Land Cover Change Detected by Satellite Data in the Agricultural Development Area of the Sanjiang Plain, China

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I Introduction

The Sanjiang Plain is located in Heilongjiang Province in northwest China. There were once many wetlands in this place, but since the 1950's much of the wetland area has been reclaimed by the Chinese government. From the 1980's, the cultivated area increased because of the introduction of Japanese agricultural technology (Ganzey, 2005). By studying satellite maps the authors aim to acquire basic data for wetland conservation and agricultural development and to examine closely the consequences of the unregulated reclamation of wetland.

The wetlands are distributed on various landforms in the study area. The reclamation, occurring with varying degrees of intensity on the different landforms, affects the environment around the wetlands in different ways. In this study a landform map, based on ground truth, is made in advance; and the distribution and the characteristics of wetlands on selected landforms are determined. The wetlands are sorted on satellite images, and croplands are sorted out by two kinds of satellite data. The landforms on which the wetlands were reclaimed are examined. Additionally, the results are compared with statistical data.

II Method

In this study, to clarify the landform where the wetlands were cultivated in the Sanjiang Plain (Fig. 1), JERS-1/SAR data were used because only JERS-1/SAR used L-band, which was most capable of observing soil water in 1990's when much of the wetlands were reclaimed.

Haruyama and Shida (2006) made a landform map by JERS-1/SAR data and calculated the flooded area by determining a threshold using dry and rainy season SAR data. Ito (2007) classified flooded areas by determining a threshold, set by using a flooded area and a non-flooded area as base regions. Ishizuka et al. (2006) calculated the area of rice paddy using a set of SAR data taken in the rice planting and rice growth seasons. Here, GIS data were used to delete misclassified pixels by masking the area which was not rice paddies. Hess et al. (2003) classified land cover in the Amazon Basin by the difference of back scattering of dry and rainy season JERS-1/SAR data.

Ito (2007) mentioned that pixel-based analysis of SAR was difficult when the threshold method was applied. However in this study, the authors tried to calculate the area of wetlands by using optical data with SAR data and searching for the optimal threshold by empirical cumulative distributions for back scattering. Here, distortion of SAR images were ignored because the study area was very flat.
As for reclaimed land, false color of Landsat/TM was used because land cover could be distinguished with a high degree of accuracy by visual observation of the texture on the images (Nagasawa, 2002).

Table 1 shows the path row and date of JERS-1/SAR and Landsat/TM data used in this study. Because the water in the rice paddies drained off in late August (Sakon, 2005), the authors used the satellite data of September to distinguish between wetlands and rice paddies. Among SAR data, all images taken in September were available in the years of 1992 and 1996. TM data taken in 1992, 1993, or 1996 were used. The Frost Filter which was proposed in 1982 by Frost et al. was applied to remove speckle noise, which was characteristic of the SAR data. A geometric correction based on the geodetic projection WGS84 was applied by use of affin transformation.

Ground truth was conducted in late September 2006, the same month as the SAR data. To conduct ground truth more widely, positional information was recorded by a GPS (Garmin eTrex Venture) and the types of land cover. Positional information, where 50m distances from the car were plotted on the SAR images using the height of the car to remove the effect of the road, and NRCS (normalized radar cross-section) on each pixel were obtained. NRCS was used to make the SAR digital recordings independently of the equipment used. The linear transformation used was: NRCS [dB] = 10log(I_0/IP) - CF, where I is the digital SAR value and CF is the conservation coefficient. Because SAR data in this study were processed after 2000, CF = 85.15 (Shimada, 2002).

GPS data of the wetlands were obtained by walking in the wetlands. Vegetation on the wetlands was also recorded. The heights of slightly elevated areas were measured with a hand level (Nobel K50-1560).

To make the landform map, SAR data in September 1996 and SRTM (Shuttle Radar Topography Mission) were used. SRTM were 100m mesh elevations from the home page (http://www2.jpl.nasa.gov/srtm/). The lineament of SAR was suitable not only for information about soil water, but also for making the landform map (Japan Photogrammetry Associates, 1998).

For construction of the landform map, landforms were classified on the following bases. River: areas covered with water, including the Amur, Songhua, and Ussuri rivers and their tributaries. Mountains: areas of high elevation. NRCS readings were high and lineations marking the valley borders were clearly identifiable on satellite images. Floodplain: elevations were low. Areas around rivers where there were traces of water flow were clearly evident. Areas of shallow water table were defined as lower floodplains. Where a shallow water table was not evident, the area was defined as a higher floodplain. Natural levees were included in the higher floodplain.
classification. *Swampy area on the terrace*: elevations were lower than the neighboring area and there were scattered areas of water table within a dry area. *Dissected terrace valley*: elevations were lower than the neighboring area, NRCS readings were low but there was little water surface. *Alluvial plain*: all areas not categorized above. Two terraces were observed on the alluvial plain.

With a submerged area being defined as "wetland", the discrimination ratio between NRCS empirical cumulative distributions of wetland and non-wetland area (Fig. 2) was used as the threshold to classify wetland. Here, the thresholds were respectively calculated in 1992 and 1996 SAR images. Dried wetland areas by declining ground water level were considered as non-wetland areas. It was not problematic that submerged areas were defined as wetland because rainfall was small in September in this study area.

The areas framed by irrigation ditches were classified as reclaimed areas by visual observation on Landsat/TM. The non-reclaimed area was masked on wetland images by SAR; and the wetland area in the reclaimed region was calculated, because the reclaimed area by TM contained the area under drainage after the reclamation of wetland. The area of cropland was calculated by subtracting the wetland area in the reclaimed area from the reclaimed area on each landform.

The study area contained the four regions of Fuyuan, Tonjiang, Fujin, Raohe. The cultivated area of the four regions was abstracted from the Statistical Yearbook of Heilongjiang (1991-1999). The cultivated area change in the 1990's was determined.

### III Result and Discussion

The verification of conformity between ground truth in 2006 and satellite data in 1990's was conducted by TM data of 2006 and the 1990's (Fig. 3). As a result, the large areas of cropland from ground truth were cultivated until 1992 and 1996, because they were near the main road where cultivation had been relatively easy. So, it was considered that ground truth in 2006 could verify satellite images in the 1990's.
Figure 5. Cross-sections of wetlands on the selected landforms. The numbers in the circles are the locations which accord with those of Figure 4. Wetlands are between the sets of two triangles.

wetlands on the lower floodplain and dissected terrace valley, there were some submerged areas in

which *Typha latifolia* could be seen. In the wetlands on the swampy area of the terrace, there were alternately dry areas and wet areas. There were many kinds of plants such as *Spiraea* sp., *Pteridophyta*, Umbelliferae gen. sp. *Artemisia* spp. and some small trees such as *Quercus* sp. and *Betula* sp. on the dry area; and there was simple vegetation of Gramineae gen. sp. on the wet area. In the wetland on the alluvial plain, there were also alternately dry areas and wet areas like the wetland on the swampy area of the terrace; but it was drier than

Fig. 4 shows the landform map from JERS-1/SAR and SRTM. It became clear that the research points of wetland determined by ground truth on the alluvial plain and the swampy area on the terrace remained wetland among the cropland, and almost all the area on the alluvial plain and some area of the swampy region on the terrace were cultivated from 1996 to 2006 (Fig. 3, 4). The forms and vegetation of the wetland differ on different landforms (Fig. 5). *Calex* spp. and Gramineae gen.* spp. which are typical plants in wetlands were the main vegetation in the wetlands on all landforms. In the

Figure 6. Histograms of NRCS (normalized radar cross-section) values for main land cover. "n" means the number of NRCS pixels. The breadth of the vertical axe are 30%. The black triangles show the average of 1996; the gray triangles show the average of 1992.
Table 2 Discrimination ratio of wetland and calculated threshold NRCS on selected landforms.

<table>
<thead>
<tr>
<th>Landform</th>
<th>Discrimination ratio of wetland</th>
<th>Threshold NRCS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alluvial Plain</td>
<td>90%</td>
<td>84%</td>
</tr>
<tr>
<td>Dissected Terrace Valley</td>
<td>73%</td>
<td>72%</td>
</tr>
<tr>
<td>Swampy Area on the Terrace</td>
<td>98%</td>
<td>68%</td>
</tr>
<tr>
<td>Lower Floodplain</td>
<td>72%</td>
<td>63%</td>
</tr>
<tr>
<td>Mountains</td>
<td>95%</td>
<td>56%</td>
</tr>
</tbody>
</table>

Fig. 7. The areas, from satellite data, of wetland, croplands, and other features on each landform.

the alluvial plain.

Cropland had increased on all landforms. The entire area of the wetlands had decreased 332,088 ha during four years, from 1,042,555 ha in 1992 to 710,467 ha in 1996, whereas the entire area of cropland had increased 307,805 ha, from 402,662 ha in 1992 to 710,467 ha in 1996. The area most changed was the alluvial plain; wetland had decreased 257,534 ha (from 728,389 ha in 1992 to 470,855 ha in 1996), and cropland had increased 289,274 ha (from 385,170 ha in 1992 to 674,444 ha in 1996). That is, wetland on the alluvial plain had been mainly cultivated. The area of wetland on the lower floodplain, mountains, and the higher flood plain had decreased respectively 36,042 ha, 57,112 ha, and 12,947 ha; and the area of crop land had increased 4,203 ha, 14,238 ha, and 7,811 ha, respectively. Conversely, the area of wetland on the dissected terrace valley and the swampy area of that terrace valley had increased 14,804 ha and 5,464 ha respectively; and the area of cropland had increased 11,851 ha and 15,871 ha respectively.

The statistical data from Statistical Yearbook of Heilongjiang was fragmentary (Fig. 8). The sum of the cultivated areas in the four regions was 709,764 ha, almost the same as the crop land from satellite data (710,467 ha).

To date there exist several methods of determining the threshold of SAR data (Ito, 2007). Here the method of using the maximum discrimination ratio of empirical cumulative distributions for NRCS was determined to be effective.

* gen.: genus.
IV Conclusion

Alluvial plain: about 1/3 of the wetland in 1992 had changed into crop land by 1996. From field investigations, it was determined that the remaining wetlands were drying. Swampy area on the terrace: Almost all the wetlands were uncultivated. Dissected terrace valley: Again almost all wetlands were not cultivated, possibly because there was a stream on the lowest area, and the conditions were similar to those of the flood plain. Mountains: Again, almost all the wetlands were not cultivated either, probably because the steep landform was not suitable for cultivation. Lower flood plain: Almost all of the wetlands had not been cultivated from 1992 to 1996, but there were cultivated areas in 2006. Because elevations are low in lower flood plains and flood plains are vulnerable to flood, cultivation on flood plains should be avoided.

Sustainable land use planning should consider the ecological and water-holding functions of wetlands based on wetland features which are different for different landforms. In this study, land cover change was determined efficiently and objectively. The results should contribute to rural planning and wetland conservation in the future.

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References


