# IMPACTS OF RECLAMATION ON DISTRIBUTION AND TRANSPORT OF IRON IN SOILS OF SANJIANG PLAIN, NORTHEAST CHINA

CHEN X.[1], CHI G.[1], HUANG B.[1], KAWAHIGASHI M.[2], SHI Y.[1] AND YOH M.[3]

[1] *Institute of Applied Ecology, Chinese Academy of Sciences, China*

[2] *College of Bioresource Science, Nihon University, Japan*

[3] *Tokyo University of Agriculture and Technology, Japan*

## SUMMARY

Intensive wetland reclamation and concomitant water management in Sanjiang Plain exert profound effects on dissolved iron formation and transport, affecting the primary production in the neighboring marine environment. In this report, the distribution and transport of iron in three wetland soils under various land uses were studied, and the importance of irrigation in the function of paddy fields as a source to export iron to rivers was estimated. Cultivation generally increased the accumulations of crystallized iron and amorphous iron in the 0-60 cm surface soil layer. The changed distribution of soil iron under cultivation was ascribed to the hydrological condition-driven changes in formation and transport of dissolved iron, irrigation of iron-containing groundwater, soil weathering and plowing. In particular, greatly reduced percolation and groundwater irrigation in the paddy fields and no or little water percolation in the upland fields have been causing continued long-term impacts on dissolved iron formation/transport and iron distribution in the cultivated soils. Based on representative scenarios for water budget in the paddy fields and typical levels of dissolved iron in surface runoffs and groundwater, the function of the paddy fields as a source to export iron to rivers was estimated to be greatly reduced, and might even shifted to be a sink. The overall trend in export of iron out of flooded soils of Sanjiang Plain was also discussed.

## INTRODUCTION

Wetlands in Sanjiang Plain, Northeast China occupied an area of about 53000 km$^2$ in 1949, 19500 km$^2$ in 1980 and about 9000 km in 2000 (ZHOU and LIU, 2005). The disappeared wetlands were mainly converted to agricultural lands, primarily paddy fields. Meanwhile, water management in Sanjiang Plain was concomitantly carried out, establishing drainage systems and water diversion projects to divert surface runoffs from neighboring mountainous regions. As a result, the function of wetlands in regulating hydrological condition of Sanjiang Plain has been greatly reduced. In the past several decades, while temperature increase in Sanjiang Plain (ZHOU et al., 2009) could be explained as a phenomenon linked to global warming, the decrease of precipitation would be at least partly ascribed to the diminishing functioning of wetlands there. In addition, heavy use of groundwater in paddy fields has been causing the decrease of groundwater table in Sanjiang Plain, further exerting a water-shortage stress on the remained natural wetlands.

Such changed hydrological conditions in both natural and cultivated soils also have changed the biogeochemical cycling of soil iron in Sanjiang Plain, affecting the export of iron into rivers and the primary production in the neighboring marine environment. In this report, we performed an evaluation of the influence of land use and the concomitant hydrological change on iron distribution and transport in soils of Sanjiang Plain. The importance of irrigation in the function of paddy fields as a source to export iron to rivers was also estimated.

**METHODS AND MATERIALS**

Soil samples taken from three soils under various land uses at 11 sites of Sanjiang Plain (Figure 1 and Table 1) were analyzed at intervals of 0-10, 10-20, 20-30, 30-40 (20-40 for MD soil), 40-60, 60-90 and 90-120 cm for total iron (Fet), alumina-silicate-associated iron (Fes), free iron-oxide iron (Fed + Fes = Fet), crystallized iron (Fec) and amorphous iron (Feo). Organic carbon and pH were also measured.

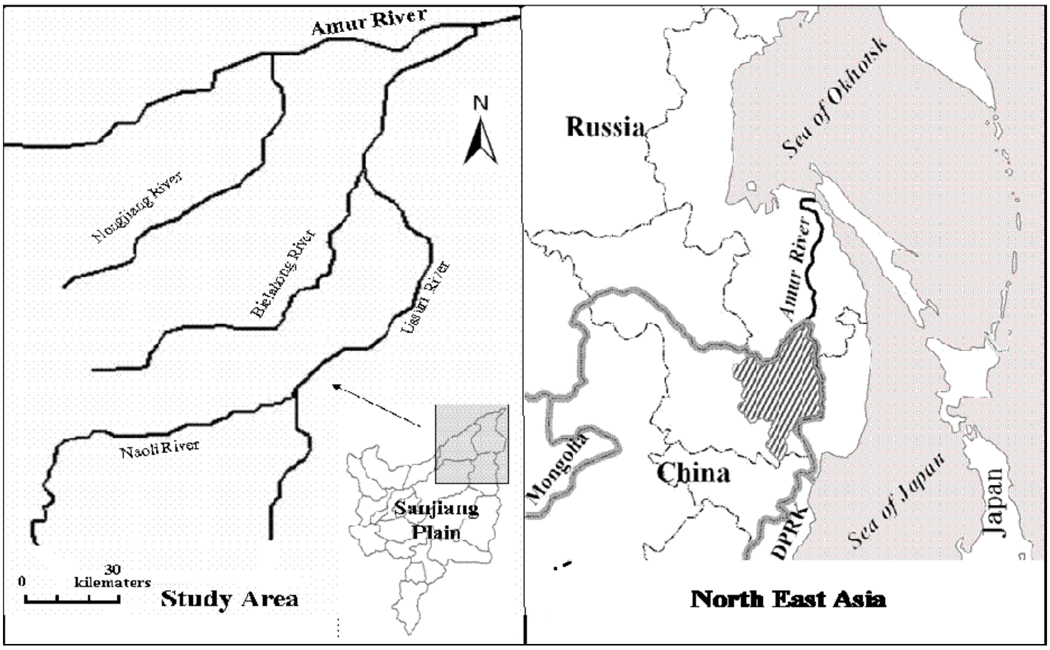


*Figure 1 Locations of experimental sites in Sanjiang Plain*

*Table 1 Experimental sites in Sanjiang Plain*

| Site name | Location | Soil | Land use | Years of cultivation |
|---|---|---|---|---|
| MS-W | 47°17.122′N, 133°46.110′E | Marsh soil | Wetland | |
| MS-W-P-23 | 47°17.122′N, 133°46.076′E | Marsh soil | Paddy | 23 |
| MS-W-U-23 | 47°17.073′N, 133°45.877′E | Marsh soil | Upland | 23 |
| AB-W | 47°44.244′N, 133°31.212′E | Albic soil | Wetland | |
| AB-W-P-2 | 47°44.216′N, 133°30.580′E | Albic soil | Paddy | 2 |
| AB-W-P-11 | 47°39.479′N, 133°30.471′E | Albic soil | Paddy | 11 |
| AB-W-U-4 | 47°44.482′N, 133°31.253′E | Albic soil | Upland | 4 |
| AB-W-U-15 | 47°44.236′N, 133°30.625′E | Albic soil | Upland | 15 |
| MD-W | 47°31.918′N, 133°52.987′E | Meadow soil | Wetland | |
| MD-W-P-10M* | 47°31.609′N, 133°53.047′E | Meadow soil | Paddy | 10 |
| MD-W-P-10C** | 47°31.673′N, 133°53.054′E | Meadow soil | Paddy | 10 |

*: 5 meters away from the drainage ditch; **: 100 meters away from the drainage ditch

**Data analysis**

To evaluate the influence of land use on iron distribution/transport in soil, a parameter from a specific depth interval of a cultivated soil, either a form of iron (e.g., Fes) or a related environmental parameter (e.g., pH) was pooled across three types of soils and plotted against that from the corresponding natural soil, and its relative change induced by cultivation was plotted along a vertical soil profile. Based on water budget and representative levels of dissolved iron, the annual input/output of iron through irrigation of groundwater and surface runoffs in paddy fields was estimated.

## RESULTS AND DISCUSSION

**1. Influence of land use on iron distribution/transport in soil**

Despite large variations of iron in the soils under various years of cultivation, some patterns exited for Fet, Fes, Fed, Fec and Feo (Figures 2 and 3). Under cultivation, Fed-based iron was mainly responsible for Fet increase in the 0-60 cm layer; the increase of Fec-based Fed in the 0-60 cm was greater than Feo; relative small extents of increase of Fes was also fund in the surface layers, especially in the very recently cultivated soils.

The increased accumulation of iron generally found in the cultivated soils was the joint results of the changes in formation of dissolved iron, duration and extent of water percolation, use of iron-containing groundwater, soil weathering and farming practice such as plowing.

Organic carbon was reduced, especially in the upland soils, and pH was also found in a trend of increasing in most cases (Figure 4). However, hydrological conditions in the cultivated soils generally did not favor microbial formation of $Fe^{2+}$-based dissolved iron, especially in the upland soils. More importantly, cultivation induced changes in hydrological conditions were so great (e.g., conversion of natural wetlands to paddy fields shortens the flooding duration from 210 days to not more than 120 days), that the amounts of water being percolated were greatly reduced in the paddy soils (Table 2), and negligible in the upland soils. Subsequently, percolation of dissolved iron was greatly reduced in the paddy soils, and became negligible in the upland soils. Furthermore, the popular use of iron-containing groundwater for irrigation would also contribute to the accumulation of iron, especially amorphous iron in the surface layers of the paddy fields. The amount of input of iron through irrigation was expected to be much greater than the output through surface runoff in the paddy fields (Table 3).

In addition, farming practice, especially plowing would also greatly affect the distribution of iron in the cultivated soils, especially in the recently cultivated soils such as AB-W-P-2 and AB-W-U-4. Increased soil weathering in the cultivated soils would also be expected due to increased variations in soil moisture and temperature, affecting iron weathering and distribution.

Even the location of a paddy field relative to the drainage ditch could significantly affect the distribution of soil iron. For example, MD-W-10-M is only 5 meters away from the drainage ditch and MD-W-10C is 100 meters away. The intensity of lateral flow in

MD-W-10-M would be presumably much greater than in MD-W-10-C, resulting in greater accumulation of Fed-based iron accumulation in the 0-60 cm layer (Figures 2 and 3).

All these changes induced by reclamation would contribute to the changed distribution of iron in the surface layers of the cultivated soils, among which, hydrological changes, including changes in flooding and percolation and use of groundwater for irrigation would have a continued long-term impact on dissolved iron formation/transport and hence iron distribution in the cultivated soils.

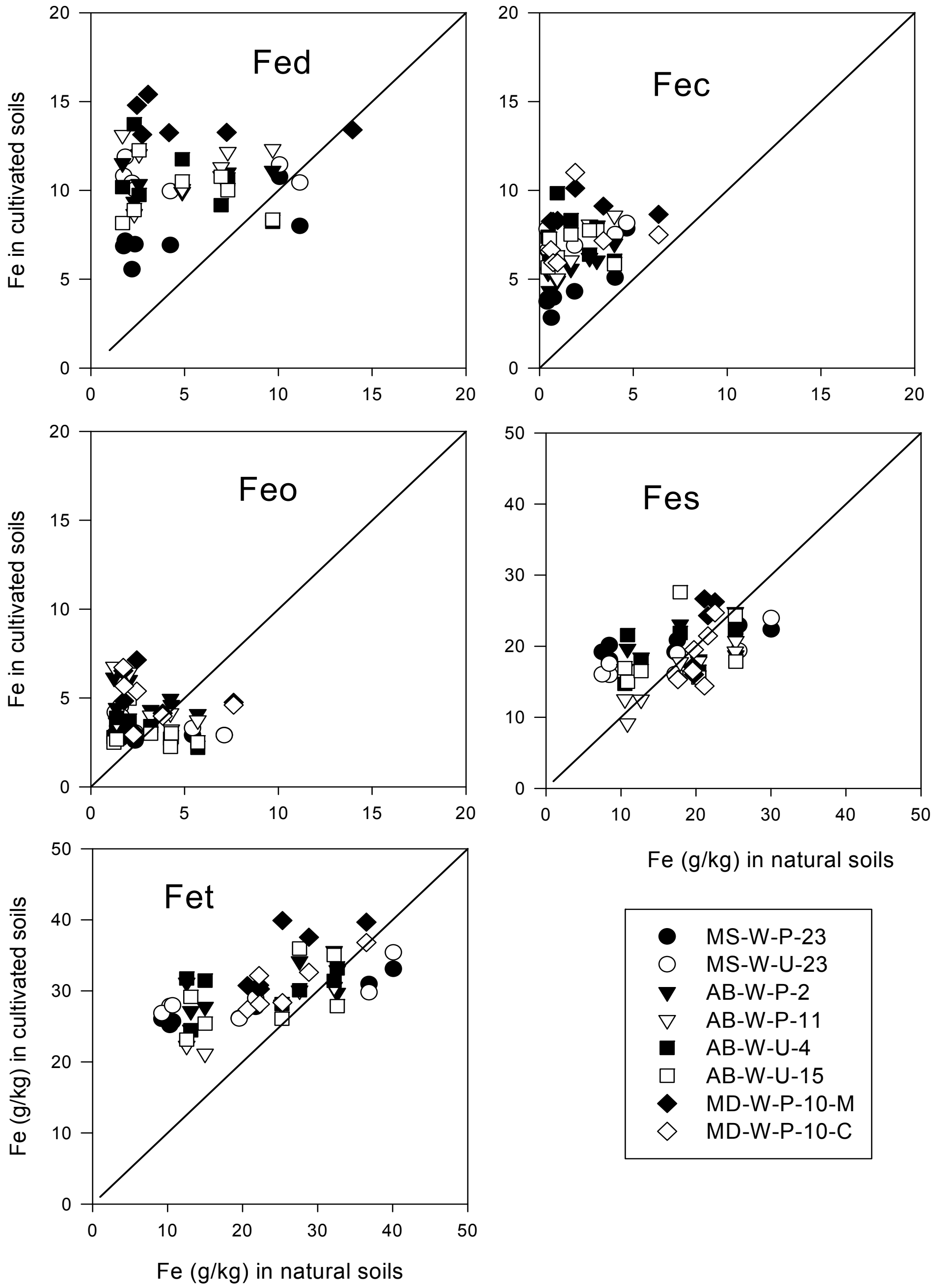


*Figure 2. Impact of land use on iron in soils of Sanjiang Plain*

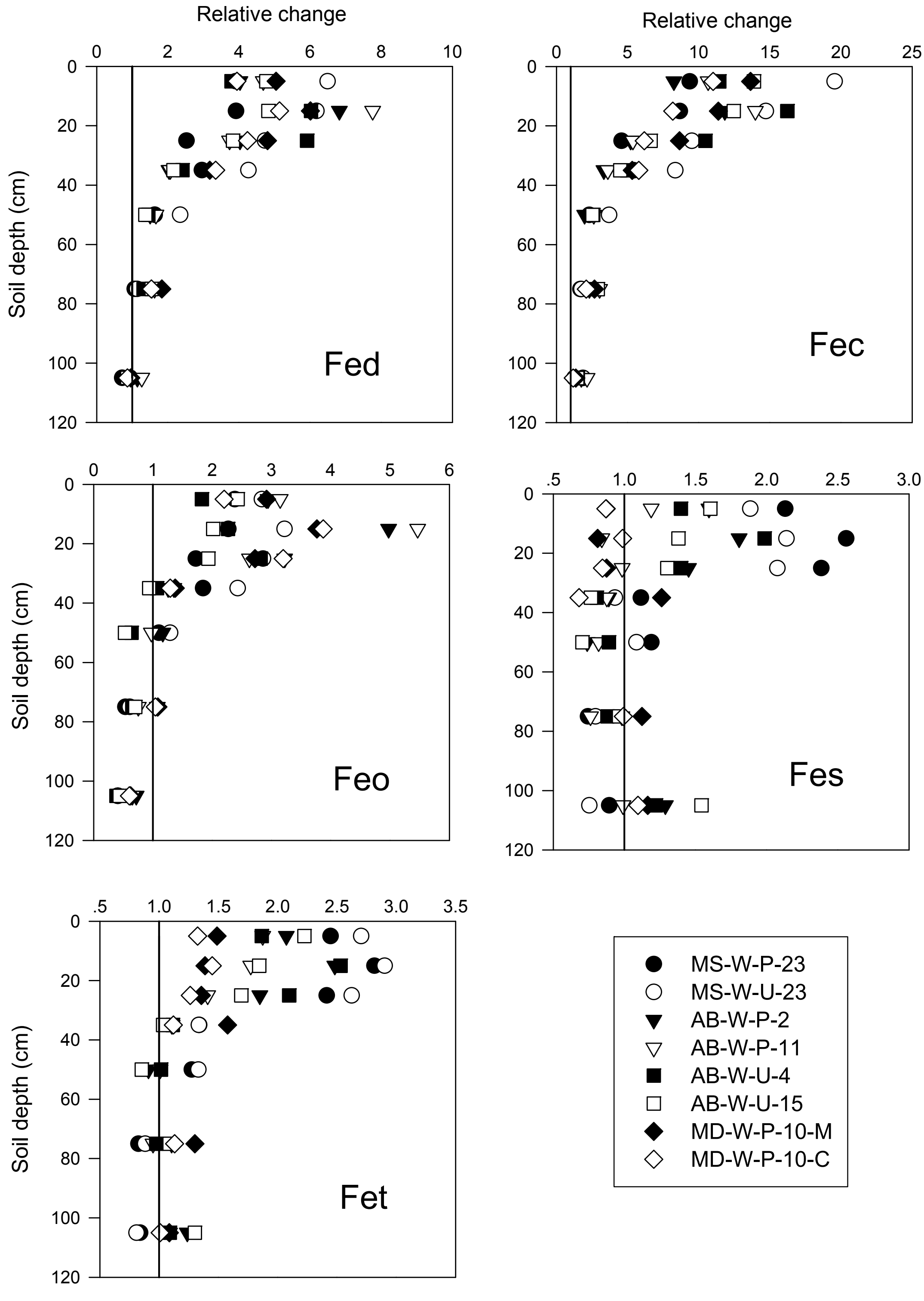


*Figure 3. Vertical profile of relative change of iron induced by cultivation*

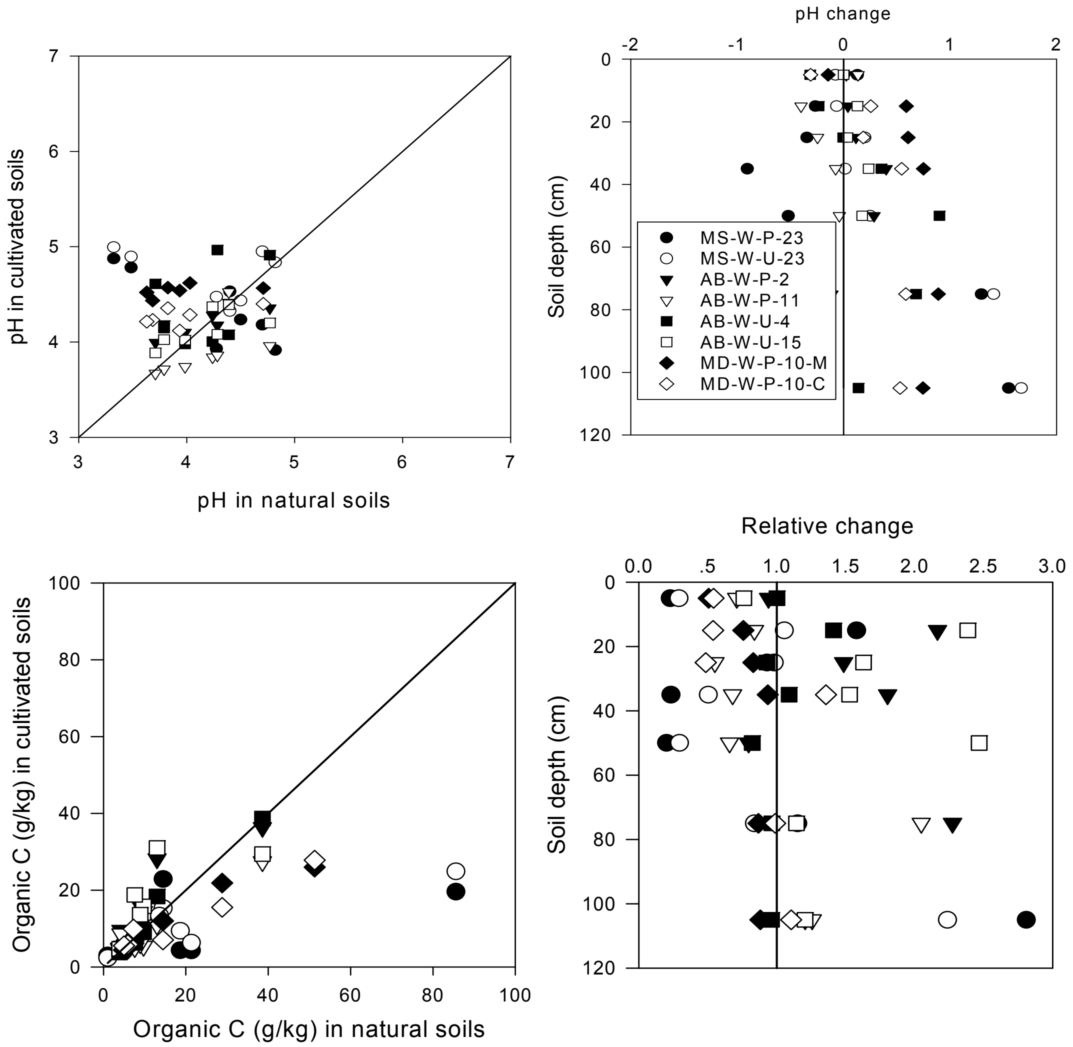


*Figure 4 Cultivation induced changes in soil organic carbon and pH*

**2. Estimation on input/output of iron in natural wetlands and paddy fields**

Estimation of the scales of iron input/output through surface runoffs and irrigation in paddy fields (Table 3) was performed based on water budget (Table 2) and representative levels of dissolved iron in surface runoffs and irrigated groundwater (Table 3). When a wetland was cultivated, the amount of iron input through irrigation was much higher than the amount iron output through surface runoff. Meanwhile, the amount of dissolved iron being percolated in the paddy fields was also expected to be reduced much. Hence, its function as a source exporting iron to rivers through surface and surface outflows was greatly reduced, and might even shifted to be a sink, when the amount of dissolved iron being percolated were lowered to <3.2 $g/m^2/yr$, which is equivalent to 80 mg/L dissolved iron being percolated at 0.42 mm/d for 120 days in a year.

*Table 2 Water budget ($mm/m^2/yr$) in natural wetlands and paddy fields of Sanjiang Plain*

| Process | Scenarios in natural wetlands* | | | Scenarios in paddy fields** | | |
|---|---|---|---|---|---|---|
| | A | B | C | A | B | C |
| Precipitation | 550 | 550 | 550 | 400 | 400 | 400 |
| Evapotranspiration | 1150 | 1150 | 1150 | 750 | 750 | 750 |
| Inflow | 1500 | 1000 | 800 | | | |
| Irrigation | | | | 1000 | 750 | 400 |
| Surface runoff | 500 | 200 | 100 | 450 | 300 | 0 |
| Percolation | 400 | 200 | 100 | 200 | 100 | 50 |

*: the three scenarios were created based on evapotranspiration for comparison with those in paddy fields. Actual relative ratios of surface runoff and percolation in natural wetlands vary, depending on inflow, soil type and distance to rivers/drainage systems. **: Rice growth period from May to September. Scenario A represents traditional average level of groundwater irrigation, Scenario B represents traditional low level, and Scenario C represents economical level of nowdays (FU, 2002)

*Table 3 Input/output of iron in paddy fields of Sanjiang Plain (g/m$^2$/yr)*

| Process* | Level of dissolved iron (mg/L) | Input/output of iron (g/m2/yr) |
|---|---|---|
| Irrigation | 10.0 | 7.2(4.0-10.0) |
| Surface runoff | 3.0 | 0.75 (0-1.40) |

*: The contribution of each process was estimated based three representative scenarios for water balance in paddy fields (Table 2) (FU, 2002) and representative levels of dissolved iron in irrigated groundwater and surface runoffs in Sanjiang Plain.

### 3. Trends of Soils of Sanjiang Plains as the source of iron to rivers

Organic matter contents and pH in the paddy soils still favor $Fe^{2+}$-based dissolved iron formation once water condition is favorable, although there is a trend of pH increase, possibly lowering the stability of dissolved iron (Figure 3). The hydrological condition is the key factor regulating the formation and transport of dissolved iron in paddy and upland fields, primarily through limiting the percolation of dissolved iron. In the natural wetlands, iron is increasingly becoming less mobile due to increased chance of non-flooding, and harder to be exported through surface and subsurface outflow s due to lowered surface water level.

Overall, Heavy use of groundwater, primarily for paddy fields, is expected to continue in Sanjiang Plain. Wetlands, with an area less than 20% of the total area of Sanjiang Plain, will play an important but weakening role in regulating the hydrological condition of Sanjiang Plan in the future under a warmer and drier climate. Surface/subsurface outflows in both natural and cultivated soils expected to decrease, weakening their function to export iron into rivers.

## REFERENCES

FU Qiang. 2002. Study on the Modern Building Models & Optimum Technique--Application of Water Saving System for Well Irrigation Rice in Sanjiang Plain. ENGINEERING SCIENCE 4(6):p44-55

ZHOU Zhiqiang, LIU Tong. 2005. The current status, threats and protection way of Sanjiang Plain wetland, Northeast China. Journal of Forestry Research,16(2)：148-152.

ZHOU Demin, GONG Huili, WANG Yiyong, KHAN Shahbaz and ZHAO Kuiyi. 2009. Driving Forces for the Marsh Wetland Degradation in the Honghe National Nature Reserve in Sanjiang Plain, Northeast China. Environmental Modeling and Assessment, 14(1): 101-111