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CLASSIFICATION OF WETLAND VEGETATION USING AERIAL PHOTOGRAPHS BY CAPTIVE BALLOON CAMERAS AND AERO NIR COLOR VIDEO IMAGE, KUSHIRO NORTHERN WETLAND IN JAPAN

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ABSTRACT: The overall goal of this research is to develop an algorithm for classification of specific vegetation patterns and community types in wetland. It is based on aerial balloon photo interpretation and aerial Near Infrared (NIR) color sequence video images with high resolution. We focused on the following definite objectives. 1) Making vegetation maps by mosaicking balloon photos with high resolution and discussing about the efficiency for the classification of wetland vegetation in Kushiro wetland, located in the eastern part of Hokkaido, JAPAN, 2) Application of balloon mosaicked photos as training data for classification of aerial NIR color video images with high resolution, 3) Classification of wetland vegetation using aerial NIR color video images taken from not only nadir angle but also off-nadir angle, 45 degree zenith. We extracted training data by using balloon photographs for the classification of vegetation on video images taken from Nadir angle and overlaid with the images taken from off-Nadir angles. We got 27 categories of each vegetation and 10 types of vegetation community with higher accuracy classification: two vegetation community types in low-moor; aquatic plants and *Chamedaphne-Alunus-Phragmites*, three types in transition-moor; *Carex*, *Chamedaphne* and *Carex-Phragmites*, and five types in high-moor; *Sphagnum* bog, *Sphagnum*-dwarf shrub, dwarf shrub-alpine plant, *Carex*-alpine plant and *Sphagnum*-alpine plant-*Carex*. In consequence of this research, it concluded that availability of high resolution training data such as balloon mosaic photos were obviously useful to classify NIR color video images of typical wetland vegetation. We found that considering the bi-band combination of both nadir and off-nadir video images were effective to apply to classify specific wetland vegetation such as *Phragmites* and *Sphagnum* bog mixed with shrub and each community types in wide range.

1. INTRODUCTION

Intensive monitoring of environmental changes in wetlands is in urgent necessity since the ecosystem of wetland vegetation such as peat mosses and alpine plants are so fragile. Detecting the slight changes of vegetation enables us to perceive how the natural environment of precious wetlands is to be under influence of environmental changes (Yamagata, 1999). It is necessary to obtain precise vegetation distributions in wide range in order to understand extension of migration belts and the biodiversity to preserve wetland vegetation (Yamagata, 1999).

Satellite monitoring is one of the available platforms for wetland vegetation though, more proximate platforms to the earth such as an airplane and a balloon are necessary for the detail monitoring, since units of wetland vegetation are often smaller than resolutions of satellite sensors (Yamagata, et al., 1995). Recent studies show that multiangular reflectance measurements of vegetation have a lot of information on canopy structure as well as species types (Christensen et al., 1993; Qi et al., 2000; Miyamoto et al., 2001). By using an airplane or a balloon platforms, one can choose combinations of view angles and wavebands that are appropriate to sensing the objects more easily than by using satellite. Combinations of different platforms that have not only different view angles and wavebands, but also different resolutions have also potentials for better monitoring of wetland, since a finer resolution often means a smaller area of the monitoring.

In this study, we tested a combination of an airplane and balloons as platforms for monitoring of wetland vegetation in Kushiro wetland, located in Hokkaido, Japan. NIR color video sequence images were taken by an airplane at 900 m height, and color photographs were taken by a captive balloon system at 100-200 m height. The video images and the photographs were interpreted with the ground observations of multiangular spectral reflectance and plant species description (miyamoto et al., 2001). We set two tasks to attain the object: 1) Making vegetation maps from high-resolution mosaicked photos taken by captive balloon. This technique was used to classify vegetation in Kushiro wetland; 2) Application of balloon mosaic photos as training data for classification of aerial NIR color video images taken from Nadir and off-Nadir, 45 degree zenith.

2. SITE SPECIFICATION

Our study site is located in Akanuma area in Kushiro wetland (N 43°6' 19", E 144°21' 23") (Figure 1). Kushiro wetland is the largest wetland in Japan, spreading over 18,290 ha and was designated as the first Ramsar site of Japan in 1980. Akanuma area is legally appointed as the specially preserved area and characterized by high biodiversity and high spatial heterogeneity of egetation especially in Kushiro wetland. Low moor is spread near lake Akanuma, and transitional and high moors are spread away from the lake. *Alunus* and *Phragmites* dominated in low-moor, *Chamedaphne* and *Carex* dominated in *Sphagnum*, alpine plants and dwarf shrubs dominated in high moor as broad categories, respectively. The coverage of the aerial video image is 250m × 1025m and that of balloon photo observation area is 230m × 460m.

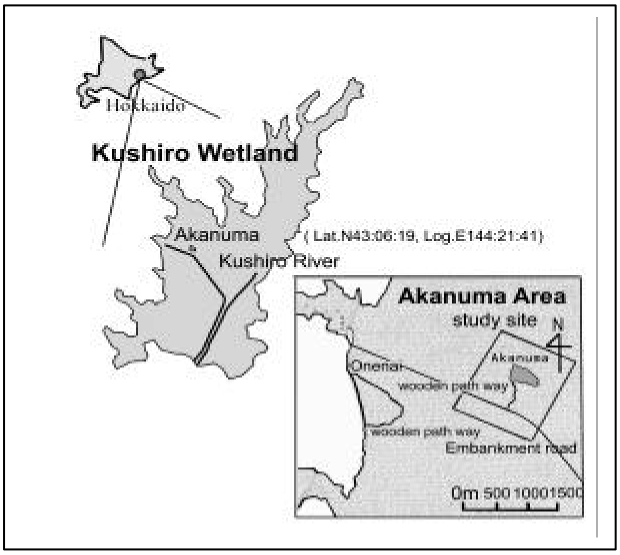

Figure 1. Study site, Akanuma area in Kushiro wetland

3. METHODOLOGY

3.1 Vegetation Research and Position Coordinates

We tried a combination of an airplane and balloons as platforms for monitoring of wetland vegetation to make vegetation map in detail (Figure 2). The vegetation research (Jun 30 - July 2 in 1998 and July 26 - 27 in 2001) was carried along the wooden path way in the direction of North-South, 59 points of 1m × 1m size quadrates and 52 points of 10m × 10m size quadrates were set. While in the direction of East-West, 52points of 20m × 20m size quadrates were set every 20m. At each quadrate, dominance and sociability were measured.

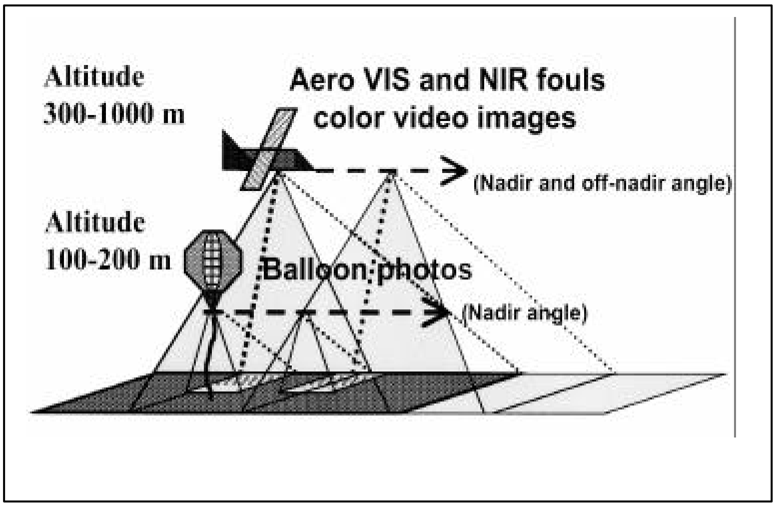

Figure 2. Balloon photos and data acquisition of NIR color video images

The tie points between the video image and the photograph image were extracted by human eyes and overlaid. The position coordinates were measured using two sets of ground positioning system (GPS , Trimble Corp., 4600LS) by carrier phase DGPS. We set 21 signals (30 cm × 20 cm) in each 20 m along the wooden pathway in Akanuma area. Ground control points set on the embankment and measured the electronic control points located in Kushiro by rapid static GPS survey. Air to ground targets on the wooden pathway were measured by kinetic survey. The position coordinates were converted to 13th plane rectangular coordinates using the data sets of electronic control points provided by National Geographical Survey Institute in Japan. The video and photo images were interpreted in relation to multiangular spectral reflectance and plant species description data (Miyamoto et al., 2001) observed at 10 points in Akanuma area at the same day as the video images (Jun 30 - July 2 in 1998). The photo images were taken according to each vegetation research area.

3.2 Mosaicked Aerial Balloon Photographs

Aerial color photographs were taken by two captive balloons (Helium gas) from nadir view at 100-200 m height on the 2nd of July in 1998 (Table 1)(Figure 3). The photographs were taken on both sides along the wooden pathway. The observation area covers 230m × 460m. The still camera shutter on the balloons was radio controlled an the normal focal length of the camera was 28mm. Each photo was scanned at 600 dpi and overlaid by human eyes and scanned at 600dpi. Each vegetation and community layer was created by human eyes and overlaid with video images taken from Nadir angle only. The resolution of the photographs was 15 cm / pixel. The position coordinated 23 photographs were mosaicked by using ERDAS IMAGINE Ver.8.4. The mosaic photo image was interpreted from ground observation of plant species at each quadrates and vegetation description along a wooden road.

Table 1. Aerial captive balloon photograph

altitude: 100 – 200 m
coverage size : 15 m×20 m / scene, 50 m×70 m / scene
coverage area: 230m×460m
number of scene: 66 scenes
focal length of still camera: 28mm
resolution: 15 cm / pixel


Figure 3. Aerial captive balloons.

3.3 Aero NIR Color Video Image

NIR color video (SILVACAM, VTT Automation Co., Finland) sequence images (Table 2) were taken by an airplane (Dornier., Do228-200, National Aerospace Laboratory of Japan) from nadir view on 30 June, 1998 at 900 m height. The coverage of the aerial video image is 250m × 1025m. The algorithm is for registration of video sequence imagery by matching of tie points of tie points on time sequential two still images and calculating coefficients of the transformation function. One 750 × 480 pixel size image was taken in every 1/30 second and the 500 video sequence images were overlaid using an algorithm (Kushida et al., 1999) of tie points extraction based on image matching, and registered to UTM WGS 84 coordination system using ground control points (GCPs).

Table 2. NIR color video image

altitude: 900 m
coverage size: 300 m × 700 m
bands: Green, Red, NIR
survey airplane: Dornier., Do228-200
NIR color video: SILVACAM, VTT Automation Co., Finland
observation angle: Nadir and off-Nadir, 45 degrees
resolution: 30 cm / pixel
focal length: 28mm
film size: 36 mm,
number of overlaid images: 500 scenes
image size: 750 × 480 pixel

The processing speed was 15 - 20 images / minute in a PC equipped with Windows 98, 500 MHz processor, and 128MB RAM. By way of this method, one can reduce white noise 1/10 - 1/30 as much as that of the original still images. The composites of have no gaps that take place in the boundary of the composites of photographs to prevent correct classification (Kushida et al., 1999). The resolution of the aerial video images were 30 cm / pixel. Filed of view of the video was 45 deg., and the normal focal length and the film size of the camera were 28mm and 36mm. Each image has three bands, Green, Red and NIR.

As for the Classification of vegetation of aerial NIR color video images taken from not only nadir angle but also off-nadir angle, 45 degree zenith. The Nadir images were overlaid with that of the off-Nadir and six bands images were generated. First, only the images taken from Nadir angle was clustered (ISODATA) by using extracted training data by mosaicked balloon photo interpretation and the detailed vegetation map was composed. Secondly, overlaid with images taken from both angles were clustered in the same way. Thirdly, The combination of bi-band indices considering both angle, Nadir and off-Nadir, was taken.

4. RESULTS AND DISCUSSION

4.1 Vegetation Maps Composed By Balloon Photo Interpretation

We got 27 categories of each vegetation and 10 types of vegetation communities with higher accuracy classification. The mosaic photo image (Figure 4) interpreted from ground observation of plant species and community types, along the wooden road in the center of the image, we can see darker parts near the lake corresponds to waterlogged area with aquatic plants and lighter parts away from the lake corresponds to high moor in broad perspective. In detail, small green patches of low-moor inside high-moor area that were not appear on the video image were extracted on the balloon photo images. From that small patches, we could identify the difference of sub community types between *Carex-Equisetum*, *Carex-Phragmites* and *Carex-Phragmites* comparing with the ground vegetation research and the mosaicked balloon photos with high resolution.

Figure 4. Mosaicked balloon photographs

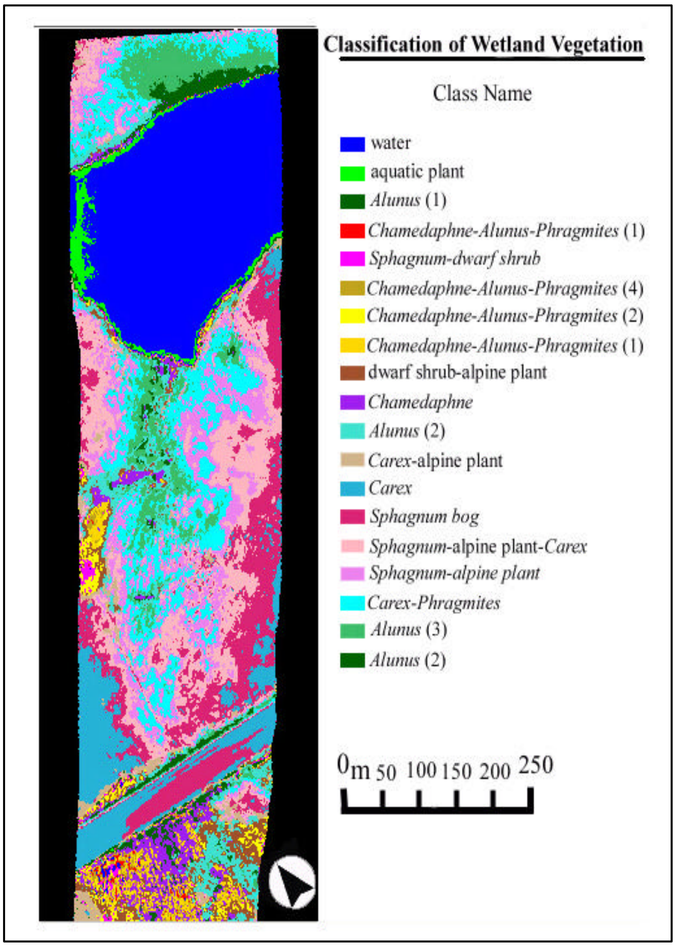

Figure 5. Clustered NIR color video image composed by photo interpretation as training data, mosaicked balloon photos

4.2 Bi-Bnad Combination Specific to Typical Wetland Community Types

As for unsupervised classification of the video image, it was hard to extract differences of vegetation within each of high, transition, and low-moors. On the other hand, classification of the video image taken from Nadir angle supervised by the finer resolution photos and the ground observation data divided the wetland vegetation into the following 10 types of community categories: two types of low-moor (1. aquatic plants and, 2. three types of *Alunus*), three types of transition-moor (1. *Chamedaphne*, 2. *Carex*, 3. *Carex* and *Phragmites*) and five types of high-moor (1. four types of shrub mixed with different kinds of mosses, 2. shrub mixed with alpine plants, 3. *Carex* mixed with alpine plants, 4. *Sphagnum* bog, 5. mosses mixed with alpine plants and *Carex*) (Figure 5). In the supervised classification, the training area on the video image can be chosen as pure pixels. In supervised classification without the photo image, though the training data is a mixture of pure pixels and mixed pixels because of the video image's lower resolution. The former classification fitted to the ground observation than the latter. The supervised classification also gave the difference of vitality of *Alunus*.

Concerning the bi-band indices of the video images (Table 3), we could see remarkable differences and detect *Phragmites* –*Alunus* type in the image of $VI\_{45\ deg}$ (; $NIR\_{45\ deg}$ - $Red\_{45\ deg}$). As for the image of R/NIR* (; Red_{Nadir} / $NIR\_{45\ deg}$) and G/NIR* (; $Green\_{Nadir}$ / $NIR\_{45\ deg}$), Carex- alpine plants, especially mixed with short shrub could be apparently discriminated from other vegetation in high-moor. The pools with *Sphagnum* bog could be eliminated especially in the image of $R/NIR\_{45\ deg}$(; $Red\_{45\ deg}$ / $NIR\_{45\ deg}$) (Figure 6). .

Table 3. bi-band indices concerning off Nadir, 45 deg. image

$NDVI^* = (NIR_{\_Nadir} - Red_{\_45 deg.}) / (NIR_{\_Nadir} + Red_{\_45 deg.})$	(1)
$NDVI^{**} = (NIR_{\_Nadir} - Red_{\_45 deg.}) / (NIR_{\_Nadir} + Red_{\_45 deg.})$	(2)
$VI^* = (NIR_{\_Nadir} - Red_{\_45 deg})$,	(3)
$VI^{**} = (NIR_{\_Nadir} - Red_{\_45 deg})$	(4)
$G/R^* = Green_{\_Nadir} / Red_{\_45 deg}$	(5)
$G/R^{**} = Green_{\_45 deg} / Red_{\_Nadir}$	(6)
$G/NIR^* = Green_{\_Nadir} / NIR_{\_45 deg}$	(7)
$G/NIR^{**} = Green_{\_45 deg} / NIR_{\_Nadir}$	(8)
$R/NIR^* = Red_{\_Nadir} / NIR_{\_45 deg}$	(9)
$R/NIR^{**} = Red_{\_45 deg} / NIR_{\_Nadir}$	(10)

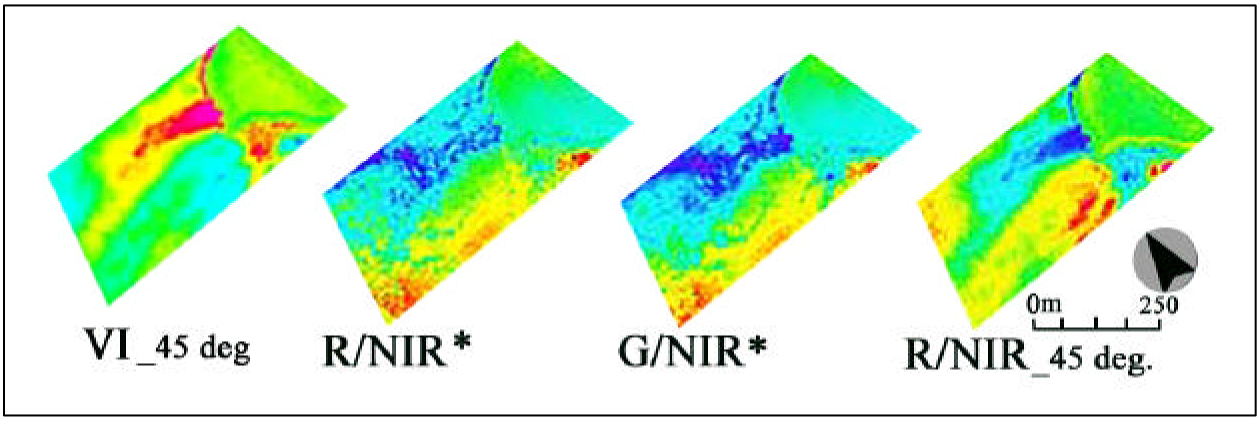

Figure 6. Remarkable differences could be seen in the image of $VI\_{45\ deg}$ (; $NIR\_{45\ deg}$ - $Red\_{45\ deg}$) showing *Phragmites* –*Alunus* type. Carex- alpine plants, especially mixed with short shrub could be apparently discriminated from other vegetation in high-moor in R/NIR* (; Red_{Nadir} / $NIR\_{45\ deg}$) and G/NIR* (; $Green\_{Nadir}$ / $NIR\_{45\ deg}$). Ppools with *Sphagnum* bog could be seen especially in the image of $R/NIR\_{45\ deg}$(; $Red\_{45\ deg}$ / $NIR\_{45\ deg}$).

In consequence of this research, it concluded that availability of high resolution training data such as balloon mosaic photos were obviously useful to compose wetland vegetation map precisely and classify NIR color video images of typical wetland community. In addition to above we found that considering the bi-band combination of nadir and off-nadir video images (Figure 7) were effective to classify and identify specific vegetation and typical community such as different kinds of mixed shrub types, *Alunus -Phragmites*, *Sphagnum* bog mixed with short shrubs of *Ladum* and pools with mosses with shrubs of alpine plants in each vegetation types in wide range.

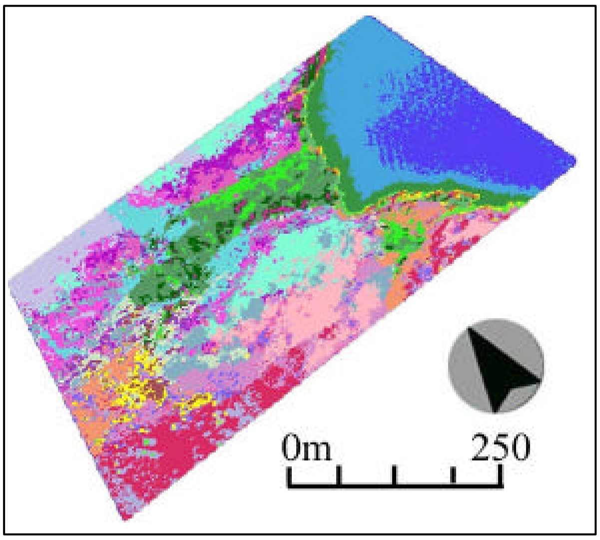

Figure 7. Nadir images overlaid with off-Nadir, 45 deg. images (six bands) were classified

5. CONCLUSIONS

Following three statements are concluded in this study.

1) We made mosaicked balloon photos of Akanuma area with high resolution and specified typical vegetation patterns and community types. The vegetation maps were composed by photo interpretation based on the ground vegetation research and position coordinates observation. We found thathigh resolution training data acquisition such as balloon mosaic photo observation was obviously useful tools to compose wetland vegetation maps in some extended area precisely and easily. And it was effective to classify NIR color video images of typical wetland community especially *Carex* mixed types.

2) We classified wetland typical vegetation patterns and community types using aero NIR color video images at Nadir and off-Nadir angle. The unsupervised and supervised classification were carried out by using the training data of mosaicked balloon photos.

3) We clarified that bi-band combination of Nadir and off-Nadir, 45 deg. video images were effective to classify and identify specific vegetation such as different kinds of mixed shrub types in each wetland vegetation.

6. ACKNOWLEDGEMENTS

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