CHARACTERISTICS OF SPATIAL DISTRIBUTION OF PLANT COMMUNITIES AT THE HIGH MOOR IN KUSHIRO WETLAND USING AERIAL COLOR PHOTOGRAPHS OF SUPER HIGH SPATIAL RESOLUTION

K. Yoshino[a], S. Kawaguchi[b], F. Kanda[c], K. Kushida[d], F. Tsai[e]

[a] Graduate School of Systems and Information Engineering, University of Tsukuba, Japan, - sky@sk.tsukuba.ac.jp
[b]Kushiro Parks and Greenery Association, Hokkaido, Japan, - little-lily.mikeneko@cpost.plala.or.jp
[c] Faculty of Science, Hokkaido University of Education Kushiro Campus, Japan, - kanda@kus.hokkyodai.ac.jp
[d] CFES, University of Toyama, Japan, - kkushida@sci.u-toyama.ac.jp
[e] CSRSR and Civil Engineering Department, National Central University, Taiwan, - ftsai@csrsr.ncu.edu.tw

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ABSTRACT:

The ecosystem of wetlands has precious natural environment to be preserved in the world. In order to sustain valuable wetlands ecosystems for a long time, it is very important to frequently monitor the state of wetland ecosystems, to carefully watch the environment, and to earlier warn the environmental change. In this research, using high spatial resolution of color photographs taken with a 35 mm non-metric camera mounted on the cabled balloon flown over the high moor near Akanuma in Kushiro wetland, characteristics of spatial distribution of wetland plant communities are studied in terms of application and interpretation of remote sensing data for wetland environment monitoring using geostatistics, texture analysis, and landscape metrics.

Outcomes of this research are summarized as follows.
1. An ultra fine and reliable vegetation map, of which nominal spatial resolution is 2cm by 2cm, with 40 plant community types at the time of the summer in 1998 was originally created, which is covering about 15ha of the high moor, for the baseline map for ecological studies near Akanuma.
2. The optimal spatial resolution for monitoring vegetation in this area by remote sensing is smaller than a half meter.
3. Concentric spatial distribution of typical wetland plant community groups is clearly distinguished and confirmed in the ultra fine vegetation map through visual interpretation and spatial analysis using GIS application tools.
4. Results of this research show that remote sensing of high spatial resolution greatly serves for wetland environment monitoring and wetland studies.

1. INTRODUCTION

The ecosystem of wetlands is playing a lot of roles on regional natural environment; for example, functioning as important entities for regional carbon and nutrient cycles, hotspots of biodiversity, and landscape services for tourisms. Wetlands are thought to have precious natural environment to be preserved in the world. In order to sustain valuable wetlands ecosystems for a long time, it is important to continuously monitor the state of wetland ecosystems, to carefully watch the environment, and to earlier warn the environmental change. Remote sensing is one of the powerful tools for monitoring unreachable wide ranges such as wetlands, although remote sensing needs to pay many careful attentions to apply it to environment monitoring and to interpret their results. In this research, using high spatial resolution of colour photographs taken with a 35 mm non-metric camera mounted on the captured balloon flown over the high moor near Akanuma in Kushiro wetland, characteristics of spatial distribution of wetland plant communities are studied in terms of application and interpretation of remote sensing data for wetland environment monitoring using geostatistics, texture analysis, and landscape metrics.

2.STUDY SITE and AERIAL PHOTOGRAPHS

2.1 Outline of High moor near Akanuma, Kushiro wetland

Kushiro wetland is the largest wetland in Japan and it is located in the eastern part of Hokkaido Island, northern Japan (43:01N, 144:17E, 5 m in altitude). This region was categorized as a cool temperate zone with a mean annual temperature of 5.7 degrees centigrade and annual precipitation of 1040 mm. Kushiro wetland is much abundant in herbaceous vegetation with a large extent of high moor. This wetland has been assigned as preservation area in the National park since 1987(Tsuyuzaki et al. 2004). Akanuma(43 deg. 6 min. N, 144deg. 21min. E) is the small lake encompassed by high moor in the western part of Kushiro wetland. It shows the climax stage of the transition of wetland vegetation. Thus, the nature around Akanuma is valuable for conservation. Recently, the landscape of Kushiro wetland is apparently coming to look different from that of several tens years ago. Wetland has been drier(Nakamura, 2002), the habitat of alders(*Alnms japonica*) has expanded(Kanda and Hoshi 1982; Oki 2002), and the extent of Kushiro wetland itself has been smaller, due to urbanization and development of agricultural lands in surrounding area of Kushiro wetland(Tsuyuzaki et al. 2004). Moreover, some local natural researchers have pointed out some tiny changes of the distribution of plant communities of high moor are possibly occurring. So, the spatial distribution of plant communities in high moor near Akanuma should be mapped and watched in detail.

2.2 Aerial photographs for analysis

2.2.1 Captured balloon system and Camera system: Plant communities in high moor are spatially very complex and full of variety. In order to draw a map of vegetation in detail to the extent of individual plants, the usage of low altitude aero-photographs are more effective to cover a wide extent with some accuracy than the ground survey by researchers. In this research, colour aero-photographs were taken from the captured balloon flown over Akanuma in low altitude for analysis. On this captured balloon, a non-metric 35mm colour film camera, which were radio controlled, was loaded. In order to make the balloon compact and light, this camera system had no monitoring TV camera. A ground operator released the shutter randomly following his guesses of balloon height and position. More than one hundred shots were taken with three film cartridges in the study site in the morning on July 4 and 5 in 1998.

2.2.2 Ground control points: Prior to taking aero-photographs, thirty ground control points made of white paper or plastic panels (hereafter called GCP) were arranged over the study area and their ground geographic coordinates were measured with a pair of differential GPS receivers. After D.P.E. of colour films, twenty four GCPs were identified on photos. Those geographic coordinates of DGPS were converted to the coordinates of the 13th zone of the Japan plane orthogonal coordinates. Geometric errors of DGPS measurement is less than 1 to 2cm, according to the operational manual. More details on the captured balloon system, camera system, and GPS receivers used in this research are referred in Miyamoto et al.(2004).

3. ORTHO-RECTIFIED DIGITAL COLOR MOSAICKED IMAGE

3.1 Original colour photos

Among about 100 aero-photographs shots, photos of better quality were visually selected to cover the study site. They were magnified by 4.8 times larger than the dimension of a 35 mm file, and printed. They were about 115 mm by 173 mm in dimension. After that, they were digitised with a flat-bed type colour image scanner with the resolution of 1200 dpi. Each digital image of the photo has about 8,200 pixels by 5,500 rows in TIFF format and each pixel in an image file has 24 bits with three colours (RGB).

3.2 Air-triangulation and image rectification

Air-triangulation and image rectification were conducted on abovementioned digital images of balloon photos of Akanuma with following procedures using ERDAS Imagine 9.1 and LPS 9.1(ERDAS Inc.). **First**, three elements of interior orientation, focal length of the lens of the non-metric camera used and principal point location of the film were decided for the image rectification by analytical photogrammetry(Wolf and Dewitt 2000). If possible, these parameters are to be estimated in situ(Leica 2000). Other parameters can be estimated using with ground coordinates of the ground control points(Murai et al. 1980; Murai et al. 1984). In this research, the focal length of the lens and the principal point location of film are assumed to be constant between all the photos of Akanuma, then, they were estimated using other films which were particularly taken with the same camera. **Second**, image orientation was conducted using LPS9.1(Leica Photogrammetric Suite), a optional package of ERDAS Imagine 9.1 in order to remove image distortions as much as possible. Using twenty four ground control points of which 3D ground coordinates were measured with DGPS and more than 100 tie-points which were digitised on overlapped photos, a bundle adjustment could be applied to compute exterior and interior orientation parameters. After twenty times of iterations, the computation for image orientation was converged. The final RMSE on the twenty four ground control points are smaller than 0.3 m in average. The maximal correction of the standard error is 9.689. The elevation of the camera in the balloon ranged from 47 m to 187m over Akanuma. **Third**, image rectification of each balloon image was conducted using estimated parameters of elements of interior and exterior orientation for each image in order to remove image distortion as much as possible. The sampling grid size was 2cm by 2cm as following the magnitude of the positioning error by DGPS survey of the GCPs. Consequently, very fine rectified and allowable-precisely geo-located colour images were obtained.

3.3 Mosaic image of this site

After all the balloon image which were selected to analyse were rectified and geo-located, they were simply mosaicked using a mosaic tool of ERDAS Imagine and LPS so that the final mosaicked image looked better in terms of colour balance, contrast, geologic rectification accuracy and so on. This is because that advanced image mosaicking in the ERDAS Imagine tool uses a complicated algorithm and then, the final mosaicked image may lose the true edge information between colour contrast caused by the difference of land cover characteristics such as vegetation difference. In the overlapped area of two images with some unevenness on the ground surface, there are different appearances due to the differences of lens positions of both images. It is called relief displacement on the rectified images. In this research, these relief displacement were ignored because the strict removal of relief displacement between adjacent images requires a special technique named stereo-scoping or stereo-matching in digital photogrammetry. The final mosaicked colour image covers the extent of about 15ha(300m along west- east by 500m along north-south) from the southern edge of Akanum to the embankment. Some differences of colour, contrast and texture are perceived.

4. IMAGE SEGMENTATION and INTERPRETATION

4.1 Image classification with object based segmentation

The first objective of this research is to make a precise vegetation map of high moor near Akanuma in Kushiro wetland using very high spatial resolution colour aero-photographs. Almost of the vegetation map in the extend area have been drawn by specialists through their visual interpretation of aero-photographs. However, this very fine mosaicked image of balloon colour aero-photographs makes vegetation specialists' interpreting or identifying plant communities based on colour difference difficult and gives interpreters a lot of loads to draw the outlines of plant community boundaries by hand because the shapes of plant community boundaries are too much complicated.

In order to draw complicated boundaries of plant communities and to make rough vegetation classification by polygon based supervised classification, a computational algorithm based on object based segmentation was applied to the mosaicked image of the study site. The eCognition ver.3 (Definiens Inc.) was used. It was developed for image segmentation based on local texture, colour contrast and shape parameter of polygonal edges. It produces polygons with homogeneous characteristics of these factors in vector form depending on predefined thresholds of colour and shape indices.

This object based segmentation of image was conducted on each rectified balloon image in order to obtain consistent classification result in an image. Used thresholds of colour and shape indices for eCognition were 0.5 and 0.5, respectively. The spatial size of segmentation was decided by several times of trial and error.

4.2 Interpretation of plant communities

After segmentation of images, each polygon was classified by supervised classification using training data of plant communities, which were identified through the intensive ground truth of vegetation conducted by vegetation specialists. The basis of plant communities in this study site was investigated by Kanda et al.(1982). The names of plant communities in this study site were tabulated in **Table 1**. Totally, forty kinds of plant communities were identified at the ground truth, excluding four other categories such as (1) water surface named pool and deer trails, (2)wooden path and ground control points which are very bright, (3)pasture grass and (4)water surface of Akanuma. Using training data corresponding to polygons, all the polygons divided by eCognition were classified with the maximum likelihood classification method(MLH). In this manner, the classes of plant communities were assigned to all the polygons(over 300,000 polygons totally) image by image.

At this point, an important attention should be paid on these classification maps. That is the inconsistency of classification results among images. As each photo had difficulty to be adjusted among each other due to different contrast, viewing angle, sun illumination and thin clouds at the time of shots. Consequently, even though MLH classification was conducted on each image with training data, the results of vegetation classification are still in low reliability. Very intensive re-interpretation of plant communities and careful validation over the extent of the study site were required. For these re-edition(more than 30 times of re-interpretations and revisions) of vegetation maps, almost one year had to be taken by a well trained vegetation specialist using an editing tool of ArcGIS. After that, a temporal mosaicked vegetation map was checked and validated by a plant ecology specialist of Kushiro wetland who has a plenty of experience and knowledge, then, this heavy operation was finished.

4.3 Ultra fine vegetation mapping

At last, all the rectified and classified images were mosaicked considering the appearance of final mosaicked image of this study site, considering whether it looks consistently or not. **Figure 1** shows the ultra fine vegetation map of the high moor near Akanuma after many times repeated interpretation of plant communities and revision of classification in this study site. Visually, this final map seems very good and reflects the actual spatial distribution of plant communities near Akanuma.
In this ultra fine vegetation map, five regions in which typical plant communities of wetland are dominating are distinctly seen in bands from the north to the south; from Akanuma to the embankment with colour difference. These bands are surrounding Akanuma. Using this ultra fine vegetation map in vector form, a ultra fine vegetation map in raster form was also created. Its grid size is 2cm by 2cm.

5. Results of spatial pattern analysis and discussion

5.1 Landscape metric analysis of the high moor wetlands vegetation

The ultra fine vegetation map of Akanuma(hereafter, called Akanuma vegetation map(AVM)) created in this research has detailed ecological information on plant communities, especially on spatial arrangement of high moor plant communities. Using AVM in vector form, some quantitative values of landscape-metrics, which were related to patch size, density, shape and edge, were computed using Patch Analyst for ArcGIS(ESRI Inc.), a free extension tool of ArcGIS. It computes a set of principal characteristics of Landscape of the target scene such as mean patch size, patch density, mean shape index, total edge length, mean patch edge length and so on. **Table 1** shows the outline of the results of the patch analysis. Studying **Table 1**, dominant plant communities or very minor plant communities in this site are quantitatively found out.

5.2 Texture analysis of plant communities by Co-occurrence matrix

The results of the patch analysis conducted in the former section do not hold spatial correlation between plant communities. Since the AVM in raster form totally consists of more than 300,000 pixels of which grid size is 2cm by 2cm, spatial aggregation to larger pixels of sub-meter in size is necessary as taking accounts of huge memory size for computation. A simple low-pass filtering with majority-rule was conducted on the raster AVM using 15 x 15 window size which is equal to the grid size of 30cm x 30cm, in order to reduce the file size of the raster AVM. In this operation, the most dominant plant community in the window(15 x 15) was newly assigned to the new large pixel of 30cm by 30cm. Comparing the total areas of individual plant communities in both raster AVMs, there were not so much difference.

In order to understand the spatial relationships between individual plant communities, texture analysis is popular in the academic communities such as landscape ecology, metric geography, and also image processing. Texture analysis is operated based on co-occurrence matrices. Co-occurrence matrix is defined by the direction of a pair of pixels to count the occurrences of classes. In this research, the co-occurrence matrix was derived as counting eight pixels of all directions around the central pixel from the aggregated raster AVM. The resultant co-occurrence matrix is a square matrix of 44 by 44, since there are 44 types of plant communities in this study site. The matrix has some clusters in off-diagonal positions. This means that some plant communities are prone to adjoin each other or to co-exist at the same location such that the plant community of #51, other plant communities such as #22,71,73 of plant communities may co-exist with high probabilities within sub-meter. Every plant community has several types of other plant communities with high probabilities adjacently.

5.3 Spatial correlations between plant communities: Density distribution and geo-statistics

While, the analysis with a co-occurrence matrix gives us the probability of co-existence of pairs of plant communities, the geo-statistics gives us the other insights about the spatial correlations in terms of density distribution of individual plant communities. In order to apply geo-statistics to the categorized spatial dataset such as the raster AVM, 44 raster datasets of density distribution for individual classes in the original AVM were derived from the original raster AVM. The distribution of density of the plant communities were computed by using 15 x 15 smoothing window on the binary image data of the individual plant communities derived from the original raster AVM. These density distribution datasets of individual plant communities were finally re-sampled to the new raster datasets with the same grid size of 30 cm by 30 cm same as the aggregated raster AVM.

The values of the pixels of each plant community, which represent the density of that plant community in the area of 30cm x 30 cm, were extracted with the coordinates, and new text files were created. Using these three variables; plant community density, x coordinates and y coordinates, the semi-variance of plant community density was computed plant community by plant community with 'Surfer 9(Golden Software Inc.)', an application software which can compute semi-variograms. Three groups of semi-variograms were found. The first is the group of semi-variograms which have clear ranges. The second is the group of semi-variograms which have unclear ranges because their range are very short. The last is the group which have no ranges. The ranges of semi-variograms of plant communities are from 60cm to several meters. These semi-variograms imply that the spatial resolution for monitoring the dynamics of plant ecosystems around the study site should be at least smaller than a half meter such as 20-30 cm in this site.

In addition to the abovementioned analysis such as texture analysis, landscape metrics analysis and geostatistics, the composition of plant communities was quantitatively analyzed using the raster AVM. First is a kind of transect analysis. Second is on the dependency of plant community compositions on window size within rectangular windows at random locations. They show interesting results which characterize the unique spatial patterns of wetland vegetation in the high moor area of Kushiro wetland.

6. Conclusions

As a conclusion, outstanding outcomes of this research are summarized as follows.

1) An ultra fine and reliable vegetation map, of which nominal spatial resolution is 2cm by 2cm, with 40 plant community types at the time of the summer in 1998 was originally created, which is covering about 15ha of the high moor, for the baseline map for ecological studies near Akanuma. The optimal spatial resolution for monitoring vegetation in this area by remote sensing is smaller than a half meter.

2)Concentric spatial distribution of typical wetland plant community groups is clearly distinguished and confirmed in the ultra fine vegetation map through visual interpretation and spatial analysis using GIS application tools.

3) Results of this research show that remote sensing of high spatial resolution greatly serves for wetland environment monitoring and wetland studies.6) Results of this research show that remote sensing of high spatial resolution greatly serves for wetland environment monitoring and wetland studies.

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Table 1 List of Plant communities at Akanuma site and renges of semivariograms

Code	ID	Japanese name of plant community	Scientific name of plant community	Semivariogram Range(m)	Number of Polygons	Area(m^2) Maximum	Area(m^2) Sum	Area(m^2) Mean	Area(m^2) SD	Perimeter(m) Maximum	Perimeter(m) Sum	Perimeter(m) Mean	Perimeter(m) SD	Mean Shape Index MSI	Edge Density ED	Mean Patch MPE
1	11	Nemurokouhone	*Nuphar pumilum*	1.3 - 1.5	277	142.9	389.7	1.4	8.9	493.8	2565.4	9.3	33.6	2.12	271.4	9.3
2	12	Nemurokouhone-Mitsugashiwa	*Nuphar pumilum - Menyanthes trifoliata*	1	116	3.8	32.9	0.3	0.5	31.3	463.8	4.0	5.4	2.09	49.1	4.0
3	21	Mitsugashiwa	*Menyanthes trifoliata*	10	314	131.3	671.3	2.1	10.9	677.2	5586.0	17.8	61.7	3.02	590.9	17.8
4	22	Mitsugashiwa-Kakitsubata	*Menyanthes trifoliata - Iris laevigata*	5(*1)	1971	968.8	2663.9	1.4	22.2	4917.8	23084.9	11.7	115.1	2.58	2441.9	11.7
5	23	Mitsugashiwa-Mujinasuge-Yoshi	*Menyanthes trifoliata - Carex lasio carpa* var.*occultans - Phragmites australis*	N/A	1121	9.6	453.8	0.4	0.6	97.3	6202.8	5.5	7.5	2.34	656.1	5.5
6	24	Kakitsubata-Mizugoke_sp-Mitsugashiwa	*Iris laevigata - Sphagnum* sp *- Menyanthes trifoliata*	1	237	3.5	91.1	0.4	0.6	48.5	1379.0	5.8	7.4	2.50	145.9	5.8
7	25	Sagishuge-Kakitsubata-Yachiyanagi	*Eriophorum gracile - Iris laevigata - Myrica gale* var. *tomentosa*	1.5	1826	73.8	926.4	0.5	2.0	1035.7	12569.6	6.9	27.0	2.42	1329.6	6.9
8	26	Yachisuge-Mizudokusa-Kakitsubata	*Carex limosa - Equisetum fluviatile - Iris laevigata*	N/A	2897	17.5	885.4	0.3	0.8	179.3	12797.8	4.4	9.3	2.15	1353.7	4.4
9	27	Mujinasuge-Mizudokusa-Kakitsubata	*Carex lasio carpa* var.*occultans - Equisetum fluviatile - Iris laevigata*	2.4	1581	20.4	567.2	0.4	1.0	163.6	6196.4	3.9	8.3	1.90	655.5	3.9
10	28	Yachisuge-Kakitsubata	*Carex limosa-Iris laevigata*	2.5	306	44.1	398.1	1.3	3.8	344.9	3995.7	13.1	29.9	2.95	422.7	13.1
11	31	Hann_noki	*Alnms japonica*	4.6	938	34.0	370.1	0.4	1.8	177.8	3999.0	4.3	11.7	2.04	423.0	4.3
12	32	Hann_noki-Himeshida-Yamadorizennmai	*Alnms japonica - Thelypteris palustris - Osumunda cinnamomea*	2.4	199	7.9	48.1	0.2	0.7	74.7	665.1	3.3	7.1	1.98	70.4	3.3
13	33	Himeshida-Yamadorizennmai	*Thelypteris palustris - Osumunda cinnamomea*	N/A	22	1.8	11.6	0.5	0.4	22.3	155.3	7.1	5.0	2.66	16.4	7.1
14	41	Yoshi	*Phragmites australis*	N/A	602	3.4	138.7	0.2	0.4	32.6	1992.1	3.3	4.9	2.01	210.7	3.3
15	42	Chishimagariyasu-Iwanogariyasu	*Calamagrostis neglecta - Calamagrostis langsdorffii*	1.3	2035	39.0	1316.9	0.6	1.3	389.4	16839.6	8.3	13.5	2.71	1781.3	8.3
16	43	Iwanogariyasu-Yoshi	*Calamagrostis langsdorffii - Phragmites australis*	1.6	124	49.1	86.9	0.7	4.5	350.6	769.8	6.2	32.0	2.04	81.4	6.2
17	44	Yoshi-Yachisuge	*Phragmites australis-Carex limosa*	1.6	797	247.0	1176.4	1.5	9.0	1889.0	11272.1	14.1	69.6	2.86	1192.4	14.1
18	51	Yachiyanagi	*Myrica gale* var.*tomentosa*	N/A	2854	4.7	391.1	0.1	0.3	55.3	7341.4	2.6	4.6	1.96	776.6	2.6
19	52	Yachiyanagi-Mujinasuge	*Myrica gale* var.*tomentosa - Carex lasio carpa* var.*occultans*	N/A	1385	10.9	358.7	0.3	0.5	45.7	5164.4	3.7	4.9	2.06	546.3	3.7
20	53	Himewatasuge-Yachiyanagi	*Scirpus hudsonianus - Myrica gale* var. *tomentosa*	2	3466	17.9	3009.1	0.9	1.2	185.2	33950.8	9.8	11.8	2.81	3591.3	9.8
21	54	Ippannsuge-Iwanogariyasu-Yachiyanagi	*Carex tenuiflora - Calamagrostis langsdorffii - Myrica gale* var. *tomentosa*	1.8	886	18.7	511.5	0.6	1.2	221.6	6773.6	7.6	13.6	2.58	716.5	7.6
22	55	Iwanogariyasu-Yachisuge-Yachiyanagi	*Calamagrostis langsdorffii - Carex limosa - Myrica gale* var. *tomentsa*	2.4	2661	15.9	2101.7	0.8	1.0	154.2	27212.9	10.2	11.4	3.09	2878.6	10.2
23	56	Yoshi-Yachiyanagi	*Phragmites australis- Myrica gale* var. *tomentosa*	4	350	31.8	248.0	0.7	2.5	230.7	2608.0	7.5	19.0	2.37	275.9	7.5
24	57	Yoshi-Yachiyanagi-Kakitsubata	*Phragmites australis - Myrica gale* var.*tomentosa - Iris lasiocarpa*	3	5394	289.2	7359.2	1.4	6.9	2308.9	66295.5	12.3	54.6	2.60	7012.7	12.3
25	61	Watasuge	*Eriophorum vaginatum*	2	8883	72.3	5741.3	0.6	1.8	581.1	64620.2	7.3	14.8	2.39	6835.5	7.3
26	62	Watasuge-Iwanogariyasu	*Eriophorum vaginatum - Calamagrostis langsdorffii*	1.5	3167	17.5	1843.0	0.6	1.1	180.1	22589.5	7.1	10.9	2.48	2389.5	7.1
27	63	Watasuge-Yachisuge-Kakitsubata	*Eriophorum vaginatum - Carex limosa - Iris laevigata*	2.8	1662	14.9	774.2	0.5	0.7	103.7	10350.8	6.2	8.0	2.46	1094.9	6.2
28	64	Kotanukimo-Watasuge-Tachigiboushi	*Utricularia intermedia - Eriophorum vaginatum - Hosta rectifolia*	2.8	757	10.6	481.5	0.6	1.1	82.3	5103.6	6.7	8.8	2.44	539.9	6.7
29	65	Mujinasuge-Watasuge-Chishimagariyasu	*Carex lasio carpa* var.*occultans - Eriophorum vaginatum - Calamagrostis neglecta*	1.8	2914	28.8	1121.2	0.4	1.0	286.9	15865.6	5.4	10.8	2.30	1678.3	5.4
30	71	Tsurukokemomo-Mizudokusa-Iwanogariyasu	*Vaccinium oxycoccus - Equisetum fluviatile - Calamagrostis langsdorffii*	3.6(*1)	13094	3468.2	11411.2	0.9	30.5	18143.6	96671.9	7.4	159.8	2.15	10225.9	7.4
31	72	Mizugoke_sp-Yachiyanagi-Tsurukokemomo	*Sphagnum* sp *- Mirica gale* var.*tomentosa - Vaccinium oxycoccus*	1.8 - 2.0	3622	8.6	840.0	0.2	0.5	105.6	12640.2	3.5	6.2	2.04	1337.1	3.5
32	73	Yoshi-Iwanogariyasu-Tsurukokemomo	*Phragmites australis - Calamagrostis langsdorffii - Vaccinium oxycoccus*	3	21884	653.8	5057.4	0.2	4.8	4657.9	59057.8	2.7	35.1	1.74	6247.1	2.7
33	81	Isotsutsuji-Yachitsutsuji(Horomuitsutsuji)	*Ledum palustre* var.*diversipilosum - Chamaedaphne calyculata*	2.4	21865	888.3	16514.1	0.8	10.3	5765.8	166133.0	7.6	74.6	2.16	17573.4	7.6
34	82	Isotsutsuji-Mujinasuge-Sugigoke	*Ledum palustre* var.*diversipilosum - Carex lasio carpa* var.*occultans - Polytrichum juniperinum*	1	3072	3.7	362.0	0.1	0.3	43.5	6902.8	2.2	3.8	1.91	730.2	2.2
35	83	Isotsutsuji-Watasuge	*Ledum palustre* var.*diversipilosum - Eriophorum vaginatum*	0.7	7123	13.1	891.1	0.1	0.4	128.2	14721.5	2.1	4.4	1.80	1557.2	2.1
36	84	Chamizugoke-Isotsutsuji-Yachisuge	*Sphagnum fuscum - Ledum palustre* var.*diversipilosum - Carex limosa*	3 - 3.2	18398	52.0	3421.6	0.2	0.9	384.2	48963.5	2.7	7.9	1.88	5179.3	2.7
37	85	Chamizugoke-Murasakigoke-Yachiyanagi	*Sphagnum fuscum - Sphagnum magellanicum - Myrica gale* var.*tomentosa*	1.6	9675	11.1	1892.5	0.2	0.5	147.4	26519.1	2.7	5.6	1.88	2805.2	2.7
38	86	Gannkourann-Isotsutsuji-Nikkoushida	*Empetrum nigrum* var.*japonicum - Ledum palustre* var.*diversipilosum - Thelypteris nipponica*	1	16358	5.8	2004.9	0.1	0.3	66.4	35116.4	2.1	4.0	1.85	3714.6	2.1
39	87	Nikkoushida-Isotsutsuji-Yachisuge	*Thelyteris nipponica - Ledum palustre* var.*diversipilosum - Carex limosa*	N/A	20121	15.2	4047.4	0.2	0.6	148.1	56061.9	2.8	5.8	1.89	5930.2	2.8
40	88	Murasaki_mizugoke-Yoshi-Yachitsutsuji(Horomuitsutsuji)	*Sphagnum magellanicum - Phragmites australis - Chamaedaphne calyculata*	2.2	36807	568.4	10460.4	0.3	3.4	3094.6	114728.0	3.1	20.2	1.84	12135.9	3.1
41	91	Pools or Deer_trails		4	3611	28.8	1029.5	0.3	1.3	106.7	8784.2	2.4	6.4	1.71	929.2	2.4
42	92	Akanuma pond		N/A	1	2146.5	2146.5	2146.5	0.0	2951.6	2951.6	2951.6	0.0	17.97	312.2	2951.6
43	99	Wooden path or Landmark		N/A	112	114.9	208.9	1.9	12.0	810.5	1574.2	14.1	86.1	1.96	166.5	14.1
44	100	Bank vegetation(Grass)		0.8(*1)	19	79.7	79.9	4.2	17.8	81.2	87.2	4.6	18.1	1.39	9.2	4.6

(*1) has a clear trend: combined with a Linear model N/A means the curve of semivariogram has no range.

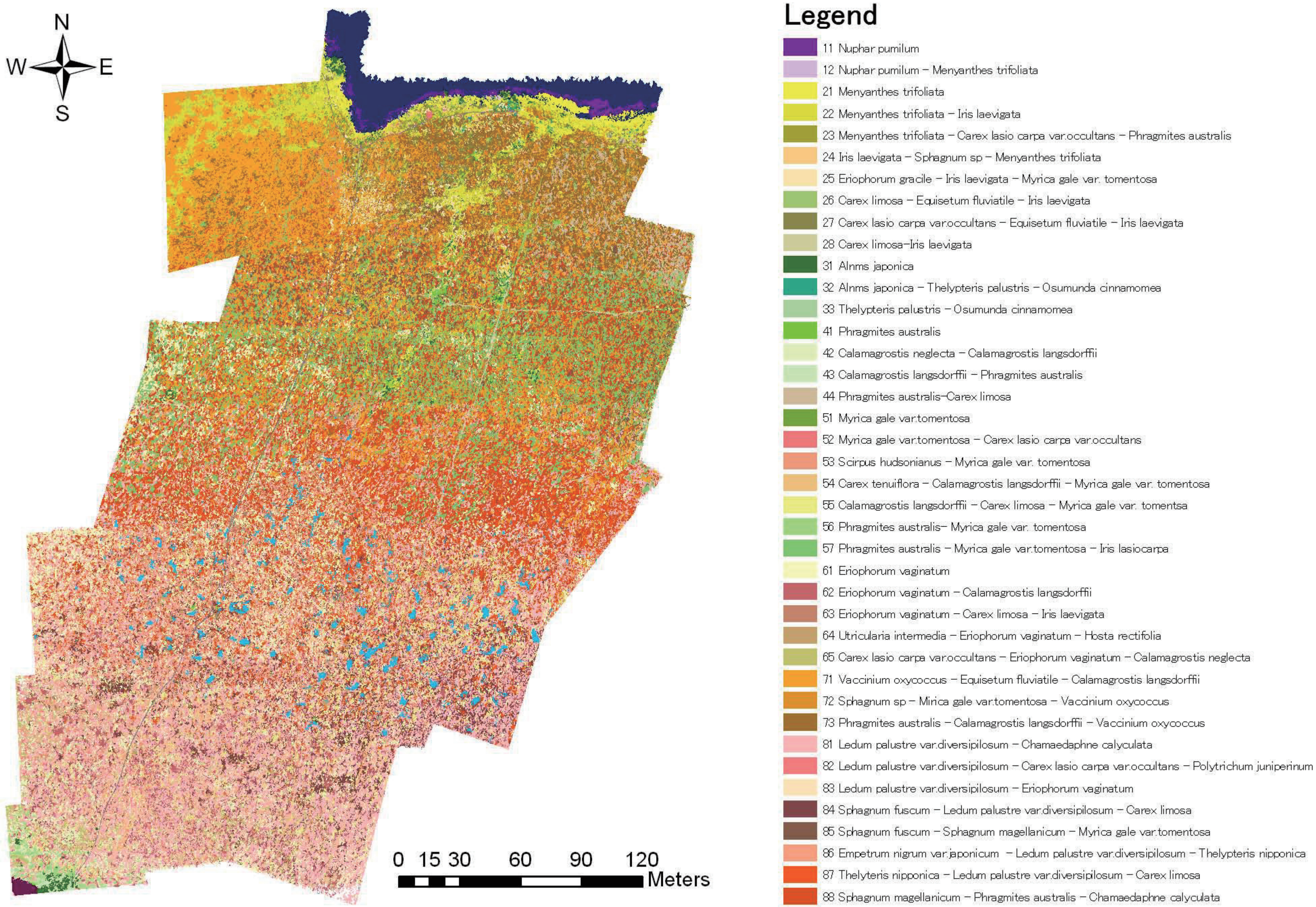

Figure 1 Ultra fine vegetation map of the high moor near Akanuma