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Effects of farming on the soil seed banks and wetland restoration potential in Sanjiang Plain, Northeastern China

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ABSTRACT

Seed bank is an important source of regenerative material in wetlands, and can be of value in the restoration of farmed wetlands if the seeds can survive periods of cultivation. A seed bank assay of soils from sedge meadows was conducted to determine the extent to which seeds are maintained during farming for various lengths of time. Soils from natural sedge meadows, soybean fields and paddy fields farmed for 1–30 years were collected in Sanjiang Plain, northeastern China. Soils were placed in a glasshouse setting in freely drained condition. We found that species richness and seed density in sedge meadows were higher than in soybean and paddy fields. There were significantly negative effects of the length of time of farming on the seed bank in soybean fields. Important wetland species survived cultivation as seeds within 10 years (e.g., *Calamagrostis angustifolia* and *Polygonum amphibium*), but most sedge meadow species disappeared when farmed for more than 10 years in soybean fields. Species richness and seed densities of species kept in a very low level in paddy fields farmed for various periods. Key structural dominants *Carex* species maintained with low seeds in natural wetlands and soybean fields farmed for 1–5 years, and tussock-forming *Carex* (e.g., *Carex* appendiculata and *Carex* meyeriana) were all absent in farmed fields. The structure of the seed bank was related to environmental factors including latitude, number of years farmed and field water depth as based on Non-metric Multidimensional Scaling analysis. Critical components of the vegetation are not maintained in seed banks, which may make these floodplain wetlands difficult to restore via natural recolonization. To re-establish the structure imposed by tussock sedges, specific technologies (e.g., planting, hydrochory) might be developed to encourage the development of tussocks.

1. Introduction

Soil seed banks provide seeds for the redevelopment of plant communities, and can be important component of the ecological restoration of degraded ecosystems (Middleton, 1999, 2003), particularly if the species remain viable in the soil for long periods of time (van der Valk and Davis, 1978; Nishihiro et al., 2006). If the seeds of key structural dominants are missing from seed banks, farmed fields can be difficult to restore to wetland, for example, tussock-forming sedge meadow (*Carex*; Kettenring and Galatowitsch, 2011). Interest in seed banks for aiding the rehabilitation and reconstruction of damaged wetland ecosystems is growing (Middleton, 2003; Hong et al., 2012; Wang et al., 2013) because of the recognition that wetlands have important ecological functions (Mitsch and Gosselink, 2007). Nevertheless, for seed banks to be used successfully in wetland restoration, it is important to recognize the limitations that these may have for restoration, particularly after disturbances such as farming (Middleton, 1999, 2003). Researches in European and North American suggest that important components of vegetation are often missing from farmlands or grazing lands (Bakker et al., 1996; Galatowitsch and van der Valk, 1996; Middleton, 2003; Stroh et al., 2012).

The rate of seed loss and the wetland restorability after farming might depend on the wetland type, the duration of the farming and the longevity of the seeds (Wienhold and van der Valk, 1989; Middleton, 2003). Long-lived seeds could remain viable in the soil for long periods of time so it is possible for these species to regenerate after long-term farming, while it is easy for short-lived seeds to disappear from seed bank (Middleton, 1999). Seeds of many sedges are long-lived, so they might be able

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to remain viable in the seed bank of sedge meadow for extended periods, but for certain species viability was lost in <3 years (Leck and Schütz, 2005). Schütz (2000) reported that the longevity for 10 *Carex* species could be estimated from seed bank studies and was at least 10 years, while van der Valk et al. (1999) found that the viability of three *Carex* species dropped to 1% to 7% after only twelve months. A study in prairie potholes wetland indicated that wetland species were maintained in seed banks despite farming, but that the density of some species decreased over time, especially if farming continued for more than 20 years (Wienhold and van der Valk, 1989). Another study found that sedge meadow species failed to recolonize in farmland cropped for decades via natural recolonization in prairie pothole wetlands (Mulhouse and Galatowitsch, 2003). Similarly, dominant woody species with short-lived seeds such as *Taxodium distichum* and *Nyssa aquatica* were poorly represented in the seed banks of both farmed and intact fields in baldcypress swamps in the southeastern United States, which made these floodplain wetlands difficult to restore via natural recolonization (Middleton, 2003).

In 1998 to protect wetlands, the Heilongjiang Provincial Government suspended wetland development to prevent further conversion to farmland; this edict was reinforced in June 2003 with the provincial adoption of the regulation on wetland conservation (Li, 2008). This province developed plans for wetland restoration of >150,000 ha of farmland in the Sanjiang Plain, and their forestry department began implementation of the restoration program.

The Sanjiang Plain, located east of Heilongjiang Province in northeastern China, is an alluvial floodplain that includes one of the largest freshwater wetland areas in China (Zhao, 1999). In the past 50 years, wetlands have been extensively drained and used for agriculture in the Sanjiang Plain. In 1954, wetlands covered over half of the total land area but have decreased by 77% during the past 50 years (Wang et al., 2011). Dry farmland is the main traditional agricultural type in Sanjiang Plain, and soybean (*Glycine max*) is the main crop. To the dual effects of the technology development and the restriction of the economic factors, large amounts of dry farmlands have been converted to paddy fields since the early 1980s (Liu et al., 2001). We asked the following research questions: (1) How does the composition of seed banks change among the three management types (soybean fields, paddy fields and natural sedge meadows)? (2) How does the seed bank structure change as the length of time of farming increased and what is the value of farmed seed banks for restoring the vegetation of sedge meadow? (3) Which environmental factors influence the composition of seed banks in these sedge meadows, and soybean and paddy fields?

2. Materials and methods

2.1. Study site

Study sites are in Nongjiang River watershed, which is 14.8% of the area of Sanjiang Plain. Nongjiang River basin is located in the confluence of the Songhua, Heilongjiang and Wusuli Rivers in a vast alluvial floodplain. In the year of 1954, wetland covered more than 72% of this area (1,058,364 hm^2). Large-scale wetlands have been reclaimed for soybeans since 1950s (Zhao, 1999). The transformation of agriculture type occurred from 1990 to 2010 in Nongjiang River watershed, and the characteristic of the landscape pattern change was that large amounts of soybean fields were converted to paddy fields during this periods. The areas of soybean fields and paddy fields reached 764,391 hm^2 and 303,973 hm^2 respectively, and wetlands covered less than 12% of this area (200,186 hm^2) in the year of 2005 (Xue et al., 2012). The transformation of the Sanjiang Plain for grain production was achieved at considerable cost to the environment. Construction of immense networks of drainage channels, pumping stations, and flood control dikes have destroyed millions of hectares of peatland, further altering the water cycle of entire watersheds and destroying wetland biodiversity (Zhao, 1999).

In this study, the seed banks of the soybean fields, paddy fields and intact sedge meadows were compared throughout the reach of the Nongjiang River (Fig. 1), where sedge meadows are concentrated in Heilongjiang Province near the southern edge of the sub-arctic zone. We sampled soybean fields, which had been converted from sedge meadows for various periods of time (1–30 years), and paddy fields which had been converted from soybean fields for various periods of time (1–30 years). Soybean and paddy fields are usually tilled at the end of May and harvested in October. Along with these farm fields, adjacent sedge meadows that were still unconverted also were sampled. We also sampled one soybean field, one paddy field and three intact sedge meadows at the

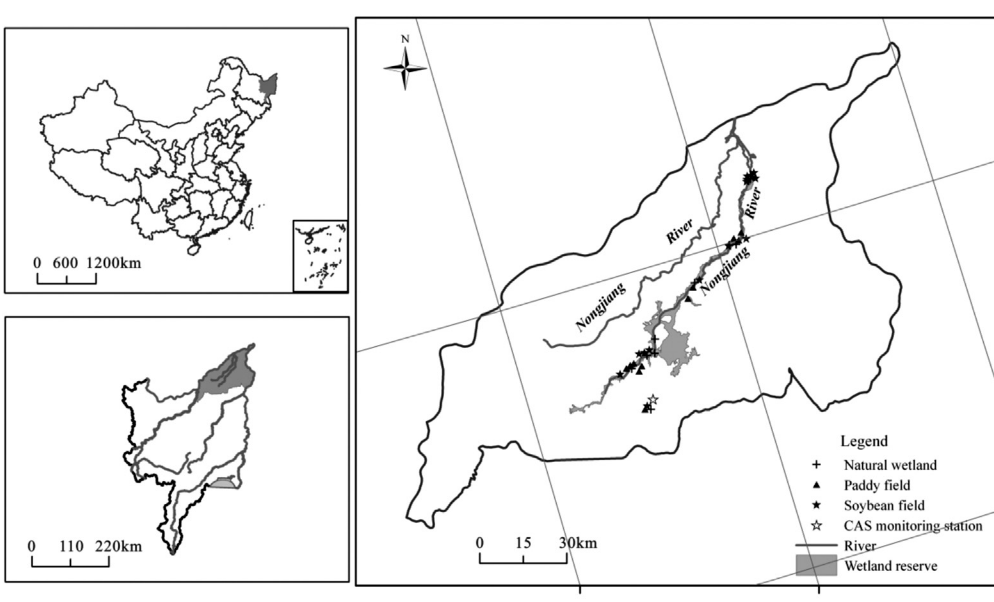

Fig. 1. Site locations for seed bank samples locations along the Nongjiang River, Sanjiang Plain, China.