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Report on Amur-Okhotsk Project

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2008 January 28th-29th. Amur-Okhotsk Project meeting at Sapporo

Water sampling at Sanjiang Plain

Wetland research at Sanjiang Plain

Ice core drilling at Alaska

Ice core drilled at Mount Wrangell

Forest burning at Russian forest

A burnt trunk

Hydrogical observation at a small stream

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Preface

It is my great pleasure to publish the "Report on Amur-Okhotsk Project No. 5". This is the latest summary of our activities conducted in the frame work of the project. Topics given here range from marine biogeochemistry to agricultural economics. One might think that they are too diverse but I am now confident that many of the project members derive benefit from their crossing research boundaries.

In FY 2008, the Amur-Okhotsk Project entered its 4th year of a 5-year Full Research endeavor. It is time for all of the project members to consider whether we are achieving our goals or not. Since our project will be evaluated in February 2009 by the Project Evaluation Committee, we need to reach our preliminary conclusions before January 2009. I hope that all of the project members read the present reports very carefully and be ready for further discussion.

I would like to thank all of the contributors for submitting their inspiring research results without which this project could not have been developed to this point. My special thanks are given to our Russian and Chinese colleagues for their countless effort in conducting these joint works in such vast regions. Finally last but not least, I thank Ms. Tamaki Kawaguchi, an assistant of the Amur-Okhotsk Project, for her timeless effort in editing this report. She also revised the website of the project just recently and I would recommend you to access the website http://www.chikyu.ac.jp/AMORE/ to check the latest news of the project.

Project Leader: SHIRAIWA Takayuki
Research Institute for Humanity and Nature

REPORT OF THE RESEARCH EXPEDITION IN THE SEA OF OKHOTSK FOR 2007

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1. INTRODUCTION

The Research Expedition in the Sea of Okhotsk for 2007 has been carried out in the period from 5 August to 15 September in 2007 by *R/V Professor Khromov* of Far Eastren Regional Hydrometeorological Research Institute (FERHRI), Vladivostok, Russia. This expedition was a collaborative research activity between following 4 institutes, FERHRI, Research Institute of Humanity and Nature (RIHN), Institute of Low Temperature Science, Hokkaido University (ILTS) and Ocean Research Institute, University of Tokyo (ORI).

The purposes of this research expedition were to understand the present transport processes of land-derived materials, especially iron, from Amur River to the Sea of Okhotsk and Pacific Ocean and their historical variability, with special emphasis on the intermediate water ventilation along east coast of Sakhalin and the vertical mixing process around Kuril straits. This research expedition had following subjects.

1) To clarify the vertical and horizontal distribution of iron and related substances in water masses of the Sea of Okhotsk, especially in areas of Amur River mouth, northern and eastern continental shelves and slopes off Sakhalin, and the area around Kuril straits.

2) To quantify the physical processes, which transport iron and related substances from Amur River to Pacific Ocean, such as shelf tidal mixing, intermediate water formation, East Sakhalin current and turbulent mixing processes around Kuril straits.

3) To reconstruct historical changes in the budget and the deposition rates of iron and related substances to the sediment on slope and deep basin of the western Sea of Okhotsk, together with past changes in water temperature & salinity in both of shelf bottom and offshore surface waters.

4) To infer the contribution of aerosol, which supply iron from atmosphere to the surface water, in the Sea of Okhotsk.

2. PROGRAM OF THE EXPEDITION AND ITS IMPLEMENTATION

2.1. CTD observations, Water Chemistry and Biogeochemistry

2.1.1. CTD observations

Purpose. The purpose of CTD (Conductivity, Temperature and Depth probe) casts was to examine the water characteristics in the Sea of Okhotsk from the Sakhalin Bay and around Sakhalin Island through the Kuril Straits (especially Bussol' Strait), in order to elucidate the influence of the Amur River water and dense shelf water on the Okhotsk Sea water-masses and on bio-chemistry in the Sea of Okhotsk and the North Pacific.

Data Acquisition. The CTD/Carousel water sampling system was used to acquire water samples and CTD data (pressure, temperature and conductivity). The CTD is Sea-Bird 911 plus system, and Seabird Carousel bottle release systems were used. The CTD/rosette held twelve 10-liter Niskin bottles with Teflon coating for iron measurements. The CTD instruments were equipped with a dissolved oxygen sensor (Sea-bird SBE43), transmissiometer (Wet lab C-Star) and altimeter (Data sonic PSA-900D). The CTD-frame was deployed via the right-side A-frame at the sites described in Figure 1, 2.

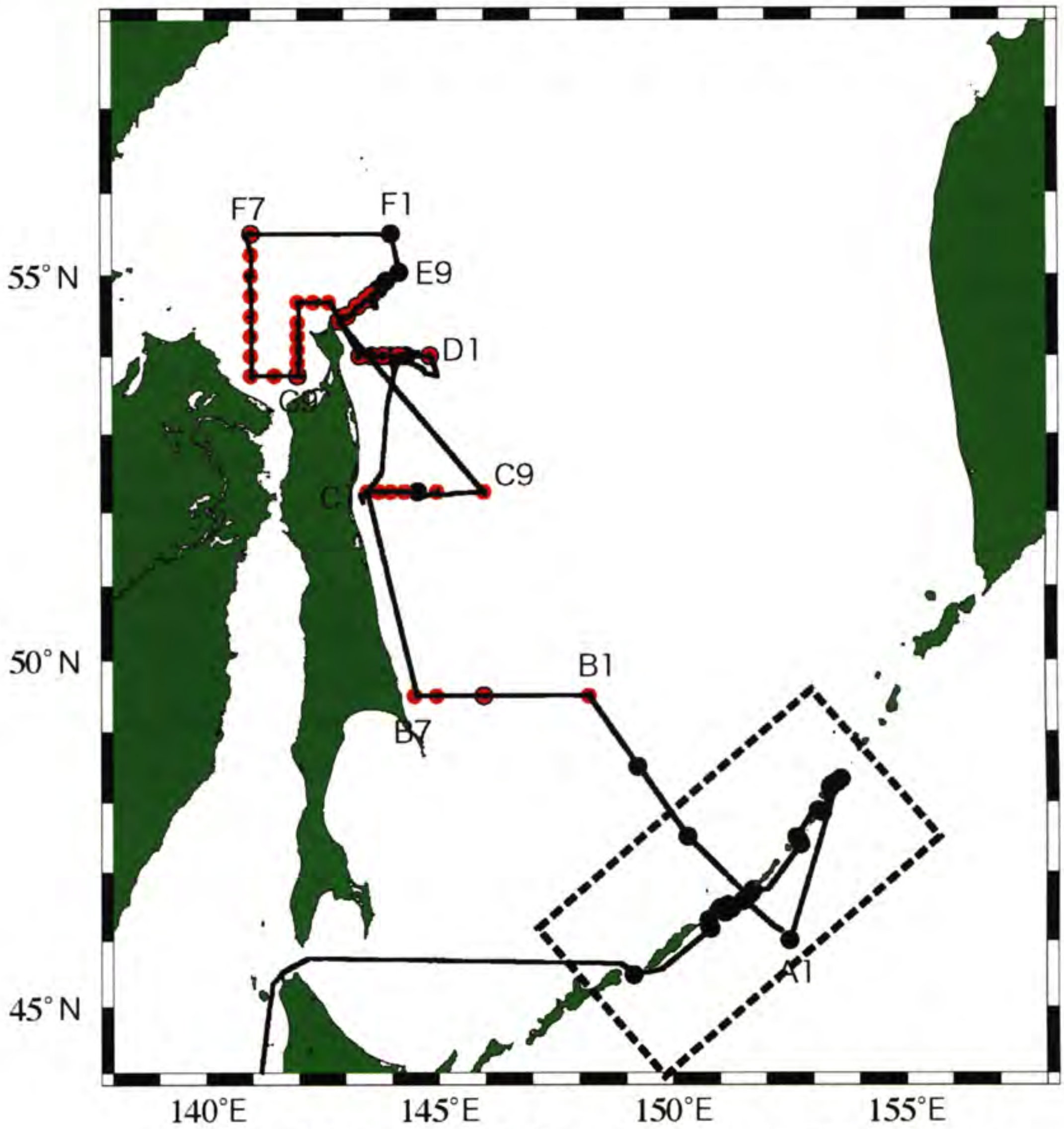

Figure 1. Cruise Track of the Research Expedition for 2007 (Whole area)

Water samples were drawn for dissolved oxygen and salinity at most of the CTD casts. However, in Kuril strait areas, water samples were analyzed for dissolved oxygen and salinity only about once a day to calibrate the CTD and DO sensor. The samples of dissolved oxygen were analyzed by Winkler method using an automated titration system with a colorimeter. Salinities were analyzed with a Guildline Portsal 8410A salinometer, using a computer interface and software. IAPSO Standard Seawater, batch P-146, served as the standard.

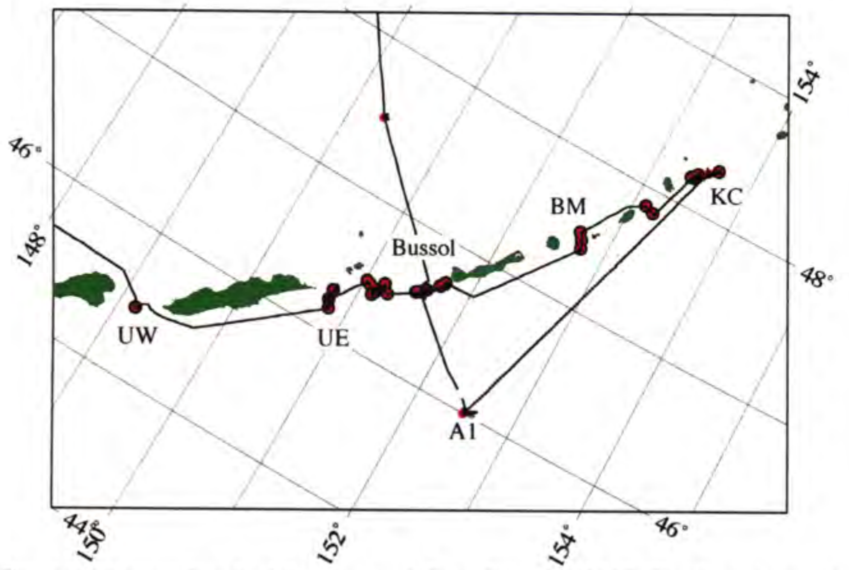

Figure 2. Cruise Track of the Research Expedition for 2007 (Kuril straits area)

Data Processing. Conductivities and dissolved oxygen obtained by CTD sensors at each bottle level will be merged with the results from bottle salinity and oxygen analyses. Bottle salinity and oxygen concentrations will be calculated and compared with the CTD data. CTD performance will be monitored by means of these comparisons. Final processing of CTD data will be completed at a later date.

2.1.2. Water Chemistry and Biogeochemistry

Purpose. One of the most important goals of this cruise is to grasp direct evidences of the tight connections between land and ocean ecosystems through material transports via river and shelf systems. Main targets are riverine iron and related substances, which are dissolved and/or suspended in the water of the Sea of Okhotsk. In order to clarify the spatial distributions of iron and related substances, water samplings were performed during all of the CTD casts from the areas near Amur River mouth to Pacific Ocean. Suspended particles were also collected using "in-situ large volume water filtering systems" at several CTD stations.

Water Samplings and Sample Treatments. Waters were collected during the CTD casts. In addition, surface water was continuously analyzed for nitrate concentration using underway waters supplied from engine room, although the nitrate analyzer did not work well during the cruise. Water samples during CTD casts were distributed into various sizes of clean bottles for on-board and/or on-shore analyses. Some water samples were directly filtered through filtration unit attached to the Niskin bottles to collect dissolved forms of chemical components. Particle samples were also collected using the "in-situ large volume water filtering system" besides the CTD/water sampling at various water depths, especially focusing on the dense shelf water and its outflow to slope and basin areas around Sakhalin Island. The in-situ filtration was conducted by WTS-LV system (McLANE Inc.) with 1.0 μm pore size polycarbonate filters at the stations mainly on the slope and shelf areas.

Water and Particle Analyses. The distributed waters and filter samples are to be measured on the following list of chemical and biogeochemical parameters. Some of them have been analyzed on board, and the rests are to be analyzed on shore.

Substance	Number of water samples *	Analytical Method or Instrument	Measurement Remarks
Basic properties			
Salinity	All, except for Kuril strait areas	Guildline Port-Sal	On board
Dissolved Oxygen	All, except for Kuril strait areas	Winkler method (Titrated by Oxidation –Reduction Electrode)	On board
Nutrients	All	Continuous Flow type of Auto Analyzer	On shore
Biogeochemical parameters			
Iron (dissolved and total)	All except for Kuril strait areas	Chemiluminescence method (Kimoto-Denshi, EN-701)	On shore (partly on board)
Chlorophyll a	All, but only shallow layers at some stations	Fluorescence Spectrophotometer (Turner, 10-AU)	On board
Chromo-Dissolved Organic Matter	Almost all, except for Kuril strait areas	3D-fluorescence method	On shore
Carbon chemistry			
Dissolved Inorganic Carbon	Almost all, except for Kuril strait areas	CO_2 coulometer	On shore
Dissolved Organic Carbon	Almost all, except for Kuril strait areas	High Temperature Combustion method	On shore
Other Properties			
Metal Composition (Particles)	Mainly on slope and shelf	Atomic Absorption and/or ICP/MS	On shore

* "Number of water samples" indicates that how much water samples collected by CTD/carousel systems are applied for the analyses of the corresponding substances.

2.2. Shear Probe Observations

Purpose. Around the Kuril Islands in the Okhotsk Sea, tidal currents are strong and the vertical mixing is expected to be large and to contribute to the material circulation and resulting biological activity as well as the physical processes. However the mixing activity has not been directly measured. Measurements of turbulence and microstructure were performed at sites around the Kuril Islands shown in Figure 2.

Instruments and observation. A real time system of VMP2000 (Vertical Microstructure Profiler for 2000m casts) and VMP500 (smaller type for 500m casts) manufactured in Rockland Scientific Service (Victoria Canada) were used with the hydraulic motor, winch and line puller system. The fish deploys and recoveries were from the stern using A-frame and capstan. During the profiling, the ship moved as slowly as possible against the surface currents or winds in order the ship to be away from the cable and to avoid the cable cut by ship propeller.

Data acquisition and processing. Shear probe, micro-temperature probe and acceleration data were obtained in 512Hz, and the pressure and Sea-Bird temperature and conductivity were obtained in 64Hz. These were used to obtain the turbulent kinetic energy dissipation rate during 2 seconds from velocity shear spectra. Very preliminary data of diapycnal mixing coefficients of density in the interval of 1dbar were processed during the cruise. But the careful treatments are necessary to make final data because the probes are quite sensitive and the Sea-Bird sensors had troubles with water invasion and also because the data is frequently influenced by various matters.

2.3. Sediment Coring and Surface Sediment Samplings

Purpose. Although the present situations on the transport of iron and related substances from the Amur River and their influences on the biogeochemistry in the Sea of Okhotsk and the northwestern North Pacific Ocean can be addressed in the physical and biogeochemical oceanographic studies in this expedition, the situations must have varied largely in the past. Especially, impacts of climate changes and anthropogenic activities on the material transports through the Amur River and the Sea of Okhotsk should be understood carefully by paleoceanographic studies using sediment cores and related materials in order to predict future changes in the biogeochemical linkages between land and ocean in this region. There are two parts of the paleoceanographic studies in this expedition. One major part is to collect several meters (5-7m) of sediment cores from 8 sites on the continental slope and basin off Sakhalin in the western Sea of Okhotsk and analyze chemical properties of the sediment cores for reconstruction of past environmental changes, especially changes in material transport processes from Amur River, during Holocene and the last glacial period. The other minor part is to collect modern and past molluskan shells from continental shelf sediments around Sakhalin and analyze their chemical compositions, especially stable oxygen isotope ratios, for estimation of past seasonal and inter-annual variations in temperature and salinity of the shelf bottom waters which is affected by seasonal sea-ice formation and Amur River discharge.

Sediment Samplings. Three types of sediment samplers (Smith-Macintyre Type of Grab Sampler, "Ashura" type of Multiple Corer (60cm of core pipe length) and a Piston Corer (8m of core pipe length)) were applied in this research expedition. Sediment cores were collected using both of the Multiple Corer and the Piston Corer at 8 stations on the slope and basin areas off east and north coast of Sakhalin. Surface sediments were collected for mollusk shell samplings using the Grab Sampler at many sites on the shelf areas.

Sample Treatments. Piston Core samples, most of which consisted of 5-7 m lengths of sediment, were divided into 1m length of core on board immediately after recovery and stored in the refrigerator until the precise sub-samplings and chemical analyses on shore. Multiple Core samples collected at the same locations as Piston Core were sliced at 1cm intervals on board, packed in plastic bags and stored in refrigerator or freezer until the chemical analyses on shore. Surface sediments collected by the Grab sampler were sieved using 5mm mesh to separate larger size of mollusk shells from sedimentary particles immediately after samplings and only the mollusk shells were stored for further species identification and chemical analyses on shore.

Chemical Analyses. Piston Core and Multiple Core samples are to be analyzed on the items such as major sediment components (total organic carbon, carbonate, biogenic silica, lithogenic silica), C/N ratio, terrestrial and marine organic molecules, major element compositions measurable by XRF, ice-rafted debris, ^{14}C contents and magnetic susceptibility for core chronology. Mollusk shells in surface sediments are to be identified of their precise species names and analyzed further for micro-scale distributions of the stable oxygen isotopic ratios across growth lines of typical large specimen.

2.4. Aerosol Samplings

Purpose. In general, land-derived iron is believed to be supplied to ocean surface via atmosphere by aerosol. Because the Sea of Okhotsk is located on the eastern end of Eurasia continent, huge amount of aerosol containing iron must be supplied to this area by the strong westerly. In order to estimate the relative importance of the iron from Amur River, it is necessary to monitor and quantify the iron load from atmosphere in the Sea of Okhotsk. Therefore, aerosol samplings were conducted in this research expedition.

Observation. Aerosol samples were collected with a High Volume Sampler during the cruise (Aug. 9 – Sep. 11). Wind direction was continually monitored and the sampler was turned off if there was any risk of contamination by exhaust from the ship's stack. The samples were collected on the 90 mm Teflon filter and the filters were changed when total volume reached over 100 m^3.

Sample analyses. Teflon filters with collected aerosol samples are to be used for analyzing major ions (Na^+, Ca^{2+}, SO_4^{2-}, NO_3^-) and trace metals (Fe, Al) at on-shore laboratory. Soluble major ions and trace metals are to be extracted from the filters and analyzed by ion chromatography and ICP-AES.

3. CONCLUDING REMARKS

In general, the program of this expedition was successfully completed with the combined efforts of Russian and Japanese specialists. In particular, it is notable that clean water samplings were successfully performed on *R/V Professor Khromov* in this expedition as well as last year. The quality of collected waters was monitored during the cruise by on-board analyses of trace amount of iron, and apparent contaminations of iron from the vessel have never been identified. This success is greatly owing to Russian efforts to clean up the vessel before the cruise and Japanese carefulness to avoid any kind of contaminations at all procedures during the samplings of water.

In this cruise, the piston core operations were successfully carried out at many sites to collect long sediment core samples, besides the water column observation. These successes clearly indicate the wider applicability of *R/V Professor Khromov* to the areas of oceanographic observations other than hydrometeorological studies.

4. ACKNOWLEDGEMENTS

This expedition was successfully completed with the effort and patience of many peoples, and with the good weather condition throughout the cruise. We would like deeply to appreciate Captain Alexander D'YACHENKO of the R/V Professor Khromov and his fine crews for their outstanding works during this cruise; without them, none of this expedition would have been possible.

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IMPORTANCE OF TIDAL MIXING PROCESS AT KURIL STRAIT FOR IRON SUPPLY TO WESTERN SUBARCTIC PACIFIC, OYASHIO REGION

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ABSTRACT

Vertical iron distributions were investigated on the cruise around the Kuril Straits in 2006 summer, (kh06-cruise). Detailed profiles from Kuril Strait suggests that the iron-rich Okhotsk Sea intermediate waters (OSIW) influence the surface layer around the Kuril Straits and the iron was re-distributed to the wide range of density in the water column, probably due to the strong diapicnal mixing affects the chemical properties of the OSIW. This process raises the surface iron concentrations with macro-nutrients concentrations, and the water will be subsequently transported to the Oyashio region. The significantly higher ratios of iron to nitrate in mixed layer in the Kuril Strait than eastern subarctic Pacific (ESP) were observed in this study. A greater supply of macro-nutrients and substantially higher seasonal nutrient utilization in the Oyashio region, compared with ESP, might partially be explained by a larger upward iron flux in the Kuril Strait. The consideration of mixing process with re-distribution of macro- and micro-nutrient at the Kuril Strait is essential in our understanding of the biological production and biogeochemical cycles in the Oyashio region of the western subarctic Pacific (WSP).

1. INTRODUCTION

Recent study clearly indicated that iron limits phytoplankton growth, especially during the summer, in the western and eastern subarctic Pacific [Tsuda et al., 2003; Boyd et al., 2004]. The eastern subarctic Pacific (ESP) oceanic time series station showed little seasonal variation in phytoplankton increase [Boyd and Harrison, 1999]. In contrast, the western subarctic Pacific (WSP) is often more productive in its lower trophic levels, especially during the bloom season from spring to summer in the Oyashio region [Saito et al., 2002]. A very large biological drawdown of *pCO2* in the WSP was also observed during this period [Takahashi et al., 2002]. Since iron limits phytoplankton growth during the summer in the WSP, there are considerable interests in determining the source and seasonal timing of iron input, which can lead to a steady spring phytoplankton bloom as found in the Oyashio region.

Nakatsuka et al., [2002; 2004] pointed out that, in the Sea of Okhotsk, there is an efficient system of sediment material transport from the north-western continental shelf to the open sea via intermediate water transportation (DSW, OSIW), the ventilation processes.

Other studies also found that injections of large amounts of POC and DOC from the Sea of Okhotsk led to increase DOC concentrations in the NPIW [Hansell et al., 2002; Hernes and Benner, 2002]. Additionally Nishioka et al., [2007] and Nakatsuka et al., [2007] indicated that the intermediate waters in the WSP receive their primary source of iron through the ventilation processes originating in the Sea of Okhotsk. This source of iron is distributed to subarctic waters in the WSP area, and the form of the introduced iron is mainly in the particulate phase. However, the mixing process of the iron-rich intermediate water to surface of subarctic water in WSP have not completely understood yet.

Many previous studies clearly indicated that strong vertical mixing occurs around the Kuril Straits. The diapicnal mixing around Kuril Straits strongly affects the temperature and salinity properties of the OSIW [Tally et al., 1991; Wong et al., 1998; Yamamoto et al., 2002]. Nakamura and Awaji [2004] performed numerical experiments to study tidally generated internal waves in the Kuril Straits and showed that tidal mixing was able to reach down to the OSIW. Furthermore, surface winter turbulent and mixing is stronger and deeper in the WSP than ESP, especially Oyashio - Kuroshio inter-frontal region [eg. Suga et al., 2004]. Surface water properties in the Oyashio region is obviously influenced deeper layer water properties by the mixing processes.

Extrapolating from these previous studies, there is a possibility that the iron-rich intermediate waters may influence the surface layer around the Kuril Straits, and thus raise the surface and subsurface iron concentrations in the Oyashio region with subsequent transport and winter mixing. In this study, we investigate oceanic surface and deep iron distributions at the Kuril Strait. Then, we argue for the possibility of the influence of this source of iron on the spring bloom in the Oyashio region and biogeochemistry of WSP, which is one of the highest biological productive areas in the world oceans.

2. METHODS

2.1. Observations around the Kuril Islands

Seawater sampling was conducted from the *R/V Kromov* to observe vertical distributions of iron in the *Bussol* Strait, one of deepest strait in the Kuril Strait, in 2006 summer. The observation stations are indicated in Figure 1. To characterize vertical profiles of iron concentration, seawater samples and hydrographic data were collected using a clean CTD-carousel multiple sampler (CMS) system which housed twelve acid cleaned Teflon coated 10-L Niskin-X bottles. For sub-sampling from the Niskin-X sampler, 0.22 μm Durapore filters (Millipac 100, Millipore Corp.) were connected to the Niskin-X spigot, and the filtrate was collected in acid-cleaned 125-ml LDPE bottles (Nalgene Co., Ltd) under gravity pressure. The filtrate and unfiltered samples were used for iron measurement at onshore laboratory. Nutrients concentrations were also analysed in water samples collected from the same stations.

2.2. Iron measurement

The unfiltered and filtrate samples were adjusted to pH <1.8 with addition of 0.05 M of HCl, and the these samples were adjusted to pH 3.2 with addition of 2.4 M ammonium -10 M formic buffer and ammonium solution just before analysis. Our defined "dissolved iron" concentrations (that is, leachable iron in 0.22 μm filtrate at pH 1.8) and "total iron" concentrations (that is, dissolved plus leachable iron in unfiltered sample at < pH 1.8) were measured by FIA chemiluminescence detection system (Obata et al., 1993). All sample treatments were performed in a laminar flow clean-air hood in a clean-air laboratory. Nutrients and chlorophyll a concentrations were also analysed for water samples. Hydrographyic data was also collected at all stations using a CTD.

3. RESULTS AND DISCUSSION

Nishioka et al. [2007] reported changes of dissolved iron, nitrate, surface mixed layer depths (MLD) and chlorophyll a, in the surface of the Oyashio region (Figure 2, cited by Nishioka et al., 2007). They found that Oyashio region has clear seasonal variability of dissolved iron concentrations in the surface mixed layer along the monitoring line A-line. High nutrient levels in the surface mixed layer occurred in winter (~ 25 μM nitrate), due to the deep vertical mixing (~ 200 m) in winter, which delivered high nutrient subsurface water into the surface. In spring, thickness of the surface mixed layer decreased and the nitrate concentration was drawn down to 2 ~ 10 μM nitrate due to biological uptake in spring bloom. The seasonal changes in dissolved iron level was similar to that of nitrate in the surface mixed layer. The dissolved iron concentration observed in the surface mixed layer of the Oyashio region reached a maximum in January, and kept high throughout winter (ave. 0.6 nM). As the development of the spring diatom blooms, the dissolved iron levels decreased to < 0.2 nM.

The relatively high dissolved iron levels in the surface mixed layer in winter season, before the phytoplankton bloom, in the Oyashio region can be explained by three possible sources: 1) input of soluble aerosol iron, 2) turbulent vertical winter mixing of dissolved iron from the subsurface layer and 3) tidal mixing at Kuril Strait and lateral transport into the surface layer. Regarding 1), the observed frequencies of dust events in 2003 were 0 both in January and February, 6 in March, 7 in April and 2 in May [Japan meteorogical agency]. The monthly variation of the dust events was clearly inconsistent with the seasonal change in dissolved iron in the surface mixed layer of the Oyashio region in 2003. Hence, the aeolian dust input would be a minor process for the phenomenon. As for 2), Nishioka et al., [2007] indicated that their time series data can support the importance of the upward flux of iron by deep winter mixing in this region. One of the proof or evidence for this is that the seasonal change in dissolved iron behaves similar to that of nitrate in the surface mixed layer.

In this paper, we mainly focus on to regarding 3). Total and dissolved iron concentrations at the Bussol strait were measured, and vertical profiles of iron are shown in Figure 3. The water temperature and salinity profiles on the Bussol Strait showed well mixed distributions from surface to intermediate layer (~ 600 m). The dissolved iron concentrations in the well mixed water, from surface to intermediate waters, are obviously higher than that found in the surface water in the WSP and the Oyashio region (~ 0.6 nM) [Nishioka et al., 2007] (Figure 2). Previous studies clearly indicated that strong vertical mixing occurs around the Kuril Straits. The diapicnal mixing around Kuril Straits strongly affects the temperature and salinity properties of the OSIW [Tally et al., 1991; Wong et al., 1998; Yamamoto et al., 2002]. Nakamura and Awaji [2004] performed numerical experiments to study tidally generated internal waves in the Kuril Straits and showed that tidal mixing was able to reach down to the OSIW. These detailed iron profiles from the Bussol Strait suggests that the iron-rich Okhotsk Sea intermediate waters (OSIW) influence the surface layer around the Kuril Straits and the iron was re-distributed to the wide range of density in the water column, probably due to the strong diapicnal mixing affects the chemical properties of the OSIW. It has been reported that the Oyashio region waters originate partly from Sea of Okhotsk water with 26.6-27.5 $\sigma\theta$ [Yasuda et al., 2001] and that this density range also corresponds to the iron-rich intermediate waters (NPIW) in the Oyashio region and the other region of the WSP. Therefore, the mixing process at Kuril Strait raises the surface iron concentrations with macro-nutrients concentrations, and the water will be subsequent affected to the Oyashio region.

The dissolved iron to nitrate ratio in the well mixed water in the Bussol Strait are summarized with the ratio in the waters of the Oyashio region, the WSP and the ESP in Table 1. The ESP consistently contains 0.004 nM Fe/μM NO3 in the subsurface gradient. On the other hand, the well mixed water in the Bussol Strait have similar order of number (ave 0.036 ~ 0.073, respectively) to the subsurface water of the Oyashio and the WSP (ave 0.044, 0.052, respectively), and have significantly higher ratios than ESP (0.0004) (Table 1). The consideration of mixing process with re-distribution of macro- and micro-nutrient at the Kuril Strait is probably essential for explain the higher iron to nitrate ratio in the subsurface water of the Oyashio region and WSP. Thus, winter vertical mixing in the Oyashio region and the WSP supplies more iron than in the ESP. A greater supply of macronutrients and substantially higher seasonal nutrient utilization in the WSP and Oyashio region [Tsurushima et al., 2002; Harrison et al., 2004], compared with ESP, could be explained by a larger upward iron flux in the WSP and Oyashio regions. Thus, the mixing process with re-distribution of macro- and micro-nutrient at the Kuril Strait and subsequent water transportation is probably one of important process for explain higher biological nitrate utilization and steady increases in phytoplankton biomass in the Oyashio regions.

4. CONCLUSION

We reported vertical iron profiles in the Bussol Strait and discussed importance of the mixing processes at Kuril Strait for distribution of micro- and macro-nutrient in the Oyashio and WSP water. The process can explain the high dissolved iron to nitrate ratio in the WSP and the Oyashio region, which lead higher biological nitrate utilization. Our findings contribute to a better understanding of the mechanisms influencing biological production and biogeochemical cycles in the subarctic Pacific.

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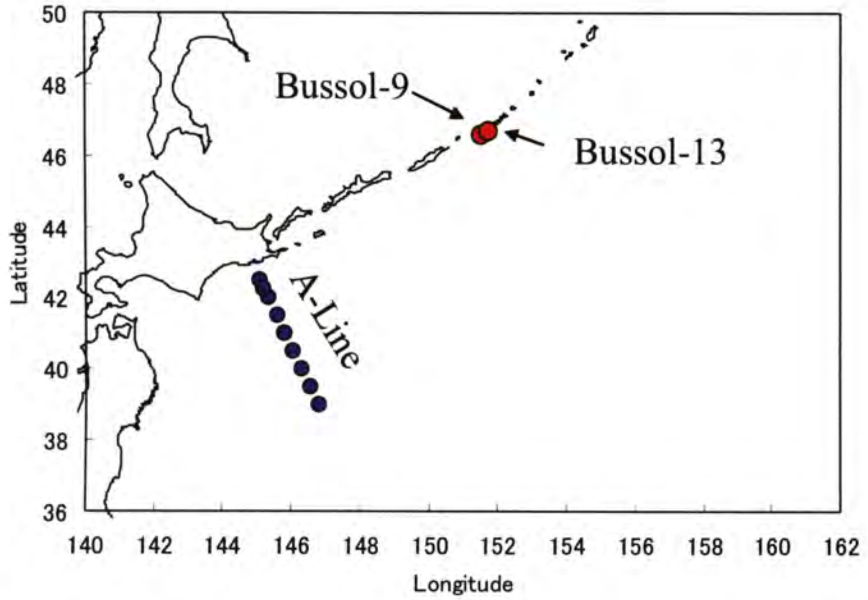

Figure 1. Chart of the western subarctic Pacific area with sampling locations in this study. Stations at the Bussol strait indicated by filled red circles are observed total iron an dissolved iron concentrations in August, 2006. Time-series observations were conducted by Nishioka et al. [2007] from January to the end of May in 2003 at stations along "A-line".

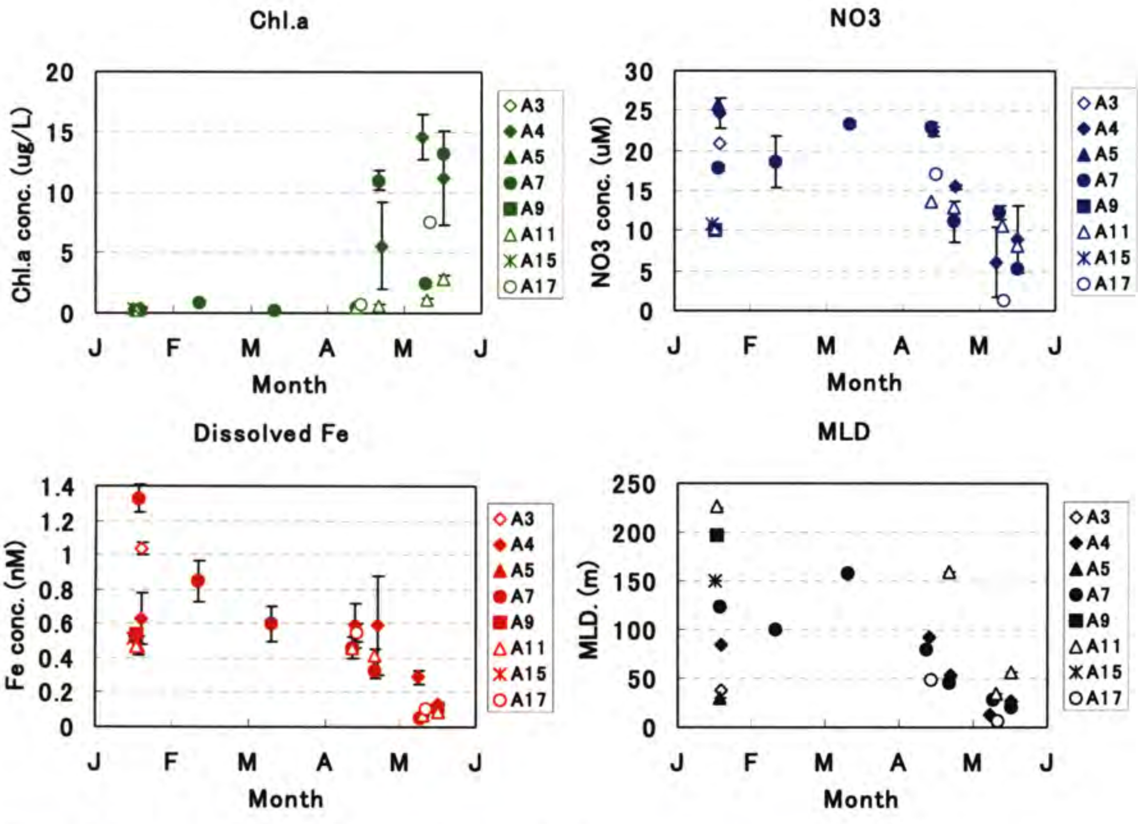

Figure 2. Seasonal variations in sea-surface dissolved iron concentrations, nitrate+nitrite concentrations, and chlorophyll a concentrations, and surface mixed layer depth from January to the end of May, 2003, along the "A-line" (After Nishioka et al., 2007)

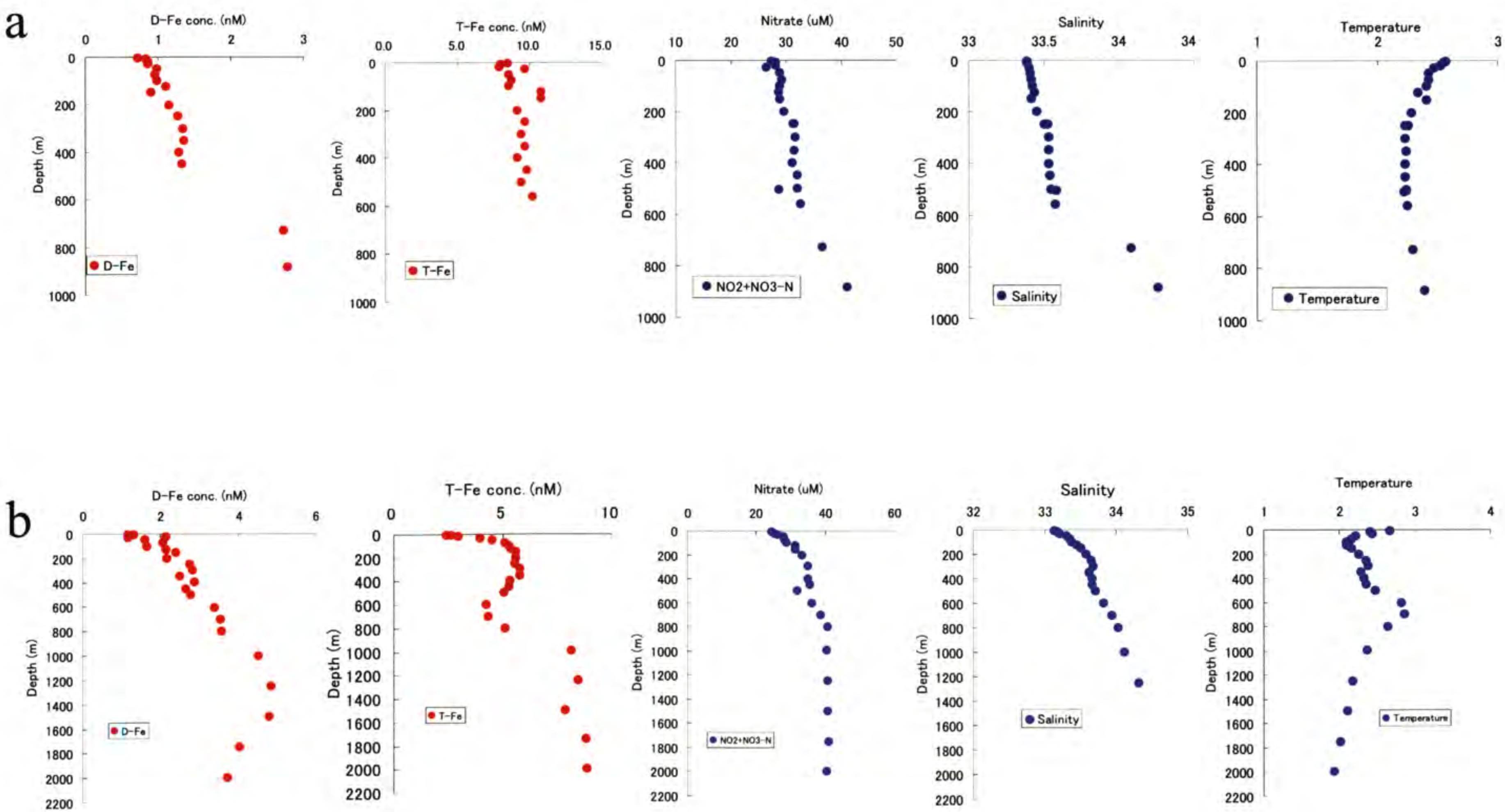

Figure 3. Vertical profiles of Dissolved iron (D-Fe), Total iron (T-Fe), Nitrate + Nitrite, Salinity and Temperature at Bussol Strait (a;Bussol-13, b:Bussol 9).

Table 1

Dissolved iron to nitrate ratio in the water of western and eastern subarctic Pacific

Water	Ave. D-Fe conc. (nM)	Ave. Nitrate+Nitrate conc. (μM)	D-Fe/N ratio
Mixed water at Bussol-9	2.35 ±0.74	31.4±5.0	0.073±0.015
Mixed water at Bussol-13	1.06±0.21	29.5±1.8	0.036±0.005
Dense Shelf Water	5.23±0.88	27.4±0.74	0.19±0.03
Intermediate water in the Oyashio	1.28±0.34	41.8±4.2	0.023±0.015
North Pacific Intermediate Wwater	1.10±0.20	40.6±2.8	0.027±0.004
Subsurface water at Oyashio	caluculated from subsurface gradient, Nishioka et al., 2007		0.044
Subsurface water at WSP	caluculated from subsurface gradient, Nishioka et al., 2007		0.052
Winter mixed layer in the Oyashio	0.85±0.12	18.6±3.2	0.048±0.12
Subsurface water at ESP	caluculated from subsurface gradient, Nishioka et al., 2007		0.004

D-Fe: dissolved iron, WSP: western subarctic Pacific, ESP: eastern subarctic Pacific

GEOCHEMICAL BEHAVIOR OF DISSOLVED IRON IN WATERS FROM THE AMUR RIVER, AMUR-LIMAN AND SAKHALIN BAY

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INTRODUCTION

To understand the input of iron from river to ocean, we need to study the geochemical behavior of iron in estuarine environments. Complex geochemical reactions occur in estuaries due to the mixing of freshwater with seawater. The distribution of iron in estuaries is well documented and the dissolved iron is found to be largely removed, the major fraction being on suspended particulate materials through colloid flocculation (Sholkovitz, 1976, Fox and Wofy, 1983, Fox, 1988, Guo et al., 2000). It is important to study the fractionation of dissolved iron and its geochemical forms in estuaries because of estimation on flux of dissolved and particulate iron forms, and study on the transport processes and bioavailability. The purpose of this study is to elucidate the geochemical behavior of iron in the estuary of Amur River, Amur-Liman and Sakhalin Bay.

MATERIALS AND METHODS

Location is shown in Figure 1. Water samples were taken from surface and bottom layers at nine stations on the early August in 2006. Salinity and turbidity were measured *in-situ* by a water checker (TOA DKK WQC-24). Dissolved iron in the water samples was measured by ICP-MS. Dissolved + acid leachable iron concentration was measured by colorimetry with 1.10 phenanthroline after the addition of HCl and the filtration. Dissolved organic carbon (DOC) concentration was determined by wet chemical method (Levshina and Karetnikova, 2008). The iron content of soil and river bottom sediment was measured by ICP-MS following total acid digestion with a mixture of $HCl+HNO_3+HF$.

RESULTS AND DISCUSSION

Figure 1 shows concentration of dissolved + acid leachable iron, turbidity and DOC concentration at each sampling station. The concentration of dissolved + acid leachable iron ranges from 1.78 mg/l to 2.96 mg/l at St. 1-3 in the estuary. The dissolved iron concentration filtered with GF/F filters and 0.2 μm membrane filters was 0.25-0.33 mg/l and 0.02-0.04 mg/l, respectively. Iron is dissolved as colloidal particles in freshwater environments. The dissolved + acid leachable iron rapidly decreases at St. 5 in the Amur-Liman. Above 90% of dissolved and acid leachable iron, that is some part of suspended solids, is removed by the mixing of freshwater with seawater. The similar removal rate for iron is presented at estuarine environments (Sholkovitz et al., 1978, Kraepiel et al., 1997, Ouddane et al., 1999). The decrease in iron concentration that colloidal fraction of iron is coagulated during the mixing at the liman. The non-conservative behavior of iron has been observed at estuaries (Sholkovitz 1976, Boyle et al., 1977, Sholkovitz and Copland, 1981, Fan et al., 2008, etc.).

The turbidity, concentration of dissolved + acid leachable iron and dissolved organic carbon (DOC) as a function of salinity is presented in Figure 2. The decrease in turbidity from the freshwater to the seawater indicates a removal of suspended solids by a concave curvature of the data. On the other hand, the concentration of dissolved + acid leachable iron sharply decreases above salinity of 3.0. The DOC concentration decreases with increase in salinity linearly. Terashima and Nagao (2007) carried out laboratory mixing experiments for dissolved iorn in the presence of river humic substances. They have shown the removal of dissolved iron up to 86% by the mixing, and the value agrees with the field research results at Amur-Liman. The discrepancy in removal behavior among iron, DOC and suspended solid indicates the formation of iron oxyhydroxides (Fan et al., 2008). Unfortunately, the detection limit of iron using analytical method in this study is 0.02 mg/l so that we can't elucidate the concentration of dissolved iron in Amur-Liman and Sakhalin Bay. Nakatsuka et al. (2007) have shown that the concentrations of dissolved iron in surface water at the sites close to the Amur River mouth are two orders magnitude higher than the Oyashio intermediate water. Therefore, iron in the Amur-Liman is coagulated, but some part of iron may be still dissolved in saline and seawaters.

The particulate iron is not precipitated on the surface sediments at Amur-Liman and Sakhalin Bay. The surface sediments collected by Ekman-berge bottom sampler during our research cruise are sandy and we did not recognize the presence of fine particles such as iron oxyhydroxides and clay minerals. The iron content of surface sediments in the Amur estuary is one-third lower than that of surface soil and sediments at the Lower Amur River (Table 1). The acid leachable iron was presented in the range of 6.7 to 84 μg/l for the bottom layer at Sakhalin Bay (Nakatsuka et al., 2007). Therefore, iron precipitated from water column may be transported from Amur –Liman to Sakhalin Bay.

FUTURE STUDIES

In 2008 we will make plan for the research on the Amur estuary, Amur-Liman and Sakhalin Bay to understand behavior of coagulation and transport of iron in the mixing zone between freshwater and seawater. Three types of filters with pore size of 0.7 μm, 0.2 μm and 0.02 μm will be used to study existent forms of iron in saline and marine environments. Dissolved and colloidal organic matter may be critical intermediates in controlling the fate and transport of iron (Guo et al., 2000, Pokrovsky and Schott, 2002). We also study association of humic substances with iron in the mixing zone by field and laboratory experiments. Organic ligands such as humic substances, a major fraction of DOC in river water, play an important role of behavior of trace metal ions because of strong complexation

(Viers et al., 1997, Matsunaga et al., 1998). The geochemical forms of iron are a key parameter to understand bioavailability of iron in marine environments.

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Table 1.
Fe content in surface samples from soils and river bottom sediments in the Lower Amur River and its estuary.

Sample	Area	No of sample	Fe content (%)	
			Range	Average
Soil	Lower Amur River	18	2.94-6.54	4.7±1.2
River bottom sediment				
	Lower Amur River	16	3.91-6.79	5.7±0.8
	Estuary	1	1.68	1.68

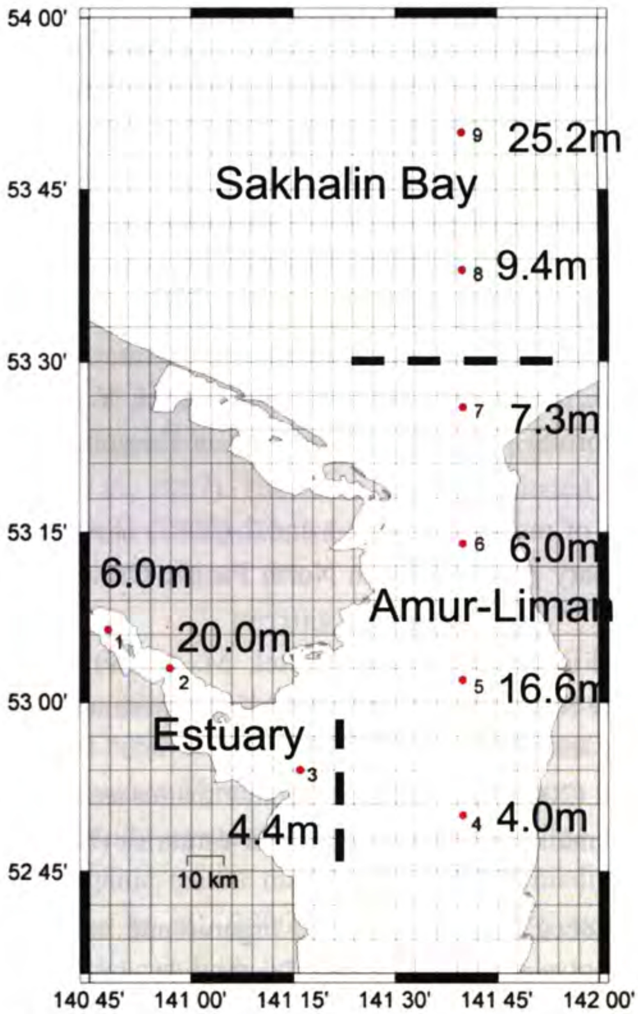

Figure 1 Sampling stations in estuary of the Amur River, Amur-Liman and Sakhalin Bay. Water depth in each station indicates in this figure.

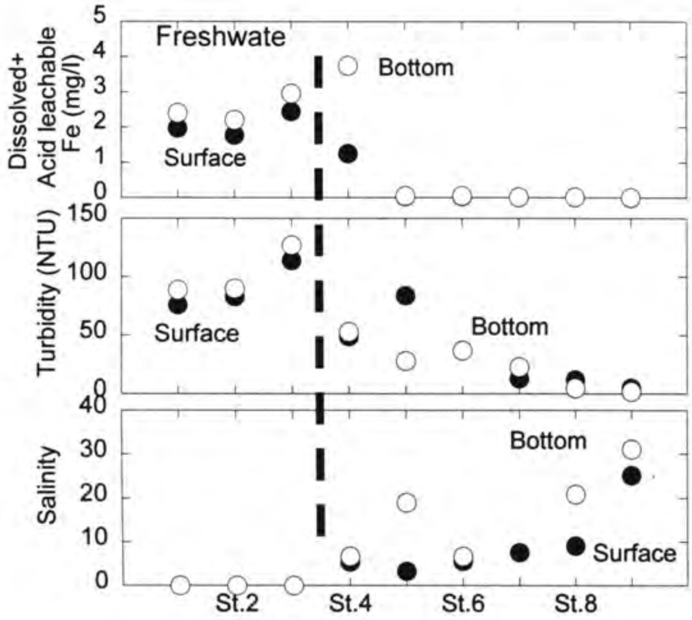

Figure 2 Turbidity, concentration of dissolved + leachable iron and salinity in estuary of the Amur River (St.1-3), Amur-Liman (St.4-7) and Sakhalin Bay (St.8-9).

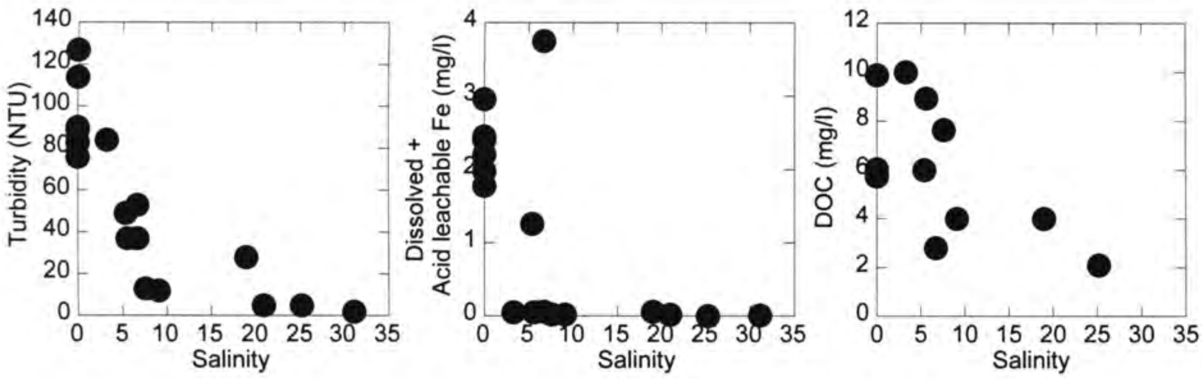

Figure 3 Turbidity, concentrations of dissolved + leachable iron and dissolved organic carbon (DOC) as a function of salinity.

HYDROCHEMISTRY OF BOGS AND RIVERS IN SWAMPED MASSIFS OF THE LOWER AMUR

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Bogs and swamped massifs are expanded in vast areas of the Amur Basin. Only in the Middle-Amur Plain they cover the area of 36 000 km^2. Studies of bog water chemical composition started in 1976 in the Evoron Lake Basin. They revealed certain regularities in the formation of bog water chemical composition and their dependence on biogeocenotic specifics of the bogs (Ivanov et al., 1979).

Further studies in the Middle Amur region, carried in 1987 – 2002, produced new data on the formation of bog water chemical composition, observations of seasonal dynamics of biogenic and organic substance content, identification of various factors that effect these substance concentrations in water (Ivanov, 1989; Ivanov, Shesterkin, 1989).

In spring, when snow starts to melt, the lowest values of mineralization and pH (up to 15 mg/dm^3 and 4.4 respectively) and the lowest levels of biogenic element concentrations are observed in bog water. At this time of the year iron concentrations in water do not exceed 0.3 mg/dm^3, ammonium ion concentrations – 0.20 mg/dm^3, phosphate ion concentrations – 0.02 mg/dm^3, organic matter (COD_{MN}) – 30 mg O/dm^3. Only water colority is increasing (> 100^o). Higher concentrations of these elements are observed only in bog areas damaged by fire. In the Kiinsky bog massif phosphate ion concentrations reached 1.78 mg/dm^3, iron concentrations – 0.39 mg/dm^3 and organic matter– 22.7 mg O/dm^3. Water colority in fire-burnt areas was 150^o and pH was 5.49.

Melting of the peat deposits at the beginning of summer causes the increase of organic matter and biogenic substance concentrations in bog water. Thus, in the bog massif near the Slavyanka village water colority at this time reaches 625^o, organic matter concentrations (COD_{MN}) are about 90.6 mg O/dm^3 and iron content is 2.68 mg/dm^3. With water temperature rising (> 29^o) biochemical processes in the peat deposits and leaf debris are accelerated and biogenic and organic substance concentrations in bog water increase significantly.

Observations, undertaken in the bog massif near the Slavyanka village in June – July 1990, revealed noticeable fluctuations of dissolved substance concentrations in waters there. The smallest concentrations were registered in the rainy period when bogs were rather full of water. Ammonium ion concentrations in water at that time changed within the range 1.08 – 2.29 mg/dm^3 and organic matter (COD_{MN}) varied within 31 – 77 mg O/dm^3.

Chloride and sulphate ion concentrations in water were little different from their concentrations in the atmospheric precipitation in Priamurje. Slavyanka massif data did not differ much from the data received during the field works in the bog massifs of the Evonon Lake Basin, implemented in 1977-1978. The data, collected in the Evoron Basin, showed pH values as low as 4.35 and increased levels of concentrations of organic matter (COD_{MN}) to 148 mg O/dm^3, ammonium ions –

to 4.5 mg/dm^3 and ion compounds to 25 mg/dm^3 (Ivanov et al, 1989; Shesterkina Ivanov, 1981). Following O.A. Alekin's (1970) classification according to their chemical composition bog waters in the Evoron Lake Basin are of the calcium group, the first class. Among the main ion group sulphate ion showed the lowest concentrations or was not detected.

In the dry period biogenic and organic substance concentrations were summer time maximal. Value of pH changed within 4.10 – 4.35, ammonium ion concentrations varied within 1.7 – 8.9 mg/dm^3, iron changed from 0.86 to 3.44 mg/dm^3, organic substance (COD_{MN} and COD_{CR}) values were within 118 – 156 mg O/dm^3 and 118 – 177 mg O/dm^3 respectively.

Studies, undertaken in autumn 1987 in a big bog massif between the rivers Manoma and Anui, also revealed marked differences in biogenic element distribution in waters of this massif (Shesterkin et al., 1989). Although pH (5.35 – 5.60) and mineralization (16 – 23 mg/dm^3) did not vary much, significant fluctuations were observed in iron concentrations (1.15 -7.64 mg/dm^3), ammonium ion concentrations (1.46 – 2.44 mg/dm^3) and organic matter (COD_{MN}) (41.1 – 70.6 mg O/dm^3). Similar concentration levels were registered before water freezing and in the bog massif near Slavyanka (Ivanov, Shesterkin, 1989).

In winter peat deposit freezing causes significant dissolved matter increase due to cryogenic concentration processes. Thus, in the Slavyanka bog massif iron concentrations reached 5.1 mg/dm^3 and organic substance content (COD_{MN}) increased to 199 mg O/dm^3 (Ivanov, Shesterkin, 1989). Water pressing out from the peat in some cases may cause even higher increase of dissolved substance concentrations, including iron. Water colority in the streams was up to 675^o and iron concentrations were about 29.4 mg/dm^3.

Waters of draining bogs, swamped areas and small rivers differ in chemical composition from bog waters. River waters in dry periods are characterized with high concentrations of ammonium ion (up to 12.6 mg/dm^3), iron (up to 4. 9 mg/dm^3) and organic matter (COD_{MN}) (up to 85 mg O/dm^3). Values of pH are not increased in these rivers.

Small rivers formed in areas of high swamping significantly effect chemical composition of big tributaries of the Amur River. Most noticeable is the bog impact in the Gorin River Basin. Hydrochemical research in this region was carried out in 1986-1987.

The Gorin River is one of the biggest tributaries in the Amur lower reaches. The river is 390 km long and the area of its basin is 22 400 km^2. When entering the Evoron-Chukchagirskaya Plain the Gorin River flows through a huge bog massif, formed by the Khurmulinskaya (500 km^2) and Kharpinskaya (866 km^2) maris. The rivers Khurmuli, Kharpin, Elgany and a big number of small streams, running right into the Gorin River, drain this bog massif. The area of bogs in the Evoron Plain is 2184 km^2, the water runoff is first directed into the Evoron Lake and further on through the Devyatka River reaches the Gorin River. The total share of bogs and swamped areas in the Gorin River Basin is 23%.

Many streams drain the Khurmulinskaya and Kharpinskaya maris. The biggest of them are the Kharpin and Khurmuly rivers with basin areas 2900 km^2 and 1940 km^2 respectively. Dissolved substance concentrations in these rivers do not differ much from the respective concentrations in bog waters (Table). The highest concentrations of biogenic substances are observed in Khurmuly water and in small streams without names. In the main ions group sulphate ion is not registered in these streams and chloride ion concentrations are low (less 0.5

mg/dm^3). Season specifics include maximal concentrations of biogenic elements and organic substance and minimal concentrations of mineral substances at the end of summer – beginning of autumn after the monsoon rains. At this time of the year organic substance discharge dominates the discharge of mineral substances. When the rainy period is long, chemical composition of water changes from hydrocarbonate-calcium to hydrocarbonate-magnesium and organic substance and iron concentrations decrease. Phosphate ions appear in water.

The flow of bog waters into the Gorin River causes significant changes of river water chemical composition. In the mountainous upper reaches of the river water is highly transparent and has low content of organic substances (4.6 mg O/dm^3). According to their chemical composition Gorin waters are classified as of the hydrocarbonate class, calcium group, I type [1]. In the main ion group chloride ion concentrations are low in this water and are similar to those in bog waters. Biogenic substance concentrations are also low. Ammonium ion and iron concentrations in this river passage do not exceed 0.33 and 0.36 mg/dm^3. After the Gorin River enters the Evoron-Chukchagirskaya plain and Devyatka River and other small streams, which drain the Khurmulinskaya and Kharpinskaya maris, add their waters to the Gorin, its water chemical composition sharply changes. Mineralization value drops from 40.4 to 33.1 mg/dm^3, ammonia nitrogen concentrations increase twice, ion increases 4.4 times and organic substance concentrations increase (COD_{MN}) 5.5 times.

Table.

Water Chemical Composition in Small Rivers of Swamped Massifs of the Gorin River Basin (in mg/dm^3 and mg O/dm^3).

Date	pH	Na^+	K^+	Ca^{2+}	Mg^{2+}	Cl^-	SO_4^{2-}	NH_4^+	Fe	COD_{MN}	M
Kharpin River											
30.08.87	-	2.1	0.6	4.4	2.9	0.3	0.0	1.73	1.49	37.3	48.2
Khurmuly River											
5.07.87	6.78	2.1	0.4	4.2	2.5	0.4	0.0	0.85	1.56	17.6	43.4
30.08.87	-	1.3	0.5	3.3	2.2	0.3	0.0	1.56	0.95	42.3	40.1
Bezymyanny stream											
5.07.87	7.10	2.4	1.0	-	-	0.6	0.0	1.33	4.24	18.6	-
30.08.87	-	1.3	1.0	5.2	3.2	0.4	0.0	1.37	4.94	51.5	-
Elgany River											
30.08.87	-	2.8	0.8	3.8	1.5	0.4	0.0	0.87	0.96	44.8	26.8
Pukka river											
5.07.87	6.65	2.7	0.6	-	2.0	0.7	0.0	1.33	2.10	19.8	-
30.08..87	-	1.7	0.6	2.8	1.7	0.3	0.0	1.86	0.87	-	28.0

The biggest effect on Gorin water composition bog waters produce in winter, when, due to the decrease of dissolved oxygen in water, concentrations of ammonia nitrogen and iron, mostly oxide, increase.

Thus, bog waters in the Lower Amur are characterized with increased concentrations of biogenic elements and organic substances and with low concentrations of the main ions. Bog water inflow into the river net causes the increase of river water colority, concentrations of ammonia nitrogen, iron and organic substances.

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STREAM FLOW DISTRIBUTION BETWEEN THE SUB-CHANNELS WITHIN THE MIDDLE-AMUR PLAIN

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The Amur River has the biggest drainage area among the Pacific rivers and flows on the border of nature zones. These river specifics together with a number of natural and anthropogenic factors determine unstable water runoff regime, river-bed process intensity, temperature and ice regimes peculiarities. That is why water and terrain Amur ecosystems are highly dynamic and weakly withstanding external (including anthropogenic) impacts. Intensive economic activities in the Amur Basin in the last 50-60 years sharpened many ecological problems.

The proportion of river flow between the sub-channels is mostly unstable within the flat areas, characterized with a wide floodplain and main river-stream division into numerous sub-channels. Even moderate economic activities in these areas cause the disturbance of the existing balance and redistribution of water flow between the channels (Chalov, Puleva, 2001; Chalov, 2001).

In is known that rivers near big cities suffer different impacts of water-related needs and activities. Different hydraulic constructions (embankments, dams, water reservoirs, etc.), river-bed straightening and deepening, material extraction from the river bottom for construction purposes significantly effect riverbed process dynamics. Besides, most anthropogenic impacts on the river take place near the cities and big towns as they pollute the river with industrial and sewage waters.

The Amur passage under our studies is situated within the Middle-Amur Plain, which stretches north-west for 650 km (between the Khingansky and Komsomolsko-Kiselevsky narrowings). Its maximal width is 200 km and total area is 92.3 thousand km^2. The Amur floodplain, up to 30 km wide, is in the center of the plain. The rest of the plain is covered with flat depressions of ancient lakes, plane patches of river accumulation and alluvial cones of big river drifts (Ussuri, Anui, Gur, Tunguska, etc.), inclined towards the river. The plain is spotted with separate high mountain massifs up to 950 m above the sea level, hilly uplifts with gentle slopes (near Pereyaslovka village, along the Amur from Knyaze-Volkonskoe village to Sarapulskoe village) and single hill outliers. Most of the plain surface is swamped (Encyclopedia.., 1995).

The Amur Valley from Khabarovsk to Komsomolsk-on-Amur is characterized with interchange of river narrowings and floodplain expansions, where the main river stream is split into numerous sub-channels of different configuration and size (Kim, Makhinov, 1991; Chalov, 2001). These peculiarities determine water regime specifics at different stages, such as flood wave spreading, intensive stream flow redistribution between the sub-channels, plain flooding regime.

Floodplain massifs undergo intensive erosion and accumulation processes. Lateral shifts of the riverbed, formation of sand bars and attachments to river islands, meandering of subsidiary channels, and sediment accumulation on channel banks contribute to the floodplain relief diversity (Makhinov, Kim, 1993). All these factors make the pattern of water stream redistribution very complex.

There are several floodplain expansions in the Middle-Amur Plain.

The present studies are focused on the three of them, situated near Khabarovsk, Amursk and Komsomolsk-on-Amur.

The floodplain expansion near Khabarovsk begins from the Khazakevicheva sub-channel juncture and ends at the bridge across the Amur at Khabarovsk. The Amur here has a wide floodplain (maximal width is 20 km), cut with many sub-channels. Upper and lower the expansion the floodplain is much narrower. The passage under study is characterized with several sub-channels and a big number of islands. The sub-channel system of this expansion is called the Khabarovsky hydrosystem.

Two big tributaries join the Amur in this expansion, namely the Ussuri from the right and the Tunguska from the left.

The last expansion within the Middle-Amur Plain is 35 m long with maximal width of 15 km. Near the City of Amursk the river splits into a great number of sub-channels of different water-carrying capacity. Besides the main Amur stream the biggest sub-channels are Padalinskaya, Old Amur, Galbon, Dippinskaya, Sandinskaya. The biggest tributary joining the Amur here is the Gur River. Big floodplain lakes, such as Bolon, Khummi, Ommi, Padali, Mylki, Khorpinskoe can be found in this expansion.

In 2007 the Amur water content was comparatively not high (Fig.1). After a rather low winter-low-water point (-150 cm above the "0" mark on the Khabarovsky water measuring station graph) the water level due to spring floods rose up to 224 cm by the end of May (May 31). Then a comparatively short (about 20 days) summer low water period was observed. Minimal water level dropped to -47 cm (July 19). Summer and autumn rain-flood period in August and September showed two peaks of moderate capacity (171 cm above the "0" mark on the Khabarovsky water measuring station graph, observed August 4 and September 7) and lasted for about a month and a half. Than the water level gradually and smoothly decreased and reached its minimum before the river-freezing.

Redistribution of the stream flow between the sub-channels is a rather complex process, especially in the Khabarovsky hydrosystem as the riverbed here undergoes constant morphologic changes. Constant expansion of the Pemzenskaya sub-channel is coupled with the Kazakevicheva sub-channel clogging and the Amur shallowing near Khabarovsk. In December 2005 dams were constructed on the Pemzenskaya and Beshenaya sub-channels reducing their water flow, especially in winter. Thus the water flow in the main stream increased, causing in some places bank washing out and river bottom deepening.

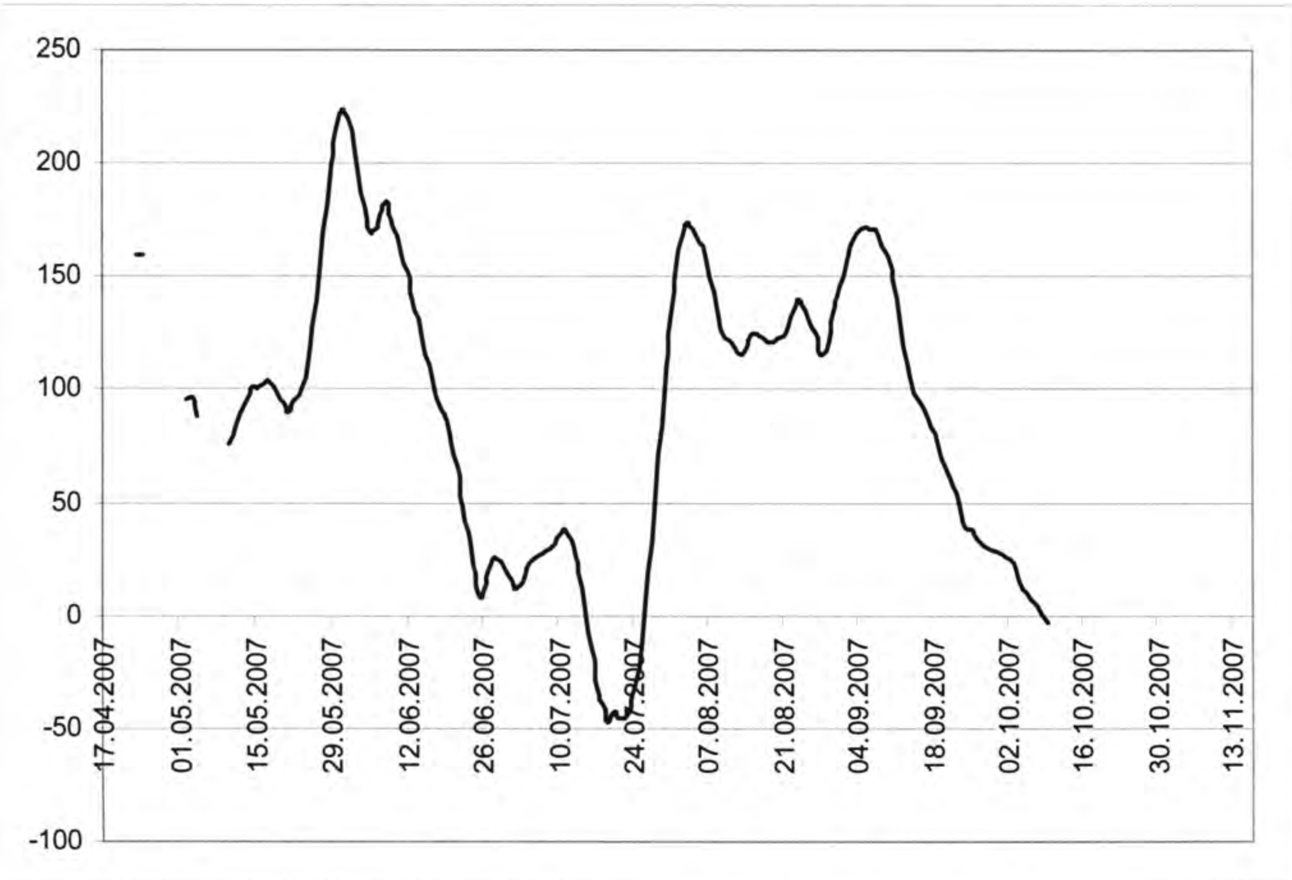

Fig. 1. A Graph of Amur Water Level Fluctuations near Khabarovsk in May – October 2007.

Water and bottom sediment sampling and discharge measuring were carried out in several Amur River passages in September 2007. Water discharge measurements are presented in Table 2.

Water discharge was measured in time flood decrease and its values are not high.

At Khabarovsky hydrosystem the biggest share of the stream flow (over 80%) belongs to the Amur main stream, where high water velocity values are registered (1.15 m/sec). 20% of the main stream flows through the Amurskaya sub-channel and velocity values reduce to 0.51 – 0.55 m/sec. Hydraulic engineering facility construction significantly reduced Pemzenskaya sub-channel flow but water velocity values remained high (1.19 m/sec). In the Beshenaya sub-channel the water flow was not noticeably reduced. Hydraulic engineering facility construction did not impact water runoff in the Amurskaya sub-channel.

In the floodplain expansion near Amursk the biggest share (57.7%) of the stream flow belongs to the main Amur stream. About one third of it is directed into the Padalinskaya sub-channel and a little more than 10% flows through the Old Amur, which is being intensively sedimented in the last decade. Maximal velocity values were registered in the main river stream (1.02 m/sec) and in the Padalinskaya sub-channel (1.00 m/sec). In the Old Amur sub-channel they reduced to 0.60 m/sec.

Table 2. Measured Hydrologic Characteristics

№	River, station	Water discharge, $м^3$/sec	Effective cross-section area, $м^2$	Mean water velocity, м/sec	Turbidity, g/$м^3$	Suspended matter discharge, kg/sec	Stream flow share, %
1.	Amur - 19 km	8710	7580	1.15	46.6	406	80.5
2.	Amurskaya sub-channel - mouth	1450	2830	0.51	28.3	41.0	13.4
3.	Chumnaya – sub-channel - mouth	666	1220	0.55	47.1	31.4	6.15
4.	Pemzenskaya sub-channel - lower the dam	3080	2580	1.19	32.0	98.5	28.5
5.	Beshenay sub-channel - lower the dam	820	1360	0.60	40.0	32.9	7.58
6.	Amur – Dippy village	7670	7490	1.02	48.4	371.2	57.7
7.	Padalinskaya sub-channel – Lower the entrance	4060	4050	1.00	44.3	180.0	30.5
8.	Old Amur sub-channel – Padali lake	1520	2520	0.61	63.1	96.1	11.4
9.	Unnamed sub-channel – Padali lake	152	279	0.54	26.8	4.07	1.14

Quite a long passage of the riverbed in the Amur lower reaches is formed in the conditions of evident riverbed transformations. This riverbed is of a multi-channel type and is characterized with several channels of different size and length that form a complicated hydrographic system. The morphological analysis revealed in the Middle-Amur Plain an interchange of river passages with highly split channels and passages with few channels, repeating every 40-50 km. Maximal width of the split-channel passage is 30 km.

The field research undertaken in 2007 and earlier data obtained by the IWEP FEB RAS on assessment of stream flow redistribution into sub-channels, river-bank dynamics near Khabarovsky hydrosystem and Komsomolsk-on-Amur, as well as suspended matter discharge allowed revealing new information on current conditions of riverbed processes in the middle and lower reaches of the Amur.

The construction of dams at the entrance of the Pemzenskaya and Beshenaya sun-channels changed the direction of the riverbed process dynamics near Khabarovsky hydrosystem. Still, due to high summer floods and the time after the dam construction being short, the changes of the riverbed and banks structure in the Amur main stream lower the hydraulic facilities are not significant. At the same time, a noticeable decrease of erosion processes below the dams on the Pemzenskaya and Beshenaya sun-channels is observed.

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BIOGENIC STUDIES OF POLICYCLIC CARBONS DISCHARGE FROM THE AMUR RIVER INTO THE FAR EASTERN SEAS

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INTRODUCTION

The Amur River discharges into the Far Eastern seas various chemical elements and organic substances. It is rather difficult to assess the impact that each biochemical component produces on the marine ecosystems. It is also hard to determine priority factors that regulate interrelations between production and destruction processes. Productivity of the Far Eastern seas depends on many abiotic and biotic factors and among them toxic substances, which impact is of noticeable importance for the development of primary producers (phytoplankton), energy transport though the trophic chains and for mechanisms of different-genesis organic substance destruction with the microbial complexes participation.

The priority task of the Amur-Okhotsk Project is to reveal factors that regulated the Okhotsk Sea productivity. An important focus is given to biogeochemical transport from terrestrial ecosystems to the Amur River and further on from the Amur to the Okhotsk Sea (Narita, Shiraiwa and Nakatsuka, 2004).

The guiding scientific concept is based on revealing regularities of iron ion impact on marine ecosystem productivity, including studies of biogeochemistry of iron in seawater and the role of riverine input from the Amur River to the estuarine mixing systems and coastal waters in the Okhotsk Sea. Special focus is given to the river discharge of suspended substances, which also include humic substances, i.e. stable organic substances of natural origin. Iron can dissolve as the complexes with humic substances and the suspended particles (Kuma, 2004; Terashima, Nagao, 2007). Suspended matter may also include other stable organic compounds.

There are many factors of the Amur River pollution with stable organic substances, including chlorine-containing pesticides, biphenyls and polycyclic aromatic hydrocarbons (Kondratjeva, 2005). The most significant factors are the transboundary pollution of the Amur from the neighboring Chinese territory, emission from electric power facilities and vehicles, forest fires and the Bureya dam, being filled in at present (Kondratjeva et al., 2007). Studies of water ecosystem pollution with polycyclic aromatic hydrocarbons (PAHs) are of great importance as these substances are highly toxic for organisms of all organization levels, can fully accumulate in hydrobionts and transport through the trophic chains.

SOURCES OF PAH PENETRATION INTO ECOSYSTEMS

At present PAH contaminate all biosphere components. They penetrate to the atmosphere with industrial wastes, exhausts of vehicles, emissions of power plants and forest fire smoke. Sources of PAH in water ecosystems are atmospheric precipitation, surface water runoff, and waste water discharge from oil refineries. Being transferred through the atmosphere PAHs contaminate soils, ground and surface waters. In spring a volley discharge of PAH accumulated in winter is formed due to snow and river ice melting.

Anthropogenic PAH are mostly the products of organic matter pyrolysis, including oil, coal, peat, shale, etc. Hundreds of cancerous and mutagenic active compounds are identified among anthropogenic PAH and their analogs. Indicators of industrial pollution are pyrene, fluoranthene, 1,12-benzperylene, 3,4-benzfluoranthene и 2,3-o-phenylenepyrene. 1,12-benzperylene prevails in internal combustion engine emissions.

Intensity of PAH transfer and their stability depends on the time of the year. In winter when much coal, wood and hydrocarbons are burnt such PAH as chrysene, benzperylene, benzfluoranthenes and anthracene are transferred through atmosphere and contaminate the snow cover. In summer phynanthrene, fluoranthene, pyrene, chrysene and benzperylene, present in rain waters, can be transferred with the surface runoff into water ecosystems, contaminate soils and be absorbed by plants (Rovinsky et al., 1988).

In bound state PAH can be transferred for long distances and distributed far from their sources of origin. During fires, when lots of smoke is produced and photochemical oxidation is reduced, the degree of ecological risks of PAH transfer to other regions and sedimentation on soil and water surface increases. Although carcinogenicity of PAH has not been proved for all these substances, it is known that all of them tend to accumulate in different organisms and are highly toxic. Moreover, PAH mixtures with other substances may increase toxicity of water media.

The World Health Organization (WHO) proposed 16 priority substances to assess ecological risks of PAH pollution, such as naphthalene, acenaphthalene, acenaphthene, anthracene, fluorene, phynanthrene, fluoranthene, pyrene, chrysene, tetraphene, 3,4-benzfluoranthene, 11,12- benzfluoranthene, 3,4-benzpyrene, 1,12- benzperylene, 2,3-o-phenylenepyrene, 1,2,5,6-dibenzanthracene. Due to WHO's recommendations PAH concentrations in drinking water should not exceed 0.2 mg/l (Maistrenko et al., 1996). There are no recommendations on total PAH content in fishing waters due to the possibility of their accumulation in various organs and tissue of hydrobionts. Some PAH substances cause endocrine system diseases, reproduction function disorders, pregnancy complications, spontaneous abortions, infantile mortality, new-born children pathology (abnormalities and genetic changes), mental retardation and children development anomalies. Adolescents under PAH impact can develop disorders of organs of sense, bone and muscular system, immune and hormone status and other functions.

STUDIES OF THE AMUR RIVER POLLUTION WITH PAH

Studies of PAH content assessment in Amur water lower Khabarovsk city were conducted in 2002 under the interdisciplinary project "Ecological crisis on the Amur and health conditions of indigenous peoples of the North" sponsored by a charity organization «Landesverband der Inneren Mission E.V.» (Munster, Germany) (Kondratjeva, 2005). Up to present difference nature conservation services and the Far Eastern Nature Resource Department did not monitor stable toxic substances in the surface waters of the Amur. The analysis of the seasonal pollution of the Amur River with PAH showed that in summer in the certain river passages lower Khabarovsk the total PAH content in water 10 times exceed their winter values.

In summer forest fires contribute much to the Amur pollution with stable organic substances. In 2002 research of natural water pollution with PAH was carried out based on highly efficient liquid chromatography following international standards (EPA 625). The analysis of seasonal contamination of the Amur River with persistent polyaromatic hydrocarbons revealed that in summer, at some sites of the River lower Khabarovsk, their overall concentration was 10 times greater than in winter.

All water samples collected in 2004 in the Amur from the Sungari juncture to Nickolaevsk-on-Amur revealed benz(b)fluoranthene. In fact, this hydrocarbon did not decompose and is discharged from the river to the Amur liman (Tab. 1).

Table 1. PAH Qualitative Composition in Water Samples, Selected in the Amur River and the Amur Liman in Summer 2004.

Sampling Sites	Dominating Compounds
1.Middle Amur (mouths rivers Zeya, Bureya, Sungari)	Benz(a)anthracene Benz(b)fluoranthene Chrysene
2. Lower Amur (from Khabarovsk to Nickolaevsk-on-Amur)	Naphthalene Anthracene Fluorene Phynanthrene Benz(b)fluoranthene
3. Amur liman (in the direction of the Okhotsk sea)	Naphthalene Phynanthrene Fluorene Benz(b)fluoranthene Benz(g,h,i) perylene
4. Amur liman (in the direction of the sea of Japan)	Anthracene Dibenz(a,h)anthracene Phynanthrene

As shown in Table 1 maximal PAH diversity occurs in summer time and most of them are discharged with the river runoff in the Okhotsk Sea direction. In river freezing time ¾ of the river runoff is directed to the Sea of Japan. At low temperatures the rate of stable organic matter transportation and destruction reduces. Thus is seems most important to study spatial distribution of PAH in the Amur Liman in winter and assess ecological risks of PAH transport into the Sea of Japan with the Amur runoff.

In August 2005 more detailed studies of Amur pollution with PAH were undertaken in the Amur tributary junctions from Blagoveschensk to Khabarovsk (Kondratjeva et al., 2007). Various combinations of PAH were identified in water samples collected at different hydrological stations. Most changes in PAH content were revealed in the transboundary river passages. For example, at the Sungari juncture anthracene and pyrene with concentrations of 0.014 ng/l prevailed at the left bank, which belongs to Russia, in the middle of the river they were lower the detection limit, where as at the left bank, which belongs to China (Heihe city), phenanthrene (0.032 ng/l) and anthracene (0.021 ng/l) were identified.

Even higher phenanthrene and anthracene concentrations were found in surface and bottom water layers at the Bureya juncture. There are lots of PAH potential sources in the Upper Bureya region, such as coal mines, coal combustion for power, swampy areas, flooding soils and forest vegetation to form Bureya dam. Our studies showed that phenanthrene and anthracene prevail in the Bureya mouth. They are supposed to originate from the water drainage area including the Bureya dam. Sunken wood also contributed to PAH migration into the water media. Less PAHs were carried with Zeya waters. Lower the Amurzet check point down the Amur River water samples revealed the dominance of anthracene.

TRANSBOUNDARY POLLUTION WITH PAH

Our studies showed that the Amur tributaries discharge different combinations of PAH (Kondratjeva et al., 2007). Thus, the Sungari discharged benz(b)fluoranthene in the highest amount (Fig. 1). Benz(b)fluoranthene mostly originates from petroleum and coal combustion, diesel and benzene engines work. It is known that oil refinery process results in production of phenanthrene, fluoranthene and benzene derivatives.

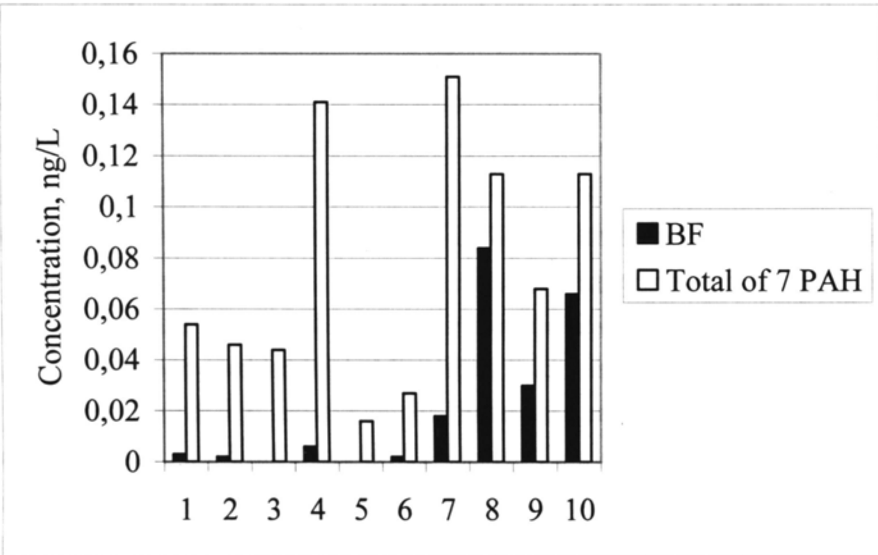

Fig. 1. Benz(b)fluoranthene (BF) content and the total content of 7 PAH components in surface water of different Amur river passages: 1- 2 km upper Blagoveschenck city, 2 – Zeya mouth, 3 - 1 km upper the Bureya juncture, 4 - the Bureya juncture, 5 – Amurzet check point, 6, 7, 8 - 4 km lower the Sungari juncture (left bank, middle, right bank), 9, 10 - 5 km upper Khabarovsk (middle, right bank).

PAHs were not revealed at the control stations (Amurzet). In the upper river passages it was found in micro admixtures. Most differences were found in samples, collected 4 km lower the Sungari juncture at the left (Russian) and right (Chinese) banks.

Additional data on the transboundary pollution of the Amur with PAH were collected after the technogenic accident at the oil refinery in China (Jilin city) in November 2005. The accident aftereffect analysis showed that the river water flow, contaminated with nitrobenzene, accelerated PAH concentrations. It happened due to PAH capacity to dissolve in water. In fact, this accident in China had a lot of inherent ecological aftereffect to be revealed in the long future and cause an unpredictable impact on the Sungari and Amur ecosystems. In this respect seasonal fluctuations of maximal ecological risks should be noted. In winter benzene was identified in ice and a part of toxic elements sedimented at the river bottom.

In March 2006 the Russian-Chinese monitoring of the Sungari basin revealed pyrene. Fluoranthene was identified across the river section with maximum values at the bottom layers. Twenty kilometers upper the Sungari juncture only naphthalene was revealed in the surface waters. Marked high concentrations of naphthalene were found in bottom waters at the middle of the river near the city of Fuyan (16.1 microg/l). It may be explained with PAH destruction in the bottom sediment layers and their migration into the water mass.

Three months after the technogenic accident it was found that water, ice and bottom sediments in the Sungari River were contaminated with PAH. Total content of 14 PAH components in surface waters upper Harbin city was 0.109 microg/l. High PAH concentrations remained up to the Sungari lower reaches. Lower the Sungari juncture near Nizhneleninskoe phenanthrene, pyrene and benz(b)fluoranthene were identified. Ice, most polluted with different ingredients, was near Tsyamusi city close to the right bank of the river. This ice contained many clay particles and had a strong smell. In this ice the highest concentration of total PAH (0. 348 microg /l) and maximal phenanthrene concentration (0. 131 microg /l) were observed. Components that were present in water during the nitrobenzene spill participated in the chemical composition of this ice. High concentrations (microg /kg) of such PAH as pyrene (31,4), perylene (26,6), benz(e) pyrene (24,4), chrysene (13,6), naphthalene (8,6) were revealed in bottom sediments of the Sungari River. In the Amur bottom sediments collected in the zone of the Sungari impact PAH concentrations were even higher. For example, perylene concentration was 128 microg /kg and benz(b+j)fluoranthene concentrations was 112 microg /kg. Bottom sediments lower the Sungari juncture had a high capacity to accumulate many toxicants including PAH, phthalates and trace metal ions.

After river freezing the main amount of benzene and PAH passed into water media. Thus in May 2006 fluoranthene and pyrene dominated in Sungari waters in the passage Harbin – Tsyamusi – Tuntsyan. Total PAH in the Amur upper the Sungari juncture was 0.015 microg /l. Lower the Sungari juncture PAH content at the right river bank was 0.036 microg /l (surface waters) and 0.021 microg/l (bottom waters). Most soluble in water PAH are not carcinogenic, but when exposed to ultra-violet radiation they transform to compounds highly toxic for water organisms and water fowl. That is why the number of potential risk factors due to the technogenic accident increased in summer.

BIOGENIC STUDIES IN THE AMUR LIMAN

Complex quality assessment of water in the Amur liman was carried out in August 1997. Significant differences in water quality formation were found between discharge directions into the Okhotsk Sea and the Sea of Japan. The major portion of organic matter of different origin and maximum phenol compounds content were identified in the main stream opposite the Orimif Island. Organic matter, difficult to mineralize, was found discharged more into the Okhotsk Sea than to the Sea of Japan. Higher content of labile forms of phenol compounds (0.009 mg/l) was also evident. Bioindication did not reveal labile nitrogen-containing organic matter in the water samples. Near the Pronge village (Sea of Japan direction) hydrobiologic water quality parameters were much better. In fresh and seawater mixing zone at the Sakhalin traverse water quality improves as compared to the Orimif Island area. Nevertheless, labile and persistent organic substances are registered. These though preliminary data allow concluding that in summer time River discharge cause active processes of organic matter production and destruction in the shallow Amur River liman. The main portion of persistent components is carried out in the Okhotsk Sea direction. A much lower self-purifying parameter is also registered here (Kondratjeva, 2004).

In 2004 the share of river discharge in pollution of marine areas with PAH was estimated with a bio-indication method. Water sampling stations in the Amur Liman were grouped according to river runoff distribution specifics in summer as follows: 1 group – the northern part with a maximal discharge of pollutants from the Amur; 2 group – the southern part with a minimal substance discharge in the direction of the Tatar Strait. Correlation analysis was used to study the interrelations between the structure of microbial complexes (TGB– total number of heterotrophic bacteria , AMB – ammonifying bacteria, NB– nitrifying bacteria, PhOB – phenol-oxidizing bacteria), which take part in different-genesis organic matter destruction and transport, and the content of easy-accessible carbohydrates in water (glucose – Gl), hydrocarbons (Hyd), naphthalene (Naph) and products of PAH transformation, i.e. salicylic acid (Sal), pyrocatechol (Pyr). It was revealed that in the zone of the main Amur runoff along the Northern waterway towards the Okhotsk Sea (Table 2) that the correlation between the total number of microorganisms (TGB) and their capacity to utilize salicylic acid, one of PAH transformation products, is high and positive (r=0.92). The correlations between the number of phenol-oxidizing bacteria (PhOB) and their activity to utilize salicylic acid and naphthalene, intermediate product of cyclic hydrocarbon transformation were as high as r=0.99 and r=0.93 respectively and the correlation between the bacteria growth rate in naphthalene and its transformation product pyrocatechol was r=0.92.

Such results give grounds to confirm that the Amur River discharges various aromatic compounds of phenol group, including products of microbiologic transformation of PAH. It is shown with PhOB growing in number, their capacity to destruct and transform PAH in model systems. Correlations with hydrocarbon pollution were not revealed. This factor turned out to be less important for microbiocoenose development.

In the southern part of the Amur Liman biochemical processes significantly differed from those in the Northern waterway (Table 3). First of all, a high correlation (r=0. 83) between the total number of microbial complexes and their growth rate on glucose. It may be associated with an intensive growth of autotrophic organisms (phytoplankton and macrophytes) in shallow water, as well as with their excretion products of carbohydrate nature. High correlations between PhOB growth in number and their capacity to grow on pyrocatechol (r=0. 99) and salicylic acid (r=0. 99) were also registered. Pyrocatechol and salicylic acid may result from the destruction of aromatic compounds of autochthonic origin and of PAH that belong to suspended matter, accumulated in bottom sediments. When water sampling was carried out navigation, especially open-coal shipments, was very active in the Tatar Strait. Anthracene, found in water, indicates atmospheric transfer of coal dust that explains its presence in suspended matter.

Table 2. Matrix of Correlations between Microbial Complex Structure and their Activity on Different Substances in the Amur Liman North

	TGB	AMB	NB	PhOB	Hyd	Sal	Naph	Pyr	Gl
TGB	1,00								
AMB	0,98	1,00							
NB	0,99	1,00	1,00						
PhOB	0,84	0,70	0,74	1,00					
Hyd	-0,74	-0,57	-0,62	-0,99	1,00				
Sal	0,92	0,81	0,84	0,99	-0,94	1,00			
Naph	0,58	0,38	0,44	0,93	-0,98	0,85	1,00		
Pyr	0,22	-0,01	0,06	0,71	-0,82	0,59	0,92	1,00	
Gl	0,44	0,63	0,58	-0,11	0,28	0,05	-0,47	-0,78	1,00

Table 2. Matrix of Correlations between Microbial Complex Structure and their Activity on Different Substances in the Amur Liman South

	TGB	AMB	NB	PhOB	Hyd	Sal	Naph	Pyr	Gl
TGB	1,00								
AMB	0,97	1,00							
NB	-0,89	-0,74	1,00						
PhOB	-0,81	-0,94	0,45	1,00					
Hyd	-0,65	-0,43	0,93	0,08	1,00				
Sal	-0,71	-0,87	0,30	0,99	-0,08	1,00			
Naph	-0,92	-0,78	0,99	0,52	0,90	0,37	1,00		
Pyr	-0,83	-0,94	0,47	0,99	0,11	0,98	0,54	1,00	
Gl	0,83	0,65	-0,99	-0,35	-0,96	-0,19	-0,98	-0,37	1,00

A positive correlation between hydrocarbon content in water medium and active transformation of naphthalene (r=0. 90) proves that water in contaminated with hydrocarbons and PAH from the sea vessels.

The method of initiated communities was used to assess potential capacity of water microbial complexes (MC) to transform PAH. Naphthalene and phenanthrene was added to a sterile mineral solution M9 (10mg/10ml). Surface water from the Amur Liman was used as inoculum. Solution colority changes (600 nm) and biomass accumulation (490 nm) served as indicators of transformation intensity. Cultivation temperature was 23-25°C. The experiment lasted from 30 to 140 days. Numerous PAH, discharged into the Amur from its tributaries, especially those combined with suspended matter do not fully transform in the mainstream and are discharged in the Amur Liman. MC from the Amur Liman revealed 2 phases of phenanthrene transformations: colority changes were observed in the first 30 days and biomass accumulation took place in the next 100 days. This not only proves PAH transformations, but also indicates intermediator utilization. Pyrocatechole and hydroquinone analogs were identified in colored products. MC adapted to naphthalene grew well on pyrocatechole. Most active were MCs from shallow water areas, where suspended matter from the Amur River sediments.

CONCLUSION

Thus, Amur River pollution with stable polycyclic aromatic hydrocarbons is caused by various anthropogenic factors. Mort significant are forest fires, Bureya river runoff and transboundary transfer of PAH with water and suspended substances from the Sungari river, most dominant of which are being of the anthropogenic origin. There are zones of PAH accumulation in bottom sediments lower the Sungari juncture and in the Amur lower reaches. Most PAH slowly decompose in bottom sediments and their decomposition products penetrate into water media and form sources of chronic pollution of water ecosystems with aromatic substances. Most stable PAH migrate throughout the entire Amur stream, come to the floodplain lakes and are discharged into the sea areas. Considering a high biological activity of polycyclic aromatic hydrocarbons it is vitally important to implement deep and detailed studies of fish resources state in the Amur lower reaches, the Amur Liman and bio-productivity of the Okhotsk Sea, as there is a significant threat of toxic organic substance accumulation in organisms and transport through the trophic chains. They constitute a high risks for hydrobionts, birds, animals and health of people.

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SPECIFICS OF ORGANIC SUBSTANCE GEOCHEMICAL MIGRATION AND PHYTOPLANKTON DISTRIBUTION IN THE SYSTEM AMUR RIVER – AMUR LIMAN

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Keywords: river and sea waters, organic carbon, bacteria plankton, bacteria benthos

1. INTRODUCTION

Organic substances (OS) are inseparable components of natural waters. Their composition and concentration in natural waters are determined with a complex of many processes of different nature and rate. Being genetically connected with natural waters organic substance serves as an indicator of water processes and water quality and effects the intensity of life processes in the water object. The presence of organic substances in natural waters is the main living condition for most organisms in various water objects, including lakes, rivers, and seas. There are no ecosystems in biosphere, which are absolutely independent from neighboring ecosystems. That is why there is a constant exchange of organic substances between these ecosystems. At the same time the amount of migrating organic matter is much less than that accumulated in the ecosystems, especially marine ecosystems (Humitake Seke, 1986). Organic substances in ecosystems undergo constant transformations while organisms are alive and produce energy, using organic substances.

Organic substances, dissolved in marine water are qualitatively less diverse than in land water objects. Marine surface water layers are the areas where a process of primary OS regeneration is extensive, similar to vegetation regeneration process in land areas (Datsko, 1959). Further development of other marine living forms depends on the intensity of primary product production, in which phytoplankton- synthesizing and hemo-synthesizing bacteria take part.

The studies of the system "river – liman – sea" will allow revealing mechanism specifics of OS transformation and transport from rivers to seas and oceans. OS behavior specifics in boundary areas have been studied by many scientists both in Russia and other countries (Almazov, 1962; Artemjev, 1993; Environmental Biogeochemistry, 1983 and others).

The aim of this paper is to assess OS concentrations and OS formation regularities in the surface waters in the system "the Amur River – the Amur Liman".

2. RESEARCH OBJECTS AND METHODS

The research was implemented in June 2007 under the Project of the Far Eastern Branch of the Russian Academy of Sciences "Complex Field Research of Natural Environment in the Amur River Basin (2004 – 2008)". As it was carried out in the Amur Liman, the

Tatar Strait and the Sakhalin Bay, it made possible revealing certain specifics of organic carbon discharge with Amur waters into the Amur Liman.

Water was sampled in the surface water layers (0.5 m) in the Amur estuary and in the area of river and marine water mixing, following the adopted sampling site plan as shown in Fig. 1. Organic substance concentrations were analyzed in 23 water samples and various microbiological parameters were analyzed in 19 samples.

Water samples were filtered on board of the research vessel "Professor Gagarinsky" through 0.45 mcm-pore Whatman filters and dissolved organic carbon (DOC) was measured in the filtrate. Then samples were frozen and transported for further analyses to the Institute of Water ad Ecology Problems FEB RAS. Total organic carbon (TOC) and DOC were measured with standard methods for chemical analyses of natural water (Datsko, 1959; Alekin, 1977). Bulk content of organic matter was estimated by multiplying TOC by the coefficient K = 2.

Microbial analyses included such parameters as total number of bacteria (TNB), number of heterotrophic bacteria (HB), saprophytic bacteria (SB), oligocarbophytic bacteria (OB) on standard mediums (Handbook…, 2005). To analyze samples from the river and sea water mixing areas microbial plantings were in media of similar composition with a 3% marine salt additive. Counts were expressed with the number of colony-forming units (CFU) of microorganisms in 1 ml of water.

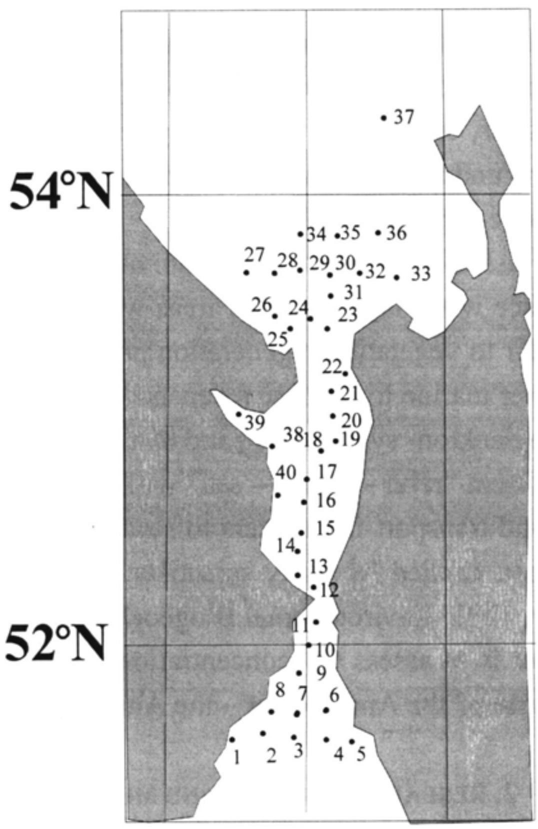

Fig. 1. Water Sampling Station Scheme

3. RESEARCH RESULTS AND DISCUSSION

Organic carbon in studied waters was present mostly in the dissolved form (77.0-97.7%, 90% TOC at average). DOC values varied from 2.1 to 8.4 mg L^{-1} and the mean value was 5.0 mg L^{-1} (Fig. 2). The highest DOC content was registered in the Amur estuary (St. 38-40) and is caused by the river discharge. The area of desalinated water with maximal content of OS of river origin vastly stretches from the Amur Estuary in the north-east direction towards the Okhotsk Sea (from St. 38-40 and further on to St.24). The curve of DOC distribution in the studied waters does not correlate with the desalination line.

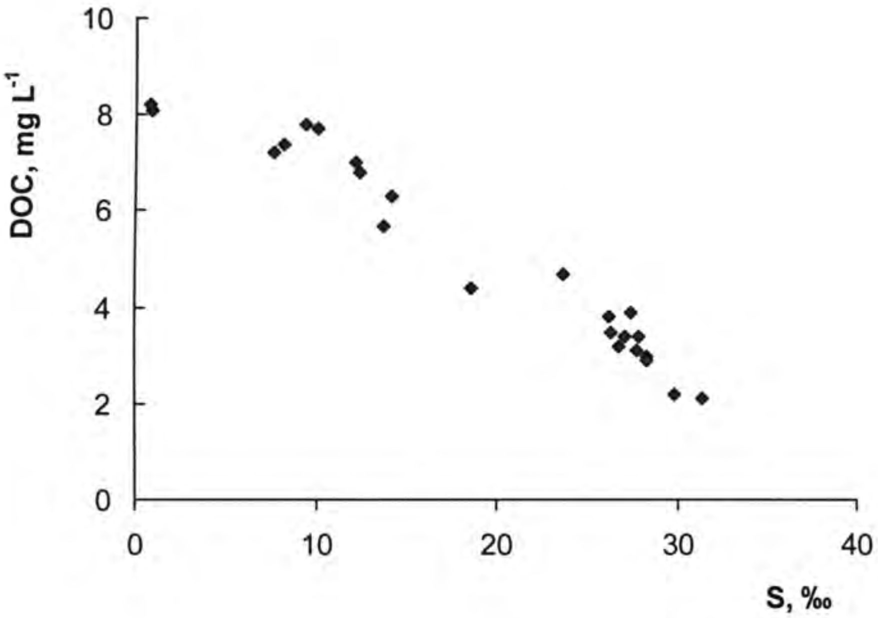

Fig. 2. DOC in the Surface Water Layer in the Amur Liman, the Tatar Strait and the Sakhalin Bay in Correlation with Water Salinity in June 2007. *Note* - salinity at 1-2 m depth*

Due to biogeochemical, and mostly physical and chemical processes (flocculation – adsorption – desorption) on all stages of river and sea water mixing, dissolved (DOS) and suspended organic substances (SOS) undergo inter-changing processes. Most intensive DOS changes into SOS occur in the Amur Liman under water salinity 6-12‰. With salinity increase these processes become more equal.

Microbial analysis showed that TNB fluctuated between 0.62 and 2.83 million cells ml^{-1}. Minimal TNB values were registered in the Tatar and Nevelskoy Straits and near the Chastye Islands. Maximal TNB values were registered at the Station 24, where the Amur stream continues in the direction of the Okhotsk Sea, and lower Nickolaevsk-on-Amur. Areas adjoining the estuary are characterized with big quantity of bacterioplankton that plays the key role in utilization of organic substances discharged from the river.

Table 1. Number of Heterotrophic Bacteria in the Surface Water (counts on standard media)

Station №	TOC, мг L^{-1}	TNB, million cells ml^{-1}	Number of microorganisms, 10^3 CFU ml			SB/HB	HB/SB	TNB/SB 10^3
			SB	HB	OB			
15	4.5	0.89	1.97	0.3	0.08	6,6	0,15	0.45
16	6.0	0.96	0.07	0.7	3.3	0,1	10.0	13.70
17	8.4	1.02	0.17	5.7	-	0,03	33.5	6.00
18	8.3	0.91	0.18	0.3	4.2	0,04	23.9	5.06
22	7.8	1.47	0.18	0.7	8.0	0,01	98.3	8.17
24	7.5	2.84	0.10	0.3	7.4	0,06	16.0	28.40
29	5.9	1.02	0.29	1.2	0.4	0,24	4.1	3.51
32	3.3	1.03	0.06	1.5	0.2	0,04	25.0	17.17
36	7.9	1.23	0.73	0.7	0.4	1,04	0.96	1.68
38	10.9	1.37	0.04	0.9	1.1	0,04	22.5	34.25
39	10.1	1.63	0.26	2.2	5.3	0,09	8.5	6.37
40	11.3	1.08	0.28	0.75	0.6	0,37	2.7	3.86

Number of HB, counted on RPA:10 medium, fluctuated within the range 0.3 – 17.7 thousand CFU ml^{-1}. Maximal values were observed at Station 22 and may be associated with the impact of surface runoff from the Sakhalin Island. High values of GB number were also registered at Stations 17 and 18. The number of OB that utilize low OS concentrations fluctuated from 008 to 8 10^3 CFU/ml. Maximal number of SB, which react to high concentrations of weakly decomposed OS in water, was found at Station 15 near the Chastye Islands. In surface water, sampled at other stations, the number of this bacteria group was much less. SB/HB ratio in water sampled at this station significantly exceeded this coefficient value at other station, including Stations 16 – 18, situated along the Amur water flow. This fact indicates that possibly weakly-decomposed organic substances come with water runoff from the islands and not with Amur water. The reverse ratio HB/SB, which characterizes the eutrophication level, was lower 4 only at Stations 15, 36 and 40. This is characteristic for eutrophied ecosystems (Margolina, 1989). The situation in the sampling period at Stations 15 and 36 seems to be caused with incoming of weakly-decomposed organic substances. According to the State Standard 17.1.3.07 – 82 (State Water…., 2001) the water in the desalination zone studied is ranked quality-class II. Minimal ratio CFU/SB was registered at Station 15, although TOC values were relatively not high. This fact may be associated with effective microbiological utilization of organic substances. Number of halotolerant forms of SB fluctuated between 01. 10^2 – 4.38 10^3 CFU/ml. Maximal bacteria numbers were registered at Station 15 and in the direction of the Okhotsk Sea at Stations 29 and 36 (the Sakhalin Bay) (Table 2). It is caused with specifics of SB monoculture growth and stimulating effect of marine salt.

Table. 2. Number of Indicator Halotolerant Heterotrophic Bacteria in Surface Water (count on medium with a marine salt additive)

Station №	TOC, мг L^{-1}	TNB, million cells ml^{-1}	Number of microorganisms, 10^3 CFU ml^{-1}			SB/HB
			SB	HB	OB	
3	4.1	0.75	0.4	0.20	0.02	0.20
6	3.8	0.62	0.01	0.20	0.03	0.05
7	3.0	0.84	0.02	0.12	0.06	0.17
8	3.7	0.95	Not identified	0.20	0.05	Not identified
11	3.6	0.94	0.08	0.40	0.07	0.20
12	3.3	0.84	Not identified	0.25	0.02	Not identified
15	4.5	0.89	4.38	16.20	0.98	0.27
16	6.0	0.96	0.05	0.90	0.06	0.56
18	8.3	0.61	0.15	3.20	0.09	0.05
22	7.8	1.47	0.13	0.90	1.10	0.14
24	7.5	2.84	0.17	0.30	1.00	0.57
25	3.5	1.08	0.23	0.90	0.02	0.26
29	5.9	1.02	1.91	2.30	0.11	0.83
32	3.3	1.03	0.86	3.10	Not identified	0.27
36	7.9	1.23	1.55	3.80	0.04	0.41

Maximal number of halotolerant HB was registered at Station 15 and at Stations situated in the Sakhalin Bay. SB/HB ratio reveals a significant role of HB in OS utilization.

4. CONCLUSION

The Amur discharges into the Amur Liman organic substances mostly in a dissolved form. At different stages of fresh and salt water mixing water dilution proper does not take place, and transformations of dissolved into suspended substances and reverse transformations take place. Besides, OS accumulation might also take place in the Sakhalin Bay part that adjoins the Amur Liman.

According to the microbial population response the total phytoplankton quantity in 2007 reached 2.68 million cells ml^{-1}. According to microbiological indicators only water at Stations 15, 36 and 40 in the sampling period corresponded to eutrophied water objects. Bacterioplankton quantity depends on river runoff, Amur water level and peculiarities of fresh and salt water mixing. Bacteria, which utilize organic substances of low concentrations, played the main role in utilizing OS in the Amur Liman waters. This is associated with composition specifics of suspended organic substances discharged from the river. SB played a significant OS utilization role in areas, where weakly-decomposed OS are discharged with the river runoff (near the Chastye Islands).

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BIOGEOCHEMICAL BEHAVIORS OF DISSOLVED IRON IN SANJIANG PLAIN, CHINA: DISCHARGE, CHEMICAL FORMS, AND YEAR-TO-YEAR VARIATION

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1. INTRODUCTION

Water-logged conditions can be an important terrestrial Fe source to aquatic environments by promoting iron dissolution due to reduction. The results of our research in 2005 and 2006 in the Sanjiang plain has shown that high concentration of dissolved iron is present not only in natural wetlands but also in paddy field. However, it remains ambiguous whether paddy field actually acts as an dissolved Fe source to discharge it downstream, where water movements are strongly controlled by farming practices. When little of water be drained out of paddy field, it cannot play a major role even if its water contains high concentration of dissolved Fe. Thus, the actual hydro-biogeochemical situation was studied in paddy fields in Sanjiang plain by 1) a door-to-door investigation about water management practices from farmers and 2) a measurement of water infiltration rate into paddy soil.

Additionally, we show here the results about a possible importance of colloidal Fe as a chemical forms of dissolved Fe, which we have not determined previously, and about a large year-to-year variation of dissolved Fe concentration in a wetland site between 2005 and 2007 probably affected by an annual hydrological regime.

2. MATERIALS AND METHODS

A door-to-door investigation about water management in paddy field

We visited a wide range of paddy fields in the Sanjiang plain in the beginning on June, 2007 (15 places) and in the end of August (4 places) (Fig. 1). The way of farming practices in respective paddy fields was surveyed by interviewing farmers, particularly on water managements.

Measurement of water infiltration rate in paddy field

Water infiltration rate, an important indicator frequently used to represent the water permeability of paddy field when flooded, was measured by a simple method. Paddy soil under water surface was covered with a small chamber. A decrease in water volume in this closed system resulting from water infiltration was measured volumetrically; a change in water volume with time was monitored using a measuring pipette. The infiltration rate (V mm d^{-1}) is calculated from the following equation:

$$V = 1440 \times (y \times a) / (t \times A)$$

where y, a, t, and A are a change in water level in pipette (mm) over the measurement period of 2 minutes, the cross sectional surface area of the pipette (cm^2), the time for measurement (min), and the cross sectional surface area of the cylinder (cm^2), respectively. The value 1440 is a coefficient to convert data from minute basis to day basis (60min＊24h).

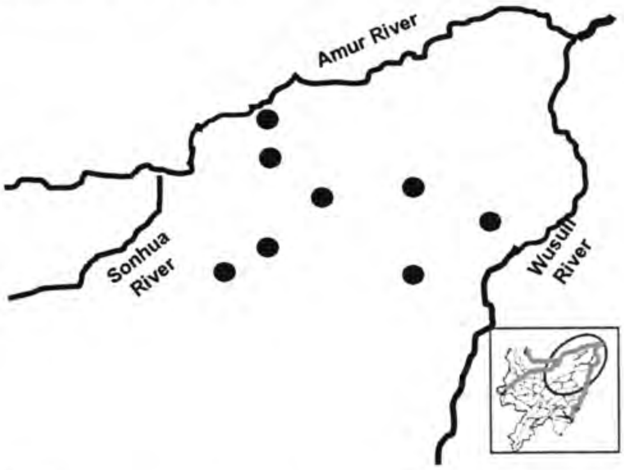

Fig. 1
Location of paddy field sites in Sanjiang plain, China, where door-to-door hearing was conducted

Research about soil interstitial water and surface water in natural wetland

The soil interstitial water and surface water was sampled at the Sanjiang wetland ecological experimental station (47°35'N, 133°31'E) in August, 2007. The soil interstitial water was collected from the depths of 10cm, 50cm with a tension lysimeter technique, and surface water (0cm) was collected by a plastic bottle directly. Chemical analyses were made by the methods described in our previous report.

Iron chemical methods about colloid and other forms

Fractionation and respective analytical methods of iron species are illustrated in Fig. 2. Colloidal Fe is measured as follows; after a filtration with a 0.45μm disposable filter, water sample was acidified (1mL conc. HCl /100ml) and then filtered with a molecular weight cut off of 50,000 disposable filter. It is assumed that colloidal Fe has MW more than 50,000 and consequently removed by this filter, whereas organic-bound Fe is expected to have MW less than 50,000 and pass through it. The filtered water sample was preserved in a glass vial pre-burnt at 550°C and analyzed with an atomic absorption photometer (HITACHI, Ltd.Tokyo Japan. Z-8000). The colloid Fe concentration was calculated from the difference with and without filtration by MW 50,000 cut-off filter.

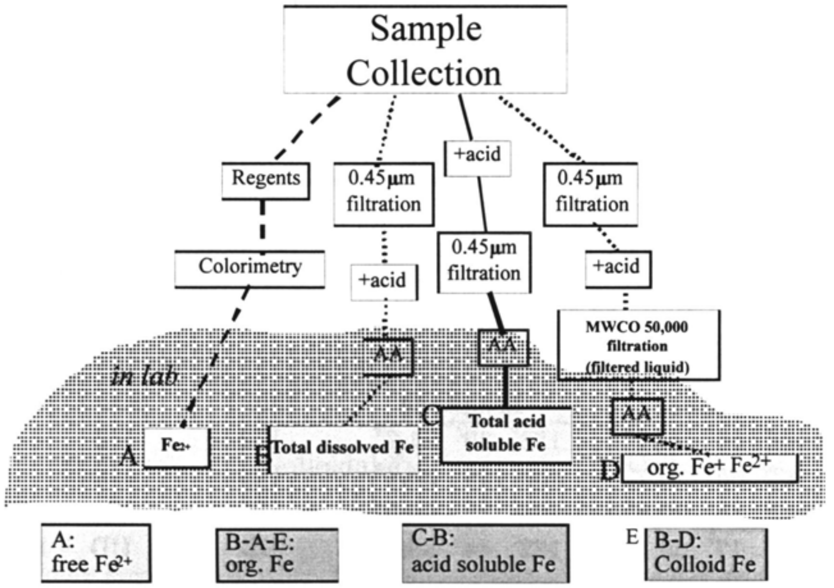

Fig. 2
Fractionation and analyses for Fe species

3. RESULTS AND DISCUSSION

Water dynamics in the paddy field

Major information collected through a door-to-door investigations to farmers are as follows. Of the total 19 rice paddies surveyed, only one farm (the "859 Farm") uses river water; most of farms (18 among 19) use groundwater as an irrigation water. Most of the farms pumped groundwater up from of depth of approximately 40 m to 50 m. Electric pumps were used to pump out the groundwater. Paddy fields of "859 Farm," the only farm to use river water, were located close to the Wusuli River with a distance of approximately 17 km.

The agricultural practices common in Japan, namely mud leveling (late April), intermittent drainage (mid-June to early July), and drainage (late August to early September), are also common in paddy fields in the Sanjiang Plain. But a noticeable difference from Japan is a re-use of paddy water; in many farms, the drainage channels are blocked to store overflowing water, except on an occasion of heavy rain. Flowing irrigation technique, as often in Japan, is not applied to paddy fields in Sanjiang Plain. Irrigation is carried out just to supplement paddy water decrease due to evapotranspiration. Efforts to reuse surface water and efficient use of rainwater as much as possible arise from a motivation to reduce ground water pumping. Such a situation to save irrigation water suggests that outflows of surface water from paddy fields are basically quite limited.

The measurement of infiltration of paddy water beneath the soil showed that water infiltration was extremely low at any sites (Tab. 1). This situation stands to reason when considering an intrinsic small hydraulic gradient and a prevailing low-permeable clay layer in the soil. This result suggests that discharge of surface water from paddy field through underground can be regarded negligible in this region.

Results from the above studies represent that there may be little way for surface and soil water to go out from paddy fields in Sanjiang plain, with an exception of flooding period. Thus, it is suggested that the transport of dissolved Fe into rivers is fundamentally restricted in paddy fields even if its water would have high iron concentrations. It is expected that the land use change from wetlands to rice paddies contributes to significantly lower the source intensity of dissolved Fe.

Table 1. Water infiltration rate in paddy fields measured at four farms in Sanjiang plain (June, 2007)

Farm No.	Latitude	Longitude	Site 1	Site 2
1	47° 35′ 29.7″	133° 39′ 24.7″	UD	UD
2	47° 35′ 29.7″	133° 39′ 24.7″	UD	UD
3	47° 35′ 20.8″	133° 29′ 58.0″	UD	UD
4	47° 17′ 35.1″	132° 44′ 35.0″	UD	UD

UD: under the detection limit (≤ 0.2mm d^{-1})

Dissolved iron concentration and forms in the soil interstitial water

Chemical analysis of total dissolved Fe in surface water and soil interstitial waters in wetland sites showed that the concentration was highest at a depth of 10cm and was decreased at depths of 0 cm and 50 cm. In contrast, acid soluble iron concentration was highest at a depth of 0cm (surface water) and drastically decreased with the increase in soil depth. Such patterns found for different Fe species were essentially the same as those observed in 2005 and 2006, enabling us to confirm the trend of vertical profile for dissolved iron in wetlands.

In 2005 and 2006, three dissolved Fe species were analyzed: total dissolved Fe, organic-bound Fe and free Fe^{2+}. In 2007, in addition to the above species, colloidal Fe was also analyzed. The result of relative proportion of dissolved Fe species (free Fe^{2+}, colloidal Fe and organic-bound Fe) in a wetland site is shown in Fig. 3. Colloidal Fe comprised approximately 80% of dissolved Fe, while organic-bound Fe and free ferrous iron accounted for only 15% and 5%, respectively. It was found from the analyses in 2007 that dissolved Fe is dominantly present as colloidal Fe at any depths in a wetland site.

The vertical distribution of total dissolved iron concentration in wetland in summer period is compared among 2005, 2006, and 2007 in Fig. 4. The overall level of dissolved Fe was appreciably higher in 2006 than in 2005 at the identical wetland site. The annual precipitation and monthly precipitation in August are both higher in 2006 (630 mm and 172.5mm) than in 2005 (480 mm and 126.2mm). The dissolved Fe level in 2007 was also comparatively high, being nearly equivalent to that in 2006. The precipitation data has not yet been available for 2007, but the water level was appreciably elevated on the period of this observation. The results thus suggest that dissolved Fe concentration in surface and interstitial water in a wetland site could vary, possibly affected by the hydrological regime.

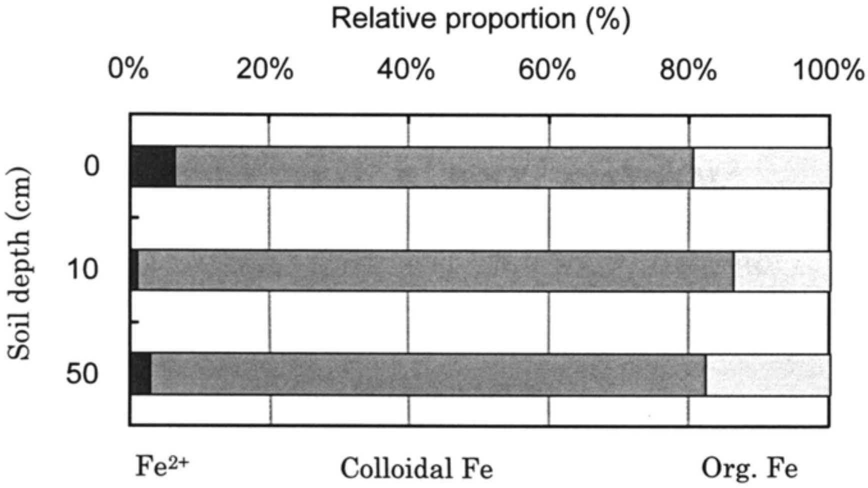

Fig. 3
Relative proportion of three dissolved Fe species as a function of depth in a wetland site (August, 2007)

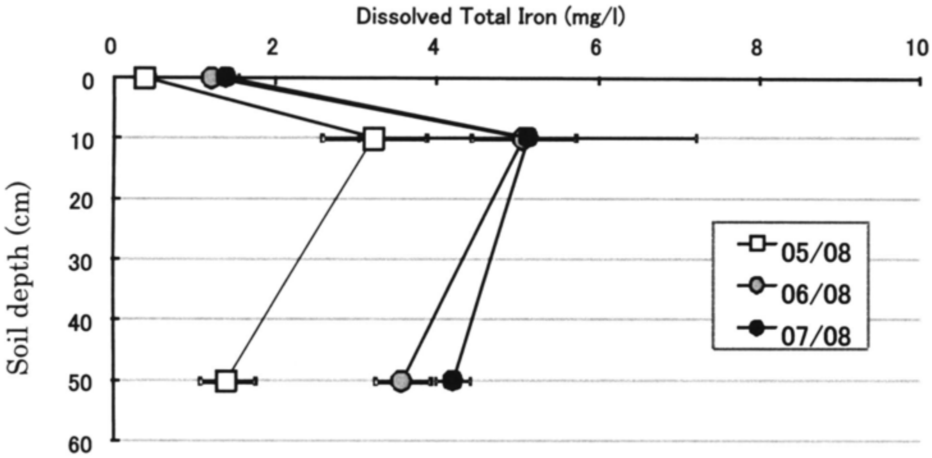

Fig. 4
Comparison of vertical distribution of total dissolved Fe in a wetland site in summer among different years

EFFECT OF LUCC ON CONCENTRATION OF IRON IN AQUATIC SYSTEMS AND FLUX OF VARIOUS FORMS IRON IN MAIN RIVERS IN THE SANJIANG PLAIN

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INTRODUCTION

Iron in river waters is one of most primary sources for ocean iron. Wetland and groundwater are important source of dissolved iron due to the reduced condition. Now, Land use and land cover change has changed environment of wetland and groundwater greatly. So, LUCC plays an important role in affecting the concentration of iron in river waters in the Sanjiang Plain. With the rapid development of drainage channel system and reclamation of marshes to upland and paddy land in the past 50 years, cultivated land area has been increasing to 5.24Mha in the year of 2000 from about 0.79Mha in the year of 1949. Accordingly, the wetland area was decreased to 0.84Mha in the year of 2000 from 5.35Mha in the year of 1949 (Liu, *et al.*,2000; Li, *et al.*,2002). The change of marsh land was showed in Fig.1.The rapid expansion of agriculture over the past 50 years has radically changed LUCC. This conversion of natural vegetation to managed agricultural systems has not only reduced biodiversity and impacted regional climates, but also altered biogeochemical cycle. In particular, LUCC and the expansion of modern agricultural practices has significantly increased leaching of chemicals to the surface waters, that will lead to the degradation of aquatic ecosystems worldwide (Matson *et al.*, 1997; Carpenter *et al.*, 1998). Therefore, the Sanjiang Plain has become a representative region in China and East Asia to understand the influence of LUCC both in degree and extent on dynamics of transport mechanism and biogeochemical cycle of iron and other elements.

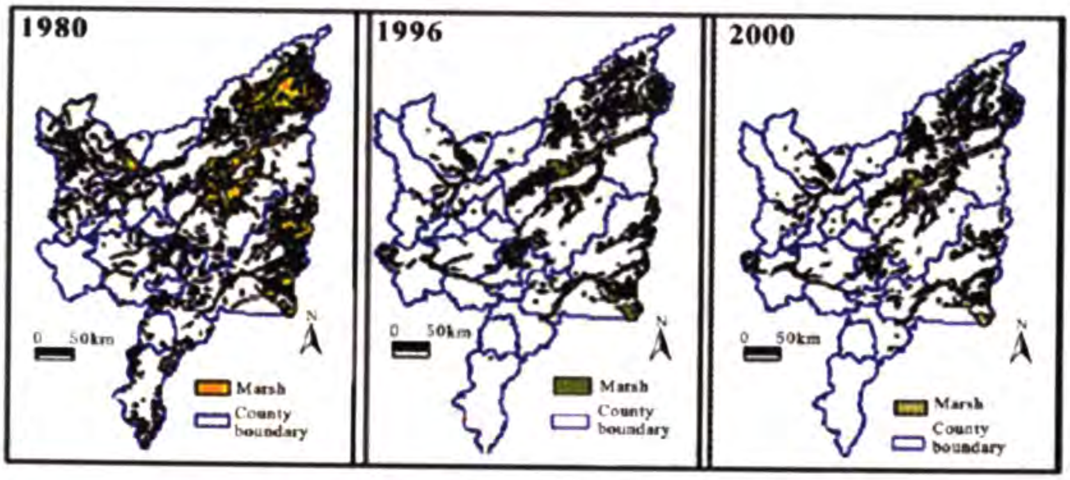

Fig. 1 Change of marshy wetland in Sanjiang Plain

Iron is an essential micronutrient for almost all organisms. In cells, iron can exist in more than one oxidation state, and catalysis of redox reactions and electron transport are two major functions of iron containing enzymes. Iron is present in the active centers of cytochromes and iron-sulfur proteins, e.g., ferrodoxin, which are important components of the photosynthetic and respiratory electron transport chain (Butler, 1998; Falkowski, 1997; Sunda, 1991). Iron has been proposed to co-limit phytoplankton growth in several marine environments (Mills, *et al.*, 2004; Morel and Price, 2003; Schulz *et al.*, 2004).

Iron may exist in surface and subsurface waters as simple hydrated ions and inorganic and organic complexes of low molecular weight. The speciation of iron in natural water, and their overall concentration, significantly affects water quality and bioavailability. The environmental importance physicochemical status of iron in aquatic ecosystem has been widely studied because of its importance in the prediction of transport, bioavailability and the fate of iron. Knowledge about the chemical speciation of Fe (see Fig.2) in natural water is important in interpreting biological and geochemical cycling in aquatic ecosystem. Binding iron in complexes with inorganic, and particularly with naturally occurring organic substances, are often regarded as main existing forms in ocean.

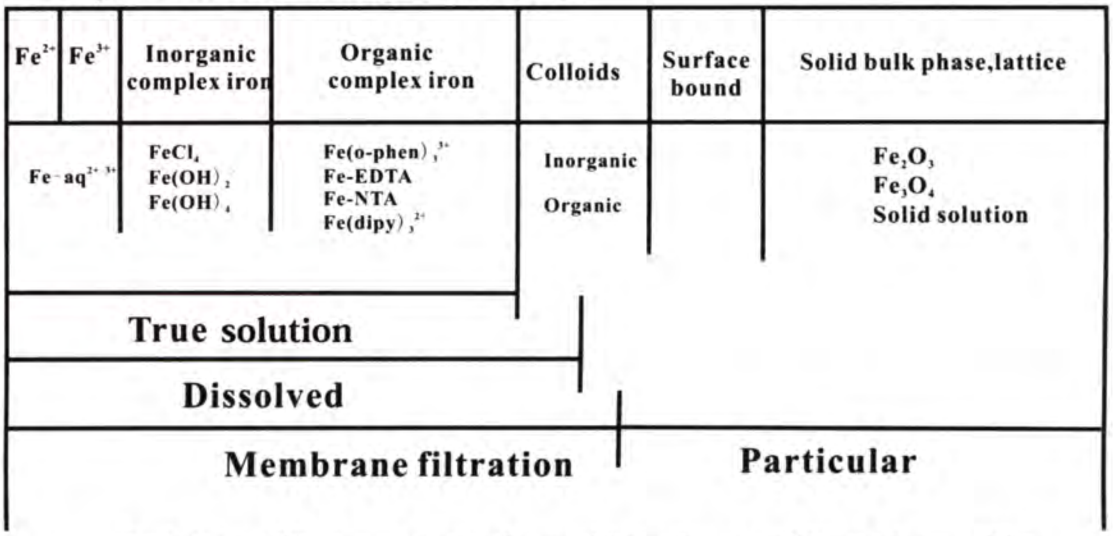

Fig.2 Forms of Fe species in natural water (Werner Stumm and James Morgan, 1996)

A limited number of papers investigates the spatial distribution of the concentration of free ion forms of iron (Fe^{2+} and Fe^{3+}) in surface and groundwater in the Sanjiang Plain (Pan Y.P., *et al.*, 2007). Moreover, the forms of iron transport and concentration fluctuation with LUCC in the Sanjiang Plain are still poorly documented. The aim of research in the year of 2007 is to gain additional insights into iron speciation, and effect of LUCC on concentration of iron in aquatic systems and flux of various forms of iron in main rivers to the Okhotsk Sea.

MATERIAL AND METHOD

2.1 Study Sites

The Sanjiang Plain was one of the largest marshy distribution regions in the Amur Basin. There are three main river systems, including Amur River, Ussuri River and Songhua River.

This region, because of its available accessibility and the presence of agricultural and industrial activity, can be considered as an environment disturbed by human activities. The velocity of river flow was higher in summer than spring and autumn, so as the flux. River water was frozen in early November and melted in late April. During frozen period, the ice layer thickness was about 50 cm to 100 cm, and the velocity of flow was slow in main rivers such as Amur River, Ussuri River and Songhua River. For the small rivers, such as Yalu River, Bielahong River, Naoli River and Nongjiang River, frozen layer is closed to river bed owing to small flow during winter. It is interesting to note that the main rivers were turbid in summer and autumn, and the color was brown in small rivers flowing through marsh owing to the high concentration of DOC from wetland.

With reclaiming intensively of marshes over the past 50 years, the much ditch systems were built in order to discharge standing water in wetland and farm land. But now, they were used as a channel to output the overflow from paddy field in the growing season. Through the rice-growing season from May (seeding) to September (harvesting), the shortage of rainfall usually occurred and is unfavorable for the rice production. As a result, the use of groundwater for irrigation is an important and common ways in the Sanjiang Plain, resulting in the decrease of the groundwater level.

2.2 Sampling and Analyses

Water samples were collected from rivers, agricultural drainages and wells in July 2007, August 2007, and October 2007, respectively. The sampling schedules were depicted in Tab.1 and the sampling sites were showed in Fig.3.

Table 1 Sample numbers in 2007 in the Sanjiang Plain

No	mm/ dd / yy	Groundwater	River water	Agricultural drainage	Total samples number
1	July 23-26,2007	7	11	2	20
2	August 27-30,2007	5	11	4	20
3	October 13-16, 2007	4	10	2	16
Sub-total		16	32	8	56

River and drainage samples were collected with a polymerized sampler at 50cm depth below the water surface. Wells for irrigation or pumping water were chosen as groundwater sampling site.

Water samples were collected using a special column sampler (Teflon). After collection, water samples was immediately stored in a portable refrigerator (0~4℃) until further treatment (filtration, acidification and measurement).

Chemical analysis of the samples was carried out at the laboratory of Northeast Institute of Geography and Agricultural Ecology, CAS within one week after the collection. The measurement methods of all items are listed in Tab.2.

Table 2 Measurement method and analyzer

Items	Method	Analyzer	Remark
NH_4^+,NO_3^-,NO_2^-,PO_4^{3-}	Colorimetry	SKALAR-SAN^{++} Model Continuous Flow Analyzer (Holland)	In lab
K, Na, Ca, Mg, Total dissolved Fe and Mn	AAS	GBC 906 Atom Absorption Spectrophotometer(Australia)	In lab
SiO_2	Colorimetry		In lab
DOC	Oxidative Combustion-infrared Analysis	SHIMADZU TOC-V_{CPH} Model Analyzer(Japan)	In lab
IC	Low Temperature and Acidification Combustion-infrared Analysis		
Fe^{2+}	Ferrozine Absorption Spectrophotometer Method (ferrozine mono-sodium salt, pH=4.6, wavelength =562nm)	Fe^{2+} Analyzer(China)	Field*
Fe^{3+}	Ferrozine + Ascorbic Acid; Absorption Spectrophotometer Method (Ascorbic acid can reduce ferric to ferrous.)		
Complex iron	Estimated from the difference between total dissolved iron and free iron.		
Acid soluble iron	Add 0.5mL of conc. HCl per 50mL of water samples, then filtrate with Whatman GF/F glass fibers, finally use AAS method to analyze conc. of iron (Acid soluble iron)	AAS	In lab
Acid soluble particulate iron	The difference between acid soluble iron and total dissolved iron.		
HCO_3^-	Titration（pH = 4.4 at end point）		Field*
pH, EC, WT, SAL (Salinity), TURB(turbidity)	Electrode Method	HORIBA U-10 (Japan)	In situ

*Measured within 12 hours. The laboratory is attached to Northeast Institute of Geography and Agricultural Ecology, CAS.

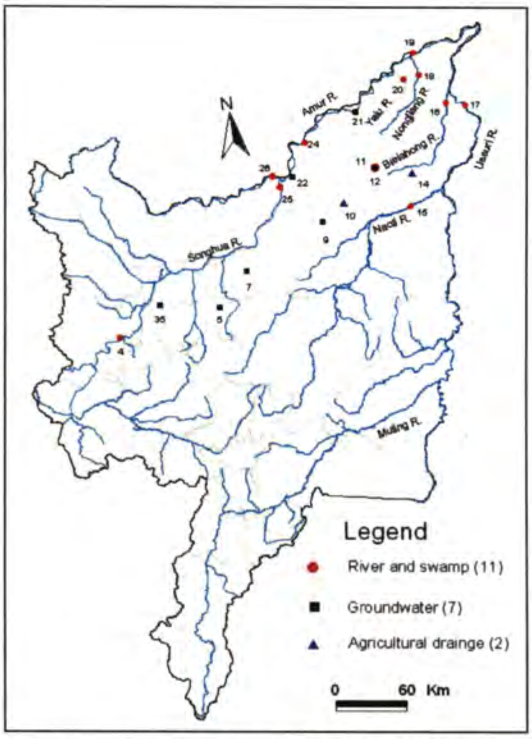

Fig.3 Sampling Location in 2007 in the Sanjiang Plain

RESULTS AND DISCUSSION

3.1 Effect of LUCC on Various Concentration of Free Iron Ion in River Waters

Taking Naoli River as an example, the drainage and use of marshes for agricultural fields in the Naoli River watershed occurred in past 50 years with intensive population growth, resulting in the decrease percentage of wetland up to 87% from 1985 to 2000 (Liu, 2005). During this period, the concentration of free iron was decreased sharply with wetland reclamation (Fig 4). This phenomenon was also observed in other river waters in the Sanjiang Plain. Hence LUCC is one of the major factors influencing the concentration of total dissolved free iron.

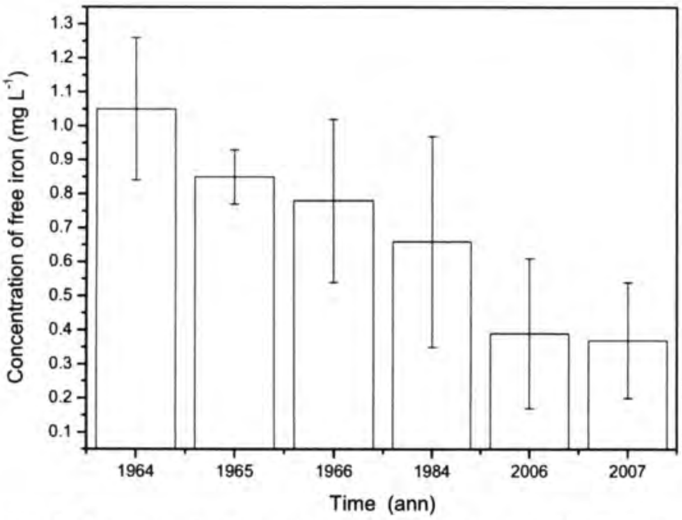

Fig.4 The concentration of iron at different time in Naoli River (hydrology document of Amur watershed, 1960-1985)

The mechanism of effect of LUCC on biogeochemical process of iron is still unclear due to lacking historical data, and should be studied in further. However, various concentration of iron can proceed through the following possible pathway: (1) the main source of iron is wetland, because of cultivation, output of iron from wetland decreases accordingly. (2) wetland soil is in anaerobic condition and Fe^{3+} transforms to Fe^{2+} with the action of iron bacteria. Furthermore, water-solubility of ferrous compound is higher than ferric compound's. Cultivation changes the environmental condition, which make a mass of production of Fe^{3+}. Some part of Fe^{3+} separate from water in the form of deposition. (3) In addition, some other factors, e.g. rainfall, contamination and so on, may be also the controlling factor. Hitherto, we lack a clear picture of the relative importance of above pathways in the mechanism of iron with Land-Use/Cover Change in freshwater systems.

Although something may be unclear, the fact is that a sharply reduction of free iron in river waters have influenced seriously ecosystem of Okhotsk Sea.

3.2 Concentrations of Free Iron, Complex and Suspend Forms of Iron in River Waters

Complexed iron was estimated from the difference between total dissolved iron and free iron. In river waters, the dissolved compounds are the main forms in which iron exist. Iron migrates mainly in ferric ion and complexed iron forms (Fig.5). Differences in the speciation of iron are related with internal process in river waters and chemical properties of iron.

Due to the aerobic environment/condition in the river, the concentration of ferric ion is higher than ferrous ion. Iron in suspended particles is less typical because the turbidity of the river waters is low. Average concentrations of suspended substance were 0.13mg L^{-1}. Maximum concentration of acid soluble particulate iron, 0.62mg L^{-1} was observed in the first usual discharge period (July).

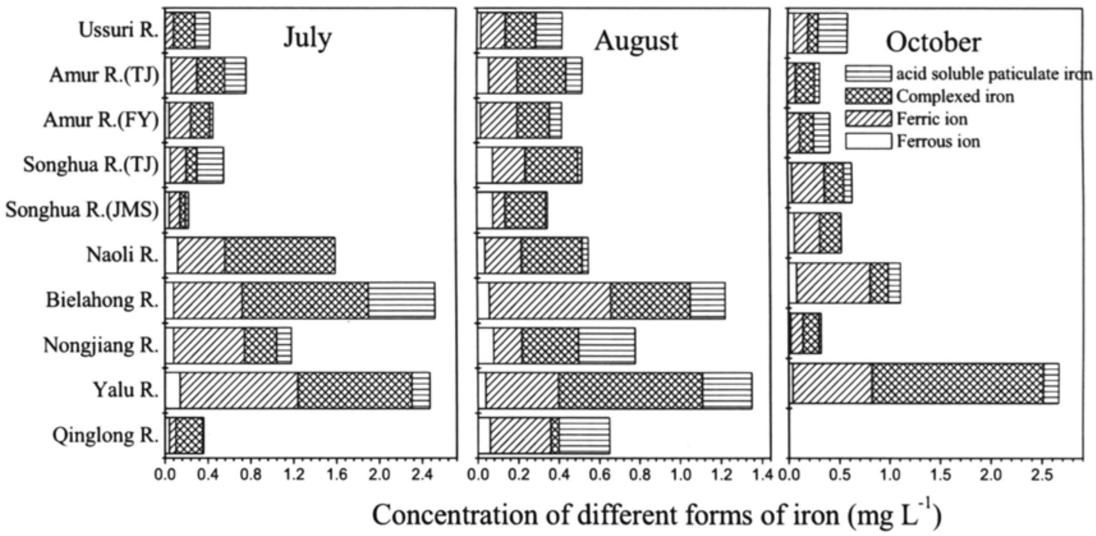

Fig.5 Concentration of different forms of iron at different time

In flood period (August) and the second usual discharge period (October), the concentration of acid soluble particulate iron decreased to 0.28~0.01 and 0.29~0.01mg L^{-1} respectively. The mean concentration of free iron including ferric and ferrous ion was 0.35mg L^{-1}.Maximum concentration (1.24mg L^{-1}) was found in July. In August and October, the concentration of free iron decreased to 0.66~0.14 and 0.82~0.08 mg L^{-1} respectively. At the same time, higher concentration of complex iron was observed in the river which derives from the marsh including Yalu R., Bielahong R., Nongjiang R., Naoli R. and Qinglong R., because high concentrations of DOM in river waters were causing active complexation, a process that can dominate the fate of iron. According to this, two parts of the river can be divided: one part is the main river including Songhua R., Amur R. and Ussuri R which represent the typical freshwater river; the other part is marshy river.

However, none of the four kinds of iron (Fe^{2+}、Fe^{3+}、complex iron、acid soluble particulate iron) concentrations correlate with significantly DOC. The nature of DOM in estuarine and seawater is complex, but is thought to include humic acids, fulvic acids, glycollic acid, peptides, proteins, amino acids, lipids and polysaccharides. In coastal waters and estuaries, DOM may also include anthropogenic chelating ligands such as ethylenediaminetetraacetic acid (EDTA), nitrilotriacetate (NTA), phosphonates, citric acid, tartaric acid and surfactants from anthropogenic sources. Indeed, organic compounds with an extremely high selectivity and affinity for iron maintain 99% in organically complexed dissolved form (Nolting *et al.*, 1998; Völker and Wolf-Gladrow, 1999; Hutchins *et al.*, 1999), but not all of the organic matters are complexed with iron. In other words, DOC can not reflect the real concentration of organic matters binding with iron, but only can reflect the whole trend.

Our three times investigations demonstrated that most dissolved iron in river waters was present as ferric ion and complex compound and this two fractions of dissolved iron account for 73%~82% of total concentration of iron.

3.3 Influence of Agriculture Drainage on the Fate of Iron in River Waters

There are so many irrigation channels in the Sanjiang Plain which discharge into the main rivers or marshy river finally, affecting biogeochemical process of iron. The influence of agricultural drainage can be showed in Table 3, as compared to July and October.

The concentrations of four species of iron show differences at different time with the marshy river concentrations of iron being higher and more variable than the main river concentrations (Tab.3).

Table 3 Difference in iron concentrations between main rivers and marshy rivers

item	main rivers [a]			marshy rivers [b]		
	July	August	October	July	August	October
Fe^{2+} (mg L^{-1})	0.04	0.05	0.03	0.09	0.06	0.05
Fe^{3+} (mg L^{-1})	0.15	0.13	0.17	0.58	0.32	0.47
Cmplexed iron (mg L^{-1})	0.20	0.15	0.19	0.76	0.35	0.56
Acid soluble particulate iron (mg L^{-1})	0.13	0.06	0.12	0.15	0.19	0.07

[a] Main rivers represent typical big river derived from freshwater source, including Songhua R., Amur R. and Ussuri R

[b] Marshy rivers represent small branch river derived from marshy wetland, including Yalu R., Bielahong R., Nongjiang R., Naoli R. and Qinglong R.

In cultivation periods (August), the concentrations of ferric and complex iron were lower, and the variation trend of acid soluble particulate iron concentrations in the main river was not consistent with in the marshy river as compared to July and October. Agricultural drainage nearly happened in August. Therefore, agricultural drainage has an influence on the concentrations and existing forms in river water-bodies. Some impacting factors of agricultural drainage on the biogeochemical process of iron in river water-bodies can be involved as follow: (1) Groundwater irrigation. In the Sanjiang Plain, groundwater irrigation is applied widely in the most of farms. The mixing between groundwater with lower concentration of iron and river water means perturbations to the system (such as variable inputs, dilution, and transformation of circumstance). (2) Fertilization. It is known that adding fertilizer in the cultivated land will indirectly make the concentrations of element of N and P being higher in the agricultural drainage waters, which may accelerate the growth of microbe. A mass of microbe are able to consume the organic matter in water and prevent the production of organic ligands from binding with iron. (3) The rainfall. August is the high flow period for river as it is the rainy season in the Sanjiang Plain. Because of high rainfall, the overall controlling factor is river flow, which may not only dilute the concentration of iron but also change the environmental condition in river waters. Iron may be more easily adsorbed to particles during the high flow periods, especially in the marshy river.

3.4 Competitive Complexation of Iron by Organic Ligands (Ferrozine)

The ferrozine (monosodium salt hydrate of 3-(2-pyri-dyl)-5,6-dipheny l-1,2,4-triazine-p, p'- disulfonic acid) reagent proposed by Stookey (1970) which reacts with divalent Fe to form a stable magenta complex species is used. Ferrozine reacts extremely rapidly with inorganic Fe(II) at pH 8.1 to form a purple colored complex with maximum absorbance at 562 nm in 2 min and continue to replace weak organic ligands from complexed iron in about 30 h (Ohji and Yoh, in prep). These results suggested that the slow increase in absorbance is explained by the slow displacement of Fe(II) from the organic ligands.

After 30h, the concentrations of both ferric and ferrous ion increase significantly (Fig.6). The results show that Ferrozine, as a kind of strong organic ligands, has ability to replace complexed iron from weak ligands. The result of iron concentration can represent free iron and complex iron at 3 min and 30h respectively and the concentrations of ferric and ferrous iron are about 2 and 6 times higher respectively at 30h than those of at 3 min. In other words, ferrous iron exists primarily as form of complex iron in river waters.

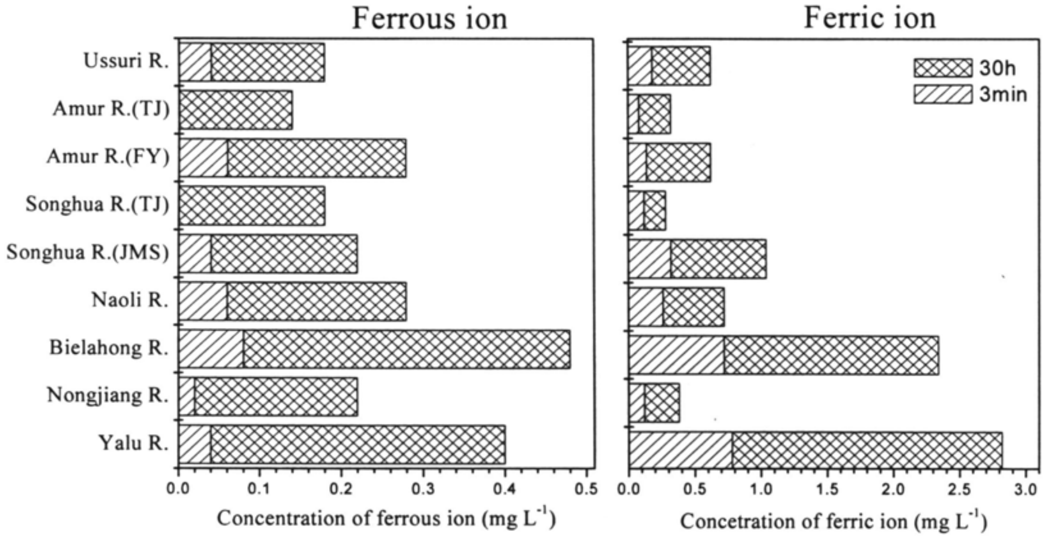

Fig.6 Changes in concentration of free iron with time after adding the FZ to water samples

3.5 Variation of Iron Concentration with the Sample Preservation Method

To check the effect of different method of water sample preservation on the concentration of iron, we introduce two kinds of sample bottle to preserve the water samples: plastic battle and ground-glass stoppered flask, which can represent opened system and closed system respectively. The water samples were collected from 15 sample stations including surface water and groundwater by two types of sample bottle. Fig.7 and Fig.8 show the free iron concentrations for samples using different method of sample preservation in river waters and groundwater. There are little difference between the two methods for free iron concentrations in river waters. However, the concentrations of ferrous ion preserved by plastic bottle are 30.2% lower compared to those of stoppered flask and the concentration of ferric ion preserved by plastic bottle are 54.8% higher in groundwater.

It is known that the circumstance of a groundwater is anaerobic and the redox balance of a groundwater is generally maintained by the relative rates of atmospheric O2. Therefore, the extraction of a groundwater may destroy the redox balance of iron, which may cause a conversion between ferrous ion and ferric ion. Indeed, both of the methods affect the result of concentration of iron, but the circumstance of closed system of stoppered flask may be more closed to the actual groundwater environment. So we collected groundwater samples in stoppered flask in 2007.

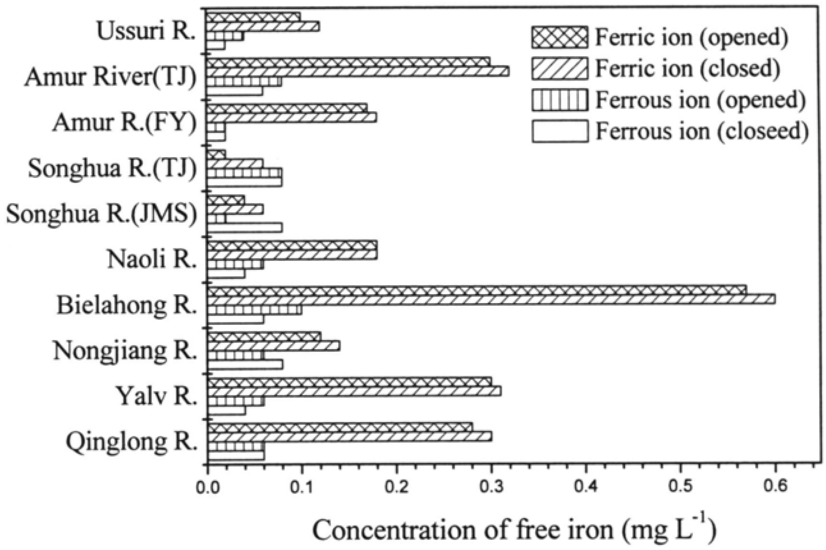

Fig.7 Comparison between different method of sample preservation about free iron concentration in river waters

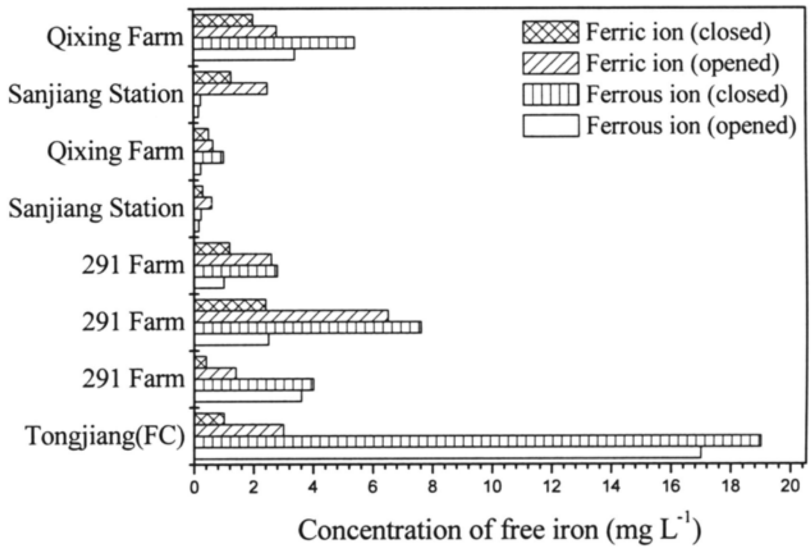

Fig.8 Comparison between different method of sample preservation about free iron concentration in groundwater

3.6 Runoff Outflux of Iron from River Waters in the Sanjiang Plain

The Sanjiang Plain is locates in temperate zone and has a character of continental monsoon climate. Annual rainfall is about 550-600 mm and there is a frozen periods during November and April. Therefore, the variation of runoff flow is great at the different seasons.

Exploitation of wetland destroys the surface plant and water circumstance, accelerates drought of the climate, and affects the rainfall and runoff in the Sanjiang Plain, which cause the variation output flux of iron in river waters. With the rapid expansion of agriculture, rainfall and runoff of marshy river had a decreasing tendency since the 1950's (Yan *et al.*, 2004).

Liu *et al.* (2003) collected and calculated the hydrological data of different rivers including China and Russia in the region (Tab.4).

Table 4 Average annual runoff of different rivers

River	Drainage basin acreage/km^2	Hydrological Station	Catchment acreage/km^2	Average several years runoff/10^8 m^3
Amur R.	1843000	Khabarovsk	1630000	2664.8 [a]
Ussuri R.	187000	New Soviet	186000	411.6 [b]
Songhua R.	545639	Jiamusi	527795	688.4 [c]

[a] The value is calculated from 1896-1990

[b] The value is calculated from 1940-1990

[c] The value is calculated from 1940-1990

Based on the flow data above and mean concentrations of four forms iron, the annual output of iron transporting with runoff from different rivers in 2007 is estimated in Tab.5. Compared with the data of 2005 and 2006 (Fig.9), the output of iron in 2007 was significantly low due to decreased concentration of iron.

Table 5 Annual output of different forms iron in 2007

River	Concentration/ runoff flux	Fe^{2+}	Fe^{3+}	Complexed iron	Acid soluble particulate iron
Amur R.	Average concentration/mg L^{-1}	0.04	0.16	0.19	0.12
	Average runoff flux/ 10^8 kg yr^{-1}	0.10	0.43	0.50	0.31
Ussuri R.	Average concentration/mg L^{-1}	0.02	0.13	0.16	0.10
	Average runoff flux/ 10^8 kg yr^{-1}	0.01	0.05	0.06	0.04
Songhua R.	Average concentration/mg L^{-1}	0.05	0.15	0.16	0.09
	Average runoff flux/ 10^8 kg yr^{-1}	0.03	0.10	0.11	0.06
Total	Average concentration/mg L^{-1}	0.11	0.44	0.51	0.31
	Average runoff flux/ 10^8 kg yr^{-1}	0.14	0.58	0.67	0.41

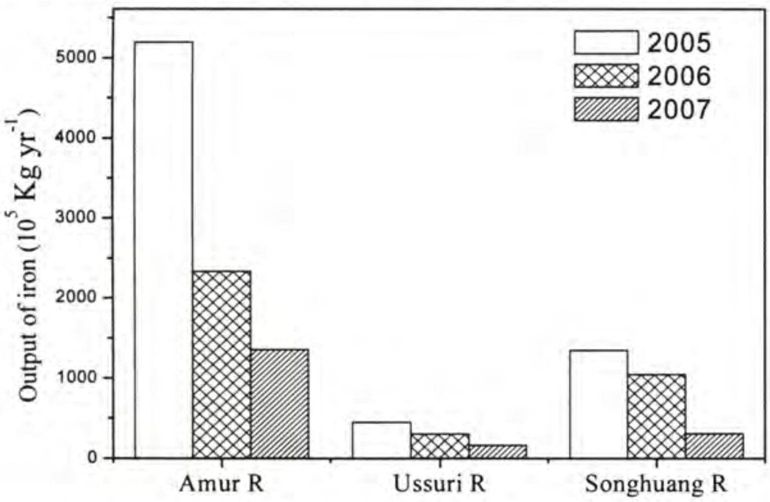

Fig.9 Different output of total iron in different time

CONCLUSION

The main results of this study can be summarize as follows: (1) In the study sites, the concentration of free iron exhibited a higher variation and the rapid expansion of agriculture reduced sharply the quantity of iron in river waters over past 50 years. This result led us to know that wetland is one of the major sources of iron. (2) Iron migrates mainly in ferric ion and complexed iron forms in river waters. There are significant differences in iron chemistry between high and low flow period due to internal process in river waters. (3) The concentrations of iron in marshy rivers are higher and more variable than those in the main rivers. Because marshy rivers are abundant in organic matters, an excess of ligands can be derived from marshy rivers. (4) Ferrozine is a high affinity and selectivity compounds, which can make equilibrium attain reasonably rapidly. Therefore, FZ reacts extremely rapidly with ferrous ion to form a purple colored complex in 2 min and continue to replace iron from other weak organic ligands in about 30 h. Through the experiment of competitive ligands, we found ferrous iron exists primarily as form of complex iron in river waters. (5) According to the data of average annual runoff from four rivers, the average runoff flux of four species can be calculated (see Tab.5).

LUCC has destroyed the wetland environment, changed the runoff outflux of iron to the ocean, and indirectly affect the ocean ecosystem. In addition, LUCC also changes iron forms in river water, which may affect the bioavailability and the fate of iron. Cultivation changes the aquatic condition (from anaerobic to aerobic environment), and influence indirectly the fate of iron.

PERSPECTIVE FOR FURTHER RESEARCH

Our field observation revealed that LUCC has destroyed the wetland environment, changed the runoff out-flux of iron to the ocean. In addition, LUCC also changes iron forms in river waters and groundwater, which may affect the bioavailability and the fate of iron. However, the biogeochemical process of iron in river waters and groundwater during the irrigation and discharge periods and composition of complex iron have not been known yet. Considering the bioavailability of complex iron which is primary forms in river waters, we should focus on the characteristic of organic matters binding with iron and understand the influence of the complex process on the bioavailability of iron. And also we should focus on what controls the soluble iron species in surface water and microcosmic factors in surface water environment with the development of LUCC. Some results may implicate LUCC is an important factor to variation of iron concentration. But how does it influence? Marshy wetland only functions as supply of iron? Maybe some problems must be considered further.

ACKNOWLEDGE

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EFFECTS OF LAND USE CHANGE ON THE DISTRIBUTION AND MOBILITY OF SOIL IRON IN SANJIANG PLAIN, NORTHEAST CHINA

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1. INTRODUCTION

Sanjiang Plain kept its name of "the Great Northern Wilderness" until the reclamation in mid-1950s, and wetland stretched continuously and accounted for 80.2 % of the total area of plain part of the Sanjiang Plain up to 1949. However, the wetlands on the plain have gone through 4 periods (1956-1960, 1960-1977, 1980-1986 and 1986-the present) of large-scale reclamation from 1956 to the present. The objective of the present study was to elucidate the characteristics and affecting factors of the vertical distribution and mobility of soil iron under different land use patterns in Sanjiang Plain, with a purpose to evaluate the effects of land use change in this region on adjacent marine ecosystems.

2. MATERIALS AND METHODS

1) Sampling sites

Between two upper reaches of Amur River—Naoli River and Nonjiang River in Sanjiang Plain, soil samples were collected from 12 sites having three land cover types including natural wetlands, paddy field and upland field converted from wetland (Table 1). The objective of the present study was to elucidate the characteristics and affecting factors of the vertical distribution and mobility of soil iron under different land use patterns in Sanjiang Plain, with a purpose to evaluate the effects of land use change in the region on adjacent marine ecosystems.

Table1. Sampling sites in Sanjiang Plain region

Sampling sites	Location	Soil type	Land use type	Reclamation history
Site 1	47°16.152'N, 133°45.797'E		Wetland	Without reclamation
Site 2	47°17.122'N, 133°46.110'E		Wetland (adjacent to Site 4)	Without reclamation
Site 3	47°31.706'N, 133°52.871'E		Paddy field	5 years
Site 4	47°17.122N, 133°46.076'E	Marsh soil	Paddy field	23 years

Site5	47°31.708'N, 133°52.872'E		Upland field	5 years
Site 6	47°17.073'N, 133°45.877'E		Upland field	23 years
Site 7	47°35.269'N, 133°30.146'E		Wetland	Without reclamation
Site 8	47°44.244'N, 133°31.212'E		Wetland	Without reclamation
Site 9	47°44.216'N, 133°30.580'E	Albic soil	Paddy field	2 years
Site 10	47°39.479'N, 133°30.471'E		Paddy field	11 years
Site 11	47°44.482'N, 133°31.253'E		Upland field	4 years
Site 12	47°44.236'N, 133°30.625'E		Upland field	15 years

2) Analytical methods

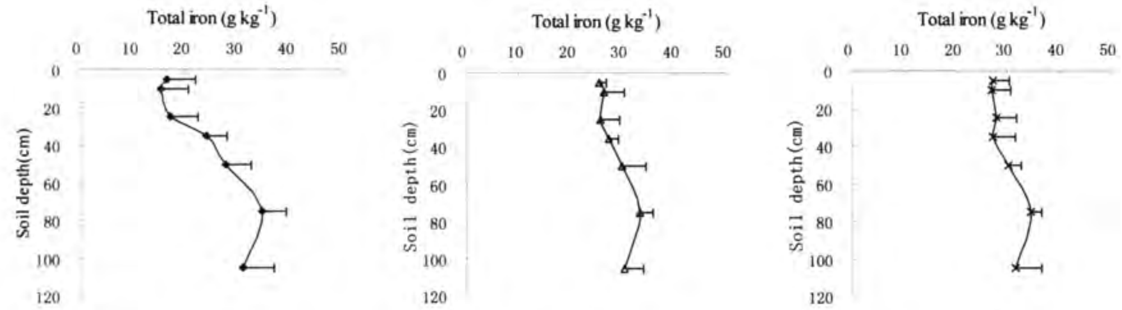
The soils from each core were loosely disaggregated, air-dried at room temperature, and passed through 2 mm mesh sieve to determine pH, and through 0.25 mm mesh sieve to determine total iron (Fe_t), free iron oxides (Fe_d), amorphous iron oxides (Fe_o), and organic carbon (OC).

The Fe_t content was determined by a flame atomic absorption spectrophotometer (Aanalyst 200, America) after sodium carbonate fusion digestion. Fe_d was extracted by sodium hydrosulfite - sodium citrate - sodium bicarbonate (DCB) at pH 7.0, and determined by phenanthroline colorimetry (AnaltikjenaAG, Germany) (Mehra and Jackson, 1960). Fe_o was extracted by acidified ammonium oxalate at pH 4.0, and determined by phenanthroline colorimetry (AnaltikjenaAG, Germany) (Schwertmann, 1973). The notation Fe_d refers to a combination of crystalline and poorly crystalline iron, whereas Fe_o refers only to poorly crystalline iron occurring in the soils.

3. RESULTS AND DISCUSSION

1) Vertical distribution of Total iron

Soil Fe_t in wetland was increased with depth, and its concentration at the depth of 60-90 cm was 150.6% higher ($p < 0.05$) than that at the depth of 0-10 cm. Fe_t in the profiles were decreased in the sequence of upland field > paddy field > wetland (Figure 1).



a) wetlands b) paddy c) upland

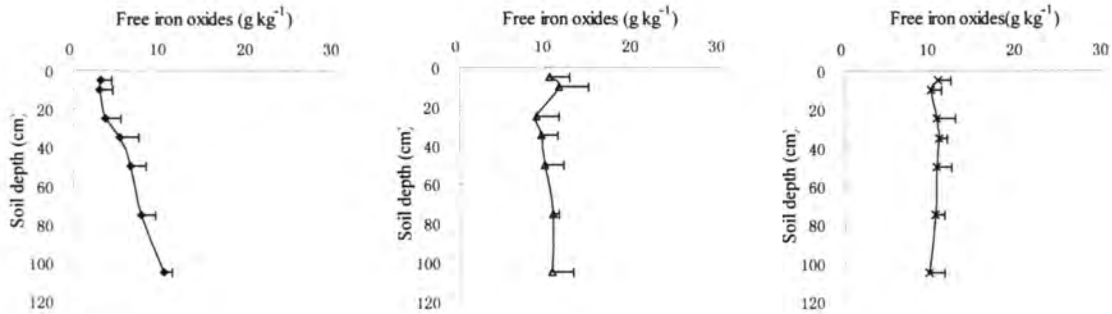
Figure 1. Vertical distribution of total iron in soils under three land cover types

Fe_t concentration in wetland increased with depth, and was great higher at the depth of 60-90 cm than in surface soil. Such a vertical distribution could be explained by gleization which often occurred in flooded soil, and implied that a significant amount of iron was leached out from topsoil (Schwertmann and Murad 1990). Under cultivation, a redox layer at lower positions occurred due to the artificial disturbances, and the horizons with high accumulation of iron were characterized by highly variable redox conditions. Significant amounts of leached iron from topsoil, which moved vertically within the soil profile, were deposited in subsurface soil where a good aeration occurred, preventing the further loss of iron as a solute.

2) Vertical distribution of free iron oxides and weathering ratio

Soil Fe_d in the profiles were decreased in the sequence of upland field > paddy field > wetland. In wetland, the Fe_d concentration at the depth of 60-90 cm was 150.6% higher ($p < 0.05$) than that at the depth of 0-10 cm. At the depth of 10-20 cm, it increased by 270.9 % ($p < 0.05$) in paddy field and 231.4% ($p < 0.05$) in upland field, compared to wetland (Figure 2).

Soil Fe_d/Fe_t (weathering ratio) was increased with depth below 10 cm in wetland which had a similar pattern with the distribution of Fe_d. Land use change led to a Fe_d/Fe_t increase of 44.0 % ($P < 0.05$) in paddy field and of 65.9 % ($P < 0.05$) in upland field at the depth of 20-40 cm (Figure3).



a) wetlands b) paddy c) upland

Figure 2. Vertical distribution of free iron oxides in soils under three land cover types

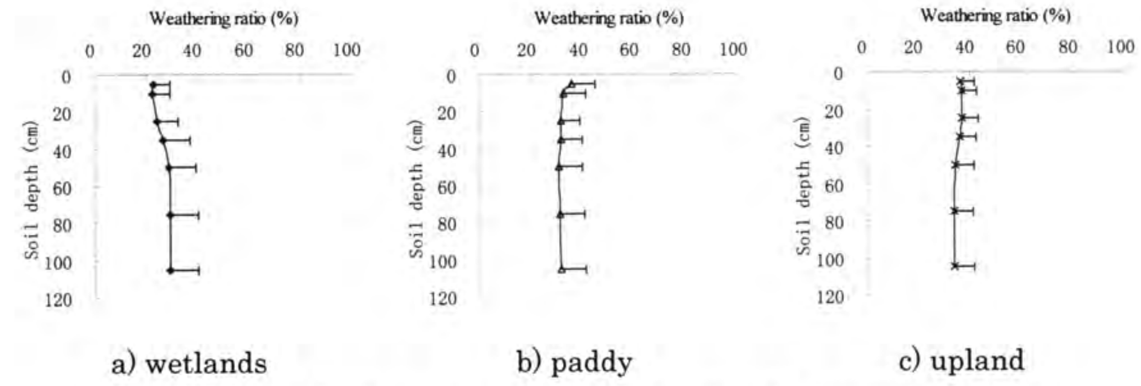


Figure 3. Vertical distribution of weathering ratio in soils under three land cover types

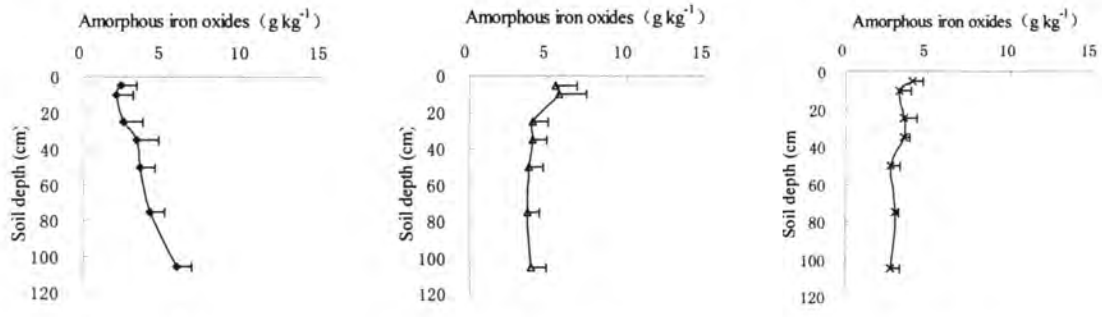
The similar trend and remarkable positive relationship between Fe_d and Fe_t showed that different Fe_t concentration undoubtedly contributed to the observed differences in the mean concentrations of Fe_d in wetland, paddy field and upland field. Similar trends were found in other studies, *i.e.*, a parallel trend of Fe_d and Fe_t in soil occurred, and Fe_d preferentially accumulated in well-aerated horizons (Blume and Schwertmann, 1969).

Fe_d/Fe_t is considered as a useful indicator of soil formation processes and pedogenic environments, and of importance in distinguishing soil types and differentiating soil horizons (McKeague and Day, 1966; Blume and Schwertmann, 1969). In our study, the higher Fe_d/Fe_t in cultivated land revealed that the impact of reclamation might also add to the Fe_d concentration difference by modifying weathering rate. Weathering is known to be related to soil temperature and moisture content, and is likely to be increased by farming practices. The increased Fe_d concentration promoted by increased weathering and erosion rates has been reported in other studies (Collins and Jenkins, 1996).

3) Vertical distribution of amorphous iron oxides and active ratio

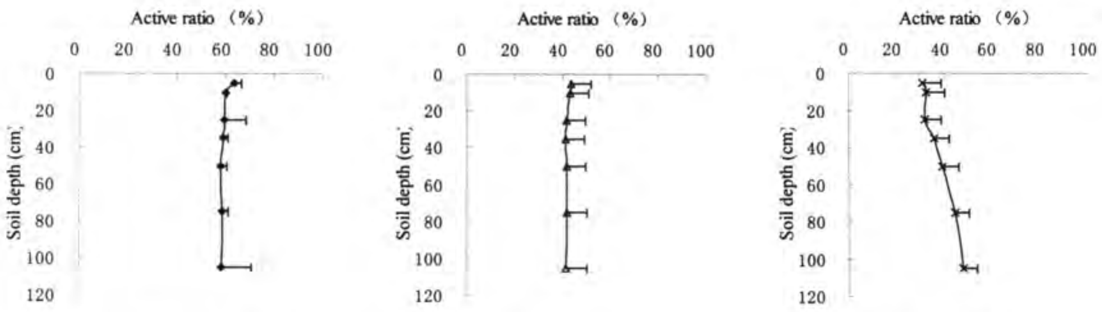
The total mass of Fe_o in the upper soil layers (0–40 cm) tended to be greater ($P < 0.05$) in cultivated land than in wetland, but wetland stored a higher amount of Fe_o at the depth below 60 cm (Figure 4).

Fe_o/Fe_d (active ratio) is used as a measure of the proportion of amorphous iron in total iron oxides, and characterizes the inhibition of better crystallized forms by organic matter or other components (Blume and Schwertmann, 1969). The Fe_o/Fe_d distribution at the 12 sites showed that land use change led to a significant decrease of the Fe_o/Fe_d along the profile ($P < 0.05$). In the top 20 cm layer, the Fe_o/Fe_d in paddy field was higher than that in upland field, while no significant differences were found below 40 cm (Figure 5).



a) wetlands b) paddy c) upland

Figure 4. Vertical distribution of amorphous iron oxides in soils under three land cover types



a) wetlands b) paddy c) upland

Figure 5. Vertical distribution of active ratio in soils under three land cover types

Iron oxides can be presented in soils in various forms. The less crystallized the iron oxides, the more readily reduced by microbes. The greater reduction of less crystallized forms of iron oxides might reflect the fact that the less crystalline iron oxide forms were more soluble, and had greater surface area than highly crystalline iron oxide forms (Lovley 1987). Therefore, Fe_o identified in numerous soil environments was the most reactive iron oxide in soils (Chen and Barak 1982). The spatial distribution of Fe_o and Fe_o/Fe_d reflected a more dynamic aspect of the removal processes of iron oxide associated with podzolization and gleyization than that of Fe_t and Fe_d.

Comparing with wetland, the total mass of Fe_o in cultivated land was greater in upper soil layers (0–40 cm) and less in 90–120 cm layer, while the Fe_o/Fe_d was decreased in the whole profile. These differences could be explained by the low level of Fe_t which might have played a role in the Fe_o concentrations in the upper layers of wetland. The results of Fe_o, Fe_d and Fe_o/Fe_d suggested that reclamation could promote the production of Fe_d and retarded the formation of Fe_o. In comparing with Fe_o concentration which was proposed as an indicator of crystallization of soil iron oxides, Fe_o/Fe_d ratio could better reflect the effects of land use change on the mobility of soil iron oxides. The decrease of the Fe_o/Fe_d after reclamation were due to the changes of soil physical and chemical properties such as OC, pH and moisture content which had great correlate relationships with Fe_o/Fe_d (date not shown) (Dick 1983; Wander etal. 1998; Needelman etal. 1999; Bohn etal. 2001).

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FOLIAR FE CONTENTS OF DOMINANT TREE AND WATER-EXTRACTABLE FE OF SOIL IN FORESTS IN THE NORTHEASTERN CHINA

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1 INTRODUCTION

Forest communities are biological processors of terrestrial-aquatic interfaces. Forest plants directly take up and store nutrients. On the other hand, nutrients are also released with the decomposition of plant debris, contributing to the modification of runoff chemistry. The leaching of organic or mineral products at the surface of living vegetation provides potential additional effects on water chemistry. Therefore, the forest community is closely correlated with the nutrient biogeochemical processes in forested watershed.

Fe is an important nutrient for productivity of marine ecosystem. Terrestrial ecosystem is an important source of Fe transporting to the aquatic ecosystems. In relation to the impacts of forest vegetation on hydrological processes, it is clear that research is needed to reveal the soil-vegetation interaction. The objectives of this study are to determine the spatial pattern of Fe in soils and trees; and to reveal the tree-soil interaction controlling Fe biogeochemical cycling in forested watersheds within Amur Basin.

2 MATERIAL AND METHODS

2.1 Study site

This study was conducted at three sites, Liangshui (47°11'N, 128°53'E), Hanyue (47°15'N, 128°50'E) and Songling (50°54'N, 124°27'E), located in the northeastern China. Liangshui and Hanyue sites belong to the Xiaoxing'an Mountains, which native vegetation is typically warm-temperate mixed forest of *Pinus koraiensis*-deciduous broadleaved species. Because of forestry development, most of the primary forests were harvested during the past century. Except for a small area of the primary forest, most land was covered by secondary forests and plantations. The dominant tree species are *Pinus koraiensis*, *Picea koraiensis*, *Larix gmelini*, *Betulla* spp., *Fraxinus mandshurica* and *Juglans mandshurica*. At Hanyue site, most of the forests are plantations planted after 1950. The soil types at Liangshui and Hanyue sites are mainly brown forest soils at upland and peat soil on riparian area.

Songling site belongs to the Daxing'an Mountains, which native vegetation is the cool-temperate coniferous forest dominated by *Larix gmelini*. Most of the land was covered by secondary forests. The dominant tree species are *Larix gmelini*, *Betulla* spp., and *Alnus* spp. Forest fires are frequent in this area, which become the most seriously natural disturbance on the forest. The dominant soil types are dark brown forest soils.

Table 1. Outline of the sampling forest stands

Location	Position	Site conditions	Species and growth
Liangshui Site (Natural Reserve)			
LS1	47°10.956'N	420m asl, upper slope 20°	korean pine old-growth,
	128°58.690'E	loam	Hmax 30m, DBHmax 83cm
LS2	47°11.053'N	410m asl, lower slope 9°	birch secondary forest, 52 yr
	128°53.242'E	clay	1300/ha, H 17m, D 18cm
LS3	47°11.043'N	460m asl, upper slope 24°	larch plantation, 52 yr
	128°53.461'E	clay-loan	4400/ha, H 21m, D 25cm
LS4	47°11.053'N	410m asl, lower slope 9°	natural spruce old-growth
	128°53.242'E	clay	1300/ha, H 17m, D 18cm
LS5	47°11.454'N	363 m asl, riparian zone	natural spruce-birch mixture
	128°53.738'E	peat 30 cm, lower sandy loan	1300/ha, H 17m, D 18cm
Hanyue Site (Harvesting area)			
HY1	47°15.030'N	376 m asl, riparian zone	birch-alder-larch secondary
	128°49.975'E	sandy loan	H:10-12m; DBH:10 cm
HY2	47°15.738'N	430m asl, slope 20°, loan	larch plantation, 50 yr
	128°50.628'E	mid-slope	H: 18-20m; DBH: 23cm
HY3	47°14.008'N	330m asl, flat valley	spruce-larch-birch secondary
	128°50.336'E	sandy loan	H:12-20m; DBH:14cm
Dailing Site (Forest fire area)			
DL1	50°54.547'N	630m asl, slope 6°, clay	H:8-10m, DBH: 6-12cm, 6000/ha
	124°26.800'E	low-slope	larch-birch secondary, 40 yr
DL2	50°54.547'N	654m asl, slope 16°, clay	larch-birch secondary, 60 yr
	124°26.800'E	mid-slope	Mean H 14m, DBH 17cm
DL3	50°54.673'N	590m asl, flat, peat	birch-larch secondary, 50 yr
	124°26.552'E	riparian zone	burned in 2004
DL4	50°54.400'N	615m asl, slope 13°,	larch-birch secondary, 50 yr
	124°26.605'E	low-slope, clay-loan	burned in 2004

2.2 Field survey

The field survey was conducted during August-October, 2007. At each site, different stands were selected to investigate the properties of the soils and foliar nutrients of dominant tree species. The sampling stands included the primary forests, secondary forests, and plantations, and secondary forests (at Songling) damaged by forest fire in 2006.

In each sampling stand, the soils were collected from the soil profile for different layers. The fresh leaves and needles were collected from 3 trees for each species in the growing season. The fresh litter was collected from forest floor for each species. The general conditions for the sampling stands were showed in Table 1.

2.3 Chemical analysis

Soil pH was measured in 1:2.5 soil : water by Horiba compact pH meter. Soil electronic conductivity was measured in 1:5 soil : water suspension by Horiba compact EC meter. Total N was determined by a Kjeldahl autoanalyzer. Subsamples of soils analyzed for available P were extracted using the Bray II method. Subsamples equivalent to 20 g dry soil were extracted with 100 ml ultrapure water. The extractions filtered with GF/F glass-fiber filter were used for analysis of water-extractable components (P, K, Ca, Mg, Fe). The extracts were frozen until analysis. Plant materials were digested with HNO_3-$HClO_4$ reagent, and the digests were used for analyzing the contents of P, K, Ca, Mg, and Fe. K, Ca, Mg and Fe were measured by atomic absorption spectrometry (TAS-990AFG, Beijing). P was measured by Flow Injection Analyzer (FIAStar 5000, FOSS).

3 RESULS AND DISCUSSION

3.1 Soil chemical properties

Table 2 showed the general chemical properties of soils under the different stands at different sites. Soil pH was lower in the riparian stands than in the upland stands at all three sites. In larch plantations, soil pH was lower at Hanyue than at Liangshui. Soil ECs were highest at Hanyue and lowest at Songling. Among forest types, soils under larch plantation had rather higher EC than other stands except for the riparian alder-birch secondary forest at Hanyue (157 μS/cm in A horizon).

Table 2 Concentrations of water-extractable nutrients of soils in different forests

Site &	Soil	pH	EC	TN	Avail P	water soluble nutrient (mg/kg soil)				
Plot	depth	(H_2O)	μS/cm	g/kg	mg/kg	P	K	Ca	Mg	Fe
Liangshui										
LS1	Natural pine old-growth stand (upper slope)									
	A	5.65	82.6	7.472	19.338	3.829	0.471	1.713	0.372	0.127
	AB	5.75	34.3	3.611	16.026	3.398	0.416	1.524	0.349	0.113
	B	5.80	27.5	2.836	4.601	1.743	0.338	1.031	0.271	0.083
	C	6.05	21.5	2.522	2.814	0.916	0.211	0.767	0.166	0.049
LS2	Natural secondary birch stand (lower slope)									
	A	5.75	87.2	4.824	13.316	2.692	0.372	1.331	0.301	0.091
	AB	5.80	38.6	3.309	12.561	2.213	0.299	1.154	0.257	0.085
	B	5.95	30.4	2.429	8.617	1.537	0.207	0.818	0.192	0.063
	C	6.00	19.6	1.713	5.225	1.126	0.132	0.673	0.138	0.034
LS3	Larch plantation stand (upper slope)									
	A	5.95	103	5.301	8.736	2.572	0.309	1.426	0.257	0.086
	B1	6.10	30.8	3.066	10.248	2.108	0.213	1.103	0.202	0.071
	B2	5.90	25.3	1.848	5.003	1.369	0.134	0.633	0.112	0.033

Table 2 Continued

LS4	Natural spruce stand (riparian)									
	A	5.45	77.2	8.184	13.973	2.704	0.239	1.373	0.217	0.113
	AB	5.60	43.6	4.123	9.925	1.469	0.182	0.891	0.179	0.092
	B1	5.65	41.4	2.734	5.116	1.036	0.155	0.664	0.119	0.069
	B2	5.60	18.2	1.682	2.396	0.723	0.107	0.501	0.103	0.037
LS5	Natural spruce-birch mixed stand (riparian peat)									
	A	5.35	31.8	10.024	5.837	2.352	0.247	0.934	0.207	0.122
	B	5.60	10.7	3.371	2.992	1.176	0.133	0.619	0.128	0.061
Hanyue										
HY1	Secondary alder-birch stand (riparian)									
	A	5.35	157	10.217	16.331	4.113	0.352	1.053	0.268	0.139
	B1	5.30	110	6.359	10.502	3.606	0.282	0.734	0.223	0.112
	B2	5.55	47.2	4.022	6.614	2.533	0.247	0.539	0.151	0.089
HY2	Larch plantation stand (upper slope)									
	A	5.65	79.2	4.811	6.837	2.982	0.337	1.207	0.291	0.126
	AB	5.70	31.6	3.634	3.992	1.633	0.279	1.004	0.238	0.103
	B	5.70	23.7	2.036	3.608	1.117	0.153	0.825	0.201	0.079
	C	5.85	14.8	1.549	2.215	0.616	0.102	0.631	0.143	0.053
HY3	Secondary spruce-alder-birch stand (riparian)									
	A	5.45	97.4	8.231	8.913	2.673	0.281	1.036	0.255	0.103
	B1	5.55	67.6	4.167	5.336	1.779	0.236	0.839	0.203	0.116
	B2	5.80	32.2	1.759	3.282	0.904	0.137	0.712	0.156	0.081
Songling										
DL1	Natural larch-birch secondary stand (mid-slope)									
	A	5.80	37.6	3.864	21.035	3.617	0.341	1.558	0.311	0.091
	B1	5.95	21.2	2.336	17.104	3.234	0.259	1.312	0.293	0.086
	B2	5.90	13.6	1.520	7.226	2.479	0.163	0.861	0.226	0.061
	C	6.10	10.3	0.963	3.652	1.051	0.117	0.657	0.177	0.041
DL2	Natural larch-birch secondary stand (low-slope)									
	A	5.70	41.1	4.344	25.114	3.771	0.375	1.476	0.334	0.113
	B1	5.85	23.3	3.031	16.566	3.106	0.303	1.393	0.298	0.101
	B2	5.90	17.5	2.008	8.612	2.394	0.224	0.745	0.219	0.076
	C	5.90	11.7	1.106	4.407	1.773	0.139	0.572	0.166	0.052
DL3	Natural larch-birch secondary stands damaged by forest fire (low-slope)									
	A	5.65	48.3	3.623	9.338	3.219	0.336	1.802	0.323	0.083
	B1	5.60	26.1	2.176	11.513	2.631	0.271	1.426	0.254	0.102
	B2	5.80	15.8	2.014	5.802	2.008	0.219	0.861	0.207	0.079
	C	5.95	12.5	1.038	3.136	1.106	0.144	0.663	0.173	0.047
DL4	Natural larch-bircch-alder seondary stands damaged by forest fire (riparian)									
	A	5.45	43.7	6.026	7.494	2.731	0.237	1.737	0.272	0.107
	B1	5.65	18.4	3.409	12.291	3.594	0.249	1.352	0.230	0.106
	B2	5.90	13.6	2.132	4.227	1.034	0.109	0.973	0.201	0.083

In general, the total N in soil was higher at Hanyue and Liangshui than at Songling. However, the available P in soil was greater at Liangshui and Songling than at Hanyue (Table 2). Soil water-extractable P was higher at Songling than the other sites. However, soil water-extractable Fe was higher at Hanyue than the other sites. At Liangshui, soil water-extractable Fe was somewhat great in old-growth pine-broadleaf mixed forest. In addition, soil of riparian stands usually had relatively higher content of water-extractable Fe.

At Songling, the contents of water-extractable Fe were greater in riparian and low-slope zones than in the upper-land zone whether disturbed by fire or not. However, the fire-disturbed site had significant low content of water-extractable Fe in the surface soil layer.

Table 3 Nutrient concentrations in leaf of the major tree species

Tree species	Leaf	N	P	K	Ca	Mg	Fe
		(g/kg)					(mg/kg)
Liangshui							
Larix gmelinii Rupr.	Fresh	14.57	0.307	3.61	4.07	3.23	203.6
	Fallen	11.13	0.155	2.88	4.51	2.11	227.2
Picea koraiensis Nakai	Fresh	8.82	0.201	3.25	5.33	2.09	157.4
	Fallen	7.29	0.088	2.62	5.84	1.76	178.7
Pinus koraiensis S. et Z.	Fresh	11.26	0.215	3.67	4.59	3.13	157.4
	Fallen	8.92	0.093	3.06	4.71	2.07	173.1
Betulla platyphylla Suk.	Fresh	20.12	0.273	5.71	7.17	3.79	151.2
	Fallen	17.08	0.117	4.46	7.29	3.13	159.4
Alnus hirsuta Turcz.	Fresh	31.17	0.346	3.46	8.58	2.79	133.6
	Fallen	26.59	0.182	3.07	8.46	2.37	141.7
Tilia amurensis Rupr.	Fresh	19.59	0.331	6.34	6.97	3.48	213.6
	Fallen	15.77	0.178	4.78	7.34	2.81	216.7
Hanyue							
Larix gmelinii Rupr.	Fresh	13.27	0.294	3.01	4.57	3.02	224.7
	Fallen	9.82	0.133	2.33	4.43	2.16	239.5
Betulla platyphylla Suk.	Fresh	21.27	0.227	4.67	6.79	3.54	164.3
	Fallen	17.82	0.136	3.95	6.82	3.03	170.2
Alnus hirsuta Turcz.	Fresh	29.33	0.318	3.24	9.37	2.93	141.9
	Fallen	26.61	0.146	2.88	9.49	2.34	152.5
Dailing							
Larix gmelinii Rupr.	Fresh	11.67	0.231	3.24	5.11	2.82	173.3
	Fallen	7.29	0.086	2.51	5.34	2.07	185.9
Betulla platyphylla Suk.	Fresh	17.59	0.205	3.66	6.91	3.38	145.6
	Fallen	13.24	0.083	2.91	6.84	2.91	151.1
Alnus hirsuta Turcz.	Fresh	25.45	0.281	3.16	8.06	2.96	133.8
	Fallen	21.38	0.147	2.59	8.37	2.14	138.4

3.2 Fe contents in leaves and needles

Table 3 showed the chemical composition of leaves and needles of the dominant trees at different sites. The concentration of Fe in fresh needles and litter of larch (*Larix gmelinii* Rupr.) was lowest at Songling and was greatest at Hanyue. At Songling and Hanyue, larch had the greatest concentration of Fe compared to the other tree species. At Liangshui, Amur linden (*Tilia amurensis* Rupr.) had the greatest concentration of Fe in fresh leaves. However, the highest concentration of Fe was found in foliage litter of larch. Alder (*Alnus hirsuta* Turcz.) had low concentration of Fe in both leaf and litter at all three sites compared to the other trees.

The total N was greatest in alder and lowest in Korean spruce (*Picea koraiensis* Nakai). For the same tree species (e.g. larch, alder and birch), the highest N concentration was found at Liangshui and the lowest at Songling.

3.3 Tree-soil interaction and its impact on Fe biogeochemical cycling

In order to reveal the relationships between water-extractable Fe and other soil chemical properties, linear regression was used. The result demonstrated that the concentration of water-extractable Fe was significantly and positively correlated with soil total N (Fig. 1) and water-extractable OC (Fig. 2), which indicates that DOC-fixation may be the dominant form in the extractable Fe. In addition, soil total N content was significantly correlated to soil extractable OC (Fig. 3). This suggests that Fe leaching can be controlled by DOC in forest ecosystems.

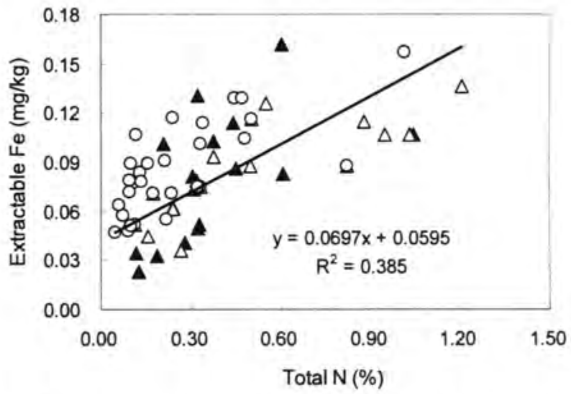

Fig. 1 Relationship between soil extractable Fe and total N in different sites (▲: Liangshui; □:Hanyue; ○:Songling).

Fig. 4 showed the relationship between soil water-extractable Fe and dissolved Fe of stream water in the three sampling sites. The concentrations of dissolved Fe in stream water were somewhat low, particularly at Songling site (ranged from 0.102~0.186 mg/L at Liangshui; 0.176~0.277 mg/L at Hanyue; 0.057~0.067 mg/L at Songling). Similarly, the concentrations of water-extractable Fe of the surface soil under the dominant forests were lower at Songling than at Liangshui and Hanyue. The content of dissolved Fe of stream water was significantly and positively correlated with the soil water-extractable Fe (Fig. 4).

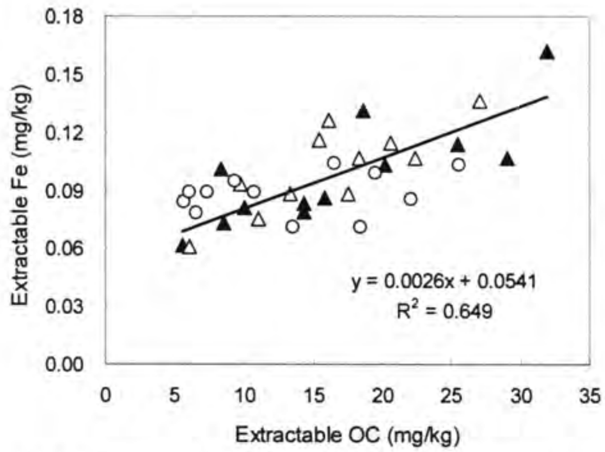

Fig. 2 Relationship between soil extractable Fe and extractable OC in different sites (▲: Liangshui; △:Hanyue; O:Songling).

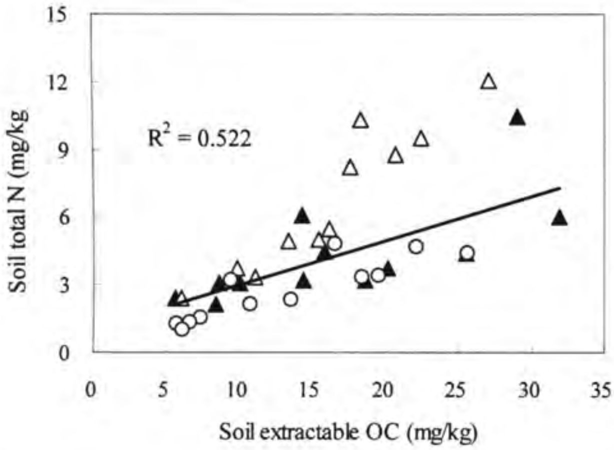

Fig. 3 Relationship between soil total N and extractable OC in different sites (▲: Liangshui; △:Hanyue; O:Songling).

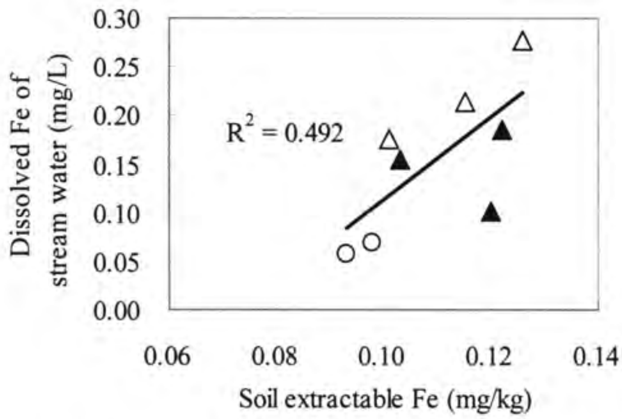

Fig. 4 Relationship between soil extractable Fe and the Dissolved Fe of stream water in different sites (▲: Liangshui; △:Hanyue; O:Songling).

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The authors thanks Zhang K, Sheng HC, Liu B, Li H, Liu Y for help during the field survey, and Deng WX, Wang Q and Huang Q for assistance in chemical analysis. Songling Forestry Bureau and Liangshui Experimental Forest, Northeast Forestry University are greatly acknowledged for permission to conduct field work.

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SPECIFICS OF CONCENTRATIONS AND DISTRIBUTION OF DISSOLVED ORGANIC CARBON IN THE GASSI LAKE BASIN (LOWER AMUR, RUSSIA)

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1. INTRODUCTION

Migration of organic matter in nature is very important for the global and regional geochemical processes on the Earth. Close correlation between organic matter of biosphere, soils and sediment rocks is described by the Russian scientists V.I. Vernadsky (1954), F.P. Vinogradov (1964), A.I. Perelman (1968), V.A. Kovda (1985). Our knowledge of organic matter migration (including its humus component) from surface ecosystems into water ecosystems is still insufficient. It is also true with natural systems of Priamurje, where soil formation is determined with peculiar combinations of hydrochemical conditions, relief and soil-forming ricks (Far Eastern South…, 1969). It is also known that migration processes play an important role in regulating the content of atmospheric air and water in rivers, lakes and bottom sediments (Artemjev, 1993; Orlov, 1998).

The present study focuses on systematizing and assessing results of research of organic matter content and dynamics in soils and surface waters in the Gassi Lake Basin.

Comparing to other regions of the Lower Priamurje, this territory has suffered insignificant technogenic impact and can serve as a model area for hydrological, hydrochemical and soil-hydrochemical studies. The analysis of the field observation data, obtained in July and September 2006 and July 2007 by the three Russian-Japanese expeditions to the Gassi Lake Basin, allowed to reveal certain regularities in organic carbon discharge in the drainage system under study.

2. RESEARCH OBJECTS AND METHODS

The Gassi Lake is situated in the north-eastern part of the Lower Amur plain in the Amur floodplain (Fig.1).

The area of the lake is 30 km^2. Two sub-channels connect the lake with the Amur River. The mean water level in the lake is 25.2 m. Water level regime in the lake much depends on the water level in the Amur. In time of floods in the Amur the Gassi Lake is overfilled with water and during the Amur low water period the lake gets shallow. During the winter low water period the lake is completely frozen through. Lake banks are not high and in the north-east they are covered with woods. Water transparency fluctuated within the range 60 – 100 cm (Surface Water Resources of the USSR, 1970).

The Gassi Lake basin area is 2420 km^2 and includes the basins of the rivers Khar, Pikhtsa with their tributaries, as well as swampy plain areas, weakly drained with streams (the Babchi River). Swamps take 45% of the basin area, and the rest area is covered with woods and sparse-grown trees, 25% of which are coniferous-broad-leaved woods.

The water regime of the Gassi Basin rivers is described as the far-eastern type, with a marked predominance of the rainfall run-off (60-85% of the annual run-off). In the warm time of the year (April – October) water amount is increased due to abundant rainfalls and run-off fluctuations are significant, making the form of the hydrograph ridge-like. Five or six floods are usually observed in the Gassi Basin rivers in the warm time of the year. Hydrochemical research was carried out in the north-eastern area of the basin at the rivers Babchi, Khaso, Malina, Kartanga with its tributaries and Lake Gassi (Fig.1).

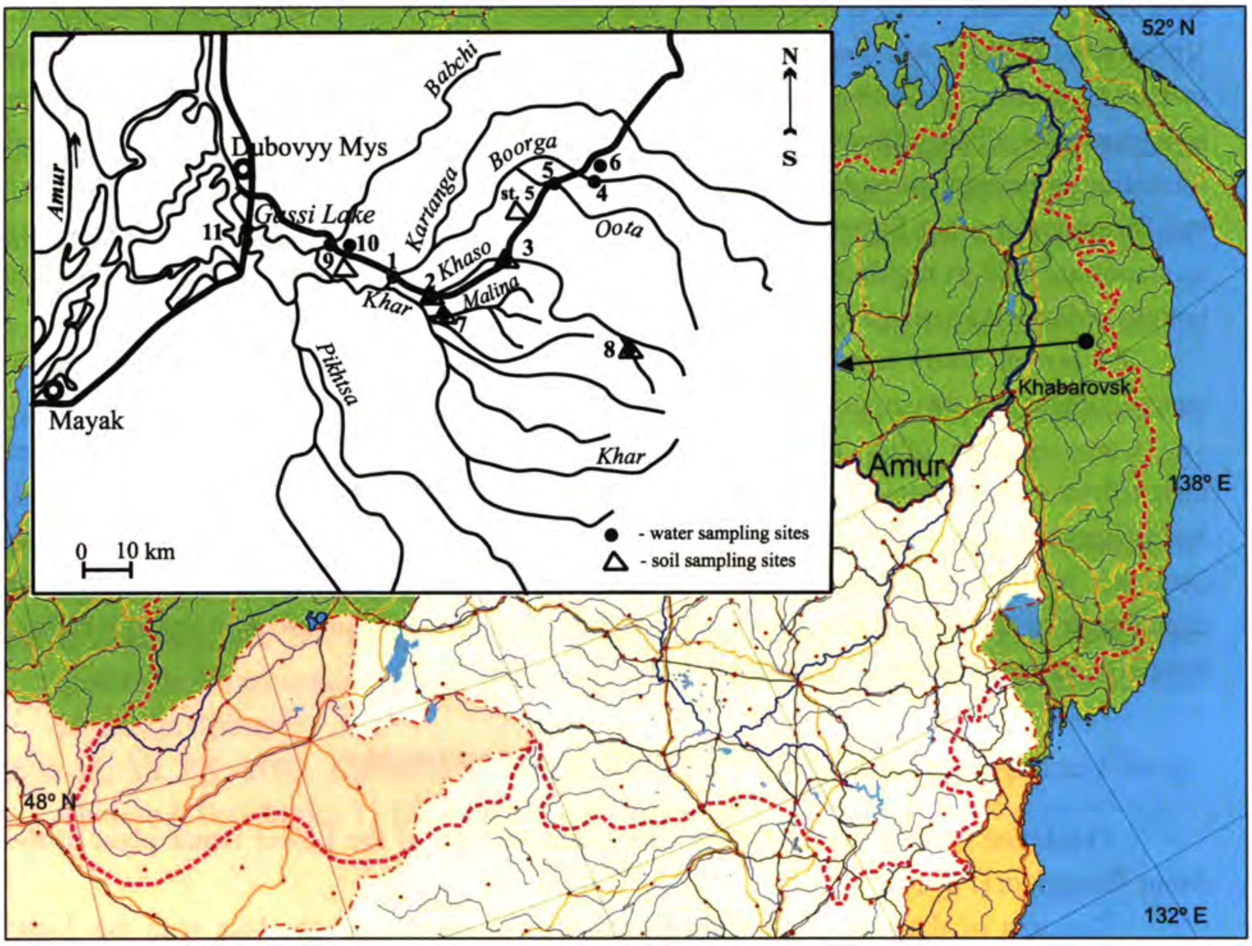

Fig. 1 Geographical Position of the Gassi Lake

The research in the studied area was focused on soil specifics description based on samples selected to study physical and chemical characteristics. River and lake water was sampled from the close-to-surface horizons in the stream middle as follows: in 2006 – in July when rain floods started to decrease and in September – in the low water period; in 2007 – in

July in the low water period. Water level in the Amur at that time was not high and thus water run-off from the Gassi Lake into the Amur was observed.

Color index (CI), determined with Co-Pt scale (degrees) of water, is used to characterize organic matter (OM). Dissolved organic carbon (DOC) in water was determined with L.P. Krylova's method of dry burning in a quartz tube (Alekin, 1997). A water sample of 0.5 l was filtrated through a 0.45 μm filter (Whatman) and DOC was measured in the filtrate. Humus acids (HFA), i.e. humic (HA) and fulvic (FA) acids were determined with a DEAE-method (Krasyukov, Lapin, 1988; Standard methods..., 1989). Potentiometry was used to analyze humus acids, i.e. water pH. Bulk content of organic matter was determined by multiplying TOC by the coefficient 2.

The following parameters were analyzed in soil samples: pH of the water extract; exchange-absorbed base content (Ca^{++} and Mg^{++}) with a complex sociometric method (Arinushkina, 1970); organic carbon (C_{org}) with I.V.Turin's method with photometry to finish (Belchikova, 1970). In the upper soil horizons carbon content was determined with a water extract (C_{som}) using E.V. Arinushkina's method (1970). In some soils lysimetric waters were sampled 50 cm deep (with a capillarimeter method) and total and dissolved carbon was analyzed with I.V.Turin's method.

Water discharge was measured to assess organic matter discharge in rivers and the Gassi Lake.

3. DISCUSSION OF RESEARCH MATERIALS

Amount and dynamics of water run-off in the Gassi Lake Basin, as well as dissolved (and suspended) organic matter discharge mostly depend on the amount and annual distribution of atmospheric precipitations, landscape structure and soil cover specifics.

Gassi Basin soils are ranked among insufficiently studied areas of Lower Priamurje. Soil characteristics and dissolved substance discharge specifics are associated with specifics of the Far Eastern soil facies (Liverovsky, 1969; Ivanov, 1979; Ershov, 1984). One of the main soil processes here is the formation of burozem in the mountains and plains.

In the Gassi Lake Basin different soil types correlate with sharply marked geomorphologic levels, i.e. mountain water divines, mountain slopes, low-mountain and hilly foothills and lowland plains. The medium-high mountain water divine (600-800 m above the sea level) separates the lake basin from the Anui and Khor river basins and is characterized with mountain brown taiga and brown taiga illuvial humus soils under the dark-coniferous forests (spruce, fir).

Usually the brown taiga soil is characterized with a rather thick peaty forest litter. Very often a humus horizon is weakly marked and is not thick. Spots of seasonal gleification may be observed in the mineral part of the soil profile. As for their granulometric composition these soils may be described as loam with a high content of hard rock debris and chippings. Rock exposures are often observed. Eluvial-deluvial basalt and andesite-basalt deposits are widely spread in the area under research.

Yu.A. Livertovsky pointed out the remarkable correlation between brown taiga illuvial humus soils in the Lower Priamurje with the highly-fragmental weathering crust composed of Lower-Quaternary effusive rocks. The steep sloped relief, fragmented character of soils and the weathering crust contribute to an active substance discharge with water. Water run-off in the area under study is composed of the surface, inner-soil infiltration and side flows.

In the brown taiga soil (section H-1, Table 1.) of the water divine between the Gassi Lake Basin and the Anui River medium reaction was weakly acid in the upper horizon and acid in more deep horizons (Table 1).

Table 1. Organic Matter and pH Content in soils of the Gassi Lake Drainage System (dry weight)

Horizon index, depths	pH, 1:10 H_2O	C_{org}, mg kg^{-1}	C_{som}, mg dm^{-3}
Mountain brown taiga illuvial humus soil – (H-1)			
AO_{pr} 2-4см	6.20*	125.4	1.52
A_{pr} 4-10(12)	4.45	141.0	4.52
B1h 10(12)-17	4.36	157.8	-
B2h 17-27	4.70	198.2	–
BC 27-37	4.97	59.6	–
BC 37-43	5.43	30.9	–
Brown forest soil (between the rivers Svetlaya and Uta) – st.5			
O 0-6	5.71*	389.2	1.49
A1 6-20	4.84	67.7	2.27
B1 20-32	5.62	8.6	–
B2 32-46	5.55	10.4	–
Humic gley soil (Burga River Valley) – st. 4			
O 0-5 (6)	6.32*	421.2	6.12
A(H) 5 (6)-13(14)	5.37	220.1	3.06
B1 13(14)-20	5.52	72.0	–
B2 ниже 20	5.58	67.7	–
Soddy burozen (brown forest) soil (Left Khaso River) – st. 3			
O 0-7	5.67*	382.0	–
A1 10-15	5.53	265.5	4.3
AB 15-27	5.37	98.1	–
BC 27-52	5.58	85.2	–
Peat humic gley soil (Malina River) – st. 7			
AT 10-15	4.85*	244.0	-
TM 20-30	4.68*	115.9	4.17
CG 30-40	5.59	14.6	–
Peat gley (Babchi River) – st. 9			
T1 20(30)-42	5.21*	376.0	2.8
T2 42-60	5.24*	450.2	–

Note: "-" in the table and further on in other tables means "not defined" - 1:25 H_2O.

The sum of exchange bases throughout the soil profile is not big. A noticeable increase of the absorbed Ca^{++} и Mg^{++} is registered in the AO_{pr} upper horizon and BC horizon (0.15 mol kg^{-1}). In the first case it is caused by the evident biogenic accumulation, and in the second case it is caused by the dismissal of bases, especially magnesium bases, resulting from the geochemical process of inner-soil weathering of minerals (mainly basalt rock plagioclases). Low content of bases in the profile middle (0.06 mol kg^{-1}) may result from the washing-out with the inner-soil moisture run-off.

A low content of bases in the profile middle might be caused by their washing-out with inner-soil moisture runoff, which is a peculiar feature of soils on the mountain slopes. Bases leaching with fulvic acids, the acid part of humus, seems to take place. Low pH values indicate acid, and even highly acid media in the profile middle. A high C_{org} content is specific not only to the upper soil horizons, but to the whole profile. Humus is very mobile and is present nearly in all horizons. High concentrations of mobile iron (12-37 g kg^{-1}) are observed up to the depth of 40 cm in the profile of the section H-1. Below its content is rather low (1.8 g kg^{-1}). Humus and iron presence is evident in the soil color (chocolate-brown and ochre-brown color tones). Accumulation of weakly decomposed organic matter in the upper soil horizons and high mobility of iron-humus compounds constitute specifics of brown taiga illuvial humus soil.

The next macro-landscape level is composed of low-mountain and hilly landscape (200-400 m above the sea level). The rivers Pikhtsa, Khar and their tributaries (Uta, Khaso, Burga, Kholgoso) drain this area. Coniferous-broad-leaved forests are abundant here and the rest of the territory is covered with secondary small-leaved forests (birth, aspen). Larch dominates close to the lowlands. This landscape is characterized with transitional accumulative regime of moisture and substance migration, i.e. substance discharge is combined with its inflow from the upper layers and further accumulation. Migration flows depend much on the inner-soil side water run-off. High degree of basalt rock weathering and significant soil profile thickness characterize this part of the basin. Significant accumulation of clay fractions in the fine earth contribute to substantial moisture of soils. In the second landscape level loan and clay-detritus brown forest soils (burozems) are common.

Under the forest litter typical burozems have a developed humus horizon with a high content of humus and a mineral profile of yellow-brown uniform color. Thickness and detritus presence in soil may vary depending on the geomorphologic conditions. Mean reaction of the typical brown forest soil under the coniferous-broad-leaved forest (2-06, st. 5) is close to neutral, the humus horizon with an acid media being exclusion. Ca^{++} и Mg^{++} content in A1 и B1 horizons (0.20 и 0.17 mol kg^{-1}) is noticeably higher than in the brown taiga soils, which contributes to a more complete neutralization of acid humus formation products.

The soil of section 2-06 (st.5a) is characterized with a very high C_{org} content in the AO horizon (up to 390 mg/kg),which indicates a high coniferous-broad-leaved forest productivity and organic matter intensive accumulation in the forest litter. C_{org} content in the A1 humus horizon is high (about 70 mg kg^{-1}), which is specific to the burozem soil type formation. Down the profile, as stands true to all the brown forest soils, C_{org} content quickly reduces and is 8.6-10.4 mg/kg^{-1} at a half meter depth. Forest soil forming processes as a whole have a marked accumulative character (especially pertaining C_{org}, biogenic bases, iron compounds).

The valleys close to the rivers that drain the mountain landscapes (Kartanga, Burga, Khaso, Left Khaso, etc.) are formed with big-size pebble or sandy-pebbled alluvium, and as such they play an important role in the formation of the surface water filtration runoff. Mixed forests here are composed of Manzhurian ash, elm, Korean pine, poplar, Asian bird cherry with the variety of hygrophilous grasses (fern, nettle, sedge, horse-tail, etc.) and form humic gley soils. Most of the season they are rather moist being close to ground waters (50-60 cm). Still thanks to a good filtration there is no durable moisture.

Humic gley soils are covered with water for a short time during floods. When the water runs away the soil surface has a thin layer of clay sediments. Morphological composition of plain soils indicates an intensive accumulation of humified plant residue in the upper part of the soil profile (section 4-06, st. 4). Forest litter (horizon O) is from 3 to 6 (7) cm thick with well-marked fermentative layers (L, F+H). Reaction of the medium is neutral. Humic horizon A(H) is usually of black-brown or black color with a fine-particle structure and weakly acid reaction of the medium. Both horizons have high C_{org} content. Accumulation of the absorbed Ca^{++} и Mg^{++} (0.40 mol kg^{-1} in the horizon AO) also contributes to this. Below the profile base content reduces compared to the upper horizons, but still remains in high values. The highest C_{org} and exchange-absorbed bases contents in the organogenic part of the profile mark humic gley soils out of the river plains among all the other soil types in the Gassi Lake Basin.

A flat plain takes the most part of the Gassi Lake Basin with absolute heights 30-50 m above the sea level and in the river valleys they are less than 30 m above the sea level. Geochemical landscapes of this plain are of sub-aqua-accumulation type. The layer specifics include a weak draining capacity (flat relief of the surface and pressed watertight clay sediments), swamping and peat sediment accumulation. Peat deposits in grass and sphagnum bogs with shrubs and low Daurian larch are 0.2 to 1 m thick. They retain most of atmospheric precipitations and water runoff from the foothills. In July and September 2006 the bog water level exposed to the surface. The role of rivers in the drainage within the plain is not high and expands only to area close to the river beds (Prozorov, 1972). Peat (P) and peat-mineral (PM) horizons have a weak acid reaction of the medium (section 7-06, st. 7). The sum of the absorbed bases is not big, i.e. 0.14 mol kg^{-1} and in the mineral horizon it reduces to 0.06 mol kg^{-1}.

The revealed analytic data show that high organic matter resources are the peculiarity of the soil cover in the Gassi Lake Basin. Still their formation within various landscape levels is uneven and there is a misbalance between accumulation of decomposed organic residue (forest litter, humic and peat horizons) and humic matter proper (humus accumulative horizons of soil). A slowed decomposition of plant residues mostly of coniferous litter is specific to brown taiga soils of the first landscape level (the upper reaches of the Burga, Uta and Khaso rivers). It predominates humification processes. The main result of such biochemical process direction is the formation of a significant amount of water- and acid-soluble forms of organic matter and their penetration into the soil solution. This organic matter forms have a capacity to transport (illuviate) down the soil profile. Current research show that a water-soluble part of humus acids in forest soils is mostly formed in forest litter. They play an important role in the formation and migration of soluble organic and mineral complex compounds and, thus, in the formation of quality of water that drains soil and landscape as a whole (Ananenko, Fridland, 1983; Elpatjevsky et al., 2000; Matyushkina, Levshina, 2005).

Studies of water extracts from soils showed that C_{som} in brown taiga illuvial humus soils under the spruce and larch forest (section H-1) was high, i.e. 1.52 and 4.52 mg dm^{-3} for the horizons AO_{pr} and A_{pr} respectively (Table 1) or 12 and 32% of the total organic matter resource in these horizons.

High moistening and relatively high draining capacity of these soils assist to active transport of C_{som} from the upper horizons down the soils profile and probably even beyond its bounds. The smallest C_{som} content (1.49 mg dm^{-3}) was found in forest litter of brown forest soil between the rivers Svetlaya and Uta (the second landscape level). It seems that most of it is averaged with bases, richly present in leaf fall and forest litter. Transport of C_{som} down the profile may be also slowed down due to the pressed and less fragmented soil structure.

It is known from publications (Ivanov, 1976; Elpatjevsky, 2000) that mobile humus migration through the soil profile is not typical to brown forest soils. In humic gley soils in the valleys of the draining rivers (Burga, Left Khaso and others) C_{org} content in the upper horizons is high and more carbon migrates from the forest litter into the water extract and less from humus horizon than in brown forest soils. Even less C_{som} is registered in the surface horizon of weakly decomposed peat between the rivers Babchi and Kartanga (only about 2.8 mg dm^{-3}). The formation of a water-soluble carbon in peat-bog soils of around-lake plain mostly depends on the decomposition rate of peat deposits.

C_{org} mobility in soils also indicates its discharge into lysimetric water. Total carbon in lysimetric solutions of the soil profile under study fluctuated from 9 to 79 mg dm^{-3}. Minimal values were registered in brown forest soils under coniferous-bread-leaved forests (between the rivers Svetlaya and Uta and in the Khaso River upper reaches), whereas minimal values characterize peat-bog soils of the swamped foothill plain. Still, in lysimetric waters of plain in-shore shoal in the Gassi Lake DOC was not high (about 13 mg dm^{-3}). It may be explained with dilution, when solutions contacted lake waters. It should be noted that the share of suspended carbon in lysimetric solutions was less 10% of total carbon, and as such this carbon migration form in soil waters was neglected. Although only few data on lysimetric solutions were obtained, still they allow predicting a high degree of involvement of organic carbon in migration of moisture and substances in the landscape of the studies area.

The research conducted in 2006 showed that the rivers of the north-eastern part of the Gassi Lake drainage system significantly differ in their DOC content, which changed from 2.4. to 39.8 mg C dm^{-3} (Table 2).

Table 2. Hydrochemical Water Parameters of Lake Gassi and its Tributaries in 2006-2007

Station Number (Fig. 1)	Sampling site	Sampling time	pH	CI, grad	DOC, mg Cdm^{-3}
1	Kartanga River	July, 2006	6.62	280	16.2
		September, 2006	6.95	332	27.1
		July, 2007	7.20	130	6.15
2	Khaso River (lower bridge)	July, 2006	7.50	152	6.9
		September, 2006	7.05	156	12.2
		July, 2007	6.68	65	2.7
3	Khaso River (upper bridge)	July, 2006	7.50	59	6.8
		September, 2006	7.40	68	5.1
		July, 2007	6.75	60	3.6
4	Uta River	July, 2006	7.55	112	8.3
		September, 2007	7.40	45	2.4
		July, 2007	–	–	–
5	Burga River	July, 2006	7.35	70	3.5
		September, 2006	7.40	84	6.0
		July, 2007	–	–	–
6	Stream running into the Burga River	July, 2006	6.04	470	39.8
		September, 2006	–	–	–
		July, 2007	–	–	–
7	Malina River	July, 2006	7.03	480	36.7
		September, 2006	6.72	432	33.6
		July, 2007	–	–	–
8	Left Khaso River	July 2006	–	–	–
		September, 2006	7.57	17	4.5
		July, 2007	7.40	47	3.4
9	Babchi River	July, 2006	6.83	490	18.5
		September, 2006	6.31	520	32.8
		July, 2007	6.66	120	38.0
10	Bog	July, 2006	–	–	–
		September, 2006	5.70	450	51.2
11	Gassi Lake	July, 2006	6.97	255	30.4
		September, 2006	7.14	330	28.0
		July, 2007	7.80	65	3.7

The lowest DOC concentrations (2.4 – 8.2. mg C dm^{-3}) and, thus, not high color index values were found in waters of middle reaches of Uta, Khaso, Burga, Left Khaso rivers, i.e. within the low-hill transit-accumulation landscape. In the autumn low water period dissolved carbon content decrease was very small. At the same time, waters which run from various swamped streams into the rivers under study in the flood period were characterized with high colority and DOC content up to 40 mg C dm^{-3} (the stream running into the Burga River). Significant DOC increase was also observed in streams that drain sub-aquatic-accumulative landscape of a swamped around-lake plain. Waters of the lower reaches of Kartanga and Malina rivers and the Babchi River in July revealed DOC concentrations that were 4–5 times higher than waters of foothill rivers. Comparison of DOC concentrations in lysimetric and river waters show that in July 2006 approximately 45% of C_{som}, came into the rivers from foothill areas and 38% came from the swamped plain. In September 2007 the C_{som} discharge decreased and was 34% and 31% respectively. Thus, there was no significant increase of C_{som} discharge from the bogs, although DOC concentrations in bog waters were higher (51.2 mg C dm^{-3}) in the low water period. It seems to be associated with much DOC fixation in the peat substrate.

The amount of HFA in studied waters of the Gassi Lake drainage varied significantly. In foothill areas river waters in July contained 1.5–4.2 mg C dm^{-3} of HFA and in September – 1.3–2.2 mg C dm^{-3}. Not-high HFA contents explain low colority (17-112 degrees) of water in the rivers Khaso (the upper bridge), Uta, Burga, Left Khaso, especially in autumn. HA and FA ratio is rather wide (from 6 to 16 times). When rivers (Babshi, Kartanga, Malina) enter the swamped around-lake plain, HFA content in them sharply increase up to 7.5 – 14.8 mg C dm^{-3} and in July and to 10.2 – 16.6 mg C dm^{-3} - in September. The waters with high HFA concentrations were of brownish color and had a high color index of 280–520 degrees and more. A water ratio between HA and FA was also registered here. Bog waters revealed maximal humus compound contents and also the highest colority. HFA concentrations were 1.5–2.5 times higher compared to bog rivers. Bog water enrichment with humus substances occurs due to their inflow with flood river, underground and slope runoff, and mostly due to humification of OM of peat deposits (Prozorov, 1972).

High DOC concentrations were registered in the Gassi Lake both in flood time and in low water, 30.4 mg C dm^{-3} at average. Water color index was also high (3000 degree at average). In July dissolved carbon content in the lake was 2 times higher compared to the incoming rivers in spite of the fact that the rivers were flooded. It can be explained with maximal development of inner production processes in the lake itself. In September the amount of carbon discharged from the rivers and carbon concentrations in lake water was fixed at one level. HFA content both in July and September differed, but insignificantly and was rather high, i.e. 6–7 mg C dm^{-3} (45% of DOC at average).

The second water sampling and analysis in 2007 showed that organic matter content in the studied rivers was noticeably lowed that in 2006. At the same time, DOC concentrations varied significantly. The Left Khaso and Khaso rivers, which run through foothill and low-hill territory, had relatively low DOC concentrations that correspond to low colority values. Kartanga River, which runs mostly through the swamped accumulative plain, had DOC concentrations that exceeded those found in the Khaso River more than two times. DOC content in the swamped Babchi River was 38.0 mg C dm^{-3}, very close to DOC values in swamp waters. The decrease of organic matter content in 2007 in the studied waters (except the Babchi River) is explained by the low water in the rivers and as the result of it the decrease of humic substance inflow from the mountainous and the plain parts of the Gassi Lake drainage system. High DOC content in the Babchi River seems to be due to their connection with swamp waters, which is proved with relevant chemical and physical parameters (pH).

Gassi lake water in 2007 revealed not high values of DOC, 4.0 mg C dm^{-3} at average, which are much lower than in 2006. That is why the color index of water was low as well (65 degrees at average).

Organic matter discharge in the rivers under study and the lake itself was estimated based on water runoff and TOC data (Fig. 2).

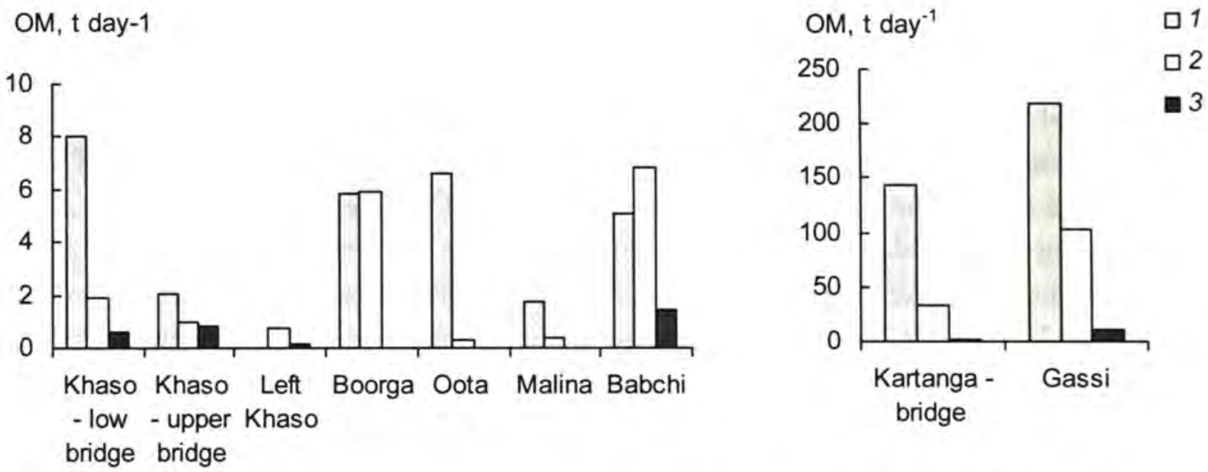

Fig.2. Changes in Organic Matter Discharge with River Water in the Gassi lake Basin in July 2006 (1), September 2006 (2) NS July 2007 (3).

The direct correlation between water amount in rivers and OM discharge is revealed. In the maximum water level period (July 2006) in the rivers under study the highest OM discharge was registered as coming from the Kartanga River (148 t day^{-1}). In summer 2006 the total OM discharge from the Gassi Lake was 220 t day^{-1}, but in autumn it was reduced two times. In a low water year of 2007 OM discharge reduced dozens of times and more (e.g. it reduced 70 times at the Kartanga River). Organic matter discharge from the Gassi Lake was 10.2 t day^{-1}. Similar OM discharge data and its dynamics were obtained for other lakes of the lower Amur, namely the Kizi, Kadi, Khavanda and other lakes (Levshina et al., 2006).

4. CONCLUSION

Organogenic soil horizons are proved to be the main source of water-dissolved carbon in the Gassi Lake Basin. They include forest litter and mull earth, humus and peat horizons, which have a high content of organic matter. Organic matter discharge into the rivers under the present study is much impacted by the landscape peculiarities, amount of precipitation, drainage capacity of soils and underlying bottom mountain rocks.

River waters of the basin studied may be categorized as having high organic matter concentrations, especially in high water periods. In low water periods organic matter discharge reduces ten times. In rivers, flowing through swampy areas (the Babchi River) a reverse picture was observed, i.e. organic matter content increased. Organic matter discharge and content in Gassi Lake showed the same regularities as revealed in the mountain river area of the basin.

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FOREST POLICY REFORM OF RUSSIAN FEDERATION

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INTRODUCTION

Revised Forest Code of Russian federation was passed Duma in December 8th, 2006 and came into force from January 1, 2007. Deliberation process of the Code was in turmoil for years, but at the last stage Putin administration rushed to promote passage of legislation. Ministry of Natural Resources and Forest Agency, which are competent authorities for forest policy and management, could neither prepare related regulation and orders nor organizational structure which implement revised Code at the time of enforcement. During year 2007, related regulations and orders have been established, and the reorganization of forest administrative system was almost completed in the beginning of 2008.

Revision of the Forest Code and reformation of organizational structure of forest administration were full-fledged and its impact of forest management and use of forest resources is expected to quite large. This report is aimed to analyze the current state of reformation, its historical significance and possible result of the reformation.

FUNDAMENTAL DIRECTION OF REVISION OF FOREST CODE

Fundamental direction and background of the policy reform was considered as follows.

Firstly, forest land and resources was kept as federal ownership, and privatization of the ownership was fundamentally not admitted. In 2004, draft code was submitted to Duma which opened the private ownership of forest. Reason that the Government try to open the private ownership is as follows; to achieve consistency with Land Codex which allowed private ownership, to respond request from timber industry. However, there were strong opposition from the public and the government withdrew this version of draft. Most of the people are not familiar with large scale private ownership, and anxious that private land holder might barraged out public forest use, so they express strong distaste for privatization of forest. Russian government also did not open the ownership of local government. It is considered that the government intended to hold decisive power to forest policy and management through ownership.

Secondly, forest administration system was decentralized and most of forest management authority was delegated to local government. Local forest management system was also transferred to local government. Putin administration has been worked to construct centralized administrative framework to restructure governing system, and diminish authority of local government. Popular election system of governor was abolished and governor is now appointed by the President. It is considered that with completion of centralized system, Putin administration allow decentralized forest policy system to establish local based and effective forest management and use.

Thirdly, forest administration was reorganized to separate by functions. Putin administration has policy to separate economic and administrative function, and economic function should be implemented by private sector. Based on this concept, forest management operation – regeneration, tendering, thinning and so on – was categorized as economic function, and ordered to be separated from forest management body. To attain this goal, leskhoze was reorganized to new structure. Most of the staff of leskhoze were dismissed, and only small number of them were employed by newly established "lesnichestvo", which is pure administrative body for forest management. About half of dismissed staff was employed by newly established national forest operation companies, and the balance will completely lost their job.

Fourth, governing intervention to forest use was minimized; assignment of logging lot was simplified, and lease right is "commercialized". Concerning simplification of the assignment, logging permission ticket was abolished, and lease holder could implement logging activities under approved development plan without getting individual logging permission. Concerning "commercialization" of lease right, revised code does not restrict transfer of lease right, and Russian government endorsed the liberalization of sublease and settlement of mortgage to lease right. Minimization of government intervention will result enlargement of the right of leaseholder, and make their forest use activities easier. At the same time, the revision also enlarges duty of lease holder, and obliged to carry out forestry operation and forest fire prevention work. These reforms were considered to intend to screen out small scale company and to promote large scale company, which could responsibly manage leased forest.

MAJOR CONTENT OF THE REFORM

Distribution of authority of forest policy and management

As mentioned earlier, many of forest policy and management authority was delegated to local government. Fundamentally, federal government is responsible to constitute legal framework and local government set concrete policy and management direction and implement forest management. According to this direction, local forest management was transferred from Federal Forest Agency to local governments. Figure 1 showed organizational structure as of January 1st, 2008.

At the Federal level, Ministry of Natural Resources (MNR) is responsible ministry for forest policy and establish institutional framework. Forest Agency is subordinate agency of MNR and responsible to establish institutional framework for federal forest management and to implement monitoring and national inventory. Federal Inspection of natural resources is responsible to inspection of compliance to federal laws and regulation.

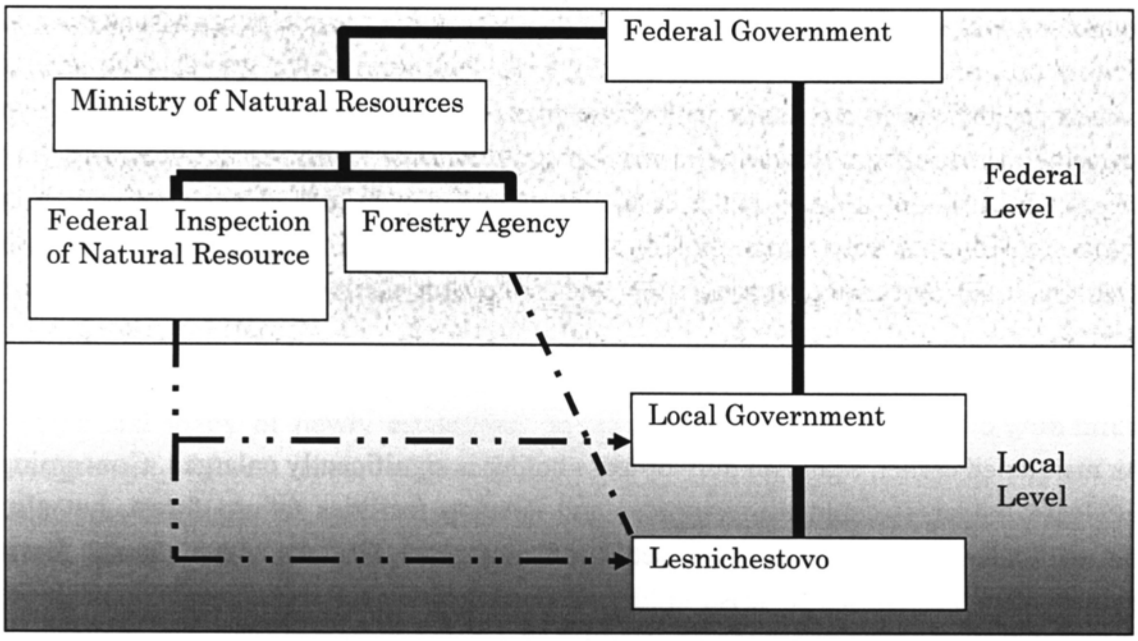

Fig 1 Organizational structure of forest administration in Russia

Local government is responsible to make forest plan and distribute right to use forest. Lesnichestvo carry out field level forest management organization under supervision of local government.

Assignment of forest lease

Forest leaser is assigned through auction. Auction is organized by local government, but in detailed procedure is determined by Federal Government. Under the former system, successful bidder was determined based on not only bidding price but also proposal of contribution for local economy and so on. However, it is considered that there were risk of arbitrary administration and corruption. Revised Code clearly defined that successful bidder is decided only by auction price.

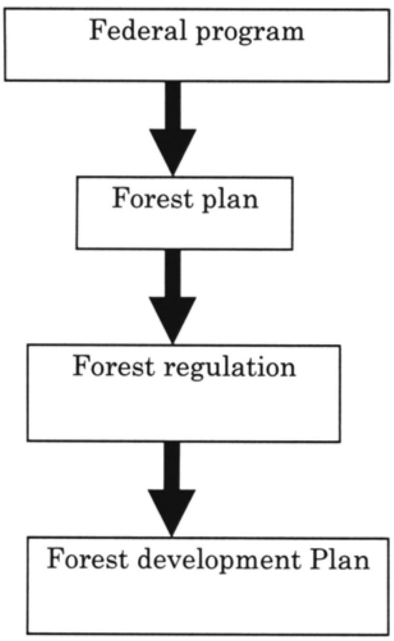

Fig 2 Forest planning system

Forest planning system

As shown in Fig 2, forest planning system consists from four stages. Federal government is responsible to establish Federal forest policy and program, which set fundamental direction of forest policy and management in the Russian Federation. Forest plan is made by local government and approved by federal government. Local government should define current conditions and use of forest resources, and fundamental direction of use, protection, and regeneration of forest resources. Each lesnichestvo should make forest regulations in consistent with forest plan, and local government approves it. In forest regulations, regulation for use, regeneration and protection should be defined in 10 year term. Lease holder is obliged to make forest development plan and to get approval from lesnichestvo. With this plan, lease holder should describe plan to use forest resources permitted by lease agreement, regeneration and protection method, wildlife conservation measures and so on.

Right and duty of lease holder

As mentioned earlier, right and duty of lease holder is significantly enlarged. Concerning right of lease holder, it could use resources and develop facilities to use forest, but also allowed to underlease, sublease, and settle of mortgage. On the other hand, forest management duty is imposed to lease holder. It should carry out regeneration, protection, tendering and fire suppression operation to forest, and develop fire prevention system.

HISTORICAL SIGNIFICANCE OF THE REFORM

Table 1 showed historical development of forest policy framework.

Under the Soviet regime, forest was owned by USSR government, and policy, management and use of forest was centrally controlled. After the collapse of USSR, major issue of reform in forest policy was as follow;

Define ownership of forest resources
Define authority of each administrative organization and separate administrative and other function
Transfer to market economy; Privatization of lespromkhoz, Create market based forest assignment system

Concerning 1st point, ownership of forest was kept as federally ownership. As there are strong opposition from the public towards private ownership, introduction of private ownership is quite unlikely in near term.

There have been frequent reform concerning for 2nd point. Under Elytsin administration, decentralization was carried on to strengthen government base through support from governors. Forest policy framework was also decentralized, and local government became played important role for forest policy and management. However, Putin administration, which aimed to reconstruct "Strong Russia", has centralized whole institutional system. Forest policy system was not exception, and with revision of Forest Code in 2004, all the authority of local government concerning forest policy was deprived. Forest Code of 2006 decentralized forest policy system again, but it should be recognized that delegation of authority was made by strong central government, and central government has kept decisive power.

Separation of economic function from administrative body at the field level was defined in revised code of 2006 first time ever and radically. Fundamental reform of leskhoze was also first time ever since its establishment in 1930's. These reforms will have profound impact on forest management at the field level.

Concerning transfer to market economy, privatization of lespromkhoz was completed in 1990's and many of newly established private timber industry have become quite active. Assignment of forest resources among users has become competition based. Revised code of 2006 was thorough this system and defined that assignment should be done only based on bid price. Revised code also minimizes administrative intervention and gives broad discretion to forest user. Forest users also obliged to carry on forestry operation. These reforms are to intend that forest user to play central role forest management at assigned area and to support to develop large scale timber company.

Revision of Forest Code in 2006 is landmark stability and will have profound effect on whole forest management and use.

CONCLUSION

Revision of Forest Code in 1996 and associated forest policy and forest administrative reform was carried out by the initiative of inner circle of Putin administration. Ministry of natural Resources and Forest Agency, which are responsible for forest policy, carried little weight in the reform process, that means direction of reform faithfully reflect the intent of administration.

Policy system was decentralized and local government has become central player of forest policy and management at the local level. Capacity building to formulate policy and plan at the local level has become important and emerging issue.

There are concerns about weakening of forest management ability at the field level as the reformation of new lesnichestvo system. Establishment and development of forest operation company is uncertain at current stage. It should keep continue to monitor implementation of forestry operation by these newly established company and lease holder.

The revision of Forest Code intends to lease forest lot to timber company which has enough facilities and capacity to carry out forest management. The revision also allows to commercialize lease right. It is expected that lease right will concentrate to the large scale timber company.

Direction and content of the policy reform and reorganization of forestry administration has become clear. However, how there reform and reorganization be implement, and effect to forest management, use and timber industry activities are remain in doubt. Monitoring of implementation of the reform and reorganization should be kept continue.

Table 1 Historical development of forest policy framework of Russia

	Former USSR	***Fundamental Forest Law of 1993***	***Forest Code of 1997***	***Revise Forest Code of 2004***	***Revised Forest Code of 2006***
Responsible organization of forest policy	Central Government	Central government (partly raion)	Central and local government	Central government	Central and local government
Forest management organization	Federal organization	Federal organization	Federal organization	Federal organization	Organization of local government
Field level forest management organization	Leskhoze : both administrative and operational work	Leskhoze : both administrative and operational work	Leskhoze : both administrative and operational work	Leskhoze : both administrative and operational work	Lesnichestovo; Only administrative function
Assignment of right of forest use	Planning economy	Competition, but protect vested interest	Competition	Competition	Auction
Fundation of Implement of use right	Order of government	Logging ticket	Logging ticket	Logging ticket	Forest development plan
Disposition of use right	Not allowed	Not allowed	Not allowed	Not allowed	Allowed
Duty of user	Ordered by government	Participate management operation based on contract	Participate management operation based on contract	Participate management operation based on contract	Obliged to implement management operation

RECENT DEVELOPMENTS OF THE SINO–RUSSO TIMBER TRADE IN THE AMUR BASIN

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I. INTRODUCTION

An analysis of China's trade flows of the past ten years reveals that among various forest products, it is log imports that have increased the fastest in both proportion and volume. For example, from 1996 to 2005, the country's total log imports grew from 3,186,000 cubic meters (m^3) to 26,309,000 m^3, meaning that the import volume grew by a factor of more than seven over ten years. It should be noted that the annual incremental growth in volume roughly corresponds to the reduction in China's domestic timber supply, which is linked to the implementation of its Natural Forest Protection Project (NFPP). Over the same period, the share of Russian timber as a share of China's total timber imports shot up from 17 percent in 1996 to 68 percent in 2005, suggesting that logs from Russia have been making up for China's supply-demand gap.

Timber is transported from Russia to China by rail, ship, ferry, and truck, but the majority is moved by rail. As shown below, most of the timber transported from Russia to China passes through inland border corridors.

Several studies were conducted on the condition of the Sino–Russo inland border timber trade in its earlier stage of development (i.e., Yamane and Lu 2000), but no detailed studies on its progress and prospects have been published since, despite its continued growth.

Thus, the purpose of this paper is to provide an outline of recent Sino–Russo timber transportation routes and timber flows, as well as the progress of development, with the goal of further clarifying the details and characteristics of changes that have occurred. A preliminary analysis is later provided on timber trade statistics for individual customs gateways on China's side of the Amur Basin, as well as an outline of the latest changes in timber trade policy of both countries. Finally, the impacts of the latest policy changes on the future of Sino–Russo timber trade flows are discussed.

II. TRANSPORTATION ROUTES AND THEIR DEVELOPMENT

1. Variation of route

The routes used to transport timber from Russia to China can be roughly divided into the following:

i. From Eastern Siberia or the Russian Far East by rail on branch lines of the Trans-Siberian Railway to the border, and then by rail or truck into China.
ii. From near border areas and then carried across to China by truck or ferry.

iii. From Eastern Siberia or the Russian Far East by rail on the main line of the Trans-Siberian Railway to timber export seaports such as Nakhodka and Vladivostok in Primorsky Krai, and then shipped to seaports in China such as Dalian and Tianjin.
iv. From Eastern Siberia or the Russian Far East by rail along the Baikal-Amur Railway to Russian timber export seaports such as Vanino and Sovgavan. A variation of this route is often used, where logs are exported from Nikolayevsk-na-Amurla at the river's mouth. Recently, as river transportation on the Amur River has opened up for trade, routes leading to China's river ports have also gradually been opened up. Among such sea-to-river routes, there is a new one that starts at a seaport such as De-kastri and Sizuman, and then up the Amur River to river ports in China. In this case, logs are sometime reshipped from Nikolayevsk-na-Amurla.
v. From Khabarovsk and Primorsky Krai by truck directly to timber export ports such as Olga, and then shipped to major seaports such as Dalian, Qingdao, etc.

From among these five routes, the first two have been the main ones used to export timber from Russia to China. More than 80 percent of the timber trade between the two countries in 2004 crossed via inland border points (Figure 1).

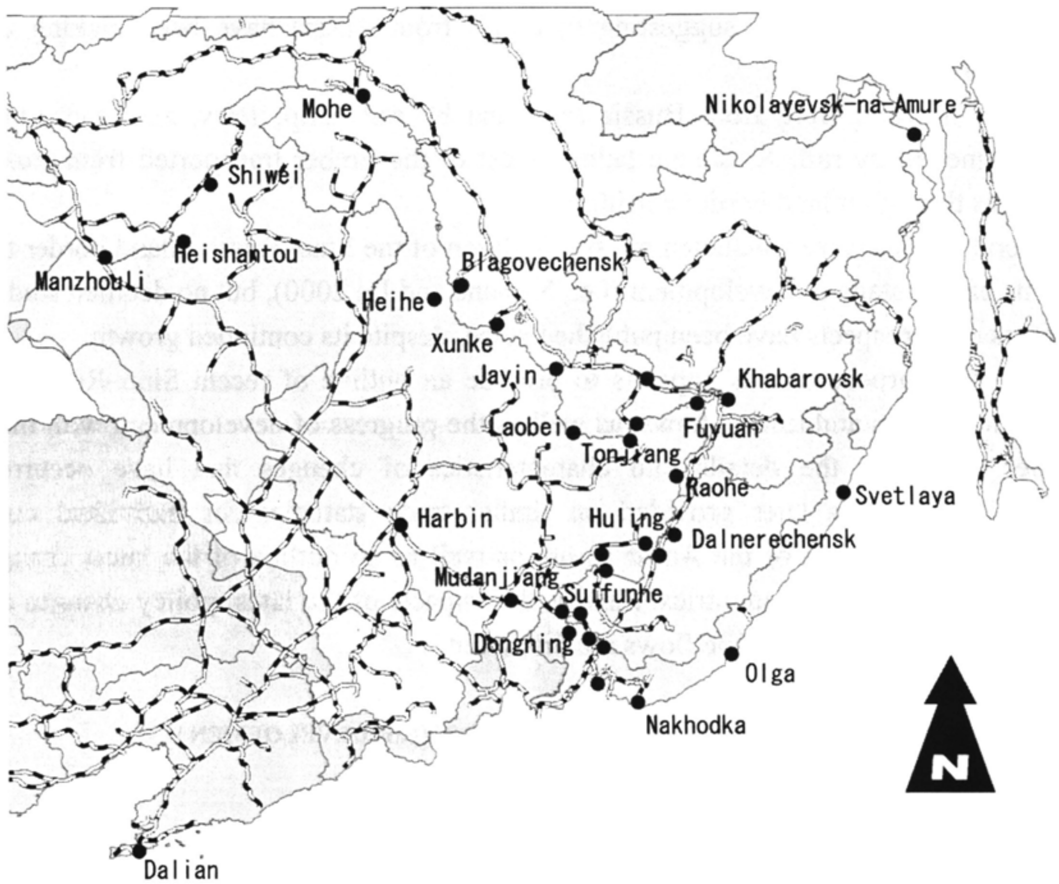

Figure 1. Maps of Amur Basin.

2.

In the main channel of the Amur River watershed of the Amur Basin, the Manzhouli gateway in the Inner Mongolia autonomous region is the only route connecting directly to

Russia's Zabaykalsk, Chita Oblast. There are also two small routes used in the province, and eight small or medium-sized gateways in China's Heilongjiang province, where Russian timber is transported by truck or ferry from Amur Oblast, Jewish Autonomous Oblast, and Khabarovsk Krai (Table 1).

Among them, Manzhouli is the major gateway. In 1992, this once-small border city was one of the first inland border cities opened up by the People's Republic of China. After 2000, the city developed dramatically, including construction of a new domestic airport connecting to Beijing and Harbin, as well as highways leading to Harbin, the capital of Heilongjiang province, through Hailar. Manzhouli started establishing an import material-processing zone in 2003, and the project has progressed steadily since. A wood-processing area was established in the zone in 2004, and now more than 40 Russian wood-processing enterprises are in operation there. As log imports from Russia increased, freight yards were enlarged in 2004 to expand capacity, and a new yard is planned for construction in 2008.

The Heihe gateway in China, which connects to Blagoveshchensk, the capital of Amur Oblast, was established as a free trade zone on the border, and includes relatively new construction projects such as a cross-border river bridge and highways leading to Harbin. The Tongjiang gateway, which connects to Leninskoe in Jewish Oblast, also had its river port upgraded to increase capacity. The city also has highway construction projects leading to Harbin. Other small gateways on China's side such as Mohe and Fuyuan have also been expanding their gateway capacity.

3. Gateways in the Ussuri watershed in the Amur Basin

In the Ussuri watershed of the Amur Basin, the Suifunhe gateway in Heilongjiang province is the only corridor connecting directly by rail to Russia's Grodekovo station (in Pogranichnyy) in Primorsky Krai. The distance to Ussuriysk and Vladivostok is 123 kilometers (km) and 230 km, respectively. Suifunhe was opened up as one of the first border cities, like Manzhouli and Heihe, in 1992, and is a core of Sino–Russo timber trade, especially from the southern part of Far East Russia.

The railroad gateway is a 24-hour operation with an annual handling capacity of more than six million m^3 having been expanded in stages since 2000, and now the improvement of its cargo terminal station (Suifunhe North Station) has been completed. The gateway has a road connection with Russia, constructed in 1990, and it connects with a highway leading to China's Harbin through Mudanjiang. An already approved highway project will connect to Manzhouli.

Other small routes include the Bikin–Raohe (or Jao-ho) river corridor (Khabarovsk Krai to Heilongjiang province), the Markovo–Hulin river bridge corridor (Primorsky Krai to Heilongjiang province), the Turiy Rog–Mishan land corridor (Primorsky Krai to Heilongjiang province), and the Poltavka–Dongning road corridor (Primorsky Krai to Heilongjiang province). Trucks can cross the border along the Bikin–Raohe and Markovo–Hulin corridors during the winter when the rivers freeze.

Among the small gateways on the China side, Dongning, which lies near Suifunhe, around 154 km from Ussuriysk in Primorsky Krai, has grown rapidly in the last five years. The first stage of construction along the corridor of the Dongning–Poltavka border trade zone was completed by 2005, and then the town began trial operations of its Sino–Russo international trade market. The small border town has already seen branch highways constructed to connect to the Suifunhe–Harbin route. Additionally, previously suspended rail operations on the railroad connecting to the Mudanjiang–Suifunhe line were resumed and extended to the border, and the Dongning railroad station was also established. The plan is to connect this railroad to the railway on the Russian side, which leads to Ussuriysk, a project already approved by Russia's central government. Once this project is completed, this improved corridor will have a transport capacity as great as the Suifunhe–Grodekovo corridor. In addition to these upgrades, the Raohe customs office was completed renovated and expanded its handling capacity. There are also several other projects being planned, such as the construction of a bridge crossing the river, a free trade zone, and a highway development leading to Harbin through Fujin.

In contrast to these improvements on China's side, gateway improvements on Russia's side still lag behind, with no significant progress since the Soviet era, although railroad construction connecting to Dongning and the improvement of loading capacity at the Grodekovo station are being considered.

Table 1. China's border gateways to Russia in the Amur Basin

Watershed	*Large gateway*	*Small/medium-sized gateway*
Main Amur	*RW, RD: Manzhouli in INM*	*WT: Heishantou, Shiwei in INM* *WT: Moho, Heihe, Sunwu, Xunke Jiayin, Luobei (Fujin), Tongjiang Fuyuan in HJN*
Ussuri	*RW, RD: Suifunhe in HJN*	*WT: Raohe in HJN* *RD: Mishan and Dongning in HJN* *RD: Hulin in HJN*

Notes: INM = Inner Mongolia autonomous region; HJN = Heilongjiang province
RW = railway connection; RD = road connection; WT = water connection

III. TIMBER FLOWS FROM THE AMUR BASIN THROUGH LAND BORDER GATEWAYS

1. General trend

The volume of timber flowing from the Amur Basin in Russia to China increased significantly from 1996 to 2005, growing from 476,000 m^3 to 15,872,000 m^3, in tandem with the trend of China's total timber imports (Table 2). The share of the basin's timber trade against total imports is around 80 percent, indicating that the Amur Basin is a core area of Sino–Russo timber trade. Softwood and hardwood logs are the main imports, at more than 90 percent, but this share has been dropping gradually.

In comparing the two watersheds, the Ussuri and the Amur, the volume of timber flow from the Ussuri watershed was more than 60 percent in 1996 compared to the basin's total, and was larger than that from the main Amur Basin. In 1997, however, the flow from the main Amur Basin reached a 50 percent share and then increased to around 60 percent. As for the types of log exports from Russia to China, there are major flows from both watersheds, but the flow of sawn wood from the main Amur watershed has increased gradually since 2002. The share of sawn wood imports from the main Amur watershed was 50 to 70 percent, and this fact indicates that the Zabaykalsk–Manzhouli corridor has been the main route for the Russian sawn wood trade. This is because most imported sawn wood is processed at enterprises located in remote areas such as Irkutsk in East Siberia and Krasnoyarsk in West Siberia, and then transported to China by rail.

Table 2. Timber import volume from Russia to China with a special focus on the Amur Basin

Unit: 1,000s of cubic meters (m^3)

Water-shed	*Main Amur*				*Ussuri*				*Amur Basin*		*China's total imports from Russia*	
Gateway	*Manzhouli*		*Others*		*Suifunhe*		*Others*					
Year	*LG*	*SW*	*LG*	*SW*	*LG*	*SW*	*LG*	*SW*	*LG*	*SW*	*LG*	*SW*
1996	*147*	*3*	*19*	*1*	*272*	*4*	*30*	*0*	*468*	*8*	*529*	*11*
1997	*382*	*6*	*14*	*0*	*381*	*4*	*14*	*0*	*791*	*10*	*949*	*11*
1998	*665*	*7*	*16*	*1*	*561*	*2*	*8*	*1*	*1,250*	*11*	*1,591*	*12*
1999	*1,784*	*41*	*135*	*8*	*1,341*	*14*	*18*	*4*	*3,279*	*66*	*4,305*	*82*
2000	*2,070*	*82*	*144*	*7*	*2,038*	*32*	*10*	*3*	*4,261*	*125*	*5,931*	*158*
2001	*2,932*	*182*	*457*	*1*	*3,144*	—	*4*	—	*6,537*	—	*8,766*	*308*
2002	*5,264*	*383*	*624*	*15*	*4,678*	*90*	*6*	*31*	*10,572*	*520*	*14,806*	*552*
2003	*5,241*	*397*	*563*	*14*	*4,954*	*103*	*6*	*19*	*10,765*	*533*	*14,368*	*561*
2004	*6,975*	*612*	*769*	*7*	*5,245*	*124*	*9*	*25*	*12,997*	*767*	*16,962*	*799*
2005	*8,095*	*720*	*783*	*14*	*6,097*	*132*	*5*	*28*	*14,979*	*893*	*20,045*	*1,057*

Note: LG = logs; SW = sawnwood
Source: Compiled from Chinese customs trade statistics by the author.

2. Large gateways

The timber flows through the two major gateways, Manzhouli and Suifunhe, have grown sharply over the last ten years, but the types of wood vary depending on the origin of the timber. Based on interviews conducted at the Manzhouli gateway, the logs imported are mainly from East Siberia, partly near border regions such as Chita Oblast and Amur Oblast. As for Suifunhe, most logs are transported mainly from Far East Russia, but the softwood logs such as red pine and larch originate in East Siberia.

As for the species or types of imported timber, the Manzhouli gateway sees mostly softwood, but the import of broadleaf logs such as birch increased after 2002 (table 3). After the establishment of an ambitious processing complex in the city, around one third of imported logs are roughly processed and then transported to secondary markets for further processing. Most recently, some of the processed Chinese-made products made of Russian wood have been transported back through Russia for export to Europe.

On the other hand, many hardwoods are imported from Russia through Suifunhe, the major gateway in the Ussuri watershed. In the mid-1990s, before China's NFPP was instituted, most imported timber was hardwood logs. Even until recently, the hardwood flow accounted for about 30 percent (more than 50 percent monetarily) of total imports, despite the fact that softwood imports have grown sharply. Of the total hardwood border trade from Russia to China, around 70 percent is transported through this corridor, indicating that Suifunhe is the key gateway for hardwood trade, where large imports are seen of hardwoods such as ash and oak from the southern part of Far East Russia. According to trade statistics in the first half of 2004, the share of total imports of hardwoods such as ash, oak, linden, and elm is more than 20 percent by volume and more than 40 percent by value.

In Suifunhe, Russian timber-processing industries have been developing since around 2000, and about 30 to 50 percent of imported logs are now processed in the city. In the early stages, most enterprises processed semi-finished products, but the production of value-added products such as laminated lumber has been increasing over the last three to five years. Consequently, there are a lot of processing factories in a limited city area, so the shortage of sites available for new factories has been emerging as a limit to further development. Thus, Suifunhe's city government stepped up efforts to expand its industrial base, and it finally decided to relocate small primary processing factories to the neighboring city of Suiyang in an effort to accommodate more factories.

Table 3. Russian timber flows at China's two major gateways in 1997 and 2002

Units: 1,000 m^3

		Logs		Sawnwood	
		1997	2002	1997	2002
Suifunhe	Softwood	3.3	3,909.6	0.4	36.6
	Hardwood	378.0	768.6	3.3	52.7
	(Oak)	5.3	146.6	0.2	26.0
Manzhouli	Softwood	381.6	5,185.0	5.8	330.1
	Hardwood	0.0	79.0	0.1	53.3
	(Oak)	0.0	0.0	0.0	0.0

Source: Based on Chinese customs trade statistics compiled by the author.

3. Small and medium-sized gateways

The recent share of timber flow of both logs and sawnwood passing through small and medium-sized gateways in the Amur Basin is around 5 percent, so these gateways are still a very small part of the overall Sino–Russo timber flow. The gateways where flows exceed more than 100,000 m^3 are Tongjiang, Luobei, and Fujin, and all are in the main Amur watershed. Among them, the import volume transported through the Tongjiang gateway has increased annually, and it reached around 500,000 m^3 in 2005. At the Mohe gateway, which is located at the head of the Amur River, imports were around 100,000 m^3 after 2001, despite the fact that the customs office only opens in winter when the river freezes. This is partly due to the convenience in transportation, as the distance between Mohe and Dzhalinda on the Russian side of the gateway is only 1.5 km, and a branch of the Trans-Siberian railroad reaches to Dzhalinda.

The level of imports at Heihe, one of the first Chinese border cities to open up, like Manzhouli and Suifunhe, decreased after 1999, and has been steady at around 30,000 m^3 in the last few years. The import volume at Fuyuan, which connects to the city of Khabarovsk in Khabarovsk Krai, has remained around 20,000–60,000 m^3 since 2000. Flows at other gateways have been around 10,000 m^3, with some fluctuation, while timber imports passing through Xunke, Raohe, and Mishan are very small.

Gateways where timber flows exceed more than 10,000 m^3 are Luobei in the main Amur watershed, and Hulin and Dongning in the Ussuri watershed. From among these, the flow at Dongning has been growing steadily since 2000. On the other hand, the import volume through Heihe was more than 10,000 m^3 around 2000, but it has recently dropped sharply to almost zero.

In examining timber flows by tree species, most were softwood logs being moved through the gateways in the main Amur watershed, except for 1998 when the NFPP was launched in China. In contrast, it was mostly hardwood logs transported through the gateways in the Ussuri watershed before 1997, but the share dropped drastically after that (table 4). At the same time, the volume of sawnwood was rather high compared to logs. To uncover the reason why there are differences in timber flows at the small and medium-sized gateways, it is necessary to carefully examine other factors, such as the state of development in wood-processing facilities near each gateway, the geographic relationship with nearby major corridors, the handling capacity of customs points, transportation infrastructure, and the location of Russian timber product suppliers.

Table 4. Share of timber flow by type of wood through gateways in the Ussuri watershed compared to the total through all small and medium-sized gateways in the Amur Basin

Unit: %

	Logs		*Sawnwood*	
	Softwood	*Hardwood*	*Softwood*	*Hardwood*
1996	*0.00*	*60.86*	*9.3*	*17.3*
1997	*0.00*	*51.06*	*0.0*	*7.7*
1998	*6.09*	*26.78*	*59.4*	*1.3*
1999	*7.56*	*4.48*	*27.9*	*6.0*
2000	*0.80*	*5.41*	*11.3*	*18.9*
2001	*0.41*	*0.46*	—	—
2002	*0.32*	*0.63*	*15.7*	*51.8*
2003	*0.23*	*0.82*	*20.5*	*37.3*
2004	*0.02*	*1.15*	*40.6*	*36.9*
2005	*0.04*	*0.56*	*41.6*	*25.6*

Source: Based on Chinese customs trade statistics compiled by the author.

IV. RECENT CHANGES IN THE TIMBER TRADE POLICIES OF RUSSIA AND CHINA

1. Russia boosts log export tax

In February 2007, Russia's central government announced a graduated but sharp rise in log export taxes to take effect after July 2007, and then carried out the first step as planned (Table 5). The new system of export taxes on Russian timber has been in operation since then. The previous export tax on soft logs was 6.5 percent or 4 Euro/m^3 (around US$5.2), but in July 2007 it was increased to 20 percent or 10 Euro/m^3. Finally, after January 2009, the tax is set to increase to 80 percent or 50 Euro/m^3. The export tax rate on hardwood logs, such as oak, beech, and ash, and even semi-finished products is also set to rise sharply. This drastic and far-reaching policy change is, in essence, a log export ban, and it will most likely lead to a significant drop of log exports from Russia to China in the near future.

China, being the top importer of logs from Russia, has suffered a serious impact by this action, and the prevailing view of China's wood industry is that their efforts to shift their supply of raw wood materials away from domestic supplies to Russia's logs will suffer a setback.

2. Adjustment of China's trade taxation policies in preference of Russian timber

In recent years, step-by-step moves by China to deregulate or reduce trade taxation on Russian timber products—which fueled a steady increase of timber trade between Russia and China—were announced one after another in order to control the trade of processed timber. This kind of adjustment was eventually made to cover value-added wood products.

One key adjustment was the gradual reduction of the value-added tax refund rate. Since China's central government announced major adjustments to this rate for export products in January 2004, significant adjustments, including cutting or eliminating the tax refund rate, were repeatedly issued. The announcement issued in July 2007 listed 2,831 items for control, and value-added wood products such as plywood also had refund rate cuts. Additionally, non-renewable wood products, such as disposable wooden chopsticks, were listed as prohibited and restricted items for processing trade.

Table 5. Russian export tariff on logs after 2007

Item	*Rate / Minimum amount*	*Jul. 1 2007*	*Apr. 1 2008*	*Jan. 1 2009*
Softwood logs	*%*	*20*	*25*	*80*
	Euro/m^3	*10*	*15*	*50*
Hardwood logs	*%*	*24*	*24*	*50*
	Euro/m^3	*10*	*10*	*80*
Poplar	*%*	*5*	*5*	*50*
	Euro/m^3	*10*	*15*	*50*
Semi-finished products with bark thickness of 15 cm or less	*Euro/m^3*	*20*	*25*	*80*

Changes linked to the announcement have been expanding the list of controlled processed timber items for added-profit trade since the fall of 2006. In a new list, issued in August 2007, many wood products such as wood furniture, wood panels, and plywood were included as controlled products and items subject to actions. Wood-processing trade enterprises handling these items are required to submit a deposit amount equivalent in currency to the custom duty and value-added tax from now on. No permits are being issued for new foreign capital enterprises, and existing enterprises are required to increase their guarantee deposits for value-added products in improvement trade. On the other hand, processing trade enterprises located in regions inland are exempted from the deposit requirement and given favorable treatment. Thus, the Russian wood-processing trade enterprises, many of which are located in coastal regions and produce products on the controlled products list, will face difficulties in producing enough profit, and will consequently likely switch to more value-added wood production or relocate to interior regions.

V. DISCUSSION

There is a strong possibility that Sino–Russo inland border trade in the Amur Basin will be more active with an increase in volume over the next 10 years. Timber flows through the two key gateways, Manzhouli and Suifunhe, are especially expected to grow even more, because their handling capacity is being rapidly increased and there has been a build up of Russian wood-processing enterprises over the last five years.

One challenge that lies ahead is the growing competition with other import raw materials, such as oil and metals, for transportation infrastructure. In order to avoid problems such as this, there is a certain possibility that the import of semi-processed Russian wood products—some of them produced by Chinese wood-processing enterprises in Russia—might increase sharply, partly due to Russia's raising of its log export tax, and so highway transport of timber in China will become more prevalent.

There is also some potential that the past upgrading of small and medium-sized gateways will bring more diversity to timber flows from Russia to China, but any change strongly depends on the progress of Russia upgrading its gateways. Since semi-finished wood products are lower in volume and lighter in weight compared with logs, these import flows will become more flexible and diversified depending on the location of manufacturing enterprises making final products.

China's recent changes to its trade policy, to some extent, will possibly prompt the establishment of enterprises around several border gateways that manufacture final products, and so the structure of the wood-processing industry will likely change. Furthermore, because of Russia's new export tariff on logs, the past pattern of timber trade—i.e., Russian logs imported across the inland border, transported to coastal industrial areas in China for processing and manufacturing, and then exported to foreign countries—will likely be altered significantly.

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FORMATION AND OPERATION OF PADDY FIELDS AGRICULTURE AT THE SANJIANG PLAIN
A PRE-RESEARCH OF FARM HOUSEHOLDS BOOKKEEPING ANALYSIS

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OUTLINE

1. INTRODUCTION: FRAMEWORK AND ISSUES

This paper focuses on the development of paddy fields and the management of rice farming and a brief establishment of land use order in Sanjiang Plain, which is a large wetland area formed with the Amur River, the Songhua River and the Ussuri River. The study area is concentrated on X State Farm that mainly exports rice to Japan and the location is relatively close to a base area of Jiamusi City in Heilongjiang Province.

Research have been conducting in this area since 1997(Park et al., 1999, 2001), and it was found out that paddy fields have been decreased from 1999 to 2002 and the large areas have been changed to dry fields. But the drastic conditions found in 2003(Sakashita et al., 2004). The main reasons were that drop in market rice price has been decreased by natural disasters and overproduction of rice (excess of supply). However, the rice price has been increased again from 2004. Therefore, it is necessary to conduct further studies to reinvestigate the recent trends and the actual situation of rice farming. It is because the management stability of rice farming is a key determinant for the succession of land use.

Primary data and case studies are used in this study. The data were collected from 10 farm households of one production group (PG) those who belongs to different farm scales. The 10 farm households kept their farm-records (cash revenue and expenditure, work diary and interview records) separately for one year from spring of 2007 to 2008. As a pre-research, this study has been conducted on top officers of the production group to hearing their personal opinions and the 10 farm households, and arranged the trends of rice farming management with a focus on the paddy fields development history.

2. DEVELOPMENT OF PADDY FIELDS AND POSITION OF FOCUS AREA AT X STATE FARM

2.1 Development of paddy fields at X State Farm

The Songhua River and its five tributary rivers (Fuerji River, Shitou River, Heli River, Alingda River and Wulong River) run within the boundaries of X State Farm. Annual rainfall is 550-600mm, mainly concentrated in the months of July and August [Note 1]. The farm can be generally divided in three regions , namely West region, East region and Southwest region.

The West region has elevated areas with Alingda River and Yuanbaoshan Dam and almost all the areas outside the dam were used for field crop farming (the dam is used by external institutions). The East region lies between Fuerji River, flowing in east–west direction, and the Heli River. Paddy field farming is the major use of land, supported by two irrigation areas; a groundwater well irrigation adopted in 1989, and the Fuerji River dam irrigation (PG No. 18). Part of PG No. 16 and No. 18 are involved in field farming. The Southeast region is also supported by two irrigation systems; an irrigation area of reservoir (dam, dam No. 1- 5 and satellite dam) from the low wetland along the Heli River (PG No. 12), and a groundwater well irrigation area, adopted in 1993 (PG No. 17).

The oldest irrigation facilities project in the farm is the enclosing bund of Heli River in the Southeast region, originally designed by Japanese immigrants using willow trees. The enclosing bund was reconstructed into a fixed concrete dam in 1988 now irrigating 1000ha including Hegang City of Tangyuan Prefecture. The irrigation areas in the farm are 300ha. It provides irrigation to PG No.12, through Dam No.2 and 3. The second part is Fuerji River dam in the east, the dam was completed in 1982. It was designed to provide irrigation for 400 ha, but it actually provided water for 667 ha for PG No. 18. Part of the PG No. 20, 21 and 27 utilized the water from this dam from 1982. In addition, since this dam was built, a dam of PG No. 16 was built in 1999 and has been irrigating 133 ha.

Nowadays, new areas developed the barren and dry fields under paddy cultivation are irrigated by a groundwater well constructed from 1989. This is part of a program called the 'Sanjiang Plain Agriculture Multidiscipline Development Plan' planned by the Baoquanling Management Bureau in 1987 with construction work starting in 1989. X State Farm is under control of this bureau. Until 1991, 10 production groups, mainly PG No. 29, of East region irrigated 4,667ha. From 1992 to 1993, 5 production groups but mainly PG No.17 opened up another 4,000ha for farming in the Southeast Region (PG No.13 and east). Then PG No. 15, 16, 24, 25 and part of 27 started farming in another 4,000ha from 1996 to 1997. It is standard that one groundwater well pumps up 10ha worth of water for irrigation. In order to increase the water temperature, 4% of the irrigation area, 40a, was installed with water storage pond. Generally, one farm household owns one groundwater well.

As a result, a groundwater well irrigation covered an area of 12,666 ha, dam irrigation

2,000 ha, and the rest of the 13,333 ha were fields. The percentage of paddy fields in the West region was 6%, the East region 55%, and the Southeast region 93 %. The following study is about PG No. 17 from the Southeast region that only produces paddy fields from 1993, and has high percentage of groundwater well irrigation.

2.2 Characteristics of Production Group No. 17

The PG No. 17 is located in the Southeast region, and until 1990 its irrigation source was mainly provided by the Songhua River. However, in 1991, irrigation from the river was suspended, and since then the dam has mainly played drainage functions rather than irrigation. The reasons for the change are because of its difficulty to pump water, as there was a lack of water supply from the river, and the repeated flooding during the rainy season.

Since 1992, there has been planned promotion of a groundwater well irrigation. In 1992 and 1993, the production group started the well-digging project. The digging was conducted by contract with construction companies; the farm households would be responsible for the cost where 50 % of the cost could be financed loan by the state farm. The two finance loan periods are one-year and three-years, and the repayment of the loan is either by cash or by commodities.

With construction of groundwater wells, many areas rapidly changed into rice farming. In 1994, out of 673.7ha, 552.6ha (82%) had been changed into rice farming. The 121.1ha areas left along the rivers are lent to the surrounding villages as field farms, since conditions in these areas were unsuitable for rice farming [Note 2]. PG No. 17 has specialized in rice farming since 1994. As shown in Figure 2, Table 1, the paddy fields are composed of 15 blocks, and the small blocks are areas rent out to farms. There are 65 households, and one an average, each household has 8.5ha land.

There were 70 groundwater wells and one groundwater well irrigates 7.9ha of farmland. On average, every farm household has one groundwater well. The farmland were less than 5ha for 9 households, 5-7.5 ha for 19 households, 7.5-10ha for 18 households, 10-12.5ha for 11 households, 12.5-15ha for 4 households, and more than 15ha for 4 households. The number of farm households within different operation scales will be illustrated later. Groundwater wells irrigate 37 households, which are 57% of the total number, due to the groundwater wells' irrigation ability, and other very small scale and large scale households are irrigation by groundwater wells.

The farm households were selected in this study are as follows: two large scale farm households for more than 10ha (No.7, 14.4ha;No. 2, 12.0ha); three upper-medium scale farm households for 7.5-10ha (No.4, 9.9ha; No.3, 9.0ha; No.6, 8.0ha); three lower-medium scale farm households for 5-7.5ha (No.8, 7.2ha; No.9, 6.5ha; No.5, 5.0ha); one small scale farm households for less than 5ha (No.10, 4.1ha) were selected for focusing of this study.

In addition, from 2003, there had been selected by XM Fine Rice Processing Co. Ltd., about 90%'s area has been cultivated on contract. Also, on the during production process, it has to follow all the instructions by XMFRP Co, such as species, fertilizers, pesticides etc. The organization of top officials of the Production Group composed of one chief, one secretary, one assistant chief (one of them would do the statistics), one accountant (do the accounting of management area as groundwater well) and three technicians.

The responsibility of the Production Group has a big change since the adoption of the 'Liangfeizili' policy. The 'Liangfeizili' policy is that farm households have to be responsible for both production and daily lives related cost. Due to the policy, the Production Group is not involved in services of transporting production resources to farm households' yard, guarantee for funding, adjustment for crop rotation during field crops era; but concentrate on farm policies, transmission of orders and collect money by deputy.

3. Key features of Paddy fields development by Production Group No. 17

3.1 History of rice farming and a situation of direct management era in Production Group No.17

The history of PG No. 17 can be traced back in 1930. In the past, the area of Manchuria-Mongolia Pioneer Group conducted large scale rice farming only until the 1940s.

The channel, called 'Wuzhixian', developed by the pioneer group is still being used today. After the pioneer group has withdrawn the area, a lot of the paddy fields farming areas were abandoned. However, with the establishment of the Helihe Farm (rehabilitation farm for imprisoned criminals) in 1952, after liberalization, the remaining paddy fields and those abandoned, were restored for rice production, and were transformed as paddy field farms, which was unusual during that time. In 1968, the Cultural Revolution Periods, educated young people were forced to work in farms, replacing the criminals. With no sophisticated knowledge about rice farming, these young people gradually converted the paddies into fields. However, most of the paddy fields in No. 2-2 block (27.9ha) and No. 5 block (61.7ha) were kept. In 1979, part of Helihe farm was merged by X State Farm (PG No. 12, 13, 14, 17, 22, 34 and 35). The PG No. 5 of Helihe Farm became PG No. 17 of X State Farm.

Until 1982, the farm was nationally operated, and therefore the workers remained as manual labor. Under a group-oriented working structure, workers were divided into four different teams: cultivators, mechanics, stockbreeding, and architecture. The first two teams held by far the largest number of workers; up to two thirds of the whole workforce. The workers in the mechanics team were in charge of fixing and maintaining the machineries necessary for farming, and had the most technical knowledge among all. Therefore, these workers were relatively highly educated and were considered as "specialists" in the farm.

3.2 Conversion of the government-run farm system to farm households' contract system

In 1982 and 83, the contract system, already used in general farm villages, was introduced to the State Farms. At this point, the number of farm households were 86, cultivated acreage of 483.1 ha. Of them, 400 ha is dry field and a mere 83.1 ha is paddy field. For heavy machinery, they possessed 8 tractors (one 54 ps and one 75ps) and 2 combine harvesters. The contract system was separate for field farming and rice farming.

As for dry field farming, several members of the mechanic's team shared machineries and operated in large scales during 1982-83. However, the Production Team later on changed their strategies where cultivators (39 households) were each given 2ha of land, and former mechanic teams would receive contract for cultivation with their machineries. Although, cooperative operation still remained as the majority for former mechanic team. 35 members of the mechanic team were divided into several groups, 6-14 members each, who shared about 1-2 machineries within their group.

For field crops (main products were wheat, bean, and corn) , a rotation of one year wheat – two years soy beans – one year corn was suggested. However, the low yield and low buying prices of wheat and the troublesome labor of growing corn, made these two crops unappealing to most farmers, causing continuous cropping of high value soy beans (Table 3). Thus, a strengthening of the overseeing system was introduced by the administrators of the Production Group to reinforce rotation cropping in order to restore soil capabilities.

For paddy farming, 2 ha for one household was distributed to 12 households. The remaining areas were left as extra, and were able to be utilized upon request.

3.3 History of paddy fields development

The paddy fields development can be divided in two periods: the incentive measures to switch from dry field to paddy fields from 1985, and planned full-scale switch to rice farming in 1993. During that time, here was special attention to 'invited farm households' which is farm households from the outside of the State Farm that have the know-how of rice farming [Note 3]. The PG No.17 introduced the 'invited farm households' proactively from 1989. In the first year, only six households have joined, after that three to five households have joined every year. It becomes stable after latter part of 1990s, and terminated in 2001. Currently, within the 65 households of the Group 17, there are 36 laborers in the farm (first generation laborers are 33, second generation laborers are 3), the remaining 29 people are employed laborers (invited farmers).

From 1985, there was a promotion period for switching into rice farming, but there was limitation for the increase of paddy farming areas, mainly because of techniques of cultivation. Within the case studies, 3 households developed paddy fields during this period. For case No.2 in 1985, a case of existing farm households, 4 people cooperatively undertook an area of 15ha (Block 5). At that point, it was a wheat field, but the four converted 10ha into paddy fields, with an average of 2.5ha per person. This was a successful case. For the case No.1 in 1989, a case of invited farm households, 6 households have emigrated from Hua-Nan Prefecture with introduction by friends. In terms of the Production Group, 16ha in 8-3 blocks were evenly divided among 6 households, 2.7ha each. The Farm constructed two new groundwater wells (diameter 20cm, depth 20cm) to be shared among the 6 households. Total cost of groundwater wells for 6 households was 20,000Yuan and per household was 3,333Yuan, and the cost should be returned within three years. However, the initial year turned out to be unsuccessful, and this led two out of the 6 new households, dropped out and returned to Hua-Nan. The 5.4ha of land initially owned by the 2 households that left was divided by the rest, adding 1.35ha to their original size. Each farm household had 4.05ha of land. In 1991, another 2 households dropped out, and today only 2 households are left. This situation shows that the starting period of rice farming was very difficult.

Although the second stage started from 1993, basically all areas have converted into rice farming in 1994 because the rice price recovered, and the government effort to improve the land, etc. An additional reason was that the PG No. 17 had relatively low topographical features that it was easier to have rice farming from the water resource management point of view. Although X State Farm started rice farming in 1985, which was mentioned earlier, they prioritized the PG No.22 which had the lowest topographical features among all, and therefore delayed the transition of PG No. 17 for 10 years.

With the transition to rice farming, the land use rights were distributed to the farm households who had been doing joint operation till then in 1993. As a result, the farm households were forced to operate individually. The restored paddy fields work in 1993 was uniformly done in the production group. And the costs for the works was 15,000Yuan per ha, and most of the costs was used for groundwater wells and seedling houses. The groundwater wells and seedling houses were constructed uniformly in 1993-94 and 1996 respectively.

As preferential treatment to the transition of dry fields to paddy fields, the agricultural tax and rent for the initial year was exempt. On the other hand, the heavy machineries for dry field farming were no longer used, and a gradual shift to paddy field machinery was observed. However, the finance loans from the farm were abolished.

4. CHARACTERISTICS OF RICE FARMING MANAGEMENT AND ECONOMICS OF FARM HOUSEHOLDS

4.1 Mobility of workers at farm households and change of scale

First, the retention rate and scale changes of farm household can be clarified with Table 4. The table was created from a series of data on cultivated land area for each farm households between the years 1994-2006. Most of all, the 73 households in 1994 dropped to 65 households in 2006, a decrease of 8 households. However, from 1994 to 2006, out of 52 households, 21 households migrated, 13 households immigrated. In 1994, the migration rate was 29%. At that point, in 1994, there were already numerous numbers of invited farmers, and the rate of existing farms was only 55.4%. It was found that mobilization of some areas were very high. According to Table 5, migration happens after decrease in rice farming income, especially in 2003 during which rice farming area dropped dramatically throughout the farm. Following are the changes of the hierarchy of scale.

As mentioned earlier, management scale was mainly medium that range from 5 to 10ha, but the highest migration rate was seen in the group that owned less than 5ha (40%), which illustrates the larger impact of drop in rice prices on relatively small scale farmers. On the other hand, immigration concentrated in the medium scale class, with the largest scale not exceeding the 10-12.5 ha range. Out of the 19 large scale households, 6 households have actually increased their scale during this time. Therefore, even though there was fluctuation of rice price, certain stock of rice was available exclusively in these large scale farm households. We should investigate the details of scale expansion. Following is the study of ten households that had scale-increase. The basic information is shown in Table 6.

The composition of family is relatively small, from three to five family members; half of the main operator's age was less than 40 years, which is quite young. The rage of scale is from 4.1ha to 18.3ha. Most of the large scale farm is invited farm households, and small scale farms are immigrants or farms with other subsidiary work.

According to the changes of farmlands in Table 7, all the five large scale farm households (until 9ha) have scale increase. No.1 and No.2 developed their paddy fields during the first period, and moreover, they returned their initial fields in return for another with better conditions. In this process, they also increase their scale by further borrowing groundwater well conditioned fields. In the case of No.8, already mentioned earlier, this farm is stuck with the initial paddy field with bad conditions, unlike the case with No.1 and No.2 who traded them with better fields. They were unable to take advantage of the opportunities to increase their farmlands. Unlike normal farming villages where increase of farmland will involve payment of land prices, this nationally owned farm does not require this. Instead, however, the new incoming farmer is obligated to pay beneficial expenses for the use of existing facilities, such as groundwater wells, etc. It is obvious that it is necessary to have the renewal fee of groundwater well, and investment of machineries and facilities that can meet the scale increase. Following are the characteristic of machineries at different production scale and, income and expenditure.

4.2 Characteristics of rice farming management in different scales, revenue and expenditure

The above-mentioned scale increase was bolstered by the advance in agricultural machinery. Table 10 explains the adoption and renewal of machineries and facilities situations. As for tractors, the Rotary Tiller stage was between the mid 80's to mid 90's. No.1, one of the largest scale households, introduced 25ps in 1998, followed by an introduction of 40ps in 2004. In the middle scale range, 30ps was introduced in the 2000's. In the smallest scale range, contract (200Yuan/ha for both plowing and rotary) has been the main means of farming.

The earliest introduction of rice planter was by No.1 in 1993, mid 90's in the upper-middle scale class, and 2000's in the lower-middle scale class. The machine was a six-row planter made in Yanbian, and the quick spread was partly due to the fact that it was affordable (10,000 Yuan each). Although they had seedling houses, the smallest scale class had to rely this as groundwater well, on contracts. The seedling houses are introduced in every farm households, transformed from its initial brick structure, largely with the help of finance loans from the farm. In the 2000's, expansion of houses has been done, corresponding to its scale. This was financed through individual funds or resources.

For combine harvesters, only No.1, 7, and 3 own this large machinery. These 3 households have established a large machinery system. Since all farm households financed this 50,000-60,000 Yuan investment with their personal funds, it is fair to state that these farm households possess considerable amount of savings. For other farm households, most of them, except for No.5, switched from hand harvesting to contracts (500-750 Yuan/ha) between the years 1999-2004. No.5 still continues to harvest with man-power. No.3 (9ha), who introduced the combine harvester in 2006 is willing to accept a consignment contract, and with the payment, it wishes to pay off the initial investment. As conclusion, mechanization in the harvesting stage shows the greatest disparity between the operation scales.

In the past, the large scale production in Sanjiang Plain mainly depended on hiring contract laborers during planting and harvest time. Now tractors, the rice planting machine, four-lines combine, ordinary combine harvesters are available for planting and harvesting. There is a clear relationship between operation scale and mechanization. The large scale farmers have advancement in machineries, however, the small scale farmers still harvest partly by hands and partly by contracting machines. The contract fee is relatively high and contractors can use this as part of repayment for the large machineries.

Table 11 shows the income and expenditures of different operation scale. 2004 data is used instead of 2005, an outbreak year of the rice blast. In terms of total income, there is a rule of certain production amount from each ha. Unit crop differs from 7.5 tons to 9.9 tons, and obviously small scale farmers have low production amounts. In the case of expenditures, the rent is about 30 percents to 50 percents. This high percentage of land rent limits the income of farm households. In addition, it is found out that hiring fees range from a few percentages to close to nearly 25 percent. Even though there is advancement in machineries, the cost for temporary contract is high. The results also showed that the net income does not always correspond to scale.

In all cases, the gross income is 100,000-200,000 Yuan, and net income is 60,000-10,000 Yuan which implies that rice farming operation has higher stability, both technologically and economically.

5. CONCLUSIONS:

Objectives about Farm Households Bookkeeping Analysis

This study has arranged with regard to the history of paddy fields development and the current conditions of rice farming by the hearing survey from the production group and its 10 farm households in Sanjiang Plain.

The findings of the study concluded that a certain degree of stability as well as scale expansion in a group of farm households despite of most of the farm households have the highly mobile characteristics in this area. In comparison to the late 1990s, it can be understood that the mechanization level has been upgraded greatly, and that the technical basis of large-scale management has been strengthened.

However, it will lead to the situations of the farm economy unclear, if only according to the hearing survey. Therefore it is necessary to analyze elaborately, especially regarding the land rent-bearing capacity and the ratio of employment expenses to production cost in the large scale operation of farm households.

Therefore, as mentioned earlier, farm households kept farm records for one year. After this, the present study resolves this remaining task.

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NOTES

1. There is a waterworks department in X State Farm, initially designed to control flooding. Total extension of the levee is 110km. Three drain pump (15 m^2/sec) are installed in the Songhua River, the Heli River, and PG No.19.
2. The operation team decides the tenancy rate. However, rates have risen from its initial 300 Yuan in 1994, up to 1,500 Yuan today. Exceptions hold in case the farmer receives damage from flooding; the fees are exempt.
3. For details, see Park *et al.*, 1999, p.226

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MEDICAL-ECOLOGICAL STUDIES IN THE AMUR BASIN (RUSSIA): TO PROBLEM OF ONCOLOGY

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Russia's part of the Amur basin is found to be one of the least ecologically studied territories of Russian Federation so far. The Khabarovsk Territory as a significant part of the region is characterized by rather extreme climatic conditions and evident physical-geographical contrasts determining high heterogeneity of the territory – existence of separate geographical areas [4]. The existence of the vast geochemical provinces with, sometimes, extremely high content levels of many microelements is to appear as particularity of the territory as well [2]. For instance, more than 40 % of the region is referred to the areas with high radon-disaster. A lot of facts point to existence of natural factors array for high cancer risk among human population there. So, the development of research for "cancer ecology and geography" is considered as an actual scientific issue.

Non-obviousness of the natural oncology risk factors obstructs their separation from the general number of external (environmental) blastomogenic factors and, thus, requires a particular methodical approach development to make adequate oncology-epidemiological analysis. Usually, it is difficult to reveal the natural background influence upon cancer risk in big cities due to ambience is basically determined by strong anthropogenic (industrial and urban) impact. Obviously, the methods and principles of studying of natural *malignant tumors* (MT) factors should be different ones for the subpopulations in settlements without big and middle industrial enterprises. This criterion corresponds to the settlements with the less than 5000 population. The revealed regularities of distribution of main MT forms (cancer of lungs, gullet, belly, large intestine and breast) throughout different climate and geochemical provinces in the Khabarovsk Territory that has appeared as a result of our comprehensive studies before.

The main issues of studies of the Amur inhabitants were defined as follows:

1) development of methodology for epidemiological research for the influence of natural environmental factors upon cancer risk increase;

2) research for levels, structures and onsets of oncology diseases among humans who have been living in small settlements of Khabarovsk Territory in 1982-2006 years;

3) development of methodological approach to the combined geographical and medical clustering the territory;

4) mapping the main MT forms distribution throughout of the Amur region;

5) within the framework of the environmental studies, initiation of ecology-biochemical monitoring in order to make the systemic assessment of the role of microelements concentration in ground and underground water (including radon water)

as well as climate features in the rising risk of main MT forms and other social significant diseases (SSD).

We realize the interdisciplinary studies for these SSD forms' origin and their territorial distribution whys using the mathematical modeling and new information technologies methodology. There were studied the features of the different diseases spread, including MT, as a result of human activity influences, without taking into account the facilities of ecological-geographical (especially landscape-(hydro)geochemical) taxonomy. In the most general sense, any landscape-(hydro)geochemical clustering is considered as a division of territory by number of areas distinguished by several parameters, which are to render certain influence upon the considered disease risk increase. By geographical method of so-called "zoning" (division into districts or sub-regions, or clustering process), the same territory might be portioned out in different ways on areas that are to be different ones by disease forms [4, 7]. However, territorial position of chosen area itself, aside from the factors, taken into account when zoning a given territory, is put into the analysis and complemented by obtained information about factors, which are determined by their geographical position. The natural, demographic, social and other issues are to be subsumed to such additional information. These factors are entirely to be taken into account in explanation of studied disease spread character in given areas.

In this article, a methodology of ecological-geographical clustering in order to analyze the population epidemiology data is shortly presented. Specified clustering method was applying when studying MT spread among the children within the Khabarovsk Territory. MT spread assessment is considered to be impossible without determination of minimum number of observation units, or taxa. By a lot of reasons, such taxa are to be nor areas, neither administrative territories.

The territory of Russia's Far East seems very vast and, thereby, lies within several natural zones. Climate features of the largest plain, the marshy Middle-Amur Plain (Sanjiang Plain within China), vary significantly from the North to the South, and, likewise, depend on relief and sea vicinity. Different parts of that territory are very irregularly inhabited ones and characterized by the different economic development level. Administrative districts, though, are more homogeneous according to economic development degree, but, as a rule, are characterized by the non-high number of population. This obstructs to get a reliable picture of spread of such rare phenomena as, for instance, MT among children of the region. Thereby, optimum taxon is presented to be neither vast territory, nor territory with the small population, but area nearing to administrative districts.

A lot of natural and anthropogenic factors directly impact upon human population health status. The offered ecological-geographical clustering is to take into account possible influence of natural environment and social-economic conditions upon arising risk of noninfectious lethal diseases among human population of Russia Far East. A specific method of physical-geographical clustering was applying for assessment of territorial spread of SSD, for instance, MT spread among children [5].

The main feature of children's leucosis distribution throughout the Far East appears to be presence of several areas with high sick rate. These areas with high sick rate among boys are insulated one from another and have different climate-geographical conditions. Standard disease factor equaled to 26.4 occasions per 100,000 male-babies there. Specified frequency of leucosis among boys is estimated in Upper-Zeya and Selemdzha as well as in Zeya-Bureya localities (the northern part of the Amur basin). In contrast with average value of the sick rate level, relative chance (RC) of appearance of leucosis factor in these districts seems really high one (RC = 1.47-2.13; assessment reliability is more than 0.95). Over the most of the Amur region, leucosis widely spreads, but less for girls than boys. At the same time, for some areas high levels sick rate among girls were revealed. Thus, over the North Sikhote-Alin' area, standard sick rate has reached 19.4 occasions per 100,000 of female-baby populations, but in Zeya-Bureya area this factor was 8.9. Specified frequency of leucosis distinguishes some girl populations of the biggest cities of region - Blagoveshchensk and Khabarovsk. Average annual standard factor sick rate in these cities was is 8.6 and 6.0 occasions per 100,000 girls accordingly. Against mean regional level sick rate, RC of leucosis appearance among girls over all territories mentioned was estimated as rather high one (assessment reliability is more than 0.95). Meanwhile, there was marked the territorial distribution unevenness of leucosis both among boys and girls. In different studied areas, standard factors of sick rate and relations of chances differ greatly from average regional value. As far as these differences are observed in some areas in comparison with average regional value due to the geographical clustering method, so, natural environment, probably, renders a certain influence upon children's leucosis territorial spread.

What phenomena to be put under study those are oncological diseases of lungs, gullet, belly, large intestine and breast cancer as well as medical-ecological background status of the Amur region as a whole.

Methods of study of general sick rate and death-rate due to MT of key sites nearing small settlements (with population amount less than 5,000):

- analysis of notices of patients who the first time in life gets diagnosis about cancer or other MT,
- analysis of neglected case protocols,
- analysis of oncological dispensary observation cards,
- analysis of histological studies casebooks,
- analysis of autopsies protocols,
- analysis of medical certificates and acts on deaths,
- and measurements of natural radiation background levels within areas around small settlements with use of aero- and space survey data and GIS.

What is already done to date? What is to be basis for further medical-ecological research [4-7]? What is done is follows:

1. There analyzed a dataset on microelement contents (lithium, beryllium, vanadium, chromium, cobalt, zinc, honeys, gallium, germanium, strontium, arsenic, rubidium, yttrium, zirconium, molybdenum, silver, tungsten, lead, thorium, uranium) in soil and ground in sites around certain small settlements.
2. In sites around certain small settlements as well, there studied nitrate, nitrite, zinc, cuprum, iron, magnesium, potassium, lead, arsenic, quicksilver concentration in surface water.
3. With use of weather monitoring data by Far-East Regional Department of Russia State Hydrometeorological Service and relevant data catalogues, there were estimated main climatic features within sites around certain small settlements.
4. There was implemented the statistical processing of "rough" intensive and extensive factors, their average error, age sick rates, standard factors by direct and inverse methods, average error of standard factor, cumulative factors, relative risk factors, multifactor correlation and regression analysis, discriminate analysis and information modeling.
5. There were mapped the main forms MT spread on the basis of oncology-epidemiological clustering of the Khabarovsk Territory.

Ideology of information modeling methodology in ecology, medicine, medical informatics and human biology develops some original game-theoretical models (GTM) of human population behavior and its adaptation to extreme conditions, as well as uses the system methodology when analyzing human impact on ecosystems and back impact upon human population in developed areas of Russia Far East. The original hypothesis on features of MT generation among children subpopulation [5] and aborigines of the Amur region was formulated [12]. The interrelations between water contamination factors (such as organic matter, toxic metals and microelements) and inherent reasons for oncogenesis were studied by means of information modeling method with using data on medical-ecological monitoring of the Amur basin [4, 5].

We designed information models of social-economic issues of public health system management in the Khabarovsk Territory on the example of noninfectious lethal and socially significant forms of non-lethal diseases. There were elaborated the mathematical model of global information-technological processes impact upon social-economic and eco-psychological issues of living in the Amur basin, as well as main socio-dynamical scenarios of this region development and population life quality alteration in Russia Far East with taking into account the losses due to SSD. One of these diseases further studies ways sounds to be comprehensive ecological-geographical studies over the Amur basin. This way seems at this moment to be the most quickly developing direction of epidemiology not only of infectious, but noninfectious pathology as well. Cancer-epidemiology is considered to be important section of noninfectious lethal diseases epidemiology. The preference is given to multifactor basis of MT generation; the impact of pathogenic combination of environment and constitutional-genetic factors upon an individual is to be considered. There is laid large meaning to environment creating SSD levels, particularly if we talk about regional features. Climate-geographical factors, feeding features, air and water pollution issues, as well as contacts with domestic and industrial chemical and physical carcinogens etc are included in these features.

Along with human impact, factors of natural environment and its change play certain role in processes of induction and promotion of many noninfectious diseases. Cancer epidemiology studies regularities of MT distribution over the Amur basin and is conditioned by natural environment. These studies are aimed on the malignancies spread features. This problem is referred to the field of analytical epidemiology, which is to dare for particular methods quite often within the framework of population studies. In number of analytical epidemiology issues there is found research for the factors of small intensity that, nevertheless, are to determine MT spread regularities. One should refer to such factors the environment impact on an organism, among which some ones have low probability to induce tumors in contrast with individual risk factors, spreading over the territory, as well as influence on the whole or on the most of population living on this territory. The research for factors of small intensity by cohort methods or by the method of "event-checking" as a rule appears to be inefficient. Population epidemiological analysis allows overcome contradictions of standard epidemiological studies. It includes study of the whole population, living on the under investigation territory. Herewith factors of frequency sick rate, death rate etc. within administrative regions (settlements) are to be studied, but as mentioned, a number of natural (warm-up conditions, solar radiation, microelements contents in ground etc.), social (joblessness rate, average profit per capita etc.), demographic (birth rate levels, death-rate, migration characteristics etc.) and other factors also might be referred to parameters of small intensity.

Let's consider hydrobiochemical issues among a lot of ecological problems over the Amur Basin. Drinking water quality of is one of the main factors effecting on a person's health status. Consumption of spoiled water promotes dysfunctions of all, without excluding, the organs and organism's systems to lead to a lot of heavy diseases development and significantly reduce one's life length. Particularly this is correct for children as far as if water content in adult organism is 60-70 %, in infant organism – 80 %, but five-month embryo consists of water by 94 %. In turn, quality of drinking water in the water-supply system depends on three main factors: 1) pollution degree of natural water reservoirs; 2) the methods of water treatment on water-production stations; and 3) state of water-delivery network. At presence, harmful admixtures in the Amur and underground water that feed nearby-Amur settlements, mostly adulterate the drink-water quality. Deterioration of the Amur environment is inseparably connected with atmosphere pollution, soil and water contamination by products of agricultural, industrial and domestic activity. As far as water is produced for drinking only from underground and open water sources, it is necessary to stress that due to natural water cycle, in combination with high dissolution ability of water, almost total contamination being concentrated in sewages of industrial and agricultural enterprises and in domestic sewages, one way or another, comes in water-supply systems. A lot of contamination, by sewages or via other ways, figuratively goes back to the people, and thus human-altered environment influences directly upon one's health.

Depending on danger degree, array of heavy metals is split into several classes. The first, the most dangerous class includes arsenic, cadmium, quicksilver, selenium, lead, zinc. The second class contains cobalt, nickel, copper, molybdenum, stibium, chromium; and vanadium, tungsten, manganese, strontium are united into the third one. The higher class of heavy metal danger, the less concentration of poison chemicals and mineral fertilizers widely-used in the agriculture, in atmosphere, soil, food and water, so, the smaller its dosage are to make toxic, mutagenic or carcinogenic effect. At present, more than 1,000 names of poison chemical matters are known over the world. Many of them do not be dissolved, but accumulated in organisms for many years. Natural water is deteriorated by such toxic admixtures as pesticides – toxic chemicals that are applied for planting and wood protection from vermin. Pesticides are easy dissolved in water and so easy fall on the ground, infiltrate and go into streams and lakes, for example, with rainstorms. The pesticides' impact on one's organism could be specific and nonspecific one. Specific action is show as an effect of that toxic material, which stipulates an action of pesticides. So, pesticides, contained quicksilver, are to generate specific diseases, like Minamata disease. Nonspecific effect of pesticides means their abilities of chronically small doses to reduce immune system state, to cause mutation genetic code, as well as different tumors. Besides, in natural water reservoirs there are to be present the herbicides – organic compounds, used in the agriculture for the struggle against weeds, and, also, nitrates – anions of nitric acid used as fertilizers. Excess of nitrate-ions concentration level over more then 50 mg/l makes water dangerous for health. In one's organism nitrates are able to form the components of food nitrosamines that induce MT. In the digestive tract, up to 65 % of nitrate-ions become nitrite-ions, which fall into the blood and tissue of organism. Children of breast age are particularly sensitive to nitrites – by 100 times more than adults. That is conditioned by insufficiently developed children's ferment system as well as greater their hemoglobin's liability to oxidation by nitrites [6, 7]. Specific effect of nitrite-ions is considered to create methemoglobin, which is not capable to carry oxygen to organs and tissues. This generates a figural breach in shelter of organism's transport functions and oppresses its ferment system, which adjusts the cells' breath. First, the organs of digestion and nervous systems are to fail. At nitrites concentrations in water as 1.2 – 2.0 g/l (that corresponds to 45 % level of total hemoglobin cytophylaxis) develop lethal cases.

The list of all synthetic organic materials, which are to be present in natural water bodies, numbers more than thousand names. A lot of these materials are known to possess carcinogenic and mutagenic nature. The best-investigated poly-aromatic hydrocarbon is considered to be 3.4-benz(a)piren. This compound is created as a result of organic fuel combustion. So, its concentration around fuel-energy enterprises, heat supply plants, as well as in places of motor transport concourse or traffic, is particularly high. This matter is referred to the first class of danger and induces oncological diseases. *Regulations for surface water protection from sewages contamination* assumed in Russia, determines general and special standards of quality factors and water objects. Part of non-soluble contamination accumulated on special paper filters, is to be identified as weighted matter. Content of the most dangerous soluble organic compounds is often estimated just by the value of biochemical oxygen demand (BOD_5). General regulations are that total water mineralization is to not exceed 1000 mg/l, soluble oxygen content in water in winter is to be not less than 4 mg/l, in summer – not less than 6 mg/l. Acid capacity of water (BOD_5) is to be not more than 2 mg/l. Concentration of lignin must not exceed 2 mg/l. Organoleptic regulations include the upper limits of iron, methylmercaptane and phyrphulole content. Water bodies used for fish-breeding are controlled according to their special requirements regarding oil, some oil products and phenols content. Sanitary-toxicological regulations establish the limits of such compounds as nitrate-ions, trivalent chromium, manganese, lead, quicksilver, fluorine, potassium, calcium, magnesium, sodium, sulfates, chlorides, phosphates, rhodanides and formaldehyde. Toxicological requirements limit content of ions ammonium, cuprum, zinc, 6-valent chromium, cadmium, arsenic, tin, aluminum. In water cyanides and pesticides are to be absent. Quality features for surface water are established practically throughout the whole nomenclature of requirements to water quality. Acidity, oxygen content, BOD_5, total mineralization, concentration of chlorides, sulfates, nitrates, nitrites, phosphates, oil products, cuprum, chromium, zinc, lead, nickel, iron as well as bacterial contamination are to be included in the number of water quality characteristics to be estimated. Set of episodic contaminants includes such harmful compounds as pesticides, cadmium, cobalt, fluorine, arsenic, strontium, quicksilver, aluminum. Benz(a)piren, tethraplumbum dioxins, quicksilver, tellurium, beryllium, boron, lithium, molybdenum behavior as well as pathogenic enteroviruses are studied poorly to date. Majority of these matters are exceedingly dangerous [5, 6]. According to categorization of natural water bodies by contamination degree, water is to be considered:

1) clean one if $BOD_5 < 1$-3 mg/l and suspended matter content < 1-10 mg/l,
2) polluted one if 3-6 and 10-50 accordingly;
3) dirty one if 6-15 and 50-100 accordingly;
4) very dirty one if $BOD_5 > 15$ and suspended matter content > 100.

Amur is located between 2 and 3 gradations (by [3, 6]).

Sanitary status of Amur nearby water-supply pump stations of Khabarovsk-city is assessed to be non-satisfied, and the increased degree of potential epidemiological danger was assigned to Amur. Part of water tests is found to exceed hygienic microbiological standards by 23.4 %, and in every third water test there are discovered viruses [12]. In Annual Reports by State Committee of Ecology, in 1991-2001, a lot of tests in water-treatment plant demonstrate microbiological contamination of the Amur water, meanwhile amount of normal samples reduced from 56.8 % down to 15.1 %. Similar results are received in popular bathing places in Amur nearby the city [6]. Water quality nearby Khabarovsk water-supply pump stations in 1999-2001 is recorded to become worse one. According to results of laboratory analyses, percentage of polluted samples taken from of water-supply sources has risen from 11.1 % up to 23.9 % [7].

In 1970-80, due to specific medicine (chemical) scent detected in several winter fish samples, a question about the Amur phenol contamination has arisen. "Phenol problem" has got a new breath at February 1996, when in the Amur water samples nearby the Tunguska River mouth extremely high concentration of phenols (904 mg/l) has been allegedly registered. Every autumn and winter in 1998-2004, chemical scent was being detected again in autumn salmon [1]. However, as a result of studies conducted by IWEP in the June-November 1999, there was established that chemical scent of fish did not connect directly with the increased phenols content in the Amur water. Scenting matter are studied to-date to have human-made nature as a result of sewage by oil treatment plants and chemical industry and its dynamics is controlled by water temperature conditions through chemical and biochemical oxidation rate. A lot of flourishing shallow lakes within and nearby the Amur floodplain in summer are studied to be sources of certain amount of natural phenols due to algae's activity, that is why concentration of phenol reaches up to 10 mg/l there [3]. Meanwhile, the total lake inflow in Amur, when low water stage period occurs, is valued as 10-20 % (once in a while up to 30 %) of the Amur flux [11]. So, there is considered to be comparatively low phenols content in the Amur water and be distinctive by its seasonal distribution [1, 3]. At winter period the ice cover does not allow to intake oxygen, required for oxidations of dissolved organic matter (DOM) and hydrobionts' breath, in the water [9]. Dissolved oxygen consumption is to reduce concentration of DOM and to worsen water quality due to accumulation of highly toxic products of incomplete disintegration of organic materials. Simultaneously, water flux diminishing, at the average by order in contrast with warm period, conditions the corresponding increase of loading rate of wastes upon quality of the Amur water. Because of the low temperature, the winter rate of DOM mineralization is lower than summer one by several times [9]. Joint action of these factors, at long-term low-water period in the Amur basin particularly, brings to that river is unable to treat all the pollution itself, and toxic compounds are to be accumulated in the Amur ecosystem. Herewith these circumstances, a lot of organic compounds are to be destructed in anaerobic conditions with formation of intermediate fugitive products, which tincture non-natural scents to water and fish [1]. This can have crucial effect upon sanitary-ecological status of the river water [8].

Transition of certain pollutions from ice in spring into water is shown as particularity of formation of the river water chemical composition [10]. Certain metal compounds such as tin, lead, chromium and silver ones as well as some oil products accumulate in the snow and ice cover from human-made aerosols [6]. Ammonium nitrogen appeared to be one of toxic matters, which deteriorate the river water. In the Amur water, ammonium nitrogen comes with water influx from a lot of rivers, lakes and swamps, atmospheric precipitation, industrial and domestic sewages, and sewers from agricultural fields and farms as well. Usually atmospheric precipitation contain small amount of ammonium ions, however their concentration increases significantly in the snow cover on the territory subjected by wildfires, and reaches up to 6.28 mlg/l, while the highest concentration of ammonium ions is recorded in swamp water in the July-August, when decomposition of organic matter in water goes intensively [14].

At the meantime, in Khabarovsk city the permanent water quality control in water-supply system where coagulants of new generation like aluminum oxide are used, led to quite perfect quality of drinking water by majority of parameters, and by microbiological factors first of all. If in 1991 amount of samples with unsatisfactory microbiological factors was 8.2 %, but in 2001 it was only 1.7 %. Percentage of tests with bad quality of water from departmental water-supply network for a specified period also reduced markedly: by chemical factors, it became 72.5 % compared with 60 % before; by microbiological it was revealed as 21 % against 5 % before. Meanwhile, however, quality of water from departmental water-supply network stays worse in contrast with municipal one, especially during flood period. The further improvement of water quality in water-supply network, under existing water-treatment technology and quality of pipelines, looks to be impossible [4, 6]. Water quality deterioration in the Khabarovsk Territory is studied to be caused by unsatisfactory sanitary-technical state of water-delivery networks, which damaged by more than 60 % [4, 5]. There is registered the fact that in 1995 year, for instance, number of damage occasions in water-supply pipelines of the Khabarovsk Territory has been registered to be 998. About 70,000 people (11.6 % of Khabarovsk population) use non-standard water, including water characterized by excess of State Sanitarian Standards regarding Fe content (33,000 people), manganese content (8,000 people) and chlorine content (70,000 people) [13].

Because of enormous amount of water quality factors, this comprehensive problem is to be considered in three main aspects. First of all, within ecological-medical aspect, the Amur basin natural water status, including water quantity, the current recommendations on protection and conservation of water resources and also on water use, are to be valued. This aspect has state sound, but quite often inter-state one, as well. Thereby, the comprehensive program aimed to the nature protection and rational (sustainable) land use in those countries, whose territories includes the Amur basin, are to cover three groups of parameters of land use management: 1) level of possible influence on the natural ecosystems; 2) preventing the deterioration of natural environment; 3) investment of nature protection and use of water ecosystems resources. Certainly, the nature protection and rational land use planning over given territory is to include such issue as water resources protection against contamination threatening people's health. According to complexity and interdisciplinarity of the Amur contamination problem, its resolving is considered to be possible just within the framework of certain Amur basin Development Program. Undoubtedly, such Program is to be based upon methodology of agreement between different regional and departmental development strategies, and also on the theory of management in conflict and uncertainty conditions facilitated by GIS, databases (DB), knowledge bases (KB) and remote management networks (RMN), could be applied.

GIS, DB, KB and RMN are applicable to the considered area and correspond to needs of ensuring of system parameters control adequacy to methods and models of manage-decision concerning the functioning and development of active complex systems – nature-society systems, as well as technology development of hetero-hierarchical electronic and computing neuron-networks as remote control structures. Thereby, there is stipulated the development of technology of decision making in man-machine managerial systems that include bases and principles of building the planning systems of decision making (DMS), architecture of DMS and presentation of knowledge in the system.

In order to resolve such class of problems there was designed global and local models of situations {S} and decisions {R}, allowing to describe different aspects of presentation of situations ensemble, and to form the classes of players, situations, decisions – so, functional conditions of person making the decisions (PDM) and etc. There were designed the algorithms corresponding to categorizations, recognitions and forecasting as a component both situations, and decisions. Creating of game-theoretical models (GTM) for the description of PDM behavior in conditions of given limited or global conflicts are described in [15] regarding the alive systems. Herewith, the "players" appear not just as policy-makers and managers (managers make decisions in the process of operative management, monitoring and control of the ecosystem behavior), but as other engaged persons on different management levels as well. Received on GTM building in the field of water-ecological issues, certain regularities are possible to be spread upon other kinds of land use as well. In [4, 12] there were elaborated the principles of software, information facilities and ergonomics to realize GTM mentioned above within the framework of information-recognition systems on the example of self-organizations processes of open thermodynamic system, which objects of alive nature are considered as.

Along the realization of separate positions of shortly formed problem, in practice (active area of management), high professionals in different areas of knowledge: modeling, planning, designing, making the managerial systems, construction, service etc. are to be attracted, regardless of their citizenships. Finally, how will change Amur itself and the Amur River basin functions in current century with climate change, population change, technological development and urbanization of this region, depends on the whole set of actions, first, in the international scale.

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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.

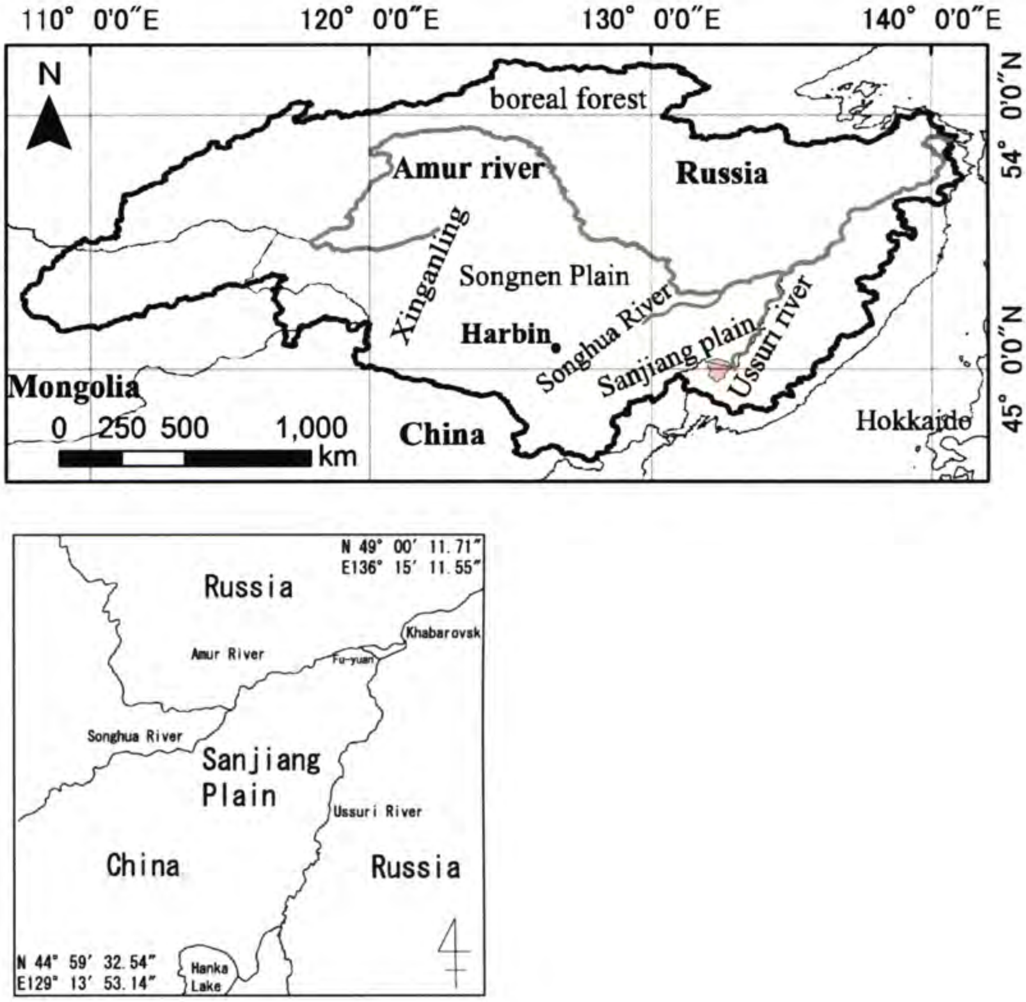


Figure 1.
Amur Basin (upper figure) and Sanjiang Plain and rivers (lower figure: the gray area shows the "triangular area" unaffected by human activity, black circle shows the location of Hong Hua Natural Reservation Area.)

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				

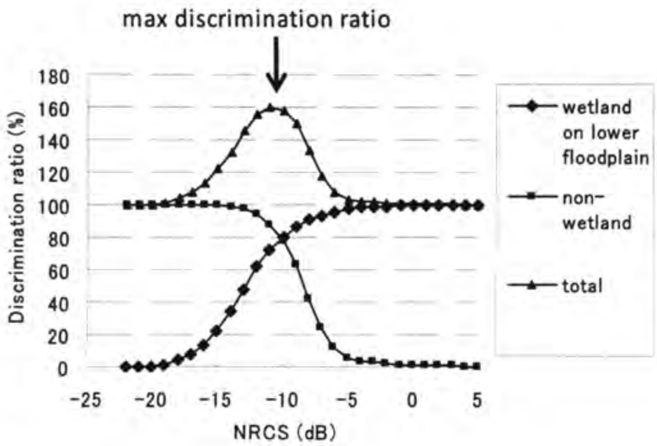


Figure 2.
Empirical cumulative distributions for NRCS of wetlands and non-wetlands on lower floodplain. The sum of the distributions is the Discrimination ratio. Threshold increases from -25 dB; more pixels are sorted as wetland and fewer pixels are sorted as non-wetland.

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:

NRCS [dB] = $10log_{10}(I^2)$ - 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

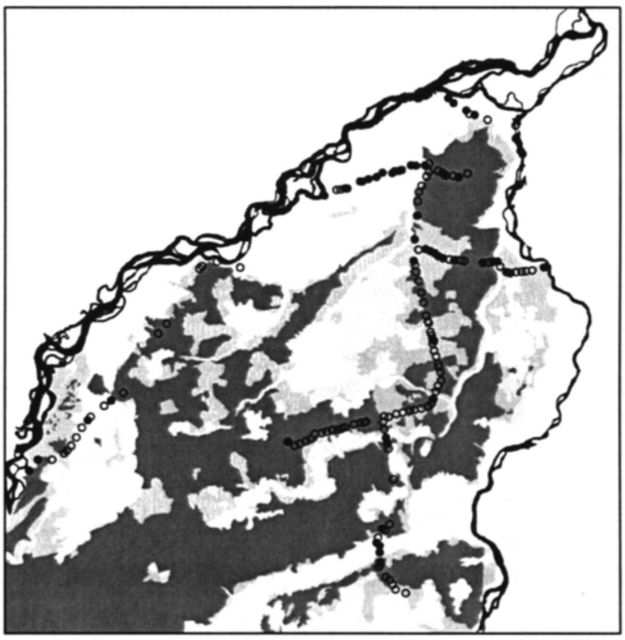


Figure 3.
Research points from ground data and cropland from Landsat/TM (○: cropland; •: wetland; black: water surface; light gray: crop land in 1992; middle gray: crop land in 1996; dark gray: crop land in 2006).

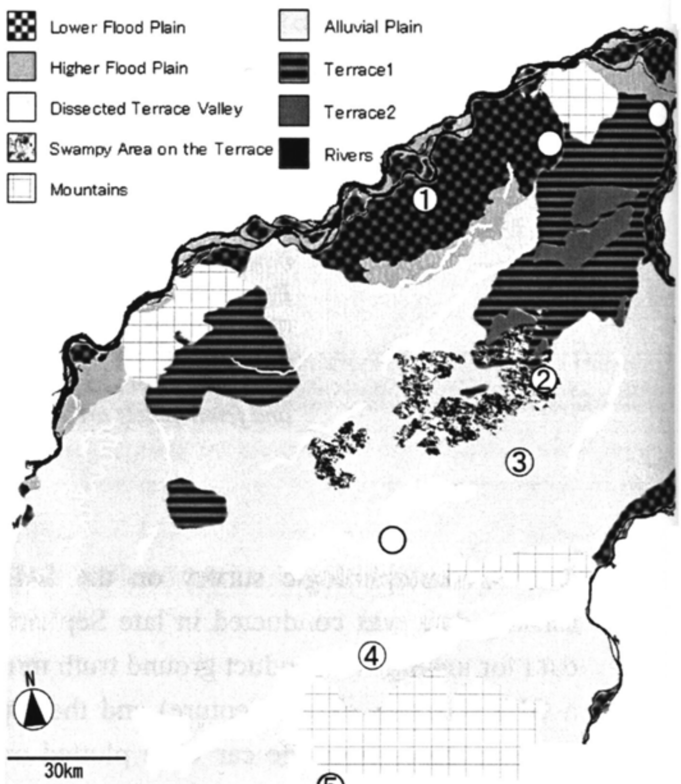


Figure 4. Landform map from JERS-1/SAR data of September 1996. Circles show the wetland areas where field investigations were carried out in this study. Cross-sections were made at the point of the circled numbers.

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.

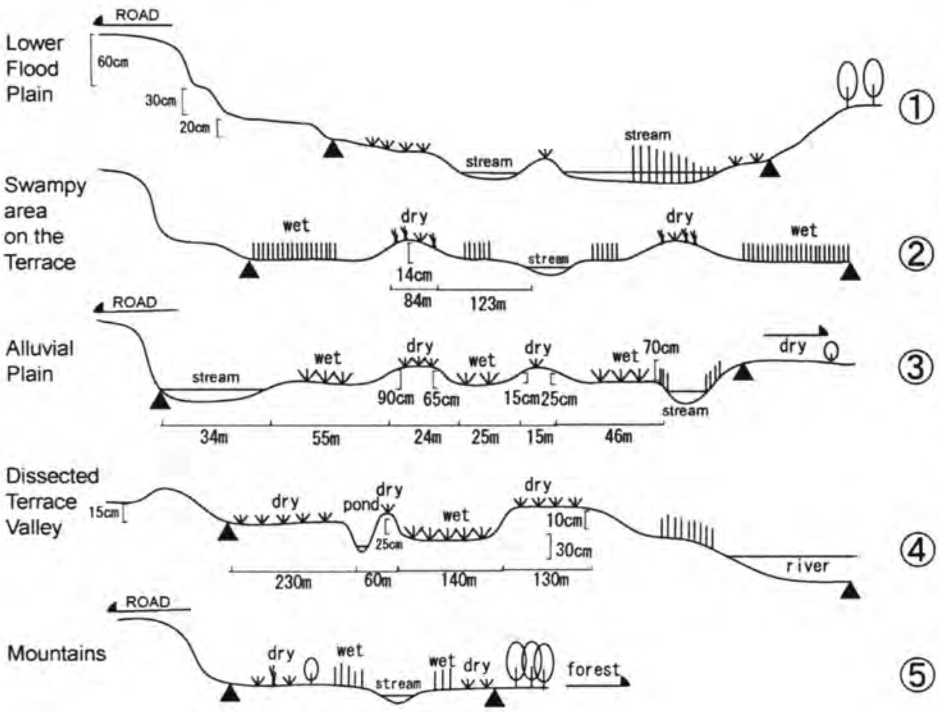


Figure 5.
Cross-sections of wetlands on the selected landforms. The numbers in the circles are the locations which accord with those of Figure 4. Wetlands are between the sets of two triangles.

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.

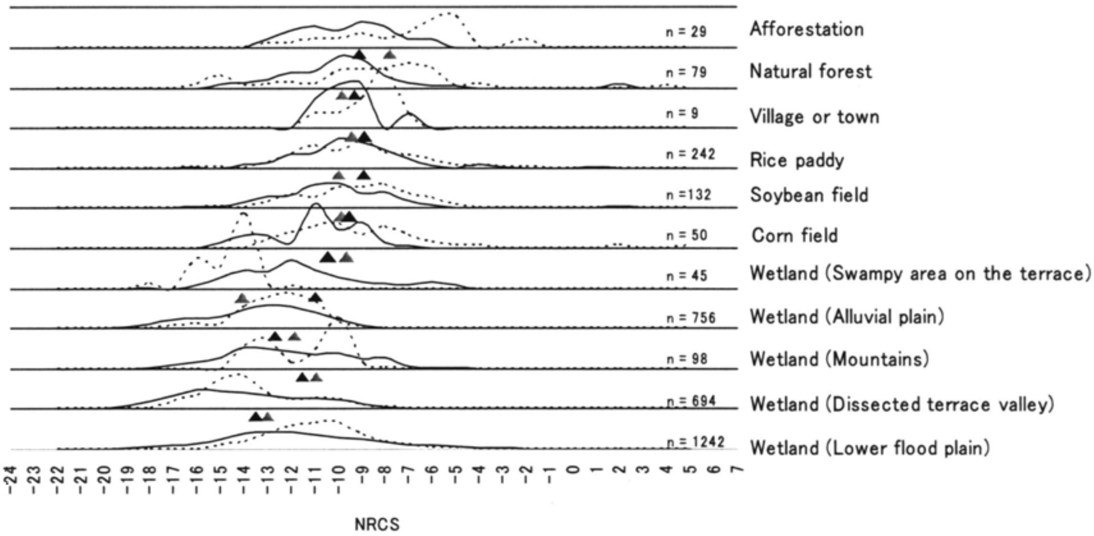


Figure 6.
Histograms of NRCS (normalized radar cross-section) values for main land cover. "n" means the number of NRCS pixels. The breadth of the vertical axe are 30%. The black triangles show the average of 1996; the gray triangles show the average of 1992.

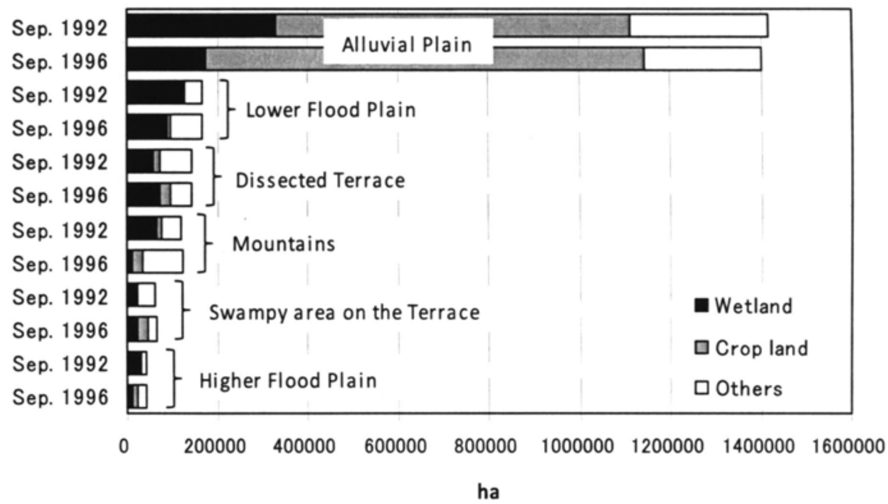


Figure 7. The areas, from satellite data, of wetland, croplands, and other features on each landform.

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.

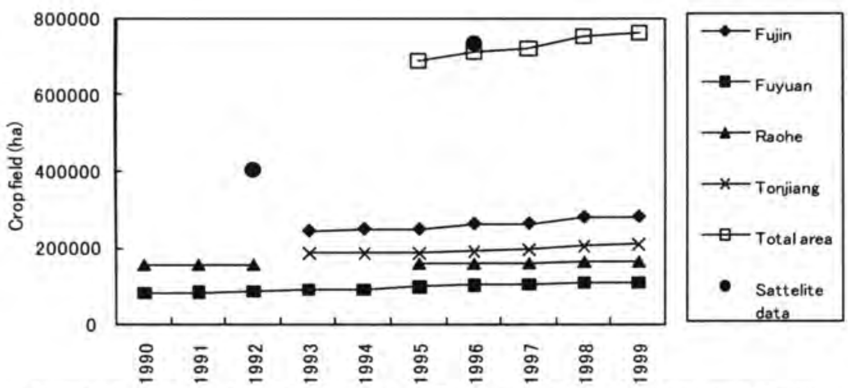


Figure 8. Cultivated area changes in Fuyuan, Raohe, Tonjiang and Fujin Regions which contain the Sanjiang Plain and the area of cropland from satellite data.

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.

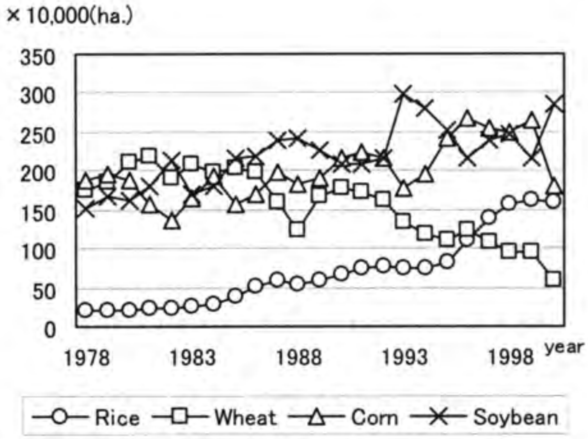


Figure 9. Transition of farm products sowing area in Heilongjiang Province

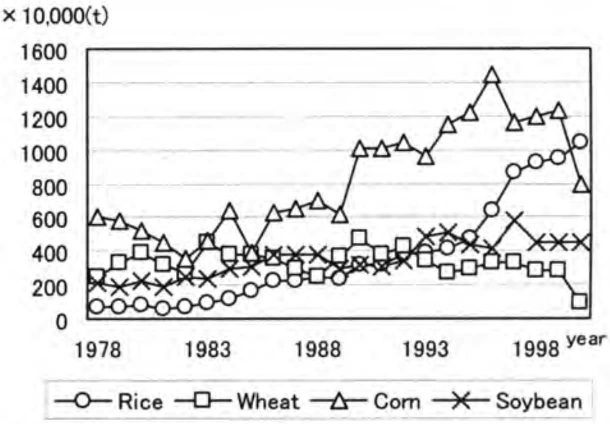


Figure 10. Transition of farm products production in Heilongjiang Province

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

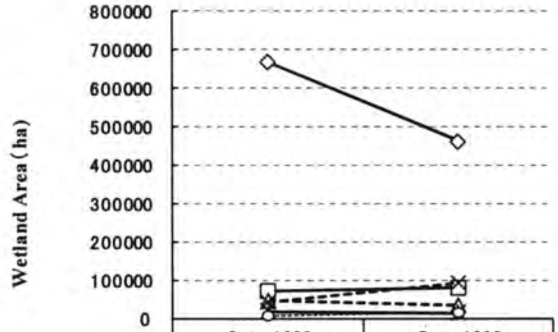
Category	1990	1995	1996
Crop lands	1.68	2.00	1.85
Neglected lands	0.12	0.09	0.09
Mining area	0.01	0.00	0.01
Aquaculture	-	0.00	0.00

(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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SALINIZED WASTELAND EXPANSION IN WESTERN NORTHEAST CHINA DURING 1975-2004

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ABSTRACT

Due to human impact under climatic variations, western part of Northeast China has suffered substantial land degradation during past decades. This paper presents an integrated study of expansion process of salinized wasteland in Da'an County, a typical salt-affected area in Northeast China, by using Geographic Information Systems (GIS) and remote sensing. The study explores the temporal and spatial characteristics of salinized wasteland expansion from 1975 to 2004, and land use/cover changes during this period. During the past 30 years, the salinized wasteland in study area have increased by 11175 ha, and in 2004 covers 32.31% of the total area, in the meantime grassland has decreased by 32534 ha and in 2004 covers only 13.15% of the study area. Grasslands, croplands and swamplands were found the three main land use types converted into salinized wasteland. The major factors influencing salinized wasteland expansion and land use/cover changes were also explored. In general, climatic factors supplied a potential environment for soil salinization. Human-related factors, such as policy, population, overgrazing, and intensified and unreasonable utilization of land and water resources are the main causes of salinized wasteland expansion.

1. INTRODUCTION

Salinization and alkalinization are the most common land degradation processes, particularly occurring in arid and semi-arid regions, where precipitation is too low to maintain a regular percolation of rainwater through the soil (Farifteh et al., 2005). Nowadays soil salinization is an increasing environmental problem throughout the world. The global extent of primary salt-affected soils due to natural factors is about 955 M ha, i.e. approximately 7% of the earth's continental extent, while secondary salinization as a consequence of human activities affects some 77 M ha (Metternicht and Zinck, 2003). Salt excess in soils has detrimental effect on crop yields and agricultural production due to poor land and water management, and results in substantial losses of arable soils, especially in the arid and semi-arid areas (Cayuela et al., 2001). Furthermore, salinity also affects other major soil degradation phenomena such as soil dispersion, increased soil erosion, and engineering problems (Metternicht and Zinck, 2003).

The globalization as well as changing environment in China is affecting land-use change. Coordinating the conflict between environmental conservation and land demands for food will continue to be a primary challenge for China in the future (Liu et al., 2005a). Soil salinization is one of the China's rural resource concerns (Rozelle et al., 1997), reduce crop yields and grassland productivity and leads to desertification. In western part of Northeast China, one of the main agricultural regions of the nation, soil salinization has been a environmental problem (Liu et al., 2002). Therefore, timely detection of Salinization/alkalinization, assessment of its degree of severity and the extent is vital.

For the researches on salinized land in western part of Northeast China, many efforts have been made to analyze current status of soil salinization, climate changes, landscape changes, influences of natural and anthropogenic factors (Pang et al., 2001; Huang and Meng, 1996; Li et al., 1998; Liu, 2001; Qiu, 2001). Yet quantitative knowledge on changes in land use at county level for long period is very little ((Pan et al., 2003), and there are no sufficient data at the landscape or regional scale to fully evaluate this problem. The objectives of this study were: (1) to assess the spatial and temporal characteristics of salina in Da'an County, a typical salt-affected area in western part of Northeast China, integrating maps and remote sensing images for a long period; (2) to demonstrate the effectiveness of combining remote sensing data in assessing salinization; and (3) to analyze possible factors influencing soil salinization and to provide useful information for improving grassland and cropland management practices and restoring the vegetation in this region.

2. MATERIALS AND METHODS

2.1. Description of the Study area

As a typical area affected by salinization in Northeast China, Da'an County (123°09'E - 124°22'E, 44°56'N to 45°46'N) is located in the northwestern part of Jilin Province, Northeast China, with an area of 4, 958 km^2. Its elevation is between 110 and 140m. The study area is characterized by a temperate, semi-arid continental monsoon climate. Seasons alternate between dry and windy springs, humid and warm summers with intensive rainfall, windy and dry autumns and long, cold dry winters. The mean annual temperature is 4.4 ℃ (1961-1990), with average maximum of 23.4℃ in July and average minimum –18.1 ℃ in January. The mean annual precipitation is 410 mm and evaporation is 1600 mm. Precipitation varies greatly within and between years. Seventy to eighty percent of total precipitation occurs between the middle of June and mid-August. The frost-free period of the study area is 137 d.

2.2. Datasets

2.2.1. Maps processing

To understand how land use cover change affects and interacts with global earth systems, information is needed on what changes occur, where and when they occur, the rates at which they occur, and the social and physical forces that drive those changes (Lambin et al., 1999). Despite ongoing research efforts on land-cover and land-use patterns, there remains a need for development of basic land-cover datasets providing quantitative, spatial land-cover information (Xavier and Szejwach, 1998).

The ARC/INFO (ESRI, 1994) GIS (Geographic Information Systems) software was used for the analysis of land use area change and the transition matrix analysis between land use types. In our study, multi-annual socio-economic statistical data, Landsat MSS images and

Landsat TM images were collected for evaluating the temporal and spatial characteristics of salinized wasteland expansion and the land use change between 1976 and 2004. Projection system of conical equal area projection doubled standard latitude (Albers) and Beijing 1954 coordinate system is selected to integrate different phase data to realize the analysis of land use data.

2.2.2. Satellite image processing and land use classification

Landsat images were used for analyzing land use change between 1975 and 2004. The images recorded in August 1975 (MSS data), June 1986 (TM data), August 1996 (TM data), and June 2004 (TM data), were selected, because land use types are easy to identify in this period when plant grows exuberantly in Northeast China. All selected images are cloud free.

The Landsat images were enhanced using the linear contrast stretching and histogram equalization to help identify ground control points in the rectification to common ALBERS coordinate system based on 1: 100 000 topographic maps of China. For each TM/MSS scene, there are at least 20 evenly distributed sites served as Ground Control Points (GCPs). Meanwhile, an efficient land cover classification system was designed and applied in the study. The land use/cover classification was conducted through visual interpretation to guarantee the consistency and accuracy of data processing. The reference data was collected from field survey or from existing land use map that have been field checked. Large-scale aerial photos were also employed as reference data in accuracy assessment when necessary. The results showed that the Kappa indices are in minimum precision 0.72 by examining the classified results of RS images in three periods.

A land use classification system was applied to Landsat image data, according to the classification put forward by Liu et al (2005b) and the Chinese national Technical Standard for Land-use Survey (Chinese National Agricultural Regionalization Committee, 1979). The classified classes in each image were grouped into seven land cover categories: croplands, woodlands, grasslands, water bodies, built-up areas including urban areas, swamplands, and salinized wasteland (i.e. salina). Croplands include paddy and dry farming land. Woodlands include forest, shrub and others (e.g., orchards). Grasslands include three density dependent types: dense, moderate and sparse grass. Water bodies include stream and rivers, lakes, reservoir and ponds, and bottomland. Built-up land includes urban area, rural settlements and others such as roads. Swamplands include lands with a permanent mixture of water and herbaceous vegetation that cover extensive areas. Salinized wasteland are lands with salina accumulation and sparse vegetation, with vegetation cover less than 5%, they represent the severely salinized areas in this paper.

2.3. Spatial analysis

In determining land use change, a cross-tabulation detection method was adopted. A change matrix was produced. Then quantitative data of the overall land use changes and gains and losses in each category can be compiled. The change matrix gives the knowledge of the main types of changes (directions) in the study area (Weng, 2002; Jia et al., 2004).

3. RESULTS AND DISCUSSION

3.1. Expansion of Salinized wasteland over the past 50 years

3.1.1. Temporal properties of salinized wasteland in Da'an County

The temporal change of salinized wasteland in Da'an County was illustrated in Figure 1.

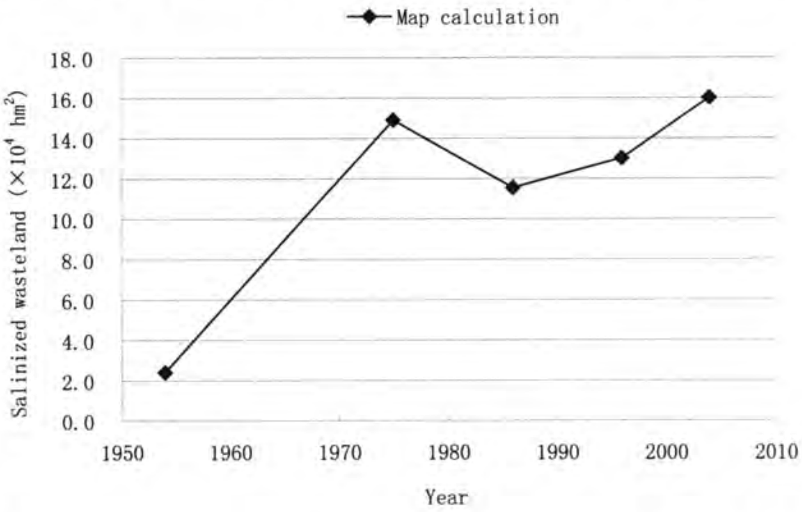


Figure 1.The temporal changes of salinized wasteland in Da'an County, Northeast China.

The salina area of Da'an County expanded from 14.90×10^4 ha in 1975 to 16.02×10^4 ha in 2004. Over the past decades, the process of expansion of salinized wasteland of the county experienced some up – down –up stages (Figure 3). During the stage of 1975-1986, the total area of salinized wasteland decreased by 22.5%, to 11.55×10^4 ha. The decrease rate was 2.0% per year. In this stage, relatively rich precipitation made some former salinized wasteland turned into swampland and brought a reduced area of salinized land.

Unfortunately, after the former abatement period, from 1987 to 1996, the precipitation showed a falling trend. Especially in 1995, Da'an County suffered great droughts during spring and summer. In addition, the excessive grazing of grassland accounted for the growth of salinized wasteland, which was related to the rapid population growth and the improved living standard since "the open-up to the outside world and the reform policy" were adopted in China. The salinized wasteland increased by 12.8% to 13.0×10^4 ha, with an annual rate of 1.3%. However, this size was still less than that in 1975 (14.9×10^4 ha). The salinized wasteland experienced another fast increase with an annual rate of 2.6% to 16.0×10^4 ha from 1996 to 2004. This increase resulted from climatic factors and anthropogenic disturbance in central part and in northern part, although the continuous heavy rainfall in 1998 somewhat lessened the salinization.

3.2. Transformation between salinized wasteland and other land use types

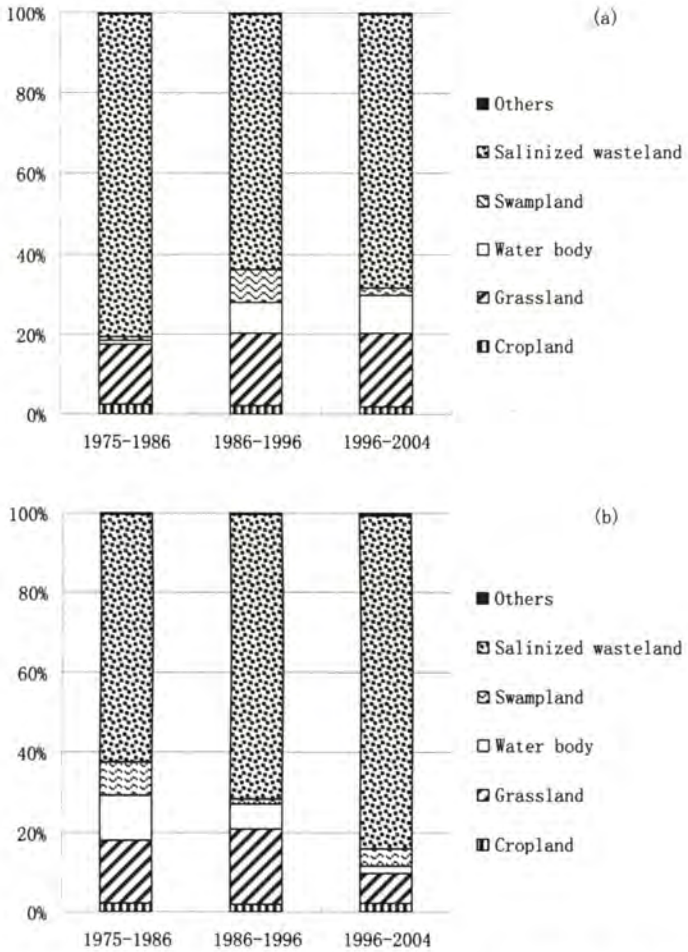


Figure 2. Area contribution of conversion between salinized wasteland and other land use types in Da'an County during four periods. (a) indicates the area contribution of land use types which were converted into salinized wasteland. and (b) indicates the area contribution of land use types which were converted from salinized wasteland.

Figure 2 demonstrated the conversion between salinized wasteland and other land use types in different periods. As shown in Figure 2 (a), increased salinized wasteland mainly originated from grassland, swampland, cropland and water bodies. Among these three land use types, grassland ranked the first. The percentage was 15.31%, 18.16% and 18.28% in different period, respectively. Proportion of salinized wasteland originated from swampland got one higher points during 1986-1996 (8.36%). This was partly attributed to drying out of swampland due to less precipitation in these two periods. The contribution of salinized wasteland originated from water body (mainly small lakes) was 7.62% and 9.72% in 1986-1996 and 1996-2004 periods, respectively, which is attributed to relatively less rainfall during these two stages.

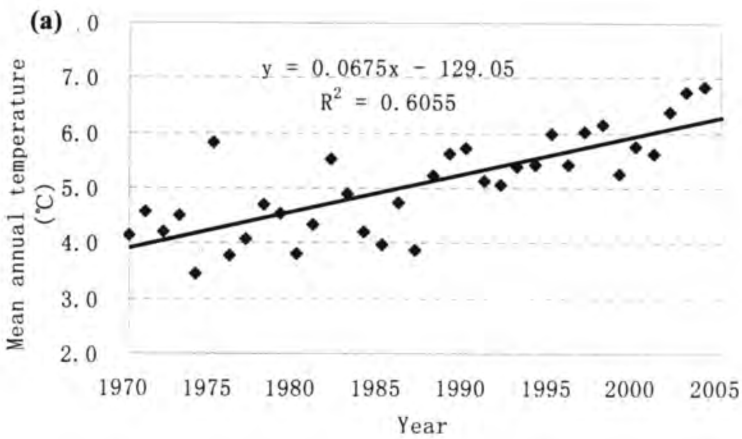
During the period 1975-2004, salinized wasteland was also converted into other land use types, such as grassland, water body and swampland. The percentage of salinized wasteland converted into water body was 11.23% and 6.33%, respectively, during 1975-1986 and 1986-1996.

3.3. Driving factors of expansion of salinized wasteland

Influenced by the climate and topography characteristics, there are two reasons for salinized land to form in this area. The first one is the dry climate, with evaporation being almost four times annual rainfall, and high mineralization of underground water, creating circumstances suitable for salt accumulation as the soil salt capacity increases gradually. The second is the unreasonable reclamation from grassland to cropland and digging canals for irrigation, which cause the underground water level to rise, and make the soil become secondary salinization.

3.3.1. Reasons of natural factors

The unfavorable hydrological conditions and dry climate accelerate salinization. On the one hand, in the last five decades, the study area have suffered frequent droughts, which led to increasing salinization and severely affected the agricultural development. Drought not only directly reduces productivity of crop and steppe generally, but also brings about soil salinization and desertification, which further indirectly affect regional sustainable development (Pan et al., 2003). On the other hand, in the West and East Piedmont of the study area, the sediments is mainly gravel and the slope is relatively steeper; there is a higher infiltration rate and faster groundwater runoff therefore, the salts leached from the top soil layers by rainfall can be rapidly transported downward by groundwater runoff. When the middle low plain is reached, groundwater runoff slows and dissolved salts are retained by soil and accumulate to high concentrations. As a result, in the middle low plain, the conditions are worse: almost stagnant groundwater, runoff without discharge except for evaporation, a shallow water table and a higher degree of mineralization, all of which are favorable for salinization. Furthermore, the semi-arid climate, characterized by low precipitation and very high evaporation, combined with unfavorable hydrological condition, increases land salinization.



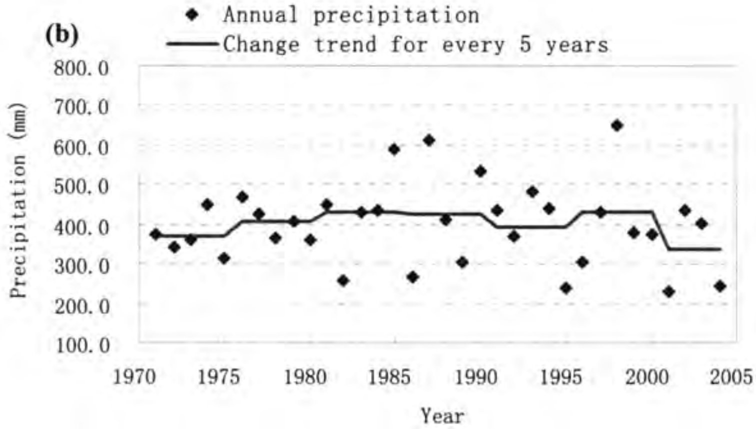


Figure 3.Changes of mean annual temperature (a) and annual precipitation (b) during 1975-2004 in Da'an County, China.

In the study area, the gradually increased air temperature led to intensive evaporation, which resulted in salinity accumulation in soil surface when precipitation was much less than normal level. In the past three decades, droughts have frequently endangered the Da'an County, thereby increased area of salinized wasteland and severely restricted sustainable development. Climate played an important role in the landscape changes.

The precipitation fluctuated in the past 30 years. To further analyze the effects of precipitation fluctuation on size of salinized wasteland, we compared the salina size obtained from maps with precipitation in that year. In 1975, the precipitation is very low (314.5 mm, 76.7% of mean annual precipitation, 410 mm). Consequently, the evaporation increased and salinity congregated on the surface with moisture, which resulted in severe salinization or aggravation of the salinizeded land, especially for swamplands in the southern part of the county. It was the reason that can't be ignored accounting for the sharp increase of salinized land in 1975 (Fig. 2) of the study area.

During the period of 1976-1986, the precipitation is relatively high compared with that in former period, some salinized land turned back into swmaplands. As a result, the increasing area of salinized land reduced and water area and swamaplands increased a little. In 1995, Da'an County suffered great spring and summer droughts, with only 60 mm of precipitation in 200 days, which not only directly reduced water area and wetlands but also caused serious damage to grassland and exacerbated land salinization. From 1996 to 2004, the precipitation changed as the trend of low-high-low. Flood in 1998 due to large continuous rainfall created some new swamplands and the following lower precipitation and more drought climate made some of the wetlands disappear, which is the major process accounting for the landscape changes in this period.

3.3.2. Socio-economic factors

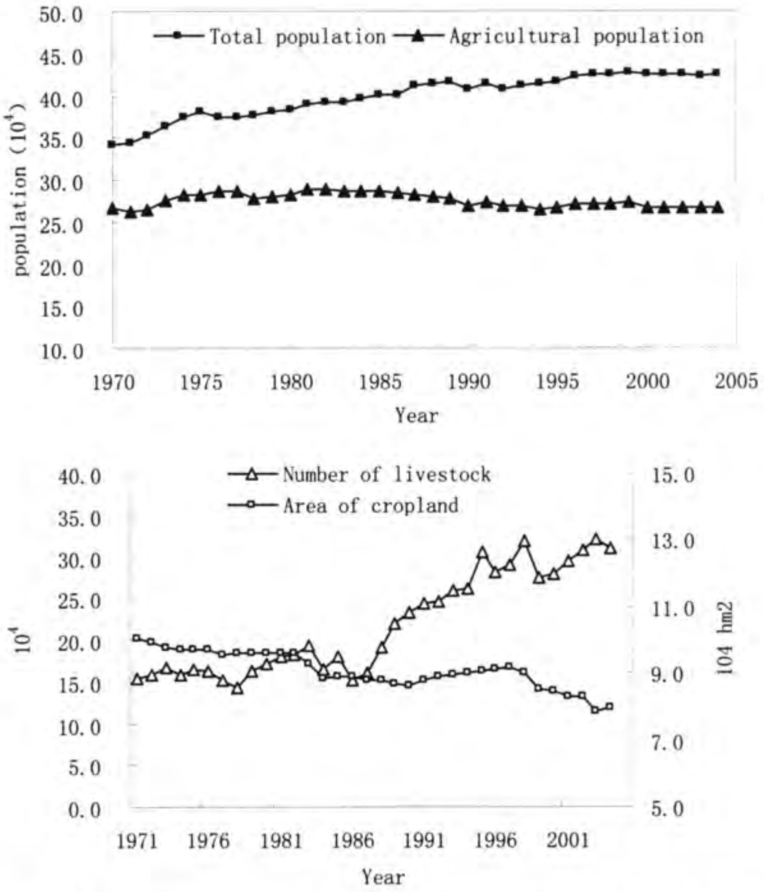


Figure 4. Changes of total population, agricultural population, cropland and number of livestock in Da'an County, China.

In this study, due to the increase in population and the concomitant requirement of grain after the founding of the People's Republic of China in 1949, the reclamation of farmland increased, which accelerated the cultivation of grassland and swampland. As shown in figure 4, total population of the study area increased by 23.2%, from 345 038 persons in 1971 to 425 216 in 2004. Agricultural population increased by 10.73%, to 266 830 persons in 2004. The rapid population growth brought a heavy burden to croplands and grasslands.

In Da'an County, agricultural and economic policies partly affected land use changes. At the end of the 1978, in order to encourage farmers, the Chinese government reformed the land tenure policy and introduced a system of household contract responsibility, in which remuneration was linked to output. In Da'an County, newly cultivated farmland increased from 1980, though was limited by the geographic situation, the percentage of total area is not so large. Owing to salinization, some of farmland had to be abandoned after reclaimed for a period, but the area of newly reclaimed farmland is less than that of abandoned cropland.

On the other hand, the unreasonable development of stockbreeding reduced the ground cover, thereby increasing the evaporation, soil temperature and soil organic decomposition. The $NaHCO_3$ and Na_2CO_3 produced after decomposition of soil organic matter are highly soluble in soil liquid at higher soil temperatures. In the past 30 years, the livestock increased greatly, from 154426 to 309456 capita (Figure 4). The excessive and unreasonable use of grassland destroyed the structure of original landscape. The area of salt-affected patch in grassland expanded, which generated a vicious circle and the depressed productivity of grassland continuously.

4. CONCLUSIONS

During the period 1975 – 2004, soil salinization expansion took place in Da'an County, Northeast China. Salinized wasteland increased by 562% in the three decades. Net increase of salinized wasteland was 135995 ha, concomitant with substantial decrease in grassland of 104697 ha. These changes bore an interactive relationship with the environment, especially increased air temperature and variable precipitation. Climate warming created a potential environment for soil saliniztion. Apart from natural factors, land use policy, economic systems and population growth were also main driving forces that jointly determined how local dwellers changed the landscape pattern. The results drawn from our study are important for scientists as well as policy makers for assessing a number of cutting-edge issues associated with global change and sustainability.

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COMPILATION OF SOIL MAP FOR THE AMUR RIVER BASIN: THE MAIN PARAMETERS

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INTRODUCTION

The accepted conception of creation of GIS-support for ecological condition research in the Amur River basin decrees that geo-information space of the geosystem should consist of three main information blocks [1]. These are National Geographical information block, Social Economic information block, and Management information block. Unified digital coverage "Soils" for the basin is an immediate constituent of the first block. It is important to note that this coverage is to fulfill several important functions in the information system. First, it supplies information about the patterns of soil cover distribution in the basin. Second, it is a verified source for compilation of a soil map for the territory of the whole basin. Third, it is a component (along with relief, vegetation, and geology) for compilation of a landscape map of the basin. In turn, the map is natural basis for planning and management of the territory's steady development. The digital coverage "Soils" has been made on Arc/Info, ArcView platforms at the detailed scale of 1:2,500,000 of common projection, according to the main rules [2]. The database (attributive table) includes separate fields with information about dominant soils, associated soils, parent material, and relief.

MATERIALS AND METHODS

The digital coverage "Dominant Soils" for the Amur River basin is based on the soil maps of the Russian Soviet Federative Socialist Republic, the Mongolian People's Republic, and the People's Republic of China. The maps were compiled over the years by members of different soil science schools and at different scales: The Soil Map of the Russian Soviet Federative Socialist Republic, Scale 1:2.5 M [3]; The Soil Map of the Mongolian People's Republic, Scale 1:2.5 M. [4]; the digital coverage "Soils of the Northeastern China", compiled in collaboration with soil scientists from China and in accord with soil nomenclature, adopted in China. Additionally, a number of soil maps at smaller scales were used [5, 6, 7, 8]. When compiling the digital coverage "Dominant Soils", the principle of preserving the source map data in the fullest was upheld [9]. For the Russian and Mongolian parts of the Amur River basin the source map data on soil mapping polygons was coded and added to the database. As for the digital coverage "Soils of the Northeastern China", its data on soil mapping polygons underwent multistage generalization with regard to the specific character of the region. Then the data was coded and added to the database. When compiling the legend of the digital coverage "Dominant Soils", the compilers took into consideration the difference between national soil classifications and nomenclatures of the source soil maps in Russia, Mongolia, and China.

The legend of the Soil Map of the RSFSR [3] includes soil names of two nomenclatures – the one used when the map was compiled [10] and the previous one [11]. The legend also has a number of newly adopted soil names which were either retained in later soil classifications in Russia [12, 13] or given at least partial correspondences. In order to avoid terminological difficulties we use soil names of the Soil Map of the RSFSR for "English Name" section of the digital coverage legend. The soil names for the Mongolian part of the Amur River basin generally coincide with the soil names of the Soil Map of the RSFSR. The legend of the Soil Map of the MPR also has a few outdated soil names that were omitted in later soil classifications [12, 13]. We found it necessary to fully retain the soil nomenclature of the source soil map in order to avoid terminological discrepancy.

The soil names for the Chinese part of the Amur River basin are diverse. Many soil names, adopted in China, correspond to Russian ones, and such soil names are preserved in our legend (e. g. Chernozems, Chestnuts, Grey forests, etc.). Some soils of the Chinese soil classification [14] do not correspond to Russian ones, but they have possible correlates among Russian soils. In the legend of the digital coverage "Dominant Soils" for the Amur River basin names of such soil are substituted by the ones, adopted for their Russian correlates. The Chinese soil names are given in parenthesis (e. g. Brownzems (Brown earths)). In a few cases the soil names, used in the legend of the source soil map, were unofficial traditional names. Such soil names were correlated to the soil names of the Chinese soil classification [14], and their possible (partial) correlates were found in the Russian soil classification. In the legend of the digital coverage "Dominant Soils" for the Amur River basin names of such soil are substituted by the ones, adopted for their correlates in Russia. The official and the traditional Chinese soil names are given in parenthesis (e. g. Chernozem-likes (Black earth or chetu).

Soils of mountainous regions of the Amur River basin that belong to the same soil classification taxon as soils of plains are not listed in "Soils of Mountainous Regions" section of the source map legends and the digital coverage legend. This section includes soils that are not found in piedmonts and plains of the Amur River basin.

The "English Name" section of our legend includes soil names, adopted for the Russian soil nomenclature in English [15, 16, 17].

The soil nomenclature of the legend of the digital coverage "Dominant Soils" for the Amur River basin is correlated to the soil nomenclature of the Revised legend of the FAO-UNESCO Soil Map of the World [18]. The correlation is based on literary data [19, 20, 21, 22, 23], electronic resource data [24], and "Dominant Soils of the World" CD data [25]. The soil nomenclature of the present legend is also correlated to the soil nomenclature of the World Reference Base for Soil Resources (WRB). The correlation is based on literary data [26] and electronic resource data [24].

RESULTS AND DISCUSSION

The legend of the digital coverage "Dominant Soils" for the Amur River basin reflects the soil nomenclatures, adopted in Russia, Mongolia, and China. Beside this, the soil nomenclature of the legend is correlated to the soil nomenclatures of FAO-UNESCO and the World Reference Base for Soil Resources (WRB).

Diverse soils of the Amur River basin are grouped in the legend in full accord with landscape and geographical zoning principle, upheld in the source soil maps in Russia [27], Mongolia, and China: soils of tundra, taiga and coniferous-broadleaved forests; soils of broad-leaved forests and wooded steppe; soils of steppe; soils of dry steppe. Hydromorphic, saline, alluvial, anthropogenic, and mountainous soils also make separate groups. Due to the paper length concerns only a part of the legend that includes zonal soil groups is given below (Table).

The complex and specific soil cover of the Amur River basin is due to the combination of contrasting natural conditions (climate, relief, vegetation, parent material) within the territory. According to soil and geographical zoning [28] the territory of the Amur River basin lies within two soil-bioclimatic belts: the boreal (temperate cold) belt and the subboreal (temperate warm) belt. Diverse soil cover of the Amur River basin reflects the specificity of the territory's bioclimatic conditions (Map 1, 2). When describing the fragments, we use soil names from "English name" section of the legend in order to fully preserve their informative value. In our opinion, these names reflect the complex character and diverse nature of the regional soil cover better than the more generalized soil names of FAO-UNESCO and WRB nomenclatures [20]. The target map scale and the character of geographical distribution of soils in the Amur River basin allowed us to preserve soil mapping polygons of the source soil maps [3, 4] at taxonomic levels of "soil type", "sybtype", "genus", and "kind". The soil names in "English Name" section reflect this low-level taxonomic division. The nomenclatures of FAO-UNESCO and WRB deal with units of higher taxonomic levels – reference soil groups and soil subunits, and these can't fully reflect diversity and specific distribution of soils in the region under study. If necessary, the legend allows easy correlation between the "English Name" section nomenclature and those of FAO-UNESCO and WRB.

The Western part of the Amur River basin (Map 1) is a part of Mongol-Manjur mountain-and-plain area of Euro-Asian subboreal steppe region [29]. This part of the basin includes bordering areas of Russia, China, and Mongolia. It is characterized by soil cover of highly complex structure and by specific soil formation conditions. Absolute heights of ridges are 1000-1200m, and those of intermontane plains bordering Lake Dalainor are 550-750m. The climate is maximum continental with highly contrasting amplitudes of temperature fluctuations. Scattered areas of grey forest soils are found in the South of Zabaikalie (Russia) within the transitional zone on taiga and steppe border. In China the transitional zone has a continuous area of dark-grey forest soils that covers the Northwestern offshoots of the Great Khingan Ridge. In Mongolia the forest-steppe zone with characteristic areas of grey forest soils is absent due to mountainous relief with mountains and basins alternating within small areas. In the Western part of the Amur River basin the steppe zone forms a continuous band that covers the Western offshoots of the Great Khingan Ridge in China, the offshoots of the Borshchovochny, Kukulbeisky, and Argunsky Ridges in Zabaikalie (Russia), and the Eastern offshoots of the Hentei in Mongolia. Chernozems of Eastern Siberian group are dominant in the soil cover of the area. These are washed chernozems, either noncalcareous or meal-calcareous. The profile of these soils is often immature, shallow, and stony. The soils undergo long periods of deep freeze. Light, luvic, and typical chernozems are found in China, meal-calcareous and noncalcareous chernozems are found in the South of Zabaikalie (Russia), and meal-calcareous contactly-meadowish chernozems are found in Mongolia.

The Zeisko-Bureinskay Plain (Map 2) has areas of specific meadow-chernozem-like soils that form a separate soil type called "the Amur prairie meadow-chernozem-like soils". They are widely used in agriculture. Their analogues – chernozem-like soils – are found in the Chinese part of the Amur River basin. They border areas of meadow soils and form band-like areas on more elevated elements of relief. Their Chinese name is black earths, and their traditional Chinese name is chetu. These soils are widely used in agriculture.

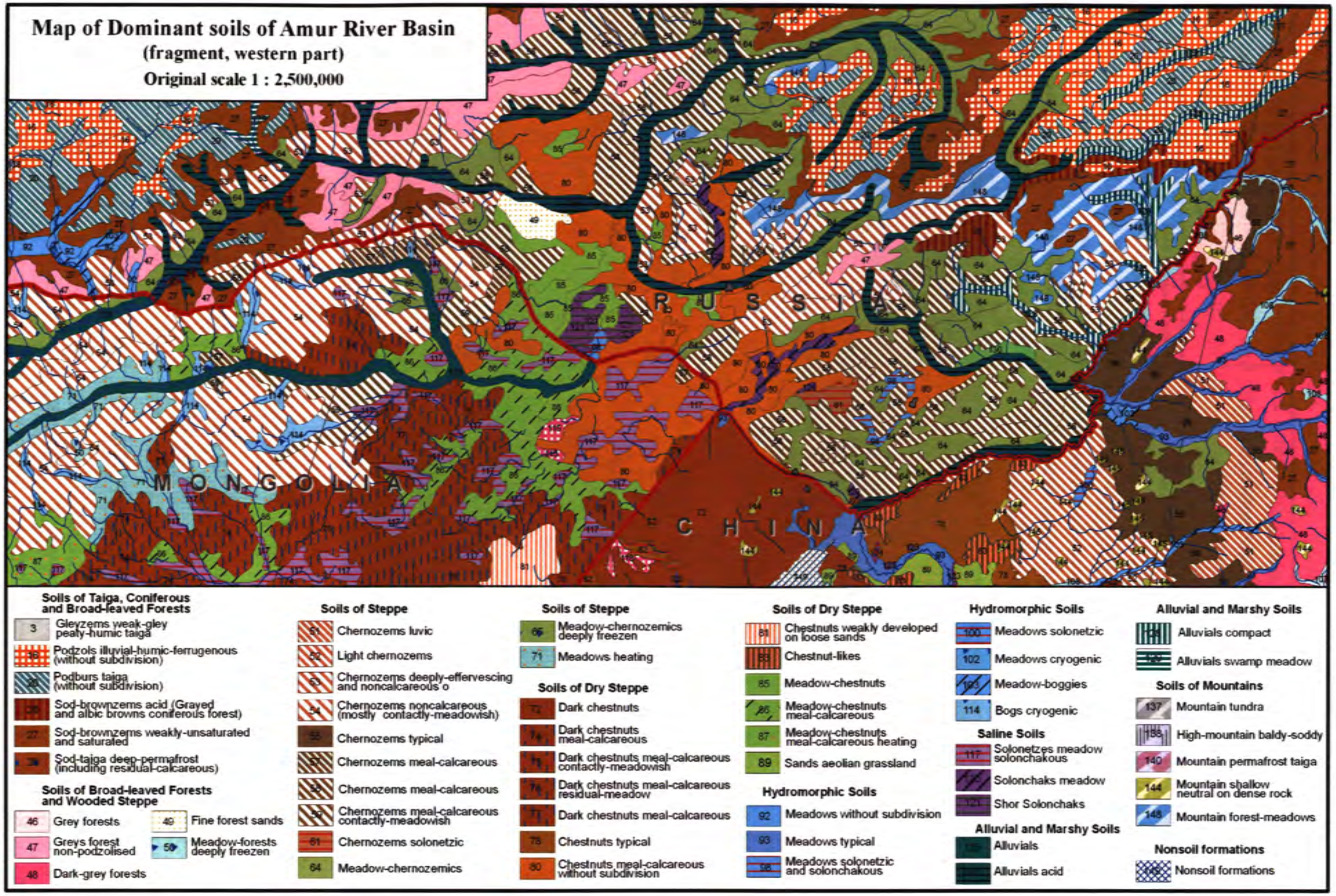
Legend of the Soil Map of the Amur River Basin (fragment)
Soil Compendium

Soil code	Soil Name		
	Name in English Russian Legend	**Name in the Revised legend of the Soil Map of the World FAO-UNESCO, 1990**	**Name in the World Reference Base for Soil Resources, 1998**
SOILS OF TUNDRA			
1	Podburs light tundra	Gelic Podzols (PZi)	Cryosols Haplic (CRha)
2	Podburs tundra (without subdivision)	Ferric Podzols (PZf)	
SOILS OF TAIGA AND SOILS OF CONIFEROUS AND BROAD-LEAVED FORESTS			
3	Gleyzems weak-gley peaty-humic taiga	Gelic Gleysols (GLi)	Cryosols Histic (CRhi)
4	Gleyzems peaty-muck taiga		
5	Taiga peaty-muck high-humic non-gleyic	Gelic Cambisols (CMi)	
6	Podzolics, mostly shallow podzolics	Dystric Podzoluvisols (PDd)	Albeluvisols Haplic (ABha)
7	Podzolic-gleys peat and peaty	Gleyic Podzoluvisols (PDg)	Albeluvisols Histic (ABhi)
9	Sod-pale-podzolics and podzolised brownzems	Eutric Podzoluvisols (PDe)	Albeluvisols Umbric (ABum)
10	Podzolised brownzems (Beijang bleached)		
11	Sod-pale-podzolics and podzolised brownzems deep-gleyic and gley	Gleyic Podzoluvisols(PDg)	Albeluvisols Gleyic (ABgl)
12	Podzolised brownzems meadow (Beijang bleached meadow)		
13	Podzolised brownzems gley (Beijang bleached gley)		
15	Podzols humic-illuvial	Haplic Podzols (PZh)	Podzols Carbic (PZcb)
16	Podzols illuvial-humic-ferrugenous (without subdivision)		Podzols Haplic (PZha)
17	Podzols dry-peaty		Podzols Histic (PZhi)
18	Podzols gley peaty and peat, mostly humic-illuvial	Gleyic Podzols (PZg)	Podzols Gleyic (PZgl)
20	Podburs taiga (without subdivision)	Cambic Podzols (PZb)	Podzols Entic (PZet)
21	Podburs dry-peaty		Podzols Histic (PZhi)

22	Podburs ochric		Podzols Rustic (PZrs)
23	Brownzems raw-humic illuvial-humic	Dystric Cambisols (CMd)	Cambisols Dystric (CMdy)
24	Brownzems raw-humic		
25	Brownzems raw-humic gley	Gleyic Cambisols (CMg)	Cambisols Gleyic (CMgl)
26	Sod-brownzems acid (Grayed and albic browns coniferous forest)	Dystric Cambisols (CMd)	Umbrisols Haplic (UMha)
27	Sod-brownzems weakly-unsaturated and saturated (Browns coniferous forest)	Eutric Cambisols (CMe)	Cambisols Eutric (CMeu)
28	Sod-brownzems gleyic and gley	Gleyic Cambisols (CMg)	Cambisols Gleyic (CMgl)
29	Sod-taiga deep-permafrost (including residual-calcareous)	Eutric-Gelic Cambisols (CMe-i)	Cambisols Eutric-Gelic (CMeu-ge)
30	Sod-calcareouses (including leached and podzolised)	Rendzic Leptosols (LPk)	Leptosols Rendzic (LPrz)
31	Volcanics ash typical	Haplic Andosols (ANh)	Andosols Haplic (ANha)
32	Dark volcanics ash	Umbric Andosols (ANu)	Andosols Umbric (ANum)
33	Volcanics ash on basi c rock	Mollic Andosols (ANm)	Andosols Mollic (ANmo)
SOILS OF BROAD-LEAVED FORESTS AND WOODED STEPPE			
34	Brownzems acid	Dystric Cambisols (CMd)	Cambisols Dystric (CMdy)
35	Brownzems acid podzolised		
36	Brownzems weakly-unsaturated (Brown earths)	Eutric Cambisols (CMe)	Cambisols Eutric (CMeu)
37	Brownzems weakly-unsaturated podzolised		
38	Brownzems gleyic and gley	Gleyic Cambisols (CMg)	Cambisols Gleyic (CMgl)
39	Dark brownzems	Eutric Cambisols (CMe)	Umbrisols Haplic (UMha)
40	Dark brownzems grayed	Dystric Cambisols (CMd)	
41	Dark brownzems albic		Umbrisols Albic (UMab)
42	Dark brownzems meadow	Haplic Cambisols (CMh)	Umbrisols Haplic (UMha)
43	Dark brownzems gley	Gleyic Cambisols (CMg)	Umbrisols Gleyic (UMgl)
44	Dark brownzem-likes	Haplic Cambisols (CMh)	Umbrisols Haplic (UMha)
46	Grey forests	Haplic Greyzems (GRh)	Luvisols Albic (LVab)
47	Greys forest non-podzolised		Phaeozems Luvic (PHlv)
48	Dark-grey forests		Phaeozems Greyi-Luvic (PHgz-lv)
49	Fine forest sands	Cambic Arenosols (ARb)	Arenosols Protic (ARpr)
50	Meadow-forests deeply freezen	Umric-Gelic Leptosols (LPu-i)	Umbrisols Gelic (UMge)
SOILS OF STEPPE			
51	Chernozems luvic	Luvic Chernozems (CHl)	Chernozems Luvic (CHlv)
52	Light chernozems	Luvic Phaeozems (PHl)	Phaeozems Luvic (PHlv)
53	Chernozems deeply-effervescing and noncalcareous on sandstones and sands)	Haplic Chernozems (CHh)	Chernozems Chernic (CHch)
54	Chernozems noncalcareous (mostly contactly-meadowish		
55	Chernozems typical		
56	Chernozems calcareous	Calcic Chernozems (CHk)	Chernozems Calcic (CHcc)
57	Chernozems meal-calcareous		
58	Chernozems meal-calcareous, including leached, typical, ordinary, southern (chernozems washed)		
59	Chernozems meal-calcareous contactly-meadowish	Haplic Chernozems (CHh)	Chernozems Haplic (CHha)
60	Chernozems meal-calcareous shallow		
61	Chernozems solonetzic	Luvic Chernozems (CHl)	Chernozems Luvic (CHlv)
62	Chernozems solonchakous	Luvic Chernozems (CHh)	

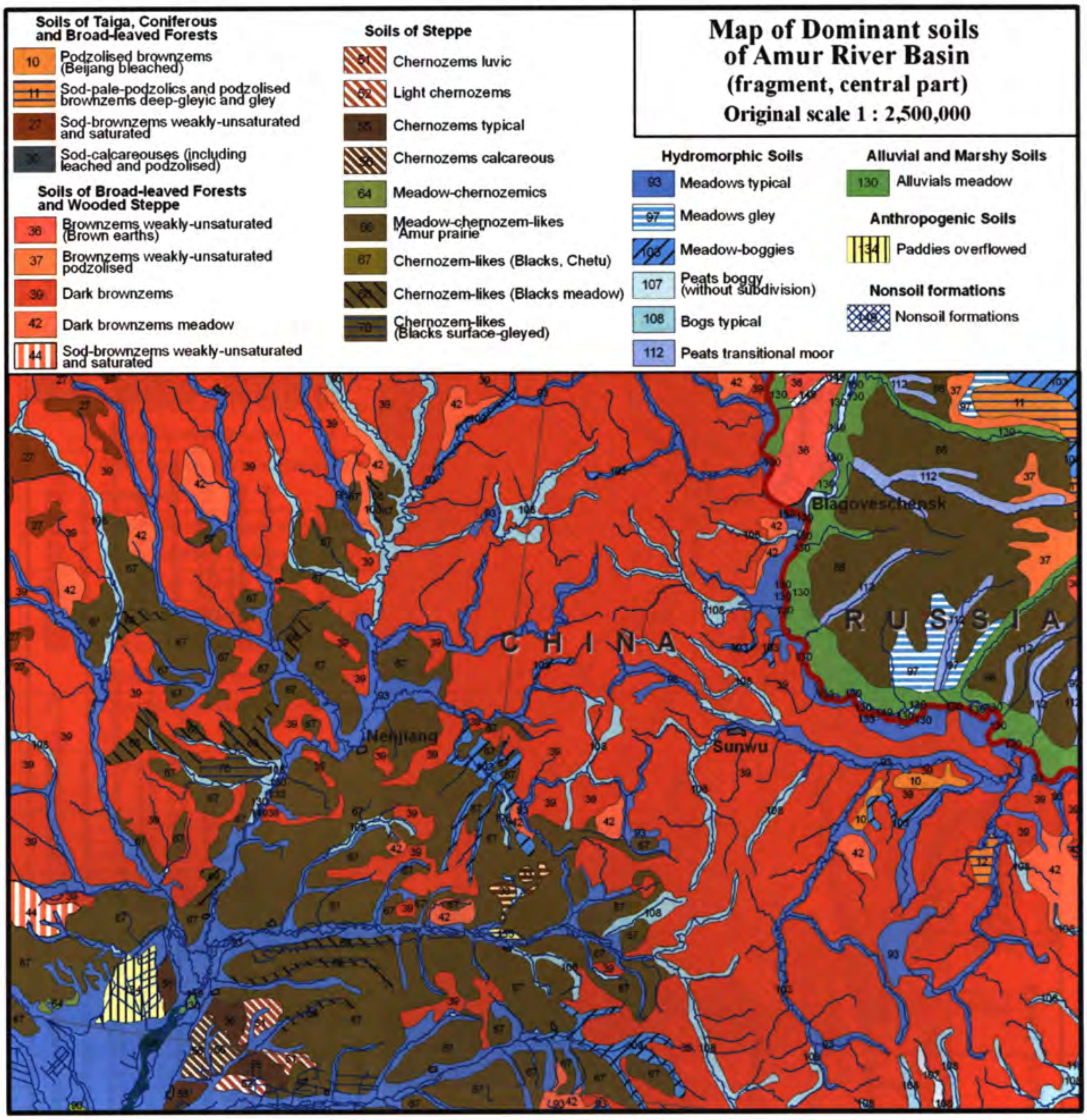
64	Meadow-chernozemics (Chernozems meadow)	Haplic Phaeozems (PHh)	Phaeozems Gleyic (PHgl)
65	Meadow-chernozemics deeply freezen	Gelic Phaeozems (PHi)	
66	Meadow-chernozem-likes "Amur prairie"	Gleyic Phaeozems (PHg)	
67	Chernozem-likes (Blacks, Chetu)	Haplic Phaeozems (PHh)	Phaeozems Haplic (PHha)
68	Chernozem-likes (Blacks meadow)	Gleyic Phaeozems (PHg)	Phaeozems Gleyic (PHgl)
69	Chernozem-likes (Blacks albic)	Albic Phaeozems (PHa)	Phaeozems Albic (PHab)
70	Chernozem-likes (Blacks surface-gleyed)	Stagnic Phaeozems (PHj)	Phaeozems Stagni-Epigleyic (PHst-pgl)
71	Meadows heating	Haplic Phaeozems (PHh)	Phaeozems Haplic (PHha)
	SOILS OF DRY STEPPE		
72	Dark chestnuts	Haplic Kastanozems (KSh)	Kastanozems Haplic (KSha)
74	Dark chestnuts meal-calcareous	Calcic Kastanozems (KSk)	Kastanozems Calcic (KScc)
75	Dark chestnuts meal-calcareous contactly-meadowish		
76	Dark chestnuts meal-calcareous residual-meadow		
77	Dark chestnuts meal-calcareous and noncalcareous shallow	Haplic Kastanozems (KSh)	Kastanozems Haplic (KSha)
78	Chestnuts typical		
79	Chestnuts meal-calcareous shallow	Calcic Kastanozems (KSk)	Kastanozems Calcic (KScc)
80	Chestnuts meal-calcareous without subdivision (chestnuts leached)		
81	Chestnuts weakly developed on loose sands	Mollic Leptosols (LPm)	Leptosols Mollic (PLmo)
82	Chestnuts solonchakous	Luvic Kastanozems (KSl)	Kastanozems Sodic (KSso)
83	Chestnut-likes	Haplic Kastanozems (KSh)	Kastanozems Haplic (KSha)
85	Meadow-chestnuts (Chestnuts meadow)	Haplic Phaeozems (PHh)	Phaeozems Gleyic (PHgl)
86	Meadow-chestnuts meal-calcareous	Calcaric Phaeozems (PHc)	Phaeozems Calcaric-Gleyic (PHca-gl)
87	Meadow-chestnuts meal-calcareous heating		Phaeozems Calcaric (PHca)
89	Sands aeolian grassland	Haplic Arenosoils (ARh)	Arenosoils Haplic (ARha)
90	Sands aeolian meadow		

Map1



Map of Dominant soils of Amur River Basin
(fragment, western part)
Original scale 1 : 2,500,000
RUSSIA
MONGOLIA
CHINA
Soils of Taiga, Coniferous and Broad-leaved Forests
3 Gleyzems weak-gley peaty-humic taiga
Podzols illuvial-humic-ferrugenous (without subdivision)
Podburs taiga (without subdivision)
Sod-brownzems acid (Grayed and albic browns coniferous forest)
27 Sod-brownzems weakly-unsaturated and saturated
Sod-taiga deep-permafrost (including residual-calcareous)
Soils of Broad-leaved Forests and Wooded Steppe
46 Grey forests
47 Greys forest non-podzolised
48 Dark-grey forests
49 Fine forest sands
50 Meadow-forests deeply freezen
Soils of Steppe
51 Chernozems luvic
52 Light chernozems
53 Chernozems deeply-effervescing and noncalcareous o
54 Chernozems noncalcareous (mostly contactly-meadowish)
55 Chernozems typical
57 Chernozems meal-calcareous
58 Chernozems meal-calcareous
59 Chernozems meal-calcareous contactly-meadowish
61 Chernozems solonetzic
64 Meadow-chernozemics
65 Meadow-chernozemics deeply freezen
71 Meadows heating
Soils of Dry Steppe
72 Dark chestnuts
74 Dark chestnuts meal-calcareous
Dark chestnuts meal-calcareous contactly-meadowish
Dark chestnuts meal-calcareous residual-meadow
Dark chestnuts meal-calcareous
78 Chestnuts typical
80 Chestnuts meal-calcareous without subdivision
81 Chestnuts weakly developed on loose sands
83 Chestnut-likes
85 Meadow-chestnuts
86 Meadow-chestnuts meal-calcareous
87 Meadow-chestnuts meal-calcareous heating
89 Sands aeolian grassland
Hydromorphic Soils
92 Meadows without subdivision
93 Meadows typical
98 Meadows solonetzic and solonchakous
100 Meadows solonetzic
102 Meadows cryogenic
103 Meadow-boggies
114 Bogs cryogenic
Saline Soils
117 Solonetzes meadow solonchakous
Solonchaks meadow
121 Shor Solonchaks
Alluvial and Marshy Soils
Alluvials
Alluvials acid
Alluvial and Marshy Soils
Alluvials compact
Alluvials swamp meadow
Soils of Mountains
137 Mountain tundra
High-mountain baldy-soddy
140 Mountain permafrost taiga
144 Mountain shallow neutral on dense rock
148 Mountain forest-meadows
Nonsoil formations
Nonsoil formations

Map 2



CONCLUSION

The digital coverage "Dominant Soils" for the Amur River basin has been compiled. It covers bordering territories of Russia, China, and Mongolia. The digital coverage enables us to analyze the soil cover of the Amur River basin as a whole. It helps us to disclose geographical patterns of soil distribution within the basin and specific characteristics of different parts of the basin.

When compiling the digital coverage "Dominant Soils", the data from the source soil maps of Russia, Mongolia, and China was preserved in the fullest, and the soil cartographic material was unified. All the data was coded and added to the database.

The resultant soil compendium includes all the diverse soils of the Amur River basin (Scale 1:2.5 M). The soils are grouped in accord with landscape and geographical zoning principle. The soil compendium includes zonal soils (soils of tundra, taiga and coniferous-broadleaved forests; soils of broad-leaved forests and wooded steppe; soils of steppe; soils of dry steppe), mountainous soils, and also such separate groups as hydromorphic, saline, alluvial, and anthropogenic soils.

Russian, Mongolian, and Chinese soil nomenclatures for the Amur River basin were correlated. Then the resultant soil nomenclature was correlated to the soil nomenclatures of FAO-UNESCO and the World Reference Base for Soil Resources.

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ROLE OF FOREST TRADE RELATIONS BETWEEN RUSSIA, JAPAN AND CHINA IN DEVELOPMENT AND UTILIZATION OF THE AMUR BASIN'S FOREST

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Forests of the Amur River Basin play one of the key roles in the system of ecological interactions inside Amur-Okhotsk region as well as provide economic interrelations between Russia, China and Japan. In the XXth century forest ecosystems of the Amur basin were heavily exploited as resource base of timber industry in the Russian Far East and Northeastern China. Long-term economic development of forest resources located on the Chinese or Russian part of basin was not driven only by the internal factors of each country. On the contrary during certain periods from the end of the XIXth to the beginnings of the XXIst centuries utilization of forests was notably determined by external influence of neighboring countries and foreign markets.

The purpose of the present work is to study participation and influence of Russia, China and Japan on the development and exploitation of the Amur basin's forests, interactions between these countries in trade and consumption of basin's timber during last 100-120 years. Different questions of timber industry development in the Russian Far East and Northeastern China, its influence on forest health and dynamics, trade by forest products have been considered in research studies of different years (Krokos, 1926; Surin, 1930; Krechetov, Sheigauz, 1973; Sheingauz, 1973, 2004, 2006; Natural resources.., 1975; Natural resource use.., 1997; Forest Sector.., 2005; etc.). Variety of those publications and other available materials provided the basis for the present study focusing on the forest relations between countries of Amur-Okhotsk region.

1. FOREST DEVELOPMENT AND UTILIZATION IN THE CHINESE PART OF THE AMUR RIVER BASIN

Economic development of the basin's Chinese part from the late 1890s until the late 1920s was notably determined by the Russian influence. It was connected with construction of the Chinese Eastern Railway (or CER) in 1896-1903. This road, built up and managed by Russians on the base of leased agreement with Chinese government, initially was constructed for realization of economic and strategic goals of Russia, but eventually it made new Manchurian territories accessible for the settlers and was oriented to rapidly growing regional economy on the foreign markets.

After the Russo-Japanese war in 1904-1905 Japan expropriated the southern part of the CER and Manchuria has been divided into 2 zones of influence. South Manchuria enclosed Kvantun Leased Territory, Mukden Province, and southern part of Girin Province, was mainly affected by Japan. The zone of the Russian influence, known as North Manchuria, consisted of Amur Province with Barga, and the northern part of Girin Province (Frizendorf, 1929). Spatially North Manchuria was located approximately within the borders of the Chinese part of the Amur Basin.

Timber harvesting data on North Manchuria in the beginning of the XXth century are small and characterize mainly activity of the large timber concessions located in the zone of the CER. As a whole, the railroad's construction and operation were the main reasons of origination and development of the large timber enterprises in North Manchuria. Majority of such enterprises were owned by Russians, some part of concessions had a joint Russian-Chinese character. Penetration of the Japanese capital into forest sector was enhanced in the 1920s.

The total output of timber and firewood in the concessions located in the zone of the CER in 1913-1925 fluctuated between 480 and 1,550 thousand tons per annum (Fig.1). About 80 % of these materials were consumed by the railroad. Only after 1922 the share of wood supplied to the private and foreign markets reached 30-50% of the total output. However a whole consumption of forest products in North Manchuria was much larger and according to estimates of Economic bureau of CER it exceeded 1-2 million tons annually. In addition to the CER's timber harvesting the Lower Sungari region produced over 500,000 tons. And huge volume of wood was logged by small local artels scattered all over Manchuria, activity of which was poorly supervised and practically not accounted (North Manchuria.., 1982; Surin, 1930).

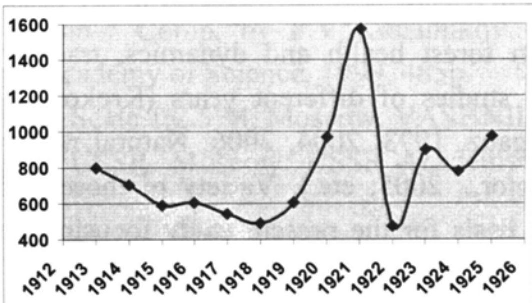

Fig. 1. Dynamics of timber and firewood output in the forest concessions located in the zone of the CER, thousand tons (North Manchuria and CER, 1927)

The share of lumber delivered from large concessions and the CER beyond the borders of North Manchuria was not large. Till 1921 volume of export did not exceed 50,000 tons. It increased quite rapidly in the beginning of the 1920s and reached 170,000 tons in 1924. Forest products were exported for the most part to the markets of South Manchuria. From there sawn timber and joists, and small aspen logs were transferred to Japan through Changchun and Dairen. Among the consumers of forest products in South Manchuria the most significant ones were the railway and Fushun collieries (North Manchuria and CER, 1927). Wood from North Manchuria had no wide access to the China's market because it has higher price owing to remoteness of forest areas from sea ports and high costs of railway transportation, and also because of differences in standards of forest products. Volumes of export to Japan also were not too much (in the second half of the 1920s Manchuria supplied less than 0.5% of the total Japanese wood import) (Surin, 1930).

In the 1920s the Russian influence in Manchuria gradually weakened because of the civil war, political and economic instability. The growing Japanese impact resulted in military invasion of Manchuria and creation of completely controlled state of Manchoukuo in 1932. Japan notably enhanced economic development of Manchuria because considered it as platform for the further gains and expansion of the Japanese Empire (Anuchin, 1948).

Figure 2 shows the dynamics of logging volumes in Manchuria in the 1920-1930s according to the official Japanese statistics. Timber logging increased most intensively after formation of new state – more than in 4 times for 7 years. At the same period the role of North Manchuria in total wood production considerably extended – from 23% in 1932 to 66.5% in 1938 (Statistical Yearbook.., 1939; The Manchuokuo Year Book, 1942).

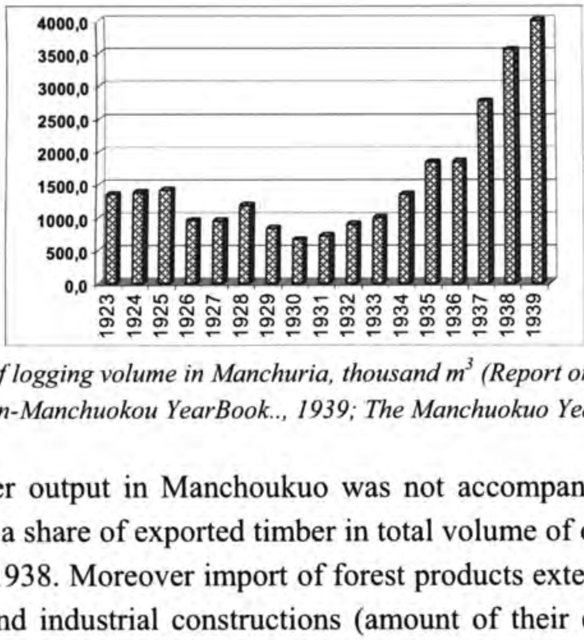

Fig. 2. Changes of logging volume in Manchuria, thousand m^3 *(Report on progress.., 1929; Japan-Manchuokou YearBook.., 1939; The Manchuokuo Year Book, 1942)*

Increase of timber output in Manchoukuo was not accompanied by growth of forest export. On the contrary a share of exported timber in total volume of output was reduced from 25% in 1932 to 3% in 1938. Moreover import of forest products extended (Fig. 3) because of development of civil and industrial constructions (amount of their contracts increased only between 1936 and 1938 more than in 2 times) and enlargement of paper-pulp industry (The Manchuokuo Year Book, 1942).

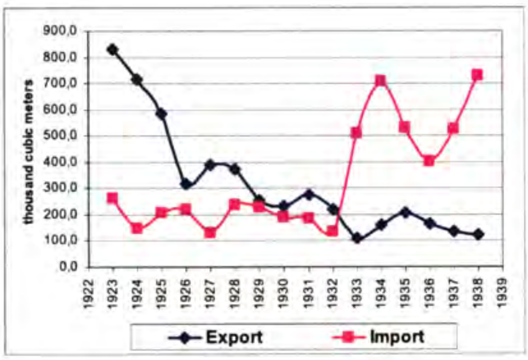

Fig. 3. Dynamic of forest import and export of Manchuria, thousand m^3 *(Report on progress.., 1929; Japan-Manchuokou YearBook.., 1939; The Manchuokuo Year Book, 1942)*

Information about economic situation in Manchuria in the 1940s is fragmentary and incomplete. But it is assumed that intensive forest cutting in the Chinese part of the Amur River Basin continued. Analyzing a history of reduction of China's forests, Yaoqi Zhang (2000) concluded that their most significant digressions occurred during wars and periods of political instability. It is possible to apply this thesis to Manchuria in the second half of the 1940s, because in the period from the ending of the World War II and Japan's leaving of the region to the foundation of the People's Republic of China in 1949 Manchuria went through multiple authority changes and military struggles. In such conditions utilization of forest probably was uncontrolled and oriented mostly to internal consumption. Some part of forest products could be transferred to the nearest areas of China or Korea.

Thus in the first half of the XXth century the development of forests in the Chinese part of the Amur River Basin was conducted under conditions of significant economic and political influence of Russia and Japan. However exploitation of forest resources in this period has been directed chiefly to satisfaction of internal regional needs in wood products. The domestic consumption of timber essentially exceeded volumes of forest export, and growth of wood consumption totally was determined by high rates of economic development of Manchurian region.

Utilization of forest resources of Northeast China in the first half of the XXth century led to notable reduction of forested areas. In Heilongjiang province it decreased almost by 50 % from 1900 to 1948 (Fig. 4).

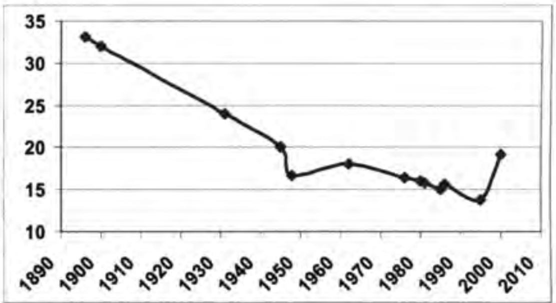

Fig. 4. Changes of forest area in Heilongjiang Province, million ha (Zhang, 2000; Ganzei, 2005)

After foundation of People's Republic of China and till present days Heilongjiang and Jilin Provinces, and Inner Mongolia Autonomous Region are the main suppliers and large consumers of wood in China. According to the data of the 1950s about 44% of forest area and around 40% of total wood stock of the country were concentrated on their territory (Natural resources.., 1975). Heilongjiang Province was the leader of output of timber industry production in the Northeastern China in the second half of the XXth century. Logging volume in Heilongjiang rapidly expanded to the beginning of the 1970s when annual output achieved 11-12 million m^3 according to data from one source (Dai, 2000, cited on Yamane, 2007, p. 114) and 15-16 million m^3 – on another data (Yamane, 2007, p. 122). In the 1990s timber harvesting decreased and at the end of the decade annual logging volume reached from 6 to 10 million m^3 on different estimations (Yamane, 2007, pp. 114, 122).

The forested area of Heilongjiang province during the examined period reduced not so quickly as in the first half of the century. In 1948-2000 forested area of province changed from 13.8 to 19.2 million ha (Fig.4) (Ganzei, 2005). The most shrinkage of the forests happened by 1995 and it was a critical point in the forest resources digression. In 1998 the government of the People's Republic of China accepted the law restricted logging of natural forests in the Northeastern China (Forest Sector.., 2005).

On the whole in the second half of the XXth century intensity of forest use in the Chinese part of Amur basin has essentially increased. Logging volumes only in Heilongjiang Province exceeded timber production of all Manchuria in 1939 in 2-4 times. Strengthening of timber harvesting in the Northeastern China coincided with realization of governmental programs of country's development – Great Leap Forward, Great Cultural revolution, economic reforms and policy of external openness in 1978, which sequentially changed each other. So development of forest resources in the region was defined by internal economic factors, policy of the national and regional development. As before, exploitation of forests of Northeastern China has been directed to satisfaction of regional and country's demands for wood. Absence of the data on commodity structure of China's export in the 1950-1980s does not allow to insist that China had no timber export in this period. But even if timber export existed it is supposed that its volume was much less than internal wood consumption. Rapid growth wood import to China since 1980s indirectly confirms it.

In 2006 volume of China's total forest product import was 141 million m^3 (round-wood equivalent). At the end of the 1990s import covered about 40 % of the country's wood consumption (Sun Syufa, 2000) while in 2005 about 75% of internal consumption of round wood has been supplied by imported forest products (Northway, Bull, 2007).

Traditionally Malaysia and Indonesia were the main suppliers of forest products to China. In the 1990s Russia also became one of the basic suppliers of wood production. In 2006 Russia provided a half of forest products imported by China, including about 70% of round wood. Russia is also one of the China's top five suppliers of lumber, pulp and paper (Northway, Bull, 2007). Among the Russian territories delivering forest products to China the Far Eastern region are playing very important role. And by the end of the 1990s - beginning of the 2000s China has turned into one of the "agents" of development of forests located in the Russian part of the Amur River basin.

2. FOREST DEVELOPMENT AND UTILIZATION IN THE RUSSIAN PART OF THE AMUR RIVER BASIN

A significant part of the Russian portion of the Amur basin spatially coincides with the most populated and economically advanced southern part of the Russian Far East region. Forests development of this territory started in the 1870s. Prior to the beginning of the 1920s forests exploitation was mostly oriented to the local consumers of wood as well as on the Manchurian territory. Growth of timber industry was determined by the general economic situation in the region. According to the estimations of A. Sheingauz (1973) total wood consumption in the southern part of the Far East (FE) was about 5.4 million m^3 in 1922 (Table

1). Population was the basic wood consumer during all shown period (1 million m^3 in 1882, 2.6 million – in 1899, 5.5 million in 1922) though a share of transport and industry's use of forest products gradually increased.

In 1928 logging volume in the FE reached 16.5 million m^3, and about 70% of timbers were harvested in the southern part of the region. One of the reasons of wood production growing in the 1920s was expansion of forest products exports (Fig. 5).

Table. 1. Dynamics of wood consumption on the Russian Far East, million m^3 (Sheingauz, 1973)

Administrative units	Years			
(borders of the 1970th)	1882	1899	1917	1922
Primorskii Krai	0.2	1.5	1.8	2.3
Khabarovskii Krai	0.5	0.9	1.5	1.1
Amurskaya Oblast	0.6	1.1	3.1	2.0
Far East Region	1.5	3.9	7.9	9.9

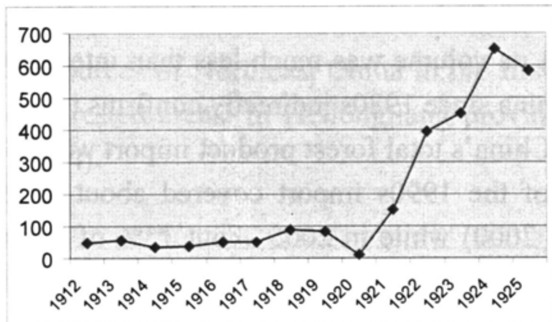

Fig. 5. Dynamic of forest products export from the Russian Far East till the middle of the 1920s, thousand m^3 (Krokos, 1926).

Efforts of wood exports from the FE region were undertaken from 1859 but only since 1907 it became regular (Sheingauz, 1973). Until the beginning of the World War I a share of the region in the Russia's forest export was less than 0.5%. In the middle of the 1920s it increased up to 15%. At the same time wood export composed about 40% of total value of the Far Eastern export (Krokos, 1926). However domestic consumption of forest products exceeded volumes of wood supplying to the foreign markets in several times.

The main recipients of the timber exported from the FE were Japan and China. Till the middle of the 1920s a share of the forest products annually exported to Japan fluctuated from 50 to 90%. As a whole the USSR supplied in the 1920s from 8 to 20 % of the wood import of Japan. Volumes of the forest products export to China from the FE sharply extended also in the first half of the 1920s. For the period from 1921 to 1924 a share of the USSR in China's wood import increased from 2% to 19.3% (Krokos, 1926; Surin, 1930).

Timber export from the FE consisted mainly of round wood. Cedar and aspen dominated in the species' structure of export. Fast growth of logging volumes at the end of the 1920s caused more intense deforestation in the (Sheingauz, 1973). However assessment of forested area's changes in the first half of the XXth century is a difficult task because of incompleteness of the necessary data. In 1923 forest lands of the Russian FE were estimated as 58.4 million ha, and to 1928 they were registered as 101.6 million ha (in Primorskii Krai – 10 million, in Khabarovskii krai - 44, and in the Amurskaya oblast – 33 million ha). This calculated and controlled area composed only 40% of really available forest resources. Full inspection and survey of the FE forests was finished only in 1957 (Sheingauz, 1973).

Volumes of forest products export remained at relatively high level till the middle of the 1930s. Then foreign trade of the Russian FE was rather rapidly reduced because of the political reasons, and in the time of the World War II it was stopped (Natural resource use.., 2005). Decrease of export occurred at the time of intensive industrial development of the Soviet Union and its Far Eastern region. Growing internal demand of lumber, firewood and building materials led to the increase of logging volumes to 31.8 million m^3 in 1940. Around 20.6 million m^3 of them have been harvested in the south of the FE region (Sheingauz, 1973).

In 1940-1947 output of wood production of the FE reduced because of the War. However in the 1950s growth of logging volumes began and continued until the middle of the 1980s. The most output of forest products in the south of the FE exceeded 25 million m^3. The decrease of production's volumes which has begun in the second half of the 1980s was accelerated by the economic crisis in the 1990s. Restoration of the logging volumes started after 1998. During almost all post-war period the crucial producers of timber in the FE were Khabarovskii and Primorskii krais, and Amurskaya oblast (Fig. 6). From the middle of the 1950s these 3 administrative units located mainly in the Amur basin supplied more than 70% of the regional timber output.

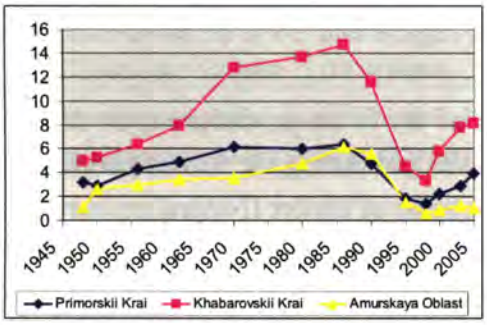

Fig. 6. Changes of logging volumes of 3 southern administrative units of the Russian Far East, million m^3 (Krechetov, Sheingauz, 1973; Industry of Khabarovskii krai, 2000; Forest complex.., 2005; Forest Complex.., 2006)

In the 1950s export of forest products from the Far East was renewed. For the period from 1954 to 1960 export of round wood increased from 2.5 thousand m^3 to 0.9 million m^3, and by 1970 volume of forest product export reached 7.0 million m^3 (Natural resource use.., 2005; Sheingauz, 2006). As a whole 20-25% of the regional output of wood production were supplied to foreign markets, and 10-15 % were taken out to other regions of the Soviet Union. In the 1980-1990s forest products were exported to 13 countries, but the principal consumers of timber were Japan (60-65%), Republic of Korea and China (Natural resource use.., 1997). Changes of volumes of forest products exported from the FE in the 1980-1990s followed by the dynamic of the regional timber output (Fig. 7). In 1995 total volume of export decreased to 4.3 million m^3 (Japan - 3 million m^3, Republic of Korea and China - 1 and 0.3 million m^3 respectively) (Sheingauz, 2006), then changes of export volumes became positive.

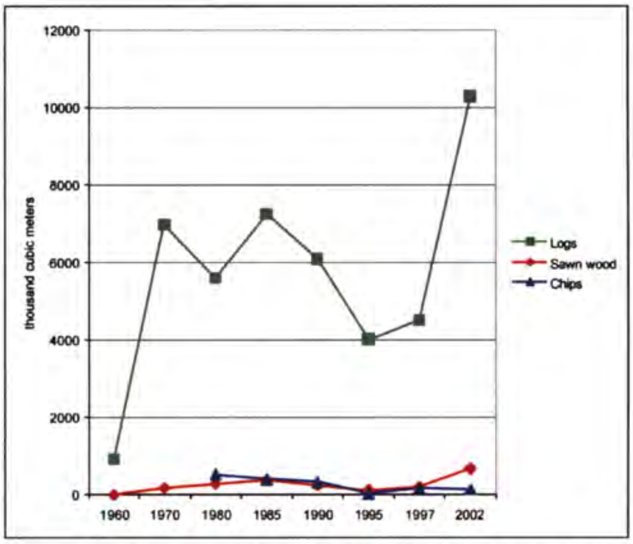

Fig. 7. Dynamic of forest products export from the Russian Far East (Sheingauz, 2004)

Generally speaking during the post-war period wood consumption inside the Far Eastern region exceeded forest products export. Situation changed in the beginning of the 1990s. As a result of the economic crisis in Russia, timber industry of the Far Eastern region was reoriented to foreign markets. At the same time regional demand for forest products notably reduced and became much less than volume of export. In 2003 about 85% of the round wood harvested in the region and 38% of sawn timber were exported from the FE (Forest Sector.., 2005).

Presently the basic part of the forest products export of the FE consists of unprocessed logs as well as in the 1920-1930s and during the Soviet period. In 2003 a share of this kind of timber was 96% of the total volume of export (Natural resource use.., 2005). So high share of round wood at the structure of timber harvesting is maintained through the exhaustive character of logging when only the best part of wood is transported from the cutting area while about 30-50% of an initial forest stock remains unused there (Forest Sector.., 2005). Negative ecological consequences of such destructive harvesting practice results in prompt expansion of the logged areas, rise of fire danger, degradation of the forest's age structure, reduction of the total wood stock and forest areas (oak, lime, pine, fir, ash forests), etc. Many researches studied development of the Far Eastern timber industry and its influence on the forest health noted that intensification of round wood export amplify some forest use problems and negative consequences of forest exploitation (Krokos, 1926; Surin, 1930; Sheingauz, 1973; Natural resource use.., 1997; Forest Sector.., 2005; etc.).

Spatially consequences of unsustainable forest land use are concentrated in a great measure in the south of the Russian Far East because located here administrative unites are supplying the significant part of the regional timber output and forest products export (95% of export in 2003). As result transformation of forest cover in 2003 was estimated at 39.8 % in Khabarovskii Krai, 42.8 % in Primorskii Krai, 59.7 % in Jewish Aautonomous Oblast, 46.1 % in Amurskaya oblast (Forest Sector.., 2005). Despite of significant transformation of forests they are still keep natural character and have potential for timber industry development (Natural resource use.., 1997).

Today the largest importers of the Far Eastern forest products are China, Japan and Republic of Korea (Fig. 8). Japan was a leader on wood export from the FE for many years up to 2001. Since 2001 the top position was occupied by China. Fast growth of export to China (in 9.3 times for 1998-2003) was greatly caused by restriction of natural forest harvesting at the end of the 1998s. In 2003 the Russian FE (or actually its 3 southern administrative units) supplied more than 40% of total Russia's forest products export to China (in value), and almost all export of deciduous timber (Natural resource use.., 2005). In 2003 Japan imported from Russia 5.3 million m^3 of round wood (35% of total country's round wood import). The share of the FE region in the total value of the Russian forest products export to Japan in 2000-2003 was about 50% (Preliminary.., 2004; Forest Sector.., 2005; Customs statistics.., 2005).

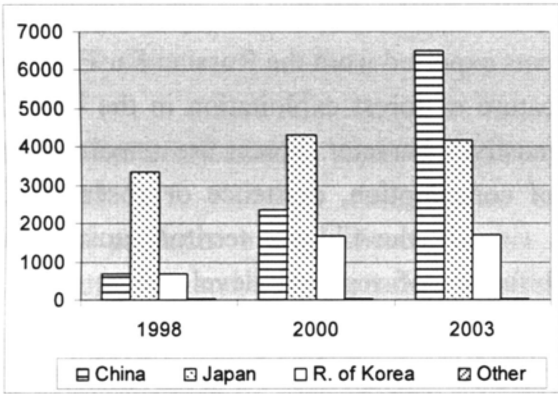

Fig. 8. Dynamic of the Far Eastern forest products imported by main countries-demanders, million m^3 (round wood equivalents) (Forest complex.., 2005)

In general present day development of timber industry and intensity of forest land use in the Russian part of the Amur River basin is considerably determined by export of forest products to China and Japan. According to the experts' forecasts demand for forests from the Russian Far East in the nearest decades will grow. However modern tendencies of forest exploitation in the region endanger the forest ecosystems health and possibility of their sustainable use in 20-30 years.

3. CONCLUSION

Analysis of the data characterized participation and interaction of the countries of Amur-Okhotsk region in the development and utilization of the Amur basin's forests allows to draw the following conclusions.

Dynamics of forest exploitation in the Russian part of the Amur basin in the 1920-1930s and from the middle of the 1950s till the present days was notably determined by external influence of the foreign markets, first of all Japan's and China's, acted to the economic activities of timber industry enterprises of the Far Eastern region. External influence on the forest development in the Northern Manchuria in the first half of the XXth century had other character. It was caused by deep penetration of Russia and Japan into politics and economy of the region.

The Russian Far East, Northeastern China and Japan being ecologically interdependent within the Amur and Okhotsk Sea basins during the XXth century have been rather closely connected by the trade of forest products. The most stable external participant of forest development and timber consumption of Amur basin's forests is Japan. It influenced on forest development in Manchuria, imported wood from the Russian part of the basin during almost 100 last years (excepting trade interruption in the 1940s – middle of the 1950s), and last decades Japan is one of the world's largest consumers of the Chinese wood goods.

Exploitation of forests in the China's part of the basin during the XXth century including the period of Russia's and Japan's influence were determined by internal wood consumption – regional and/or national. In the Russian part of the Amur Basin share of the exported forest products at the total output of their production was rather big even during the periods with high level of domestic wood consumption. Round wood always formed the main part of the forest products exported from the Russian Far East.

The common feature of forest exploitation in the both Chinese and Russian parts of Amur basin is its exhaustive character. Forest use remained unsustainable independently of dominated direction of consumption, existence or absence of external influence, political regime in the county. On the Chinese territory unsustainable forest use partly can be justified by historical factors of regional development (high population density, specific character of colonization, etc.) while on the Russian one main reasons are the state (governmental) policy of the resources development and internal economic factors.

Today ecological value of forests of the Russian part of the Amur basin grows as well as their resource meaning. In the conditions of ecological and economic interdependence Japan and China also should be interested in sustainable forest use in the Russian Far East. Their feasible participation in solution of such crucial problems of the Far Eastern forestry as illegal forest export and development of wood processing can be notable contribute to the forming of sustainable forests use in the Amur River Basin.

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IRON FLUX OVER THE SUBARCTIC PACIFIC ESTIMATED BY AN ICE-CORE RECORD FROM MT. WRANGELL, ALASKA

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INTRODUCTION

Iron is an essential nutrient for phytoplankton and plays an important role in the control of phytoplankton growth (Martin et al., 1989). Iron enrichment experiments carried out in the western and the eastern subarctic Pacific reveal that the iron limits phytoplankton growth in these areas (e.g. Tsuda et al., 2003). Possible sources of iron dissolved in surface seawater in the Sea of Okhotsk or Oyashio regions in the western subarctic Pacific are thought to be the iron-rich intermediate waters transported to surface by upwelling (e.g. Nishioka et al, 2007) and atmospheric dust (e.g. Duce and Tindale, 1991), that are lifted by dust storms generated over the Asian continent.

In order to estimate the contribution of atmospheric dust to phytoplankton groth, it is neccesary to quantitate the flux of air borne iron over the ocean. Several studies succeed at simulation of the transport process of chemical species in the atmosphere (e.g. Uno et al, 2001; Takemura et al., 2002), and at estimation of the deposition flux of chemical substances from the atmosphere (Uematsu et al., 2003) at the eastern Asia region. However, Uno et al.(2003) shows the case that simulate value of dust concentration differ by more than one order from the observation value of that in at the remote islands in Japan, and states the difficulty of quantitative prediction of dust because of complexities in accurate calculation of dust emissions. It is need to validate the output of model studies with observation data of aerosol concentrations and/or deposition fluxes. However, sufficient data on aerosol concentration and deposition have not been collected especially on the North Pacific.

Ice-core is one of suitable archives to extract deposition of chemical substances from atmosphere. Glaciers developing in the high mountains of Kamchatka and Alaska record continuous time-series of dry and wet deposition of aerosol over a few hundreds years (Shiraiwa and Yamaguchi, 2002; Shiraiwa et al., 2003). Those glacier are cold enough to prevent vertical migration of the deposited substances by melt water. Moreover, annual accumulation rate in high mountain is significantly higher than that in polar region. Therefore, the high resolution records of iron deposition can be reconstructed from these ice-cores with year to year resolution.

In this study, we reconstruct the flux of air borne iron by means of analyses of an ice-core obtained from Mount Wrangell in Alaska (Shiraiwa et al., 2004). Continuous iron profiles of ice-cores have hardly been reported apart from an ice-core from Law Dome in Antarctica by Edwads et al. (2006) because of difficulties of measurement owing to low content of iron in ice-cores and high risk of contamination. This study reports the first iron profile in an ice-core obtained from the northern North Pacific region.

SITE AND SAMPLE

Mount Wrangell (62°N, 144W, 4317m a.s.l.) is located in the lee area along pathway of atmospheric dust from Asian continent to the North America (Figure 1), and is a glacier-mantled shield volcano (Benson and Motyka, 1978). The summit caldera is crowned by a 4 x 6 km oblong, 1 km deep glacier. A 50.29-m long ice-core was drilled by an electric mechanical drill on the summit of Mount Wrangell in 2003 (Shiraiwa at al., 2004). The ice-cores had been transported to the Institute of Low Temperature Science, Hokkaido University by a freezer cargo and have been analyzed on stable isotope of water molecule, tritium content, insoluble particle (Yasunari et al, 2007), visible stratigraphy, detailed density (Kanamori, 2007), and dissolved ion species. Water equivalent depth (m w.eq.) of ice core was determined by the detailed density profiles (Kanamori, 2007). Age of ice-cores was estimated by the seasonal variation of hydrogen isotope ratio of water molecule and tritium content, and visible volcanic ash layer emitted from Mount Spurr eruption in 1992 observed in 26.82m w.eq. (Yasunari et al., 2007). The bottom of the ice-core at 50.29-m deep corresponds to 29.0m w.eq. and 1991 A.D. Since the average of annual accumulation was 2.4-2.6m w.eq., behavior of iron flux can be extracted with high time resolution.

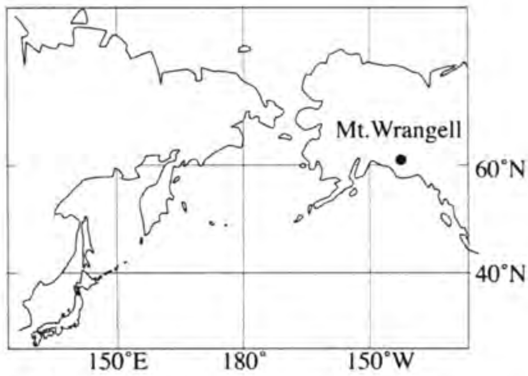

Figure 1. Location map of Mount Wrangell

EXPERIMENTAL

We used upper 30m of ice-core for analysis of iron concentration, which covers from 2003 to 1997. The ice-cores have been cut and divided into several parts along vertical axis with a band saw for each analyses described as above. For iron determination, a quarter part of ice-cores were used. The ice-cores were cut horizontally into approximately 0.25-m long sections. The outer of ice-cores are awfully contaminated with iron by drilling instrument made of metal during ice-core drilling and by blade of band saws during processing described as above. Therefore, we carried out decontamination procedure with extreme caution. After 20-mm thickness of surface of ice sample was shaved with a ceramic knife in a clean bench settled in a cold clean room (class 10,000, -20°C), the ice samples were melted in 500-mL Teflon containers in ambient temperature. Melted samples were decant to 15-mL polypropylene bottles and were acidified with nitric acid of ultra pure glade (Kanto Kagaku) to 1% immediately after melting to prevent hardly soluble elements from being deposited and adsorbing on the wall of bottles. The samples were stored for several weeks before analysis because hardly soluble elements including iron are dissolved gradually into nitric acid solution. It takes a few weeks until concentrations of these elements become stable. All materials used for sample preparation process and sample storage were cleaned in a 4M nitric acid bath for 24 hours.

Concentration of iron in the sample was determined by a graphite furnace polarized Zeeman type Atomic Absorption spectrophotometer (Hitachi model Z-2700) with pyro-coated cuvett and standard analysis condition.

RESULT AND DISCUSSION

A concentration profile of iron in the ice-core is shown in Figure 2 with that of δD profile. The iron concentrations showed relative high value in the layers above winter layers identified by minimum of δD in each year. The profile of δD shows seasonal variation with minimum in winter and maximum in summer. Therefore, the iron concentrations in the ice-core increase in ice/snow layers corresponding to spring in each year when the frequency of Kosa (Yellow dust) phenomena observed in Japan increases. Three peaks of iron concentration over 500nM, appeared in 2002 and 2001, when significant Kosa phenomena were observed in Japan (Nishikawa et al., 2003). Therefore, the profile of iron concentration in the ice-core seems to reflect the variations of activity of dust storm in Asian continent.

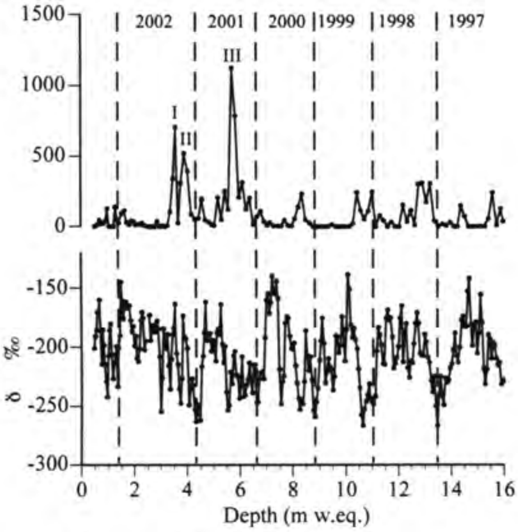

Figure 2. Profiles of iron concentration and δD of ice-core obtained from Mount Wrangell. Dashed lines indicate minimum of δD corresponding to the winter layer.

Deposition flux of iron over snow surface at the summit of Mount Wrangell is given by multiplying the concentration of iron by relevant water equivalent depth. The profile of annual and springtime fluxes of iron are shown in Figure 3a and b. Annual flux of iron ranged from 3.0 to 29 $mg/m^2 \cdot yr$. The values of iron flux are comparable to that estimated by Duce and Tindale, 1991. The iron fluxes in springtime ranged from 2.5 to 21 $mg/m^2 \cdot yr$, and made up 55-95% of annual fluxes. Annual variation of number of Kosa days and total number of Kosa days reported by Japan Meteorological Agency (Nishikawa and Mori, 2003) are similar to the variations of iron fluxes except for the datum in 2000. Consequently, it is reasonable to suppose that the iron flux on the snow surface at the summit of Mount Wrangell reflects the dust emission in Asian continent.

The iron fluxes at three peaks observed in 2002 and 2001 layers marked by "I", "II", and "III" in Figure 2 were 9.53, 6.43, and 15.0 mg/m^2, respectively. Each value is thought to be the iron flux supplied by one dust event. Generally, 2-10% of air borne iron can be dissolved in seawater (e.g. Fung et al, 2000). When 2% of the average flux of three events of $10 mg/m^2$ is dissolved in the 30-m deep mixing layer in seawater, the concentration of dissolved air borne iron in seawater becomes 0.12nM. This increase of dissolved iron supplied by one dust event can impact on the concentration of dissolved iron in surface seawater in the Sea of Okhotsk of sub nM order (Nishioka et al., 2007).

Iron fluxes estimated by ice-core records do not correlate directly with deposition fluxes over subarctic North Pacific as well as dust emission fluxes in Asian continent. The chemical signals in ice-cores are formed via several processes such as emission, transportation, scavenging, and deposition. However, there are still large uncertainties in estimates of these processes. It is also need to evaluate the representativeness of ice-core records. A ice-core reserve record of depositional substances at only a certain point. Additionally, drilling site of ice-cores in mid latitude as Alaska or Kamchatka is high mountain area far from sea surface. In order to precisely estimate the flux of chemical substances over subarctic Pacific with ice-core records, spatial distribution and vertical structure of Asian dust should be taken into consideration. Namely, ice core studies should be combined with simulative studies of chemical transport models in the new phase.

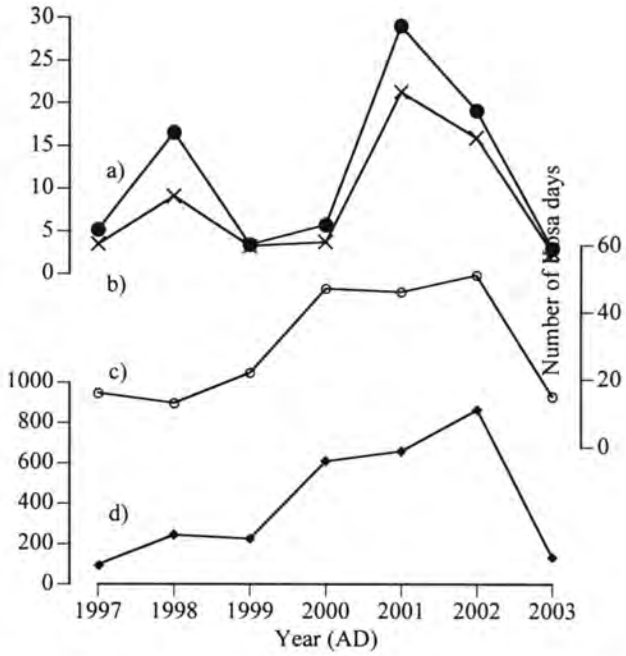

Figure 3. Annual variation of flux of iron (a), springtime flux of iron (b), the number of Kosa phenomena days (c), the total number of Kosa phenomena days in all meteorological station

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WIND- AND BUOYANCY-DRIVEN INTERMEDIATE LAYER CIRCULATION IN THE SEA OF OKHOTSK

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1.INTRODUCTION

The densest water forming in the North Pacific region originates in the northwestern shelf of the Sea of Okhotsk (SO). This water is called the Dense Shelf Water (DSW), produced when cold and salty brine is rejected as sea ice forms (Shcherbina et al., 2004). DSW can be heaved up to about 27.0 σ_θ, so that it is heavy enough to be ventilated below the pycnocline as it flows out from the shelf. Then, DSW is transported along the Sakhalin coast through the intermediate layer of a depth of about 200m to 400m. When it reaches straits along the Kuril Islands in the southern SO, it experiences strong tidal mixing, forming a low potential volticity (PV) water, and is exported out further to the Pacific Ocean; it finally becomes a source of the North Pacific Intermediate Water (Yasuda, 1997).

The ventilation of DSW, the intermediate circulation, and the tidal mixing along the Kuril Islands are also likely to compose a meridional overturning circulation in SO. Recently, Nakamura et al. (2006) focused on effects of the tidal mixing on the SO overturning circulation. In a series of numerical experiments they found that high salinity water entrained from the intermediate layer to the surface layer by the tidal mixing is essential to close the overturning circulation. That is, the entrained saline water is advected northward by the surface circulation in SO and pre-conditions the wintertime DSW formation over the northern shelf. Contrarily, DSW would not be produced if the tidal mixing were absent so that no saline water were entrained in the surface layer.

DSW carries vast materials entraining bottom sediments on the shelf including iron (Nakatsuka et al., 2002; Nakatsuka et al., 2004). Therefore, it is important to simulate DSW and its variability in order to elucidate the 'intermediate layer iron hypothesis' how iron concentration in the surface layer of the western North Pacific Ocean and SO is determined and how it impacts on bio-productivity. Although the effects of the tidal mixing along the Kuril Islands have been understood well, it is not yet clear how various other effects, such as wind, ice formation and fresh water flux interplay and impact on the generation and variability of the overturning circulation. In this report, we will describe numerical simulation of the overturning circulation and its sensitivity by varying these effects.

2. MODEL

We used an ice-ocean coupled model based on an OGCM developed at the Center for Climate System Research (Hasumi, 2000). This is a z-coordinate, primitive-equation OGCM coupled with a 2-categoly elastic-viscous-plastic ice model. Fig. 1 shows the model domain, which spans between 136-166E and 39-65N. Bottom topography is characterized by a shallow northern shelf, a central basin of about 1000m deep, and a deep Kuril basin of a depth of about 3000m, which is connected to the Pacific Ocean through straits along the Kuril Islands. Horizontal grid spacing is 0.5 degree, while 42 levels in vertical. The model is first spun up with the monthly-mean climatological ECMWF wind stress, heat flux and fresh water flux for 20 years, and is then run further for 20 years with various experimental settings. Freshwater from the Amur River is also included, whose flux is 1.5times10^3 m^3/s for April to November and 0 for December to March next year. It should be noted that no restoration was made on the sea surface temperature (SST) and sea surface salinity (SSS) in SO. We put sponge layers for the eastern and southern boundaries of the model domain. The 40th year results of each case were analyzed.

Fig. 1 Model domain and bottom topography

One of driving forces of the overturning circulation is vertical diffusion of heat and salt due to tidal mixing along the Kuril Islands (Nakamura et al., 2006). In order to represent this mixing, we added an enhanced mixing term Kz^* to the vertical mixing coefficient as an ad hoc parameterization (e.g. Nakamura et al., 2006). We used Kz^*=200 cm^2/s for a control run because it represents reasonable intermediate layer structures as described in the following sections.

3. OVERVIEW OF MODEL PHENOMENOLOGY

Sea ice distribution is displayed in Fig. 2. The model represents real sea ice features quite well; sea ice tends to cover the entire western basin in March, while there is a relatively large open ocean area in the eastern basin. There are places where ice concentration is smaller than the maximum value of 0.97 along the northern coast in the model, which may be considered as coastal polynyas in this model. Accordingly, salinity flux is large in the northern shelf, which is more than a half of the total production of sea ice in SO.

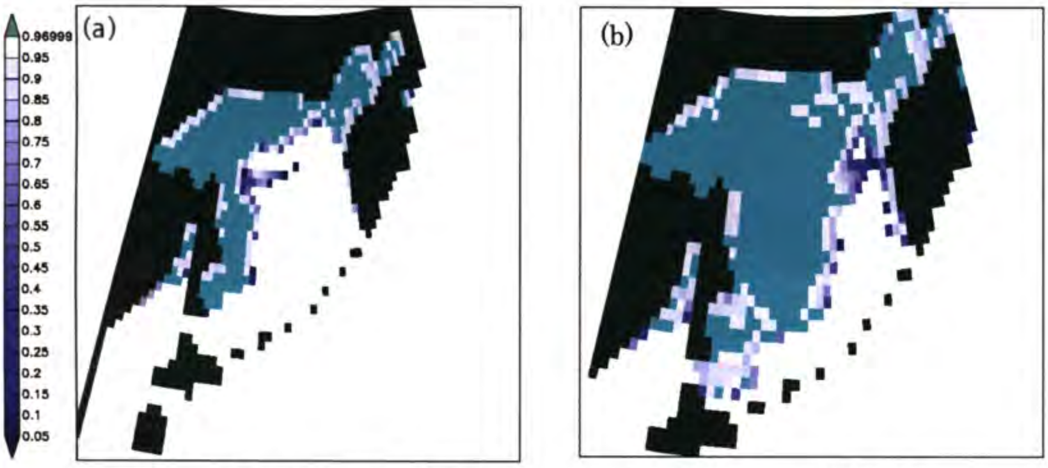

Fig. 2 Simulated sea ice concentration: (a) January, (b) March

An anti-clockwise circulation is generated in the northern and central basin. This is a wind-driven circulation as discussed by Ohshima et al. (2004). The anti-clockwise circulation is stronger in wintertime because of the larger cyclonic wind stress, although its transport is rather small, about 3 Sv. In the southern Kuril basin, a clockwise circulation is generated, which is stronger in summer. The transport is as much as 3 Sv, comparable to that of the northern anti-clockwise circulation. Further, a throughflow of the Soya Strait between the Sakhalin and Hokkaido from the Sea of Japan (the Soya warm current) is linked to the clockwise circulation in summer. This circulation is caused by the enhanced mixing along the Kuril Island.

Fig. 3 displays the potential temperature along the 26.9 sigma theta isopycnal surface in March. This density layer outcrops to the surface over the northern shelf since water denser than 26.9 σ_θ is produced at surface by high salinity flux due to brine rejection. Coldest water below -1.0 degree is found around there. This water is considered as DSW production in this model. DSW dives as deep as 200m along the east coast of Sakhalin as it flows to the south. These features of DSW are consistent with those in Itoh et al. (2003), although it is seen in a somewhat shallower depth than reality.

On the other hand, warm water is present in the southeastern region of SO. This water originates from the western Pacific Ocean through the Kuril straits, being modified by tidal mixing. Its potential temperature is about 2 degree; this is a little warmer than that in Itoh et al. (2003). This water is advected to the north along the eastern shelf by the wind-driven current. A part of the flow bifurcates to the northwest direction around 52 N, following the bottom topographic contours (see Fig. 1). Further, there is warm and deep circulation (> 400 m) in the southern Kuril basin. This is associated with the clockwise circulation caused by the localized tidal mixing along the Kuril Islands. The feature is also consistent with that in Itoh et al. (2003).

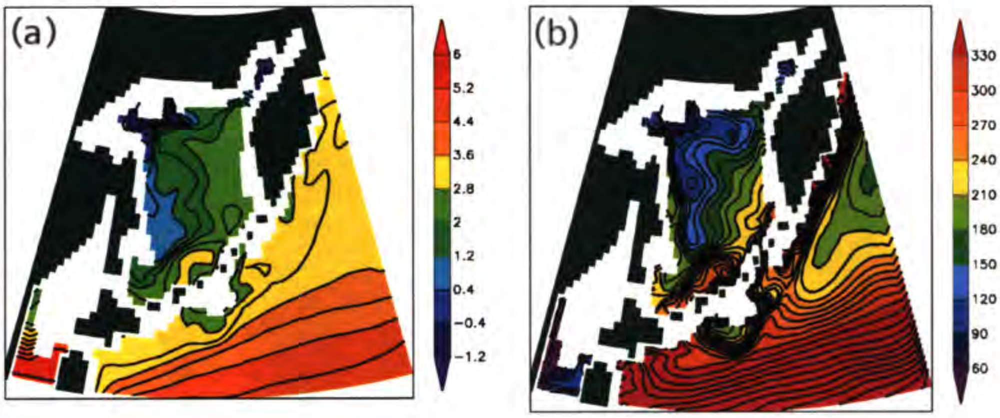

Fig. 3 (a) Potential temperature distribution on 26.9 σ_θ, (b) Depth of the26.9 σ_θ layer.

Since the intermediate layer potential temperature is quite realistic, this case may be considered as a control case in the following experiments. To our knowledge, this is the first simulation of the SO intermediate layer that is comparable to observations.

4. NUMERICAL EXPERIMENTS

4.1. Effects of tidal mixing along the Kuril Islands

This is a similar experiment to those by Nakamura et al. (2006). Four cases were done, besides the control case, with varying the enhanced tidal mixing along the Kuril Islands, where Kz^*=0, 100, 500, 1000 m^2s^{-1}; they are referred to as the Tide0, Tide100, Tide500, and Tide1000 cases, respectively. Fig. 4 shows the intermediate-layer potential temperature in September of the five cases including the control case. The potential temperature becomes low as Kz^* increases, consistent with the results by Nakamura et al. (2006). Impacts are particularly evident on the western boundary current off the coast of Sakhalin.

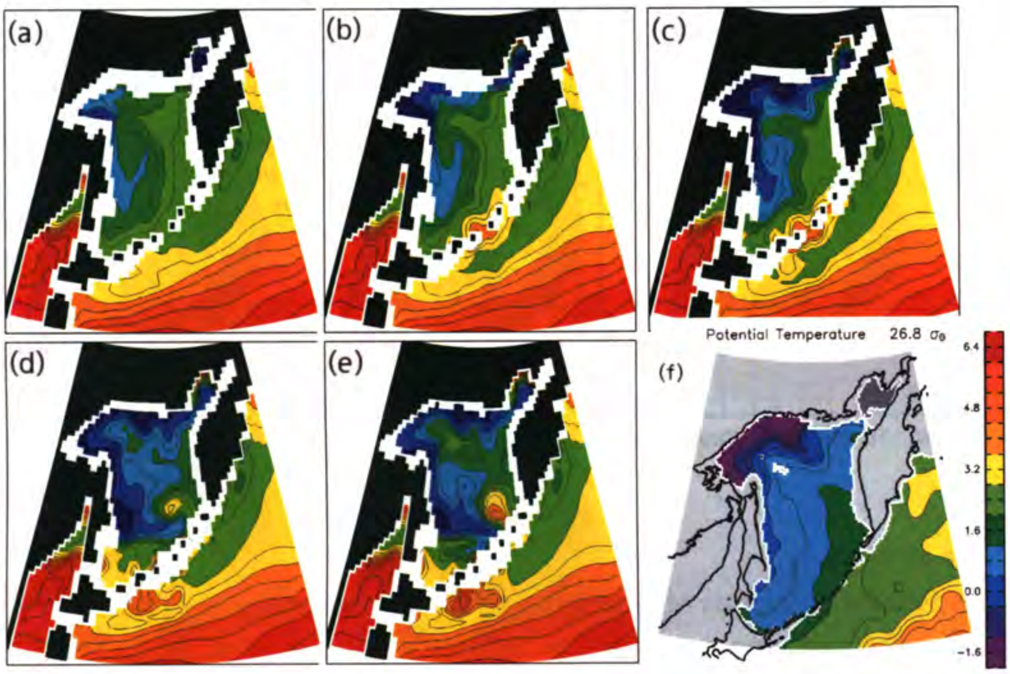

Fig. 4 Potemtial temperature on the 26.8 $\sigma\theta$level. (a) Tide0 case, (b) Tide100 case, (c) Control case, (d) Tide500 case, (e) Tide1000 case. Observed data by Itoh et al. (2002) is also displayed in (f).

Sea Surface Salinity (SSS) distribution indicates that SSS along the Kuril Islands increases as *Kz** increases. This occurs because a larger amount of deep (hence saline) water upwells there with a larger mixing region. The water in the eastern basin becomes more saline with the *Kz** increase, because the water originates around the Kuril Island is transported northward via surface anti-clockwise circulation. Consequently, the stronger mixing is a cause of saltier water over the northern shelf, resulting in producing heavier DSW. Fig. 5 summarizes relationship between SSS in SO and DSW flux across the 52N section, where DSW here is defined by potential temperature $\theta < -1$ and density rho > 26.6 sigma theta. Clearly, DSW flux increases as SSS, or the mixing along the islands, increases. On the other hand, the ice production does not change significantly among the cases. These results support the conclusion of Nakamura et al. (2006), i.e., the DSW production may increase regardless of ice formation as far as surface salinity increases due to tidal mixing.

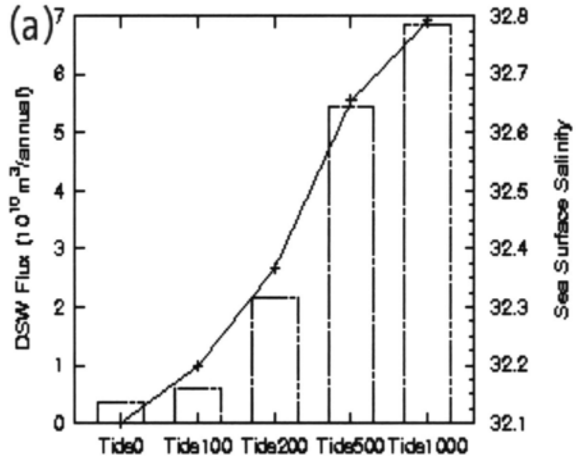

Fig. 5 Solid line with crosses denotes annual mean SSS averaged over the Sea of Okhotsk with various tidal mixing. Histogram denotes the annual DSW flux on the cross section of 53N. Tide200 here corresponds to the control case.

4.2. Effects of winds

It was found that impacts of wind strength on the overturning circulation are significant. Experiments of 4 cases are examined by multiplying factors of 0, 0.5, 1.5 and 2.0 to the control wind stress. These cases are referred to as the Wind0, Wind0.5, Wind1.5 and Wind2.0 cases, respectively. Note that the wind speed to calculate bulk flux formulae is unchanged, so that heat flux is not affected by the changes in wind.

Fig. 6 shows potential temperature distribution in an intermediate layer (26.8 sigma theta). Clearly, potential temperature decreases substantially as wind stress increases. Since the surface circulation is strengthened as wind increases, larger salt flux is transported from the south, leading to higher SSS over the northern shelf for a stronger wind. In Fig. 7, the surface salinity and DSW flux of the various wind cases, together with the Tide1000 case, are displayed. Even though the averaged surface salinity in the Tide1000 case is nearly the same as that in the Wind2.0 case, the DSW flux is much larger in the latter. This indicates that not only the SSS but also the wind-driven circulation itself is important for the DSW flux increase.

We may understand this process in a similar manner to subduction of mixed layer water into thermocline layer, although the flow here is controlled by bottom topography. If a flow passes a polynya where outcropping of a certain density occurs, the water is heaved to be DSW by salt flux due to brine rejection. DSW then subducts below the mixed layer into the intermediate layer, being controlled by topography. DSW finally joins the East Sakhlin Current. Since salinity is continually supplied from the south, SSS is kept high in the shelf region even when the DSW outflow is large. Therefore, salt flux from the shelf is controlled by the flow strength. In conclusion, the DSW flux becomes larger as the circulation becomes stronger, which cools the intermediate layer efficiently with increasing the wind factor.

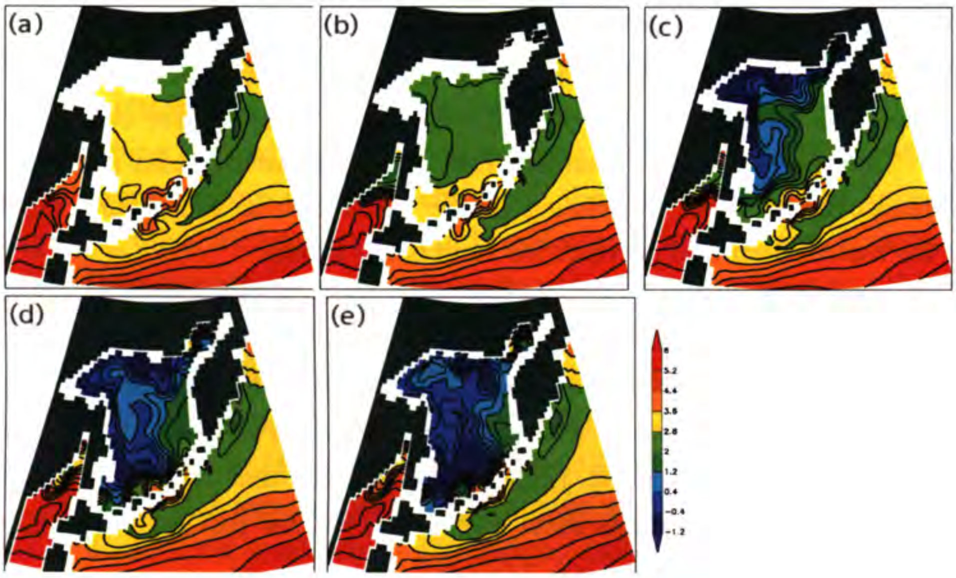

Fig. 6 Intermediate-layer potential temperature with various wind factors. (a) Wind0 case, (b) wind0.5 case, (c) control case, (d) wind1.5, (e)Wind 2.0 case, respectively.

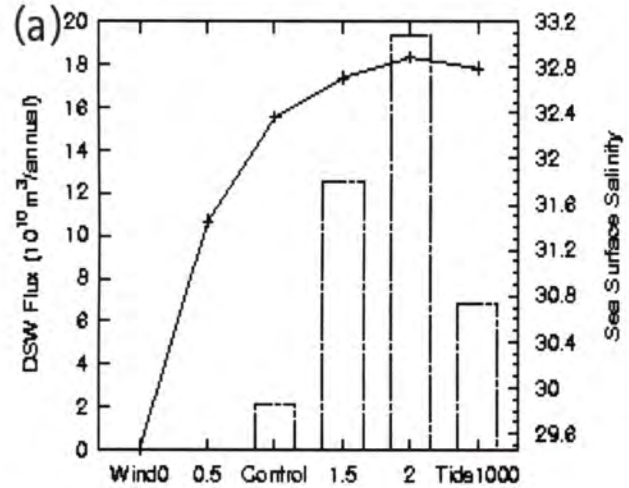

Fig. 7 Same as Fig. 5 except for various wind-factor cases. The Tide1000 case is also displayed.

4.3. Effects of air-temperature increase

In this section, effects of air temperature variations are examined by adding constant air temperature, delta Ta, to the whole region. We made 3 cases of experiments with delta Ta =-3, +3, and +10℃, referred to as the Ta-3, Ta+3, and Ta+10 cases, respectively.

Sea ice coverage is reduced greatly as the air-temperature increases. The Ta-3 case, sea ice covers whole OS region. On the other hand, there are almost free of sea ice with the Ta+10 case. The open water is expanded from the southeastern basin as air-temperature increases, because warm water originating in the North Pacific and around the islands is advected in the eastern basin and prevents SO from being frozen.

The decrease in the ice production causes decrease in DSW formation greatly. This prevents surface water from subducting to the depth of $26.8\sigma_\theta$ layer, causing the potential temperature increase. In the present study, the intermediate layer temperature rise is as much as +0.6℃ for the Ta+3 case. This is a reasonable rate of rise compared with the results of observed data by Nakanowatari et al. (2007), who showed that temperature trend in the intermediate layer of 26.8-27.0 sigma theta level is +0.6℃ for the last 50 years, when the air-temperature trend along the SO coast is 2.0±1.2℃.

4.4. Impact of the Amur River

DSW may be affected by vast amount of freshwater runoff from the Amur River, because its mouse is located at the northwestern shelf where DSW formation occurs. Surface salinity at the river mouse is less than 30 psu. After the riverine water is exported, it then flows along the eastern coast of Sakhalin toward Hokkaido coast (e.g. Itoh et al., 2003; Uchimoto et al., 2007).

We conducted an experiment in which the Amur River runoff is removed; this is referred to as the Amur0 case. Salinity increases by about 1.0 psu along the Sakhalin coast in March when the river runoff is absent. In summer when the river runoff is included, the difference becomes about 6 psu near the mouse of the river. Salinity in the southern basin also increases by 0.4 psu for the Amur0 case. It is interesting to see, however, that sea ice formation is not affected greatly by the presence or absence of the river runoff. Sea ice can form in the open ocean because the pycnocline between the surface mixed layer and the intermediate layer is strong enough to prevent the surface water from deep convection. Further, over the northern shelf region, sea ice can be produced regardless of salinity because of its shallow depth of the ocean.

Potential temperature in the intermediate layer decreases substantially (about 0.5℃) when the river runoff is switched off. It is found that the DSW is produced along the Sakhalin coast in the Amur0 case, in addition to the DSW production over the northern shelf. This provides the intermediate layer with additional cold water flux. In other words, because of the presence of the Amur River in reality, DSW formation along the Sakhalin coast is limited, and the water is not influential to the intermediate-layer properties even though polynyas can form there.

5. SUMMARY AND DISCUSSION

In this paper we described results of numerical experiments on the overturning circulation in the Sea of Okhotsk (SO), including dense shelf water (DSW) formation and intermediate layer circulation. The numerical results exhibited realistic structures of the circulation. Results may be summarized as follows:

1. The overturning circulation is composed of the ventilation of DSW over the northern shelf, the southward western boundary current in the intermediate-layer, upwelling due to tidal mixing along the Kuril Islands, and northward wind-driven surface current in the eastern basin of SO. These are consistent with those discussed by Nakamura et al. (2006).

2. The DSW flux (defined by $\theta < -1$, $\sigma_\theta > 26.6$) into the intermediate layer, and consequently potential temperature on the layer, is affected strongly by variations in the tidal mixing strength, wind-forcing strength, air-temperature rise and freshwater flux from the Amur River. The experimental results by changing tidal mixing strength support those of Nakamura et al. (2006), i.e., the DSW flux increases as the tidal mixing is strengthened.

3. Intensification of the wind-driven circulation contributes to the DSW flux increase in two ways. One is to give larger salt flux from the Kuril Islands to the northern shelf region via the northward surface current. SSS over the northern shelf increases as wind forcing increases, causing heavier DSW production. The other is to increase export of DSW, or subduction, from the shelf region into the intermediate layer. This makes the potential temperature decrease on the intermediate layer when the wind becomes strong.

4. Atmospheric warming results in intermediate layer warming through decrease in the DSW flux. The intermediate layer warming of +0.6°C responding to air-temperature increase of +3°C is a reasonable range compared with those in reality (Nakanowatari et al., 2007).

5. If the fresh water flux from the Amur River is turned off, DSW production along the Sakhalin coast increases greatly.

This is a first simulation that may be comparable to observations of thermohaline structures in the SO intermediate layer. SSS is, however, somewhat large. This gives a large outcropping area of the intermediate density (26.8 $\sigma\theta$, say), implying that larger amount of the intermediate water may be produced. Parameterization of polynyas is one of future subjects.

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LONG-TERM TREND OF DISSOLVED IRON CONCENTRATION AND HYDROLOGICAL MODEL INCORPORATING DISSOLVED IRON PRODUCTION MECHANISM OF THE AMUR RIVER BASIN

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1. INTRODUCTION

The Amur River is one of the largest trans-boundary river which runs through the boundary between China and Russia. The catchment area of the river is 2,050,057km^2 which is the nineth largest river in the world and the total length of the river is 4,350km. Thus, huge amount of fresh water is supplied by the Amur river to the Sea of Okhotsk (Ducklow et al., 2003). The Sea of Okhotsk is one of the most biologically productive regions in the world, and it supports high fisheries production. Recent studies show that dissolved iron plays an important role to maintain the biological productivity of the Sea of Okhotsk, and we suppose that one of the possible sources of dissolved iron is fresh water from the Amur river. Iron is an essential nutrient not only for the biological productivity of the Sea of Okhotsk but also for most biota. However, it is not well understood that how dissolved iron is produced and transported through the terrestial ecosystem.

This report consists of two parts. The first part is discussing about the characteristics of seasonal and inter-annual fluctuation of dissolved iron concentration in the Amur River basin. The second part is explaining about the structure of hydrological model which incorporates dissolved iron production mechanism. In addition, some simulated results are also shown. Last, perspective for future researches will be discussed.

2. TEMPORAL AND SPATIAL FLUCTUATION OF DISSOLVED IRON CONCENTRATION

Figure 1 is the long term dissolved iron concentration at Khabarovsk and Blagoveschensk. Sampling interval is not regular, but about 5 to 10 samples were collected in a year. The outstanding characteristics of fluctuating dissolved iron concentration is sharp increase during the period between 1996 and 1998 at Khabarovsk. Not the same acute increase during the same period was observed at Blagoveschensk, but relatively large increase tendency was also observed. Though the cause of this abrupt increase is not yet clarified, some possible reasons of increase will be discussed later. Another interesting aspect of change of dissolved iron concentration is that 10 to 15 years oscillation seems to exist. The first peak seems to occur during the early 1980s', and second peak is during late 1990s'.

Figure2 shows the monthly average during the period of 1960 to 1989 and the period of 1960 to 2006 at Khabarovsk and Blagoveschensk. The general characteristic of seasonal change is that highest concentration is recorded during the summer and early autumn season

(July to October). In addition, relatively high concentration is also observed during the winter season and spring season, especially in March and April. This tendency can be seen much clearer at the Blagoveschensk. And the same tendency can also be seen in the observed data in the Sanjiang plain (Yan et al. 2007). The mechanism of spring season increase of iron concentration is not yet clarified. One hypothesis is that biological process which is related to

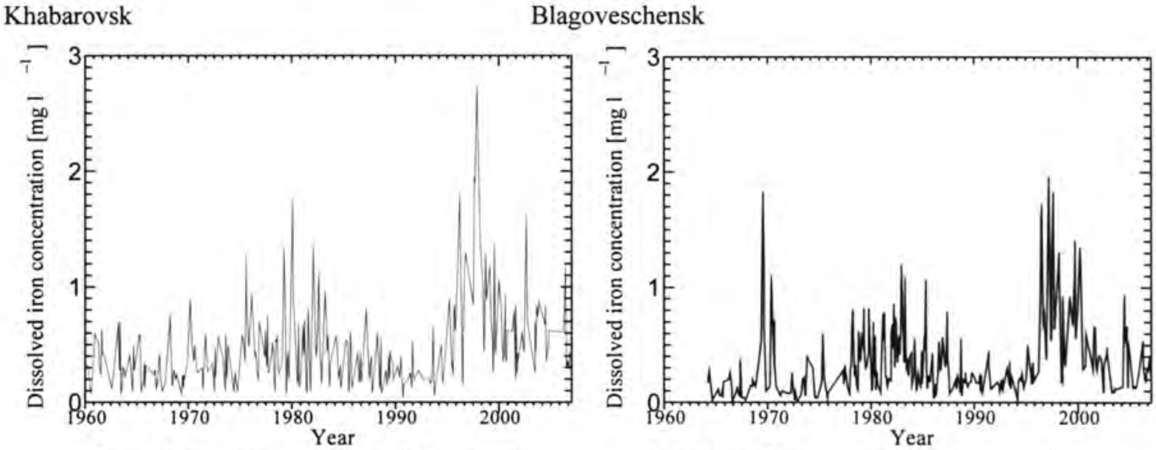

Figure1. Long term change of dissolved iron concentration at Khabarvosk and Blagoveschensk

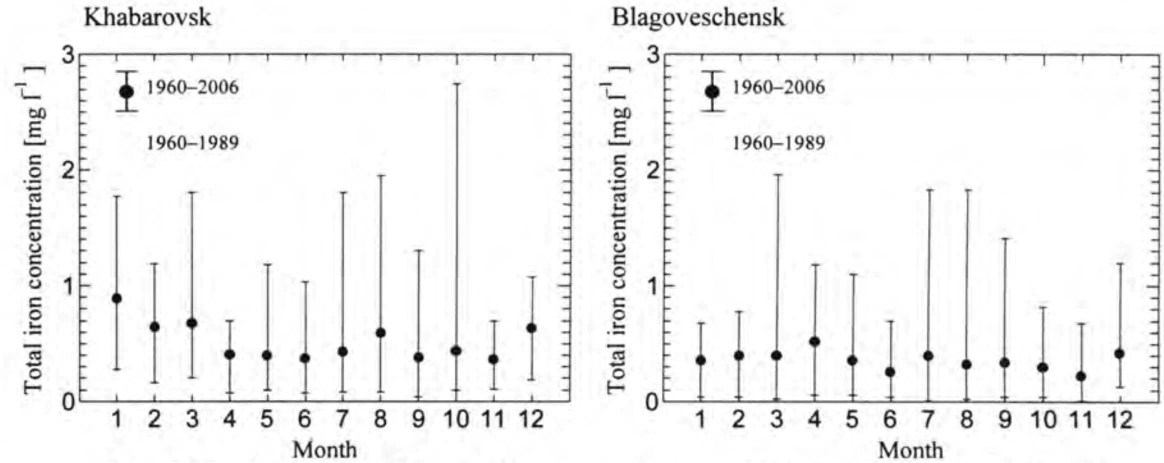

Figure2.Monthly average of dissolved iron concentration at Khabarvosk and Blagoveschensk

the soil freezing and thawing plays an important role in the phenomena.

To see the spatial trend and structure of dissolved iron concentration during the period of abrupt increase at Khabarovsk, the spatial fluctuation of dissolved iron concentration was analyzed. Figure3 shows the temporal change of dissolved iron concentration at the major tributaries which spread out in the Russian part of the Amur River basin. It seems that dissolved iron increase during the period between 1996 and 1998 is not localized phenomena, because increase trend can be observed at many observation stations. Combining with the observed data at Khabarovsk and Blagoveschensk, it can be deduced that spatially prevailing factors such as precipitation and temperature should be related.

Some possible factors which have a potential to control increases of dissolved iron concentration will be discussed in the rest of this section. Here we will consider precipitation and agricultural activity around Sanjiang plain. Figure4 shows the seasonal recipitation in (June-July-August) precipitation anomaly (climate value is calculated using the data during the period of 1970-2000) in 1997. CRU TS2.0 data (Mitchell et al, 2004) are used for calculation. It can be observed that extremely large precipitation around Sanjiang plain was occurred. If we consider the amount of precipitation in each month in 1997, there was large August. On the other hand, Figure5 shows the temporal change of the numbers of wells in the

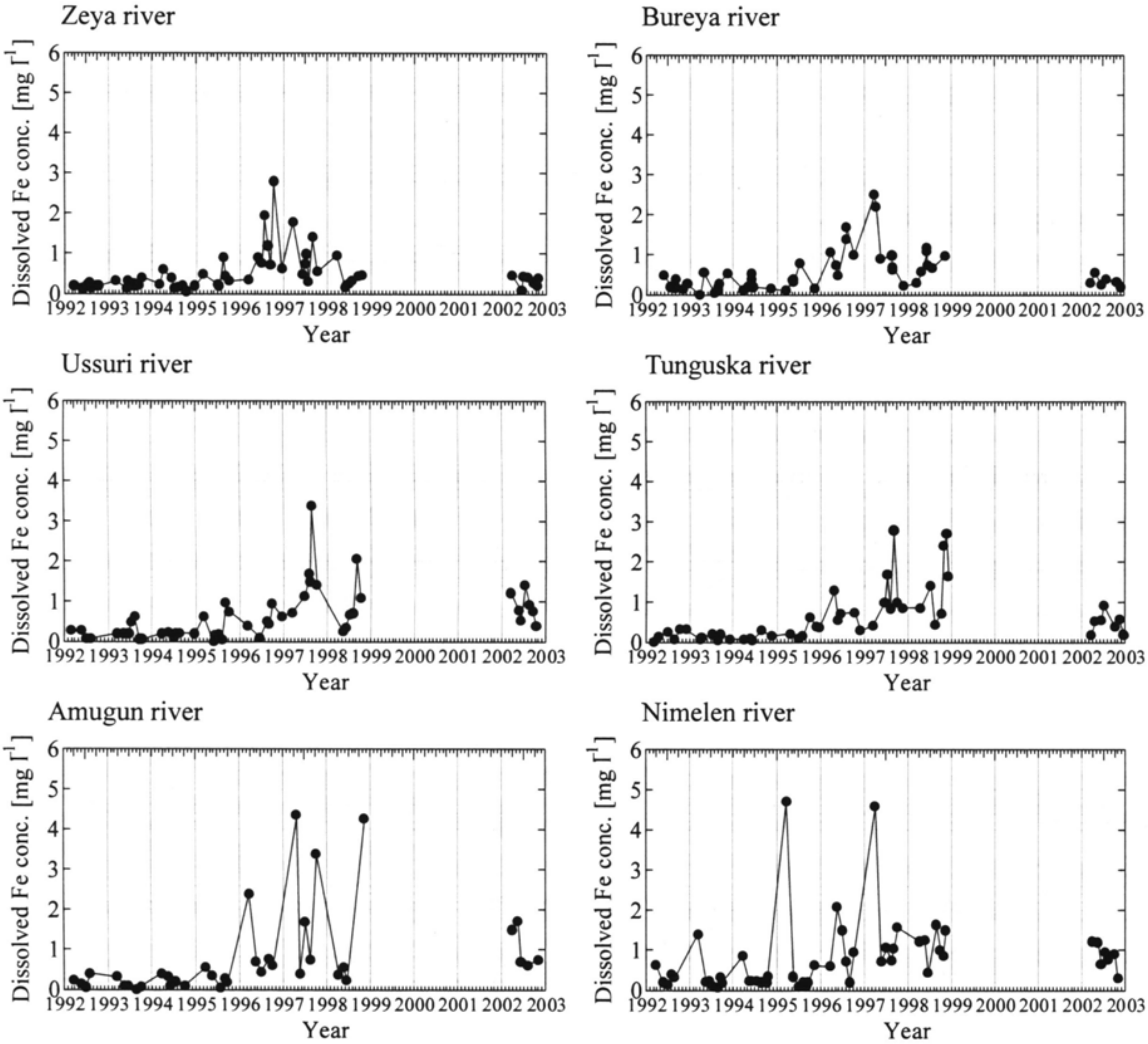

Figure 3 Change of dissolved iron concentration at the major tributaries of the Russian part of the Amur river basin during the period from 1992 to 1998 and 2002

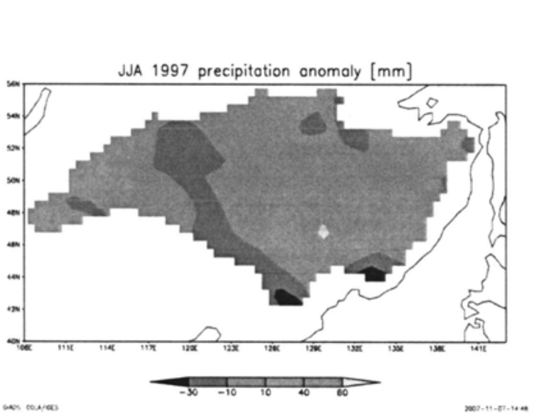

Figure4 Precipitation anomaly of during the period of JJA in 1997

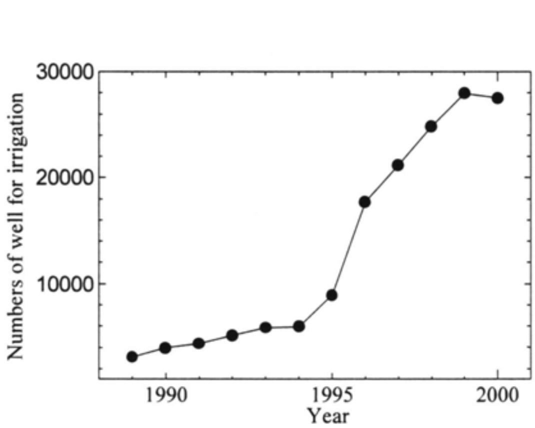

Figure5 Change of the numbers of irrigation wells in the three main national farmland in Sanjiang plain

3 national farmlands in the Sanjiang plain. Drastic increase of wells for irrigation was accelerated by conversion of dry lands to paddy fields during 1990s' (Park et al. 2001, Liu et al. 2002, Wang et al. 2006). As Yan et al. (2007) suggested, iron concentration of groundwater generally showed very high concentration larger than 10mg l^{-1}. Thus, if overflows from paddy fields occurred after a large precipitation, such water might contain highly concentrated iron. This is the one possible mechanism of high iron concentration during the late 1990s'. However, we have no clear evidence which supports this mechanism at now.

3. STRUCTURE OF HYDROLOGICAL MODEL

3.1 Concept of the model

The whole river basin is first divided into 0.5°x 0.5°grid. We consider each grid as one basin like usual Land Surface Model used in GCM. Discharge from each grid is calculated by using TOPMODEL concept as explained below. And discharge from grid is routed along the river network TRIP (Oki and Sud, 1998) shown in Figure6. Runoff routing process is calculated based on prescribed runoff velocity.

TOPMODEL that is frequently used in the hydrological modeling is one of the semi-distributed hydrolgoical models (Beven 1979, Beven 2001). Though many variations from the original version of TOPMODEL have been developed, the basic concept is not changed and effective. TOPMODEL concept was originally derived from a small scale catchment, the same concept is also used in the global scale LSMs such as MATSIRO (Takata et al., 2003).

In the model, each grid (0.5°x 0.5°) is again subdivided into 0.01°x 0.01°grid, and runoff from each subdivided grid is calculated. Schematic diagram of the model of each subdivided grid is shown in Figure7. The model consists of two parts. One is for dealing physical process which calculates runoff (TOP-RUNOFF), and the other is for dealing chemical process which calculates dissolved iron production (TOP-FE). The key concept in the model is that topographic index is related to the productivity of dissolved iron.

Figure 6 River network of the Amur river basin (TRIP)

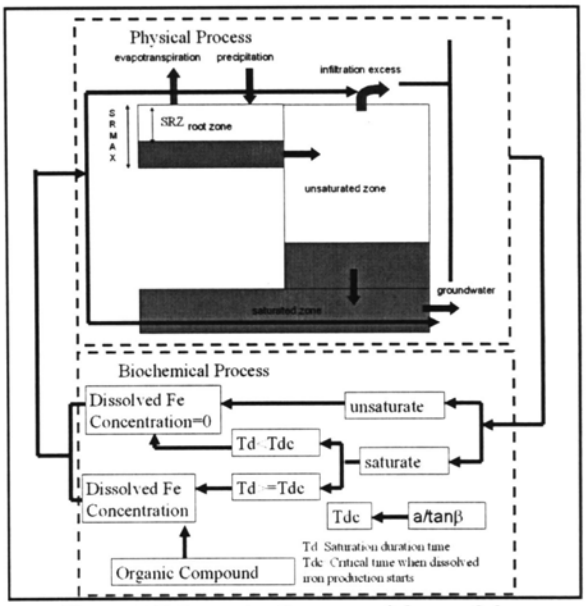

Figure7 Schematic diagram of the model

3.2 Topographic index and dissolved iron concentration

Based on the finding of relation between topographic index and dissolved iron concentration (Shibata et al. 2004, and Onishi 2007), we formulated the relationships between dissolved iron concentration and topographical index at each grid. Formula is constructed for wetland paddy fields and forest. For other land uses, it is assumed that there occurs no dissolved iron production. Figure8 shows the assumed relationships between topographic index and dissolved iron production at each grid. There must be other constraining factor of dissolved iron production such as dissolved organic carbon and annual precipitation.

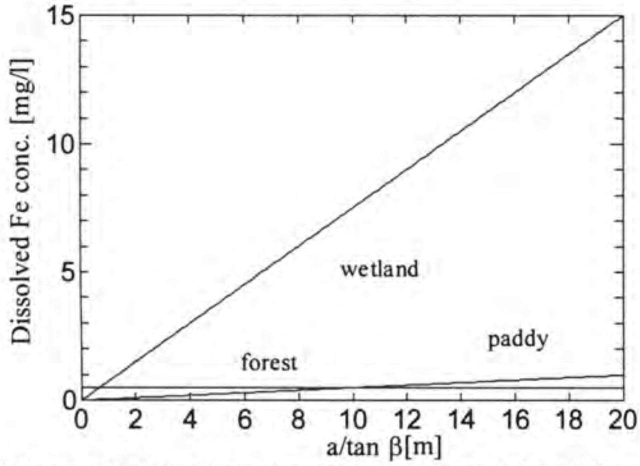

Figure8 Assumed relationships between topographic index and landuse type

3.3 Evapotranspiration

We used Penman-Monteith (Monteith, 1965) equaiton to calculate evapotranspiration rate as shown in the following equation.

$$\lambda_v E = \frac{\Delta(R_n + L - G) + \rho_a c_p (e_s - e_a) g_a}{\Delta + \gamma\left(1 + \frac{g_a}{g_s}\right)} \quad (1)$$

Here, E: evapotranspiration rate [mm d^{-1}], R_n: net shortwave radiation [W m^{-2}], L: net longwave radiation [W m^{-2}], G: soil heat flux [W m^{-2}]□ρ_a: density of dry air [kg m^{-3}], c_p: specific heat capacity of air [J kg^{-1} K^{-1}], e_s: saturated vapour pressure of the air temperature [Pa], e_a: vapour pressure of air [Pa], λ_v: latent heat of water vaporization [J kg^{-1}], Δ: rate of change of saturation vapor pressure with air temperature [Pa K^{-1}], γ: psychrometric constant [Pa K^{-1}], g_a: aerodynamic conductance [m s^{-1}], g_s: surface conductance [m s^{-1}], and, λ_v is set as 2.5 x 10^6,□γ□is set as 0.66.

3.4 Snow accumulation and melting

Before snow accumulation and melting, precipitation amount is divided into rainfall and snowfall according to the air temperature. An algorithm to divide precipitation into rainfall and snowfall is shown in the following equation.

$$
\begin{aligned}
&Rain = P, T_a \geq T_{rain} \\
&Rain = P\frac{T_a - T_{snow}}{T_{rain} - T_{snow}}, Snow = P - Rain, T_{snow} < T_a < T_{rain} \\
&Rain = 0, Snow = P, T_a \leq T_{snow}
\end{aligned}
\quad (2)
$$

Here, T_{rain} and T_{snow}: upper and lower threshold value of rainfall and snowfall division [K], T_a: mean daily air temperature [K]. In the snowpack melting process, our model adopted the simplest form of degree day method as shown in the next equation

$$M = F\max(0, T_a - T_F) \quad (3)$$

where M: melt rate as a water equivalent per unit area [LT^{-1}], F: degree-day factor [$LT^{-1}K^{-1}$], T: mean daily air temperature [K], and T_F: threshold temperature [K].

3.5 Data source and parameters

Stream flow data was obtained from two sources. One is Global Runoff Data Center (GRDC), and the other is from HYDROMET. Daily discharge amount of main stream of the Amur river is observed at Khabarovsk, Komsomo'lsk-Na-Amore and Bogorodskoy. The observed period is from 1940 to 1987 for Khabarovsk, 1940 to 2004 for Komsomo'lsk-Na-Amore and 1963 to 1987 for Bogorodskoy.

Climatic data which is needed for model simulation are net shortwave radiation, net long wave radiation, air temperature, wind velocity, specific humidity, and precipitation rate. In our analysis, we extracted these data from the National Centers for Environmental Prediction (NCEP) / National Centers for Atmospheric Research (NCAR) Reanalysis1 data sets. In generally, NCEP reanalysis2 data is reliable than reanalysis1 data. However, the main object of this research is to construct the framework of the model structure. Thus, in this analysis, we used the NCEP reanalysis1 data tentatively.

Land use and DEM data which are needed to calculate the dissolved iron productivity is compiled based on GIS data made by Pacific Institute of Geography (Ganzei et al., 2007). Hydraulic conductivity of each grid was made by linear interpolation of ISLSCP II data (Hall et al. 2005). Before running the model against the whole basin, various combinations of parameters were tested against several small sub-basins to select a reasonable parameter set which can roughly simulate runoff.

4. RESULTS AND DISCUSSION

4.1 Discharge

Figure 9 shows the observed and calculated discharge at Khabarovsk observation station from 1960 to 2002 with daily basis and monthly basis. It seems that seasonal trend of discharge can be simulated fairly well. However, discharge of summer season (from July to September) flood is generally under estimated. And, timing of peak in the simulated value is faster than the observed value. These discrepancies between observed and calculated value is not peculiar, because one parameter set was applied to the whole river basin in spite of spatial variability of hydrological parameters. It can be said that we can simulate a rough trend of seasonal discharge despite of using only one parameter set.

To investigate the spatial distribution of discharge, observed value and calculated value at the several observation stations. Though there is a limitation of accuracy because of the lack of calibration data points, general characteristics of discrepancies between observed and calculated value is that discharge in the Songhua river basin is underestimate and discharge in the headwater area such as Amgun and Shilka basin is overestimate.

4.2 Dissolved iron concentration

Figure 10 shows the observed and calculated value of dissolved iron concentration at the Khabarovsk station. In general, the result of iron concentration in winter season is relatively good, but the increasing trend during the summer season can not be simulated. The reason of summer season discrepancy might be attributed to the processes the model considers. Hydrological processes which the model considers is basically the degree of soil saturation. Based on the saturation degree and the duration time of saturation, redox condition of each landuse is parameterized. However, there are additional two processes which must be

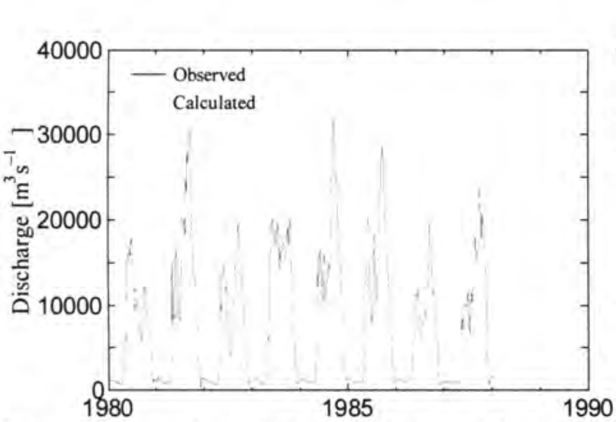

Figure 9 Comparison of discharge between observed observed and calculated value

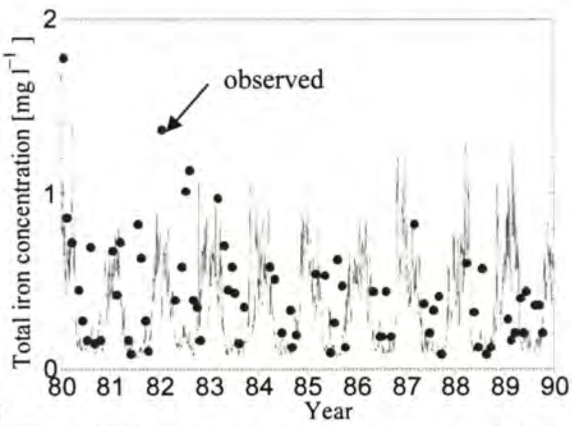

Figure10 Comparison of dissolved iron concentration between observed and calculated value

considered. One is increase of iron concentration in soils as the redox process proceeds. The other is the summer time flooding. Though it is suggested that flooding from rivers also plays a great importance to the iron transport from the findings of the project, the model does not consider the flooding process. Thus, it is suggested that flooding process must be incorporated in the m odel. In addition, the unknown mechanism of spring time increase is also not considered. This unveiled process might have less importance to the total dissolved iron flux in one year, because winter and spring time discharge is low.

5. SUMMARY AND FUTURE PERSPECTIVE

In this report, we first discussed about the characteristics of seasonal and inter-annual fluctuation of dissolved iron concentration in the Amur River basin. Through the analysis of long-term iron concentration change at the Khabarovsk station, drastic increase during the period from 1996 to 1998 was found. Possible causes such as precipitation and agricultural activities were analyzed. However, mechanism of dissolved iron increase is not yet proved.

Next, structure of hydrological model which incorporates dissolved iron production mechanism was explained. And some simulated results were shown. Seasonal change of discharge at Khabarovsk station is relatively well simulated. However, peak discharge in summer time was underestimated and timing of the peak was obviously fast. If we looked into the detail of spatial variation of discharge, discharge of the Songhua River was underestimated. In addition, hydrological and chemical processes which must be incorporated into the model were discussed.

From the analysis of spatial variation of dissolved iron concentration during the period from 1992 to 1998, increasing trend of dissolved iron concentration was commonly observed. Thus, the increase of dissolved iron must have some relation to the large scale phenomena such as precipitation and temperature. Regression analysis between iron concentration and climate parameters is a future research task. Related to the model, first, optimization of hydrological parameters to improve the predicting accuracy of flood peak discharge amount in summer time is needed. Second, progress of redox process and flooding process must be incorporated into the model.

ACKNOWLEDGEMENT

We thank all researchers of IWEP for fruitful discussion and useful insights into the long term change of dissolved iron concentration. Analysis of this report largely owes to the continuous discharge data and iron concentration data which spans more than 40 years. Here, we are grateful to the HYDROMET of their effort for measuring discharge and water sampling and analyzing.

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IRON FLUX BEHAVIOR ANOMALY IN THE AMUR BASIN IN 1990S: FEASIBLE REASONS

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ABSTRACT

The abrupt increase of the iron flux in the Amur nearby Khabarovsk in 1996-1998 is discussed. It was concluded that climate principally caused such behavior of iron.

The long-term monitoring of surface waters in the Amur River basin by Russia State Hydrometeorological Service has revealed a splash increase (by 3-4 times) of the total and dissolved iron flux at Khabarovsk in the last decade of XX.

The content of the different forms of iron in natural waters is to be a subject of several aspects of study. For instance, from the point of water-supply view, high concentration of this widespread biogenic compound deteriorates water quality and requires for special water treatment technology. On the other hand, from the point of view of that iron takes part in biotic cycle, its high inflow in sea with the river flux provides high biological productivity of marine ecosystems [1]. There already revealed that share of dissolved Fe form in the Lower Amur Region waters is to be 40-70 % of the total Fe, and in the Amur tributaries – 30-40 %, and, meanwhile, the rivers with highly swamped valleys have water with sufficiently prevailing share of dissolved Fe [2; 3].

Hydrological and geochemical studies in the Amur basin give a possibility to make a believable basis to deduce the mechanism of Fe migration behavior in the Middle and Lower Amur.

Due to extremely vast area (almost 2,000,000 km^2) the Amur basin consists of some different landscape-geochemical provinces being drained by underground and river networks that differ by Fe concentration. The main sources of Fe in underground and river waters are considered to be the soil and rock minerals which include Fe and spread in major throughout of the northern taiga part of the Amur basin [4; 5] (fig. 1). High mobility of Fe within the Amur basin is caused by formation of acid (fulvic) humus in mountain-taiga soils and peat soils, and enleaching from minerals and migration of Fe occur with supracolloidal soil and rock particles as well as with suspensions [6; 2]. "Organic" Fe (Fe-organic compounds) appears as the prevailing share of dissolved Fe in the Amur tributaries water within the Amur floodplain expansions [3].

The regular over-saturation of soils within between-mountain depressions makes the favorable environments for generation of fluent Fe compounds. The combination of over-watering and atmospheric precipitation infiltration determine together the migration of these compounds as along the soil profile as to the deeper groundwater, in that number with the pore dissolutions of hard-permeable clay bodies. Within artesian basins of the Russia South Far East, there were found out the significant increase of divalent (protoxidic) Fe contents in ground and pressure-ground water downhill [4]. Divalent Fe contents in soil-ground water beneath peat layer was found to vary in limits of 20-60 mg/dm^3, and swamping (peat layer accumulation process) rate determines as a whole the divalent Fe increase rate in underground water on the Middle-Amur / Sanjiang Plain [7].

Peat-ground water, enriched by humic acids, seems to provide just small share of Fe content in water of by-pass streams. This is due to negligible role of swamp water in the runoff generation in Amur and its tributaries during warm period (in winter almost all swamps freeze through mineral bottom and deeper). For instance, according to I. Meshchenin's estimates [8], annual runoff generated from vast swamps of the Middle-Amur Plain (they occupy totally about 13,000 km^2), is estimated to be 228 mm/y, or 94 m^3/s. This value, thus, consists less 1 % of the total annual runoff value in Amur nearby Komsomol'sk-na-Amure (the lower end of the vast Middle-Amur / Sanjiang Plain). Very often siccation of swamps and mares on the Amur plains in warm period – June-October – allows to conclude that they generate runoff actually when 1) spring thaw occurs contemporarily with seasonal frost presence, and 2) during hard summer-autumn monsoon rainfalls occur that conduces to fast over-watering of the predominantly thin (less than 1 m) peat layer of those swamps. We have to take into account, also, that prevailing part of wetlands stretches within the Amur valley bottom downstream Khabarovsk-city, and the "upstream" wetlands is mainly agriculturally developed, especially within Heilongjiang Province of China as well as in Russian part of Khanka Lake valley, and actually have lost the natural peat- humus stock to-date.

A negligible role of peat swamps as sources of Fe in the Amur water seems to be confirmed by special expedition research in August 2006. As the result, there was found the excess of dissolved Fe income to Amur by 2.0-2.5 times within mountainous gorges of its valley in comparison with its floodplain expansions [9]. Few small streams, which watersheds are located totally or almost totally within boggy accumulative plains, are to be considered in this relation as an exception, but not a rule [3].

While we recognize that underground water, drained by the Amur tributaries' headwaters, makes a significant share of their runoff [10; 11], we are to consider the soils of mountain-taiga landscapes to be the main source of Fe in the Lower Amur's water.

The dam control of Upper Zeya has mitigated the amplitude of total Fe contents dynamics, thus, in 1988 the amplitude has been observed to be 0.12-0.47 mg/dm^3 downstream the dam [12]. The increased values of Fe contents (in 1988 – 0.52-1.86 mg/dm^3, in 1994 – up to 1.15 mg/dm^3) were observed just in bottom water layers in Zeya reservoir nearby dam and were related by mentioned researchers to the reduction anaerobic ambience in this deepest part of the reservoir. Totally, it was marked a decrease and stabilization of Fe contents level in Zeya reservoir since 1978 till 1994.

Since Zeya Reservoir start-up (1975) the share of Zeya in the Amur winter flux has been steady rising. Analysis of observation data series, obtained by Far East Department of Russia State Hydrometeorological Service, demonstrates the up-trend of winter discharges in the Lower Amur since early 1980's by nearly 2 times as well as the dissolved iron contents and flux splash increase in the Lower Amur water in 1996-1998 (fig. 2-5).

Figure 3 shows steady low winter flow of Fe in the second half of 1990's, meanwhile, the winter Fe concentrations in the Amur water in 1996 and 1997 look to be much higher comparing with ones in previous and further periods (fig. 3). Supposedly, risen Fe concentrations in Lower Amur in winter 1996 and 1997 could be caused by high Fe concentration in the Zeya water that has been feeding the Amur River.

Some researchers wrote about a sharp rise of near-surface air temperature recorded by array of meteorological observation stations in the Amur Basin, both in Russia and China [13; 14]. Particularly, a deviation of average annual air temperature in 1989, 1990 and 1995, according to [13], reached and exceeded a value +1.5 ºC relative to mean temperature in basic period 1960-1990. Besides warming, in 1990's there were marked the increase of average annual precipitation sum over the Amur basin as a whole: in 1991 and 1992 – by more than 10 %, in 1995 – by 20 % in comparison with basic mean values estimated for period 1960-1990 [13]. In Trans-Baikal Region (Bakal Lake basin and the Amur headwaters) a sharp increase of annual precipitation sum has been registered in 1995 as well [15].

Comparatively sharp increase of air temperature in the Amur basin totally, and in its northern part especially, is to create the beginning (acceleration?) of the permafrost degradation – both laterally (regression of permafrost boundary to the North) and in aspect of its thickness. The permafrost zone diminishing as well as its transformation somewhere to seasonal one have been providing the infiltration of additional quantity of soil water enriched by Fe into underground water which was to income into mountain streams several years later (2-12 years, according to review in [11]).

By data obtained in Amurskiy Territorial Center of Hydrometeorology in Blagoveshchensk, mean annual air temperature, registered in meteorological stations within the Zeya basin and adjacent river basins in 1996 (see area at fig. 1), was either close to the norm or exceeded it by 1.0-1.5 ºC. At the same time, winter in 1996 as well as winter in 1995 was warmer than norm by 2-3 ºC. Spring and summer in 1996 were warmer and drier than usual ones, and autumn – rather warm and durable one.

The average annual temperature in 1997 within northern part of the Amur basin exceeded the climatic norm by 1.5-3 °C. This excess was provided by moderately warm winter, early warm (by 2-5 °C higher than usual one) spring and long warm summer. Winter precipitation amount in that year was recorded to be 130-200 % of the norm.

1998 in considered territory was in average warmer than a norm by 1-2 °C, thereby increased temperature background has been prevailing along a whole year, and mean winter temperature exceeded a norm by 2-4 °C. Summer in mountain and piedmont areas of the territory was long and warmer than common one by 1 °C, and in June-July the precipitation amount was recorded to exceed the mean value by 1.3-1.8 times, and in the Amur headwaters – by more than twice.

In the table below one can see some data about year-by-year dynamics of total Fe in water of the northern rivers of the Amur basin. These data speak about sharp increase of this element concentration by 2-3 times in 1996-1997, with that, the annual volume of sewage greatly contaminated by heavy metals, over given territory fallen from 0.678 to 0.567 m^3/s.

The fact that for some northern rivers (Tynda, Selemdzha, Bol'shaya Pera and Bureya) the Fe concentration peak has delayed for approximately 1 year (1997) in comparison with Amur and Zeya, – that fact points to the most likely "permafrost" origin of Fe contents splash anomaly.

After 1998 Fe flux in Amur nearby Khabarovsk has fallen again to $1.0\text{-}1.5 \cdot 10^5$ ton per year, while Fe concentration in the Upper and Middle Amur water has been staying higher than in 1995 at average (see table).

This Fe flux decrease, obviously, is caused by sufficient precipitation rate decrease over the Amur basin. Thus, according to studies by P. Novorotsky [13], already in 1997 annual precipitation amount over the entire basin was observed as less than 90 % of the norm, and in 2002 – less than 80 % of the mean value. Meantime, in 1998, a powerful rainfall flood occurred on the biggest Middle Amur tributaries. Totally, during the last 15 years (1991-2006) there found a smoothed steady decline trend of annual precipitation amount. Particularly, in 2001-2004 average annual values has hardly exceeded 90 % of the norm, and average annual total runoff of Amur through the same period appeared to be less by 20 % the mean value estimated for 1891-2004. Markedly, significant linear decline trends of precipitation amounts of cold period for the last 30 years were revealed in the Upper Amur basin [13].

CONCLUSION

Thus, 2 main sources of Fe income to the main rivers of the Amur Basin are to be taken into account:

1) Soils and rocks of mountain areas – commonly headwaters – where river flow is generated mainly by underground water;

2) Swamps on the vast Amur plains where some water highly enriched by Fe sometimes are drained by undeveloped network of small plain streams and quite large bypass ones.

The main reason of abrupt rise of Fe flux registered in the Amur basin in 1990's appears to be climate change – increase of air temperature and precipitation rate. The latter leads to permafrost degradation in its near-southern-edge areas and, therefore, to increased permeability of melted soils and underlying grounds. Moreover, the warmer atmospheric precipitation infiltrated into deeper underground layers, supposedly, is to accelerate the physical-chemical processes of resorption of minerals and the dissolved Fe flush-out from soils and rocks. The role of plant-soil cover on the vast area submerged by Zeya Reservoir in 1970s, in Fe flux rise in 1990's does not tracked up distinctly.

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Figures

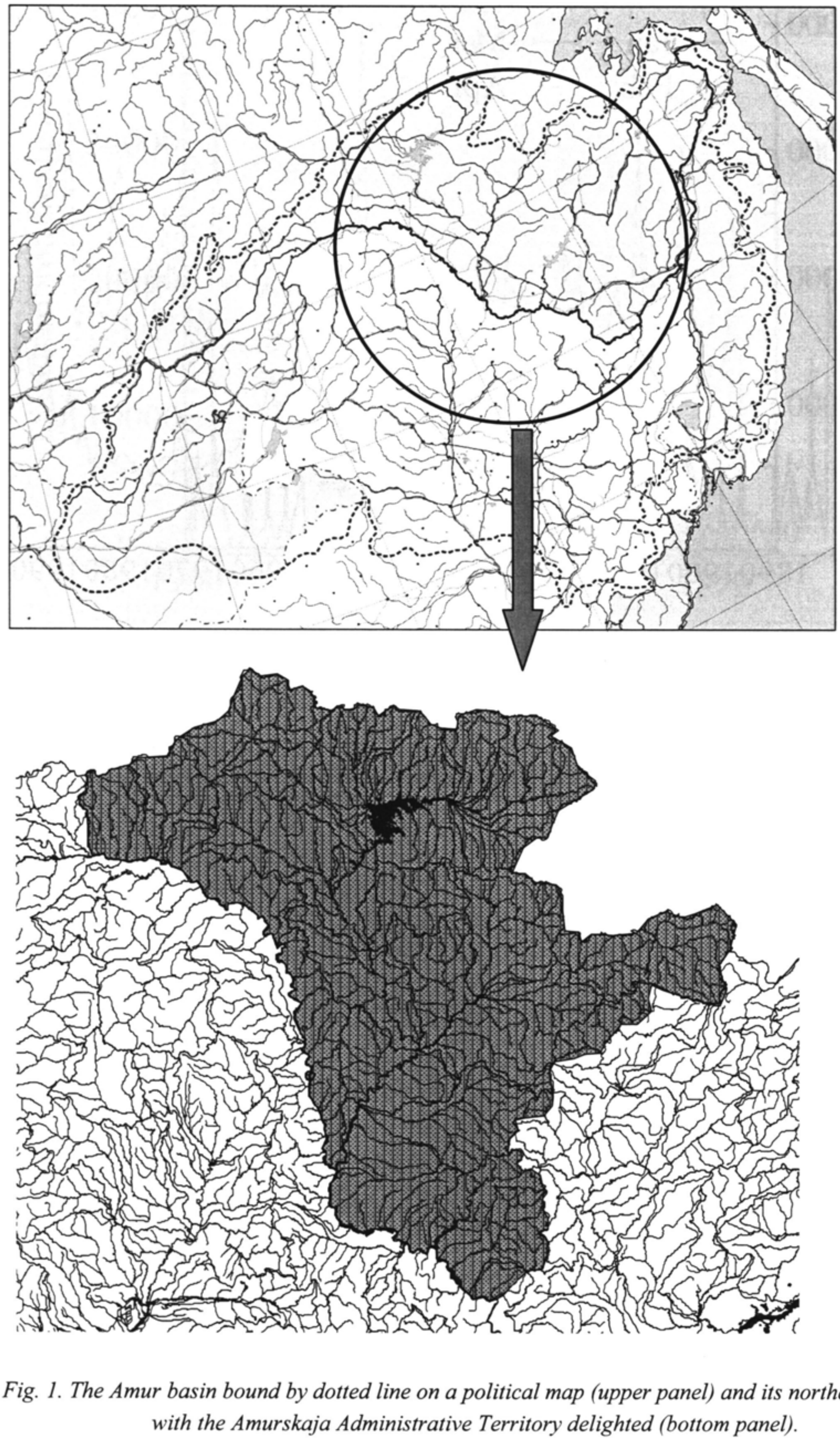

Fig. 1. The Amur basin bound by dotted line on a political map (upper panel) and its northern part in detail with the Amurskaja Administrative Territory delighted (bottom panel).

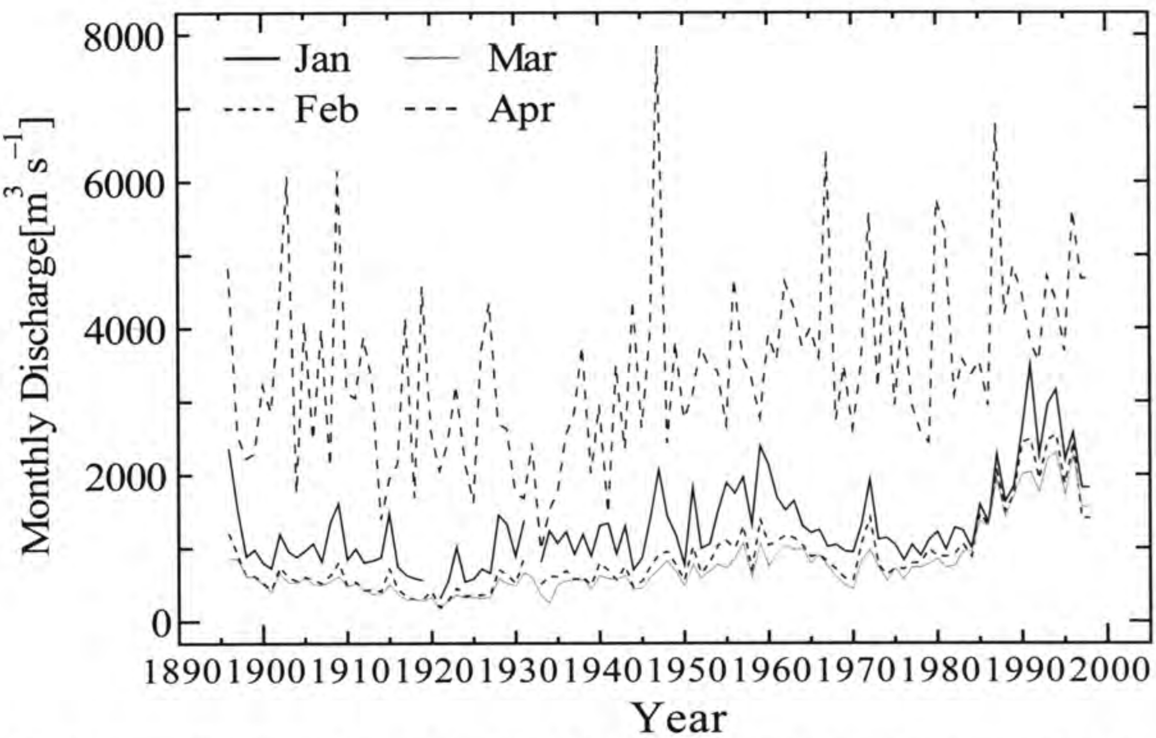

Fig. 1. Dynamics of average cold month discharges in the Amur nearby Khabarovsk. 1896-1999. Numbers at lines correspond to month since November (1) to April (6).

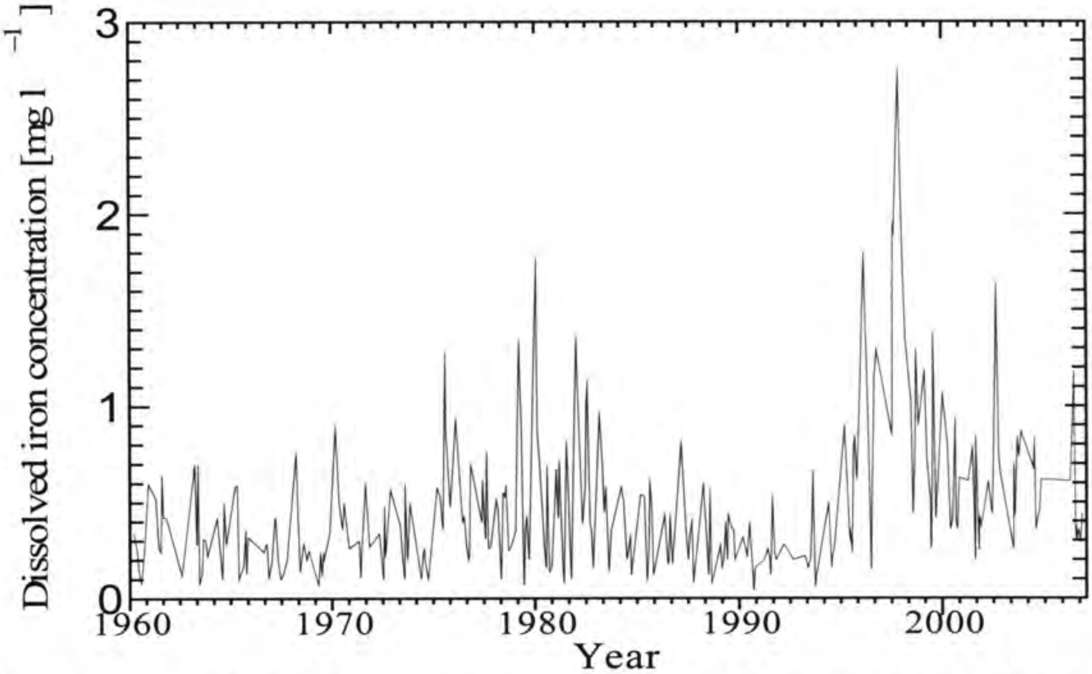

Fig. 2. Dynamics of dissolved Fe concentration monthly measured in the Amur water nearby Khabarovsk. 1960-2006.

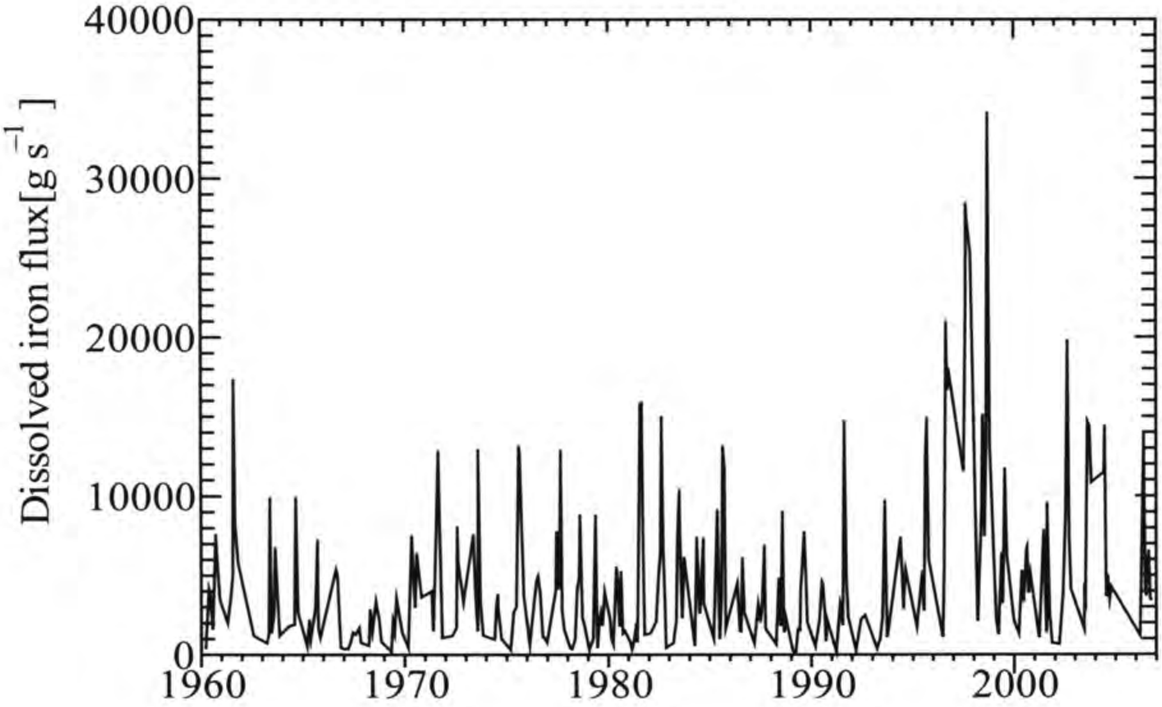

Fig. 3. Daily average discharges of dissolved Fe in the Amur nearby Khabarovsk. 1960-2005.

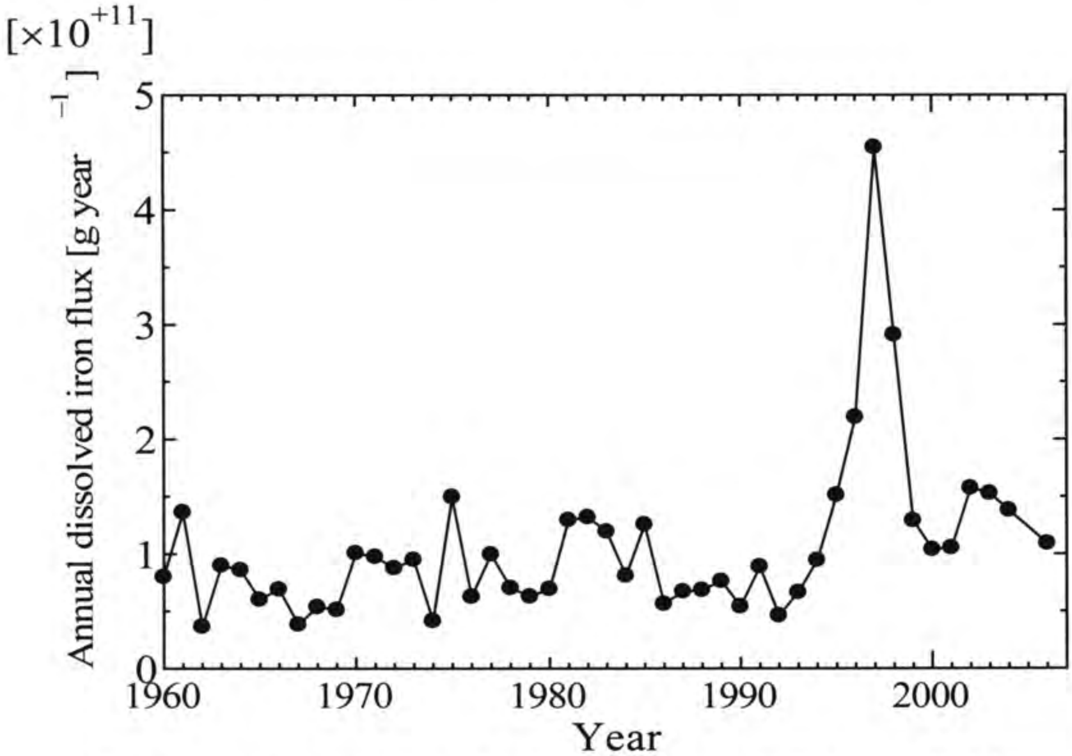

Fig. 4. Behavior of annual dissolved Fe flux in the Amur nearby Khabarovsk. 1960-2006.

Table

Average total Fe contents (mg/dm³) in the river water within northern part of the Amur Basin

River – site of observation	1995	1996	1997	1998	1999	2000
Amur – Blagoveshchensk (1 km upstream city)	0,20	1,39	1,11	0,53	0,56	0,49
Amur – Blagoveshchensk (5 km downstream Zeya mouth)	0,28	2,35	2,25	1,80	0,91	0,70
Zeya – Blagoveshchensk (1 km upstream city)	0,43	1,17	0,90	0,41	0,83	0,77
Tynda – Tynda (1 km upstream town)	0,27	0,51	1,17	0,55	0,83	0,35
Bol'shaya Pera – Shimanovsk (0,5 km upstream town)	0,66	2,47	2,65	1,29	1,36	1,24
Tom' – Belogorsk (1 km upstream town)	1,13	1,49	1,31	0,96	1,14	1,15
Bureya – Novobureysk (1 km upstream town)	0,67	0,91	1,16	0,79	0,73	0,79
Selemdzha – upstream mouth	0,54	0,34	1,30	0,81	no data	no data

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