LANDFORM AND LAND USE CHANGE OF HEILONGJIANG PROVINCE, NORTH EAST CHINA

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I .INTRODUCTION

Geomorphologic land form classification mapping method has been sophisticated by Haruyama and Shida (2006) using JERS-1 SAR data and the flooded area determining was revealed for pointing a threshold using dry and rainy season SAR data (Ito ,2007) . Both study 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. Also, GIS data has been 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. Former work in Ito (2007) mentioned that pixel-based analysis of SAR was difficult when the threshold method was applied.

As for manmade reclaimed lands, false color of Landsat TM data was used for analysis because land cover could be distinguished with a high degree of accuracy by visual observation of the texture on the images (Nagasawa, 2002).

The study field, Sanjiang Plain and surroundings area formed by three large rivers flowing in Heilongjiang Province in northeast China, has been remarkably changed for agricultural land use from wetlands since 1950's . From the 1980's, the cultivated farm land has been also increased rapidly, because of the introduction of Japanese agricultural engineering technology as for leader Mr.Hara (Ganzey, 2005). Studying satellite mapping, the authors aim to classify geomorphologic land form and relationship between wetland and landform units. And we examined the consequences of the unregulated reclamation of wetland based on the geomorphologic land form units. The wetlands are distributed on various landforms in this study area. The recent 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 JERS 1 SAR image analysis and also 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 of the Chinese government.

Ⅱ.METHOD AND DATA

In this study, firstly to clarify the geomorphologic landform characteristics where the wetlands were cultivated in the Sanjiang Plain and surrounding area(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. 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 this study area was monotone landscape and flat.

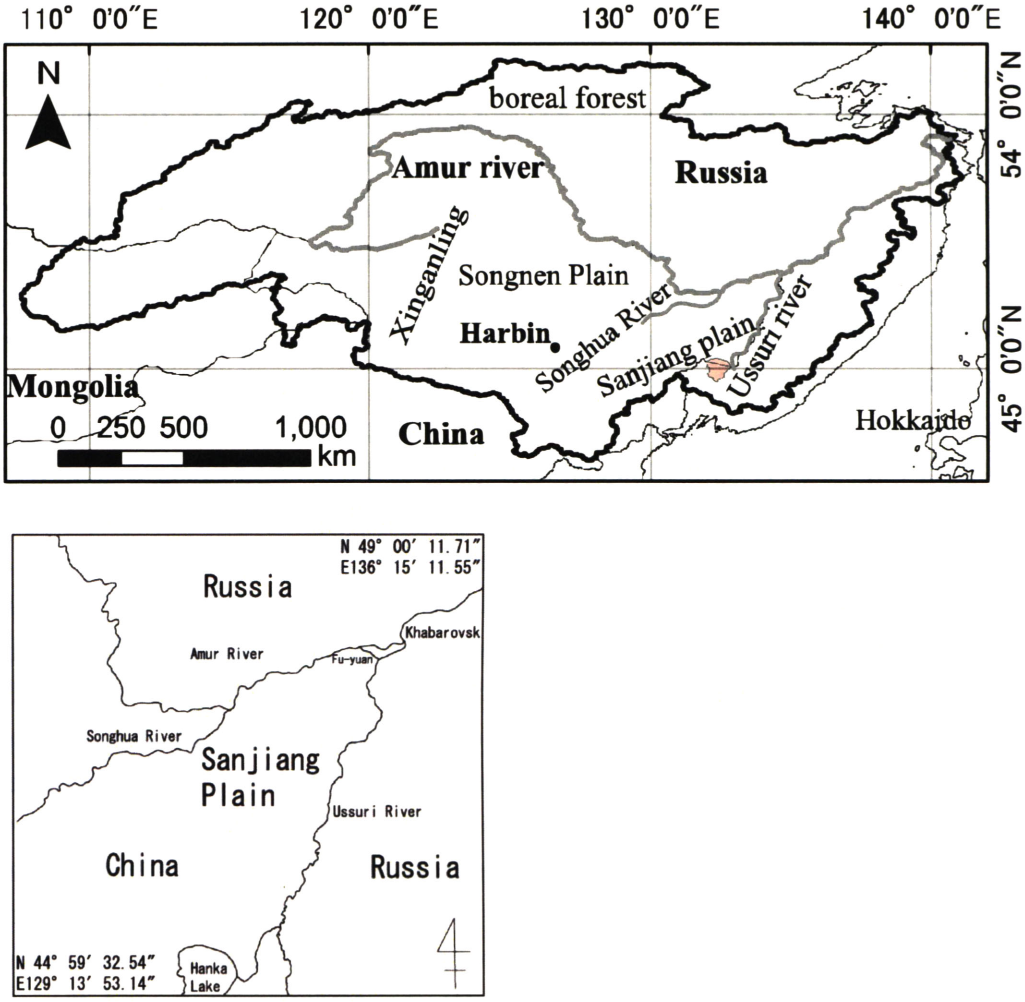


Figure 1.
Amur Basin (upper figure) and Sanjiang Plain and rivers (lower figure: the gray area shows the "triangular area" unaffected by human activity, black circle shows the location of Hong Hua Natural Reservation Area.)

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.

Table 1 Data set of this study

				SAR			
Path Row	81-220	81-221	82-219	82-220	82-221	83-220	83-221
Date	1992/9/16 1996/9/7	1992/9/16 1996/9/7	1992/9/16 1996/9/7	1992/9/17 1996/9/8	1992/9/17 1996/9/8	1992/9/18 1996/9/9	1992/9/18 1996/9/9
				TM			
Path Row	113-27	114-26	114-27				
Date	1993/4/13	1993/10/13 1996/10/21	1992/10/26 1996/9/3				

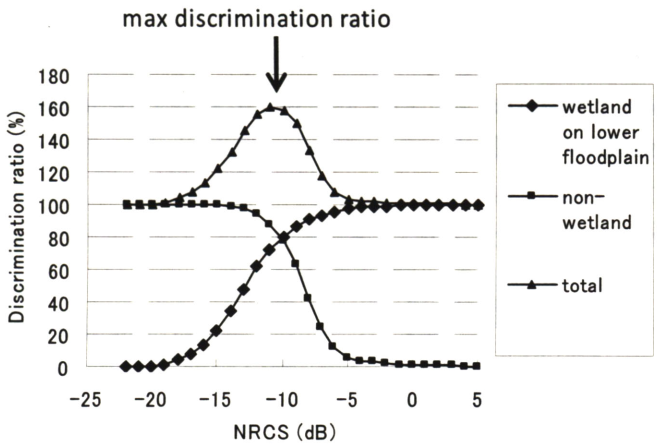


Figure 2.
Empirical cumulative distributions for NRCS of wetlands and non-wetlands on lower floodplain. The sum of the distributions is the Discrimination ratio. Threshold increases from -25 dB; more pixels are sorted as wetland and fewer pixels are sorted as non-wetland.

Geomorphologic survey on the field and ground truth for inspecting with remote sensing data was conducted in late September 2006 and 2007, the same month as the SAR data for unsing. 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:

$$\mathbf{NRCS\ [dB] = 10}\boldsymbol{log}_{\mathbf{10}}\mathbf{(I^2) - CF,}$$

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 Photogrammetory Associates, 1998).

For making the geomorphologic land classification map of the Snanjian plain, landform units were classified on the following bases.

River and water surface: areas covered with water, including the Amur, Songhua, and Ussuri rivers and their tributaries.

Mountains and hills: areas of high elevation. NRCS readings were high and lineation marking the valley borders were clearly identifiable on satellite images.

Floodplain: their elevations are low and relief structure is small. Areas around rivers where there were traces of water flow were clearly evident. Areas of shallow water table were

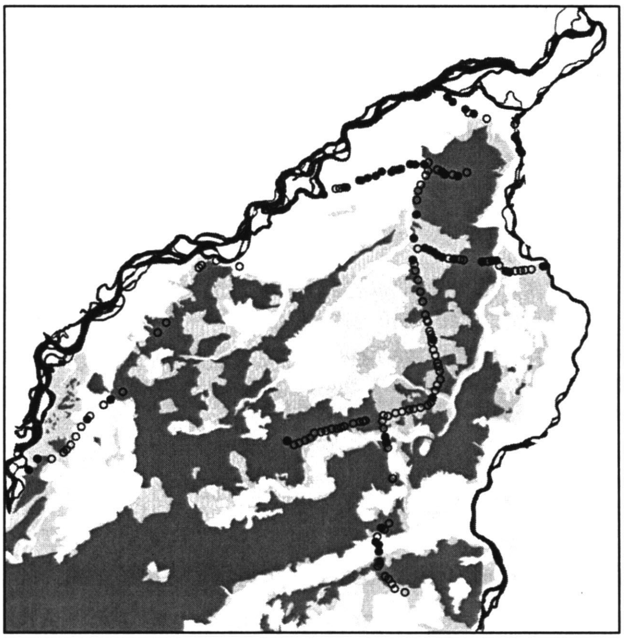


Figure 3.
Research points from ground data and cropland from Landsat/TM (○: cropland; ●: wetland; black: water surface; light gray: crop land in 1992; middle gray: crop land in 1996; dark gray: crop land in 2006).

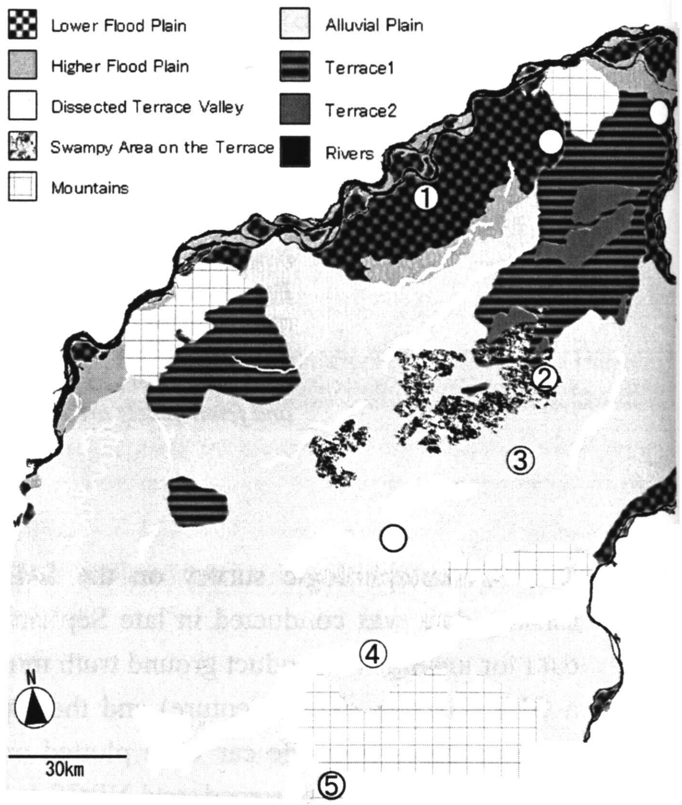


Figure 4. Landform map from JERS-1/SAR data of September 1996. Circles show the wetland areas where field investigations were carried out in this study. Cross-sections were made at the point of the circled numbers.

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.

Their 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 data. The non-reclaimed area was masked on wetland images by SAR image; 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(Fig.3 and Fig.4,Table 2).

The area of cropland was calculated by subtracting the wetland area in the reclaimed area from the reclaimed area on each geomorphologic 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

Table. 2 Vegetation of the wetland on selected landforms in the Sanjiang Plain.

Land Form	Location	Scientific Name
Lower Flood Plain	low ground	Calex spp. Nymphoides peltata Artemisia spp. Polygonum hydropiper Plantago. sp. Gramineae gen. spp. Sataria sp. Sphagnum sp. Gentiana sp. Alisma sp. Caltha sp. Inula sp.
	high ground	Alunus sp.
	under water	Typha latifolia Iris sp.
Swampy area on the terrace	high ground	Spiraea salicifolia Pteridophyta Compositae gen. spp. Umbelliferae gen. sp. Plragmites communis Artemisia spp. Sanguisorba sp. Echinochoa sp. Geranium sp. Alisinoideae gen. sp. Betula sp. Achillea sp. Quercus sp. Achillea ptarmica v. macrocephala Gentiana sp. Rumex sp. Equisetum sp. Bidens tripartita Ranunculaceae gen. sp. Gramineae sp. Plygonum sp. Polygonum thunbergii Aster ageratoides v. ovatus f. yezoensis Spiraera sp. Plygonum seiboldii Corylus
	low ground	Gramineae gen. spp.
Alluvial plain	low ground	Gramineae gen. sp. Artemisia spp. Taraxacum gen. sp. Calex spp. Rumex sp. Spiraea media v.sericea Polygonum hydropiper
	high ground	Calex spp. Taraxacum gen. sp. Betula sp.
Dissected terrace valley	high ground	Sanguisorba sp. Crisium sp. Polygonum thunbergii Calamagrostis sp. Gramineae gen. spp. Rosaceae gen. sp. Spiraera sp. Umbelliferae gen. sp. Phragmites communis Polygonum hydropiper Polugonum perfoliatum Inula sp. Taraxacum gen. sp. Compositae gen. sp. Vaccinium sp. Lysimachia thyrsiflora Gentiana sp.
	low ground	Artemisia spp. Calex spp.
	under water	Typha latifolia
Mountains	high ground	Inula sp. Crisium sp. Polygonum hydropiper Rorippa sp. Echinochoa crus-galli v.oryzicola Caltha sp. Agrostis sp. Calex sp. Alisma sp.
	low ground	Gramineae sp.

Table 3 NRCS of Wetland

	Discriminate ratio of wetland	Threshold NRCS
Alluvial Plain	84.4%	4.836
Dissected Terrace Valley	72.0%	3.563
Swampy Area on the Terrace	67.5%	4.763
Lower Floodplain	63.3%	4.449
Mountains	55.7%	4.035
Trianglar Area near Khabarovsk (Lower Flood Plain)	unknown	4.449

The verification of conformity between ground truth in 2006,2007 and satellite data in 1990's was conducted by TM data of 2006 and the 1990's (Fig. 3). As a analysis result, the broadly areas of cropland under ground truthing were already cultivated until 1992 and 1996, because they were near the main road where cultivation access had been relatively easy than other inner area. So, it was considered that ground truth in 2006, 2007 could verify satellite images in the 1990's.

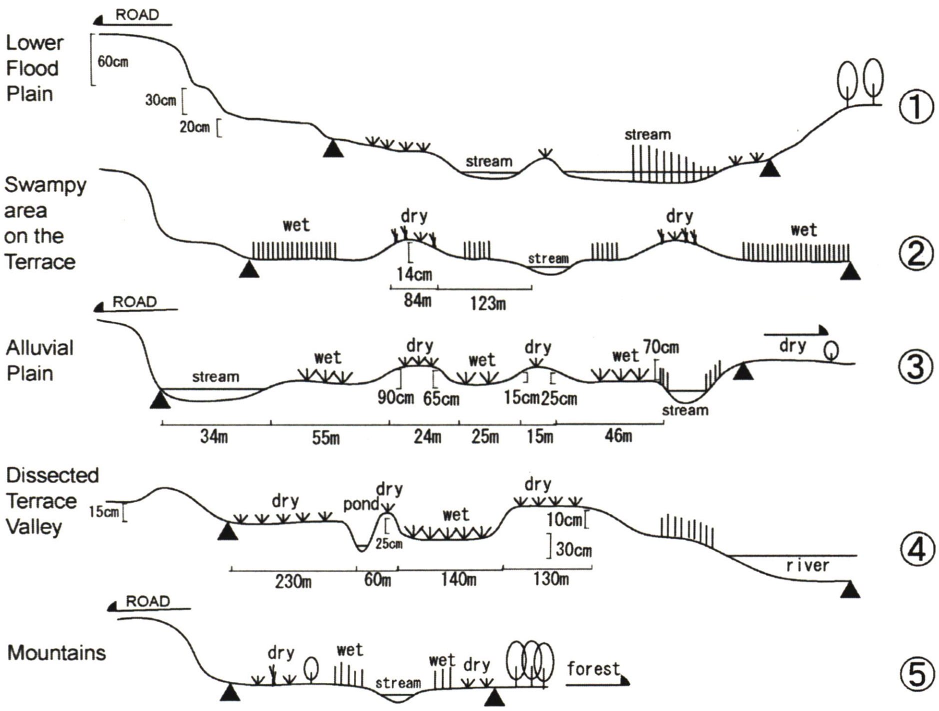


Figure 5.
Cross-sections of wetlands on the selected landforms. The numbers in the circles are the locations which accord with those of Figure 4. Wetlands are between the sets of two triangles.

Fig. 4 shows the geomorphologic landform classification map using JERS-1 SAR and SRTM. It became clear that the research points of wetland determined by ground truth on the alluvial plain and the former swampy area on the terrace remained wetland among the croplands, and almost all the area on the alluvial plain and some area of the former swampy region on the terrace were cultivated from 1996 to 2006 (Fig. 3, 4).

The forms and their vegetation of each wetland differ on different geomorphologic landform conditions (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 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 *Spiraera* 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 the wetland on the swampy area of the terrace. There were some plants which grew on dry places such as *Betula* sp. and *Taraxacum* sp. ; and there were *Calex* spp., Gramineae gen. sp., or *Polygonum hydropiper* on the wet area.

In the wetlands of the mountains, there were relatively many kinds of plants such as *Inula* sp., *Crisium* sp., *Polygonum* sp., *Calex* sp., *Geranium* sp.

The hisograms of NRCS for main land covers and wetlands on selected landforms were compared on SAR images of September 1992 and September 1996 (Fig. 6). All averages of NRCS values of non-wetland areas were higher than all NRCS values of wetlands. The averages of non-wetland land covers in 1996 were higher than in 1992 except for afforestation. The average areas of wetlands on each landform in 1996 were lower than in 1992 except for those on the alluvial plain.

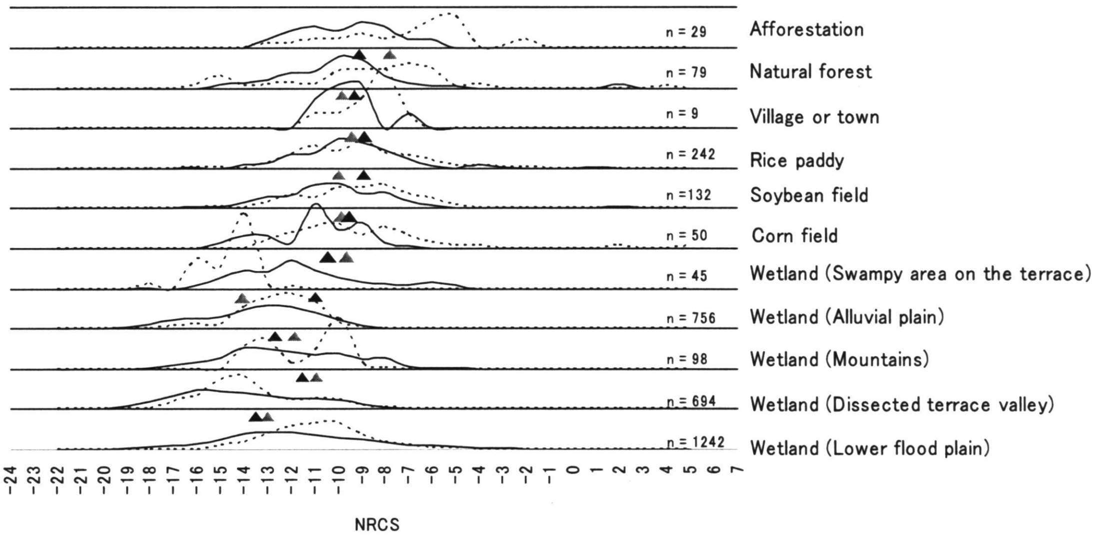


Figure 6.
Histograms of NRCS (normalized radar cross-section) values for main land cover. "n" means the number of NRCS pixels. The breadth of the vertical axe are 30%. The black triangles show the average of 1996; the gray triangles show the average of 1992.

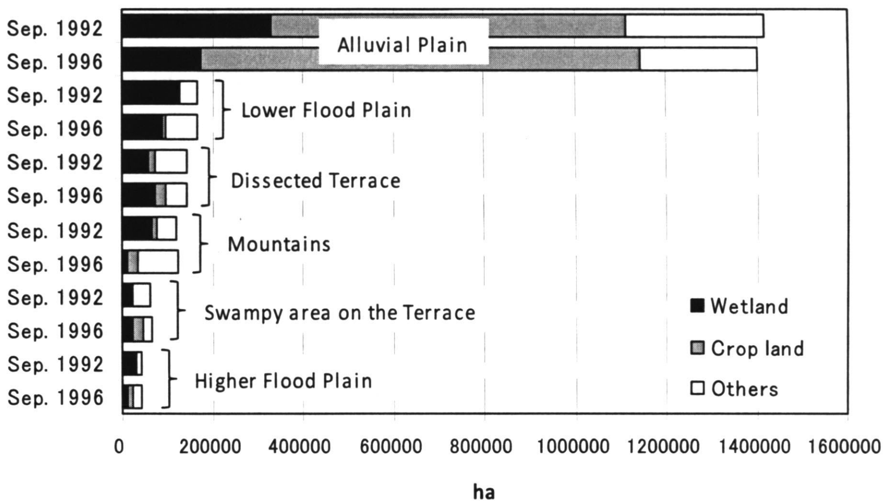


Figure 7. The areas, from satellite data, of wetland, croplands, and other features on each landform.

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 *Spiraera* 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 the wetland on the swampy area of the terrace. There were some plants which grew on dry places such as *Betula* sp. and *Taraxacum* sp. ; and there were *Calex* spp., Gramineae gen. sp., or *Polygonum hydropiper* on the wet area. In the wetlands of the mountains, there were relatively many kinds of plants such as *Inula* sp., *Crisium* sp., *Polygonum* sp., *Calex* sp., *Geranium* sp. The hisograms of NRCS for main land covers and wetlands on selected landforms were compared on SAR images of September 1992 and September 1996 (Fig. 6). All averages of NRCS values of non-wetland areas were higher than all NRCS values of wetlands. The averages of non-wetland land covers in 1996 were higher than in 1992 except for afforestation. The average areas of wetlands on each landform in 1996 were lower than in 1992 except for those on the alluvial plain.

Agricultural cropland had been increasing on all geomorphologic landform units. The entire area of the wetlands had been decreasing 332,088 ha during following four years, from 1,042,555 ha in 1992 to 710,467 ha in 1996, whereas the entire area of cropland had been increasing 307,805 ha, from 402,662 ha in 1992 to 710,467 ha in 1996. The above area mostly changed was on 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 menaing, wetlands on the alluvial plain had been mainly changed for cultivation. The area of wetland on the lower floodplain, mountains, and the higher flood plain had been decreasing respectively 36,042 ha, 57,112 ha, and12,947 ha; and the area of crop land had been increasing 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.

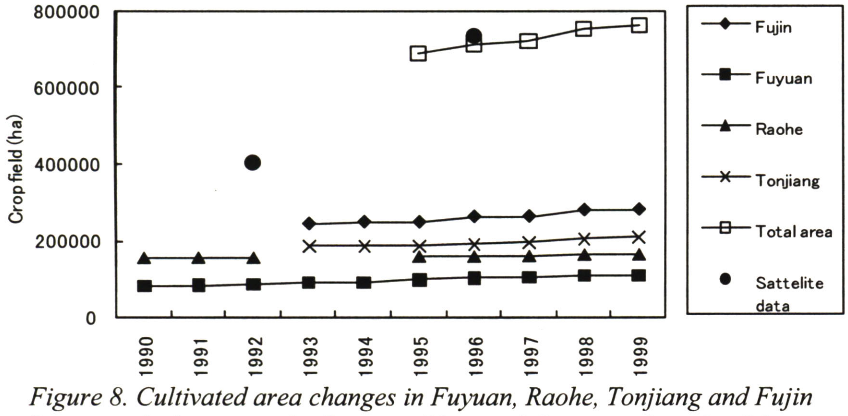


Figure 8. Cultivated area changes in Fuyuan, Raohe, Tonjiang and Fujin Regions which contain the Sanjiang Plain and the area of cropland from satellite data.

The statistical data from Statistical Yearbook of Heilongjiang province was fragmentary because of missing the data (Fig. 8). The sum of the cultivated areas in the four regions as following Fujin, Fuyuan, Pache and Tonjiang 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.

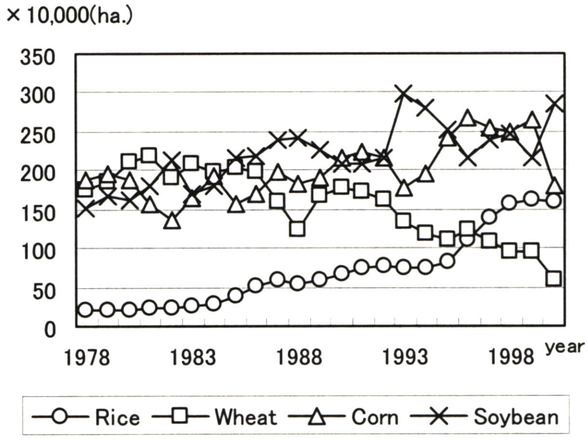


Figure 9. Transition of farm products sowing area in Heilongjiang Province

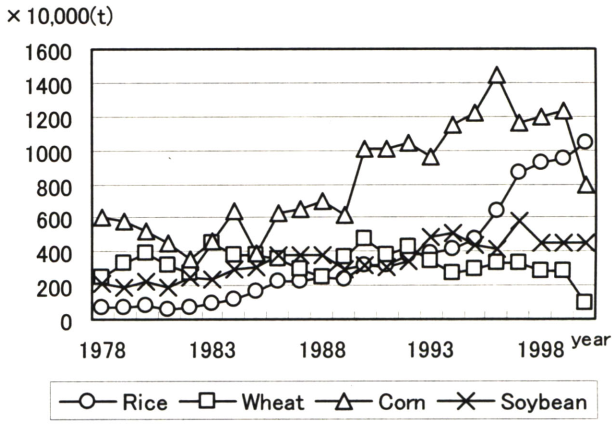


Figure 10. Transition of farm products production in Heilongjiang Province

Table 4. Areas (1/10ha) of croplands, neglected lands, mining, and aquaculture per farmer in Heilongjiang Province in 1990 and 1996.

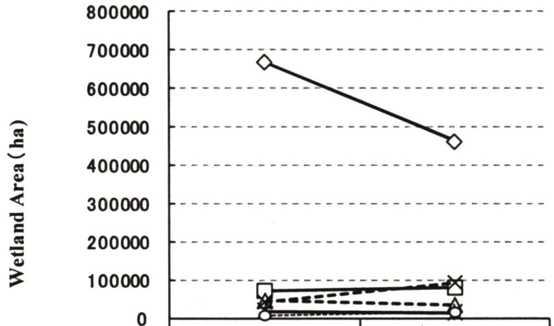
Category	1990	1995	1996
Crop lands	1.68	2.00	1.85
Neglected lands	0.12	0.09	0.09
Mining area	0.01	0.00	0.01
Aquaculture	–	0.00	0.00

(China Statistical Yearbook)

Year	1992	1994	1995	1996
Population of farmer	548.5	564.2	575.4	583.5

(China Statistical Yearbook)

Table 5. Population of farmer in Heilongjiang Province (10000 people).



	Sep. 1992	Sep. 1996
Alluvial Plain	666988.2	462621.5
Dissected Terrace Valley	73083.9	81150.4
Swampy Area on the Terrace	45067.3	33333.5
Lower Floodplain	42241.8	93717.5
Mountains	19361.4	15147.1
Trianglar Area near Khabarovsk (Lower Flood Plain)	6529.5	14869.4

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.

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