and T-P. In the Ishikari River basin, there were also positive significant correlations between the area rate of Paddy, Culti or Grass and Urban Area and, T-N and T-P. There was negative significant correlation between B-forest and T-N. The Fig.7 and Fig.8 showed the relationships between the area rates of major land use and the concentrations of T-N and T-P in the Kitakami River and the Ishikari River basin. The concentrations showed the average at all periods in the Kitakami River and the Ishikari River. In the Kitakami River, there were high positive correlations between Culti or Grass and Urban Area and, T-N, Paddy and Urban Area and, T-P. There was high negative correlation between B-forest and T-N. In the Ishikari River, There were high positive correlations between Paddy, Culti or Grass and Urban Area and, T-N, and Paddy and Culti or Grass and, T-P.

Discussion

The positive correlations suggested that the concentrations of T-N and T-P were increased with in-

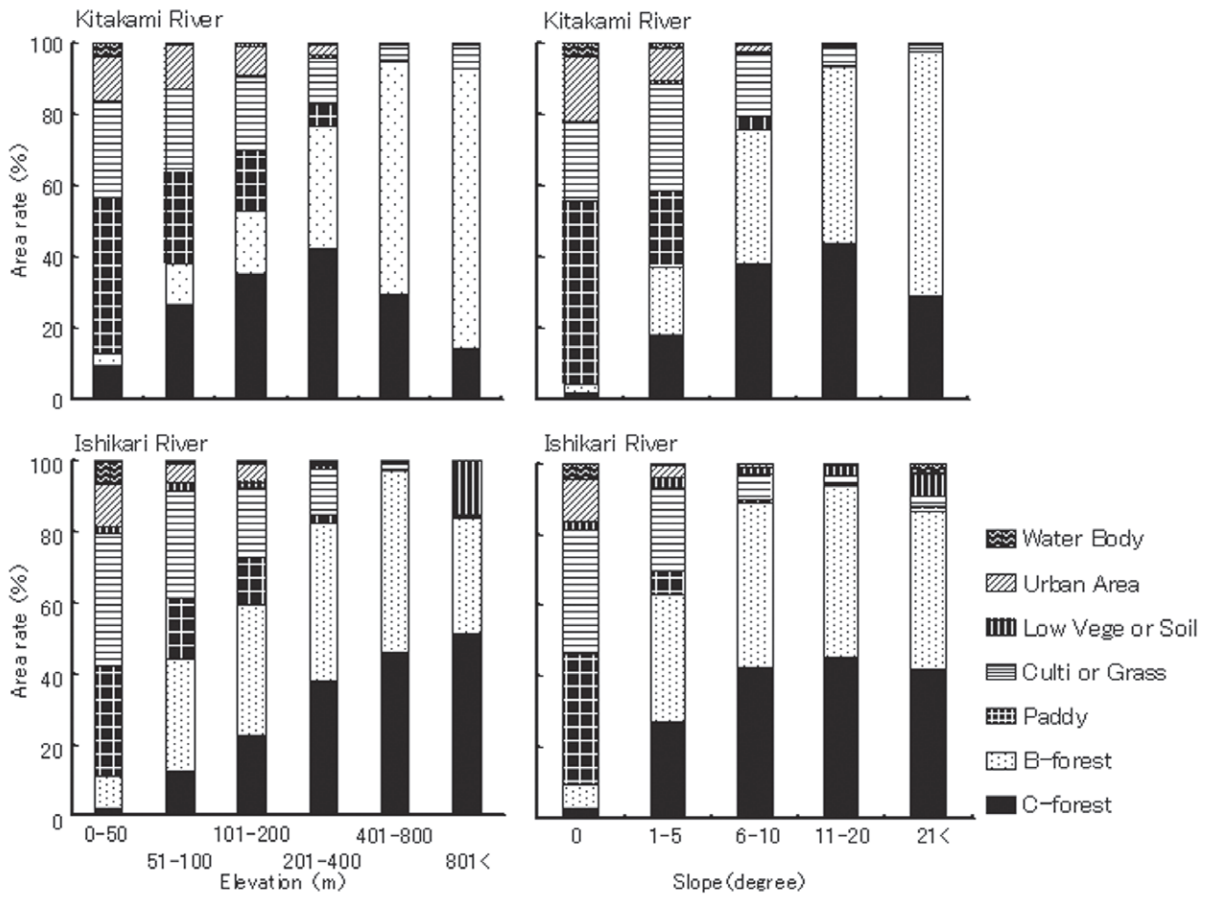

Fig.6. The relationships between the area rate of land use and the elevation and slope
The slope was calculated by the 50m DEM.

creasing the area rate of Paddy, Culti or Grass and Urban Area in both rivers. It was considered that the origin of the nutrients from the agricultural area was fertilizer, plant residual and livestock manure, and the origin from the urban area was domestic and industrial drainage.

At the Kitakami River, the negative correlations suggested that the concentrations of the T-N decreased with increasing the area rate of B-forest. It has been reported that the concentration of nitrogen in run-off water was lower than in the precipitation, that was because it was considered that nitrogen was used by trees and adsorbed to soil (Tokuch et al., 1991). Therefore, in our study, the nutrients of river water were decreased by the utilization of vegetation in a broad-leaved forest. On the other hand, at the Ishikari River, there was no correlation between the area rate of B-forest and the concentration of T-N. The B-forest distributed at low elevation and low slope area (Fig.6). B-forest, Paddy and Culti or Grass were mixed at the low elevation and low solpe. Therefore, it was considered that the effect of absorption of nutrients by B-forest was denied by the effect of these agricultural areas.

It has been reported that the concentration of T-N in the river water decreased with increasing of forest area in the region of subtropical monsoon climate in China (Yang et, al., 2007), and the nitrate levels decreased with increasing of the forest area or decreasing of agricultural land in the subtropical region of USA (Basnyat et al., 1999 and Basnyat et al., 2000). In those researches, they did not divide forest into coniferous forest and broadleaved forest. In our study, there were different results of correlations between B-forest and C-forest. There was negative correlation between B-forest and, T-N and T-P, but there was no correlation between C-forest and, T-N and T-P, in the Kitakami River (Table 2 and Fig.7). About 99 % of the broadleaved forest in Iwate and Miyagi prefecture was a natural forest and more than 90 % of the coniferous forest in these prefectures was an artificial forest (Ministry of Agriculture, Forestry and Fisheries, 2005). The C-forest distributed in lower area of slope and elevation than B-forest (Fig.6). The coniferous

Table 2. The coefficients of correlation between the area rate of land use and concentrations of T-N and T-P at the Kitakami River Basin

		C-forest	B-forest	Paddy	Culti or Grass	Low Vege or Soil	Urban Area
T-N	Apr-May	0.25	-0.65**	0.31*	0.62**	0.31*	0.61**
	Jun-Jul	0.30*	-0.48**	0.19	0.32*	0.45**	0.30*
	Aug-Sep	0.29*	-0.68**	0.39**	0.56**	0.39**	0.55**
	Oct-Nov	0.23	-0.72**	0.52**	0.63**	0.20	0.64**
	Dec-Jan	0.13	-0.67**	0.54**	0.64**	0.12	0.75**
	Feb-Mar	0.13	-0.69**	0.54**	0.68**	0.14	0.71**
T-P	Apr-May	-0.26	-0.43**	0.69**	0.56**	0.04	0.76**
	Jun-Jul	-0.11	-0.44**	0.65**	0.49**	0.02	0.47**
	Aug-Sep	-0.18	-0.38**	0.68**	0.45**	-0.05	0.44**
	Oct-Nov	-0.13	-0.43**	0.65**	0.51**	-0.10	0.52**
	Dec-Jan	-0.33*	-0.26	0.62**	0.39**	-0.09	0.62**
	Feb-Mar	-0.25	-0.39**	0.68**	0.52**	-0.04	0.63**

The sampling points were 55. The concentrations were the average from 2001 to 2005.
* 95% significant level, ** 99% significant level

Table 3. The coefficients of correlation between the area rate of land use and concentrations of T-N and T-P at the Ishikari River Basin

		C-forest	B-forest	Paddy	Culti or Grass	Low Vege or Soil	Urban Area
T-N	Apr	-0.08	-0.51**	0.57**	0.62**	-0.08	0.54**
	May	-0.23	-0.46*	0.76**	0.76**	-0.15	0.50**
	Jun	-0.06	-0.54**	0.61**	0.62**	-0.07	0.50*
	Jul	-0.30	-0.34	0.57**	0.71**	-0.16	0.64**
	Aug	-0.12	-0.49*	0.64**	0.68**	-0.11	0.53**
	Sep	-0.17	-0.33	0.52**	0.60**	-0.20	0.57**
	Oct	-0.19	-0.34	0.55**	0.63**	-0.19	0.59**
	Nov	-0.13	-0.50**	0.59**	0.63**	0.01	0.58**
	Dec	-0.13	-0.45*	0.57**	0.66**	-0.16	0.56**
	Jan	-0.18	-0.35	0.60**	0.58**	-0.13	0.53**
	Feb	-0.19	-0.33	0.60**	0.56**	-0.14	0.57**
	Mar	-0.25	-0.37	0.72**	0.69**	-0.20	0.53**
T-P	Apr	-0.16	0.00	0.18	0.32	-0.30	0.27
	May	-0.37	-0.04	0.44*	0.44*	-0.23	0.72**
	Jun	-0.49*	-0.06	0.54**	0.60**	-0.19	0.65**
	Jul	-0.58**	0.08	0.45*	0.59**	-0.28	0.57**
	Aug	-0.44*	0.04	0.46*	0.50*	-0.32	0.53**
	Sep	-0.10	0.13	-0.02	0.14	-0.37	0.26
	Oct	-0.37	-0.02	0.40*	0.55**	-0.32	0.52**
	Nov	-0.32	-0.13	0.42*	0.57**	-0.24	0.56**
	Dec	-0.21	-0.17	0.36	0.41*	-0.19	0.65**
	Jan	-0.31	-0.18	0.49*	0.47*	-0.10	0.73**
	Feb	-0.31	-0.18	0.51**	0.47*	-0.12	0.74**
	Mar	-0.30	-0.19	0.60**	0.47*	-0.16	0.64**

The sampling points were 56. The concentrations were the average from 2003 to 2005.
* 95% significant level, ** 99% significant level

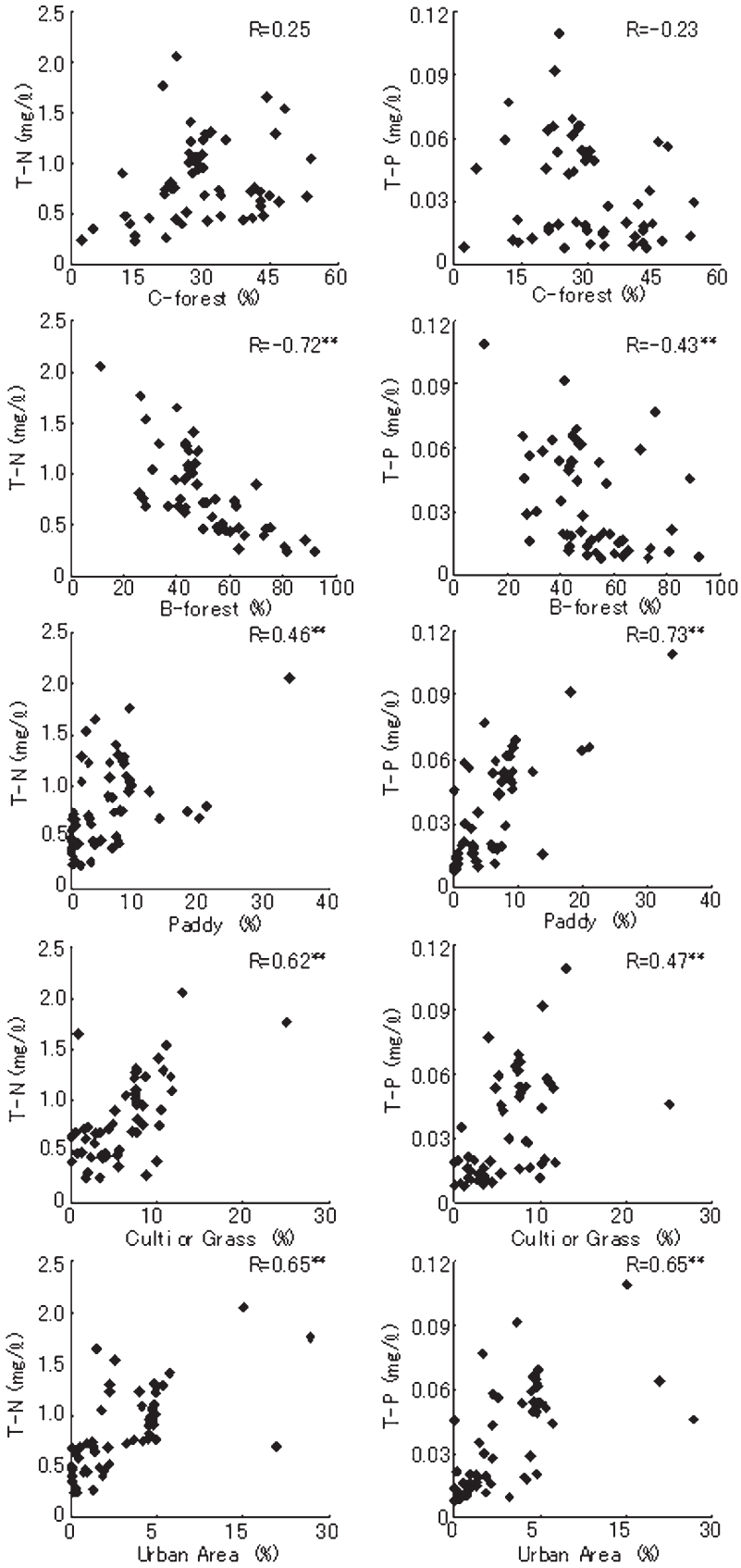

Fig.7. Relationship between the area rate of major land use and the concentrations of T-N and T-P at the Kitakami River Basin

The sampling points were 55. The concentrations were the average in all period from 2001 to 2005. * 95% significant level, ** 99% significant level

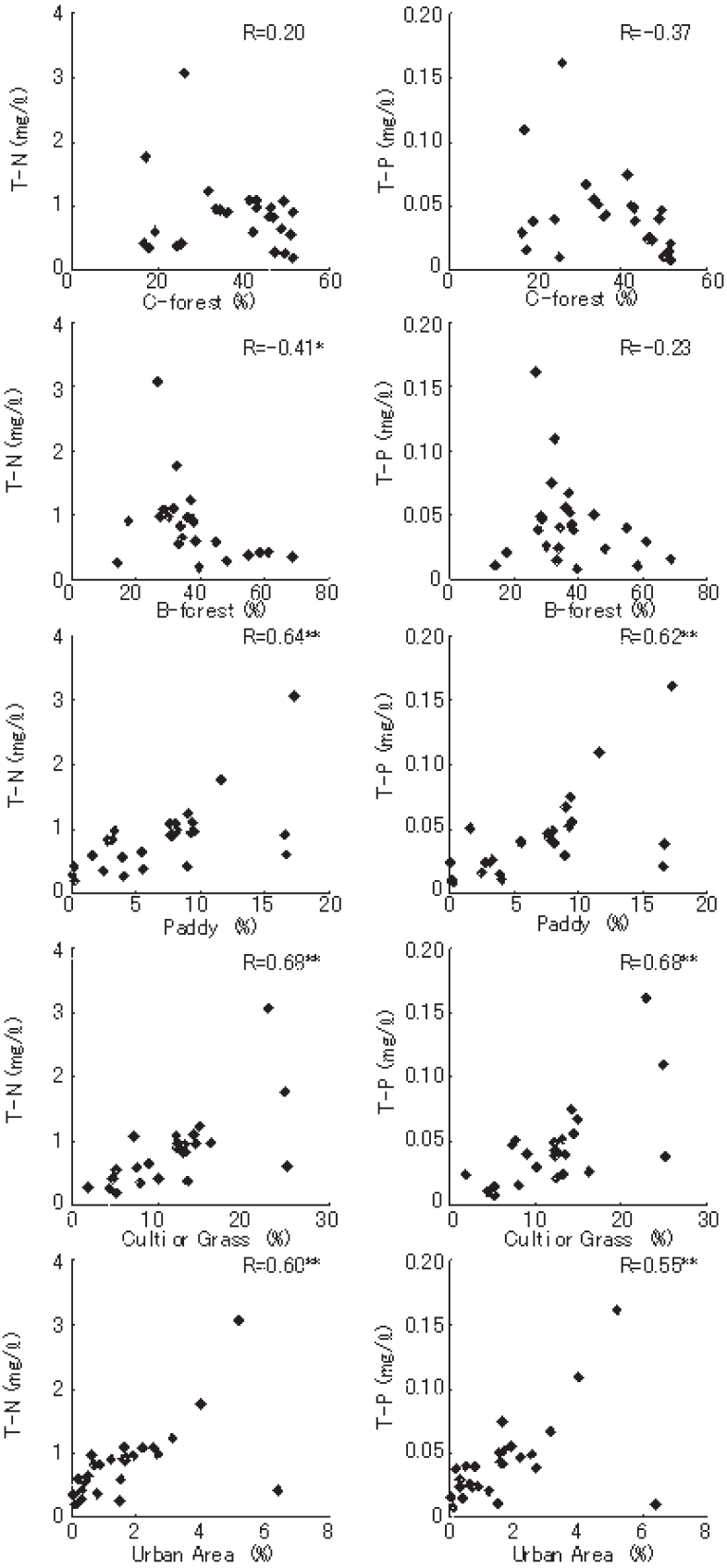

Fig.8. Relationship between the area rate of major land use and the concentrations of T-N and T-P at the Ishikari River Basin

The sampling points were 26. The concentrations were the average in all period from 2003 to 2005. * 95% significant level, ** 99% significant level

trees are planted for timber production. Therefore the coniferous forest was afforested in the area of easy management. However, the artificial forest has not been managed and that caused the degradation of the coniferous forest, because of low price of the timber. It is suggested that the uptake of nitrogen by the coniferous tree is decreased and the nitrogen flows out to the stream in older coniferous forest (Ohrui et al., 1997). In the degraded coniferous forest, it was considered that the manure or compost was applied to the artificial coniferous forest for fertilizer and the uptake of nitrogen by the coniferous trees decreased, and the nitrogen flowed out to the stream.

The Redfield ratio is famous ratio of the nutrient balance for diatom. That is C : N : P = 160 : 16 : 1(Redfield et al., 1963). The growth of diatom is limited by the nutrient that is smaller than that ratio. We used the Redfield ratio including Si and Fe (Redfield et al., 1963; Martin et al., 1989; Harashima, 2003) for the nutrients balance and compared the Redfield ratio with elemental ratio in the Kitakami River and the Ishikari River water. We could not get the Si and Fe data of both river water, and we used the data reported by Kobayashi (1961). Two sampling points in the Kitakami River and four sampling points in Ishikari River in the Kobayashi's paper were the near points in this study. The Eai River is a branch of the Kitakami River, and the Yuubari River, Chitose River and Toyohira River are branches of the Ishikari River. The concentrations of nutrients and elements ratio were showed in Table 4. In the 1950s, the P ratio was lower than the Redfield ratio. Although N and P concentration have been increased in the 2000s, especially P increased, the P ratio was also lower than the Redfield ratio. In the 2000s, the Si ratio has been tenth than a part of the 1950s ratio. Nevertheless, Si ratio in the 2000s has been higher than the Redfield ratio's. Therefore, it was considered that the dinoflagellate did not easily caused red tide in the coastal ocean near the mouth of the Kitakami River and the Ishikari River.

Conclusion

The relationships between area rate of land uses and river nutrients were investigated in the Kitakami River and the Ishikari River basin. There were positive significant correlations between the area rate of Paddy, Culti or Grass and Urban Area and, T-N and T-P. There were negative significant correlations between B-forest and, T-N and T-P. It was suggested that the concentrations of the nutrients increased with increasing the area rate of agricultural area and urban area, and the concentrations decreased with increasing the area rate of broad-leaved forest. There were different results of correlations between B-forest and C-forest, because C-forest was an artificial forest and degraded. The results suggest that N and P in the river are mainly supplied from agricultural area and urban area more than forest. We compared the elemental ratio of the river nutrients with Redfield ratio, using existing report. The P ratio was lower than the Redfield ratio both in 1950s and 2000s. The Si ratio was high in the both river comparing with the Redfield ratio. It was considered that diatom was dominant species in the coastal ocean into which the Kitakami River and the Ishikari River flow. Therefore, it was suggested that the nutrients supplied from agricultural area and urban area were not a cause of red tied but also contributed to the growth of diatoms.

Table 4. The concentrations and elemental ratio of the nutrients in the Kitakami River water in 1950s and 2000s.

		1950s				2000s			
		NO_3-N + NH_4-N	PO_4-P	SiO_2-Si	Fe*	T-N	T-P	SiO_2-Si	Fe*
concentration (mg/ℓ)	Kitakami river	0.34	0.003	9.1	0.48	0.52	0.043	-	-
	Eai river	0.14	0.003	15.6	0.32	0.96	0.049	-	-
	Ishikari river	0.71	0.006	9.8	1.17	0.84	0.055	-	-
	Yuubari river	0.75	0.003	5.8	0.25	0.61	0.057	-	-
	Chitose river	0.12	0.006	15.6	0.01	1.70	0.076	-	-
	Toyohira river	0.25	0.003	9.8	0.22	0.40	0.055	-	-
elemental ratio	Kitakami river	229	1	3071	87	26	1	227	6
	Eai river	94	1	5233	58	42	1	339	4
	Ishikari river	238	1	1637	106	33	1	190	12
	Yuubari river	504	1	1943	45	23	1	109	3
	Chitose river	40	1	2624	1	48	1	221	0
	Toyohira river	168	1	3274	40	16	1	188	2
	Redfield ratio	16	1	16-50	0.003-0.035	16	1	16-50	0.003-0.035

*Fe shows the total Fe.

The concentrations of nutrients in 1950s were quoted from Kobayashi (1961), the concentrations of Si and Fe in 2000s were quoted from Kobayashi (1961). The concentrations of T-N and T-P were the average of all period from 2001 to 2005. The ratio of N and P were quoted from Redfield et al., 1963, Fe was quoted from Martin et al,. 1989 and Si was quoted from Hirashima, 2003. The Eai river is a branch of the Kitakami River. The Yuubari river, Chitose river and Toyohira river are branches of the Ishikari River.

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Current State of Multipurpose Co-operatives in Japan, Revealed by an Attitude Survey of Rural Inhabitants

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Keywords: Japan Agricultural Cooperative, JA, multipurpose co-operatives, community needs.

Abstract

Japan Agricultural Cooperative (JA) is a major economic force in rural Japan and the local communities that comprise it. The present dramatic ageing of the population and falling birthrate in agricultural areas threaten the survival of these communities. As JA originated from mutual aid associations of small-scale farmers, based on cooperation, what kind of role can JA play in today's Japan? We conducted a questionnaire survey of all households in 29 rural settlements. Our general aim was to clarify the types of services currently needed by rural communities. We also personally interviewed 20 farmers. Our results indicate that many local residents ranked medical service, welfare and education as the most essential services for their communities. However, most of those surveyed and interviewed preferred these kinds of services to be run by local administrations (public agencies), reflecting low expectations of JA.

1. INTRODUCTION

After its defeat in WWII, Japan faced two major challenges in relation to agricultural policies. One was to institute thorough democratization by means of agrarian reforms. The other was to resolve food shortages. The Agricultural Cooperative Association Law was enacted as a part of this effort. These agrarian reforms were aimed largely at breaking the hold of landowners on vast areas of land, which had become entrenched before and after the war, and also to resolve problems of farmer tenancy. As a result of these reforms, the proportion of tenanted land in Japan dropped from 46% to less than 10%, and a unique agricultural structure emerged, unlike that anywhere else in the world, combining small-scale land ownership and small-scale farm management (Yamazaki [11, pp.1078-1079]). This pattern of agriculture was the background to the formation of Japan Agricultural Cooperatives (hereinafter JA). A key characteristic was their multiple purposes (Bannai [1, pp.15-8]). Each organization tried to maximize a diversity of economic benefits through collaboration between small farmers, by operating various different businesses, including banking, sales, purchasing and agricultural consulting. A brief history of the JA movement follows, based on research by Saeki [9], Miwa [8], The Norinchukin Bank [6], and others.

JA was first established in December 1947 as a vehicle to guide the process of democratization and agricultural reform in rural Japan. However, it eventually fell into widespread and significant financial difficulty due to weak business practices (Miwa [8, p.36]). During this period of high economic growth, agricultural production began to fall further and further behind manufacturing industry production. In order to prop up the agricultural industry, in June 1961, the Japanese government enacted the Agricultural Basic Law to usher in a new set of agricultural policies. The central pillar of this reform was the 'Agriculture Structural Reform Initiative', launched in 1962. This programme aimed especially at expanding the scale of business operations, promoting collaboration and correcting the prevailing income disparity between workers in the agricultural and manufacturing indus-

tries (Saeki [9, pp.62-3]).

Since then, JA has, broadly speaking, carried out two major organizational reforms through two sets of 'mergers'. In parallel with these mergers, JA also pursued business reforms. The first mergers were aimed at adapting new administrative districts, resulting from the mergers of towns and villages, throughout the 1950s and 60s. During this period, the merger of JA was achieved through 'selective expansion of farm household entities' as a matter of policy. This set of mergers also focused on establishing appropriate systems among geographically scattered minority groups of large scale farmers, who specialized in livestock, horticulture, and other non-rice products (Miwa [8, p.38]). The mergers included measures to bolster the business operations of JA. The second set of mergers was conducted in response to financial deregulation after 1985. In this way, the mergers that took place in the late 1980s aimed to strengthen JA's management systems and administrative functions, and enhance its banking business. At the same time, JA's three-tiered organizational structure—municipal JA at the lowest level (the end organization), prefectural JA (intermediate organization) at the middle level, and national JA at the highest level—was reviewed (The Norinchukin Bank [6, p.95]).

JA's business operations and the expansion of its services were also reviewed between the two sets of mergers, which took place all over Japan. A major turning point in this respect came with the 'basic lifestyle concept', adopted at the 'National JA Meeting' in 1970. This concept emphasized JA's involvement in providing a complete range of services not related directly to agriculture. This move was a response to the increase in urbanization and mixed-livelihood households in traditional rural areas, as growing numbers of JA-member farming households took up secondary employment or set up businesses during this period of relentless economic growth (Bannai [1,p.31]). Another factor behind JA's expansion of services was the growing number of urban workers migrating to rural areas. In 1972, annual household expenditure per head of wage-earning household was 300,000 yen, in contrast to 310,000 yen of expenditure per head of farming household. For the first time since the Meiji period—a span of more than 100 years—the household expenditure of farming households exceeded that of wage-earning households in urban areas, demonstrating that JA's 'basic lifestyle concept' was indeed a turning point (Saeki [9, p.40]). This concept was undoubtedly a response to socioeconomic trends rather than the demands of agricultural communities arising from increasing agricultural productivity, the resulting rise in agricultural income of JA members, or other reasons. The reform of JA was implemented in response to factors external to the agricultural industry, such as the growth in income from secondary sources, and the earnings derived from selling off farm land as urbanization progressed, thus increasing the number of mixed-livelihood rural households. The second set of JA mergers, which began in the second half of the 1980s, also focused on dealing with management issues facing JA, in response to financial deregulation. In this way, these mergers did not reflect the desires of JA members, nor were they founded on any logical concept.

Today, in all parts of rural Japan, the livelihoods of those whose primary occupation is farming are under pressure as the prices of agricultural commodities decline due to the internationalization of agriculture under the WTO system and the intensification of rice output adjustments resulting from excessive production. In addition, the downward pressure on population due to a falling birthrate and ageing is starting to pose a threat to the very survival of local communities. It is reasonable to conclude that agricultural areas of Japan are sustained largely by the income that farmers earn from secondary activities. This situation calls into question the current justification for JA's existence as a cooperative organization of farmers. Most current JA members are small-scale farmers. This concept dates back to a time when there was a significant disparity between the income of those working in agriculture and those working in industry. However, the *mura* (rural agricultural community) has changed significantly since the time of JA's inception in the wake of WWII—an era of a homogeneous society and independent farmers. Particularly since the 1990s, rural communities have become increasingly diverse in terms of occupations, although they remain permanently settled (Nakajima [5, p.18]). It is now widely believed that because the trends toward mixed habitation and secondary income sources have accelerated dramatically, JA, traditionally organized on the principles of a cooperative organization, faces conflicting demands. As the strongest economic force in rural areas, the JA movement must urgently exam-

ine what it can do to preserve Japan's rural communities, as well as its own existence, and then act accordingly.

Many discussions have been held to envision the ideal form of a future JA. One stated ideal is to run JA as a business that responds to the needs of JA members. This ideal is referred to as the 'needs theory'. (The historical evolution of the 'needs theory' is explained in detail by Suganuma [10].) In this paper, we will focus the discussion by limiting the topic to the 'needs of JA members and other rural residents (including non-farmers) in relation to JA business'.

Iwatani [2, p.135] pointed out that the honest attitude of farmers towards JA was that it expands its business operations only in areas where it can earn large profits, while neglecting those areas where farmers would prefer it to get involved. In other words, farmers felt that after the first set of mergers, JA has put priority on economic efficiency while disregarding the needs of its members. This comment is quite typical. The interpretation of 'needs' here is very thought-provoking, as demonstrated by an episode related by Iwatani [2, pp.133-134]. On a remote island where transportation is inconvenient, residents previously grew vegetables for their own consumption on narrow terraced fields. However, as the monetary economy pervaded the district, the idea of purchasing vegetables for money took root, allowing people to focus their energies exclusively on earning cash. Thus, they abandoned their vegetable fields. As a result, most of the residents ended up suffering from anaemia. At this time, instead of selling vegetables to the afflicted islanders to help them recover their health, the local JA sold them colour televisions. Additionally, in order to make their repayments for the televisions, the residents had to keep earning cash. This episode, titled 'anaemia and colour televisions', does not address the needs, desires or demands of JA members in relation to the various enterprises of JA—or their degree of satisfaction with JA services. It discusses the 'needs theory' in terms of the question, 'What services do local JA members consider most essential?' In other words, it discusses the 'agriculture and living' needs of local residents—that is, 'community needs'. More specifically, this episode tries to assess the needs on the basis of 'area', representing an entire local community, as opposed to assessing the particular needs of individual JA members. The needs are those related to agriculture and living for the purpose of sustaining a society (community) in the rural (agriculture, forestry, and fisheries) villages of Japan, and to enable a worthwhile human lifestyle. We shall adopt this basic perspective in this paper.

One example of a survey on the degree of satisfaction of JA members was conducted by the Management Auditing Department of the Central Union of Agricultural Cooperatives [7]. The survey found that, of the various kinds of JA activities, the greatest dissatisfaction was felt in relation to 'agricultural technology consulting', 'overall management and business of JA', and 'production material purchasing'. Dissatisfaction focused on agriculture-related activities because of a decline in the level of service to JA members after the 'wider area' mergers. This dissatisfaction may also be related to the fixed management structure of JA, whereby operating losses from agricultural management training, and sale and purchasing operations, are offset by profits generated by financial and insurance services. This structure can be interpreted to mean that the agriculture and lifestyle of residents in agricultural areas are sustained by the profits in fields of business other than agriculture. From the viewpoint of JA management, this interpretation strongly suggests that the services (business operations) needed by residents of agricultural areas (both farm and non-farm households) to ensure that their agricultural activities and livelihoods can be sustained—that is, 'community needs'—serve to indicate the appropriate direction for JA's future business expansion (forming community cooperatives).

Kitagawa [3] focused on welfare for the elderly as an area of business where local needs exist, and conducted a questionnaire survey on JA member interest in welfare for the elderly, as well as their expectations and evaluations regarding the possibility of JA providing such services. The survey considered welfare services as a test to assess whether JA can grow as a cooperative that contributes to local communities. According to the results, JA members are highly interested in welfare for the elderly, and desire to receive information on the subject. However, they hold relatively low expectations of JA as an effective provider of such services. In other words, JA members regard JA as just one of several kinds of service providers they look to, along with private companies. In this paper, this attitude is described as a 'relative view of JA by members'. Of JA's business activities, members tend to rate 'deposits' high, but 'lending'

low. Satisfaction is high overall for mutual aid (life insurance), but low for agriculture-related business, while some members rate oil supply and gasoline stations highly. This survey clearly shows that JA does not need to provide all services required to meet the needs of local communities.

Two questions arise here: (1) Which of their community needs do local inhabitants expect JA to meet by operating a business? (2) Can these business operations be profitable to JA? This paper aims principally at answering the first question through a questionnaire survey and interview survey, as described in the following sections.

2. METHOD FOR CONDUCTING ATTITUDE SURVEY OF RURAL INHABITANTS

This paper aims to elucidate the 'community needs' of rural inhabitants. We conducted a questionnaire survey of rural inhabitants, followed by an interview survey. In the questionnaire, we first asked the rural inhabitants about the extra, current business activities of JA. We asked if these services would be best executed by municipal, prefectural or state governments (public agencies), by JA, or by a private company. Respondents then ranked the most 'essential' and the most 'non-essential' business activities (services) for their communities.

Our first questionnaire survey, conducted in 2005, was directed at full and associate members of each branch office of a merged JA in Kumamoto Prefecture (JA 'A'). The list of business activities (services) in the first questionnaire is shown in Table 1 for '2005'. Many of the items are services that JA 'A' is actually providing. However, because we attempted to assess the need for all JA's business activities, we included too many items in the questionnaire. Perhaps for this reason, the respondents seemed to tire of answering the questions, and many gave up halfway through completing the survey, so that we could draw no clear conclusions from the results. Reflecting on this mistake, we narrowed down the list of business activities for '2006', as shown in Table 1. We thus distributed small-scale questionnaires in Settlement 'B' of Iwate Prefecture (plain area) and Settlement 'C' of Ishikawa Prefecture (rural-mountain area).

Table 2 shows the results of the questionnaire, conducted in 2006, relating to 'essential' and 'non-essential' business activities (services) for life in these rural communities. A small sample number for each settlement, and more than three items in the same order, is denoted by '–'. We can see that 'Medical care facilities', 'Banking' and 'Welfare for the elderly' were ranked as highly essential services. It is noteworthy that 'Sale of agricultural products' and 'Sale of agricultural supplies' are rated as less essential than the services relating to health (medical and welfare services) and finance (banking). The services rated the most 'non-essential' were 'Gambling facilities', 'Travel agencies' and 'Sale of home appliances'. Ironically, JA members regard gambling facilities as 'non-essential', yet pachinko parlours are a very lucrative JA business—so much so that large numbers of pachinko parlours are found in many rural areas. It is also of interest that JA members feel that 'Travel agencies' and 'Sale of home appliances' are 'non-essential' to JA. Overall, residents in rural areas (like urban residents) feel a strong need for medical and welfare services and banking. These businesses do not relate directly to agriculture, but rather to the concern of rural inhabitants about their current situation, threatened by a declining birthrate and an ageing and decreasing population. In addition, we can say that local residents no longer feel the need for travel agencies, which used to be a centrepiece welfare service for JA members.

When preparing for our interview survey, based on the earlier questionnaire survey, we discovered that the person who served as an organizer for the questionnaire survey of Settlements 'B' and 'C' is a JA stakeholder. We had asked that the questionnaire be distributed through the land improvement district cooperative (for Settlement 'B') and the prefectural agriculture and forestry office (for Settlement 'C'). The organizers of the questionnaire were a former JA cooperative president for Settlement 'B' and a JA staff member for Settlement 'C'. In view of these connections, the expression of local needs could not be said to be fair or accurate. In addition, we only received a small number of responses. We therefore decided to conduct the survey again, based on the items for 2007, as shown in Table 1.

We began by asking respondents to specify the kind of organization most suited to providing a specific service—a public agency, JA, or a private company. We then asked them to state which services were most 'essential' and most 'non-essential' for life in their community.

For the 2007 survey, a total of 10 settlements were

selected, with the help of a public office, in Ota-machi, Daisen City, Akita Prefecture—a community that is categorized as 'a rice farming-based plains rural area'. We distributed questionnaires to all households in the area, including non-farming households, through the former Ota-machi municipal office. Later we collected the questionnaires from these households. For the purposes of comparison, we distributed and collected questionnaires from all the farm households (including those with secondary income sources) through municipal offices in a total of 19 settlements in Bando City, Ibaraki Prefecture, which

Table 1. Questionnaire items

Implementation (fiscal) year	Specified items
2005	Gasoline stations (SS); LP gas sales; agricultural technology consulting; laundering; shipping of farm and livestock products; building and automobile-related non-life insurance (mutual) underwriting; deposits (savings) management; life insurance (mutual) underwriting; various kinds of agriculture-related lending, e.g., for purchase of farms and farming equipment; retail (home delivery) of food, clothing and daily necessities; sales of fertilizer, agricultural chemicals and household materials such as plastic; indemnification against loss of agricultural (livestock) products due to accidents/disasters; various kinds of lending for ordinary living expenses, e.g., life, education, home; sales and repair of agricultural equipment; sales and repair of automobiles; operation of direct sales outlets for agricultural products; farmland loan mediation; *parcel home delivery business*; lifestyle advisory; cooperative purchasing of fuel (fuel oil, kerosene); operation of rice production/processing facilities (e.g., 'country' elevators); operation of accommodation facilities; travel agencies; *home tuition*; operation of agricultural storage facilities; *mediation of burials and sales of tombstones*; farm work contracting; operation of cooperative fruit grading facilities; operation of community facilities (meeting halls, community centres); supply of housing land; mediation of wedding ceremonies; lifestyle purchasing; welfare for the elderly; brewing and sale of local *sake*; real estate business (agency and maintenance); automobile safety inspections; restaurant and food/beverage businesses utilizing local agricultural products; mediation of funeral ceremonies; operation of healthcare facilities for the elderly; operation of day care facilities
2006	Insurance and pensions; agricultural technology consulting; gasoline stations; banking; sale of agricultural supplies; sale of daily necessities; *medical care facilities*; travel agencies; welfare for the elderly; sale of home appliances; farm work contracting; sale of agricultural products; *gambling facilities*; lifestyle advisory; *nursery facilities*
2007	Insurance and pensions; agricultural technology consulting; gasoline stations; savings (deposits); finance (lending); sale of agricultural supplies; sale of foods and daily necessities; medical care facilities; travel agencies; welfare for the elderly; sale of home appliances; farm work contracting; sale of agricultural products; *gambling facilities*; lifestyle improvement; *nutrition education*; welfare facilities; *sale of PC software*; wedding and funeral venues and mediation; direct sale of agricultural products

The item of the italics body points at the dummy (Those businesses aren't actually being carried out in JA).

Table 2. 2006 questionnaire results

		Settlement 'B' (sample size=28)		Settlement 'C' (sample size=18)	
		Business items	Response (%)	Business items	Response (%)
'Essential' business 1st	1st	Medical care facilities	50.0	Medical care facilities	38.9
	2nd	Banking	30.0	Banking	22.2
	3rd	Sale of agricultural products	10.0	Welfare for the elderly	16.7
'Essential' business 2nd	1st	Welfare for the elderly	26.3	Welfare for the elderly	38.9
	2nd	Sale of daily necessities	21.1	Medical care facilities	16.7
	3rd	Gasoline stations	15.8	–	–
'Essential' business 3rd	1st	Sale of agricultural products	21.1	Lifestyle advisory/medical care facilities	18.8
	2nd	Sale of agricultural supplies	15.8	–	–
	3rd	Nursery facilities	15.8	–	–
'Non-essential' business 1st	1st	Gambling facilities	76.5	Gambling facilities	72.2
	2nd	Travel agencies	17.6	–	–
	3rd	Insurance and pensions	5.9	–	–
'Non-essential' business 2nd	1st	Travel agencies	35.7	Lifestyle advisory	47.6
	2nd	Sale of home appliances	28.6	Travel agencies	20.0
	3rd	Farming advisory	14.3	–	–
'Non-essential' business 3rd	1st	Sale of home appliances	30.8	Nursery facilities	36.4
	2nd	Travel agencies/gambling facilities	23.1	Sale of daily necessities/travel agencies	18.2
	3rd	–	–	–	–

More than three items in the same order, is denoted by '–'.

is a 'vegetable farming-based plains rural area' not far from the Tokyo metropolis. Based on the results, we then conducted six preliminary interview surveys during February in Daisen City, and 14 interview surveys during April.

3. ATTITUDES OF RURAL INHABITANTS TOWARDS JA

Daisen City in Akita Prefecture was established on March 22, 2005, by the merger of one city, six towns and one village—Omagari-shi, Kamioka-machi, Nishi-senboku-machi, Nakasen-machi, Kyowa-machi, Nangai-mura, Senboku-cho and Ota-machi. Daisen City is located in an inland area of southern Akita Prefecture, bordering Senboku City and Iwate Prefecture to the east, Yokote City and Misato-cho to the south, Akita City and Yuri-honjo City to the west, and Senboku City to the north. The area has long been an important transportation node of southern Akita Prefecture. Efforts are being made to enhance the infrastructure and capabilities of the area as a road and railway junction, through the Akita Shinkansen (Omagari, Kakunodate), Akita Expressway (Omagari I.C.) and other projects. Ota-machi, the area examined in this study, has no major arterial roads, expressways, or railways. There are not even any convenience stores in the Ota-machi area, which is completely agricultural, characterized by scenes of farmhouses dotted over paddy fields. The area falls under the jurisdiction of JA Akita Obako, whose local JA branch office is sited in the former JA Ota building. Agriculture in the area is categorized as 'rice farming-based plains rural'. However, more and more farmers are pursuing secondary sources of income, mainly by commuting to neighbouring areas. We chose this area because it featured in a survey by the Agriculture Department of Tohoku University (Kudo[4]) and because this study made a positive contribution to agriculture in the former Ota-machi. The local people cooperated wholeheartedly in this survey.

Bando City in Ibaraki Prefecture was also formed

on March 22, 2005, by the merger of Iwai City and Sashima City, and is fittingly called 'a garden suburb'. It is located in southwestern Ibaraki Prefecture, and borders Noda City, Chiba Prefecture, at the Tone River. Bando City thus acts as a gateway from Chiba Prefecture and metropolitan Tokyo, to Ibaraki Prefecture. The city is located within 50 km of the Tokyo metropolis. Since the Tsukuba Express began operating, the city has been well within commuting distance of the Tokyo metropolis. The entire city is designated as a 'Tokyo Metropolitan Suburb Improvement Zone'. Taking advantage of the relatively mild Pacific coast climate and its convenient location, farmers grow vegetables for the Tokyo market, rather than rice. There are several JA offices in the area. JA Iwai in particular is well known for producing branded vegetables.

1) Results of Questionnaire Surveys

Figure 1 shows the responses to the question, 'Which of the three types of organization would you prefer to see handling each of the following activities (items 1 to 20): a public agency, JA or a private company?'. The upper bar gives the responses for Daisen City; the lower bar for Bando City. JA scored relatively high on '2 Farming advisory', '6 Sale of agricultural supplies', '12 Farm work contracting', '13 Sale of agricultural products' and '20 Operation of direct sale outlets for agricultural products'. Two of these business activities ('12 Farm work contracting' and '20 Direct sale of agricultural products') are not conducted by JA in either of the two districts, and are agriculture-related items. JA scored lower, but still relatively high, on '1 Insurance and pensions', '4 Savings (deposits)' and '5 Finance (lending)'. However, for items related to medical care, welfare, lifestyle and education, a public agency was the preferred service provider. The items for which 'a private company' was most preferred were '3 Gasoline stations', '7 Sale of foods and daily necessities', '9 Travel agencies', '11 Sale of home appliances', '18 Sale of PC software' and '19 Wedding and funeral venues and mediation'.

A comparison of Daisen City and Bando City shows that for all items, a public agency is favoured as a service provider in Bando City. Another feature of the results relates to the items on which public institutions scored high—'1 Insurance and pensions', '3 Gasoline stations', '4 Savings (deposits)' and '5 Finance (lending)'. It seems that people tend to react

Fig. 1. Responses to the question, 'Which of the three types of organization would you prefer to see handling each of the following activities (items 1 to 20): a public agency, JA, or a private company?'. (proportion per activity)

with some anxiety and dissatisfaction to the idea of these activities being conducted by JA or a public agency. Furthermore, in Bando City, which enjoys particularly good access to the Tokyo metropolitan area, JA scored notably higher than Daisen City on items '7 Sale of foods and daily necessities', '9 Travel agencies' and '19 Wedding and funeral venues and mediation'. If we consider this result in the light of the high dependence on private companies, a possible hypothesis is as follows: Because access to the Tokyo metropolitan area is easy, existing private companies quickly sort themselves out by a kind of natural selection, so that JA's 'comprehensive power'—its unique ability to offset losses in one part of its business operations with profits from another part (mainly insurance/pensions finance)—could be considered a significant advantage and a favourable asset.

Tables 3 and 4 show the questionnaire survey results for Daisen City and Bando City, respectively. In both cases, the results for farming households that sell their agricultural products ('sales farmers', hereafter 'SF') and those that do not ('non-sales farmers', hereafter 'non-SF') are listed separately. 'SF' derive an income from selling agricultural produce, regardless of whether they sell to JA or not. 'Non-SF' have large-scale 'kitchen gardens', the produce of which is distributed to relatives, friends and so on, but not sold. Inhabitants who do not have agricultural land are included in 'non-SF'. Note that, in both cases, most respondents are full JA members. 'Medical care and welfare facilities' was considered 'essential' in both districts and by both 'SF' and 'non-SF' households. However, 'Gambling facilities' was considered the most 'non-essential' in both districts, and by both household categories. 'Travel agencies', 'Sale of home appliances' and 'Sale of PC software' were also frequently nominated as 'non-essential'. Comparing 'SF' and 'Non-SF' households reveals that 'SF' households tend to consider agriculture-related activities, such as 'Sale of agricultural products' and 'Sale of agricultural supplies' to be 'essential', whereas 'non-SF' households rate the 'Sale of foods and daily necessities' to be more important than agriculture-related services. Interestingly, 'Gambling facilities' shows up in the rankings for 'non-SF' households as 'essential'. The households of the rural district of Daisen City uniformly rated agricultural and medical activities as most 'essential'. In contrast, however, the households of the suburban district of Bando City did not consider agriculture-related services to be so essential. The items that are 'essential' to 'SF' households span the range of 'essential' and 'non-essential' for 'non-SF' households. These results could be attributable to the fact that the differences between the districts result from different kinds of involvement with JA—and by extension with agriculture. We can infer that, for 'non-SF' households in particular, the commonality between districts is due not only to homogenization of the social and economic conditions of the households, but also to homogenization of the services (businesses) provided to the residents of farming and urban districts.

If the 'essential' business activities shown in Tables 3 and 4 are taken to be 'community needs,' the association between the preferred provider (Fig. 1) of these needs is given below. In relation to medical and welfare-related businesses ('8 Medical care facilities', '10 Caregiving for the elderly' and '17 Welfare facilities'), a high proportion of respondents nominated 'public agency' as their preferred kind of provider. However, JA was regarded positively in relation to agriculture-related activities, while a 'private company' was the preferred service provider for '7 Sale of foods and daily necessities'. Thus, looking at different community needs, we can conclude that JA is judged to be a suitable provider only of agriculture-related services.

2) Results of Preliminary Interview Survey

After receiving the questionnaire results, we conducted preliminary interview surveys at six 'SF' households in the Daisen City (formerly Ota-machi) zone. Of the community needs of 'SF' households, JA was considered to be a suitable operator only of agriculture-related business activities (such as sale of agricultural products, farming advisory, farm work contracting, sale of agricultural supplies). The summarized results of the preliminary interviews are shown in Table 5. Half of the interviewees replied that their impression of JA was 'neither good nor bad'. Apart from farm household D, the reasons given for this valuation reveal both satisfaction (or at least acceptance) and dissatisfaction with JA. Overall, the attitude displayed by the interviewees was not characterized by opposition or disagreement. Rather, the answers indicated a strong sense of identification with JA, suggesting a feeling of 'our JA'. Note, however, that there were also comments like that of person A:

Table 3. Daisen City (formerly Ota-machi) questionnaire results

		SF Households (170) Activity	Response (%)	non-SF Households (37) Activity	Response (%)
'Essential' business 1st	1st	Sale of agricultural products	23.6	Medical care facilities	26.7
	2nd	Medical care facilities	17.1	Gambling facilities	23.3
	3rd	Farming advisory	15.4	Sale of foods and daily necessities	13.3
'Essential' business 2nd	1st	Sale of agricultural supplies	15.4	Medical care facilities/welfare for the elderly	14.3
	2nd	Sale of agricultural products	13.7	Gambling facilities	10.7
	3rd	Medical care facilities	10.3	–	–
'Essential' business 3rd	1st	Sale of agricultural products	14.0	Farm work contracting/sale of PC software	12.0
	2nd	Medical care facilities	12.3	–	–
	3rd	Farm work contracting	9.6	–	
'Non-essential' business 1st	1st	Gambling facilities	73.3	Gambling facilities	73.9
	2nd	Travel agencies	12.9	Travel agencies	17.4
	3rd	Sale of PC software	3.4	Gasoline stations/direct sale of agricultural products	4.3
'Non-essential' business 2nd	1st	Travel agencies	36.8	Travel agencies	38.9
	2nd	Gambling facilities	16.8	Gambling facilities	22.2
	3rd	Sale of PC software	12.6	Sale of PC software	11.1
'Non-essential' business 3rd	1st	Sale of PC software	23.0	Sale of PC software	27.8
	2nd	Sale of home appliances	17.2	Sale of home appliances	22.2
	3rd	Travel agencies/wedding and funeral venues and mediation	12.6	Travel agencies/wedding and funeral venues and mediation	16.7

More than three items in the same order, is denoted by '–'.

Table 4. Bando City questionnaire results

		SF Households (89) Activity	Response (%)	Non-SF Households (218) Activity	Response (%)
'Essential' business 1st	1st	Gambling facilities	18.2	Medical care facilities	25.2
	2nd	Gasoline stations/medical care facilities/sale of agricultural products	13.6	Sale of foods and daily necessities	18.9
	3rd	-	13.6	Gambling facilities	11.7
'Essential' business 2nd	1st	Medical care facilities	18.6	Medical care facilities	24.8
	2nd	Welfare facilities	11.6	Gasoline stations/savings (deposits)	10.5
	3rd	Sale of agricultural supplies/sale of PC software	9.3	–	–
'Essential' business 3rd	1st	Gasoline stations/welfare facilities	12.2	Welfare facilities	14.6
	2nd	Sale of agricultural supplies/medical care facilities	9.8	Medical care facilities/welfare for the elderly	11.7
	3rd	–	–	Wedding and funeral venues and mediation	10.7
'Non-essential' business 1st	1st	Gambling facilities	80.0	Gambling facilities	80.0
	2nd	Sale of PC software	8.9	Travel agencies	3.6
	3rd	–	–	Sale of home appliances/sale of PC software	2.7
'Non-essential' business 2nd	1st	Sale of PC software	35.0	Sale of PC software	29.1
	2nd	Travel agencies/sale of home appliances	15.0	Sale of home appliances	11.6
	3rd	Gambling facilities	7.5	Lifestyle advisory	10.5
'Non-essential' business 3rd	1st	Travel agencies	22.9	Sale of PC software	20.5
	2nd	Sale of home appliances	17.1	Travel agencies	14.1
	3rd	Sale of PC software/wedding and funeral venues and mediation	14.3	Finance (lending)/sale of home appliances	9.0

More than three items in the same order, is denoted by '–'.

Table 5. Daisen City preliminary interview results (summary)

Farm household	A	B	C	D	E	F
Settlement name	Shimoshinko	Arayashiki	Ohgihata	Eitai	Hagurodo	Minamikokaminari
Impression of JA	Neither good nor bad	Neither good nor bad	Quite bad	Neither good nor bad	Bad	Good
Reason of impression	Since JA has to deal with farming households like us, which are struggling (economically), business must be tough for them too.	I mainly grow rice, so we don't have much to do with other kinds of agricultural business.	The number of JA staff (services) per farm household has fallen since the merger, and due to poor sales strategy the burden has been shifted to the farm households.	I don't have any complaints about JA.	If farm households become corporate and handle their own sales there would be no need for JA.	The unit price for the rice we deliver to JA is not transparent. Apart from that we don't have anything to say.
Direction of JA	We want to see high-level farm households join together to form working groups, and establish production districts that have market impact. JA can serve as a bridge to this. For farming advice we want the top-level households to transfer their agricultural expertise to others within working groups.	We hear that horticultural households would like to see better farming advisory services. JA needs to review its business, but since credit and insurance are where JA makes a profit, we think these businesses should not be separated.	We need to introduce crops other than rice that can provide a stable income. JA needs to play a leading role in this.	Nothing in particular to say.	Farm households should establish a corporate structure, and handle everything, including sales, by themselves, like a company. JA needs to serve only as a financial cooperative.	All of the services provided by JA can be obtained from other providers. It's inevitable that JA has to compete in the commercial market place.

'Farmers and JA must collaborate to develop concrete proposals'. In other words: 'If we did this, then things would improve somewhat'. This lack of satisfaction could also be due to the greater physical and mental distance that has opened up between farmers and JA since the regional mergers. Apart from B and C, all interviewees are 'accredited farmers'. Farm household A grows vegetables, C grows leaf tobacco and D grows soybeans. Farm household E operates a mixed management system centred on raising *wagyu* (Japanese-style beef), while B is the only farmer in the district focused on community farming. While we can conclude that these differences definitely influenced the variety of interview responses, clearly the desire of farmers A and B to strengthen support for horticulture aligns quite closely with the desire of farm household C for the introduction of staple crops other than rice. Comments from farm households E and F show that they are resigned to the current state of JA. However, farm household E would still like to see JA provide economic backup (financing and funding of operation expenses and assistance with taxation procedures) in areas other than credit and insurance—even after the farmer incorporates his farm business to become a private enterprise operation.

Summarizing the above, we can say that the hopes held by farmers towards JA are: (1) the introduction of crop items other than traditionally grown main crops, which can return a stable income, and the creation of specialty farming districts for these, and (2) a focus on economic backup to complement farmers' business improvement initiatives (community farms, incorporation).

Farm household E also expressed the concern that even if farm households establish a corporate structure, they may not have sufficient human resources with necessary management expertise. Thus, in relation to (2), farm households expect JA to provide expertise on managing corporate operations.

3) Results of Interview Survey

During the preliminary interview survey, we could more or less confirm which business direction farm households preferred JA to take. In our interview surveys, which also included non-SF farm households, our focus was to ask if people believed that a public agency—rather than JA or a private company—should operate many of the 'community needs' services, such as medical and welfare services and education, and also to confirm the most essential services needed to live in the areas, based on the results of the questionnaire described above. Keeping these points in mind, through the interviews we re-examined the results of the questionnaire and preliminary interview survey. The interview survey was conducted over four days—from April 21 to 24, 2007—at a total of

Table 6. Interview results (summary)

Farm No.	Age	Category	Gender	Settlement	Interview site	Impression of JA	Future role of JA	Why JA should not provide medical/welfare/education services
1	59	SF	M	Hagurodo	Home	Good. I am quite old now, so I can't invest in equipment, so I rely on JA facilities (country elevator). They also helped me out with some useful technology, for direct sowing and other things.		
2	71	SF	M	Sougyou	Home	Bad. After the merger, I have not been satisfied with farming advisory services.	A system where it is not necessary to buy our own machinery (agricultural equipment leasing) would be good. It would be good if JA could manage farmland (paddies) on contract for us.	I trust public agencies to handle these services, but I wouldn't depend on JA to do so.
3	67	non-SF	M	Eitai	Home	Neither good nor bad. Apart from bank savings, we only use JA out of a sense of social obligation, so we would not suffer without JA.		
4	72	non-SF	M	Kamikosono	Home	Neither good nor bad. It is easier to get loans from JA than from banks, but since the merger, JA seems more remote than before.		It would be OK with JA, but public agencies would be better.
5	43	SF	F	Kamikosono	Home	I am not dissatisfied with JA. When we wanted to establish a production district, for *tonburi* (seeds of broom cypress), a local specialty, JA cooperated as much as they could. Unfortunately, though, local government didn't join in the effort.	I don't feel any particular need for farming advisory services, because I want to control all aspects of management myself. However, from the perspective of going corporate, I would like assistance from JA with things like management expertise, cultivation of sales channels, operation of facilities, and inventory control (not just at the time of harvest but all year round).	JA is an agricultural co-op, so it is OK for agriculture-related services. I feel that public agencies would be better for other things, however.
6	66	SF	M	Kamikosono	Home	After the merger, screening for loan qualification became very strict, but this is desirable. It is ultimately not good for farmers if JA lends out money to needy farmers even when it is likely that the loan will not be repaid.	JA needs to focus on promoting crops that generate stable income (by creating working groups), and it should specialize in agriculture-related activities. Also, I expect it to play a backup role in community-based agricultural technology consulting and incorporation.	JA has extended too far into various non-agriculture-related activities. To preserve farmland as farmland, JA must specialize in agriculture-related activities. It also needs to provide agricultural supplies more inexpensively.
7	66	non-SF	M	Uwazeki	Govt. office	JA has expanded too far into activities unrelated to agriculture. Although it is reducing the price of rice, JA is selling agricultural supplies at a higher price than home centres.	Farm work contracting.	JA has extended too far into businesses that are not related to agriculture.
8	71	SF	M	Ohgihata	Home	Even just in terms of the way JA staff communicate, JA is inferior to other private companies. Since JA is chiefly concerned with rice distribution, it lacks the ability to serve people.	Dry field farming (of crops that provide a stable income) is more laborious than rice farming. We are too old to establish a production district (scale expansion). The situation seems hopeless.	I wouldn't say that it would be impossible for JA to provide these services, but unless it worked harder than it's doing now, I don't think it would be successful.
9	58	SF	M	Ohgihata	Home	Buying agricultural supplies from JA is more expensive than going to the local home centre. JA needs to try harder to reduce prices.	What JA needs to provide, more than a gricultural technology consulting, is information about management expertise, accounting and cultivating sales channels, for farmers who want to form companies. More direct consulting, as in 'This is what you should do for your business' would be good.	I don't think that JA has the human resources to operate these kinds of businesses.
10	68	non-SF	M	Uwazeki	Home	I inherited my full JA membership. So I have always used JA, without trying other private companies. And I am going to keep using JA until I go out of business.	The unit price of rice should be more stable.	Even JA will eventually disappear I think. Medical, welfare and education are important, so I would be happier to see them left to stable public agencies.
11	57	SF	M	Uwazeki	Home	Quite bad.	Agricultural supplies are expensive. JA needs to put more effort in to its management. However, JA is better than banks in some finance-related businesses.	I think these are beyond the limits defined by the existing Agricultural Cooperative Association Law. For example, a co-op would not be able to accommodate such services. (Therefore, not possible under current conditions.)
12	54	SF	M	Kamikosono	Home		Realistically, given the aging of the population, it would be difficult to achieve our request for JA (1). It would also be difficult to achieve our request for JA (2), since providing community-based agricultural technology consulting and forming corporate structure are difficult to accomplish under current conditions.	Traditionally these have been handled by public agencies.
13	53	non-SF	M	Eitai	Workplace		Securing a stable income source over the medium to long term. The prosperity of farming districts will be closely tied to the prosperity of farming businesses.	At present JA does not have the investment capital to take on all these responsibilities.
14	41	SF	M	Kamishinko	Workplace	JA looks after us settlement by settlement. It provides more specific information, more quickly, than the private sector. It has awareness at the local level.	I don't think JA needs to do anything more than it's doing now.	
15	43	SF	M	Sougyou	Workplace		Right now, JA seems unable to respond to changes in agricultural administration, and is unsure about its policy on vegetables and other matters. I want to see JA clarify its strategy and show us the direction it is moving in.	I don't really know.
16	64	SF	F	Kamishinko	Home	Agricultural technology consulting became quite undermanned after the merger. Things got quite rough.	Since farming households cannot seem to group together themselves to form community farming or corporate ventures, I would like to see JA organize this. I don't have any particular demands of JA, but when they send people to village-level consultations.	Up to now, these things have been handled by public offices. I think it would be best to leave things as they are.
17	61	SF	M	Eitai	Govt. office	Both JA and local government administrations are doing their best.	Since even JA members do not use JA, I guess it would be difficult for JA to implement business that promotes the profit of members.	JA is already too extended in its non-core business commitments, but I would not say that it should specialize only in agriculture. But I think it needs to focus on farming instead of these other things.

17 farm households, taking approximately one hour in each case. Table 6 shows results of interview survey.

The two predominant responses from the preliminary interview survey on the business direction people wanted JA to take were: (1) the introduction of crop items, other than traditionally grown main crops, which could return a stable income, and the creation of specialty farming districts for these, and (2) a focus on economic backup to complement farmers' business improvement initiatives (community farms, incorporation). In the interview survey, some farmers expressed positive opinions regarding point (1) (farm households 6 and 13). However, some expressed doubt, saying that even if JA tries to create districts to grow such crops, ageing farm households may not be able to secure sufficient labour. Furthermore, farmers might hesitate to invest in machinery to make up for a lack of labour because they have no visible successors, or because of a perceived lack of stability in agricultural administration. Thus, even if led by JA, this initiative could be difficult (farm households 8 and 12). The most common opinions on the expectations of JA correspond to point (2) (farm households 5, 6, 9, 12, 15 and 16). Of these, services desired from JA can be further categorized as follows: (1) In-depth consulting services to guide individual farm households in detail on how they manage their operations, in addition to providing management expertise (farm households 5, 6 and 9); and (2) In cases where consensus on the question of introducing community farming and establishing a corporate structure cannot be reached, external mediation by JA to reach consensus (farm households 5, 9, 12, 15 and 16). The opinions on category (2) were expressed as a result of the following situation. In the survey area (formerly Ota-machi in Daisen City), managers of large-scale farms place the highest priority on the management of their own farms, and thus cannot spare any labour for community farming. However, the class of small-scale farmers and elderly farmers cannot participate effectively in community farming as workers. Furthermore, they have a strong attachment to their own farmland (paddies) and feel reluctant to entrust or hand over their land to other people. As for category (1), we can see that people feel a need for agricultural technology consulting—a service that JA began to withdraw after the wide-area mergers. Some farm households felt that their sense of distance from JA increased after the mergers, and that agricultural technology consulting became understaffed (farm households 2, 4 and 16). However, some farm households claimed that the agricultural technology consulting provided by JA is effective, and that JA is working hard for the good of farm households (farm households 1, 5, 14 and 17). We would guess that these opinions may differ because the agricultural technology consulting provided by JA has changed from the traditional 'bottom-up type' for small farm households, and farm households facing business difficulties, to 'selective and intensive type' for large-scale and well-performing farm households.

The surveyed rural inhabitants want many of their 'community needs', such as medical and welfare services and education, to be handled by public agencies, rather than by JA or private companies. The reason vaguely expressed for this was that these services had long been provided by public agencies (farm households 12, 15 and 16). Many also claimed that JA is overexpanding its businesses in fields unrelated to agriculture, and should instead specialize in agriculture-related businesses (farm households 5, 6, 7 and 17). A significant number claimed that JA lacks the ability to handle such businesses (lack of personnel and stability compared to public agencies; 'worry about JA's future') (farm households 2, 8, 9, 10 and 13).

The view that JA should specialize in agriculture-related businesses is possibly the flip-side of the expectation of growing crops that provide a stable income (farm household 6) and the hope that JA will supply cheaper farming materials than private 'home centres' (farm households 6, 7, 9 and 11). For example, when we addressed more in-depth questions to the farm households, we heard opinions to the effect that it might be difficult for JA to survive as a business if it specialized in agriculture-related business (farm household 6), or that JA might not be able to make a profit if it stuck to providing the services demanded by farm households (farm household 7). In short, combining these opinions with the trends in expectations of JA, mentioned earlier, farm households are aware of the fact that the services that are necessary and important to them are not necessarily profitable for JA. Yet, despite being aware of this fact, they continue to depend on JA as a 'last resort' organization, which can save the farmland (paddies) of Japan, now threatened by devastation because of a rapidly

aging society, the move by farmers to secondary income sources, reduction in acreage, and changes in agricultural administration.

The view that JA is lacking in management capabilities and worries about the future of JA seem to reflect a distrust of the JA organization, distrust of agricultural administration, dissatisfaction with the quality of JA staff, and a sense of their greater remoteness since the mergers. For example, some claimed that the communication skills of JA staff are inferior to those of private company employees (farm household 8). In addition, some felt that JA's financial services were inferior to those of banks, and that its mutual aid business was inferior to that of insurance companies (farm household 3). One farmer revealed that he inherited his full JA membership and will use JA services exclusively until JA goes out of business. However, if JA should one day disappear, he thought it desirable that public agencies take over its most important services (farm household 6). If this kind of unease in relation to JA is behind the general feeling that medical, welfare and education services have always been handled best by public agencies, it is likely that this simmering concern and distrust of JA is gradually strengthening. We would like to note the minority view of one respondent, who mentioned that many public agencies are also finding difficulty securing adequate income or funding, with the result that the financial burden for the services of such agencies will end up being met through taxes. However, if services that can be delivered reliably by private companies can be operated as businesses in a competitive market, local residents can enjoy inexpensive and high-quality services (farm household 13).

When asked what kind of services are needed for life in their communities, most farm households answered to the effect that there was nothing in particular they needed, that today's lifestyle is vastly more convenient than that of the past. We should point out that some households expressed a need for jobs to earn cash income (farm households who cannot sustain a livelihood with farming as their principal activity) (farm households 13, 14 and 16). From these results, we can conclude that people have no particular need for businesses (services) in order to live in rural areas (since such needs are already fulfilled). Nevertheless they are starting to express the most important need for sustaining a livelihood and worthwhile lifestyle (a stable cash income source in today's rural areas). In short, the current state of rural areas of Japan is not one in which JA considers 'community needs' and works to improve the livelihoods and living standards of the people. Instead, rural areas are now confronting a dangerous situation, in which people find that they need 'something' to support the very foundation of their livelihood—even in areas like Daisen City, where people are blessed with ample opportunities to earn money from secondary sources. A comment from the survey that clearly embodies this situation reveals the difficulty of making a living by growing only rice. This farmer pointed out that until recently, farm households had tried to improve their standard of living by going to work in other areas or by initiating secondary businesses. Today, farm households are struggling just to maintain their standards of living, and are finding it difficult to manage their farmland (as paddies). This farmer suggests that, just as farming was done cooperatively on a community basis when sufficient labour savings could not be achieved using machinery, the connection between people needs to be re-established to sustain the life of the community (farm household 12). We can conclude that, due to the penetration of market economics throughout rural Japan, the wide-area mergers of JA and government administration and the restructuring of these institutions due to financial pressures, a new kind of 'community need' is arising—the need to sustain the very lives of these communities. This new kind of need has not yet been grasped by public agencies, JA, or private companies.

4. CONCLUSION

In this study, we conducted a survey of 'community needs' through a questionnaire distributed to approximately 500 farm households from Daisen City, Akita Prefecture, and Bando City, Ibaraki Prefecture. To supplement the survey, we conducted interviews at approximately 20 farm households in Daisen City.

An examination of the results shows that JA members and rural inhabitants do not simply select one out of several service providers, as pointed out by Kitagawa [3], when discussing the so-called 'relative view of JA' by JA members ('JA is one of various service provider options, including private companies, to choose from'). Basically, JA farm households in rural areas need JA to provide agriculture-related services. 'Non-SF' farm households and farm households in

suburban areas tend to feel that services most important to their lives should be provided by more stable organizations. Many go as far as to claim that there is no need for JA to provide non-agriculture-related services.

In addition, since there is no clear agreed set of 'community needs' for rural inhabitants, the intended structure of JA—considering community needs, implementing services, and contributing to the lives of local people—is not established. On this point, Kitagawa [3] also stressed the discrepancy between JA's business activities and the real needs of communities. As Iwatani [2] pointedly illustrated in the 'anaemia and colour television' episode recounted earlier in this paper, the fact is that JA has pursued a business strategy that serves its own management interests; the concept of 'community needs' is raised merely to justify this business strategy. Interestingly, one interview respondent described JA's existence as being supported by 'selling things to farm households to pluck off the cash they earn through secondary (non-farm) work' (farm household 7).

As the inhabitants of rural Japan begin struggling to sustain their livelihoods, and trying to ensure the survival of their communities, very substantial 'community needs' are starting to appear. These needs are like 'blind spots', as yet unseen or unrecognized by government administrations, JA, or private companies. People expect JA to be the organization of last resort for the maintenance of Japan's farmland. The harsh reality for JA seems to be forcing it toward one of two choices: to recognize its 'blind spot' and find a way to meet these real needs, or else to destroy these 'blind spots' and thus sever its roots as an 'agricultural' cooperative.

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Use of Soil Database for Pedological Research as Exemplified by Volcanic Ash Soils

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Abstract

A soil database is a digital storehouse of soil information, and it is expected to be useful for many purposes. Several examples of using soil databases for pedological studies on volcanic ash soils were introduced. The soil databases we used are, the soil database of Ando soils in Japan (ASJ), the Tohoku University world Andosol database (TUWAD), the soil data of cultivated soils in Japan collected during 1959-1978 (DBOD), data for soil monoliths in National Institute of Agro-Environmental Sciences used for determination of elemental concentration (DSMN) and water quality data for rivers in Japan (WQRJ). These data sets have been stored as spreadsheet files, and it is easy to use them. TUWAD was used to examine criteria to define andic and vitric properties of the World Reference Base for soil resources. The DBOD was used for elucidating the involvement of exchangeable Ca and Mg in the phosphate sorption coefficient. The ASJ was used to illustrate the depletion of Si, Ca and Na, and enrichment of Al, Fe and other immobile minor elements during Andosol formation. These results were confirmed using DSMN. As shown in these examples, the soil databases are useful for testing soil classification criteria, examining the relationship between new experimental results and previously reported data, etc. It is desirable to construct a soil database that covers wide regions and research areas in the future.

Introduction

1. Advantages of using soil databases for pedological studies

Hardware and software for computers are available to manage the huge amount of soil data. Soil databases are digital storehouses of soil information, and they are promising tools for further developing pedological studies. Because soil properties change with time due not only to natural processes but also to human activities, soil databases also have historical aspects. We introduce several examples in which we have used soil databases for pedological and pedochemical studies. The examples are (i) discussion on factors affecting the relationship between oxalate extraction and phosphate (P) retention to define andic and vitric properties in the World Reference Base for soil resources (WRB, IUSS Working Group WRB, 2006), (ii) enrichment and depletion of elements during Andosol formation from tephra.

In the course of these studies, we constructed small databases in two cases (Nanzyo and Shoji, 1992; 1993; Shoji et al., 1996). In other cases, we used databases made by Japanese soil scientists due to the courtesy of their authors, and we added some experimental data to other existing databases using kindly distributed soil samples. Soil databases are useful for testing new ideas quickly, analyzing the relationship between new experimental data and previously reported data.

We use the words “volcanic ash soils”, “Andosols” or “Andisols”. The word “volcanic ash soils” is any soil derived from volcanic ash as a major parent material. Andosols and Andisols are the soils that meet or are estimated to meet the requirements defined in the WRB system and USDA Soil Taxonomy (Soil Survey Staff, 2006), respectively. We use these words depending on the individual topic and the cited literature. Although “Andosols” is used in the classification of Japanese cultivated soils, it is specified when necessary. Because we use volcanic ash in a broad sense here, it has the same meaning as tephra.

2. Databases used for the exemplifying studies

The databases mentioned below are listed in Table 1. The database for Ando soils in Japan (ASJ) was made by the Kurobokudo co-operative research group and compiled as a book by Wada (1986). ASJ includes profile description, chemical, physical and mineralogical data for volcanic ash soils in Japan. The database by Oda et al. (1987) (DBOD) includes many data selected from all over Japanese cultivated soils. The data were collected during the period of the soil fertility survey project supported by the ministry of Agriculture, Forestry and Fishery between 1959 and 1978. Soil characterization data were collected using surface and subsurface horizon soils of paddy fields, upland fields and orchards. TUWAD (Shoji et al., 1996) was constructed adding data for volcanic ash soils in the world, provided by H. Eswaran of the USDA, to ASJ and the Andisol TU database that was used to show chemical and physical characterization data for volcanic ash soils from the northern part of the circum-pacific volcanic zone by Shoji et al. (1993). We used the data for soil monoliths in the National Institute of Agro-Environmental Sciences (DSMN, Nakai et al., 2006) adding the concentrations of 57 elements (Yamasaki et al., 2001). We also used data on water quality of rivers (Kobayashi, 1971) to discuss the depletion of some elements from volcanic ash soils. The water quality data were collected during the old days between 1942 and 1959. The water samples were taken more than several times a year in each river at the boundary between mountains and the river plain in order to minimize human impact, and the mean values were reported.

Classification of volcanic ash soils

Following the activities of the International Committee on Andisols (ICOMAND) (Eswaran and Beinroth, 2000), the Andisol order was added to the USDA-Soil Taxonomy. During the course of the ICOMAND activities, they frequently used the soil database of the USDA to discuss criteria for Andisol classification (personal communication from a previous ICOMAND member). This fact suggests the usefulness of the soil database. The USDA-Soil Taxonomy is the soil classification system of the USA, although soils throughout the world are considered in it. On the other hand, WRB has been developed since 1980's inheriting soil classification system of FAO. The WRB was constructed to correlate classification systems of many countries in the world. Andosols are one of the members of 32 reference soil groups of the WRB.

1. Possible reasons for plot scattering between oxalate-extractable $Al_o+Fe_o/2$ and P retention

The requirements for andic properties of WRB (IUSS working group WRB, 2006) include five

Table 1. Databases used for the exemplifying studies

Databases	Locations of pedons	Number of pedons*	Number of horizons*	References
Ando soils in Japan (ASJ)	Japan	25	157	Wada (1986)
Database by Oda et al. (DBOD)	Cutivated lands in Japan	3343	6686	Oda et al. (1987)
Tohoku University World Andisol Database (TUWAD)	Volcanic areas in the world	260	1463	Shoji et al. (1996), Shoji et al. (1993), Wada (1986)
Data for soil monoliths in NIAES (DSMN)	Japan	78	514	Nakai et al. (2006), Yamasaki et al. (2001)
Water quality data for rivers in Japan (WQRJ)	Japan (1942-1959)	(218 rivers)	-	Kobayashi (1971)

*: The numbers show totals, and the data were further selected according to the individual purpose.

items, (i) $Al_o + Fe_o/2 \geqq 20$ g kg^{-1}, (ii) P retention percentage $\geqq 85$ %, (iii) bulk density $\geqq 0.9$ Mg m^{-3} (iv) $C_p/OC<0.5$ or $C_f/C_p<0.5$ if occurring under tephric material that meets the requirements of an albic horizon, and (v) OC<25% by mass, where C_p and C_f are pyrophosphate-extractable C and fulvic acid C, respectively. $Al_o + Fe_o/2$ of 4 g kg^{-1} or more and a P retention percentage of 25 % or more are used to define the vitric properties. Although simple requirements are desirable, a combination of three or more criteria is used for the andic and vitric properties. Among these properties, $Al_o + Fe_o/2$ and P retention are chemical properties, and there is a correlation between these two. However, it is also true that there is considerable scattering as shown in Fig. 1 (Shoji et al., 1996; Takahashi et al., 2004). Wide scattering between these two is the reason for using both of these criteria. Factors affecting the scattering in the relationship between $Al_o + Fe_o/2$ and P retention are magnetite, forms of active Al, forms of active Fe, etc.

Magnetite included in fresh tephra in various amounts is partly soluble in the oxalate solution. However, the P sorption of magnetite is small. Thus, oxalate-extractable Fe is overestimated by partial dissolution of magnetite. The P retention percentage is needed to properly evaluate the content of active Fe in an Andosol. The effect of magnetite dissolution is significant in the region near the lower limit of the vitric property (Shoji et al., 1987).

Chemical forms of active Al also affect the relationship between $Al_o+Fe_o/2$ and P retention. Although aluminum is extractable in oxalate solution from all of allophane, imogolite and Al-humus, the reactivity of these materials with P is different. Nonallophanic Andosols sorb more P than allophanic Andosols when they are compared at the same $Al_o+Fe_o/2$ value (Fig. 2). As a major form of active Al in nonallophanic Andosols is Al-humus, it is more reactive with P than allophane and imogolite. The major forms of active Al in allophanic Andosols are allophane and imogolite. According to Henmi et al. (1982) who used pure allophane and pure imoglite, allophane is more reative with P than imogolite. The reactivity of active Al with P decreases in the order of Al-humus complex > Al-rich allophane > Si-rich allophane > imogolite. Hence, nonallophanic Andisols are more reactive with P than allophanic Andosols.

Mineralogical difference in iron minerals is also responsible for the plot scattering between $Al_o+Fe_o/2$ and P retention. Goethite and haematite are not extractable with oxalate solution, although these minerals sorb P. Thus, it is expected that soils with high goethite and haematite show higher P retention than those with an average content of these minerals. Soils with high $CaCO_3$ or $MgCO_3$ content may show higher P retention than those expected from the relationship between $Al_o+Fe_o/2$ and P retention, although Andosols containing a high amount of carbonates are rare.

The above-mentioned reasons are included in the plot scattering between $Al_o+Fe_o/2$ and P retention. The criteria for andic and vitric properties are set at the center of the plot scattering (Fig. 1). Thus, $Al_o+Fe_o/2$ and the P retention percentage are mutually complementary in evaluating the amount of active Al

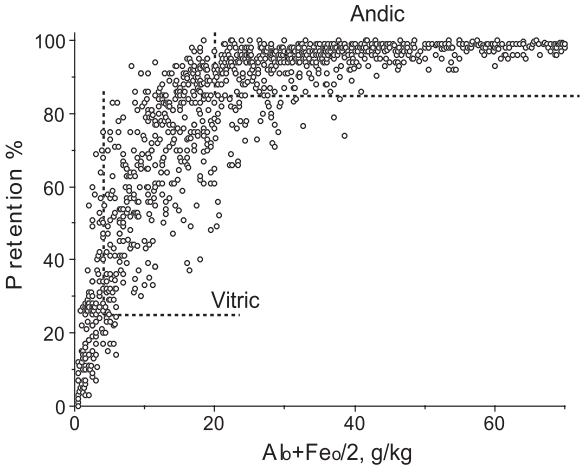

Fig. 1. Relationship between $Al_o + Fe_o/2$ and P retention of Andisols (TUWAD).

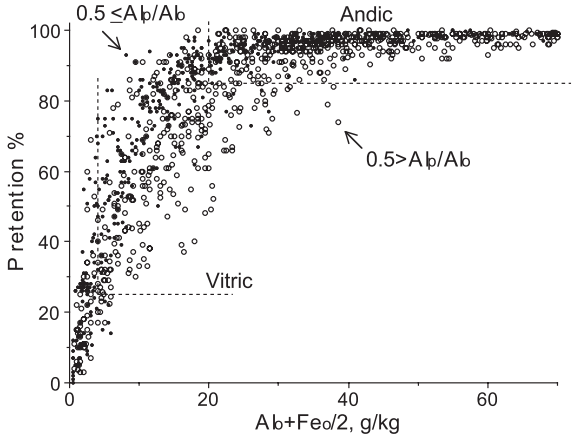

Fig. 2. Relationship between $Al_o+Fe_o/2$ and P retention percentage of allophanic (open circles) and nonallophanic (small closed circles) Andisols (TUWAD).

and Fe in soil classification systems.

2. Subdivisions of WRB Andosols

The WRB system has a subdivision of Andosols into silandic (allophanic) and aluandic (nonallophanic). The Alic subgroups, the equivalent members of aluandic Andosols were also included in some of the Andisols great groups in the USDA Soil Taxonomy. The frequency of allophanic Andosols evaluated by Al_p/Al_o values is higher than that of nonallophanic Andosols in TUWAD (Fig. 3). Accordingly, the area ratio of allophanic and nonallophanic Andosols was reported to be 3:7 in the Japanese cultivated soils by Saigusa and Matsuyama (1998) who analyzed soil samples collected at a high density per unit area. The allophanic Andosols are distributed in the areas covered by relatively new (younger than 10 ka) and abundant volcanic ashes in Japan. ASJ and TUWAD (Fig. 3) show the number of observations and the relationships between data only, and the number of observations in these databases is not directly related to the area of individual soil distribution. On the other hand, each sampling site in DBOD has an area datum.

3. Characterization of volcanic ash soils in Japan

The DBOD is useful for describing the properties of 16 soil great groups in Japanese cultivated lands. The 16 soil great groups were used in the 2nd approximation of soil classification, although 24 soil great groups are used after the publication of the 3rd approximation in 1995 (Cultivated Soil Classification Committee, 1995). Andosols or Kurobokudo in Japanese show unique chemical properties such as high P sorption coefficient (PSC), high organic carbon (OC) content, high C/N ratio, and unique physical properties such as low bulk density and low solid phase ratio (Oda et al., 1987; Iimura, 1988). In the 3rd approximation to classify the Japanese cultivated soils, a PSC of 15 g P_2O_5 kg^{-1} or more is used to key out Andosol groups. Fig. 4 shows the frequency distribution of the PSC of Andosols and other soils according to the 2nd approximation system. The PSC of Andosols is significantly higher than those of other soils. However, some of the non-Andosols also show a higher PSC than 15 g P_2O_5 kg^{-1}.

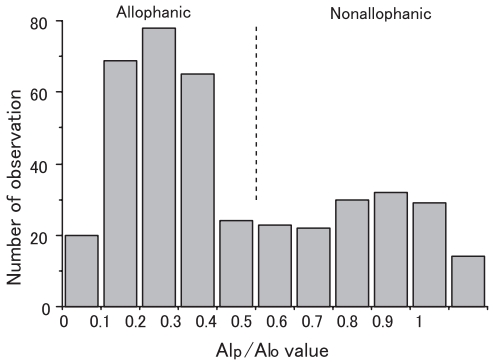

Fig. 3. Frequency distribution of the ratio of pyrophosphate to oxalate extractable Al (Al_p/Al_o) in A horizons with $Al_o + Fe_o/2$ of 1.2% or more (TUWAD).

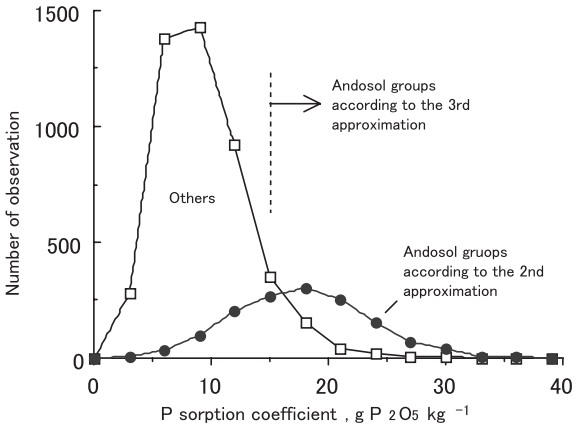

Fig. 4. Frequency distribution of the P sorption coefficient according to DBOD. Three soil great groups, Andosols, Aquic Andosols and Gleyic Andosols, are grouped into the Andosol groups. The plot at 15 g P_2O_5 kg^{-1}, for example, shows the number of observations for $12 < PSC \leqq 15$ g P_2O_5 kg^{-1}.

4. Involvement of exchangeable cations as well as active Al and Fe in PSC at pH 7

The phosphate sorption coefficient is determined using 2.5 % (0.07 mol P L^{-1}) ammonium phosphate at pH 7 and at a solution: soil ratio of 2:1. Using this sorption procedure, exchangeable Ca and Mg also react with P as well as active Al and Fe as schematically shown in Fig. 5. Crystalline P sorption products are $CaHPO_4 \cdot 2H_2O$ (DCPD) and $NH_4MgPO_4 \cdot 6H_2O$ (MAP). These phosphates are detectable by X-ray diffraction in the smectic soils after P sorption determination (Fig. 6). These reactions are most evident in the neutral smectic soils, as exemplified by Gley soils, with high exchangeable Ca and Mg. These reaction products were further confirmed when the so-

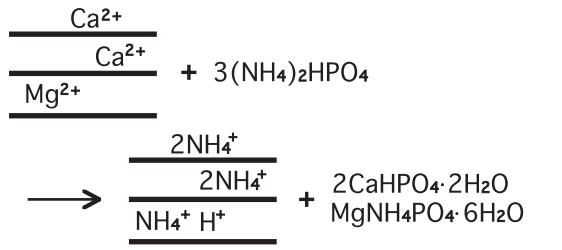

Fig. 5. Schematic representation of forming DCPD and MAP from exchangeable Ca and Mg during P sorption coefficient determination of soils.

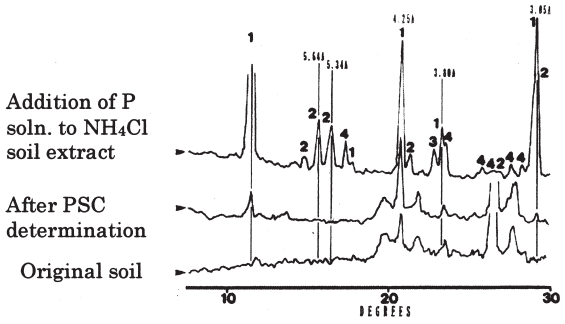

Fig. 6. XRD patterns of a smectic soil in relation to PSC determination. 1: DCPD, 2: MAP, 3: NH_4Cl, 4: $(NH_4)_2HPO_4$. DCPD and MAP precipitated in the reaction between added P and Ca and Mg extracted from the soil.

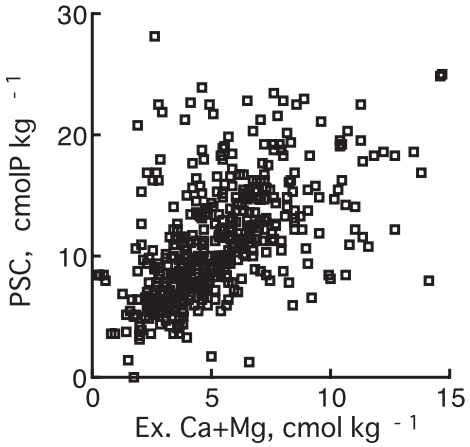

Fig. 7. Relationship between exchangeable Ca + Mg and PSC of Gley soils.

lution separated from an NH_4Cl soil suspension was reacted with P solution as shown in the uppermost XRD pattern in Fig. 6 (Nanzyo et al., 1991).

Using DBOD, a high correlation was found between the PSC of Gley soils and exchangeable Ca + Mg as shown in Fig. 7 (Nanzyo et al., 1992). After subtraction of exchangeable Ca + Mg from the PSC of the Gley soils on a molar basis, the correlation between PSC and exchangeable Ca + Mg disappears (Fig. 8). Similar results were also obtained for Gray lowland soils (Fig. 9), brown lowland soils, etc. In contrast, the contribution of exchangeable Ca + Mg to PSC of Andosols (Fig. 10) is not significant. The possible reasons are that P is preferentially sorbed by abundant active Al and Fe and that the amount of remaining P in the solution is small. Further, exchangeable Ca and Mg may be strongly sorbed by the increased negatively charged sites of Andosols with P sorption.

Subtracting exchangeable Ca + Mg from the PSC of soils other than Andosols, most of the PSC values of those soils are less than 15 g P_2O_5 kg^{-1}. Thus, Andosols are more clearly separated if the effect of exchangeable Ca + Mg is removed from the PSC of soils other than Andosols as shown in Fig. 11. Further improvement in the PSC was suggested by Nanzyo et al. (1998). As expected from Fig. 1, a single solution method to determine the PSC is not sufficient to cover a wide range of active Al and Fe contents. Fig. 1 shows that the P retention percentage is close to 100 % for the soils with a high Al_o and $Fe_o/2$ content, indicating that the amount of P added is not enough for these soils. The same is also true for the PSC. Nanzyo et al. (1998) proposed a two-solution method with an acetate buffer solution to cover a variety of soils. Because plants can use DCPD and MAP, the above-mentioned properties should be considered in the management of cultivated soils.

Genesis of volcanic ash soils

Volcanic ash is the major parent material of volcanic ash soils, although various amounts of additives are included in the volcanic ash soils. Volcanic ash is intermittently supplied in the volcanic zones of the world and the time zero of soil formation is reset when a new deposit of volcanic ash is provided. Looking at different places, there are volcanic ash soils of different development stages, providing us a kinetic viewpoint for soil formation (Shoji et al., 1993).

In the middle latitude areas, volcanic ash is frequently conveyed to the eastern side of a volcano due to prevailing strong westerly wind when the volcanic eruption is explosive. A highly explosive eruption mostly produces rhyolitic to andesitic tephra. The particle size of the deposit is reduced with the distance from the source volcano and the elapse of time during the ash fall, although the chemical composi-

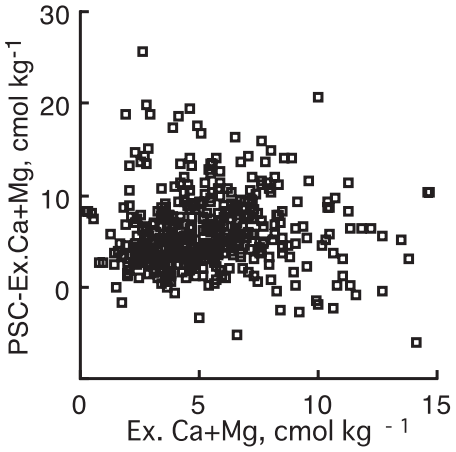

Fig. 8. Relationship between exchangeable Ca+Mg and PSC from which exchangeable Ca+ Mg was subtracted on a molar basis.

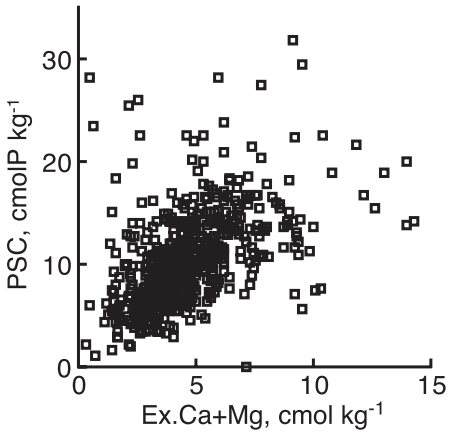

Fig. 9. Relationship between exchangeable Ca + Mg and PSC of Gray lowland soils.

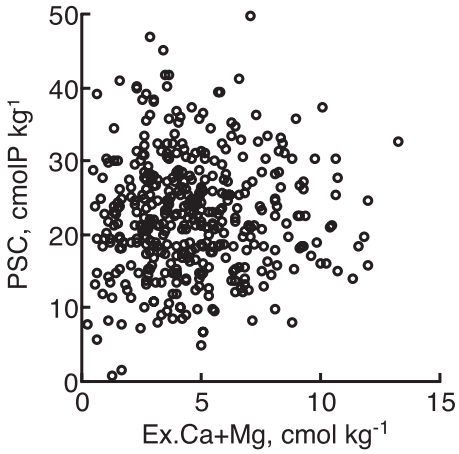

Fig. 10. Relationship between exchangeable Ca + Mg and PSC of Andosols.

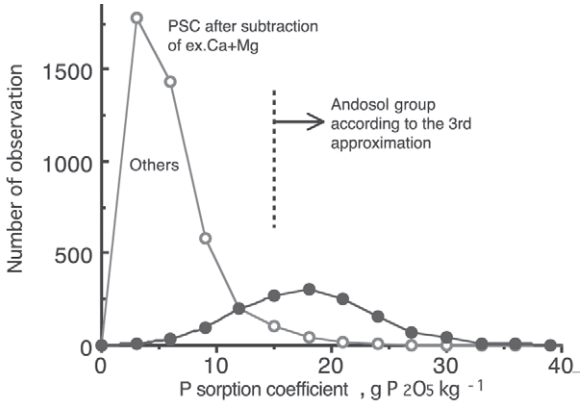

Fig. 11. Frequency distribution of P sorption coefficients according to DBOD. Three great soil groups, Andosols, Aquic Andosols and Gleyic Andosols, are grouped into the Andosol group. For others, ex. Ca+Mg was subtracted from PSC on a molar basis. The plot at 15 g P_2O_5 kg^{-1}, for example, shows the number of observations for 12 < PSC ≦ 15 g P_2O_5 kg^{-1}.

tion of volcanic glass is relatively similar. Because volcanic glass is dominant in most tephra, the chemical composition of these tephra is somewhat similar. Although mineral separation may take place with the distance from a source volcano, it may not be very pronounced as long as volcanic glass is predominant in the tephra. An example of Tarumae-a (Ta-a) tephra containing a large amount of crystalline particles is an exceptional case because the heavy mineral content steeply decreases with the distance from Mt. Tarumae and the chemical composition of Ta-a also changes accordingly (Mizuno et al., 2008). During the dormant period of a volcano, soil formation proceeds from the surface of the ash deposit depending on the factors of soil formation. The characteristic and major soil formation process of Andosols is *in situ* accumulation of active Al and Fe. Chemical forms of active Al are allophane, imgolite and Al-humus, and that of active Fe is ferrihydrite in many cases. A large amount of humus is accumulated in the A horizons. Halloysite, pedogenic opal and other secondary materials are also formed depending on the soil formation factors. In this section, we describe the effect of climate on Andosol formation, and then we focus on changes in the chemical composition of volcanic ash during the Andosol formation.

1. Enrichment of immobile elements during Andosol formation

Because the elemental composition of fresh volcanic ash (Si-rich) is greatly different from those of the secondary materials (Al- or Fe-rich) in Andosols, the concentrations of many elements are affected during this process depending on the properties of the elements. Using the data for ASJ and stored soil samples, we examined how the rock type of the volcanic ash and its weight loss during the soil formation process affect the changes in the element concentrations of Andosols (Nanzyo et al., 2007). The ASJ has information on the estimated rock-type of parent volcanic ash. A total of 95 samples of different rock types from 18 pedons of allophanic Andosols in Japan and their total concentrations of 54 elements were selected for this analysis. The principal component analysis of the concentrations of 54 elements suggested that the degree of weathering and the rock types of the parent volcanic ash are the important factors in the variation of the element concentrations in Andosols.

Relatively strong correlations between the element concentrations and Si_o, Al_o and Fe_o as well as other weathering indices were found in the andesitic 24 samples. These andesitic samples were used for detailed analysis. This rock-type group tended to show less elemental variation possibly due to the definition having a narrower SiO_2 concentration range than others.

Our preliminary study showed that the concentrations of many elements including Al, Fe increased with Si_o, Al_o and Fe_o (Nanzyo et al., 2002) indicating that these elements are enriched during Andosol formation. It was estimated that the reason for the increase in the concentrations of immobile elements was weight loss during Andosol formation. Changes in the concentrations of 54 elements were then plotted against (W_p/W_s-1) (Fig. 12), where W_p and W_s are the weight of the parent volcanic ash and the weight of the present soil sample, respectively. At time zero of soil formation, W_p was equal to W_s, and then W_p/W_s-1 = 0. When $W_p = 2W_s$, W_p/W_s-1 = 1. Assuming that volcanic glass quantitatively weathered to form Al_o and that the average Al content of volcanic glass in the andesitic volcanic ash is 69.6 g kg^{-1} (Kobayashi et al., 1976), W_p/W_s was calculated as follows on an ignition residue basis:

$$W_p/W_s = OIIR + Al_o/69.6 \quad (1)$$

The background for using the equation (1) is schematically shown in Fig. 13.

In Fig. 12, the ideal changes in concentration of im-

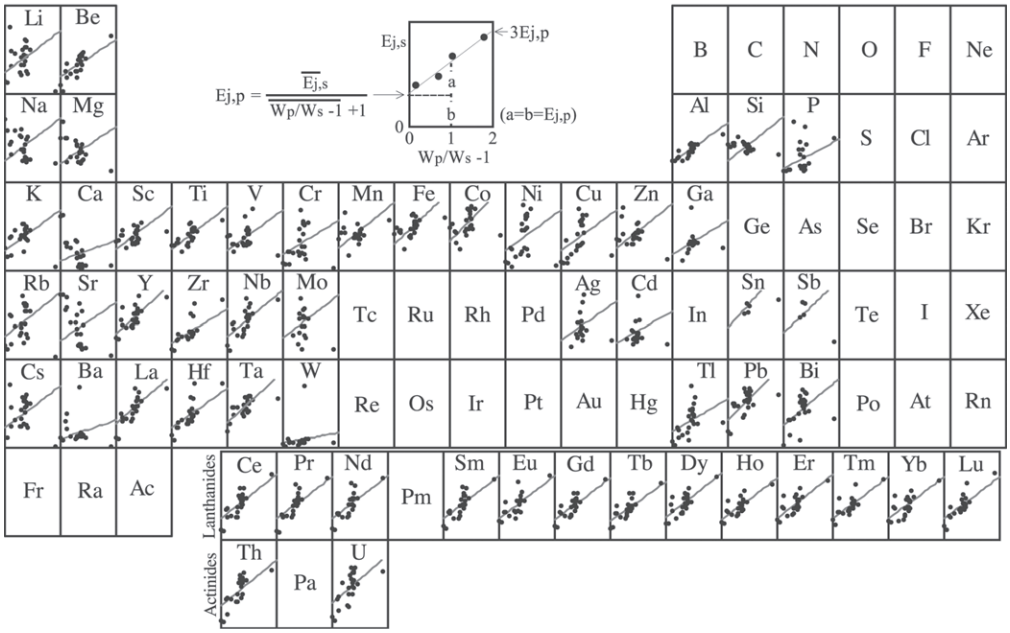

Fig. 12. Changes in element concentrations ($E_{j,p}$ and $E_{j,s}$ where p and s refer to parent tephra and an Andosol sample, respectively) with Andosol formation. All horizontal axes are the same W_p/W_s-1. The scale of the vertical axes is different depending on each element.

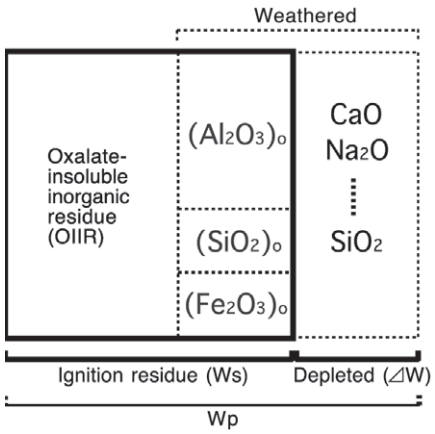

Fig. 13. Schematic representation of the relationship between the ignition residue of the soil sample (W_s) and the weight of the parent material (W_p). Oxalate-extractable Al, Si and Fe are shown in the oxide forms. Delta W (△W) is the weight loss during weathering of the parent material and is nearly equal to the summation of the weight of depleted CaO, Na_2O and SiO_2.

mobile elements are also shown as a solid line. The use of the solid lines in this figure is based on the open-system mass transport that yields the chemical gains and losses of elements in a soil sample compared with the parent material according to Brimhall et al. (1991) and Nieuwenhuyse and van Breemen (1997). In their fundamental equation, three variables of volume, bulk density and element concentration (E in g or mg kg^{-1}) were used. We simplified their equation multiplying the volume by the bulk density to give the equation (Kurtz et al., 2000):

$$W_p E_{j,p} + m_{j,flux} = W_s E_{j,s} \quad (2)$$

where p, s and $m_{j,flux}$ refer to the parent tephra, an Andosol sample and the overall mass flux of the element j into or out of the system, respectively. If an element j is immobile during Andosol development, $m_{j,flux} = 0$. The equation (2) is further simplified into the equation:

$$E_{j,s} = (W_p/W_s)E_{j,p} \quad (3)$$

Because W_p/W_s is calculated using the equation (1), the solid lines in Fig. 12 can be drawn so as to pass through the average concentration $E_{j,s}$ and the average weight change W_p/W_s. If an element is immobile during Andosol formation, its concentration is plotted along this line of each element. The theoretical $E_{j,p}$ can also be calculated using $E_{j,s}$ and W_p/W_s so long as an element is immobile.

In Fig. 12, we used W_p/W_s-1 rather than W_p/W_s so that the plots can appear near the vertical axis, converting the equation (3):

$$E_{j,s} = (W_p/W_s - 1 + 1)\, E_{j,p} = (W_p/W_s - 1)\, E_{j,p} + E_{j,p} \quad (4)$$

Among 54 elements, at least 27 (Be, Al, Ti, Fe, Y, Zr, Nb, La, Ce, Pr, Nd, Sm,, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu, Hf, Ta, Tl, Pb, Th and U) were enriched in the Andosols, and the increases in these concentrations were related to the total weight loss due to the soil formation processes. These results were confirmed using DSMN that would be reported elsewhere. Although the 24 andesitic samples include A, Bw and C horizon soils, there is no difference among them as shown in Fig. 14. In this way, the concentrations of many elements in Andosols are higher than those in other soils in Japan (Takeda et al., 2005).

2. Depletion of mobile elements during Andosolization

Silicon, Al, Fe, Ca, Mg, Na, K, Ti, Mn and P are the major elements of inorganic soil constituents. The loss of major elements is responsible for the weight loss of Andosols during the formation process. Among these major elements, the concentrations of Si, Ca and Na clearly decrease with the weight loss as shown in Fig. 12. However, the slope of the decrease in the element concentration is steeper for Ca and Na than that for Si (Fig. 15). One of the possible reasons is that Ca and Na are not the major constituents of Andosolization products but that Si is the structural constituent of allophane and imogolite. Other reasons are that Si can be sorbed by ferrihydrite and contribute to retaining its low crystallinity in Andosols and that Si is also partly retained in Andosols as pedogenic opals or plant opals.

The losses of major elements can be related to the weight loss of Andosols during their formation. Fig. 13 is also a simple model for the relationship between the weight loss (△W) and the decreases in Si, Ca and Na concentrations (oxide forms). On an ignition residue basis,

$$\triangle W = \triangle SiO_2 + \triangle CaO + \triangle Na_2O \quad (5)$$

Considering the unit weight of the parent volcanic

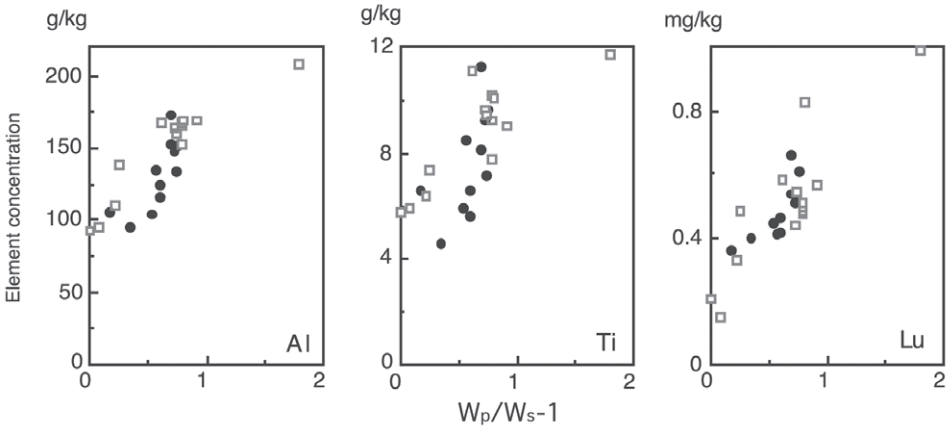

Fig. 14. Changes in element concentrations of Al, Ti, and Lu in Andosols with a decrease in weight. This figure is basically the same as Fig. 14 except that the element concentration is plotted using different symbols for A (●) horizons, and Bw and C (□) horizons.
The W_p/W_s-1 was used as the horizontal axis and $E_{j,s}$, the vertical axis. $E_{j,p}$ is then the intercept and also the slope of the solid lines in Fig. 12. If a parent tephra has a higher $E_{j,p}$ than average, the plot of $E_{j,s}$ appears over the solid line and if it has a lower $E_{i,p}$, below the solid line. If different $E_{j,p}$ values of the elements are scaled similarly, the slopes of their $E_{j,s}$ plots are also similar as shown in Fig. 12.

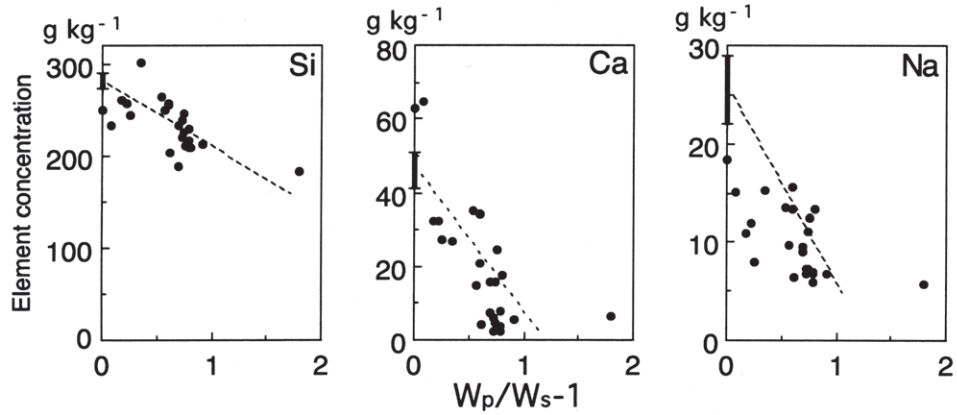

Fig. 15. Decreases in the concentration of major elements (Si, Ca and Na) in andesitic Andosols with weight loss. The thick vertical bars on the y axes shows the ranges of Si, Ca and Na concentration in the fresh volcanic ashes reported by Kobayashi et al. (1976).

ash W_p, (5) should be divided by W_p. Then,

$$\triangle W/ W_p = (\triangle SiO_2 + \triangle CaO + \triangle Na_2O)/W_p \quad (6)$$

Regarding individual elements,

$$\triangle SiO_2/W_p = (SiO_{2p} - SiO_{2s})/W_p = SiO_{2p}/W_p - SiO_{2s}/W_p = SiO_{2p}/W_p - (SiO_{2s}/W_s)(W_s/W_p) \quad (7)$$

Similarly,

$$\triangle CaO/W_p = (CaO_p - CaO_s)/W_p = CaO_p/W_p - (CaO_s/W_s)(W_s/W_p) \quad (8)$$

$$\triangle Na_2O/W_p = (Na_2O_p - Na_2O_s)/W_p = Na_2O_p/W_p - (Na_2O_s/W_s)(W_s/W_p) \quad (9)$$

In (7), (8) and (9), SiO_{2p}/W_p, CaO_p/W_p, and Na_2O_p/W_p are the average values of fresh volcanic ashes, SiO_{2s}/W_s, CaO_s/W_s, and Na_2O_s/W_s are the individual values of soil samples, and W_s/W_p can be obtained from (1). We are then able to examine the validity of (6). The left side of (6) can be calculated using the following equation:

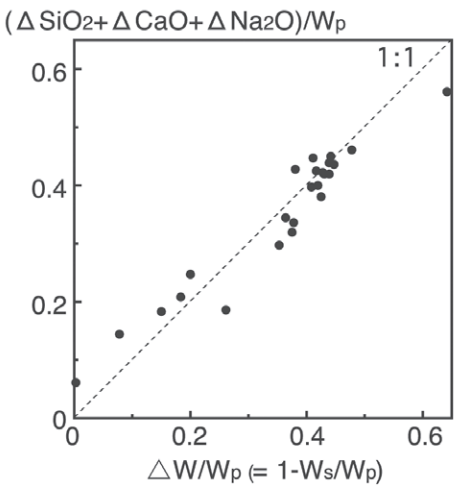

Fig. 16a. Relationship between the weight loss and the summation of the decreases in SiO_2, CaO and Na_2O.

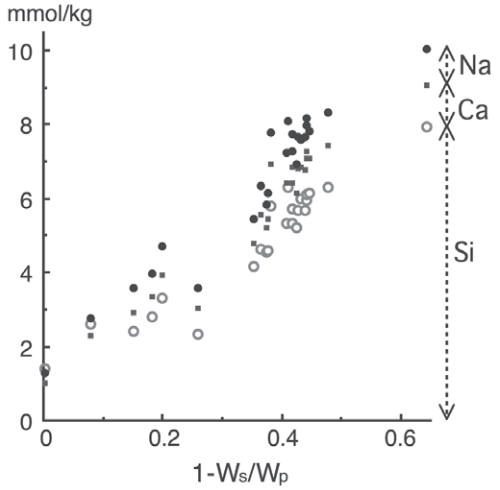

Fig. 16b. Breakdown of the weight loss into the individual loss of Si (○), Ca (■) and Na (●) on a molar basis.

Table 2. Comparison of selected atomic ratios between the depleted elements from Andosols and the dissolved elements in the river water.

	Atomic raitos		
	Si/Na	Si/Ca	Na/Ca
Depleted from Andosols	6.33a***	4.56a	0.72b
River water in the Andosol areas*	1.70b	2.61b	1.74a
River water in areas other than Andosols**	1.00d	1.24d	1.41a
All river water tested	1.24c	1.71c	1.52a

*: Rivers showing SiO_2 concentration of 20 mg kg^{-1} or more were included in the Andosol areas.

**: Rivers showing SiO_2 concentration of less than 20 mg kg^{-1}.

***: Different letters show significant difference according to Schefe's test at p=0.05.

$$\triangle W/ W_p = (W_p - W_s)/W_p = 1 - W_s/W_p \qquad (10)$$

Results are shown in Fig. 16a. This figure shows that estimation of the weight loss from the summation of $\triangle SiO_2$, $\triangle CaO$ and $\triangle Na_2O$ is identical to that estimated from Al_o formation. Conversion to molar basis and breakdown to Si, Ca and Na (Fig. 16b) indicate that the contribution of Si loss to the weight loss is much larger than that of Ca or Na loss.

It has been repeatedly stated that the Si concentration of river water is high in a volcanic area. We can understand this statement from Kobayshi (1971) who showed a close relationship between the areas of high SiO_2 concentration in the river water (WQRJ) and the allophanic Andosol areas (Saigusa and Matsuyama, 1998).

Sodium and Ca, released during Andosol formation (Fig. 15), are introduced at least partly into river water. Accordingly, the Na concentration in the river water of a volcanic area tends to be higher than those in other areas, but the Ca concentration is not different between the volcanic areas and other areas. The atomic ratios of Si/Na and Si/Ca were significantly higher in the lost fraction from volcanic ash during Andosol formation than those in the river water (Table 2). If the amount of Si in the river water is comparable to or slightly lower than that leached into the water from Andosols, the amounts of Na and Ca are higher in the river water than those expected from leaching during Andosols formation. These results suggest that other effects on the Na and Ca concentrations of the river water are greater than those from Andosol formation.

Concluding remarks

Soil databases for research purposes are constructed

according to the individual research topic. We have exemplified databases used for pedological studies on volcanic ash soils. The size of the database may be small in many cases, and the database may not necessarily be suitable for other purposes. Research studies are like living things. It is not easy to forecast the new research needs of other researchers. Thus, although researchers can utilize existing databases, they may improve them or construct new databases depending on their purposes. Even if the databases for research purposes are small and specialized, they may still be useful for creating a collection of databases by receiving offers from researchers and distributing them to new users, although it may not be so easy to follow the various changes like the version of software or operating systems. It is useful to store soil samples to distribute for research purposes, although the amount of the samples may not be infinite. The soil monolith museum in NIAES already has that kind of function.

Understanding the relationships between many individual soil data is improving, for example, as pedotransfer functions. They are useful in outlining the relationships between different data. However, if one needs information at a specific site, a direct survey is still important. In that case, the databases can play a role in providing preliminary information. Although it was beyond our reach to handle soil maps here, the combination of soil data and soil maps in various forms is useful for a broad range of users.

Further recent readings on volcanic ash soils have been edited and published by Buurman and Regalado (2007), Arnalds et al. (2006), Takesako (2006), Dahlgren et al. (2004), Arnalds et al. (2004), Bartoli et al. (2003), Matsumoto (2002), Harsh et al. (2002), Chen (2000), Ping (2000), and others.

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Ammonia Emission and Carbon and Nitrogen Balances during Acidulocomposting of Garbage

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Abstract

This study was conducted to estimate the amount of ammonia that was emitted during the acidulocomposting of garbage under thermoacidophilic conditions. In addition, the carbon and nitrogen balances of the acidulocomposting system were determined. During acidulocomposting, the mixture of garbage and sawdust was maintained at a relatively high temperature (51.0-68.0 °C), while the pH of the mixture changed from 4.5 to 5.7. Furthermore, ammonia emission during acidulocomposting was inhibited, which resulted in an overall decrease in the loss of ammonia. Finally, the dry weight and carbon losses that were observed during acidulocomposting were smaller than those that were observed during general composting and the mineralization of organic matter in the garbage was suppressed.

1. Introduction

Approximately 590 million tons of waste were generated in Japan in 2001, 47% of which was biological waste (Goto, 2005) composed of livestock waste, garbage and sludge. These types of biological waste contain high levels of nutrients such as nitrogen, phosphorus, potassium and other various minerals; therefore, they can cause environmental problems such as water pollution and malodorous pollution. Thus it is necessary to establish alternative methods of treating biological waste.

Composting biological waste is a common method that enables its effective utilization. The compost formed can be used by the agricultural industry as an organic fertilizer, and is one of the important components in recycling-oriented agricultural systems. However, a large amount of nitrogen loss occurs during the composting process due to the emission of ammonia. This emission occurs because the composting process generally proceeds under alkaline conditions (pH 7.5-9). Indeed, gaseous nitrogen losses during the composting of garbage, livestock and sludge have been estimated to be 50-60%, 77% and 68%, respectively (Kirchmann and Widén, 1994; Brink, 1995; Martins and Dewes, 1992; Witter and Lopez-Real, 1988). Ammonia emission during the composting process results in the loss of an essential plant nutrient. In addition, ammonia emission may lead to environmental problems such as eutrophication of nearby aquatic systems and soil acidification because most of the emitted ammonia returns to the surface with rainfall in the form of ammonium.

Nishino et al. (2003) proposed a new, highly practical method of accelerated high-temperature (40-65 °C) composting of garbage, which was named acidulocomposting. Acidulocomposting is autonomously sustained under acidic conditions (pH 4-6) via the production of acid by thermophilic lactic acid bacteria (Hemmi et al., 2004). Although low pH conditions are known to lead to a reduction in ammonia emission, to date, no studies have been conducted to determine if acidulocomposting leads to reduced ammonia emissions. Therefore, this study was conducted to quantify the amount of ammonia emitted during the

acidulocomposting of garbage. In addition, the carbon and nitrogen balances of an acidulocomposting system were determined.

2. Materials and methods

2. 1. Equipment

Acidulocomposting was conducted using a "Bio-Clean" (2 kg-type, Star Engineering Co., Ltd.). This system contains a reactor that can treat a maximum of 2 kg of garbage per day. The reactor contains three rotating bars that agitate the garbage, as well as a heater with a thermostat that enables a constant temperature to be maintained (Fig. 1). In addition, a control sample was composted using a small composting apparatus ("Kaguyahime", Fujihira Industry Co., Ltd.; Fig. 1).

2. 2. Garbage

Standard garbage composed of mixed boiled rice (15%), fish (12%) and vegetables (73%) was used for the composting tests (Japan Food Recycling Processor, 2006). The fish and vegetables were finely cut in a food processor fitted with steel blades.

2. 3 Composting experiments

2.3.1. Short-term experiment

A short-term experiment was conducted to compare the amount of ammonia emitted during acidulocomposting to the amount emitted during general composting. To accomplish this, garbage was subjected to acidulocomposting or control composting for 21 days. Each experiment was conducted in duplicate. In the acidulocomposting experiment, 2 kg of sawdust that had been inoculated with thermoacidophilic bacteria (TAB) were added to the reactor prior to addition of the garbage (Nishino et al., 2003). On each day during the experiment, 1 kg of garbage was added to the machine at approximately 10:00 h. The water contents of the garbage and sawdust were approximately 85 and 75 %, respectively. For the control composting test, a mixture of 7.36 kg of garbage and 0.71 kg of inoculated sawdust were added to the composting apparatus. This mixture ratio was used to provide approximately the same ratio of garbage to sawdust that was present in the mixture that was subjected to acidulocomposting at the end of the experiment.

The temperature of the mixture in the reactor was measured every day. In addition, the mixture was turned and sampled at 7, 14 and 21 days after composting was started. The weight, moisture content and pH of the samples were subsequently determined. In addition, aliquots of the samples were freeze-dried and finely ground, after which the total nitrogen and carbon contents were determined using a NC analyzer (Sumigraph NC-80S, SCAS Ltd.). Additionally, an apparatus designed to trap ammonia in the exhaust gas of the reactors was connected to each machine (Kuroda et al., 2004; Fig. 2). The sulfuric acid solution and accumulated water were then collected from the machines cooling flask at intervals of 3 days, after which the ammonia concentration of the liquid samples was determined using the indophenol method (Scheiner, 1976).

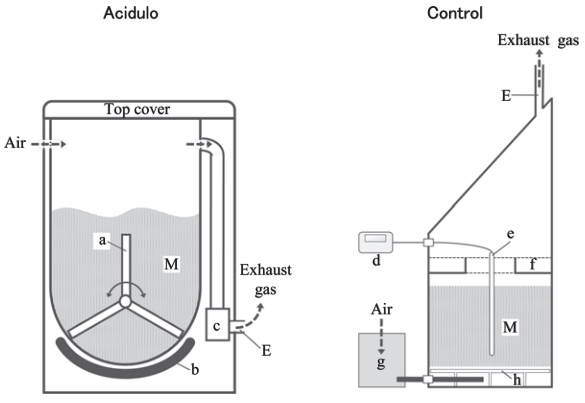

Fig. 1. Diagram of the acidurocomposting and the control composting machine. M: mixture, E: exhaust vent, a: rotating bar, b: heater with thermostat, c: fan, d: temperature data logger, e: rod with thermocouple wires, f: trap for accumulated water, g: aeration pump, h: stainless-steel mesh. Dashed arrow shows direction of air flow.

2.3.2 Long-term experiment

A long-term experiment was conducted to clarify

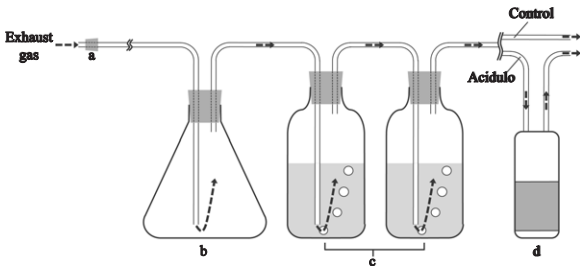

Fig. 2. Diagram of the apparatus for trap of ammonia in exhaust gas. a: connector to exhaust vent of composting machine, b: flask for cooling of exhaust gas, c: reagent bottle with 6 mol L^{-1} sulfuric acid for ammonia trap, d: aeration pump (only the acidulocomposting test)

the effect of TAB on acidulocomposting. To accomplish this, the same garbage that was used in the short-term experiment was subjected to acidulocomposting under the same conditions described above for 68 days. However, TAB-inoculated or non-inoculated sawdust was added to the reactors prior to the first addition of garbage. The temperature and pH of the mixture in the reactor were then measured every day. In addition, samples of the mixture were collected every 2-6 days, after which the weight, moisture, nitrogen and carbon contents were determined as described above.

3. Results and Discussion

3.1 Short-term experiment

Figure 3 shows the changes in the temperature and pH of the mixtures throughout the experiment. During the experiment, the temperature of the control compost fluctuated widely between 17.4 and 63.3 ° C. The temperature likely increased at the beginning of the experiment and during turning in response to increased aerobic microbial activity. Conversely, the temperature of the mixture during the acidulocomposting remained relatively constant (51.0- 68.0 °C) throughout the experiment due to the heater attached to the reactor. The initial pH of the experimental mixture was approximately 5.7. In the acidulocomposting experiment, the pH decreased to 4.5 after 7 days, after which it increased to 4.7, where it remained for the duration of the experiment. In contrast, the pH of the mixture in the control compost increased to 8.5-8.7, where it remained for the duration of the experiment. The acidification of the mixture in the acidulocomposting treatment likely occurred due to the production of organic acids such as lactic acid. The increase in the pH of the mixture in the control treatment likely occurred due to the decomposition of organic acid and the presence of ammonia formed during mineralization. Additionally, the compost mixtures became brown in both treatments. Furthermore, the control compost mixture had an ammonia-like odor, while the acidulocomposting treatment had a caramel-like and weak burning smell, which is commonly reported for acidulocompost mixtures (Nishino et al., 2003).

Figure 4 shows the amount of ammonia that was trapped by the 6 mol L^{-1} sulfuric acid solution and the accumulated water. Up to 2.3 mg g^{-1} ammonia was emitted from the control compost, while the cumulative amount emitted for 21 days was 8.2 mg g^{-1}. Conversely, almost no ammonia was emitted during acidulocomposting. It is believed that the reduced ammonia emissions that were observed during acidulocomposting occurred due to the acidic conditions. Taken together, these results suggest that the acidulocomposting system is able to suppress ammonia emission during the composting of garbage.

During the control composting experiment, the dry weight of the mixture decreased by 43 % after 21 days (Fig. 5). This drastic decrease likely occurred due to active decomposition of the organic matter in the mixture by microorganisms. Conversely, the dry weight of the compost mixture was almost the same as the input weight of the garbage and sawdust at the end of the acidulocomposting experiment, with only

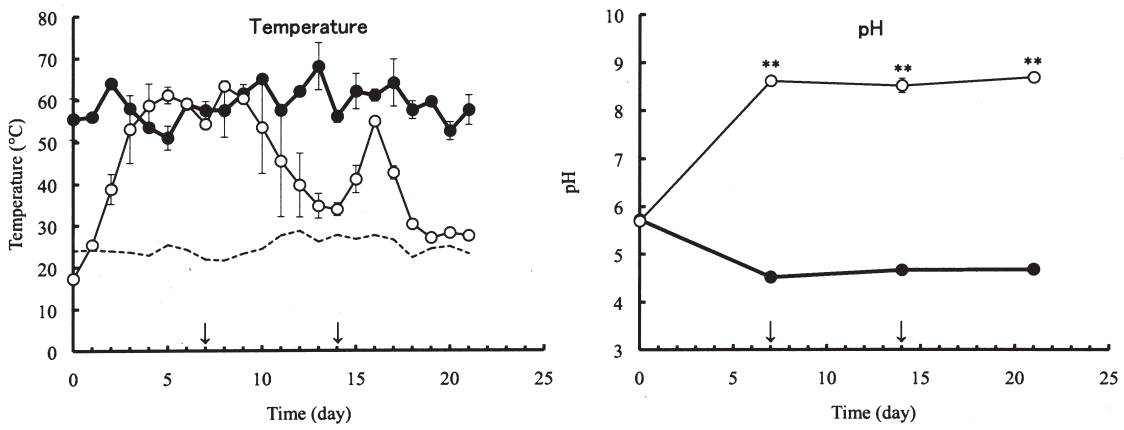

Fig. 3. Changes in temperatures and pH of the mixture during the composting in 21 days. Vertical lines indicate the standard deviation (*n*=2). Allows indicate a day of turning of mixture. Asterisk indicates significantly difference between the acidurocomposting and the control composting treatments (Student's t-test, ** *P=0.01*)
—●— : Acidulo, —○— : Control, ----- : Ambient.

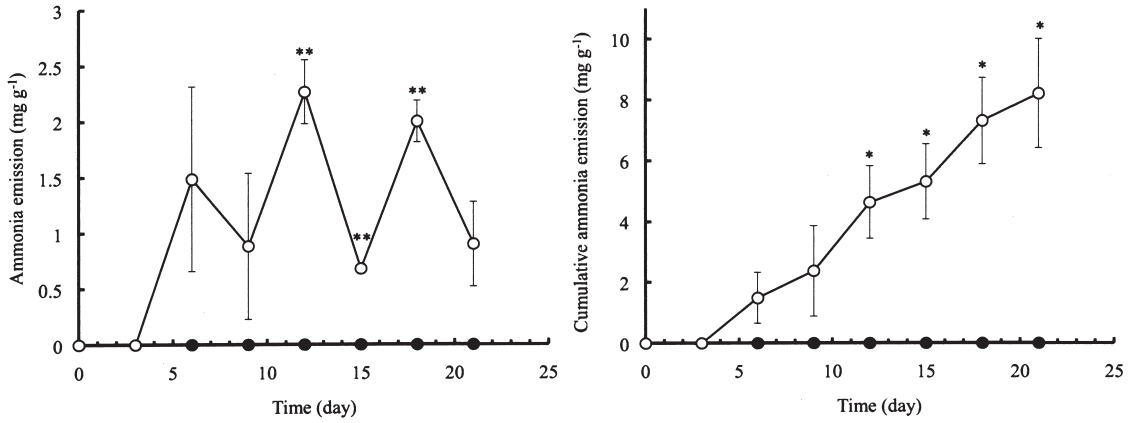

Fig. 4. Changes in amount of ammonia emission from the mixture during the composting. Vertical lines indicate the standard deviation (*n*=2). Asterisk indicates significantly difference between the two treatments (Student's t-test, ** *P=0.01*, * *P=0.05*). —●— : Acidulo, —○— : Control.

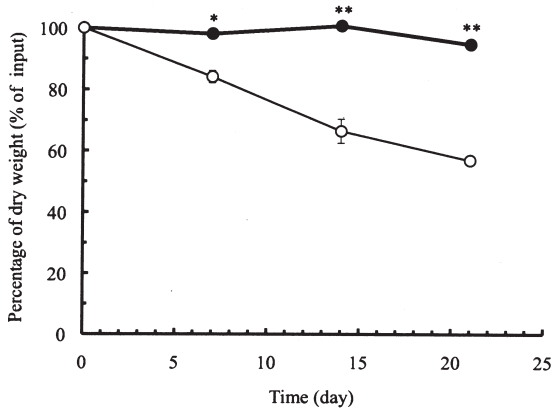

Fig. 5. Changes on percentage of dry weight of the mixture to input during the composting. Vertical lines indicate the standard deviation (*n*=2). Asterisk indicates significantly difference between the two treatments (Student's t-test, ** *P=0.01*, * *P=0.05*).
—●— : Acidulo, —○— : Control.

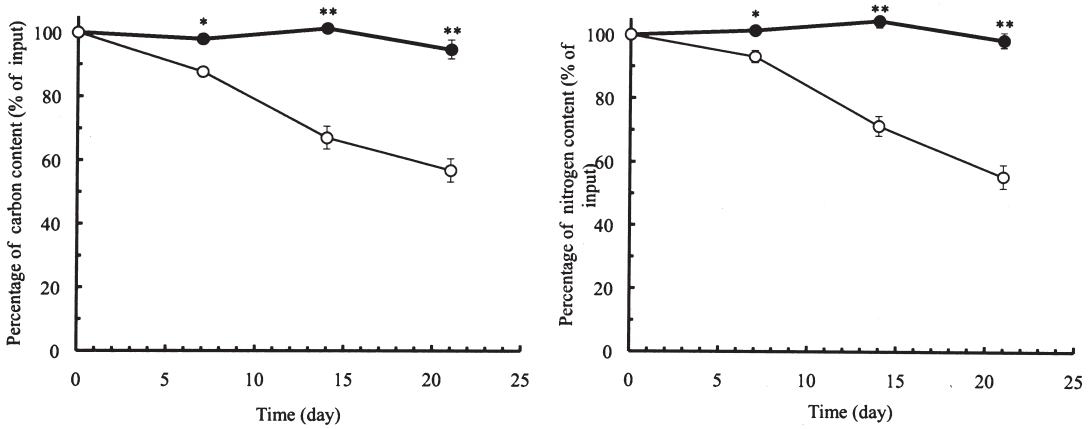

Fig. 6. Changes on percentage of carbon and nitrogen of the mixture to the input those during the composting in 21 days. Vertical lines indicate the standard deviation (*n*=2). Asterisk indicates significantly difference between the two treatments (Student's t-test, ** *P=0.01*, * *P=0.05*).
—●— : Acidulo, —○— : Control.

a 5 % decrease in dry weight being observed. These results suggest that very little mineralization of the organic matter occurred during acidulocomposting, which was supported by changes in the carbon contents of the mixture that were observed throughout the experiment (Fig. 6). Specifically, approximately 43 % of the carbon was lost after 21 days during the control composting experiment, whereas only 5 % of the carbon was lost during the acidulocomposting experiment. The nitrogen loss was also lower in the acidulocomposting experiment when compared with the control experiment. Specifically, a 2% reduction in nitrogen occurred during the acidulocomposting experiment, while a 44% reduction occurred during the control composting experiment (Fig. 6). Taken together, these results suggest that the ammonia emission was inhibited by the acidic conditions as well as the inhibition of nitrogen mineralization of the organic matter in the mixture.

3.2 Long-term experiment

Figure 7 shows the changes in the temperatures and pH of the mixtures that occurred when composting was conducted for 68 days. The temperatures and pHs differed significantly between samples that were inoculated with TAB and those that were not. Specifically, the temperature of the mixture changed from 49 to 67 °C for both treatments. In addition, the composting proceeded under acidic conditions for both treatments; however, the pHs of the mixtures decreased from approximately 5.7 to 4.8 after 10 days, and finally to 4.0.

Figure 8 shows the changes in the dry weight of the mixture and the cumulative input throughout the experiment. Inoculation with the TAB based material did not have a significant effect on the dry weight of the mixture. Specifically, the dry weight of the cumulative input material over 68 days was approximately 13.1 kg for both treatments. The dry weight of the mixtures was reduced by 8.3 and 5.3% after 68 days to 12.0 and 12.4 kg for the TAB inoculation and non-inoculation treatments, respectively. Both mixtures were brown during the early stage of acidulocomposting, after which they turned blackish brown. The overall appearance of the compost mixture did not differ between the two treatments.

Figure 9 shows the changes in the carbon content of the mixture and the cumulative amount of input carbon over the course of the experiment. The cumulative amount of input carbon was 6.3 kg at the end of the composting test, while the carbon contents of the compost mixtures were 6.0 and 6.3 kg for the TAB inoculation and non-inoculation experiments, respectively. The carbon loss that occurred during composting did not differ significantly between the TAB inoculation and non-inoculation treatments. These results suggest that carbon mineralization of the organic matter in the mixture was inhibited in both treatments as in the short-term experiment. In addition, the nitrogen content of the compost mixtures did not differ significantly between treatments, and nitrogen loss did not occur in either treatment group (Fig.10).

Figure 11 shows the changes in the carbon-nitrogen ratio (C/N ratio) of the mixtures that occurred throughout the experiment. The initial C/N ratios of the mixtures were very high (> 1000) for both treatment groups. However, the C/N ratio of the mixture was drastically reduced to around 100 within two days of the addition of garbage. Furthermore, the C/N ratio of the compost formed was finally reduced to 18, which was similar to that of the untreated garbage (about 16.3). Thus TAB inoculation of the treated material did not affect the chemical characteristics of the mixture produced during accelerated high-temperature composting. Furthermore, acidulocomposting proceeded regardless of the use of TAB inoculation in this experiment, which indicates that TAB inoculation was not necessary for acidulocomposting to occur. However, in this regard, we cannot rule out the possibility that the microorganism used in the TAB inoculation experiment was transported to the non-inoculation experiment.

Significant decreases in the dry weight and carbon and nitrogen content were not observed during acidulocomposting in the short or long-term experiments. The small amount of nitrogen loss that occurred during acidulocomposting may be advantageous for the environment and the nitrogen content of the compost that is produced. However, the small amount of carbon loss that occurred during acidulocomposting indicates that easily decomposable organic matter was present in the compost that was generated. As a result, the acidulocompost was considered similar to immature compost. Application of compost with a high content of easily decomposable organic matter could cause problems such as nitrogen deficiency in crops and the production of noxious substances (Mathur et al., 1993). In fact, Ito and Minamide

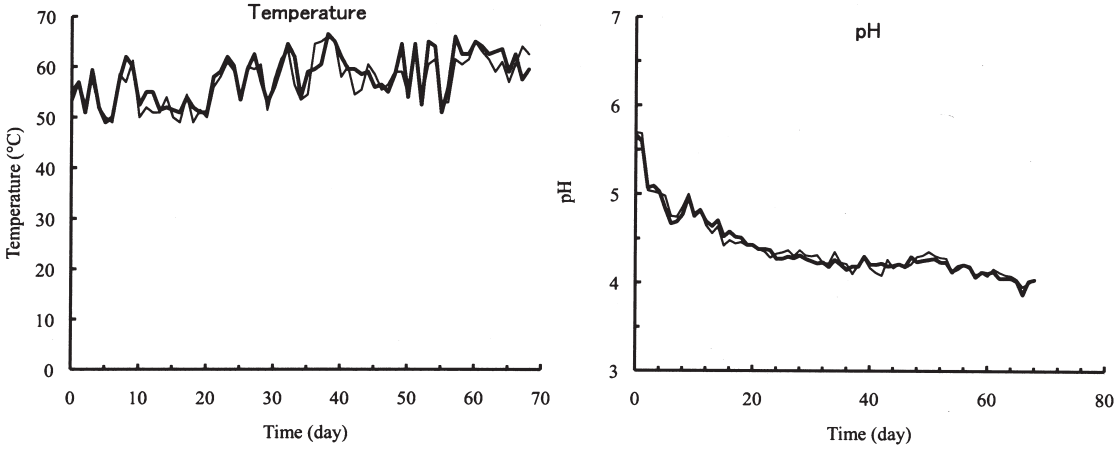

Fig. 7. Changes in temperatures and pH of the mixture during the composting in 68 days.
—— : TAB inoculation, —— : non-inoculation.

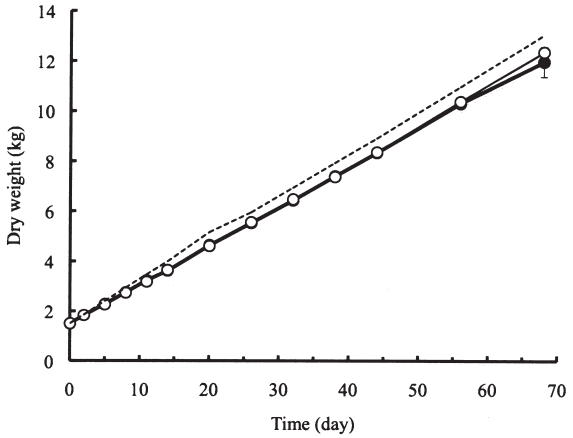

Fig. 8. Changes in dry weight of the mixture and the cumulative input during the composting in 68 days. Vertical lines indicate the standard deviation (*n*=2).
—●— : TAB inoclation, —○— : non-inoculation,
----- : input.

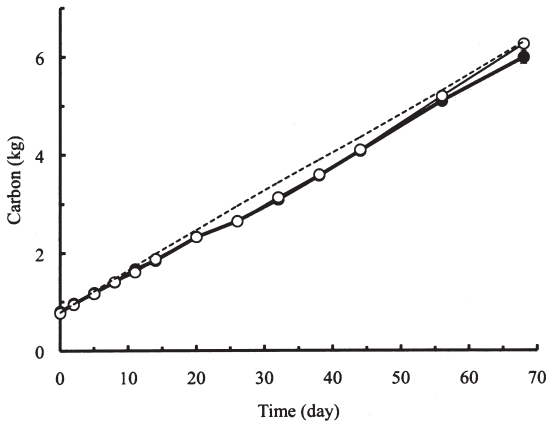

Fig. 9. Changes of carbon content in the mixture and the cumulative amount of input carbon during the composting in 68 days. Vertical lines indicate the standard deviation (*n*=2).
—●— : TAB inoclation, —○— : non-inoculation,
----- : input.

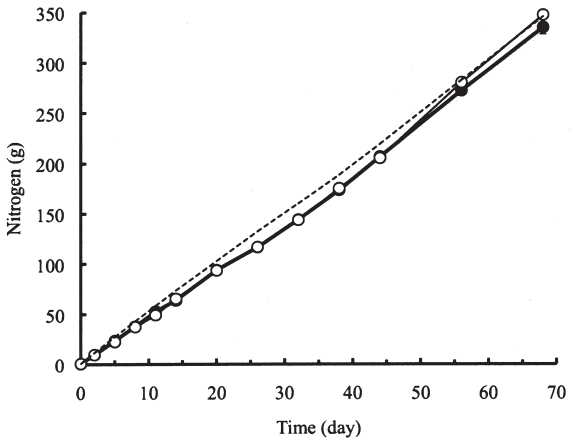

Fig. 10. Changes of nitrogen content in the mixture and the amount of cumulative input carbon during the composting in 68 days. Vertical lines indicate the standard deviation (*n*=2).
—●— :TAB inoclation, —○—: non-inoculation,
----- :input.

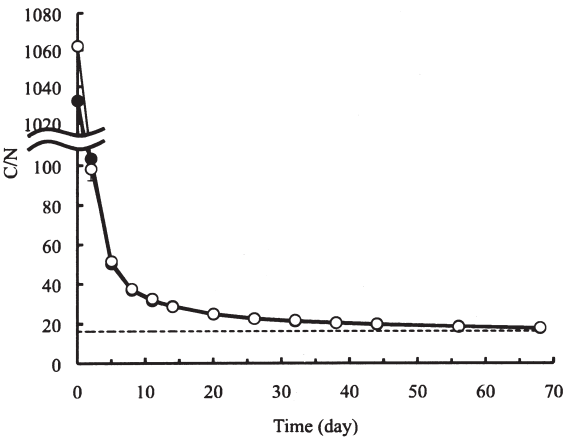

Fig. 11. Changes of carbon-nitrogen ratio of the mixture during thecomposting in 68 days. Vertical lines indicate the standard deviation (*n*=2). Dash line indicate C/ N ratio of input garbage.
—●— :TAB inoclation, —○— :non-inoculation.

(unpublished results) reported that the early growth of Komatsuna (Brasica rapa L. var. perviridis) was suppressed by the application of acidulocompost. However, Tatenai et al. (2006) reported that the application of acidulocompost enhanced the growth and tuber yield of potato (Solanum tuberosum L.). Taken together, these previously conducted studies indicate that the response of crops to the application of acidulocompost varies by species. Therefore, additional studies should be econducted to evaluate the effect of the application of acidulocompost on crop plants.

The results of the present study indicate that the acidulocomposting system evaluated here resulted in reduced nitrogen loss during composting due to the inhibition of ammonia emission. However, carbon loss was also reduced by inhibition of the mineralization of organic matter in the treated garbage.

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Measurement of Organic Phosphorus Mineralization in Non-Allophanic Andosols Using Anion Exchange Resin

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Abstract

The objective of this study was to develop a new method to measure organic phosphorus (Po) mineralization in non-allophanic Andosols by incubation of a mixture of soil and an anion-exchange resin (AER, Cl-saturated, strongly basic IRA-900) and to examine the implications of Po mineralization for soil P fertility. Five soil samples with widely different P statuses were collected from forestland, grassland, and cultivated land (corn and garlic fields). The mixing ratio of soil to AER affected the recovery rate of inorganic P (Pi) added to the soil samples along with the AER; a 1:1 ratio seemed to be optimal. Recovery rates of added Pi ranged from 68% to 74% for the five soils, and the amounts of AER-extractable Pi ranged from 2.9 to 27 mg P kg^{-1}. These recovery rates and the amounts of AER-extractable Pi were used for estimating gross Po mineralization. The amounts of Po mineralized after 42 days of incubation ranged from 3.1 to 7.9 mg P kg^{-1}, and the amounts were higher in the soils from the garlic field and the forestland than in the soils from the grassland and the cornfields. The relationship between total Po and mineralized Po suggests that this new method can be used to determine Po mineralization rates in Andosols. Our results indicate that Po mineralization is an important source of plant-available P in unfertilized forest soil.

Introduction

In most soils, organic phosphorus (Po) accounts for 30–65% of total phosphorus (Harrison, 1987). The mineralization of Po plays an important role in the cycling of phosphorus (P) in soils. Oehl et al. (2001) determined a basal daily P mineralization rate of 1.7 mg P kg^{-1} for a soil that had been managed under a bio-organic cropping system. This rate is equivalent to the equilibrium concentration of inorganic P (Pi) in the soil solution. Lopez-Hernandez et al. (1998) measured daily mineralization rates of 0.22–0.90 mg P kg^{-1} in Mollisols in the United States. In natural ecosystems and agricultural lands with a low input of P fertilizer, Po mineralization is considered to play an important role in supplying P to plants by replenishing inorganic P (Pi) in the soil solution (Sharpley, 1985). Therefore, methods for measuring Po mineralization are of interest.

Biomass P measurement and ^{32}P isotope dilution have been proposed as methods for measuring Po mineralization in soil. Biomass P has been measured by means of a chloroform fumigation method using 0.5 M $NaHCO_3$ as an extractant (Brookes et al., 1982; Hedley and Stewart, 1982). The isotope dilution method involves measuring changes in the amount of ^{32}P in soil solution (Oehl et al., 2001) or measuring the amount of ^{32}P extracted by an anion exchange membrane (Lopez-Hernandez et al., 1998). However, these methods cannot differentiate mineralized P from the Pi released from the soil Pi pool. For soils with a high P-retention capacity, such as Andosols, these methods may underestimate Po mineralization, owing to considerable Pi fixation by soils during the fumigation and extraction processes or during the equilibration process after the addition of ^{32}P.

For more precise measurement of the amounts of mineralized P and biomass P, alternative methods have been proposed. Use of an anion exchange membrane (Kouno et al., 1995) or a Bray extractant instead of an Olsen extractant (Oberson et al., 1997)

has been proposed for improving the recovery rate of P mineralized during biomass P measurements. The use of γ-ray irradiation and autoclave treatments to determine the fractions of gross P mineralization and immobilization has been reported (Zou et al., 1992). However, Po mineralization cannot be directly determined from biomass P measurements, and the γ-ray irradiation method proposed by Zou et al. (1992) is not convenient. Anion exchange resins (AER) have been used to assess the amount of plant-available Pi in soils (Amer et al., 1955; Cooke and Hislop, 1963). AER can remove labile Pi from soils without chemical alteration, pH change, or re-sorption or immobilization of Pi produced by mineralization. Parfitt and Tate (1994) developed a method for measuring Po mineralization using an anion exchange membrane with incubation after removal of labile Pi.

Volcanic ash soils (Andosols) commonly contain large amounts of organic matter and Po. Mineralization of Po in Andosols is considered to be an important P source for crops. However, Po mineralization rates for non-allophanic Andosols (Aluandic Andosols) have not been estimated.

The objectives of this study were to develop a simple method, based on the method of Parfitt and Tate (1994), to determine Po mineralization rates in soils using an AER and to determine the Po mineralization rates in non-allophanic Andosols under varied soil management systems.

Materials and methods

1) Soil samples

Soils used in this study were collected at Field Science Center of Graduate School of Agricultural Science, Tohoku University, in northeastern Japan (Table 1). Five soil samples, which had different Po and labile Pi contents, were collected from forestland, grassland, and cultivated land (two corn fields and a garlic field). The fields from which the soil samples were collected were adjacent to one another. The soils showed high P retention and large amounts of active Al and Fe and were classified as Melanic Aluandic Andosols according to IUSS Working Group (2006). Forest soil was collected from a depth of 0–10 cm, and the other 4 samples were collected from a depth of 0–15 cm. The grassland had been used for forage production for 9 years, and P-containing fertilizer had been applied at the rate of 42 kg P $ha^{-1}year^{-1}$. Phosphorus fertilizer and cattle manure compost had been applied to the garlic field at rates of 340 kg P ha^{-1} $year^{-1}$ and 27 t ha^{-1} $year^{-1}$ for 5 years, respectively. Phosphorus fertilizer had been applied to the cornfields at the rate of 87 kg P ha^{-1} $year^{-1}$ for 5 years. The Po and Pi contents of each soil differed substantially and were in the ranges of 164–391 mg P kg^{-1} and 808 –3870 mg P kg^{-1}, respectively.

Soils were air-dried and sieved (<0.5 mm) after removal of plant roots. Before incubation with the AER, the soil pH was adjusted to 6.0 using $CaCO_3$, so that Po mineralization rates for the various soils could be compared under the same pH conditions.

2) Soil analysis

Soil pH was measured in aqueous solution with a glass electrode at a soil to water ratio of 1:2.5. Organic C was determined by the Tyurin method (Tyurin, 1931). Total P was determined by the colorimetric method of Murphy and Riley (1962) after digestion by HNO_3–$HClO_3$. Po was measured by the ignition method (550 °C, 1 h) described by Saunders and Williams (1955). Available P was measured by the method of Truog (1930). Phosphate retention and the amounts of acid oxalate–extractable Al and Fe were determined by the method of Blakemore et al. (1981).

3) Preparation of anion exchange resin and extrac-

Table 1. Chemical properties of non-allophanic Andosols used in this study

	pH (H_2O)	Organic carbon (g/kg)	P retention (%)	Acid oxalate extractable Al and Fe / Al+ 1/2 Fe (g/kg)	Total P (mg P/kg)	Organic P (mg P/kg)	Inorganic P (mg P/kg)	Truog P (mg P/kg)
Forest soil	4.8	144	94	19.0	1078	270	808	3.49
Grassland soil	4.8	81	95	27.2	1759	213	1546	37.3
Corn field soil 1	6.1	79	96	24.7	2257	205	2052	72.0
Corn field soil 2	6.0	85	95	22.1	2483	164	2319	91.6
Garlic field soil	5.9	96	91	21.3	4261	391	3870	453

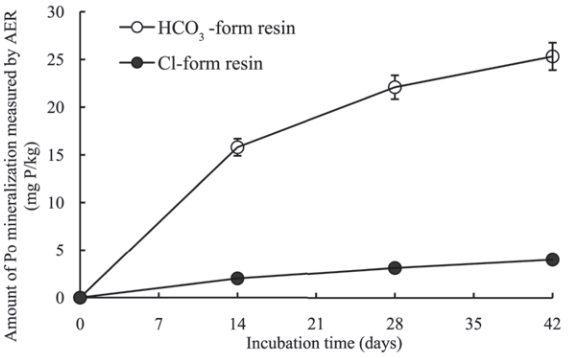

Fig. 1. Effect of saturated anion type of AER added to forest soil on soil Po mineralization (Bars show standard deviations (n=2))

tion of P recovered by resin

Preliminary studies were conducted to determine the most suitable anion for the AER. Figure 1 shows the amounts of P mineralized from the Po pool of the forest soil during incubation with a Cl-form resin and a HCO_3-form resin. The amounts of P mineralized from the Po pool were obtained by subtracting the amount of Pi extracted by the AER during a 24-h period prior to incubation (labile Pi) from the amount of Pi extracted by the AER after incubation (details described below). The HCO_3-form resin extracted much more Pi than the Cl-form resin because the soil pH changed from 6 to 7 upon the addition of the HCO_3-form resin; addition of the Cl-form resin did not affect the soil pH. Because the HCO_3-form resin artificially increased mineralization of soil Po, the Cl-form resin was more suitable for estimating Po mineralization.

The strongly basic AER resin (IRA-900 Amberlite) used in this study was sieved to less than 0.5 mm and saturated with Cl ion using 1 M HCl and 1 M NaCl. The Cl-saturated AER was washed with distilled water until the filtrate pH reached 4.5. The air-dried AER contained 20% moisture. Nearly 100% of P absorbed by the AER (10 g) was recovered after 3 extractions with 50 ml of 1 M NaCl (data not shown).

4) Measurement of Po mineralization

Incubation method

Distilled water was added to the air-dried and sieved soil to attain a soil moisture condition of 60% water-filled pore space, a value that is equivalent to the field moisture capacity. Moistened soil equivalent to 10 g of oven-dry soil was mixed with 10 g of AER in a polyethylene bag with a small hole. Three such bags were prepared and incubated at 30 °C under aerobic conditions. The soil moisture content was adjusted to the initial value every 7 days.

Measurement of Po mineralization in soils

Po mineralization in soils was measured as follows. Mixtures of soil and AER, both before and after incubation, were transferred to 100-ml plastic bottles containing 50 ml of distilled water, and the slurries were shaken for 24 h at 25 °C. Soil particles were removed by sieving (mesh size, <0.5 mm) and supersonication (5 min) after the shaking. The collected clean AER (10 g) was shaken with 50 ml of 1 M NaCl solution for 1 h to elute Pi from the AER. The resin was extracted 3 times, and the recovered Pi was measured by the colorimetric method of Murphy and Riley (1962).

The amount of P mineralized during incubation was calculated with the following equation: amount of P mineralized from the soil Po pool = (amount of Pi extracted by AER after incubation – amount of Pi extracted by AER before incubation)/recovery ratio.

Determination of the optimal soil:AER ratio for efficient capture of Pi from soils

It is possible that not all of the Pi produced by mineralization of the Po pool was recovered by the AER, because some of the mineralized P could have been fixed by soil colloids during incubation. Therefore, we examined the effect of the soil:AER mixing ratio on the Pi recovery rate. KH_2PO_4 solution (50 ml, 8.7 μg P ml^{-1}) was added to the moistened forest soil (10 g oven-dry basis) mixed with 5, 10, 15, or 20 g of AER in 100-ml plastic bottles, and the mixtures were shaken for 1 h. Two sets were prepared for this experiment. We determined the best mixing ratio on the basis of the amounts of Pi taken up by the AER.

Method for distinguishing between P mineralized from the soil Po pool and released from the soil Pi pool

Because labile Pi released from the soil Pi pool can be taken up by the AER during incubation, the Pi produced by mineralization of the Po pool had to be distinguished from the Pi released from the Pi pool in the soils. We tried to estimate net Po mineralization rates in soils by subtracting the amount of AER-extractable Pi before incubation from the amount of Pi recovered by the AER after incubation. We de-

termined the shaking time required for effective extraction of labile Pi released from the soil Pi pool. A mixture of each of the soils (10 g oven-dry basis) and AER (10 g) was shaken with 50 ml of distilled water for 3, 6, 12, 24, or 48 hours. Two sets were prepeared for each shaking time.

Determination of the efficiency of P recovery with the AER

Because mineralized P can be competitively absorbed by soil and AER during incubation, Po mineralization rates obtained by means of the above method were net values. To evaluate gross Po mineralization, we determined the recovery rate of Pi with the AER. A mixture of soil (10 g oven-dry basis) and AER (10 g) was shaken with 50 ml of KH_2PO_4 solution (8.7 μg P ml^{-1}). After shaking for 1 h, the amount of P recovered from the AER was determined for each soil.

Results and Discussion

1) Effect of soil:AER mixing ratio on recovery rate of added Pi

The recovery rate of added Pi was examined at different soil:AER mixing ratios for the forest soil. The recovery rate of Pi was significantly lower at a soil:AER ratio of 1:0.5, whereas there were no significant differences between the Pi recovery rates for mixing ratios of 1:1, 1:1.5, and 1:2, which were in the range of 73.5–75.3% (Table 2). Sibbesen (1978) reported that the amount of P extracted from soils by AER varied only slightly even when the AER:soil ratio was varied. In addition, Amer et al. (1955) and Olsen and Sommers (1982) used a resin:soil ratio of 1:1 for assessing labile P. Taken together with the results from previous studies, our results indicated that a soil:AER ratio of 1:1 was suitable for effective recovery of mineralized P.

2) Measurement of labile Pi extracted by the AER

The amounts of Pi extracted by the AER before incubation increased with the shaking time and reached their maximum values after 24 h for all 5 soils (Fig. 2). This result indicates that a shaking time of 24 h was sufficient to extract the labile Pi from the soils. The amounts of Pi extracted by the AER at 24 h were 2.9, 5.2, 8.3, 14, and 27 mg P kg^{-1} in the forest, grassland, cornfield-1, cornfield-2, and garlic field soils, respectively. The AER-extractable Pi correlated positively with the total Pi (R^2 = 0.956**, Fig. 5) and Truog P (R^2 = 0.921**). These relationships indicate that AER-extractable Pi was released from the soil Pi pool and that subtraction of AER-Pi removed before incubation from the AER-Pi removed after incubation was an effective method for determining Po mineralization.

3) The recovery rates of added Pi with AER

The recovery rates of added Pi with AER are shown in Table 3. The AER took up 68–74% of Pi added to the mixture of AER and soil. The result suggests that AER effectively absorbed Pi from soil solution, even for Andosols with a high P-fixation capacity. We used the values as correction factors to determine gross Po mineralization in this study.

4) Po mineralization during incubation

Po mineralization profiles for the 5 soils are shown in Fig. 3. These values were corrected with the amounts of labile Pi and the Pi recovery rates. Po mineralization increased with incubation time for all 5 soils. Nitrogen mineralization also occurred during the incubation experiment (Fig. 4). This result suggests that Po mineralization proceeded along with decomposition of organic matter. The amounts of Po mineralized after 42 days, which depended on the total Po contents in soils, were 4.6, 3.4, 3.1, 3.1, and

Table 2. Effect of mixing ratio of soil to AER on recovery rate of added Pi in the forest soil

Mixing ratio of soil to AER	Recovery rate of added Pi (%)	SD
1 : 0.5	69.9 a	0.95
1 : 1	74.2 b	0.55
1 : 1.5	75.3 b	0.90
1 : 2	73.5 b	1.05

There are significant difference (P<0.05) between the values with different letters by Tukey's HSD method. SD means standard deviation (n=2)

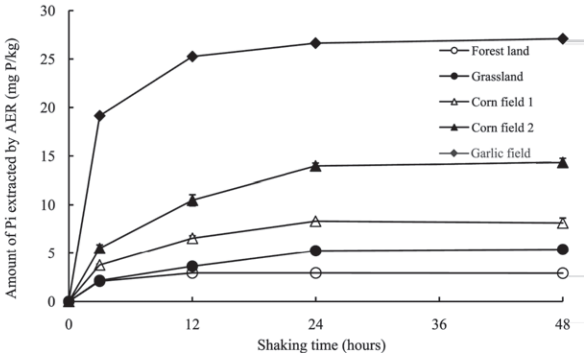

Fig. 2. Effect of shaking time on the amonuts of labile Pi extracted byAER
(Bars show the standard deviations (n=2))

Table 3. Percentage of Pi recovered by AER

Soil samples	Recovery rates of added Pi (%)	SD
Forest soil	74	0.55
Grassland soil	71	0.35
Corn field soil 1	71	0.95
Corn field soil 2	72	1.00
Garlic field soil	68	1.35

SD means standard deviation (n=2)

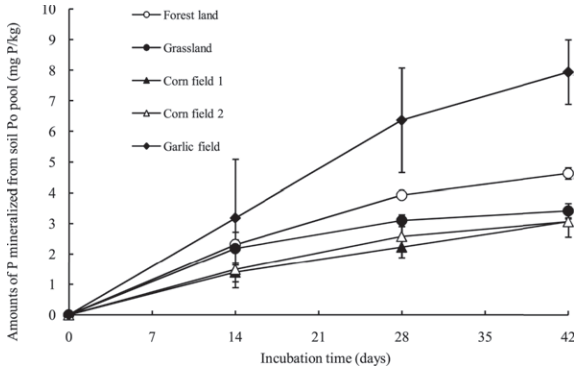

Fig. 3. Amounts of P mineralized from Po pools in non-allophanic Andosols with different land use
(Bars show standard deviations (n=3))

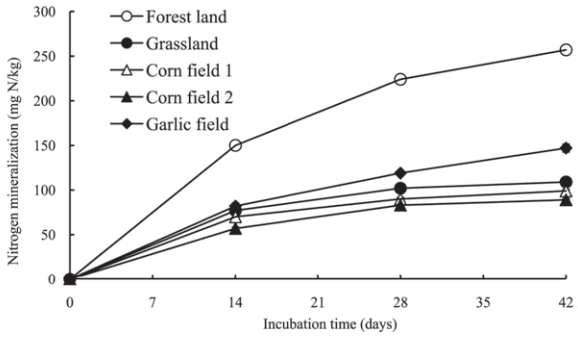

Fig. 4. Nitrogen mineralization in AER added soils during incubation
(Bars show standard deviation (n=3))

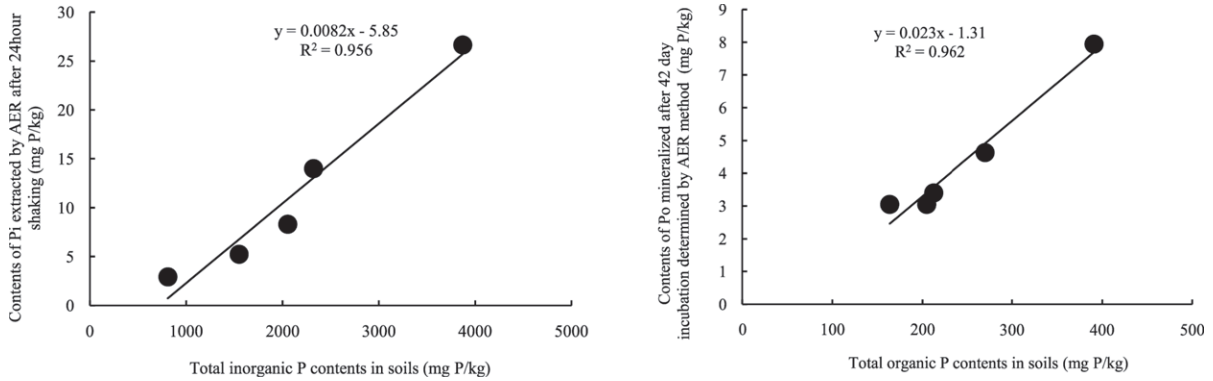

Fig. 5. Relationships between AER-Pi and inorganic P contents, and mineralized Po and organic P contents

7.9 mg P kg^{-1} in the forest, grassland, cornfield-1, cornfield-2, and garlic field soils, respectively. The amount of P mineralized after incubation for 42 days was positively correlated with total Po content (Fig. 5). Stewart and Sharpley (1987) also observed positive correlation between total Po and mineralized P in Texas soils. However, mineralized P was not significantly correlated with total Pi and labile Pi such as AER-extractable and Truog-extractable Pi in the soils. These results suggest that increased AER-P after incubation was released not from the Pi pools but from the Po pools in the soils. The method described

in this study is considered to be useful for measurement of Po mineralization in soils such as Andosols that have high P-fixation capacity.

5) Implications of Po mineralization for soil P fertility

The ratio of Po mineralized over a period of 42 days to bioavailable Pi (Truog-Pi) was 1.3 in the forest soil and <0.1 in the other soils. This result indicates that Po mineralization is an important source of P for plants in unfertilized forest soil. The percentage of Po mineralized over a period of 42 days ranged from 1.5% to 2.0% of the total Po in each soil. The amount of mineralized Po was highest in the garlic field soil, which had the highest Po content, followed by the forest soil. Po content greatly influenced the Po mineralization rates through microbial activity. Parfitt and Tate (1994) showed that the amounts of Pi released from Po in Andosols under forest vegetation ranged from 0.5 to 10.7 mg P kg^{-1} after incubation for 7 days at 39 °C. Assuming that the Q_{10} for Po mineralization is 2, the mineralization values at 14 days in this study correspond to the values obtained by Parfitt and Tate. The amounts of P mineralized after 14 days (1.3 to 3.1 mg P kg^{-1}) in our research were within the range obtained by Parfitt and Tate (1994).

In this study, air-drying and pH adjustment were carried out before incubation. These treatments were conducted to prepare uniform soil samples and measure Po mineralization under the same pH conditions. Air-drying of soil is known to reduce the biomass P and increase inorganic P extracted by $NaHCO_3$ (Brookes et al., 1982; Sparling et al., 1985). Organic P mineralization may decrease in an air-dried soil compared with a moist soil because the Pi derived from soil microorganisms killed by desiccation may be estimated as labile Pi by our method. Marumoto et al. (1982) reported that increasing the soil pH increased nitrogen mineralization. Increasing the soil pH may increase Po mineralization. Therefore, in future studies it will be necessary to measure Po mineralization using a moist soil without pH adjustment for estimating Po mineralization under in situ conditions.

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Marine Bio-Production Groups

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Integrated Field Control Group

Fukuo, A., T. Akiyama, W. Mo, K. Kawamura, Z. Chen and G. Saito (2008) Spectral detection of grazing degradation in the Xilingol Steppe, Inner Mongolia. Journal of Integrated Field Science, 5: 39-50.

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6th International Symposium on Integrated Field Science
-Understanding for each and integrated ecosystem using remote sensing-

Date: 26(Sat)-28(Mon) July 2008
Place: No.1 Room, Lecture Building, Department of Agriculture, Tohoku University, Tsutsumidori-Amamiyamachi 1-1, Aoba-ku, Sendai, Miyagi, Japan, 981-8555

International Symposium of Integrated Field Science is held every year since 2003, and the symposium themes are important topics for the integrated field science. Understanding for each and integrated eco-system is important for sustainability on the earth. We would like to discuss each and integrated eco-system using remote sensing.

Morning 26 July 2008 (Sat)

09:30-09:50 Opening Ceremony, Chairperson: Genya SAITO (Tohoku Univ.)
Yutaka NAKAI (Director General of Field Science Center, Tohoku Univ.) Welcome address
Masahiro KAWASAKI (President of RESTEC) Congratulatory address; (Reading the message by Tamotsu IGARASHI in RESTEC)

09:50-12:30 Keynote Presentation, Chairperson: Genya SAITO (Tohoku Univ.)
Joji IISAKA (Univ. of Victoria, Canada) Fusion of Field Science and Remote Sensing: "How to establish strategic approach for Global Environment Science"
Christopher D. ELVIDGE (NOAA USA) View of Humanity from Space
Lilik Budi PRASETYO (Bogor Agricultural Univ., Indonesia) Cause and Prediction of Deforestation in Java Island: Spatial Modeling Approach
Wei ZHANG (China Agricultural Univ.) Grassland Degradation and Recovery Based on Remote Sensing and GIS Inner-Mongolia
Satsuki MATSUMURA (Ocean Remote Sensing Expert) End User's Eye-View for Oceanography and Remote Sensing
Tsuyoshi AKIYAMA (Gifu Univ.) Satellite Ecology, an Attempt for Linking Remote Sensing and Ecology for River Basin Studies
Olaf NIEMANN (Univ. of Victoria, Canada) Integration of Airborne Technologies and Fusion of Multisensor Data to Enhance the Remote Sensing of Forested Environments

Afternoon 26 July 2008 (Sat)

14:00-15:30 Session A: Optical Senor, Chairperson, Yukio KOSUGI (Tokyo Tech. Univ.)
Naoko KOSAKA (Tokyo Tech. Univ.) Agricultural Field Observation Using Hyperspectral Sensor in Syonai
Yukio KOSUGI (Tokyo Tech. Univ.) Low-Altitude Hyperspectral Imaging of Naruko Integrated Field for the Interpretation of High-Altitude Observations
Yasushi YAMAGUCHI (Nagoya Univ.) Estimation of Regional Evapotranspiration by ASTER
Yoshiaki HONDA (Chiba Univ.) A study on Possibility of Land Products in GCOM-C/SGLI (Presentation by Koji KAJIWARA, Chiba Univ.)
Shigeo OGAWA (NIRE) Detection of Land Use Changes in Tsukuba City Area Using Satellite Data and GIS Data

15:40-15:00 Session B: SAR, Chairperson, Motoyuki SATO (Tohoku Univ.)
Motoyuki SATO (Tohoku Univ.) Polarimetric SAR Approaches to Integrated Field Sciences
Manabu WATANABE (Tohoku Univ.) Soil Moisture Estimation by PALSAR in Sendai (Presentation by Motoyuki SATO)

Masayoshi MATSUMOTO (Tohoku Univ.) Observation of Double Bounce Scattering from Trees by GB-SAR
Naoki ISHITSUKA (NIAES) Application of PALSAR Data for Agricultural Managements

17:30-19:00 Reception

Morning 27 July 2008 (Sun)

09:00-10:00 Session C: ALOS, Chairperson: Tamotsu IGARASHI (RESTEC)
Tsutomu YAMANOKUCHI (RESTEC) Application of ALOS Data for Glacial Lake Outburst Flood (GLOF) at Bhutan
Chinatsu YONEZAWA (Miyagi Univ.) Inventory and Monitoring of Waste Disposal by ALOS and Quickbird Imagery
Daiji ASAKA (Hokkaido Central Agriculture Experiment Station) Understanding of Planted Crops Using AVNIR-2 Data
Genya SAITO (Tohoku Univ.) Agricultural Monitoring Using ALOS Data

10:05-11:05 Session D: Forest, Chairperson, Masato KATO (Shinshu Univ.)
Takuhiko MURAKAMI (Niigata Univ.) Non-Reforestation Area Project in Kyushu Island, Japan: Role of Multi-Temporal LANDSAT/TM Data
Masato KATO (Shinshu Univ.) Forest Observation from High Spatial Resolution Image
Nobuyuki ABE (Niigata Univ.) Estimation of Carbon Stock in Even-aged Sugi Forests using Satellite Image Data
Haruo SAWADA(Tokyo Univ.) Annual Changes of Growth Condition of Forests in Russia

11:10-1:55 Session E: Grassland and arable land, Chairperson: Tsuyoshi AKIYAMA (Gifu Univ.)
Ayumi FUKUO (JIRCAS and Thoku Univ.) Monitoring of Inner Mongolia Grassland Using Remote Sensing, GIS and GPS (Presentation by Tsuyoshi AKIYAMA)
Satoshi UCHIDA (JIRCAS) Recent Expansion of Paddy Field Area in the Heilongjiang Province of China Detected by Using Remote Sensing Data
Daisuke KUNII (Tohoku Univ.) Analysis for Relationship between the Land Use of the Watersheds and the Marine Nutrients in the Rivers Using Remote Sensing and GIS.

Afternoon 27 July 2008 (Sun)

13:30-15:20 Session F: Ocean, Chairperson: Hiroshi KAWAMURA
Mitsuhiro TORATANI (Tokai Univ.) Annual and Seasonal Variability of Chlorophyll-a Concentration in the Upper Gulf of Thailand
Seiichi SAITO (Hokkaido Univ.) Operational Fisheries Oceanography Using Satellite Remote Sensing and Marine-GIS for Sustainable Fisheries
Futoki SAKAIDA (Tohoku Univ.) New Generation Sea Surface Temperature
Teruhisa SHIMADA (Tohoku Univ.) Ocean Surface Winds and Wind Waves in the Coastal Zone Using High-Resolution Satellite Observations
Hiroshi KAWAMURA (Tohoku Univ.) High-Resolution Satellite Oceanography for Monitoring the Tohoku Coastal Seas
Osamu ISOGUCHI (Tohoku Univ.) Quasi-Stationary Jets between the Subtropical and the Subarctic Gyres in the North Pacific

15:30-17:00 Session G: DMSP, Chairperson: Chris Elvidge (NOAA) - 7th DMSP international meeting -
Chris ELVIDGE (NOAA) Advances in DMSP Products, Services, and Findings
Seiichi SAITO (Hokkaido Univ.) Prediction of Japanese Common Squid (Todarodes pacificus) Potential Fishing Grounds Using GAM and GLM with Satellite Remote Sensing Data in the Japan Sea
Masanao HARA (VTI) Presumption of Carbon-Dioxide Emissions by Nighttime Lights Observed

by DMSP/OLS (Presentation by Genya SAITO)
Kan-ichiro MATSUMURA (Kansei Gakuin Univ.) Combining DMSP datasets with Google Maps and its Impacts
Toshinari KIMURA (Kyoto Univ.) Study plan using DMSP/OLS

17:00-17:30 Closing Ceremony
All the Participants, Statement of 6th IS-IFS - Recommendation of Earth Observing System to JAXA-
Genya SAITO (Deputy Director General of Field Science Center, Tohoku Univ.) Closing Remarks

All day, 28 July 2008 (Mon.)

Field trip using Small Bus:
Amamiya Campus of Tohoku University -> Kawauchi Campus -> Botanical garden of Tohoku Uiversity ->Mt. Aoba -.> Amamiya Campus

Fusion of Field Science and Remote Sensing
“How to establish strategic approach for global environment science?”

Joji IISAKA*

Department of Geography, University of Victoria, Canada
and
*** Center for North East Asia Studies, Tohoku University, Japan**

Global warming is one of most serious concerns of these days. Energy and food price are also going up very rapidly, and many people is also warring about impact to the world economy. These problems are not only related to politics and world economy but also highly related to the global warming.

Remote sensing has contributed during past several decades and is still contributing to monitor global environment changes. Without remote sensing it is absolutely impossible to demonstrate these serious problems.

Remote sensing technologies have the following advantages to monitor the earth surface changes: 1) Wide area coverge, 2) Periodic observation 3) Relatively low data acquisition cost. 4) Easy to store, retrieve, display and disseminate the observed data and much more.

However, there are some difficulties or problems with remote sensing: 1) Data acquisition timing or chancre for specific time, season or date over specific target area, 2) normalization of observed data, 4) and location.6) Spatial resolution, time resolution and energy resolution(quantization)

Conventional data analysis methods require a lot of training and test samples, and contribution from the field science to help model building, to verify and validate the results of remote sensing based analysis.

On the other hand, site observation/field measurements have different kind of problems; 1) Site selection 2) scale of sites 3) selection of information type 4) Extension of observed information 5) Normalization of observation environment and so on.

Thus, it is not so easy tasks to correlate remote sensing based information and filed based information.

Furthermore, in order to understand and identify the real causes of global environment change, further information such as geophysical, geochemical and geo-biological information should be integrated.

Now more advanced sensors such as hyper spectral sensors and polarimetric SAR sensors have emerged. Especially, the later sensor is capable to extract ground cover information without using ground truth measurements. .However, the data of both sensors requires a lot of sophisticated techniques to extract useful and applicable information, which are far beyond the classical methods. Therefore, it is highly required to employ an approach to integrate remote sensing and field science.

In this paper, it will be discussed some aspect to make a bridge between remote sensing and field science.

View of Humanity from Space

Christopher D. ELVIDGE, Ph.D.

Earth Observation Group
NOAA-NESDIS National Geophysical Data Center E/GC2, USA

The widespread use of outdoor lighting is a relatively recent phenomenon, tracing its roots back to the electric light bulb, commercialized by Thomas Edison in the early 1880s. Nocturnal lighting has emerged as one of the hallmarks of modern development and provides a unique attribute for identifying the presence of development or human activity that can be sensed remotely. Although there are some cultural variations in the quantity and quality of lighting in various countries, there is a remarkable level of similarity in lighting technology and lighting levels around the world. The primary factor affecting the quantity of lighting is wealth. Regions with high per capita income have much more lighting than regions with low per capita income. Even within affluent regions, however, lighting technology (lamps and lighting fixtures) is gradually changing, as pressure is applied to reduce night-time sky brightness and conserve energy. In some applications, night-time lights are used as a proxy for variables that are difficult to measure in a globally consistent manner, including many socio-economic variables, such as population density and gross domestic product. In other applications, the spatial distribution and quality of lighting is used as a variable directly, such as the analyses of ecological effects of nocturnal lighting, the analysis of artificial sky brightness impacts on the visibility of stars and planets, and human health effects of lighting. In this presentation we review satellite observation of nighttime lights from the U.S. Air Force Defense Meteorological Satellite Program (DMSP) Operational Linescan System (OLS) and the International Space Station.

http://dmsp.ngdc.noaa.gov/
http://spidr.ngdc.noaa.gov/spidr/index.jsp

Cause and Prediction of Deforestation in Java Island: Spatial Modeling Approach

L. B. Prasetyo, H. Kartodihardjo, S. Adiwibowo and B. Okarda

Bogor Agricultural University, Indonesia

Java is the most populated island in the world. About 70% of Indonesia population are living at the island. Having such situation, forest areas have been depleted from time to time, since converted to other land uses or degraded due to wood extraction. In 2000 forest area in Java covered of about 4.4 million hectare but in 2005 decreased to 2.4 million ha. Regardless the debate on the difference methodology of forest inventory in 2005 that resulted in under estimation figure, forest cover decrease in Java is obvious and need immediately respond. Forest area lost and its degradation have created environmental problem such as flooding, drought and landslide in many parts of Java. Spatial modeling of the deforestation will assist the policy makers to understand the process and take it into consideration when decisions are made.

Spatial modeling was done using Logistic regression. As dependent variable is percentage of forest cover and as independent variables are population density, percentage of population having agricultural sectors source of income, and percentage of population having non-agricultural sectors source of income, road density, elevation & slope. Data are drawn on thematic grid map with dimension 10 km x 10km, by using combination of ArcGIS and Erdas Imagine software. All of the thematic maps were classified into 1 or 0 based on certain criteria. Simulations then were made based on two scenarios namely increase of those independent variables as high as 2 % normal/moderate scenario) and 6% (extreme) using SPSS statistical software.

There are three factors that contribute to deforestation process, namely population, road density & percentage of having agricultural sectors as main source of income. Meanwhile, it seem that the existence of forest is due to high elevation & percentage of population having non-agricultural sectors source of income. Result of logistic regression showed that under the normal/moderate scenario in 2020 only one district/municipality of Banten will face deforestation problem, meanwhile West Java, Central Java, Jogyakarta and East Java are 7 districts, 22 districts, 4 districts and 6 districts, respectively.

Under the extreme scenarios, number deforested districts of Banten, West Java, Central Java, Jogyakarta and East Java are 2 districts, 11 districts, 18 districts, 5 districts, 26 districts, respectively. Regarding watershed boundary, in 2020 under the normal scenario there are 47 watersheds will face serious problem of deforestation and almost three times (123 watersheds) under extreme scenarios. Policy implication of the result model prediction is that the Government should take more attention to the population problem & have to create non-agricultural sectors jobs in order to reduce pressure on forest.)

The model will be validated & improved by resizing the grid to 5 km x 5km and added with some variables such as land tenure status, distance from road, and some socio-economics data which is unavailable right now (namely : income & level of literacy at village level).

Grassland Degradation and Recovery Based on Remote Sensing and GIS in Inner Mongolia

Zhang WEI and Wang KUN

China Agricultural University, China

Inner-Monggulia, used to be the fertiled field, are facing the grassland degradation in the past decades. This lead the less production and impact the environment of North China. The survey and management based on remote sensing and GIS help the people to recover the grassland and make the development sustainable.

Satellite Ecology, an Attempt for Linking Remote Sensing and Ecology for River Basin Studies

Tsuyoshi AKIYAMA

River Basin Research Center, Gifu University, Japan

1. Background

Frequent revisit with low spatial resolution satellites such as NOAA/AVHRR, and Terra and Aqua/MODIS clarified various global environmental issues. However, there are few methods to verify the accuracy of actual events on the ground. According with remarkable progress of satellite sensors moving into 21st century, it becomes possible to validate ground-based ecological processes using fine resolution satellites.

2. Satellite Ecology Program

The 21st Century COE (Center Of Excellence) Program, Satellite Ecology has been launched in 2004 at Gifu University. The target was to find the linkage between remote sensing, ecosystem ecology and micrometeorology for studying ecosystem structure and function in the mountainous landscape of central Japan. This Program aims at creating a comprehensive yet practical science "Satellite Ecology" by making regional carbon monitoring by satellite remote sensing technology which has advanced drastically. Characteristics of this Program are, meso-scale regional study, carried on mountainous landscape, complex of various ecosystems, and interdisciplinary collaboration.

3. Study area and intensive sites

The study area, Daihachiga river basin covers 60 km^2 of catchment area, 1,000m of altitude gap, includes deciduous broadleaved (DB) forests, evergreen coniferous (EC) forests, agriculture fields, and some residential areas. Two carbon flux towers were set up, one for DB forest and another for EC forest, which measure carbon dynamics between atmospheric and terrestrial layers. Inside study area, several permanent plots are settled for ecological study. Ecological observation tower was built in DB forest at 1,400 m asl., where we can directly measure several physiological phenomena of canopy.

4. Some findings

Landcover classification was carried out using multiple remote sensors such as aerial hyperspectral image by CASI, QuickBird, ALOS/AVNIR-2, Terra/ASTER, and Terra/MODIS. (2) Forest phenology analysis using MODIS/NDVI clarified difference of seasonal pattern. (3) Several ground validation methods for MODIS/NDVI were proposed. (4) LAI changes of agriculture field were estimated. (5) As the results, prototype regional carbon dynamics was calculated using land surface model into MM5.

Integration of Airborne Technologies and Fusion of Multisensor Data to Enhance the Remote Sensing of Forested Environments

K. Olaf NIEMANN

Department of Geography, University of Victoria, Canada

The successful identification and delineation of forest attributes using remote sensing technologies has, over the years, been restricted due to a limitation in the dimensionality of the data. We have typically been restricted to a single interpretive element, tone, with which to unravel structurally and floristically complex environments. This has resulted in our employing empirical models to predict structure or to invert complex ecophysiological relationships. Recent advancements in remote sensing technologies have allowed us to increase the dimensionality of the data collection thereby increasing the complexity of subsequent extraction of forest attributes.

In 2006 the University of Victoria together with Terra Remote Sensing Inc. (TRSI) in Victoria, British Columbia, collaborated on the development and deployment of an integrated multi-sensor airborne platform (MAP). This platform currently has, at its core, a full range airborne imaging spectrometer, a discrete first and last return LiDAR, and digital cameras. These sensors are integrated through a IMU and DGPS. The optimum resolution of the spectrometer is 2 metres with 490 bands, while the current LiDAR yields a point every square metre, and the digital cameras have a 25 cm ground resolution. A MAP2 system is currently in design. This will be a helicopter-based platform with a VNIR spectrometer (20 cm 200 spectral channels) and a high frequency LiDAR (up to 250 KHz).

The advantages of employing the spectrometer and LiDAR are numerous. The high spatial and spectral resolution of the spectrometer results in a large range in pixel values for a given target. In a forest this results in a drop in the signal to noise as one moves down into a canopy towards the forest floor. LiDAR data allows us to select data that are more consistent and yield higher intensity of reflected light, thus allowing for a greater classification accuracy. The LiDAR data has allowed us to explore both the horizontal and vertical structure of canopies. This yields a potential to develop a characterization of the form of the forest and develop inputs into functional models. The spectrometer gives us an insight as to the function of the forest, both with respect to the species identification (structure) as well as health.

The paper explores the symbiotic relationships between the data from the two sensors focusing on areas where one dataset enhances the utility of the other.

Agricultural Field Observation Using Hyperspectral Sensor in Syonai

Naoko KOSAKA*, Kuniaki UTO*, Yukio KOSUGI*, Kunio ODA**
and Genya SAITO***

***Tokyo Institute of Technology, Japan**
****Yamagata Prefectural College of Agriculture, Japan**
*****Tohoku University, Japan**

This study investigates the adequate selection of hyperspectral (HS) components for estimating the adequate amount of fertilizer to be applied for paddy field to keep the rice protein within a certain level, thus for ensuring the quality of the rice. The SPAD value has been generally used to estimate these values and showed its usability. However, it is difficult to obtain SPAD values over a widespread area. This study evaluates the performance of an airborne HS image. Moreover, we investigate the possibility of applying a multispectral (MS) image for the same target.

We have established multiple observation systems, such as a crane mounted HS sensor system, a balloon mounted digital camera system, and a radio-control-helicopter mounted HS sensor system. For the purpose of applying widespread satellite or airborne sensor images, we have simulated models from high spatial and temporal resolution images obtained from these observation systems. Our past studies showed the efficiency of the vegetation index (VI) "NDGI", which is generated from green and red bands, to estimate the amount of rice protein using crane mounted HS sensor images. This NDGI is also effective to estimate the degree of damage from a salt breeze on rice, and is applicable to the MS image of SPOT. Estimating methods, such as neural networks (NN), are also examined. The genetic algorism indicated the adequate selection of bands from crane mounted HS sensor images to estimate protein content of rice. A single-layer perceptron is usable to estimate the damage degree of soybean and a multi-layer perceptron estimates sucrose, glucose, and amino acid of soybean.

In this paper, we applied a single-layer perceptron, which has input nodes corresponding to band number and a single output node, and VI, which are generated from 2 bands like NDVI, to both HS and MS images. The results using HS images have high correlation with both SPAD values and protein content. The correlation coefficients by NN are 0.99 and 0.98 for SPAD and protein respectively and by VI 0.74 and 0.78. Next, we examined the possibility of MS images using simulated MS images from HS images. The correlation coefficients by NN are 0.73 and 0.40 for SPAD and protein respectively and by VI 0.41 and 0.30. Last, we investigated an ASTER satellite image. The correlation coefficients by NN are 0.51 for protein and by VI 0.49.

Low-Altitude Hyperspectral Imaging of Naruko Integrated Field for the Interpretation of High-Altitude Observations

Yukio KOSUGI*, Desjardins GUILLAUME*, Yuji TAKABAYASHI*, Sildomar T. MONTEIRO****, Makoto YAMAKI*, Kuniaki UTO* and Genya SAITO****

***Tokyo Institute of Technology, Japan **Tohoku University, Japan**
***** Ecole Polytechnique de Montreal, Canada ****University of Sydney, Australia**

1. Introduction

For interpreting images obtained by satellite or airplane systems, we often encounter the mixed pixel problem, in particular when analyzing integrated fields. In order to solve unmixing problems, obtaining pure spectral signatures will allow us to make better use of linear unmixing methods.

2. Crane mounted HS observation system

When performing ground truth observations, spectrometers are often used to get spectral signatures for each pure component. However, the FOV of spectrometers is usually too wide to separate sparse plants from the soil background. To overcome this difficulty, we use a HS sensor on a track crane, as shown in Fig,1.

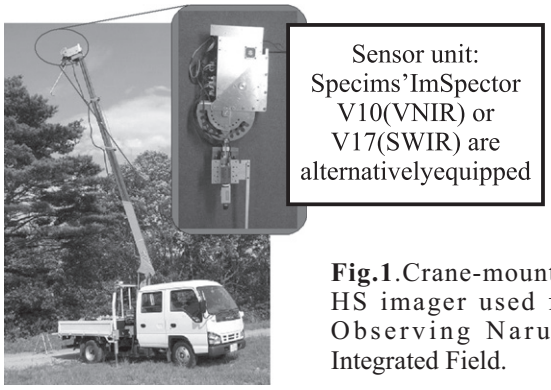

Fig.1.Crane-mounted HS imager used for Observing Naruko Integrated Field.

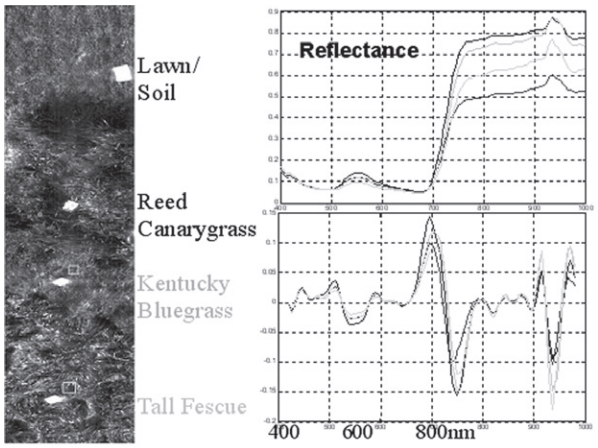

Fig.2. HS pseudo color image and the reflectance profiles of grasses. Ground pixel size is approximately 10 by 10mm.

3. Observation results

We have conducted push-bloom HS image observations, by rotating the crane arm, on 1)trees *in-situ* and cut-down twigs, 2)grass in test meadow, and 3)pastured animals. An example of pseudo color image, reflectance and 2nd order derivative profiles are shown in Fig.2, for several kinds of grasses in the test meadow.

4. Neural networks for classification of HS images

For a preliminary study of tree and grass classification, as well as for the detection of animal clusters, we have analyzed the pure spectral profiles with the aid of artificial neural networks. A standard multilayer perceptron was used for this experiment, with a single hidden layer composed of 10 sigmoid units. The network was trained using the conjugate gradient algorithm, combined with an early stopping procedure for better generalization performance.

We compared the network's performance using both the raw reflection map as input, as well as the data obtained through basic preprocessing operations, such as normalization and first/second order derivatives. This resulted in classification rates as high as 93.3% using the second order derivative on the grass classification task. The detailed results are shown in Table 1.

For the tree classification task, we further compared the sigmoid network to a radial basis function network, for both a 3 and 8 class categorization problem. For the latter task, we increased the number of hidden units to 15. The sigmoid network resulted in a classification rate of 91.5% for the 3 class problem, using the

normalized data. However, this same network fared poorly with the 8 class problem, the RBF network obtaining an average of 77.3%.

Table 1. Grass Classification Results

Preproc. Method	Gen. Class. Acc.	MSE
Raw reflectance	92.66	0.037
Normalized	92.53	0.037
2nd Derivative	93.46	0.033
Norm. + Deriv.	91.9	0.041

5. Conclusions and future plans

For small number of classes, we were able to perform classification on low-altitude HS images. In the future, we plan on introducing unmixing procedures to interpret aerial HS observations of the field based on the pure spectra thus obtained. Also, to tackle the relatively poor performance of our networks when dealing with a higher number of categories, we are currently exploring new developments in the field of neural networks, mainly Deep Belief Networks and Deep Auto-Associators, which have gained a lot of traction in the field of machine learning.

Estimation of Regional Evapotranspiration by ASTER

Yasushi YAMAGUCHI and Hemu Kharel Kafle

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Estimation of spatial distribution of evapotranspiration (ET) by combining remote sensing data and a physically based surface flux model is applied over a heterogeneous area of Nagoya, Japan. Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) data are used with the local meteorological data to estimate regional evapotranspiration using radiometric surface temperature and fractional vegetation cover as main input parameters. Our goal is to estimate ET within an accuracy of 50 W/m^2.

Higher resolution remote sensing data such as ASTER potentially can distinguish between dominant land surface types, such as clusters of vegetation, bare soil, and water bodies, and thereby derive plausible values for surface properties, such as aerodynamic roughness. Data from ASTER sensor are particularly well suited to the task, as it collects high spatial resolution (15-90m) images in visible, near-infrared, and thermal infrared bands simultaneously. Data in these bands yield estimation of surface temperature, vegetation cover density, and land-use types, which are all critical inputs to surface energy balance models for estimating evapotranspiration. ASTER is currently the only satellite sensor collecting high resolution multispectral thermal infrared images that allows for a more accurate determination of the variable spectral emissivity of the land surface and, hence, a more accurate determination of thye land surface temperature. Moreover, high spatial resolution of ASTER data allows direct comparisons against ground measurements and facilities detection of modeling limitations.

In this study a well-known two-source energy balance (TSEB) model, developed by Norman et al (1995) and modified by Kustas and Norman (1999), is used in combination with the ASTER data for the instantaneous estimate of ET over a heterogeneous area of Nagoya, Japan. Remote sensing data as well as meteorological data from 2003, 2004 and 2005 are used for different periods of time in TSEB model for estimating instantaneous ET. Radiometric surface temperature observations from ASTER are used in TSEB for predicting component latent heat fluxes from soil and vegetation, which are combined to get the total latent heat flux from the mixed area. Finally evapotranspiration is estimated by calculating the ratio of latent heat flux and latent heat of vaporization.

The estimated results are compared with ground observation data measured form flux tower of Seto Flux Tower site within the study area for validation. We concluded that the TSEB model successfully gives the ET estimation within the accuracy of 50 W/m^2.

Detection of Land Use Changes in Tsukuba City Area Using Satellite Data and GIS Data

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*** National Institute for Rural Engineering, Japan**

Land use has changed around new stations in Tsukuba city, Ibaraki, Japan, because new rail road system called "Tsukuba Express" was opened in August 2005. We extracted land use change using satellite image and existed land use map. Existed digital land use map was created in 1997 and spatial resolution is 10m. ALOS satellite was launched in January 2006 and spatial resolution of AVNIR-2 sensor is 10m. Spatial resolution of Landsat/ETM+ is 30m. We used ALOS/AVNIR-2 image acquired on 21st May 2006 and Landsat/ETM+ image acquired on 4th June 2001. It is easy to classify paddy fields and others in this season because paddy fields are flooded condition. As the results, land use/land cover change is detected around new stations and rural area. Surrounds of new stations in rural area are developed near the station (0-1000m). Surrounds of new stations in urban area are developed more far area (400m far). New residence area, big shops construction and abandoned paddy field area were extracted. Especially, abandoned paddy is distributed in small valley and muddy paddy field. Classified image from Landsat/ETM+ have some errors in river bank, because of error of position. If difference of 0.5 pixels occurs, it means 15m differences. It is bigger than one pixel size of land use map (10m). This error was not occurred in classified image from ALOS/AVNIR-2(10m resolution). As a result, ALOS/AVNIR-2 image has advantage than Landsat/ETM+ image. On the one hand, Landsat/ETM+ image have advantage to classify urban area or paddy field because it has short wave infrared bands (band5 and band7). Each sensor image has different characteristics.

Polarimetric SAR Approaches to Integrated Field Sciences

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1 Introduction

The radar technology which uses the polarization of electromagnetic wave is radar polarimetry. Radar polarimetry requires more complicated radar hardware compared to the conventional single polarization radar system, however, it provide us much more rich information. Recently, new polarimetric radar sensors such as ALOS/PALSAR are available, and we are now working for applications of this new technology.

2 Polarimetric SAR

Japan has launched Earth observation satellite ALOS in 2006, which is equipped with Polarimetric Synthetic Aperture Radar PALSAR. PALSAR is a full-polarimetric SAR in L-band (23 cm wave length). In 2007, two full-polarimetric SAR sensors including TerraSAR (X-band, Germany) and RADARSAT-2 (C-band, Canada) started operation. C-band SAR ENVISAT has started its operation in 2002, which has limited polarization function.

SAR is not affected by weather condition, and SAR interferometry is available by using single-polarization SAR such as JERS-1 and ERS-1,2, therefore, its technology has been widely accepted since 1990's. SAR interferometry has great potential in applications such as disaster prevention and precise observation of ground surface displacement.

Until recently, any polarimetric sensors were not available, and its applications have not been widely understood. The new polarimetric SAR sensors will change the situation soon

3 Radar Polarimetry

Radar polarimetry sensors measure not only the amplitude of the scattered wave, but it measures much more information of the targets. Electromagnetic wave is a vector field, and it contains information of the 3-dimentional objects, which scattered the wave. Scattering of wave can be described by a scattering matrix, which is a 4x4 complex matrix, and the radar cross section, which was used in conventional radar analysis, is only one real value of this matrix.

There are many ways to use radar polarimetric information. We discuss here about the frequency bandwidth and quantitative evaluation. Any practical radar system has limitation in its operation frequency bandwidth. The scattering is dependent on the frequency, therefore, we also have to select the operation frequency. Wave propagation material is normally suffered from strong attenuation, and the operation frequency must be low, which is the case in Ground Penetrating Radar. In these cases, the radar resolution is poor, due to the limitation of the frequency bandwidth. However, in radar polarimetry, we can get information about the scattering target without having the precise image of the targets. In addition, radar polarimetry can use new information, such as phase information included in the scattering matrix. We have used the difference of the right-hand and Left-hand circular polarization wave, which gives us the azimuth orientation angle information of the scattering objects. This is one of the examples of quantitative interpretation of SAR data, which could not be achieved by conventional single-polarization SAR.

These features of radar polarimetry should be used in agricultural applications in many ways. The wavelength used for SAR can control the penetration depth. For example C-band wave is scattered from the canopy of trees, while L-band wave can reach to the ground surface. There electromagnetic wave characteristics must be used in

wider application areas.

4 Application of Radar Polarimetry

We are developing a ground-based SAR (GB-SAR) system, which can be used in fixed ground position. WE think GB-SAR can be used for calibration of airborne and space borne SAR sensors. In addition, GB-SAR can be used for long-term observation of fixed targets. We are now applying this technology to ground surface moisture or tree evaluation. We believe these researches also develop further applications of polarimetric SAR.

Soil Moisture Estimation by PALSAR in Sendai

[(1)]M. WATANABE, [(1)]M. MATSUMOTO and [(1)]M. SATO

[(1)]Tohoku University, Japan

ALOS was successfully launched on January 24, 2006 and a huge amount of data, which includes PALSAR/ polarimetry data, has down-linked since now. One of the prospective applications for the PALSAR data is soil moisture retrieval. But frequency of observation with PALSAR for any places is limited, even if the PALSAR has a mature observation plan in advance. Our purpose is to use the GB-SAR system for increasing a chance of the polarimetry observations for any place & time, connect it with the PALSAR observation and efficiently develop any algorithms for applications of satellite SAR data, such as soil moisture & forest biomass retrieval, and so on.

In this time, we selected bare soil areas and performed the simultaneous GB-SAR field experiment with the PALSAR observation near our university, where small pebbles were covered with on April 14, 2007. The picture of the experiment is shown in Fig. 1. We carried out not only the GB-SAR measurement, but also measured surface roughness, soil moisture(or dielectric constant) in the soil by using a ground penetrating radar (GPR) and TDR. We also selected two other places as validation sites for PALSAR data and measured surface roughness and soil moisture values there. The PALSAR observation was done in the same day with an off-nadir angle of 21.5° and with the polarimetry mode. Two small corner reflectors were deployed in the field experiment sites for the purposes of the site identification and geometric calibration.

GB-SAR data with off-nadir angles of 20° and 40° were taken in each measurement. A size of the data is 4m in azimuth and 6m in range direction, but the effective size of the range is about 4m. The frequency is selected from 0.05GHz to 3.05GHz. Four metal spheres were put on a ground for a calibration purpose.

σ^0 values for each polarization, and Entropy/α/ Anisotropy are calculated from the both data. These values show well agreements in each parameter under some assumptions. We compare the parameters derived from our experiment with some models. While two classical models tends to mach the parameters, recent model show some discrepancy.

While the soil moisture value could not estimate from one of the recent model due to an out of range of a parameter space, the roughness is estimated to be 2.4cm. But the roughness derived from field experiment is 0.7cm and show large discrepancy.

Fig. 1. GB-SAR observation site

Observation of Double Bounce Scattering from Trees by GB-SAR

Masayoshi MATSUMOTO† and Motoyuki SATO‡

†Graduate school of Environmental Studies, Tohoku University, Japan
‡Center for Northeast Asian Studies, Tohoku University, Japan

GB-SAR

Full polarimetric SAR like PALSAR has an advantage to measure polarimetric behavior of forest to evaluate biomass and so on. And it is important to understand how scatterings from trees occur. It is known that the scatterings from trees are divided into three component, single scattering, double bounce scattering and volume scattering. But it is not easy for us to confirm the scattering behavior by PALSAR, because we have few opportunities that PALSAR acquires a target which we want to measure. On the other hand, full polarimetric Ground Based SAR (GB-SAR) is a kind of Polarimetric SAR which is located on the ground. It is easy to measure due to its mobility and we can use it whenever we want to carry out a measurement. This is a great advantage of GB-SAR and it enables us to analyze the scattering behavior easily. Therefore, a double bounce scattering from trees was observed by G B- SAR to analyze the scattering behavior.

Observation of Double Bounce Scattering

First, in order to observe the double bounce scattering, a wall was chosen as a target because the wall structure is quite simple case to observe the double bounce scattering. In a radar profile, we can see two reflections at same azimuth position. One is a single scattering caused by the wall and the other is a double bounce scattering caused by an interaction between the ground and wall. This measurement is quite simple case, so this measurement can easily be simulated by using FDTD method. We can confirm how the double bounce scattering occurs in this simulation.

Second, an experiment was carried out to observe a double bounce scattering from trees. Two trees named T1 and T2 were chosen as targets. Although both of the trees should have two reflections according to previous measurement and simulation, T2 has two reflections but T1 has one reflection in the radar image. As for T2, One is a single scattering caused by a surface of the tree and the other is a double bounce scattering caused by the ground and a trunk of the tree. As for T1, the reflection is a single scattering.

Effect of Soil Moisture on Double Bounce Scattering

It is thought that this difference is caused by different soil moisture of ground surfaces. Soil moisture of the ground around T1 and T2 were 15% and 28% respectively, and higher soil moisture gives higher reflection coefficient. That is the reason why the double bounce scattering was weak in T1 and we cannot see it.

Index terms

full polarimetric SAR, Ground Based SAR, double bounce scattering

Application of PALSAR Data for Agricultural Managements

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INTRODUCTION

In agriculture, the change of the ground surface is rapidly and more dynamic compared with the forest that treats vegetation too. Major farm products are harvested at half a year from several months. Therefore, it is important that "Timely" and " Periodic" observations be done in agriculture. In optical sensor, because it is influenced by the weather, "timely" observation is difficult. SAR is expected "Timely" observation.

Rice is staple food of Asia, and monitoring the area of rice is demanded. Until now, the rice paddy fields have been observed by L-band SAR such as AIR-SAR, JERS-1, Pi-SAR, and SIR. However, a "Periodic" observation by multi polarimetric L-band SAR is not done. The purpose of the research is to clarify the problem and effectiveness when measure the planted acreage of rice paddy fields in the large area using ALOS/PALSAR, which is the first in the world L-band multi polarimetric satellite SAR sensor.

RESULTS

Fig.1 shows the image of PALSAR (HH) observed in 11 May 2007. In this time, almost paddy fields are finished puddling and leveling, transplanting of rice. A dark part is seen from the north to the south like the stripe at the left of figure. It is a paddy field zone, and specular reflections have happened most in rice paddy fields. It is known well to look dark in the SAR image that the microwave cause the specular reflection where water area. On the other hand, the parts which look bright white are an urban area or forest area.

However, the all parts that appear dark circled in Fig. 1 is not rice paddy fields. The area has a lot of turf fields. Therefore, a waterless field looks dark. Those are not able to distinguish with the water.

The reason for this is that PALSAR is SAR of L band. The PALSAR of L band SAR is considered smooth even if the roughness somewhat grows compared with RADARSAT etc. of C band SAR sensor. Therefore, those turf fields are not so difference with fields filled water, look dark, occur the specular reflection, backscatter is weak.

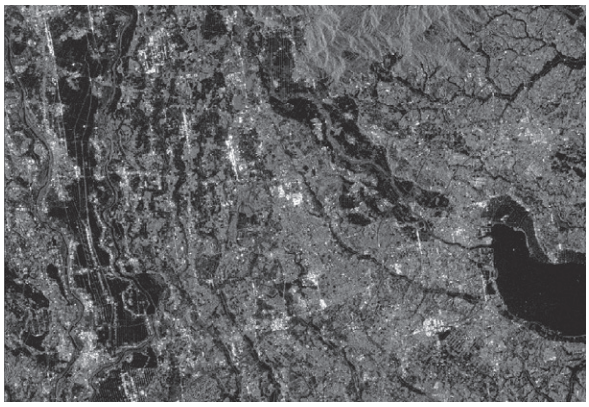

Fig. 1. PALSAR Image (11 May 2007)

I have similar results another area. it is difficult to distinguish with filled water, puddling and leveling fields, wheat fields clearly from the difference of backscatter value in the PALSAR image.

Next, I compare with growth of rice and backscatter value in the temporal PALSAR image. Fig.2 shows time series change of backscatter(dB) in HH PALSAR images and height of rice. As a result, I conclude that it is difficult to evaluate growth of rice clearly from the difference of backscatter value in the PALSAR image.

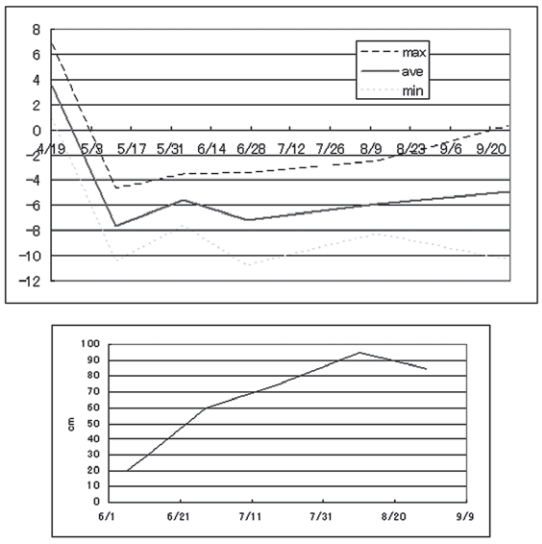

Fig. 2. Time series change of backscatter (upper) and height of rice (lower).

CONCLUSIONS

There are some study of rice paddy fields using SAR. Those are mostly use RADARSAT that is C-band sensor. If using L-band SAR, the scattering of paddy fields is different C-band SAR, and directly use same method to monitor rice paddy fields. In this time, I conclude that it is difficult to distinguish filled water, growing of rice, and some other fields clearly from the difference of backscatter value in the PALSAR image. However, we consider that it is possible to classify though it is a difficult to distinguish state of the ground in this time if PALSAR combines with the SAR image with different wavelength or the optical sensor image. In addition, it is necessary to consider also about the change done by the difference of the incidence angle. I plan to keep experimenting on the microwave-scattered characteristic in the farmland.

Application of ALOS Data for Glacial Lake Outburst Flood (GLOF) at Bhutan

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Recent global environmental change might have a relationship with retreat and melting of alpine glacier. Himalaya is the highest mountainous region in the world and several disasters are happened due to flooding of melted glacial water, which is called as Glacier Lake Outburst Flood (GLOF).

In this study we applied satellite data for the estimation of GLOF damaged area and glacial lake monitoring. We mainly used Japanese earth observation satellite ALOS (Advanced Land Observation Satellite) data. DSM data created by ALOS / PRISM sensor can delineate detailed shapes of ground features (large man-made buildings) than other DEMs like ASTER DEM and SRTM-3 data. This result shows the capability of PRISM DSM for the application of disaster prevention mapping. Geometric accuracy of Orthorectified PRISM image using above DSM is evaluated by comparison with portable GPS data acquired at Bhutan and planimetric difference between PRISM orthorectified image and GPS is RMS±12m. It is enough for the development of 1:50,000 scale map. Also the PRISM DSM is used for the estimation of GLOF damaged area. Water level of Chang Chu River raised 1.8m from usual level by GLOF occurred in 1994. Therefore, we masked the area where have 2.0m higher topography than river surface of PRISM DSM and estimated the spatial distribution of GLOF damaged area along with Chang Chu river basin. Estimated GLOF area by PRISM DSM are quite coincided with the local photos and satellite images taken at that time. The capabilities of ALOS data for GLOF mitigation are proved by these results.

It is also important to monitor the actual behavior of glacial lakes. We analyzed time series satellite data from 1969 to 2006 at Lunana district, Bhutan. Lunana district have the high possibility of GLOF disaster because there are three large glacial lakes, which name is Raphstreng tsho, Thorthormi tsho and Lugge tsho. GLOF event occurred in 1994 was caused by outburst flooding of Lugge tsho. Retreat of glacier and expansion of glacial lakes are clearly detected and expansion speed of Lugge tsho is 25042 square meters/year from the satellite time series analysis. This result shows the seriousness of potential GLOF disaster and effectiveness of satellite data for glacial lake expansion monitoring. It is necessary to monitor glacial lakes not only Lunana district but also the whole Himalayan regions.

Our study shows the potential of satellite data for the solution of this momentous disaster in two ways. One is used for the application of disaster prevention mapping and the other is for the monitoring and early warning of potentially dangerous glacial lake.

Inventory and Monitoring of Waste Disposal by ALOS and Quickbird Imagery

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Waste management is one of the expected applications for satellite imagery. Probability of waste monitoring on land area for currently-operated earth observation satellites are investigated in this study. ALOS (Advanced Land Observing Satellite) and Quickbird data are examined, respectively. Japanese ALOS has two optical imagers, PRISM and AVNIR-2, and an L-band Synthetic Aperture (PALSAR). Quickbird is a commercial high resolution satellite which is able to observe sub-meter resolution imagery.

Availability for detecting of surface change on legal or illegal waste disposal site using ALOS imageries is examined. Nominal ground resolution of PRISM (Panchromatic Remote-sensing Instrument for Stereo Mapping) imagery is 2.5 m. AVNIR-2 (Advanced Visible and Near Infrared Radiometer type 2) has 10 m spatial resolution in nadir viewing. Targets are waste disposal sites in Miyagi prefecture, Japan. A landfill block (ca. 30 x 100 m) can be recognized and temporal changes of a disposal site clearly appear on PRISM imagery. Pan-sharpen image by PRISM and AVNIR-2 is useful for image interpretation. Overlay of road vector data is helpful for interpretation of PALSAR (Phased Array L-band Synthetic Aperture Radar) intensity imagery. It has the potential to detect obvious change by movement of large block that causes double-bounce scattering.

Quickbird is a high resolution satellite of which nominal ground resolution is 0.6 m for panchromatic imagery and it is 2.4 m for multispectral imagery. Its possibility to recognize several size of rubbish is examined. A scrap yard of which size is approximately 6 x 4 m clearly appears on the pan-sharpen imagery obtained on June 2003. The same place is recognized by the image obtained on September 2006 and it had expanded to ca. 10 x 4 m. A target in the vegetation is recognizable, but almost same size target in the bare soil is difficult to find.

Spatial resolution improvement, decrease of observation intervals, and reducing the price of data are prospected for practical use of satellite imagery to waste monitoring.

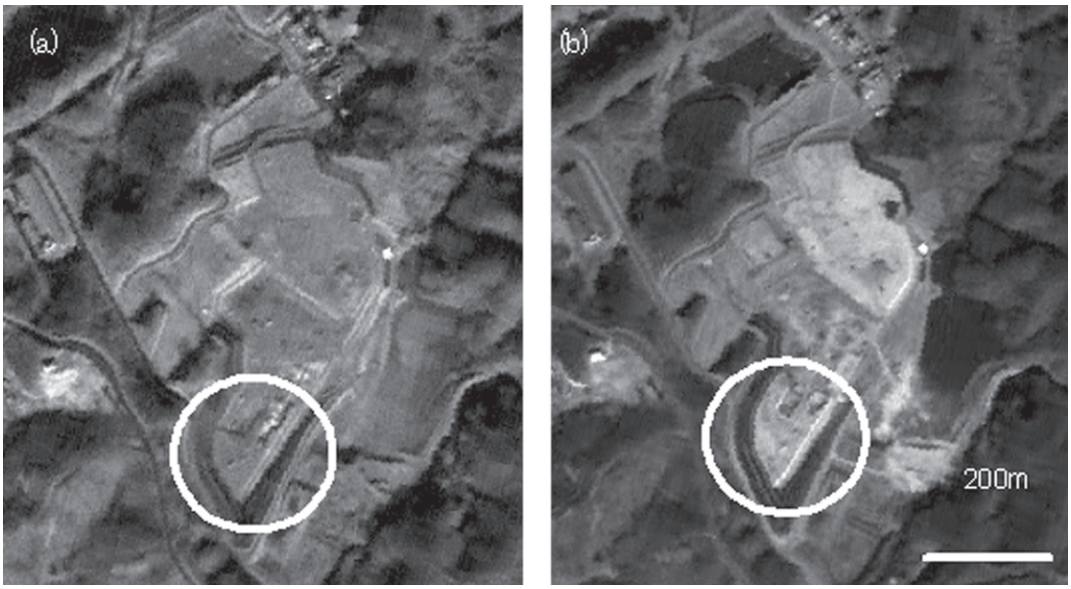

Fig.1. ALOS PRISM imagery for Ishidumori waste disposal facility in Miyagi prefecture acquired on (a) 28 December 2006 and (b) 1 March 2007. White circles show the area where temporal change is recognized.

Understanding of Planted Crops Using AVNIR-2 Data

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Since the ALOS performs observations at a comparatively high frequency in Japan, it does not receive as much restriction during observation time. Multitemporal ALOS/AVNIR-2 data in the paddy field zone in Hokkaido were used to carry out the land-cover classification of farmland and the classification of crops. The classification accuracy was examined by performing a supervised classification of major crops in the study site, such as winter wheat, paddy, soybean, azuki bean, sugar beet and onion. This was done by using ALOS/AVNIR-2 data with three scenes that had been observed on the 27th of May, the 28th of July and the 26th of August in 2006. On each observation day, the classification accuracy was above 95% for winter wheat, paddy and sugar beet, but was below 95% for soybean, azuki bean and onion. The classification of land-cover for the whole study area was also carried out by using the data from the three observation days. Regarding the area of each crop classified, the classification accuracy for winter wheat, paddy and sugar beet was high at ±10% compared to that of the statistical data for soybean, azuki bean and onion, which was low. Even the ALOS/AVNIR-2 data, for which the short-wavelength infrared region was not observed, was able to classify the paddy field with high accuracy because of the use of multitemporal data.

Agricultural Monitoring Using ALOS Data

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ALOS satellite lunched at December 2006, and the earth observation satellite has two optical sensors and one SAR sensor. Those sensors are observing at high resolution at terrestrial area, and are expected to provide us useful data for agriculture management. For development of agricultural monitoring system, we study the abilities of ALOS data for agriculture. For the reason we test the data for application of agriculture.

Japan is long country for north and south, and climatic conditions are very different, and we interpret the status of paddy fields various areas at 4th May 2006 in Japan using ANIR-2 data Image acquisition date is 4 May 2006 and it is the starting time of rice transplanting in the paddy fields. In Japan, Workers have holidays from 29 April to 5 May as the name of Golden week. Almost farmers have another jobs as employee of company and local government. The AVINIR2 data are imported in ERDAS/Imagine as the geo-coded data and made large mosaic image of Hokkaido, Tohoku, and Kanto column and Kyushu column. We can easily understanding rice transplanting situations all over Japan using AVINR2 data. Hokkaido area is not rice transplanting for cold weather, and some areas of Kyushu are not by two cropping system. Other area is just rice transplanting period in Japan.

In the East and Southeast Asian countries include Japan, growth of rice crop is at rainy season, and it is difficult to observation of the growth using optical sensor by clouds. Synthetic Aperture Radar (SAR) has the ability of pass through clouds and observing every weather condition and we are testing PALSAR ability of agriculture monitoring. Image acquisition dates are April to September in 2006. The PALSAR data of 28 April are multi-scenes from Akita Prefecture to Fukushima Prefecture. The others are one or two scenes at Shonai Area in Ymagata Prefecture. Acquisition dates of used data are as follows; 28 April, 6 June, 22 July, 28 September in 2006.

Over lay image of PALSAR and topographical map at mountain area, and there are some errors by fore shorting. That of plain area, and two images is very good fitting. There are dark fields and not dark fields, and dark fields are filled with water and not dark fields are no water. At 28 April, only a few fields filled with water, and at 6 June almost fields filled with water. At 22 July and 28 September also almost fields filled with water. At Shonai area, paddy filed managements are well known by PALSAR data

Non-Reforestation Area Project in Kyushu Island, Japan: Role of Multi-Temporal LANDSAT/TM Data

Takuhiko MURAKAMI*[,1], Tetsuji OHTA[2], Tsuyoshi KAJISA[2], Nobuya MIZOE[3] and Shigejiro YOSHIDA[3]

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Non-reforestation area means plantation stands without re-plantation after clear cutting. Recently, the non-reforestation area (NRA) has been increasing. Under such a situation, the project for NRA has started and some sub-projects have proceeded with the program. One of the sub-projects is about monitoring of actual condition of NRA. For detecting clear-cuts at broad scale, multi-temporal remote sensing played very important role. The percentage of NRA to whole clear-cutting plantation was 25%. The number of NRA points and ratio were different between each prefecture. Moreover, some hotspots were recognized on the Kernel density mapping of NRA.

Forest Observation from High Spatial Resolution Image

Masato KATOH

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Japan is one of the most extensively forested countries in the world. There are over 24 million ha (66% of the land) are forested within conifer plantations about 10 million ha. The Japanese cypress, cedar, larch, and red pine are the main planting tree species. These main plantations with 31-50-year-old trees are managed by thinning or selection cutting. However, management operations have been abandoned in some forests following the depression of timber prices or aging of the land owners. Detection of high density stands without thinning and not good condition of conifer stands occupied by shrub and broad leaved trees are required for higher productive stands and land protection purposes.

Satellites have the advantage of being able to obtain data for a large area simultaneously. Remote sensing image analysis techniques make this possibility worth pursuing. Though very encouraging, the difference of the tree species with leaf on/off high resolution images has not yet been considered though the tree crown extraction.

The purpose of study is to (i) present estimation accuracy of tree isolation and delineation crowns by four main planting species, (ii) compare leaf on and leaf off images, (iii) evaluate stand polygons derived from stand parameters and (iiii) determine under what conditions the approximate techniques are valid.

Estimation of Carbon Stock in Even-aged Sugi Forests Using Satellite Image Data

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A Japanese cedar occupies 40% of an artificial plantation of Japan, and are most artificial plantation resources. The amount of biomass of sugi plantation was presumed using satellite data. The biomass can be easily presumed from volume. Therefore, volume presumption is important. From a result of analyzing the relationship between volume and digital number of the band according to wavelength in the amount of biomasses of LandsatTM Images, the band five showed the highest correlation between volume and digital number. And, high resolution satellite image data (Quick Bird and IKONOS) were visually excellent and its position of an investigation plot is also clear. Then, the relationship between a plot volume and the digital number classified by band was analyzed. Regression was obtained between digital number of band3 and volume of Quick Bird and IKONOS . Every subcompartment volume was presumed by these regressions and the map of biomass estimated from volume were showed. On the other hand, in forest register of Japan, volume for every subcompartment has added up only one value. We analyzed volume from plot, volume from forest register and volume from satellite data and investigated whether estimated volume accuracy of which was the highest. Consequently, the estimated volume from satellite data was the best.

Annual Changes of Growth Condition of Forests in Russia

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2) System hi-dent Ltd., Japan

Phenological changes of ecosystem are closely related to the changes of natural environment, such as water, temperature, soil and solar radiation. Growth condition of vegetation and soundness of ecosystem can be evaluated, if the seasonal changes of the photosynthesis are continuously monitored. Based on these ideas, we studied to get historical information about seasonal changes of Siberian forest by satellite remote sensing data.

Authors developed the processing method named LMF (Local Maximum and Fitting) and LMF-KF (Local Maximum and Kalman Fitting), which modeled the seasonal changes by time series satellite data. It is assumed that the seasonal change for each pixel is modeled by the sum of cyclic functions and model parameters are determined by the 10 day composite satellite data. Subsequently, the technique was developed to produce a new image using model parameters for each pixel. We call this processing the LMF-KF model processing. After the LMF-KF processing to NOAA Pathfinder data for 20 years (1981-2001), we could get “clear” (cloud-free and noise-free) images with 10 days interval for both NDVI and LST. Because both the NDVI and LST are obtained from the LMF-KF processing, there are many possibilities to monitor environmental conditions in vegetated area.

The seasonal changes are well observed on the NDVI and LST individually. However, the combination of NDVI and LST shows much clear idea of the growing season and the trend of vegetation condition of each pixel. For example, we may think that the LST greater than 5 degree C or 1 degree C is the growing season and the accumulation of the NDVI during the period is related to the vegetation growth.

As the conclusion, the LMF-KF processing could successfully create cloud and noise free images of NDVI and LST with 10 days interval for 20 years from the NOAA Pathfinder data. The combination of NDVI and LST is a unique and effective methodology for studying forest conditions in this region. These data can be used for further studies on carbon fixation, such as NPP estimation in this region.

Recent Expansion of Paddy Field Area in the Heilongjiang Province of China Detected by Using Remote Sensing Data

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Development Research Division,
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China is the world largest rice producing country and rice is cultivated under various climatic conditions in the country. The Heilongjiang Province located in the northernmost is one of the major rice producing area and its contribution to the national production has been increased during the last decades. One of the major reasons of relatively high increase of rice production in this province was the growing demand of high quality rice in other provinces and another major reason was its spatial capacity to be developed for paddy field. Although annual averaged temperature is low due to the location in the high latitude zone, a considerable area of the Province except for the northernmost part exhibits the condition with potentially rice grown temperature. The trend of increase of paddy field for the whole province could be recognized by statistical information. However, available data, which might be incompletely assembled by unit area, showed limitation for analyzing the features of spatial distribution and its temporal change.

This study attempted to develop a method to estimate the area of paddy field for the whole Heilongjiang Province using MODIS data and also to analyze the features of changes of distribution of paddy field in recent years. Through the examination of two-dimensional scattergram of NDVI (Normalized Difference Vegetation Index), calculated from Band 1 and Band 2, and NDBSI (Normalized Difference Bare Soil Index), calculated from Band 1 and Band 7, the author could find a systematic pattern between the placement in the scattergram and the percentage of area of paddy field per pixel. Then, an integrated index, PI (Paddy Index), which was defined schematically in the scattergram, was introduced to formulate for estimating area of paddy field. The estimation accuracy was examined by comparing with the area of paddy field obtained from Landsat-TM data and showed a certain consistency of distribution except for a part of water bodies.

The spatial distribution of paddy field was estimated for the year from 2003 to 2007 by adopting the method mentioned above. During this period, a notable expansion of paddy field was identified in the Sanjiang Plain located in the eastern lowland part of the Province. The trend of expansion was especially accelerated after 2006. Another considerable expansion was recognized in the middle of the Province at around northern side of the major river run from west to east. Contrastively, Wuchang County located in the southern part, which was known as high quality rice production area, showed stable or even decreasing tendency of area of paddy field in this period. This might be related with the acreage of non-paddy but potentially suitable for rice cultivation area at the year of 2003.

Analysis for Relationship between the Land Use of the Watersheds and the Marine Nutrients in the Rivers using Remote Sensing and GIS

Daisuke KUNII[1)] and Genya SAITO[2)]

1), 2) Remote Sensing Lab., Field Science Center, Graduate School of Agricultural Science, Tohoku University, Japan

The main supply of nutrients for the phytoplankton at a coastal ocean is considered river water from land area. The nutrients of river water are influenced by the land use in the basin. Therefore, we studied the relationship between the land use of the river basin and river nutrients.

Study area was the Kitakami River, which lies in northeast of Japan. TERRA / ASTER and LANDSAT / TM data observed from 2000 to 2004 were used to determine the land use at the river basin. The concentration of nitrogen and phosphorous were obtained from the website of Ministry of Environment in Japan and there were 57 sampling points. First, we made land use map of the Kitakami River basin. We classified the land use into 8 classes that were coniferous forest, broad-leaved forest, mixed forest, paddy field, cultivated field or grassland, wasteland or bare soil, urban area and water area. Next, we determined the basin of each sampling point and calculated the rate of land use area in each basin. Finally, we compared the rate of land use area with the concentrations of nitrogen and phosphorous.

There were positive significant correlations between the concentration of nitrogen and the area rate of paddy field in autumn and winter, as well as between the concentration of nitrogen and the area rate of cultivated field or grassland, wasteland or bare soil, and urban area respectively in all seasons. There was a negative significant correlation between the concentration of nitrogen and the area rate of broad-leaved forest. Furthermore, we found positive significant correlation between the concentration of phosphorous and the area rate of paddy field, and also between the concentration of phosphorous and the area rate of cultivated field or grassland, and urban area.

It was supposed that the agricultural area and urban area would increase the river nutrients and the broad-leaved forest would decrease them.

Annual and Seasonal Variability of Chlorophyll-a Concentration in the Upper Gulf of Thailand

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The annual and seasonal variability in chlorophyll-a concentration was evaluated using ocean color satellite data from 1998 to 2006 for the Upper Gulf of Thailand. Satellite-derived chlorophyll-a concentration was validated using three in-water algorithms. The regional algorithm has better performance. Its correlation coefficient was 0.935 and root mean square error was 0.252 on the log scale. Chlorophyll-a concentration was estimated by using the regional algorithm, and annual was calculated. The annual average chlorophyll-a concentration increased year on year in the northwest corner and along the western coast of the Gulf, while the average was unchanged in the eastern and middle part. Seasonal variability of chlorophyll-a concentration was clear in the eastern region of the Gulf. This difference shows the difference of the exchanging water quality. In eastern region, clear water flows into from Gulf of Thailand in dry season and water is flushed. On the other hand, in western region the sea water also flows into from the Gulf along the east coast of Malay Peninsula in rainy season, but it includes eutrophic water supplied from coast region then the water is not flushed and chlorophyll-a concentration is kept higher level. Therefore marine environment in western region of Upper Gulf of Thailand become worse year by year.

Operational Fisheries Oceanography Using Satellite Remote Sensing and Marine-GIS for Sustainable Fisheries

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This paper presents an overview of a newly developed ubiquitous fisheries information system using satellite remote sensing and geographical information system (RS/GIS). The system was developed to aim for providing high value-added fisheries oceanographic information in anytime and at anywhere. We also make this system to come into wide use for especially fishermen and managers in fisheries cooperation or fisheries experimental stations. This system consists of four subsystems; MODIS (Moderate Resolution Imaging Spectroradiometer) receiving subsystem, database subsystem, analysis subsystem, and GIS subsystem (WebGIS and onboard-GIS). MODIS system provides sea surface temperature, chlorophyll-a concentration and sea ice distribution. Database manages the all products under Oracle software. Analysis subsystem produces level 1 to level 5 products, which include fishing ground forecasting of Japanese common squid, Pacific saury, Skipjack tuna and Albacore tuna. These procedures run automatically, so that the fishermen could receive information in near real time through communications satellites (maritime satellite internet services and digital packet communication services) and S-band Digital Multimedia Broadcasting (S-DMB) Service. Using satellite communication services, users can operate all products dynamically such as overlaying, measuring distance from nearest port or fishing grounds on the onboard GIS. On the other hand, using S-DMB service, users can receive several marine information and weather information as broadcasting. Those systems can help to support effective fishing activities such as economy with time for fishing ground destination or nearest landing port. This ubiquitous information services promise to promote sustainable fisheries operation and management in the offshore around Japan.

New Generation Sea Surface Temperature

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Real-time generation/distribution of New Generation Sea Surface Temperature for open ocean (NGSST-O) started in September 2003 as a demonstration operation of the GODAE High Resolution Sea Surface Temperature Pilot Project. Satellite sea surface temperature (SST) observations from infrared radiometers (AVHRR, MODIS) and a microwave radiometer (AMSR-E) are objectively merged to generate the NGSST-O product. The product is a quality-controlled, cloud-free, high-spatial resolution (0.05 degree-gridded), wide-covering (13-63N, 116-166E), and daily SST digital map. A NGSST-O demonstration operation system has been developed through cooperation with regional operational and Research and Development (R&D) agencies. Its demonstration operation continues for about three years without large gaps of the product generation. Comparing with the in-situ SSTs measured by drifting buoys, the rms error of NGSST-O has been kept about 0.9C.

Ocean Surface Winds and Wind Waves in the Voastal Zone Using High-Resolution Satellite Observations

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Wind jet is a low-level strong winds blowing from the terrestrial gaps such as straits. Because the wind jets induce highly localized and intensified air-sea-land interaction, high-resolution wind fields derived from SAR are crucial to investigate the ocean and atmosphere dynamics in coastal environment. Additionally, understanding of the wind jet and associated severe waves is now social demand for shipping, disaster prevention, marine plant maintenance, and improvement of forecast systems. Focus of a series of our studies is to illustrate the true state of the wind jets near the Japanese coast and to examine their impacts on regional air-sea-land interaction.

In this presentation, we first introduce a few case studies of terrain-induced wind jets near the Japanese coast. Based on the studies, we now pay attention to the wind jets through the straits in the Japan Sea. Only high-resolution wind fields derived from SAR can reveal the detailed structures of the wind jets. Next we examine localized wind wave responses to the wind jet using satellite and in situ observations. Then, using meteorological and wave models with high-resolution capability, validate the satellite evidences and consider the process of evolutions of wind jet and high waves.

High-Resolution Satellite Oceanography for Monitoring the Tohoku Coastal Seas

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Through the intensive Research and Development (R&D) of earth observation satellites in the last decade, the satellite-based observational functions for the global open oceans are highly enhanced. Using the established satellite components of earth monitoring, a challenge is to develop advanced observing systems for the coastal zones, where inputs from land, sea, air and people converge. It is well recognized that the ongoing global changes are increasing threats against the vulnerability of coastal zone.

Since ‘80s, we have been developing the high-resolution satellite products for ocean monitoring, i.e., visible, infrared, and active microwave sensors which all have spatial resolutions better than 1km. The A-Highers (Advanced High Spatial Resolution Sea Surface Temperature maps) are 0.01-degree grided satellite-based SST products generated from the AVHRR sensors. A detection method of high-resolution SST front has been developed using the Jensen-Shannon divergence filter. SST fronts of the Sendai bay are detected by the developed method, which shows the bay-scale river fronts, thermohaline fronts and shelf fronts.

Advanced high-resolution ocean color products can be used for monitoring marine environments and material circulations in the coastal seas. Flesh water inputs from four major rivers to the Sendai bay are considered to be important for the bay ecosystem. A case study shows that the ocean color fronts show significant agreements with the SST fronts in summertime.

Ultra high-resolution surface winds and surface wave fields can be obtained from Synthetic Aperture Radars (SARs). The surface winds drive the coastal circulation, which controls the material circulation in the coastal seas. Combining the numerical ocean and atmosphere models, the SAR high-resolution winds and waves provide new information of dynamical features.

In the presentation, I am going to introduce these application results and a future coastal monitoring system combining them.

Advances in DMSP Products, Services, and Findings

Christopher D. ELVIDGE, Ph.D.

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The only satellite sensor currently collecting global night-time lights data is the U.S. Air Force Defense Meteorological Satellite Program (DMSP) Operational Linescan System (OLS). The NOAA National Geophysical Data Center (NGDC) has been producing DMSP night-time lights products since 1994 and has worked extensively with the scientific community to develop applications for this data source. During the past two years NGDC has established new product services for OLS data including: near real time global mosaics in the geographic projection, near real time polar projection mosaics, feature identification in near real time date, plus monthly and lunar cycle cloud-free composites. In addition, NGDC has investigated the intercalibration of annual cloud-free composites of nighttime lights and the development of new applications such as estimation of gas flaring volumes, estimation of constructed surface area density, estimation of poverty rates and the assessment of human impacts on coral reefs.

http://dmsp.ngdc.noaa.gov/
http://spidr.ngdc.noaa.gov/spidr/index.jsp

Prediction of Japanese Common Squid (*Todarodes pacificus*) Potential Fishing Grounds Using GAM and GLM with Satellite Remote Sensing Data in the Japan Sea

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The Japanese common squid, *Todarodes pacificus*, is one of the most important commercial species for in Japan. The objectives of this study are to clarify the relationship between squid fishing grounds and environmental factors using statistical models and to predict the potential fishing grounds using satellite remote sensing data and Catch Per Unit Effort (CPUE) data. The generalized additive models (GAM) were applied to analyze the relative influence of various factors on the squid CPUE. Satellite data sets, NOAA/AVHRR sea surface temperature (SST), Orbview-2/SeaWiFS chlorophyll-a concentration (CHL) and AVISO sea surface height anomalies (SSHA) data from 1997 to 2000 were used to understand spatial and temporal oceanographic characteristics of the fishing grounds. We developed the generalized liner model (GLM) with transformation of GAM. The potential fishing grounds were estimated from the satellite data using the model of GLM. SST is the most important environment factor for distribution of fishing ground, and SSHA and GC is the secondary in the environmental variables. It seems to depend on ecological significance, for example SSHA and GC depend on migration, SST depends on the growth and physiology.

Presumption of Carbon-Dioxide Emissions by Nighttime Lights Observed by DMSP/OLS
−Presumption of Carbon-Dioxide Emissions Change in East Asian Region−

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A time series nighttime-light imagery observed by DMSP/OLS from 1992 to 2003 was used to extract the time fluctuation of the lights in East Asia region. The 12-years time series imagery was generated from the data observed by F10, F12, F14 and F15 of DMSP. However, the characteristic feature of the sensor was slightly different among the satellites. Then the time series data was normalized based on the data observed by F12, and fluctuation of nighttime light was classified by countries in East Asian region and by the year. The relation among classification by countries in East Asian region, the change of nighttime light, and the change of GDP and the amount of the CO_2 emissions by United Nations statistics was examined.

As a result, the possibility that the effect of the level of productivity and measures to conserve energy could be able to judge in each country was shown.

STATEMENTS

at

"6th International Symposium on Integrated Field Science -Understanding for each and integrated ecosystem using remote sensing-"

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SENDAI, JAPAN

KEYNOTE SPEAKERS

Tsuyoshi AKIYAMA (Gifu University, Japan)
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Recommendation on Earth Observations to JAXA

Participants at the 6th International Symposium on Integrated Field Science - Understanding for each and integrated ecosystem using remote sensing- held discussions on earth observations and developed the following statement for JAXA. We recognized that our society faces a large number of environmental issues which can be best addressed using a combination of satellite imagery and ground based data. There is concern that global warming may result in the increased release of carbon from ecosystems. This positive feedback may lead to earlier and more dramatic climate change impacts than have been expected. The satellite data provide the synoptic view of environmental conditions and climate change. Field and in situ data are crucial for calibrating and validating satellite data products.

We recognize that Space Agencies play a crucial role in building and operating the earth observing systems and enabling the utilization of satellite data. We endorse the GEOSS (Global Earth Observation System of Systems) effort to achieve societal benefits through the combination of data from earth observing satellites with the ground measurements and geophysical models. During the coming decades there will be substantial pressure on ecosystems associated with the continuing growth in population and resource consumption (food, water, energy, fiber). It is clear that earth observations are crucial to tracking and understanding the ongoing changes in forest, agriculture, biodiversity, water, ocean, climate as well as secure and safe life acquired by disaster management. The group expressed their appreciation to JAXA for being a lead agency in the global effort to observe the ongoing climate and environmental changes and urged JAXA to collect as much global data as possible to meet both current use and future uses that cannot yet be anticipated.

ALOS is recognized as one of the most comprehensive earth observing satellites, because of its harmonized sensors PALSAR, PRISM and AVNIR-2 with the stable platform for the integrated use. The ALOS mission concept was developed based on the Japanese heritage of space and data application science and technology in accordance with the requirement optimized among all user communities. The value of ALOS data have been demonstrated for a wide range of applications in the inventory of natural resources and survey of disaster events. Several papers presented at our symposium revealed the high value of ALOS polarimetric data and the presenters urged JAXA to collect more of this type of data. ALOS data use is rapidly increasing and can be expected to continue climbing. The growing demand for ALOS data includes both near real time and archived data. We recommend JAXA continue ALOS data collections to provide near real time data of significant events and build a long time series of archived data.

The group recognized the importance of the planned GCOM satellite series (especially GCOM-C) in providing a long-term earth observation record which will be interoperable with archived ALOS data sets. The GCOM-C/SGLI was identified as a crucial instrument for the long-term continuous global monitoring to analyze the interactions between ecosystem and climate change.

Finally, we believe that JAXA is well positioned to pioneer the development of new observational capabilities that would fill gaps in the currently available international constellation of earth observing systems. By including narrower spectral bands and short wave infrared bands it would be possible to collect data with higher information content related to the biophysical and biochemical process. Results to date from PALSAR indicate the high value of polarimetric observations from space. We encourage JAXA to consider building more capable polarimetric sensors in the future. Finally we recommend JAXA consider building sensors designed to observe the “human footprint” as a key variable in modeling global change and the economic / societal impacts of global change. In the past, earth observing systems were designed primarily to observe natural systems. Humans are recognized as the primary driving force changing the earth and its ecosystems. Yet there is very little global geospatial data measuring this human source term that drives both climate and environmental changes. We discussed three types of observations related to the human footprint: 1) moderate resolution nighttime lights (the Nightsat mission concept), 2) active remote sensing of urban volumes, and 3) the density of electronic emissions.

All the Participants of 6th International Symposium on Integrated Field Science
- Understanding for each and integrated eco-system using remote sensing-

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