Conversion between natural wetlands and farmland in the Tumen river basin: A multiscale geospatial analysis

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Abstract: Wetlands play an irreplaceable role in ecosystems, with ecological functions such as water conservation, flood prevention, biodiversity conservation, and carbon sequestration. At present, wetlands are facing severe shrinkage, especially natural wetlands. Agricultural activities are widely believed to be the main driver of natural wetland loss in many parts of the world. However, little is known about the temporal and spatial patterns of conversion between natural wetlands and farmland in Tumen River Basin (TRB). This information deficiency limits the decision-making of sustainable management of natural wetland ecosystems. TRB in the territory of China was selected as the study site, and establishes a suitable wetland classification system based on the geographical features of the region. Furthermore, Landsat data for four periods (1986-2016) were acquired from NASA and the object-oriented classification method was used to classify the landuse type and wetland type in the study site. To improve the classification accuracy, the post classification with visual interpretation was implemented. The characteristics of spatio-temporal distribution, the conversion between natural wetlands and farmland in the study period, and its driving force was derived. The main findings of this study are as follows: 1) Natural wetlands decreased by 65.12% (16,590.80 ha) from 1986 to 2016 in TRB and, of which 45.43% (7536.93 ha) occurred at the period between 1986 and 1996. It is considered that wetland loss strongly influenced by agricultural encroachment of food production; 2) In terms of the conversion between natural wetland and farmland, dry land occupies 72.30% (11994.38 ha) of the total area, and paddy fields only at 27.70% (4596.42 ha); 3) On the sub-basin scale, natural wetlands converted to farmland is the biggest portion in the Gaya River Basin (4533.79 ha),which is 27.33% in the past 30 years. While a range of national policies and population pressures have led to agricultural invasions of natural wetlands, there are also policies and management measures to protect and restore natural wetlands. The spatial differences in natural wetland-farm conversion between different watersheds indicate that governments must develop local-based sustainable management policies and natural wetland planning. This study provides the necessary important scientific information for the development of such policies and implementation plans.

1. Introduction

Wetland is an important part of the Earth's ecological environment, it is considered the most important ecosystem with forest and ocean in the word. Wetland not only provides a large amount of food, raw materials and water resources for human beings, but also plays an irreplaceable role in maintaining ecological balance, regulating climate, maintaining biodiversity and cherishing species resources, flood storage and drought prevention, water conservation, pollution, etc. (Meng et al., 2017). As the main target of agricultural development, wetland provides water source support for agricultural production (Zhou et al., 2018). However, in the face of an increasing population, agriculture and wetland resources have formed corresponding contradictions (Rebelo et al., 2009). The growing population is increasingly demanding food, so large-scale development of wetland agriculture is also. This has resulted in a constant loss of wetland area (Reis et al., 2017). Unreasonable use of wetlands undermines the development of wetland ecosystems (Neff et al., 2009), resulting in the inability of wetland ecological functions to function properly. Most unscientific traditional agricultural development models do not destroy the wetland environment and prevent wetlands from playing. Out of your own advantages. The Tumen River system is one of the important international rivers in China. It is located at the junction of China, the DPRK and Russia. The ecosystem in this region occupies a central position in the ecological network of Northeast Asia and has a diverse range of wetland ecosystems (Yu et al., 2018.). Furthermore, TRB is an important grain producing area in the Northeast China, and it is widely believed that large-scale farmland expansion from natural wetland (Niu et al., 2009). but there are knowledge gaps exist in mapping and quantifying agricultural erosion of natural wetlands, so it is difficult to determine how much of the farmland is converted from natural wetland. In addition, we know very little about the spatiotemporal patterns of natural wetland reclamation or restoration. This information deficiency limits spatially explicit decision making for wetland conservation and restoration (Wang et al., 2012; Reis et al., 2017). Remote sensing can help us describe the current state of land cover and determine changes in the land surface by using time series data (Ozesmi et al., 2002; Tian et al., 2017). These advantages make remote sensing the best way to identify transitions between different land cover categories. Using remote sensing method to analyze the transition mode and process between natural wetland and farmland in TRB will help relevant departments to formulate sustainable development policy of wetland. (Nguyen et al., 2017).

In this study, the spatiao-temporal patterns of agricultural encroachment on natural wetlands and restoration from farmland to natural wetlands in TRB from 1986 to 2016 were analyzed. Specifically, this study aims to reveal the hot spots of these transitions and to study the ways in which these transitions can be made to make recommendations for sustainable wetland management.

2. Materials and methods

2.1 Study site

The TRB in territory of China located in the Yanbian Korean Autonomous Prefecture in the southeast of Jilin Province, China. It borders Russia and North Korea and geographical range is 42° 42'55"-42° 14'54" N, 130° 15'49"-130° 52'20"E. The overall climate of the region is characterized by rainy and humid, with little rain and drought in spring and autumn, rainy and humid in summer and winter, and vertical changes in climate, in July and August. The average temperature ranges from 22 °C to 25 °C in summer. The TRB is rich in water system and has good economic benefits. The Tumen River originates from the east side of the main peak of the Changbai Mountain Range, which is on the Chinese side. There are mainly 11 sub-basins, namely Guangpinggou Basin, Hongqi River Basin, Liudong River Basin, Hailanjiang River Basin, Yueqinggou River Basin, Buerhatong River Basin, Gaya River Basin, Shitou River Basin, Mijiang River Basin. The Hunchun River Basin and the Jingxinquan River Basin. Wetland in TRB has various types, and TRB is also distributed with amur tiger, red-crowned crane and other endangered species in the world. It is not only an important ecological functional area in China, but also a pilot area of the national park system. Furthermore, it is also the core area of the ecological network in northeast Asia.

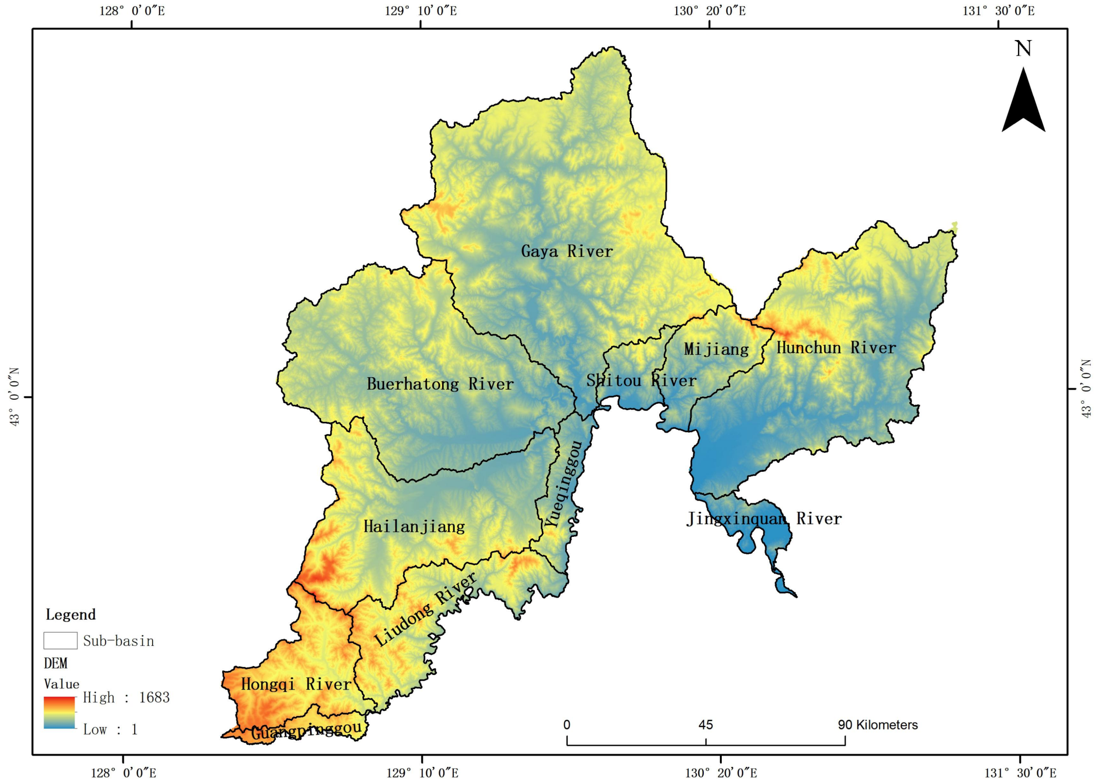

Fig.1. Study area

2.2 data source

Landsat remote sensing images, digital elevation models (DEM) maps of 1986, 1996, 2006, and 2016 were used in this study, and wetland plaque layer data, forest facies maps, and water system maps provided by various forestry bureaus.

2.3 Data Analysis

In this study, the classification of natural wetlands and farmland was carried out by using object-oriented classification method combined with human-computer interaction classification method, combined with wetland plaque layer data, forest phase map and 478 sampling points provided by various forestry bureaus to improve classification accuracy. The changes were quantified by crossing natural wetlands and farmland layers in ArcGIS software (ESRI version 10.3). Conversion matrix analysis is used to calculate the area of conversion between natural wetlands and farmland. The transition regions within each sub-basin are then mapped to record spatial patterns and hotspot regions. In order to better understand the patterns and processes of conversion between natural wetlands and farmland, this study quantifies the areas where natural wetlands in each sub-basin are affected by crop cultivation and the three periods from

1986-1996, 1996-2006 and 2006-2016. Restore the area of natural wetlands. Specifically, this study compared the spatial variation of geographic areas and also calculated the encroachment and recovery of dry farmland and paddy fields.

In addition, the 2011 Yanbian Prefecture Statistical Yearbook related to agricultural development and wetland conservation policies and related statistical data sets, including total food production, agricultural gross domestic product (GDP) and total population, are also summarized. Time changes in policy and statistical data sets are used to discuss the driving forces that control the transition between natural wetlands and farmland. Finally, management recommendations were made based on the results and discussions.

3. Results

3.1 Distribution of natural wetlands and farmland in TRB from 1986 to 2016

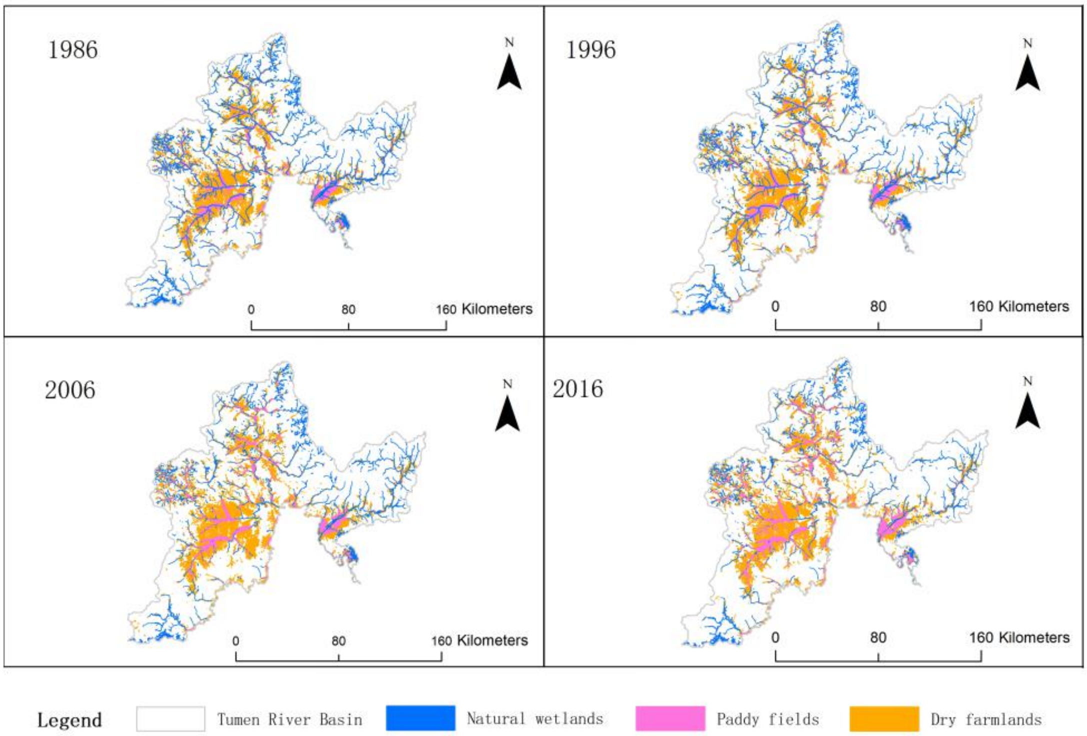

Fig.2. Spatial distribution of TRB's natural wetlands and farmland from 1986 to 2016.

The object-use classification method is combined with the human-computer interaction classification method to extract the land use information of natural wetlands and farmland. Natural wetlands includes forest swamps, shrub swamps, herb swamps, rivers and lakes; farmland dry farmland and paddy field. The ArcGIS intersecting module was used to superimpose the results of land use classification and the wetland classification obtained in the previous period, and finally obtained the spatial distribution of natural wetlands and farmland in the TRB from 1986 to 2016 (Fig. 2).

As shown in Figure 2, the natural wetlands and farmland in the TRB from 1986 to 2016 were mainly distributed in the middle reaches and showed a decreasing trend. Specifically, the area of natural wetlands decreased significantly. In 1986 (55474.53 ha) - 1996 (49180.41 ha) reduced by 6294.12 ha, in 1996 (49180.41 ha) - 2006 (43948.35 ha) decreased by 5232.06 ha, in 2006 (43948.35 ha) - 2016 (41294.51 ha) decreased by 2654.84 ha; farmland area decreased slightly, 1986 (308,410.88 ha) - 1996 (305,715.91 ha) decreased by 2,694.97 ha, in 1996 (305,715.91 ha) - 2006 (303,821.50 ha) decreased by 1,984.41 ha, in 2006 (303,821.50 ha) - 2016 (302,650.39 ha) decreased by 1171.11 ha.

3.2 Geospatial changes in agricultural intrusion into natural wetlands

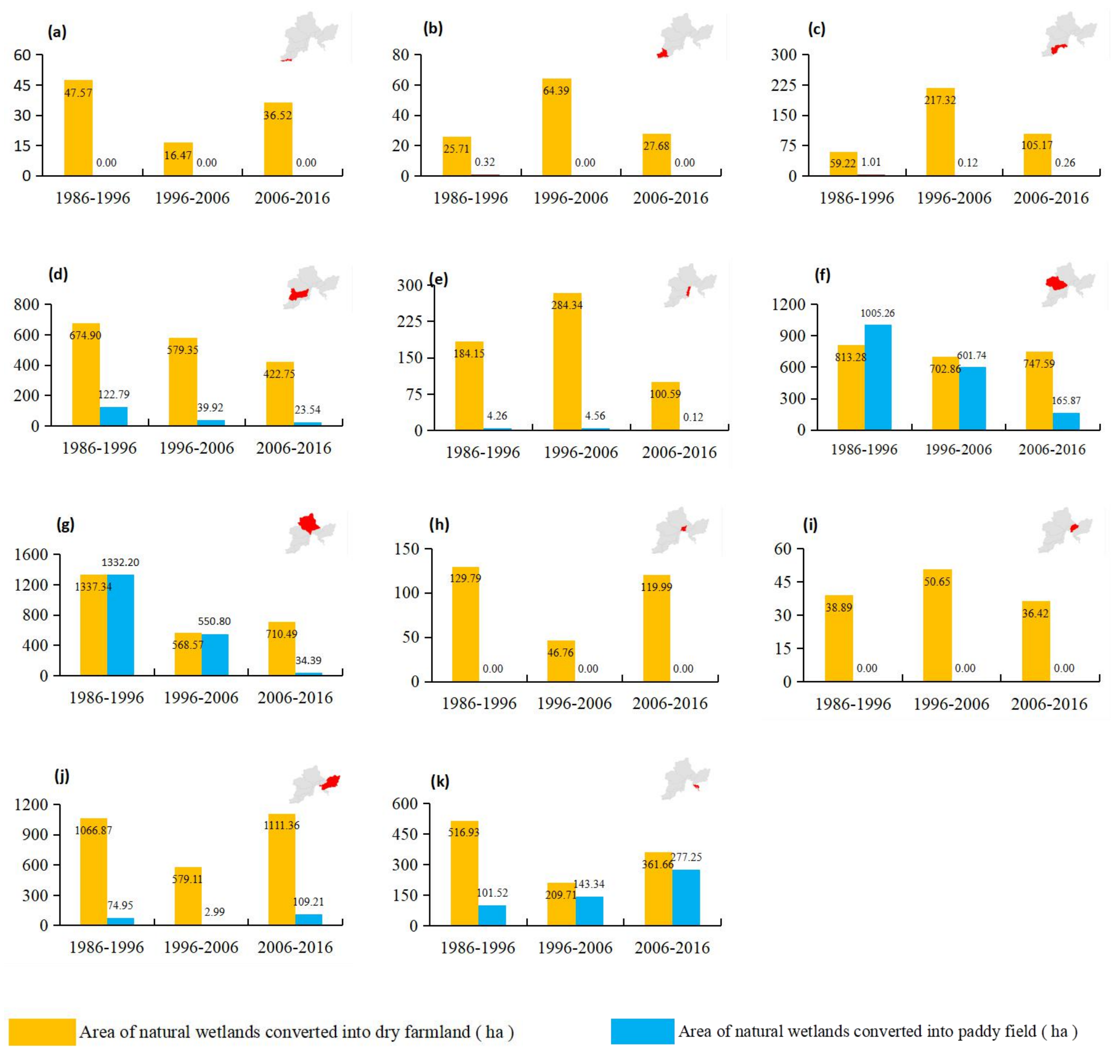

Fig.3. Spatiotemporal variation in the amount of natural wetland lost to farmland (ha) among the sub-basin in TRB: (a)Guangpinggou, (b) Guangpinggou, (c) LiudongRiver, (d) Hailanjiangjiang, (e) Yueqinggou, (f) Buerhatong River,(g)Gaya River,(h)Shitou River,(i)Mijiang,(j)Hunchun River,(k)Jingxinquan River.

As we can see in Figure 3, the Gaya River Basin (4533.79 ha , 27.33%) is the highest natural wetland decline (16590.80 ha) caused by agricultural encroachment, followed by the Buerhatong River Basin (4036.60 ha , 24.33%), Hunchun River Basin (2944.49 ha , 17.75%) and the Hailanjiang River basin (1863.25 ha ,11.23%). The natural erosion of 0.61% (100.56 ha) in the Guangpinggou watershed, 0.71% (118.09 ha) in the Hongqi River Basin and 0.76% (125.96 ha) in the Mijiang River Basin is less than 1%. Specifically, the eroded natural wetlands were mainly reclaimed as dry farmland (11994.38 ha , 72.30%), of which 22.99% occurred in the Hunchun River Basin (2757.34 ha), and 21.81% occurred in the Gaya River Basin (2616.40 ha), 18.87 % occurred in the Buerhatong River Basin (2263.73 ha). The conversion of natural wetlands to paddy fields (4596.42 ha) is mainly in the Gaya River Basin (1917.38 ha, 41.71%) and the Buerhatong River Basin (1772.87 ha, 38.57%). In the Hongqi River Basin (0.32 ha) and the Liudong River Basin (1.39 ha), almost no natural wetlands have been transformed into water paddy fields, while no natural wetlands have been converted into water paddy fields in the Guangpinggou, Shitou River and Mijiang river basins.

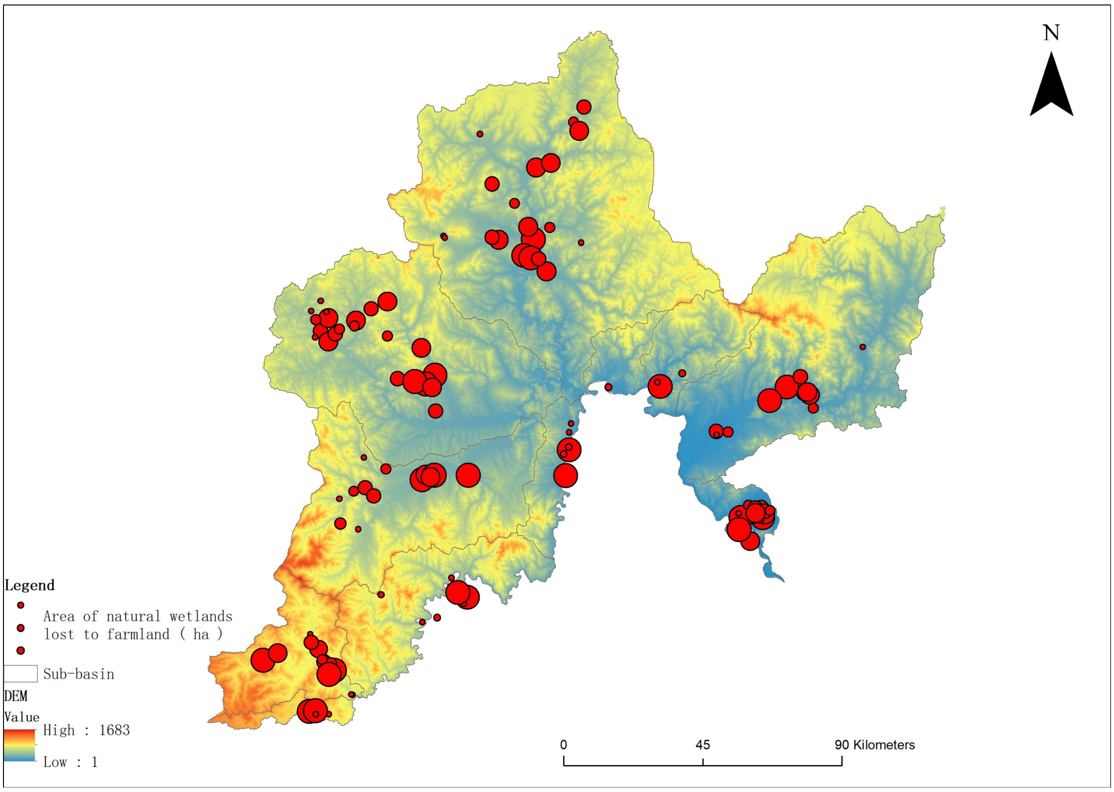

Fig.4. Spatial pattern of natural wetlands reclaimed to farmland (Bigger points denote larger areas of natural wetlands cultivated to farmland within a sub-basin).

Figure 4 shows that the natural wetlands converted to farmland are concentrated in the lower reaches of the Tumen River, scattered in the middle and upstream of the Tumen River. Between 1986 and 2016, a total of 16,590.80 ha of natural wetlands were destrGaya due to crop cultivation, including 45.43% (7536.93 ha) in the first decade and 28.11% (4662.99 ha) in the second decade. 26.46 (4390.88 ha) occurred in three decades. From 1986 to 2016, agricultural encroachment caused a 65.12% reduction in the natural wetland area of the TRB. The loss rate of natural wetlands caused by agricultural encroachment from 1986 to 1996 (753.69 ha/year) was twice that of 1996-2006 (466.30 ha/year) and 2006-2016 (439.09 ha/year).

3.3 Temporal and spatial changes in the return of farmland natural wetlands

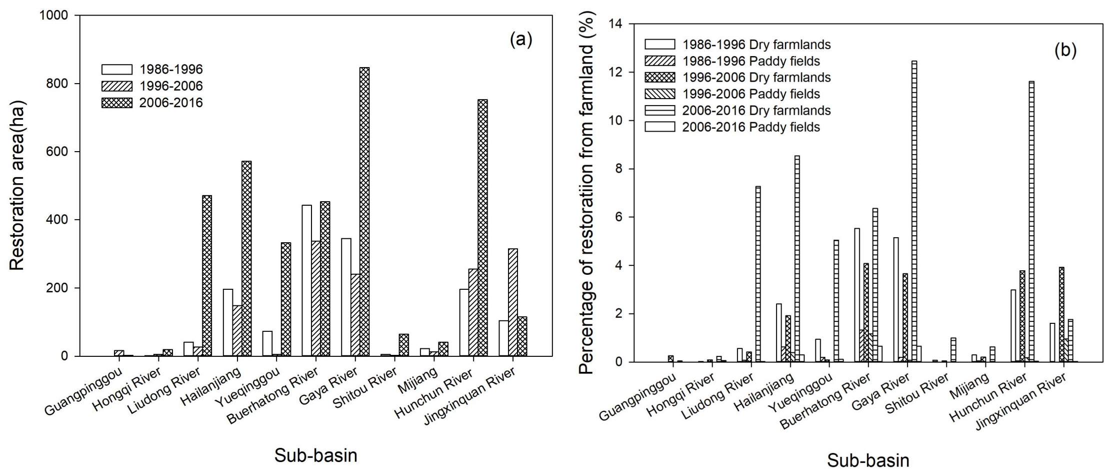

Fig.5. Spatio-temporal variation in the area of natural wetlands restored from farmland (a) and in the percentage of natural wetlands restored from farmland among different sub-basin.

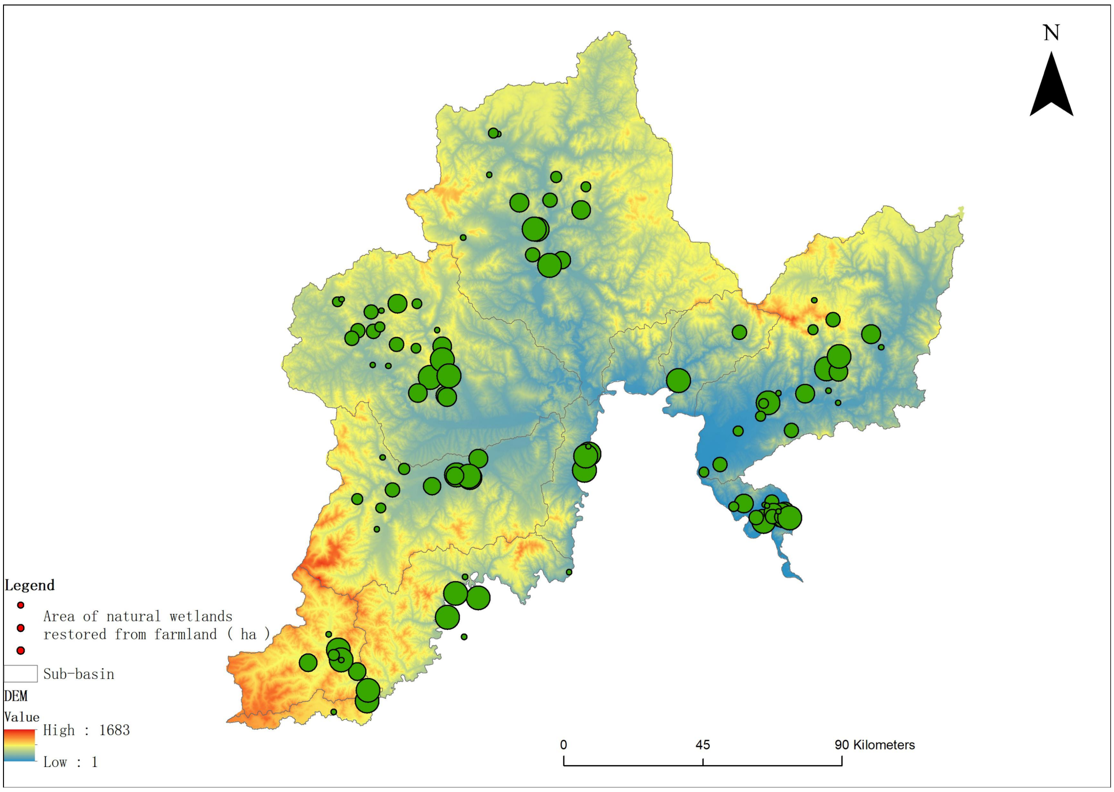

Fig.6. Spatial pattern of natural wetlands restored from farmland (Bigger points denote larger areas of natural wetlands restored from farmland within a Sub-basin).

As shown in Figure 5a, during the 30 years of observation, there are five sub-basins with larger natural wetlands recovered from farmland, including the Gaya River Basin (1433.01 ha , 22.17%) and the Buerhatong River Basin (1233.54 ha , 19.09%), Hunchun River Basin (1204.36 ha , 18.64%), Hailanjiang River Basin (916.26 ha , 14.18%) and Liudong River Basin. As shown in Figure 5b, in the remaining sub-basin, there are four sub-basin recovery areas below 2%, namely the Mijiang River Basin (75.90 ha, 1.17%) and the Shitou River Basin (71.04 ha , 1.10%). Hongqi River Basin (26.02 ha, 0.40%) and Guangpinggou Basin (19.02 ha, 0.29%). As shown in Figure 6, the natural wetlands recovered from farmland are mainly concentrated in the middle reaches of the Tumen River. In this basin, 4,412.04 ha of natural wetlands are recovered from the farmland, accounting for 64.07% of the total recovery of the TRB.

4. Discussion

4.1 Remote sensing based natural wetland and farmland location

As the result, agricultural encroachment caused 65.12% of the total reduction of natural wetlands in the TRB from 1986 to 2016. The findings support previous conclusions that agricultural activities are the most important proximate cause of natural wetland transformation (Asselen et al., 2013). In this study, the temporal and spatial variations of these transformations at multiple scales were determined. Although the patterns and processes of conversion between natural wetlands and farmland are now known, the underlying drivers of these transformations need to be understood in order to sustainably manage the natural wetland ecosystems in the TRB.

4.2 Potential drivers of conversion between natural wetlands and farmland

The area of farmland converted to natural wetland by 3669.49 ha between 2006 and 2016, and it is the maximum proportion in the past 30 years. It is considered that the central government increased subsidies for forestry to support the work of returning farmland to natural wetland, compensating for the ecological benefits of wetlands, and rewarding wetland conservation.

4.3 Management significance of natural wetlands

Although the intensity of natural wetland reclamation has been weakened during the study period and the restoration of farmland natural wetlands has been strengthened, there is an urgent need to promote sustainable and spatial change management of natural wetlands in TRB. During the study period, the area of natural wetlands recovered from farmland was 6646.43 ha, accounting for only 38.95% of the natural wetland losses caused by crop cultivation. Specifically, the goal of the Gaya River Basin should be to restore more natural wetlands. More and more natural wetland restoration projects should be carried out in this geographical area, as the area of natural wetlands recovered from farmland (1433.01 ha) is much smaller than the area occupied by the agricultural wetlands in the TRB (4533.79 ha).

5. Conclusion

Wetlands play an irreplaceable role in ecosystems, but the growing population is increasingly demanding food, so a big portion of wetland were developed by farmland in TRB, and it causes natural wetland loss. For investigating the conversion between natural wetland and farmland, Landsat data were used, and a multiscale analysis was implemented. After the results were compared and discussed, the following conclusions were derived.

1) Natural wetlands decreased by 65.12% (16,590.80 ha) from 1986 to 2016 in TRB and, of which 45.43% (7536.93 ha) occurred at the period between 1986 and 1996. It is considered that wetland loss strongly influenced by agricultural encroachment of food production;

2) In terms of the conversion type, dry land occupies 72.30% (11994.38 ha) of the total area, and paddy fields only at 27.70% (4596.42 ha);

3) On the sub-basin scale, natural wetlands converted to farmland is the biggest portion in the Gaya River Basin (4533.79 ha), which is 27.33% in the past 30 years.

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