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Characterizing the spatial pattern of marshlands in the Sanjiang Plain, Northeast China

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ABSTRACT

Over the past three decades, the marshlands in Northeast China's Sanjiang Plain have undergone dramatic loss and fragmentation. This study has analyzed the loss area and pattern of these marshlands for the period 1982–2010 using remote sensing data. The marshlands area decreased 786.69×10^3 ha until 2010. The landscape pattern changes of the marshlands and other land use types were analyzed spatiotemporally for the years of 1982, 2000 and 2010. Results showed that during the period from 1982 to 2010, the gravity center of marshlands migrated 0.2170° southward, then again 0.0848° eastward, moving it a total of 25002.59 m. Spatial distribution of the marshlands continually migrated southeastward which was influenced by the landscape characteristics, such as the location of the marshlands in the watershed, geomorphology, and anthropogenic/natural causes, such as the intensity of agricultural development, population and climatic change. The southern and northern marshlands loss rates were very different between 1982–2000 and 2000–2010. The reclamation intensity of cultivated regions in central parts inclined to north of the Sanjiang Plain had been strengthened again, and the reclamation ratio changed from less than 0.5 to nearly 0.8 even to 1 when comparing 1982–2000 with 2000–2010. Increasing air temperature would otherwise have enhanced grain yields and stimulated marshlands conversion into croplands.

1. Introduction

It is well known that wetlands are an important component of the terrestrial landscape, performing such significant ecosystem services as climate regulation, flood storage, water supply and biodiversity conservation (Costanza et al., 1997; Mitsch and Gosselink, 2000). Loss or degradation of wetland habitats can result in loss of biodiversity (Cushman, 2005), reduction in water supplies and water storage (Finlayson and Rea, 1999; Kingsford, 2000), increased soil erosion (Lee et al., 2006). Additionally, wetlands conversion for industrial and agricultural purposes has directly or indirectly contributed to an increase in atmospheric concentrations of major greenhouse gases (GHG) (Yan et al., 2008; Liu et al., 2010).

Recently, wetlands worldwide have been among the fastest of any ecosystem type to show loss rates (Balmford et al., 2002). Unfortunately, precisely complete wetlands loss data cannot be acquired because of the different definitions and techniques employed by the various assessments. In a generalized overview, the organization of economic cooperation and development (OECD/IUCN, 1996) estimates that the world may have lost 50% of its wetlands since 1900, and land conversion for agriculture is the principal cause. Increasing human land use has put wetlands at risk. Once thought to be wastelands, wetlands have been extensively drained for economic development. Direct land conversion for agricultural drainage, forestry, as well as urban construction have all caused the degradation and even the destruction of wetlands (Spaling, 1995; Mensing et al., 1998). Thus, further research is needed to produce more sustainable socio-ecosystems (Turner, 2010). Restoration actions that enhance both biodiversity and ecosystem services are necessary worldwide (Foley et al., 2005, 2011; Bullock et al., 2011). The key premise is to clarify the dynamic pattern of marshlands changes and the disturbing causes.

In geography, marshland is a type of wetlands frequently or continually inundated with water, characterized by emergent soft-stemmed vegetation adapted to saturated soil conditions. There are many different kinds of marshes, ranging from the prairie potholes

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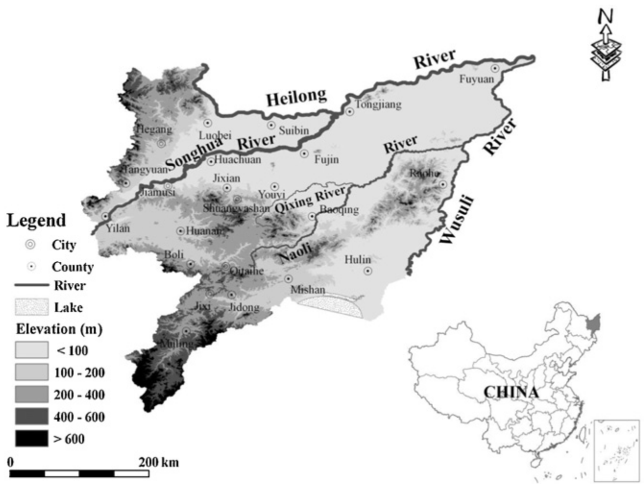

Fig. 1. Location of the Sanjiang Plain, northeast China.

to the Everglades, coastal to inland, and freshwater to saltwater. All varieties of marshlands receive most of their water from surface water, and many are fed by groundwater (United States Environmental Protection Agency, 2009). According to the Ramsar Classification System for Wetland Types (The Ramsar Convention on Wetlands, 2009) and the China Wetland Classification System (Lu, 2008), wetlands in the Sanjiang Plain are classified as rivers, lakes, marshlands, and paddy fields. This paper focuses only on marshlands and paddy fields, but does not address other wetland types.

Many studies have investigated marshlands loss and landscape changes in some portions of the Sanjiang Plain (Liu et al., 2004; Zhang et al., 2009) or over the whole region (Li et al., 2002; Wang et al., 2006). However, studies on the land use/cover change (LUCC) on the whole Sanjiang Plain after 2005 are rare (Zheng et al., 2008; Wang et al., 2011). Thus, it is necessary to examine this period. Also, there is less attention paid to the comparison of marshlands conversion into croplands over different periods. The landscape pattern indices mainly focus on the numerical comparison lack of spatial characteristics descriptions. The marshlands migration law has not been fully considered, and the spatial and temporal changes of marshlands reclamation still need to be clarified.

The objectives of this study are as follows: (1) to analyze the LUCC and fragmentation characteristics in the Sanjiang Plain from 1982 to 2010 using the landscape pattern indices; (2) characterize the gravity center migration of marshlands from 1982 to 2010 using the remote sensing data in a model environment; (3) determine the possible causes of marshlands migration and loss associated with geomorphology characteristics, agricultural development, and environmental changes, such as climate warming.

2. Geographical setting

The Sanjiang Plain (43°49′55″–48°27′40″N, 129°11′20″–135°05′26″E) is located in the northeastern part of Heilongjiang Province, China. The total plain area is 10.89×10^6 ha (Fig. 1). It is an alluvial plain deposited by the three major rivers (the Heilong River, the Wusuli River and that Songhua River) with an altitude of <200 m in most parts, in which 23 counties/cities are located. It is located in a temperate zone with a continental monsoon climate. The annual mean temperature is about 1.4–4.3 °C and the annual mean precipitation is about 500–650 mm (Wang et al., 2011). There are nine major soil types, i.e. brown soil, meadow soil, white slurry soil, marsh soil, black soil, peat soil, alluvial soil, paddy soil and sandy soil. The marsh soil types specifically include four sub-categories: peat marsh soil, humus marsh soil, mire soil and meadow marsh soil (Liu and Ma, 2002; Wang et al., 2003; China Soil Scientific Database, 2004). *Carex lasiocarpa* and *Calamagrostis angustifolia* are dominant and the coverage is up to 80–90% (Ji, 2004). Other plant communities mainly include *Quercus mongolica*, *Populus davidiana*–*Betula platyphylla*–*Q. mongolica*, *C. angustifolia* meadow and *Betule fruticosa*–Miscellaneous meadow (Yi and Niu, 1996). Agricultural reclamation is the main utilization mode of marshlands resource in the Sanjiang Plain. In the 1940s, more than 5.0×10^6 ha of marshlands existed (Liu and Ma, 2002). Land use practices significantly changed the original land cover, and the area experienced extensive reclamation prior to the mid-1980s that resulted in rapid loss of marshlands area. Agricultural development activities had made converted large amount of marshlands into croplands in this region.

3. Methods

3.1. Data sources

ERDAS 8.5 image processing software and ArcGIS 9.2 software were used for data processing. Albers equal area conic projection system integrated different spatial data. Data on acreage and fragmentation of marshlands and other land use types during 1982–2010 were acquired from remote sensing data. Land use information from 1982, 1995, 2000 and 2005 were acquired from the Institute of Remote Sensing and Geographic Information Research Center, Northeast Institute of Geography and Agricultural Ecology (http://marsh.neigae.csdb.cn/), and data from 2010 were acquired from 12 images of landsat thematic mapper (TM) remote-sensing data with a resolution of 30 m. These landsat TM images were accessed from the EarthExplorer Interface (http://edcsns17.cr.usgs.gov/EarthExplorer/) and digitized by visual interpretation technology at the GIS software environment in ArcGIS 9.2. Remote sensing images recorded from June to October were selected because land use types are easy to identify during this period, when plants grow actively in Northeast China. The accurate land use maps were successfully extracted with the detailed spatial distributions of land use types and their areas in the Sanjiang Plain.

Geomorphology data derived from 1:200 000 geomorphology map from the Northeast Institute of Geography and Agricultural Ecology. DEM (Digital Elevation Model) data with 90 m resolution was produced by the National Aeronautics and Space Administration (NASA) and the US Geological Survey (USGS) (http://srtm.csi.cgiar.org/).

The total people and grain yields data derived from the Statistical Bureau of Heilongjiang Province (1983, 1996, 2001, 2006 and 2011). The annual mean temperature and annual precipitation data derived from Reclamation Statistical Bureau of Heilongjiang Province (1978–1988, 1996, 2001, 2006 and 2011).

3.2. Data analyses

3.2.1. Patch metrics and landscape metrics indices

In this study, four indices were selected: patch density (PD), mean patch size (MPS), fractal dimension index (FD) and Shannon's diversity index (H) (McGarigal and Marks, 1995).

PD means number of patches per one kilometer, it was calculated by:

$$PD = \frac{N}{A} \tag{1}$$