ANALYSIS OF LAND COVER ON THE SANJIANG PLAIN, CHINA, USING JERS-1/SAR DATA

MUROOKA M. [1], HARUYAMA S. [2], MASUDA Y.[2], YAMAGATA K. [3] AND KONDOH A.[4]

[1]*Hokkaido Abashiri Fisheries Experiment Station,*
[2]*University of Tokyo, Graduate School of Frontier Science,*
[3]*Division of Social Studies, Joetsu University of Education,*
[4]*Center for Environmental Remote Sensing, Chiba University*

1. INTRODUCTION

The Sanjiang Plain is in the middle region of the Amur River basin of China. There are much wetland on this plain. Agricultural development by the Chinese government over the past 20 years has resulted in a considerable increase in the area under cultivation (Ganzey, 2005, Singh *et al.*, 2001). Changes to land cover in the Amur River basin as a result of the decreasing area of wetland influence the biomass of the Sea of Okhotsk, into which the Amur River flows (Shiraiwa, 2005). Consequently, an objective assessment of the human impact on the natural environment of this region is needed.

Remote sensing is a good candidate to understand the changes in land cover over time because the Sanjiang Plain is wide and flat. SAR (synthetic aperture radar) can provide high-resolution data under all weather conditions. The JERS-1/SAR program was active in the 1990s, when land cover on the Sanjiang Plain changed dramatically. The JERS-1/SAR program used the long microwave band (L-band) to which vegetation is transparent, thus allowing direct observation of the soil.

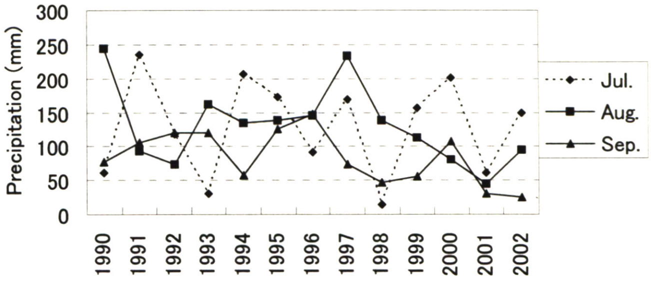
Dobson *et al.* (1995) showed that JERS-1/SAR could distinguish urban areas, forests, and grass fields. Hess *et al.* (2003) used JERS-1/SAR data from different seasons to calculate the area of seasonal inundation in the Amazon Basin. Ishizuka (2006) developed a technique to use SAR data to calculate the area of cropped paddy fields. Haruyama *et al.*(2006) produced a landform map of the Mekong delta by using JERS-1/SAR data.

We used JERS-1/SAR data here to calculate the change in area of the wetlands and to determine the types of landform on which the land cover had changed. Furthermore, we used Chinese government statistical data (Chinese Statistics Publisher, 1992-1996) to verify the land cover changes that we calculated from the satellite data.

2. STUDY AREA

The Sanjiang Plain is in eastern Heilongjiang Province, where it lies between the courses of the Songhua, Amur, and Ussuri rivers. The plain is neighboring to Russia by the Amur and Ussuri rivers (Figure 1). There was an area which was unaffected by human activity, called

Figure 1. Sanjiang Plain and rivers.
(The gray area shows the "triangular area" unaffected by human activity. Black circle shows the location of Hong Hua Natural Reservation Area..)



(Royal Netherlands Meteorological Institute)

Figure. 2. Precipitation of July, August, and September from 1990 to 2002 at the Observation Station in Khabarovsk.

"triangular area" located the opposite side of Khabarovsk. Rainfall occurs mainly from July to September on the Sanjiang Plain. The KNMI (Royal Netherlands Meteorological Institute) station at Khabarovsk (Figure 1) is the nearest observation point to the study area. Rainfall data for July to September from 1990 to 2002 are shown in Figure 2.

Liu *et al.* (2005) studied the relationship between human activities and the natural environment in northeastern China and suggested that river water levels in this area tend to rise rapidly because unregulated cultivation of wetlands has reduced the size of flood-control basins. Runoff from reclaimed and cultivated areas causes both soil erosion and riverbed deposition of soil. In 1998, these effects contributed to the most serious flood ever recorded in Heilongjiang Province.

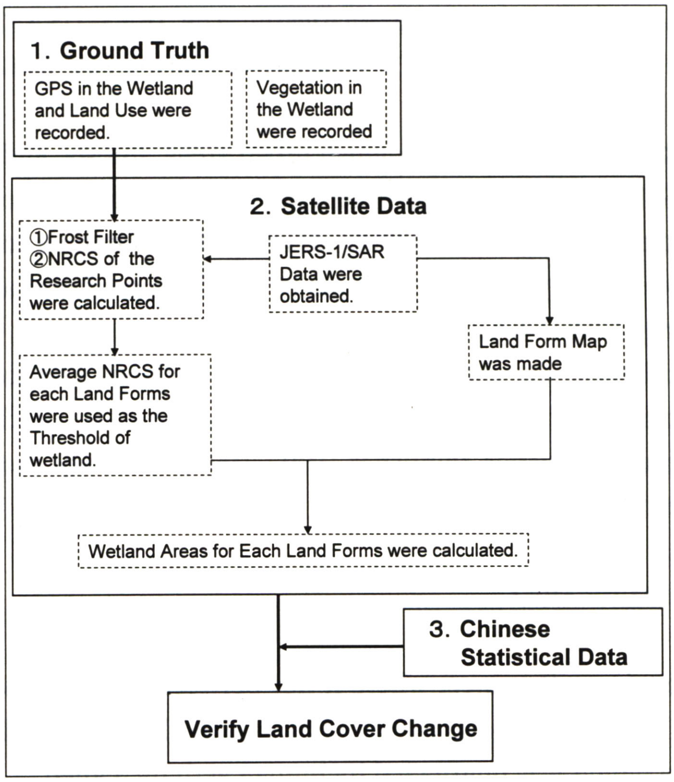


Figure 3. Flowchart of land cover change assessment by JERS-1/SAR.

The Sanjiang Plain is an important source of food for China. For example, in Jamus Prefecture, which is the main area of Sanjiang Plain, the cultivated area was 607000 ha, the soybean area was 36%, the rice area was 24%, the corn area was 17% in 2000 (Ganzey, 2005) However, environmental problems such as flooding and soil erosion have affected production in recent years. The Heilongjiang Province government halted the cultivation of wetlands by a "wetland reservation enhancement declaration" in December 1998.

3. METHODS

Figure 3 shows a flowchart of the method employed.

3.1 Field research (ground truthing)

Ground truthing was carried out in the wetland of the Sanjiang Plain in September, because at that time field production is most differing seemingly and the paddy fields are dry. Thus wetlands and paddy fields could easily be distinguished by using the NRCS (normalized radar cross-section) from the JERS-1/SAR data. NRCS was used to make the SAR digital recordings independently of the equipment used. The algorithm used was:

$$\text{NRCS [dB]} = 10 \log_{10}(I^2) + CF$$

where I is the digital SAR value and CF is the conservation coefficient (Japan Photogrammetory Associates, 1998).

In the field study, positional information in the wetland area was recorded by a GPS (GARMIN eTrex Venture). Land use and vegetation on land neighboring the wetland were also recorded. The heights of slightly elevated areas were measured with a hand level (Nobel K50-1560).

3.2 Satellite data process

For comparison with the results of the September field study, two sets of seven sheets of JERS-1/SAR data were obtained, one set recorded in September 1992 and the other in September 1996. The dimensions of one sheet of JERS-1/SAR data are 6400 × 6000 pixels, and 1 pixel represents 12.5 × 12.5 m.

Landform map was constructed from the 1996 SAR data, based on observed textures and NRCS. SRTM (Shuttle Radar Topography Mission) data recorded by NASA in 2000 were also used to check the altitude.

A geometric correction based on the geodetic projection WGS84 was applied by using the nearest neighbor method. A Frost Filter which was proposed in 1982 by Frost *et al.* was applied to remove speckle noise, which was characteristic of the SAR data.

The GPS data were plotted on the corrected SAR data and NRCS values on the pixel where the ground truthing conducted were calculated.

The average NRCS values for each landform in the wetlands were used as threshold levels to determine the wetland area. The areas within Russia and along the northern Songhua River, and islands were ignored. The wetland areas of each landform on the Sanjiang Plain were then calculated.

3.3 Chinese statistical data

By using Chinese statistical data (Chinese Statistics Publisher, 1992–1996), the change in area cultivated per farmer from 1990 to 1996, the rural population change from 1989 to 1999, and the main areas of farm production from 1992 to 1996 were determined.

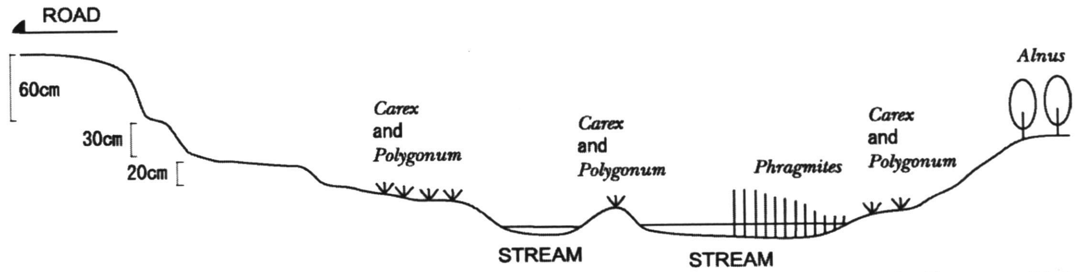


Figure 4. Cross-section of a wetland area on the floodplain of the Amur River, on the Sanjiang Plain.

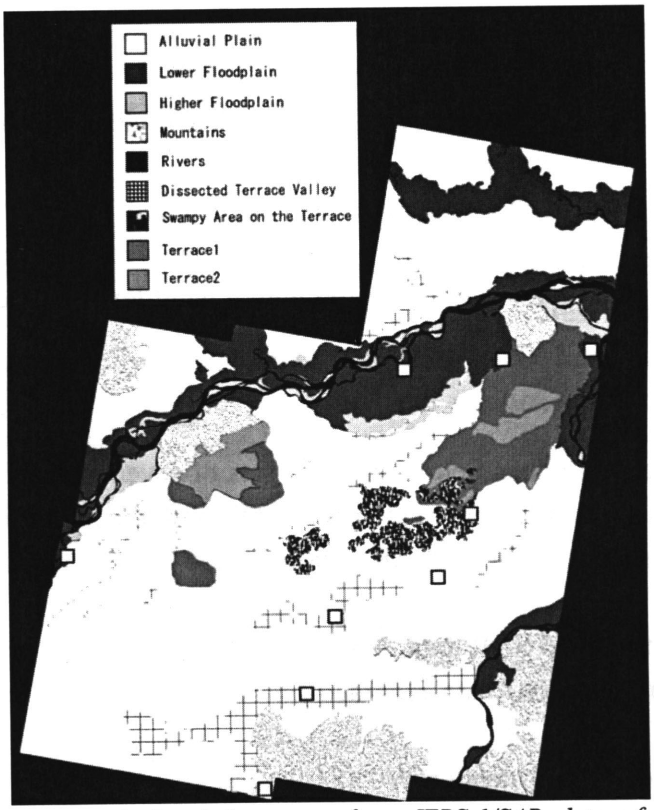


Figure 5. Land form map from JERS-1/SAR data of September 1996. Squares show the wetland areas where field investigations were carried out in this study.

4. RESULTS

4.1 Field investigation (ground truthing)

Field investigation of a wetland on the floodplain of the Amur River (Figure 4) revealed that the vegetation cover was mainly species of *Carex*, *Polygonum*, *Phragmites*, and *Alnus*. Land other than wetlands was cultivated for paddy fields, soybean, and corn.

4.2 Satellite data

For construction of the landform map (Figure 5), landforms were classified on the following basis. *River*: areas covered with water, including the Amur, Songhua, and Ussuri rivers and their tributaries. *Mountains*: areas of deep water table; lineations marking the valley borders were clearly identifiable on satellite images. *Floodplain*: areas around rivers where 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*: scattered areas of deeper water table within dry area. *Dissected terrace valley*: areas of shallow water table, but without surface water. *Alluvial plain*: all areas not categorized above. Two terraces were observed on the alluvial plain.

The ranges of NRCS values for selected landforms were compared (Figure 6). The average NRCS value was lowest for dissected terrace valleys and highest for mountains. The widest range of NRCS values was calculated for the lower floodplain. The NRCS values showed multiple peaks in their distributions, for areas of alluvial plain and swampy areas on the terraces.

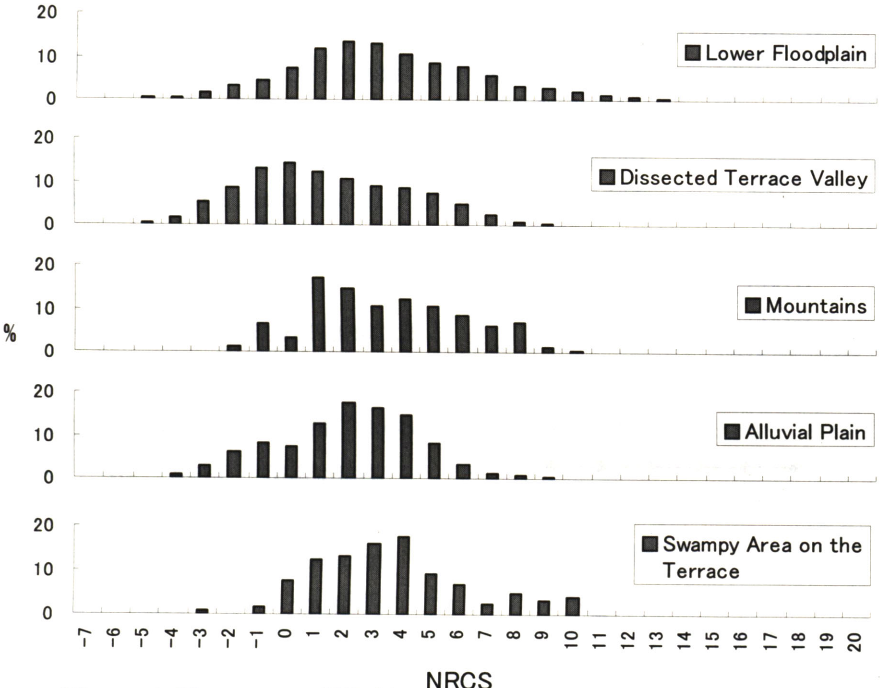


Figure. 6. Histograms of NRCS (normalized radar cross-section) values for selected wetland landforms.

The average NRCS values for each landform in the wetlands were used to define the wetland threshold. These threshold NRCS values were applied to SAR images of 1992 and 1996. A comparison of the areas of each wetland landform in 1992 and 1996 (Figure 7) revealed that between 1992 and 1996 the wetland areas on the lower floodplain increased by a factor of 2.4; on dissected terrace valley they increased by a factor of 1.8; on the alluvial plain and swampy areas on the terraces they decreased by 34% and 30%, respectively; and on the mountains they decreased by 22%. The triangular area of lower floodplain land near Khabarovsk (Figure 1), which was unaffected by human activity, tripled in area.

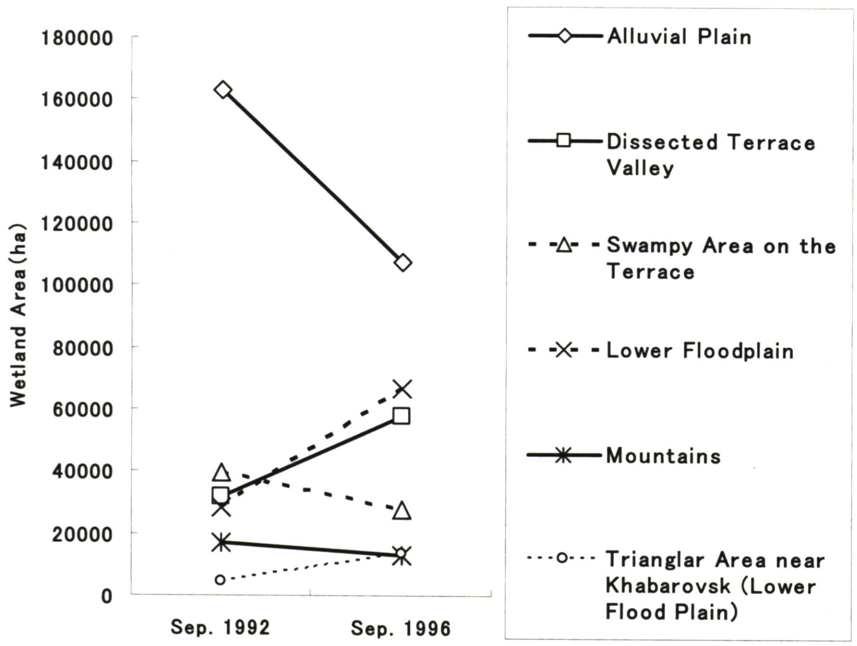


Figure 7. Comparison of areas occupied by each landform in 1992 and 1996, as calculated from JERS-1/SAR data. The "triangular area" near Khabarovsk was an area unaffected by human activity.

4.3 Chinese statistical data

From 1990 to 1996 in Heilongjiang Province, the area of land cultivated per farmer increased by 10% and that of non-cultivated land decreased by 25% (Table 1). The population of farmers slightly decreased from 1994 to 1996, and the agricultural labor force increased slightly, from 5 382 000 in 1990 to 5 835 000 in 1996 (Figure 8). From 1992 to 1996, the area cultivated for paddy fields increased by 7%, for wheat fields decreased by 30%, for corn fields increased by 11%, for soybean fields increased by 20%, and the total cultivated area increased by 2% (Table 2).

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

Category	1990	1996
Crop lands	1.119	1.236
Negrected lands	0.083	0.062
Mining area	0.005	0.005
Aquaculture	–	0.003

(Chinese Statistical Data)

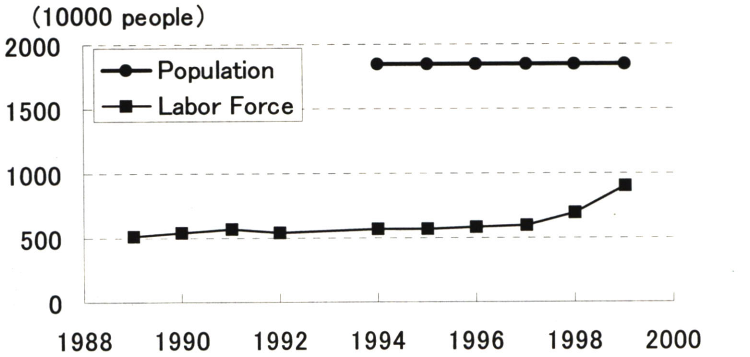


Figure 8. Population and labor force in an agricultural village in Heilongjiang Province.

Table 2. Total cultivated area and areas of main crops in Heilongjiang Province (1000 ha). There was no data of crop area in Chinese Statistical Data in 1995.

	1992	1993	1994	1995	1996
Total Seeding Area	**8479.4**	**8647.2**	**8670.0**	**–**	**8647.4**
Rice	778.4	735.5	747.1	–	835.1
Wheat	1614.6	1336.5	1198.5	–	1116.3
Corn	2165.9	1776.8	1964.2	–	2411.2
Soya	2160.2	3071.8	2940.9	–	2589.0

(Chinese Statistical Data)

5. DISCUSSION

The area of wetland in the triangular area of lower floodplain near Khabarovsk tripled from 1992 to 1996 (Figure 7). This can be attributed to high precipitation from July to September 1996 (Figure 2). However, from 1992 to 1996 the area of wetland decreased on the alluvial plain and in swampy areas on the terraces, but increased in dissected terrace valley. This suggests that cultivation of the wetlands on the alluvial plain and in old swampy areas decreased their capacity to hold rainwater and resulted in flow of rainwater into the old river courses (Figure 7).

The population of farmers slightly decreased from 1994 to 1996 (Table 1), but much crop lands were increased and much neglected lands were decreased per farmer (Figure. 8).

The total cultivated area increased from 1992 to 1996 (Table 2). The greatest increase in total area under cultivation on the Sanjiang Plain within Heilongjiang Province occurred from 1985 to 1995 (Singh and Himiyama, 2001), which suggests that this was the period when much of the wetlands of the plain were cultivated for paddy, corn, and soybean fields.

Depth to the water table in the Hong Hua Natural Reservation Area have been getting lower since the 1980s (Sanjiang Plain Wetland and Ecology Observation Station, unpublished data). Unregulated cultivation of wetlands has increased the frequency of flooding and the severity of soil erosion and salt accumulation, resulting in damage to the cultivated land. Continued flooding has the potential to make farming impossible on the lower floodplain. The extensive farmlands of the Sanjiang Plain are economically important; however, for them to remain sustainable, the wetlands must be preserved to provide a flood-control basin.

This study used quantitative analysis of satellite data over a large area to clarify the changes in land cover on the Sanjiang Plain from 1992 to 1996, and should thus contribute to planning for sustainable land use in the region.

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