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 object 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 object 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	Albic soil	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		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).

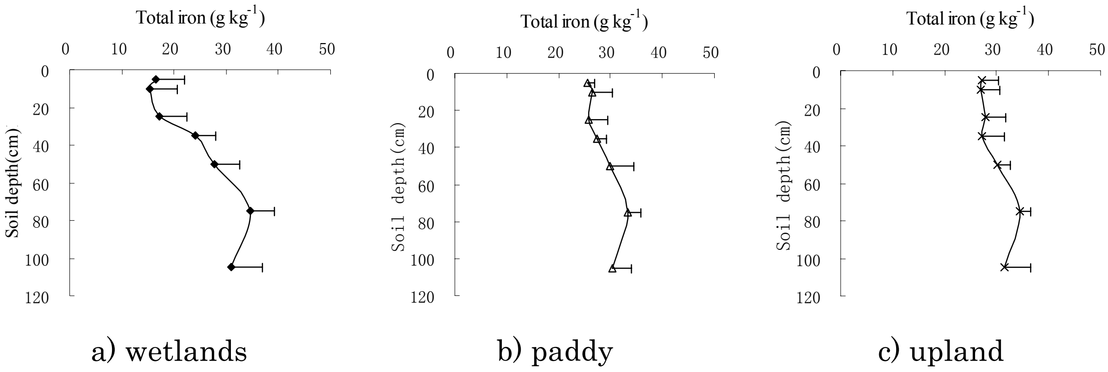


Figure 1. Vertical distribution of total iron in soils under three land cover types

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).

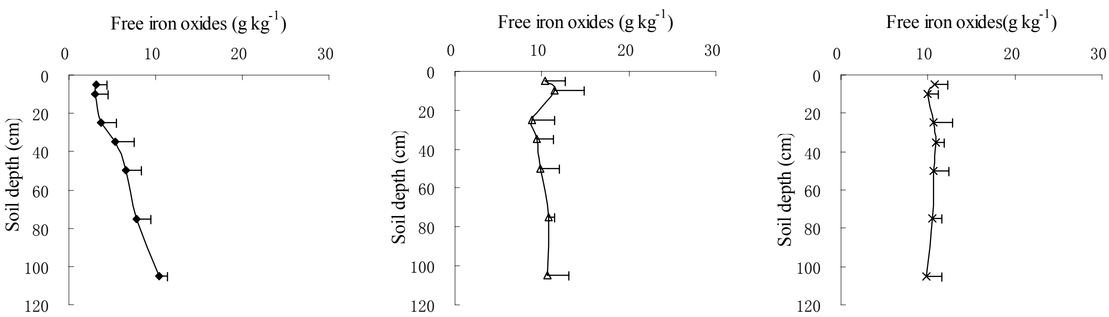
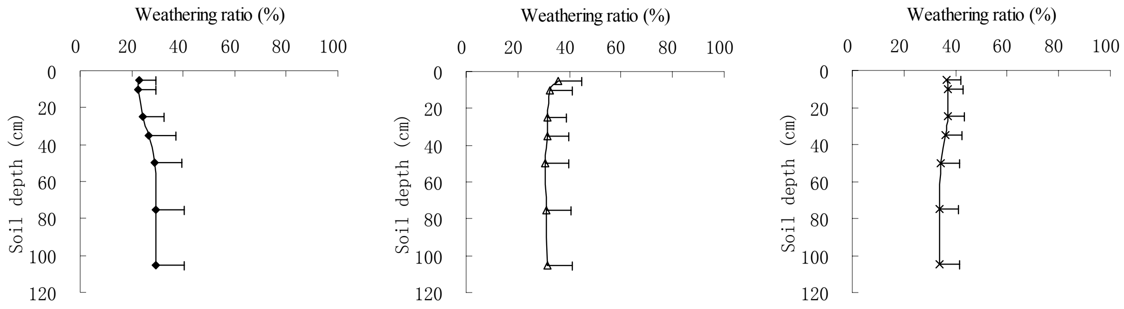


Figure 2. Vertical distribution of free iron oxides in soils under three land cover types



a) wetlands b) paddy c) upland

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).

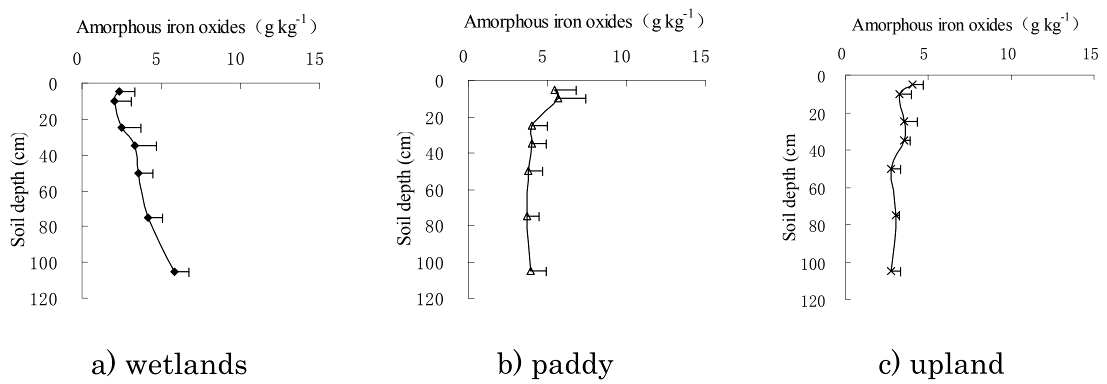


Figure 4. Vertical distribution of amorphous iron oxides in soils under three land cover types

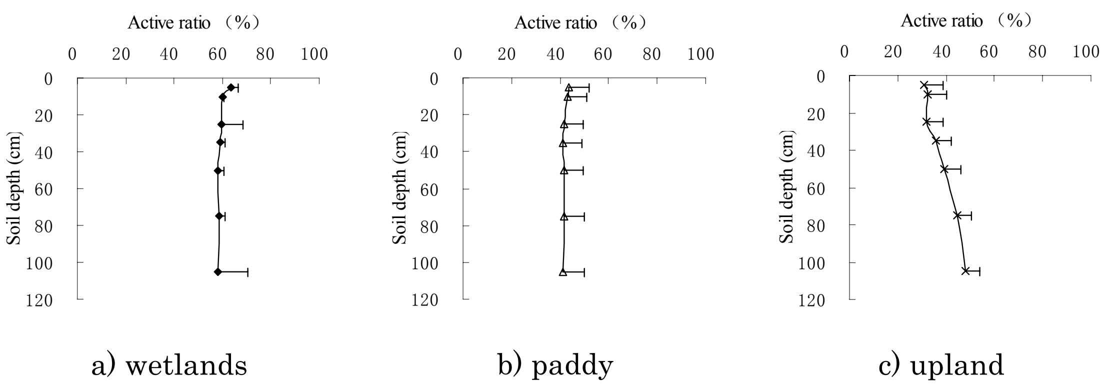


Figure 5. Vertical distribution of active ratio in soils under three land cover types

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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