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Changes in Crop Layout, Effects on Farmland Nutrient Balance: A Case Study in The West Liaohe River Basin, China

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Abstract: Estimating regional soils Nitrogen and phosphorus balance in cropland is essential to improve management practices, reduce environmental risks and develop sustainable agriculture. In this study,spatial and temporal variations in crop layout, the impact on soil N and P nutrient balance were assessed from 2000 to 2015 in the West Liaohe River Basin between 2000 and 2015. The result shows that the area of cropland is on the rise, and the spatial distribution of arable land is consistent with the distribution of the main tributaries of the West Liaohe River basin. The change in planting layout for maize and soybeans has a significant impact on the nutrient balance of farmland, which plays a critical role in modifying surplus nutrients. Nutrient surpluses on farmland were mostly concentrated in areas where maize planting layout changed between 2000 and 2015. The N nutrient surplus rate decreased by 39.3%, N utilization efficiency, increased by 70.7%; P nutrient surplus rate decreased by 3.8%, and P utilization efficiency increased by 49.3%. The average utilization efficiencies of N and P nutrients were 27.8% and 9.1%, respectively, and the utilization efficiency was low. Chemical manure is the main source of nutrients. The risk of phosphorus pollution was higher than the risk of nitrogen pollution in the West Liaohe River Basin. The lower Liaohe River Basin (below the Sujiapu) was the region with the most violent changes in nitrogen and phosphorus nutrient balance. It is recommended that reduce the amount of chemical fertilizer application, especially, reduce the amount of P application, improve the efficiency of nutrient use, and focus on strengthening pollution control in key areas such as the West Liaohe River lower reaches basin (below Sujiabao), reducing the risk of agricultural nonpoint source pollution.

Keywords: Crop layout; Nutrient balance; Chemical fertilizer; Nutrient surpluses; Nutrient use efficiency

1. Introduction

Protecting cropland and improving its quality is the basis for global food security and sustainable agricultural development [1,2]. In order to promote crop growth and increase crop yields, the use of chemical fertilizer has become the main means of stable agricultural production [3]. Since the 1980s, agricultural production in China has increasingly depended on the use of chemical fertilizers [4,5,6]. In 2014, the consumption of total chemical fertilizer in China accounted for 31% of the world's total [7]. The large use of chemical fertilizers has greatly increased the yield of crop. However, in the case of low use efficiency of nitrogen and phosphorus fertilizers, excessive fertilization, not only causes the waste of nutrients, but also causes serious environmental problems, such as groundwater pollution, eutrophication of surface waters,decline in biodiversity, water quality degradation, soil acidification, and increase in greenhouse gases [8].

Farmland nutrient balance is an important indicator of the degree of farmland pollution. Numerous studies have shown that farmland in most parts of China is in a N, P nutrient surplus in recent years [9,10]. Since 1980, N, P nutrient input has been greater

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than output in China. From 1980 to 2010, the surplus of N, P nutrients increased significantly, with the largest increase in Northeast China, followed by North and Northwest China [11]. soil surface, soil system, and Farm-gate are the main methods of estimate nutrient balance in agriculture systems worldwide [12,13,14]. Soil surface nutrient balance mainly calculated by the difference between nutrient input and output in agricultural systems [15,16]. At present, the data of crop area are mainly from statistical data, which is difficult to obtain and takes time and effort [17]. In order to obtain large scale, crop information quickly, accurately and timely, remote sensing crop monitoring research came into being. Numerous studies at home and abroad show that the use of MODIS data, combined with phenological information, can effectively extract crop planting layout in large regions [18,19,20]. Using GIS builds a database on agricultural nutrients, long-term monitoring of agricultural nutrients over time, a comparison of the data over several periods and a large-scale analysis of the spatial coverage and variation in space [21]. It can help relevant ministries to gather timely information on the nutritional balance of farmland and to scientifically evaluate the impact of regional nutritional status on the environment. As the basic administrative unit, the county area is also the smallest unit for agricultural policy implementation. Therefore, many domestic scholars use the county area as the smallest research unit to conduct research on farmland nutrient balance [22]. However, taking the county as a unit can only reflect the overall farmland nutrient balance status of the county,and it is not possible to determine the spatial distribution changes within the county, and it needs to be further accurately evaluated.

The Western Liaohe Plain is located in the "World Golden Maize Belt". In recent years, due to the influence of climate and policies, crop layout has changed significantly. Changes in crop planting structure, layout, etc. Are bound to have an impact on farmland nutrient balance. If N and P inputs exceed the needs of crop production, excess nutrients will accumulate in the soil and the rest will be discharged into water bodies through gas emissions and leaching and runoff, causing environmental pollution [23]. Soybean, wheat, and maize are the main food crops in the west Liaohe River Basin. Affected by Inner Mongolia's agricultural policies, the area sown by maize has been increasing in the recent years. Due to the influence of climate and policies, the crop layout of the West Liaohe River Basin has undergone significant changes. Changes in crop planting structure, layout, etc. are bound to have an impact on farmland nutrient balance [24, 25]. In this paper, we combine the advantages of remote sensing to interpret crop layout with MODIS data, construct a model of farmland nutrient balance, and building nutrient balance database based on GIS. Study the changes in crop layout, effects on Farmland Nutrient Balance in the West Liaohe River Basin

2. Materials and Methods

2.1. Study area

The West Liaohe River Basin is located at the junction of the three norths of the eastern section of the farming-pastoral ecotone in northern China [26]. The total area of the basin (41°05′N-45°12′N,116°36′E-124°34′E) is 1.36 ×105 km^2, and covers 17 county in Inner Mongolia Autonomous Region and 6 county in Hebei, Liaoning and Jilin provinces (Figure 1). The mountainous area of the basin is about 8.4×104 km^2, accounting for 61.8% of the basin area. Most of the West Liaohe River Basin water system is located in the northeastern part of the Inner Mongolia Autonomous Region, except for the source of the river, which is located in the north of the Inner Mongolia Autonomous Region and the lower reaches of the Inner Mongolia Autonomous Region. The upper reaches are mountainous areas and the lower reaches are alluvial plains. The 1st level tributaries of the West Liaohe River include the Laoha River, Xilamulun River, Jiaolai River and Xinkai River and are Divided into three sub-basins: Xilamulun River and Laoha River basin (upper reaches), Wulijimu River basin (middle reaches) and West Liaohe River lower reaches basin (below Sujiabao) (lower reaches). The basin is fanshaped, with the north, west and south sides

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being mountainous. The overall topography of the Liaohe River Plain is a gently inclined trend from west to east, with the lowest in the eastern region and an elevation of about 82 m, which is undulating. The West Liaohe River Basin is located in the continental monsoon climate zone. It is restricted by the Mongolian plateau airflow, with less precipitation and large seasonal changes [27]. It's geographical and climatic conditions are suitable for maize cultivation. The main food crops are maize, soybeans and wheat in this region.

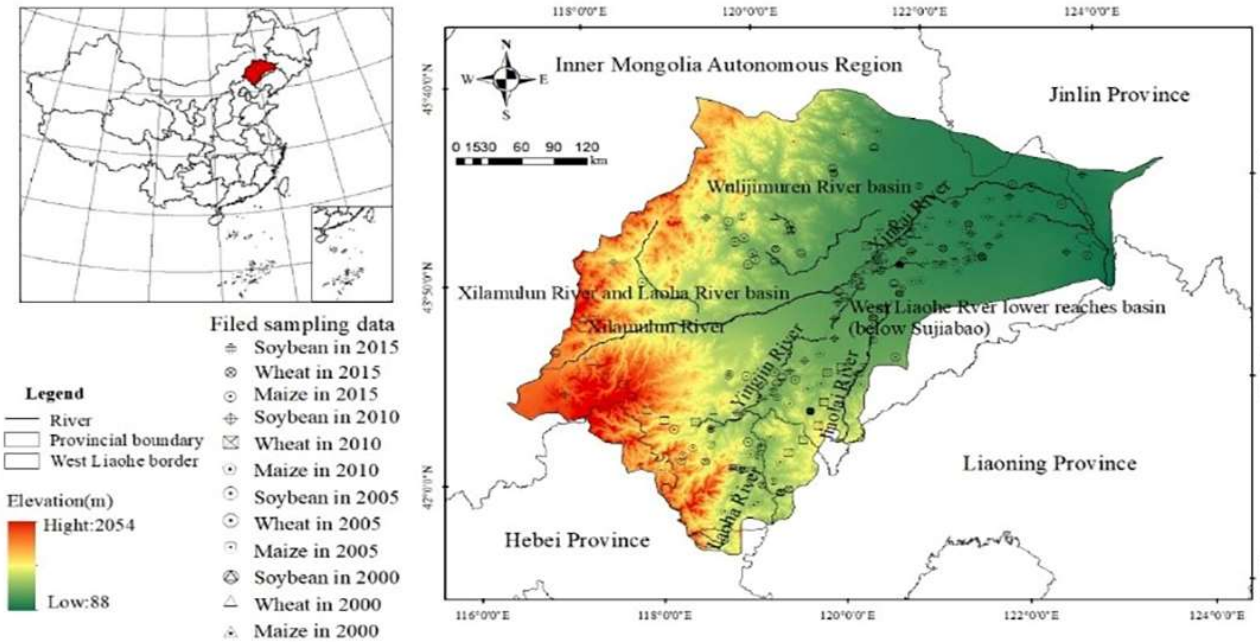

Figure 1. Location of the study area.

2.2. Data sources

2.2.1. Remotely sensed data

The remote sensing data used in this study were MOD09Q1 data [28]. MOD09Q1 is a land surface reflectance L3 product and the data are 8 day time series data at a 250 m spatial resolution for four integral years of 2000, 2005, 2010 and 2015 sourced from the National Aeronautics and Space Administration (http://modis.gsfc.nasa.gov/). MOD09Q1 data has high time resolution and rich spectral bands, which can be used to detect seasonal dynamics of NDVI in different crops [29]. This data had already undergone atmospheric correction [30]. Tile h26v04 and h27v04 were masked to cover the entire study area and projected to the Albers conical equal area projection using the Modis Reprojection Tool (MRT),the geographic coordinate system is WGS-84.The converted data is the batch cutest with the study area as the cropping frame. Calculation of the normalized vegetation index (NDVI) uses the red (RED) (620–670 nm) and near infrared (NIR) (841–875 nm) bands based on the following equation [31,32].

$$NDVI = \frac{NIR - RED}{NIR + RED}$$

Where RED is the near infrared reflectance (band 1) and NIR is the reflectance corresponding to red (band 2).

2.2.2. Crop Calendars

We have found the farm records of crops in the West Liaohe River Basin in the database provided by the Ministry of Agriculture and Rural Affairs of the Republic of China (http://www.zzys.moa.gov.cn/). In spring, maize usually sowed in early May, emerging in mid-and late May, growing rapidly from early-June to late-July, finally harvesting in mid-September. Wheat is sowed in mid-April, emerging in mid-to-late May,tillering in

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June, elongating and milking from early-July to the late-July, Grouting mature in mid-August. Soybean is normally sowed and emerged in late May, flowering from late-June to the mid-July,poding in mid-August, and harvesting in early September. The typical crop season length of all crops is about 100-120 days.

Table1. Crop calendar of the West Liaohe River Basin.

Crop	**Apr**		**May**			**Jun**			**Jul**			**Aug**			**Sep**		
	2	**3**	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**
Maize			Sowing	Emerging			Emerging-		Elongating		tasseling			Tasseling-Milking		Harvesting	
Wheat	Sowing		Sowing -Emerging				Tillering		Elongating-Milking			Harvesting					
Soybean						Sowing- Emerging			Elongating			Elongating -flowering			Poding- harvesting		

Note:1-3 representing the first ten days, middle ten days and last ten days of a month.

2.2.3. Statistical data and Field sampling data

We collected statistical yearbooks of provincial (Mongolia Autonomous Region, Hebei, Jilin and Liaoning) from 2000 to 2015, including crop planting area (spring maize, spring wheat and soybean) at the county level. We use these datasets to verify the accuracy of the remote sensing interprets the crop area. In July 2010 and July 2015, we obtained 467 GPS sampling point data of crops (soybean, wheat, maize) in the West Liaohe River Basin used as training and verification data for this study. Crop sampling points in 2010 and 2015 are determined according to the memories of farmers. If an area had planted the same crop for a continuous five years, it was a sampling point in the year 2005, and if an area had planted the same crop for a continuous ten years it was a sampling place for 2000.

2.2.4. Farmland nutrient Database

We collected 23 county-level rural population data recorded in 2000, 2005 2010 and 2015 from the National digital library of china. In July 2010 and July 2015, we interviewed separately farmers from the agricultural, pastoral, semi-agricultural and semi-pastoral area in the West Liaohe River Basin. And collected farmland nutrient data (2010,2015), including fertilizer types and amount, crop types (soybeans, wheat, maize, etc.) and yields, livestock types (pig, sheep, cattle, etc.) and amount, etc. farmland nutrient calculation data in 2000, 2005 is determined according to farmers' memories. At last, We use the farmland nutrient spatial database established by GIS to calculate N,P inputs and outputs at the Map.

2.3. Method

Fig. 2 illustrates the framework of mapping cropland, crop types using MODIS NDVI time-series data, and farmland nutrient balance model. The major steps include data collection and preprocessing, extraction of phenological features from MODIS NDVI time-series data, identification of cropland, crop types, and evaluation of the results, and Calculation of farmland nutrient balance.

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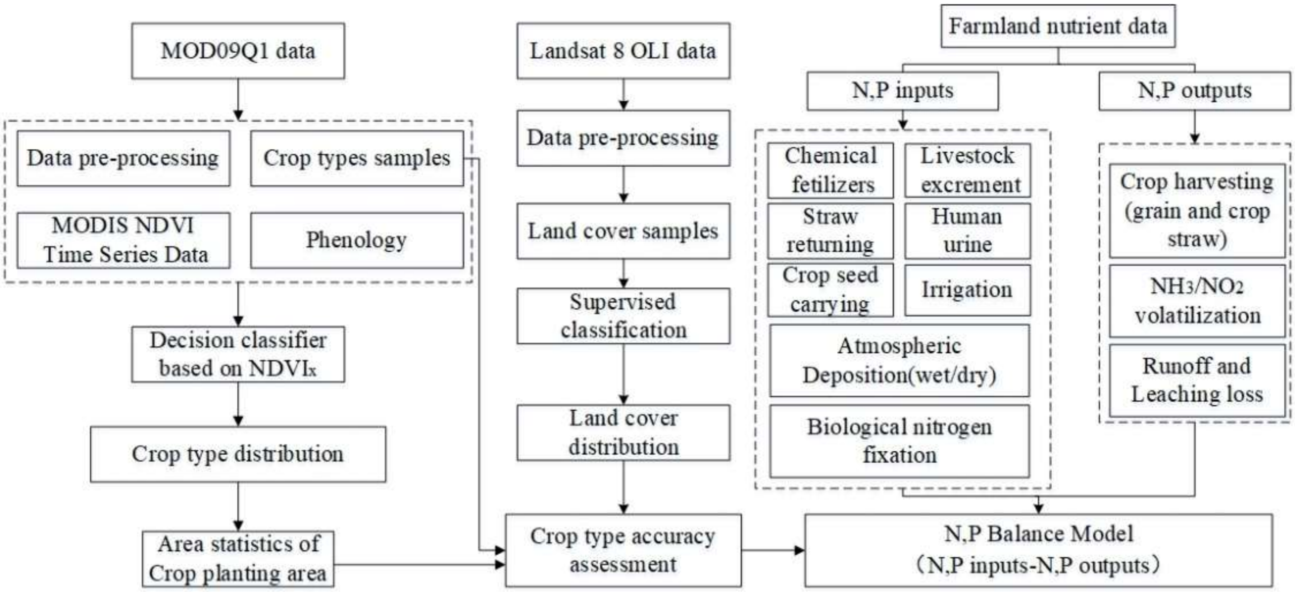

Figure 2. Framework of extracting croplands, Crop types and Farmland nutrient balance model.

2.3.1. Data collection and processing

Table 2 summarizes the datasets used in this study,including MOD09Q1 data, Landsat 8 Operational Land Imager (OLI) [33], Statistical data of crop area, GPS sampling point data of crops, Field survey data of farmland nutrient. The 8 days MODIS surface reflectance data (MODIS09Q1) with spatial resolution of 250m were used. The MO09Q1 image selected in this study needs 2 images per period to cover the West Liaohe River Basin, which are 46 images of each year. We use 4 years data, totally of 368 images. Tile h26v04 and h27v04 were mosaiced with the nearest neighbor resampling approach. The projection used is the Albers cone equal area projection,which have the minimum bias on the area calculation [34]. We use ENVI + IDL multiband batch math to calculate the vegetation index for all images, and use the Savitzky-Golay smoothing method to eliminate some small fluctuations in the temporal NDVI dataset. Finally,all images were layer stacked of each year and cover the entire study area. GPS sampling point data of crops were used as training samples for remote sensing crop recognition. Crop area statistics were used to verify the accuracy of remote sensing in identifying crop area. Farmland nutrient data are used to calculate the nutrient balance of farmland in the study area.

Table 2. Datasets used of this study.

Data	Time period	Spatial resolution	Source
MOD09Q1	2000,2005,2010,2015	250m	http://modis.gsfc.nasa.gov/
Landsat 8 OLI	2000,2005,2010,2015	30m	https://earthexplorer.usgs.gov/
GPS sampling point data of crops	2010,2015	-	Field survey in July 2010 and June 2015
Statistical data of crop area	2000,2005,2010,2015	Yearly,17 county	National Library of China , China County Statistical Year-book
Farmland nutrient data	2010,2015	-	Field survey in July 2010 and June 2015 China County Statistical Year-book

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2.3.2. Approach to mapping Crop type

Every crop type has its own characteristics in the stages of sowing, emergence, elongating, tasseling and harvest [35]. Annual NDVI time series data can clearly reflect the whole process of crop growth, the dynamic process of "elevation-reaching peak-lowering" [36]. Figure 3 illustrates the NDVI temporal profiles based on three crop types. It is worth noting that a single cropping system has only one peak stage. Spring maize is generally sown in early-May and emerged in mid-May, jointing started in late June, tasseling in mid-late July, and milk ripening and maturity in September. Spring wheat is sown in mid-April, emerged in early and mid-May,tillered and jointed in early June, eared in early July, matured and harvested in mid-August. Soybeans generally begin to sow and emerge in late May, bloom in mid-June, pod in mid-August, and mature and harvest in early September. Therefore, the NDVI values at the emergence, tasseling and maturity stages can be used to separate soybean, wheat and maize from other land types [37].

Figure 4 illustrates the strategy of using Decision tree based on three phenology features to classify crop type. According to the statistics shown in Figure 3, the following thresholds were determined:

(1) If the BGS of the crop pixel equal 129, GPK equal 217, and EGS equal 297, then the modified pixel is classified as maize

Single mode

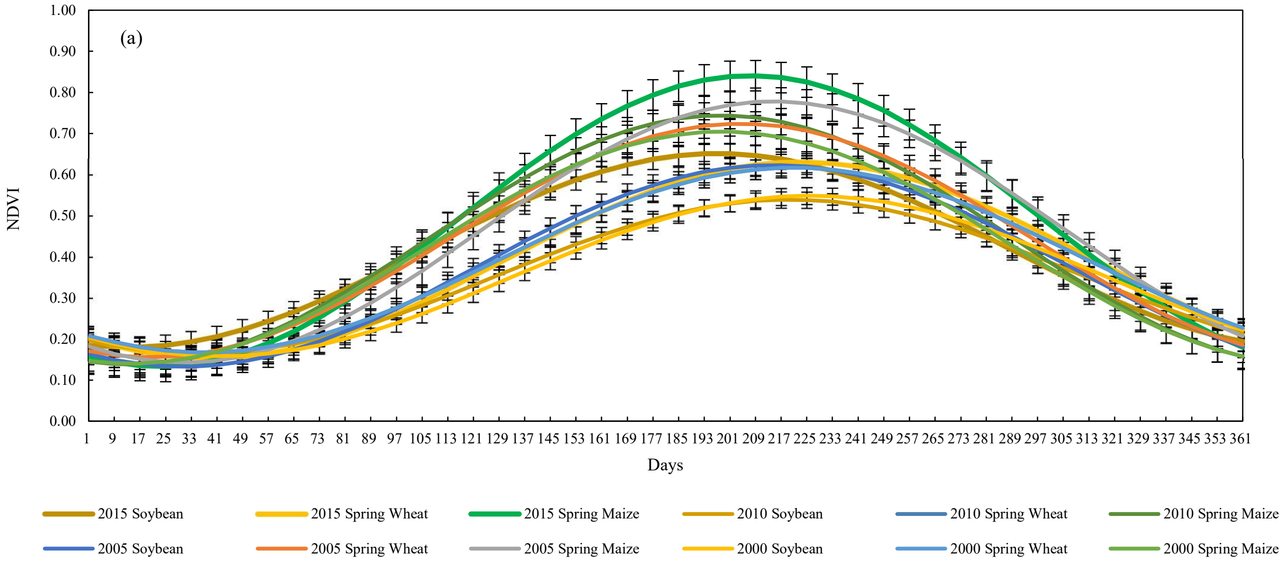
(2) If the BGS of the crop pixel equal 153, GPK equal 193, and EGS equal 353, then the modified pixel is classified as wheat

(2) If the BGS of the crop pixel equal 129, GPK equal 297, and EGS equal 217, the modified pixel is classified as soybean (Figure 3 b).

(3) T1-T9 are used to identify the NDVI thresholds of key phenological nodes (emergence, tasseling, maturity) of crops.

Min (BGS) represents the NDVI value of the crop at the seedling stage, max (GPK) represents the NDVI value of the crop during the tasseling period, and max (EGS) represents the NDVI value of the crop at maturity (See Figure 3c).

It is worth noting that the T1–T9 threshold values and BGE, EGS, GPK threshold values in the formula are different in different years and regions. Differences in crop growth caused by the phenological environment in different counties.



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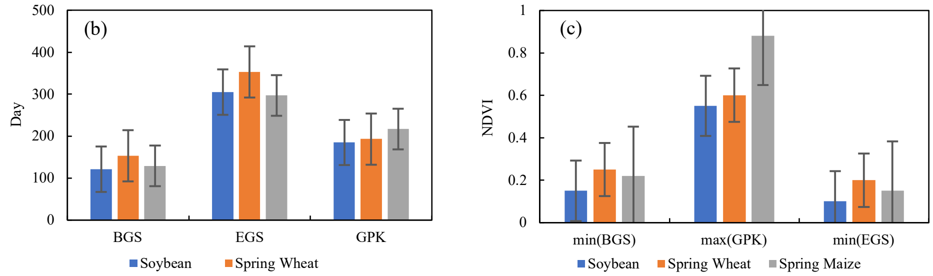

Figure 3. NDVI time series (a) and phenology features (b and c) of crop types in the west liaohe river basin. Note: NDVI, normalized difference vegetation index;BGS, start of season; EGS,end of season;GPK,Peak growth period.

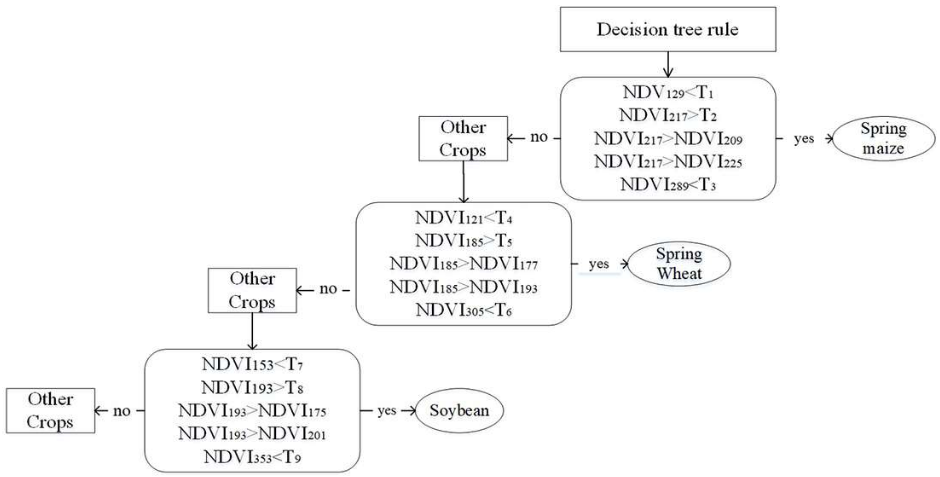

Figure 4. Decision tree rules of crop types classification in the west liaohe river basin. NDVIx, x representing days; and T1–T9 represents the NDVI values of the key growth periods of crops (BGS, EGS, GPK, max, min).

2.3.3. Accuracy evaluation of crop types map

This study applied two methods for evaluating accuracy of crop type maps. The estimated crop acreages from MODIS-NDVI were compared to the Statistical data of crop area from the CCSY. 467 GPS sampling point data of crops obtained from field survey, using for checking the accuracy of crop type maps. Overall accuracies, user's accuracies, and producer's accuracies of crop type were calculated by the error matrix respectively [38].

2.3.4. Description model of farmland nutrient balance

The nutrient input and output terms of farmland nutrient model are detailed in Table 3.The farmland nutrient input consists of chemical fertilizer input, organic fertilizer input, seed input, biological nitrogen fixation, wet and dry deposition, and irrigation water input.

The farmland nutrient output consists of straw output, seed output, chemical fertilizer and organic fertilizer NH_3/NO_2 volatilisation, runoff, and leaching output[39].The Farmland nutrient balance was calculated similar to OECD [11] and He W [40] in this study, with some modifications of input and output components at the regional scale of The West Liaohe River Basin (Fig-ure 4). See Table 3 for detailed formula. The main Eq. (1)-(3) as bellow:

$$NP_{balance} = NP_{input} - NP_{output} \quad (1)$$

$$NP_{effic} = \frac{NP_{grain\_removal} + NP_{straw\_removal}}{NP_{input}} \times 100\% \quad (2)$$

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$$NP_{surp} = \frac{NP_{input} - NP_{output}}{NP_{input}} \times 100\% \quad (3)$$

Table 3. Farmland nutrient balance Equations.

Farmland nutrient input	Farmland nutrient output
$NP_{chemical} = Aera_{crop} \times NP_{unitfert}$	$NP_{grain\_removal} = Aera_{crop} \times Yield_{grain} \times NP_{Grain\_i}$
$NP_{live} = Aera_{crop} \times NP_{unitlive}$	$NP_{straw\_removal} = Aera_{crop} \times Yield_{grain} \times SG_{Ratio\_i} \times (1 - SRate_{retur\_i}) \times NP_{Straw\_i}$
$NP_{man} = Pop_{man} \times NPExcre_{Rate\_i} \times MRate_{retur\_i}$	$N_{NO2} = (N_{chemical} + N_{live}) \times NO2_{Rate\_i}$
$NP_{straw} = Aera_{crop} \times Yield_{grain} \times SG_{Ratio\_i} \times SRate_{retur\_i} \times NP_{Straw\_i}$	$N_{NH3} = (N_{chemical} + N_{live}) \times NH3_{Rate\_i}$
$NP_{seed} = Area_{crop} \times Seed_{unitarea} \times S_{Rate\_i}$	$N_{leach} = Aera_{crop} \times NL_{Rate\_i}$
$NP_{irri} = Aera_{crop} \times I_{Rate\_i}$	$N_{runoff} = Aera_{crop} \times NR_{Rate\_i}$
$NP_{atmo(dry+wet)} = Aera_{crop} \times DW_{Rate\_i}$	
$NP_{biol} = Area_{Soybean} \times N_{Rate\_i}$	

Note: $Aera_{crop}$, crop type area(ha); $NP_{unitfert}$, N in chemical fertilizer (kg ha^{-1}), P in chemical fertilizer (kg ha^{-1}); $NP_{unitlive}$, N in livestock (kg ha^{-1}), P in livestock (kg ha^{-1}); Pop_{man}, Rural population; $NPExcre_{Rate\_i}$, Fecal urine production per person(kg); $MRate_{retur\_i}$, Proportions returned to field (%);$Yield_{grain}$,Grain yield per unit area; SG_{Ratio_i}, Ratio of straw to grains; $SRate_{retu\ \_i}$, N, in straw (%),P in straw (%);NP_{Straw_i}, Proportions returned to field (%);$Seed_{unitarea}$, Sowing amount per unit area(kg ha^{-1}); S_{Rate_i}, N in seeds (kg ha^{-1}), P in seeds (kg ha^{-1}); $I_{Rat\ \_i}$, Irrigation water nutrient (kg ha−1); DW_{Rate_i}, Atmospheric deposition rate (kg ha−1); N_{Rate_i}, Biological nitrogen fixation (kg ha−1); NP_{Grain_i}, Grain nutrient content (kg ha^{-1}); $NO2_{Rate\_i}$, NH_3 volatilization rate (%); $NH3_{Rate\_i}$, NO_2 volatilization rate (%); NL_{Rate_i}, N leaching (kg ha^{-1}); NR_{Rate_i}, N runoff (kg ha^{-1}).

Composition of farmland nutrient inputs. Fertilizer inputs consist of both chemical and organic fertilizer inputs. Coefficients for estimating chemical fertilizer input in Table 4. The application sources of organic fertilizer are wide [41], mainly including livestock manure, human feces, and crop straws, etc. The nutrient input of organic fertilizer is mainly estimated based on the nutrient content of different organic fertilizers, the corresponding input, and the ratio of straw to grain. In order to improve the accuracy of the estimation, a method was established that for considering the cultivation cycle, breeding stage, livestock feeding amount and species. Table 5 lists the coefficients used to estimate fertilizer inputs for livestock and poultry, based on field surveys. The amount of fecal, urine produced per person is 0.69 kg N and 0.46 kg P, and the return rate is 30%. List of Rural population of each county in Table 6. The nutrient input of Straw return is mainly estimated based on the nutrient content of different organic fertilizers, the corresponding input, and the ratio of straw to grain. The amount of nutrients in the straws returning to the field was calculated based on the parameter list in table 7 and table 8. Table 9 and Table 10 list the values of sowing amount per unit area and its nutrient coefficients to calculate the seed nutrient input. Based on the Field survey, the values of the nutrient load from irrigation for N and P are 8.6 kg ha^{-1} yr^{-1}and 0.5 kg ha^{-1}yr^{-1}, respectively. Symbiotic N fixation in upland was estimated by crop production and the amount of N uptake per crop production. For soybeans, the values of the Biological nitrogen fixation for N is 77 kg ha^{-1}yr^{-1}.Atmospheric nutrient deposition, including wet deposition and dry deposition, is generated from a variety of sources, such as agricultural, natural and industrial [42]. Studies have shown that in Europe, the annual sediment load is 20-50 kg ha^{-1}, while in Asia, this value drops to 4-5 kg ha^{-1}. In this research, the parameters of the N, P deposition average annual values of 9.14 and 0.58 kg P ha^{-1}yr^{-1}were set for the dry and wet deposition flux, respectively.

Composition of farmland nutrient outputs. Crop grain and straw harvest, which are the principal nutrient output in the agricultural system. According to information from field investigations, we used a simple pro-portion to estimate the amount of nutrient output of the crop harvest in this research, the values are listed in Table 11 and the other parameters are listed in Table 7 and 8. In this study, we considered ammonia volatilization

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and denitrification. The NH_3 volatilization loss rate in fertilizers was determined to be 25%, and the NO_2 volatilization loss rate in fertilizers was 1.05%.The nutrient output by leaching and runoff were estimated by the export coefficients. The leaching outputs rated in fertilizers was determined to be 16.0 kg N ha^{-1} yr^{-1}. The run-off outputs rated in fertilizers was determined to be 2.88 kg N ha^{-1} yr^{-1} and 0.23 kg P ha^{-1} yr^{-1}.

Table 4. Coefficients for estimating chemical fertilizer input.

Crop	Region	N chemical fertilizer (kg ha^{-1})				P chemical fertilizer (kg ha^{-1})			
		2000	2005	2010	2015	2000	2005	2010	2015
Soybean	1	68.3	100.5	142.5	178.5	39.8	61.5	102.0	137.3
	2	59.3	86.3	123.0	154.5	30.8	47.3	78.0	105.8
	3	59.3	87.0	123.0	154.5	24.0	36.8	60.8	81.8
Spring Wheat	1	171.0	250.5	356.3	446.3	90.0	139.5	230.3	310.5
	2	183.0	268.5	381.0	477.8	98.3	152.3	251.3	339.0
	3	157.5	230.3	327.0	410.3	75.8	117.0	192.8	260.3
Spring Maize	1	142.5	208.5	296.3	372.0	75.0	116.3	191.3	258.8
	2	153.0	223.5	317.3	398.3	82.5	126.8	209.3	282.8
	3	131.3	192.0	273.0	342.0	63.0	97.5	160.5	216.8

Note:1- Semi-agricultural half pastoral area；2-Pastoral area；3-Agricultural area.

Table 5. Coefficients for estimating chemical livestock input.

Crop	Region	N livestock fertilizer (kg ha^{-1})				P livestock fertilizer (kg ha^{-1})			
		2000	2005	2010	2015	2000	2005	2010	2015
Soybean	1	16.5	27.8	24.8	22.5	10.5	19.5	18.0	15.8
	2	36.8	63.0	56.3	51.0	22.5	41.3	38.3	33.8
	3	28.5	48.8	43.5	39.8	18.8	33.8	31.5	27.8
Spring Wheat	1	54.8	93.8	84.8	75.8	36.0	65.3	60.8	53.3
	2	84.0	143.3	129.0	115.5	51.0	91.5	85.5	75.0
	3	48.8	82.5	74.3	66.8	31.5	57.0	53.3	46.5
Spring Maize	1	28.5	48.8	43.5	39.8	18.8	33.8	31.5	27.8
	2	46.5	79.5	71.3	63.8	27.8	49.5	46.5	40.5
	3	26.3	45.8	40.5	36.8	17.3	31.5	29.3	25.5

Note:1- Semi-agricultural half pastoral area；2-Pastoral area；3-Agricultural area.

Table 6. List of Rural population of each county (Ten thousand).

County	2000	2005	2010	2015	County	2000	2005	2010	2015
Weichang	45.1	43.5	44.4	46.1	HexingtenQi	20.6	19.5	19.7	19.5
Chifeng	63.8	63.9	66.0	71.2	OngniudQi	41.8	41.6	41.3	43.5
Ar Horqin Qi	26.3	25.7	24.0	25.9	KarqinQi	32.9	33.0	30.6	30.9
Aohan	52.5	53.3	53.1	54.0	ningcheng	52.3	52.9	52.3	53.9
Horqin Zuoyi Houqi	42.6	40.3	41.6	40.3	tongliao	37.0	37.0	37.9	38.4
HorqinZuoyiZhongqi	31.2	28.7	27.7	28.3	Kailu	31.7	30.6	26.5	26.7
Hure Qi	13.2	12.0	11.1	14.0	naiman	35.4	33.1	31.0	32.2
Jarud Qi	22.3	19.9	19.4	20.7	BairinZuoi	31.0	31.5	30.0	29.6
HorqinYouyiZhongqi	17.9	17.9	17.9	18.0	Jianping	47.0	46.1	45.7	45.4
Pingquan	40.1	33.8	34.2	42.3	shuangliao	17.7	25.3	27.7	23.2
Bairin Youqi	13.2	11.9	12.7	13.1	tongyu	11.3	22.8	24.9	24.5
Linxi	19.5	18.1	18.1	18.4					

Table 7. Crop yield per unit area. (Yieldgrain kg ha^{-1})

Crop	region	2000	2005	2010	2015
Soybean	1	414.0	326.9	376.3	360.4
	2	415.6	328.2	377.7	361.8
	3	384.6	303.7	349.5	334.8
Spring Wheat	1	90.0	134.6	136.2	84.5
	2	90.0	134.7	136.3	84.5

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Crop	region	2000	2005	2010	2015
	3	74.0	110.7	112.0	69.5
Spring Maize	1	12.4	21.0	28.8	44.2
	2	12.4	21.0	28.8	44.3
	3	13.7	23.2	31.9	49.0

Note:1- Semi-agricultural half pastoral area；2-Pastoral area；3-Agricultural area.

Table 8. Parameters for estimating straw manure inputs.

Crop	Ratio of straw to grains	N in straw (%)	P in straw (%)	Proportions returned to field (%)
Soybean	1.6	17	0.20	17
Spring Wheat	1.1	0.65	0.08	40
Spring Maize	2	0.92	0.15	32

Table 9. Sowing amount per unit area. (kg ha^{-1})

Crop	region	2000	2005	2010	2015
Soybean	1	2069.1	3094.2	3131.7	1942.7
	2	2060.4	3081.2	3118.6	1934.6
	3	2475.9	3702.5	3747.4	2324.6
Spring Wheat	1	6264.9	4947.2	5693.9	5453.7
	2	6260.7	4943.8	5690.0	5450.0
	3	4171.3	3293.9	3791.1	3631.1
Spring Maize	1	2074.0	3514.4	4831.2	7419.0
	2	2077.1	3519.7	4838.5	7430.3
	3	1959.5	3320.4	4564.5	7009.5

Note:1- Semi-agricultural half pastoral area；2-Pastoral area；3-Agricultural area.

Table 10. Coefficients for estimating the seed N/P input.

Crop	N in seeds (kg ha^{-1})	P in seeds (kg ha^{-1})
Soybean	5.3	0.14
Spring Wheat	2.1	1.24
Spring Maize	1.6	0.15

Table 11. Coefficients for estimating the Grain N/P 0utput.

Crop	N in grain (%)	P in grain (%)
Soybean	5.3	0.48
Spring Wheat	2.1	0.41
Spring Maize	1.6	0.27

3. Results

3.1. Precision verification

We use remote sensing data (MOD09Q1) to carry out remote sensing extraction of spatial distribution information of the crop area in large areas. The accuracy of extraction depends on the resolution of remote sensing image and the setting of NDVI threshold of decision tree models. The accuracy verification of this study is carried out in terms of spatial precision and area accuracy. According to statistics, the area accuracy of the classification is above 80%. The accuracy of the training sample extraction model in every year is more than 82%, the Producer's Accuracy is above 87%, the User's Accuracy is above 84%, and the kappa is above 0.84 (Table12). This shows that the accuracy is relatively high and meets the application requirements of this study. At the same time, it also shows that it is

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feasible to use phenology Information for division crop layout, and the decision tree classification methods can be applied to the extraction planting patterns.

Table 12. Accuracy assessment for the crop maps in the West Liaohe River Basin.

Years	crop	Statistical data（ $\times10^4$ha）	Remote sensing data（$\times10^4$ha）	Area Precision（%）	Producer's Accuracy（%）	User's Accuracy（%）	Overall Accuracy（%）	kappa
2000	Maize	48.3	34.5	71.4	95.1	95.0	85.6	0.87
	Wheat	10.7	8.0	74.9	81.2	83.3		
	Soybean	10.1	10.6	95.6	87.0	73.0		
2005	Maize	70.5	74.7	94.0	96.0	87.0	88.2	0.87
	Wheat	4.5	3.5	76.6	75.0	88.2		
	Soybean	8.6	7.9	91.6	95.0	90.0		
2010	Maize	104.0	103.1	99.1	90.5	75.0	82.3	0.85
	Wheat	3.9	2.7	70.0	86.0	82.9		
	Soybean	8.1	6.6	81.1	73.1	90.0		
2015	Maize	131.2	143.6	90.5	89.5	73.9	83.6	0.78
	Wheat	4.4	3.1	70.5	85.3	92.9		
	Soybean	1.6	1.3	79.7	96.5	82.9		

3.2. Description of Crop planting spatial pattern

3.2.1. Temporal and spatial distribution characteristics of main crops

We divided the West Liaohe River into three major areas, including Xilamulun River and Laoha River basin (upper reaches), Wulijimu River basin (middle reaches) and West Liaohe River lower reaches basin (below Sujiabao) (lower reaches). The spatial pattern of maize planting is clearly consistent with the distribution of the major tributaries of the West Liaohe River. The spatial distribution of wheat and soybean planting is relatively scattered and has no obvious distribution characteristics. In terms of time and space, the planting area of the West Liaohe River Basin has changed significantly from 2000 to 2015 (Figure.5d). The planting area of crop increased from 53. 1$\times10^4$ha in 2000 to 148. 0$\times10^4$ha in 2015 (Table8), an increase of 1.8 times. The planting area of soybean showed a decreasing trend, which decreased from 10. 6$\times10^4$ha in 2000 to 1. 3$\times10^4$ha in 2015, a decrease of 87.6%, mainly concentrated in the Wulijimu River basin (middle reaches) and West Liaohe River lower reaches basin (below Sujiabao) (lower reaches). The planting area of wheat decreased first and then increased, and the overall decreasing trend was reduced from 8. 0$\times10^4$ha in 2000 to 2. 7$\times10^4$ha in 2010, and then increased to 3. 1$\times10^4$ha in 2015, a decrease of 61.4%, which was scattered of the West Liaohe River Basin.

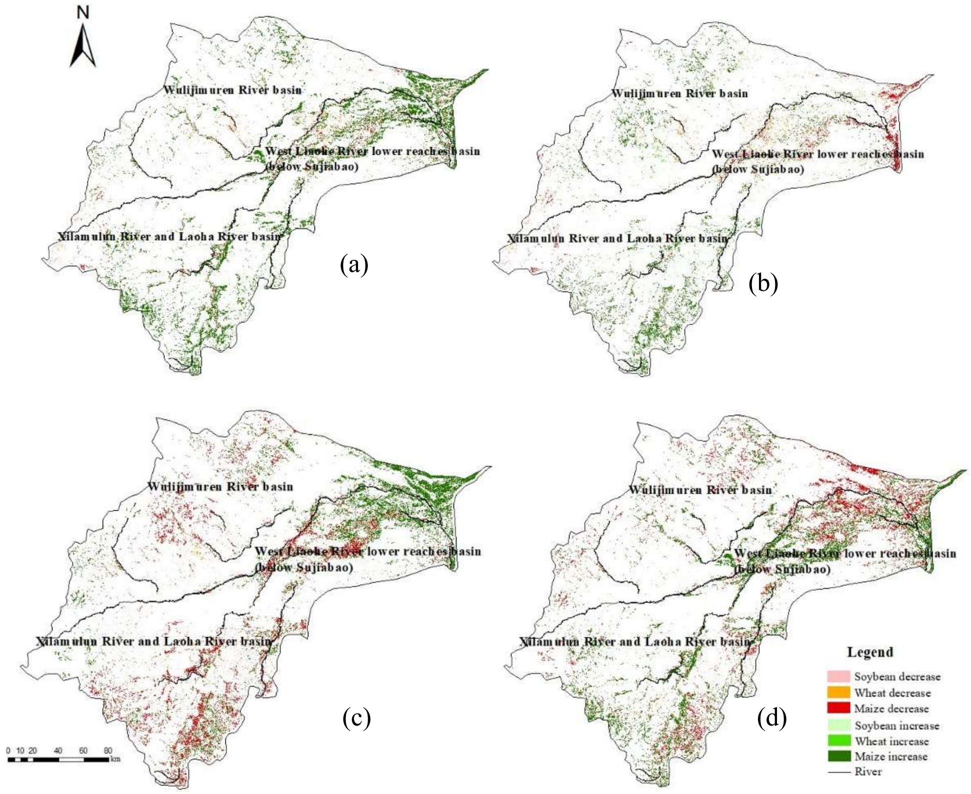

Figure 5. Dynamic changes of major crops spatial distribution in 2000~2005(a),2005~2010(b),2010~2015(c),2000-2015(d).

3.2.2. Major crop transfer changes from 2000 to 2015

The transfer change of main crop from 2000 to 2015 was mainly represented by the conversion of soybeans and wheat into maize (Figure.6). The area of soybean->maize is 4. 4×10^{4}ha, and the area of wheat->maize is 3. 1×10^{4}ha. The contribution rate of these two crops of maize area increase is 58.66% and 41.34%, respectively. From the perspective of the year, the transfer change of main crop in 2000-2005 was mainly represented by the conversion of soybeans and wheat into maize (Figure.6a). The area of soybean->maize is 6. 9×10^{3}ha, and the area of wheat->maize is 8. 7×10^{3}ha. The contribution rate of these two crops of maize area in-crease is 48.27% and 51.73%, respectively. The transfer change of soybeans in 2005-2010 was mainly reflected in the conversion of maize into soybean (Figure.6b). The area of maize->soybean is1. 2×10^{3}ha, and the contribution rate of maize to soybean increase is 102.23%. The transfer change of wheat is mainly represented by the conversion of wheat into maize, the area of wheat->maize is 4. 9×10^{3}ha, and the contribution rate of maize in wheat area reduction is 100.93%. The change of soybean transfer in 2010-2015 was mainly represented by soybean and wheat transformed into maize (Figure.6c). The area of soybean->maize was1. 6×10^{4}ha, and the area of wheat->maize was 5. 2×10^{3}ha. The contribution rate of two crops of maize area increase was 87.64%, 12.36%. In summary, except for 2005-2010, the other years showed the conversion of soybean->maize, wheat->maize. The transfer of maize in 2000-2015 is more dramatic, mainly due to the conversion of soybean->maize, wheat->maize (Figure 6d).

As can be seen from Figure 7, the reduction of soybean and wheat planting area is mainly due to its own reduction, that is, the conversion of soybeans and wheat into other cash crops or other land types (garden, woodland, grassland, etc.). Secondly, the conversion of soybeans and wheat to maize is also an important reason for the reduction of soybean and wheat planting area. Although most soybeans and wheat are converted to maize, the main reason for the increase of maize planting is the increase in its own planted area, the area of other cash crops or other land types (gardens, woodlands, grasslands, etc.) converted into maize accounts for 90% of the increase in maize planting area.

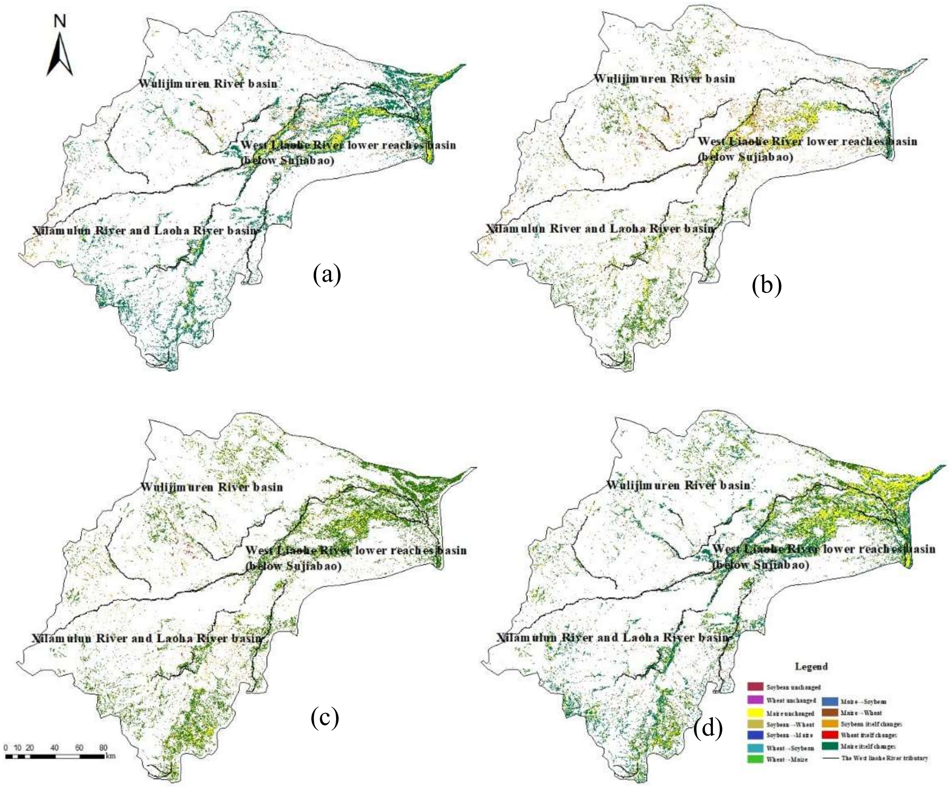

Figure 6. Spatial distribution of changes in major crops in 2000~2005(a),2005~2010(b),2010(c)~2015(c),2000~2015(d).

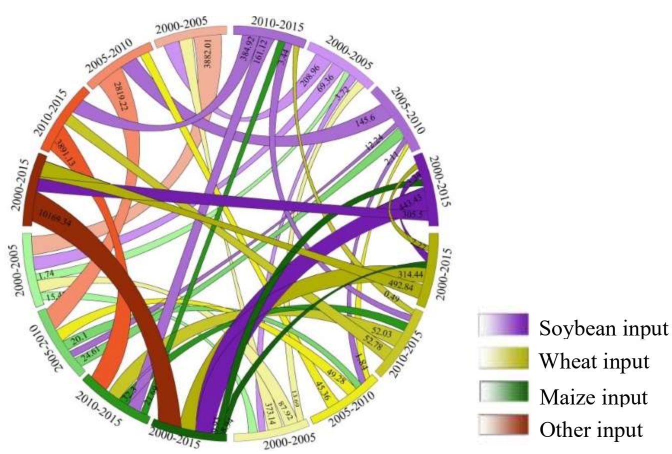

Figure 7. Major crop transfer changes in 2000,2005,2010 and 2015(×10^3ha).

3.3. N, P Input, Output and Balance

3.3.1. N and P input-output

Total amounts of N input and output increased from 237. 7×10^3t N and 130. 3×10^3t N in 2000 to 725. 4×10^3t N and142. 4×10^3t N in 2015, equivalent to an average of 469.6 and 165.4kg N ha^{-1} of 573.5 and 348.2kg N ha^{-1} (Fig.8a, b), separately. From 2000 to 2010, the change in total amounts of N input and output showed an upward trend. Total amounts

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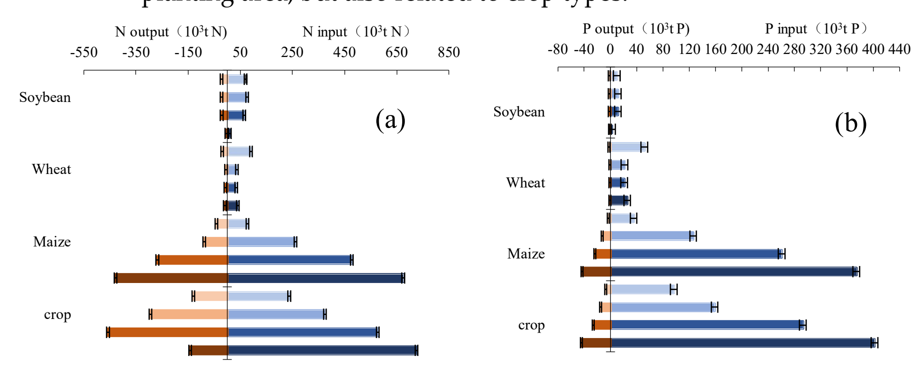
of N input increased more than the N output from 2000 to 2010. Then total amounts of input continued to increase from 2010 to 2015, And the N output is decreased (Figure 8a). The changes in N unit input and output showed increasing trends from 2005 to 2015, but decreasing from 2000 to 2005(Figure 8b), Unit input is greater than the output. Total amounts of P input and output increased from 96. 3×10³t P and 7. 1×10³t P in 2000 to 401. 8×10³t P and 44. 1×10³t P in 2015 (Fig.8c), equivalent to an average of 190.3 and 14.1 kg P ha^{-1} to 317.6 and 34.8 kg P ha^{-1} (Fig.8d), separately. The changes in P input and output are showed increasing trends from 2000 to 2015, and the increasing in P input was greater than P output from 2000 to 2015 (Fig.8c, d). P unit input and output show an increasing trend from 2000 to 2015. For soybean, from 2000 to 2015, the change in total amounts of N input showed a trend of increasing first and then decreasing, but the change in total amounts of N output showed a downward trend, and the change in total amounts of P input and output showed a trend of increasing first and then decreasing. For wheat, from 2000 to 2010, the change in total amounts of N, P input and output showed a downward trend, the change in total amounts of P input and output showed an upward trend from the 2010 to the 2015. For maize, the changes in total amounts of N, P input and output showed increasing trends from 2000 to 2015.

Unit amounts of N input and output of soybean increased from 670.0 kg N ha^{-1} and 216.7 kg N ha^{-1} in 2000 to 745.9 kg N ha^{-1} and 238.4 kg N ha^{-1} in 2015. Unit amounts of N input and output of wheat increased from 1149.8 kg N ha^{-1} and 242.0 kg N ha^{-1} in 2000 to 1325.8 kg N ha^{-1} and 294.2 kg N ha^{-1} in 2015. Unit amounts of N input and output of maize increased from 239.1 kg N ha^{-1} and 130.3 kg N ha^{-1} in 2000 to 552.6 kg N ha^{-1} and 350.7kg N ha^{-1} in 2015. Unit amounts of P input of soybean increased from 91.7 kg P ha^{-1} in 2000 to 178.4 kg P ha^{-1} in 2015. Unit amounts of P output of soybean decreased from 15.9 kg P ha^{-1} in 2000 to 15.2 kg P ha^{-1} in 2015. Unit amounts of P input and output of wheat increased from 653.2 kg P ha^{-1} and 28.4 kg P ha^{-1} in 2000 to 820.0 kg P ha^{-1} and 23.9 kg P ha^{-1} in 2015. Unit amounts of P input and output of maize increased from 108.9 kg P ha−1 and 10.0 kg N ha^{-1} in 2000 to 306.4 kg P ha^{-1} and 35.3 kg P ha^{-1} in 2015. For soybean, from 2000 to 2015, the change in unit input and output of N showed a trend of increasing first and then decreasing. The changes in P unit input showed increasing trends, but P unit output showed a trend of increasing first and then decreasing from 2000 to 2015. For wheat, from 2000 to 2015, the change of unit amounts of N, P input and output showed a trend of decreasing first and then increasing. For maize, the changes in N, P unit input and output showed increasing trends from 2000 to 2015.

The N, P input of the three crops is greater than output from 2000 to 2015. Total amounts of N input and output are shown as maize> soybean > wheat, but P total input and output are shown as maize > wheat > soybean. Unit amounts of N input and output are shown as wheat > soybean >maize, but P unit input and output are shown as wheat > maize> soybean (Figure8 a, b, c, d). It can be seen by the laws of the different crops in N, P input and output, the farmland N, P input and output are not only related to the crop planting area, but also related to crop types.



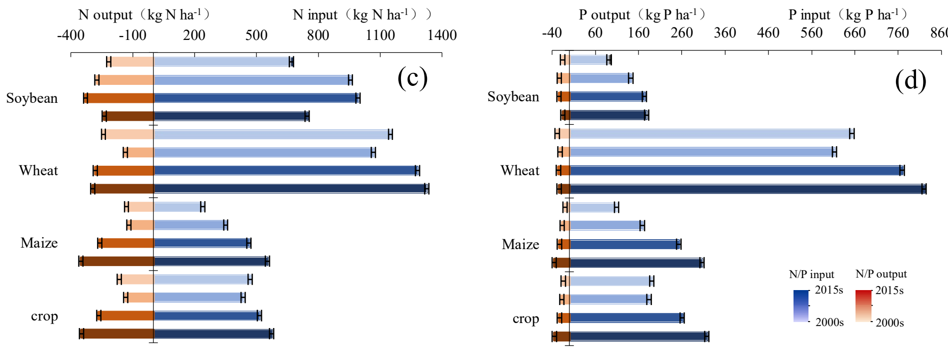


Figure8. N,P input and o utput (a,b,c,d) of different crops in the Liaohe River Basin from the 2000s to the 2015s.

3.3.2. N,P input-output component

To further explore the source of N and P inputs and outputs, we averaged the ratio of N, P input and output components to total input and output for four years. Chemical fertilizer and seeds were the main source of N, accounting for 49.9% and 28.9% (Figure.9a). Chemical fertilizer was the main source of P, accounting for 64% of total P input (figure. 9b). Secondly, organic fertilizer is also an important source of N and P inputs, accounting for 16.1% and 17.5% respectively. However, other N, P inputs (such as irrigation, atmospheric deposition, biological N fixation) had limited effect because they account for only 5.1% and 0.5% of total N and P inputs to the West Liaohe River Basin, respectively. Crop and straw harvest were the main venues for N, P output, accounting for 38.7%, 25.9% and 38.6%, 60.2% of total N, P output, respectively (Figure.9b, d). NH_3/NO_2 volatilisation, runoff, leaching is also the route of N or P output. These nutrients lost into the atmosphere or water, causing pollution. It is worth noting that the NH_3/NO_2 volatilisation accounted for a large proportion of the total N output, which was 25.9%. Other N, P outputs (such as leaching, runoff) account for a little proportion of the total N, P output, account for only 9.5% and 1.2% of total N and P outputs to the West Liaohe River Basin, respectively.

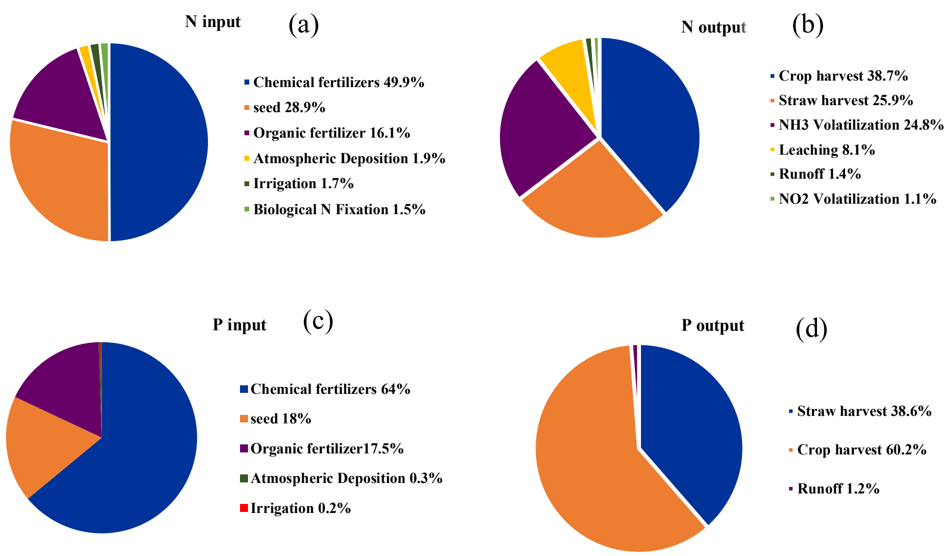


Figure9. The average ratio of N (a,b)and P(c,d) nutrient input and output components to total input and output in the West Liaohe River Basin from 2000 to 2015.

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3.3.3. N,P balance

The N and P inputs are greater than the output in the West Liaohe River Basin from 2000 to 2015. The unit N surplus showed a downward trend as a whole, from 304.2kg N ha^{-1} in 2000 to 225.3 kg N ha^{-1} in 2015. The N surplus of soybean increased first and then decreased, but the overall increase trend. N surplus of soybean increased from 453.4 kg N ha^{-1}in 2000 to 507.5 kg N ha^{-1}in 2015, an increase of 11.9%, with an average annual increase of 0.8%. The N surplus of wheat and maize showed an increasing trend. The N surplus of wheat increased from 907.8 kg N ha^{-1} in 2000 to 1031.7kg N ha^{-1}in 2015, an increase of 13.6%, with an average annual increase of 0.9%. The N surplus of maize increased from 108.9 kg N ha^{-1} in 2000 to 201.9 kg N ha^{-1} in 2015 (Figure10. a), an increase of 85.5%, with an average annual increase of 5.7%. In terms of crop types, the N surplus is expressed as wheat > soybean > maize. The unit P surplus increased overall, from 176.3 kg P ha^{-1} in 2000 to 282.8 kg P ha^{-1} in 2015. The P surplus of soybean, wheat and maize showed an increasing trend. The P surplus of soybean increased from 75.5 kg P ha^{-1} in 2000 to 163.2 kg P ha^{-1} in 2015, an increase of 1.2 times and an average annual increase of 7.7%. The P surplus of wheat increased from 624.9 kg P ha^{-1} in 2000 to 796.1 kg P ha^{-1}in 2015, an increase of 27.4% and an average annual increase of 1.8%. The P surplus of maize increased from 98.9 kg P ha^{-1} in 2000 to 271.1 kg P ha^{-1} in 2015 (Figure10. b), an increase of 1.7 times and an average annual increase of 11.6%. In terms of crop types, the P surplus is expressed as wheat > maize > soybean.

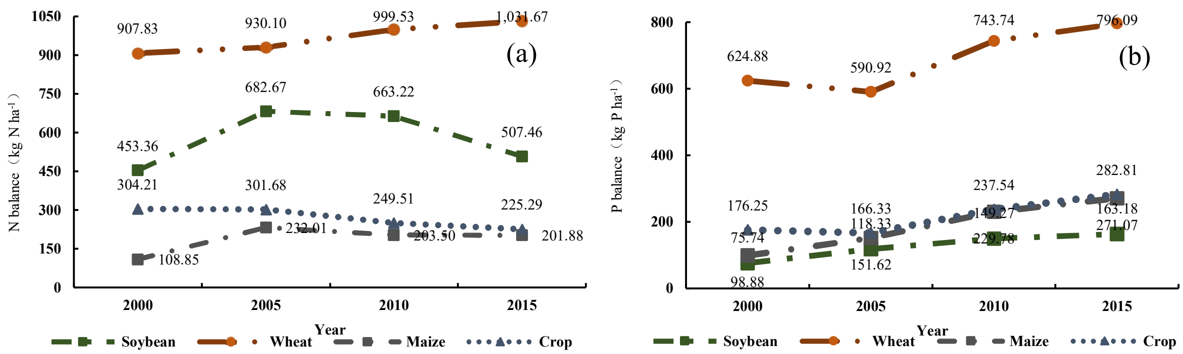


Figure10. N and P nutrient balance of crops from 2000 to 2015.

3.4. Nitrogen use efficiency and Nutrient surplus ratio

Nitrogen use efficiency (NUE) and nitrogen surplus ratio on cultivated land in the West Liaohe River Basin (NSR) was 20.6 and 64.8% in 2000, 26.3 and 69.3% in 2005, and 28.1 and 48.5% in 2010, respectively, and 36.3 and 39.3% in 2015 (Figure.11a). Phosphorus utilization efficiency (PUE) and phosphorus surplus rate (PSR) was 7.2 and 92.6% in 2000, 9.4 and 90.4% in 2005, and 8.8 and 91.1% in 2010, respectively, and 10.9 and 89.0% in 2015 (Figure.11b). In space, the N surplus rate changes greatly (Figure.12), and the N surplus changes smoothly (Figure.13). In 2015, the N surplus is concentrated in 35%~45% (Figure.12d), and the P surplus is concentrated in 85~90% (Figure.13d) in the West Liaohe River Basin. NUE, NSR and PUE, PSR values all show differences in time and crop type. Crop NUE increased to the highest value (36.3%) from 2000 to 2015. Compared with NUE, crop NSR showed the inverse trend from 2005 to 2015 and decreased to the lowest values (39.3%) in 2015.From the perspective of different crop types. Soybean NUE increased to the highest value (26.6%) from 2000 to 2005, and then decreased to the lowest values (21.8%) from 2010 to 2015. Compared to the Soybean NUE The Soybean NSR showed the inverse trend from 2000 to 2015, and increased to the higher values (68.0%). Wheat NUE decreased to the lowest values (9.8%) from 2000 to 2015. Compared with NUE, Wheat NSR increased to the highest values (87.2%) in 2005 and decreased to the lowest values (77.8%) in 2015. It is worth noting that maize NUE increased to the highest value (38.2%) from 2000 to 2015. Compared with maize NUE, maize NSR showed the inverse trend from

2005 to 2015, and decreased to the lowest values (36.6%) in 2015. The variation of NUE and NSR in maize is the same as that of crops (Figure 11a).

Soybean and wheat PUE decreased to the lowest value (8.4%, 2.9%) from 2000 to 2015. Compared with PUE, soybean and wheat PSR showed inverse trends, soybean and wheat PUE increased to the highest value (91.5%, 97.1%) from 2000 to 2015. It is worth noting that the maize PUE increased to the highest value (11.4%) from 2000 to 2015. Compared with PUE, the maize PSR showed the inverse trend. The maize PSR decreased to the lowest value (89.0%). This is the same as the change in crop PUE and PSR (Figure 11b).

NUE is the proportion of crop intake to nutrient input. The nutrient input structure is the proportion of nutrients from various sources to nutrient input. From the NUE, PUE and N, P nutrient input structure, it can be seen that the nutrient contribution of fertilizer is always greater than the absorption of crops, and the N and P amount of crops are 54.4% and 13.4% of the nutrient contribution of fertilizer, respectively. The nutrient contribution of livestock and poultry excrement is less than the amount of crops absorbed, and the N and P inputs of livestock and poultry excrement are 18.8% and 18.9% of the N and P of crops, respectively. The West Liaohe River Basin is an alternate farming and animal husbandry belt, and the combination of agriculture and animal husbandry is conducive to the improvement of N and P utilization. If the nutrient loss of livestock and poultry excrement is applied as a fertilizer to the farmland, the planting industry in the West Liaohe River Basin can completely eliminate the excrement produced by livestock and poultry farming.

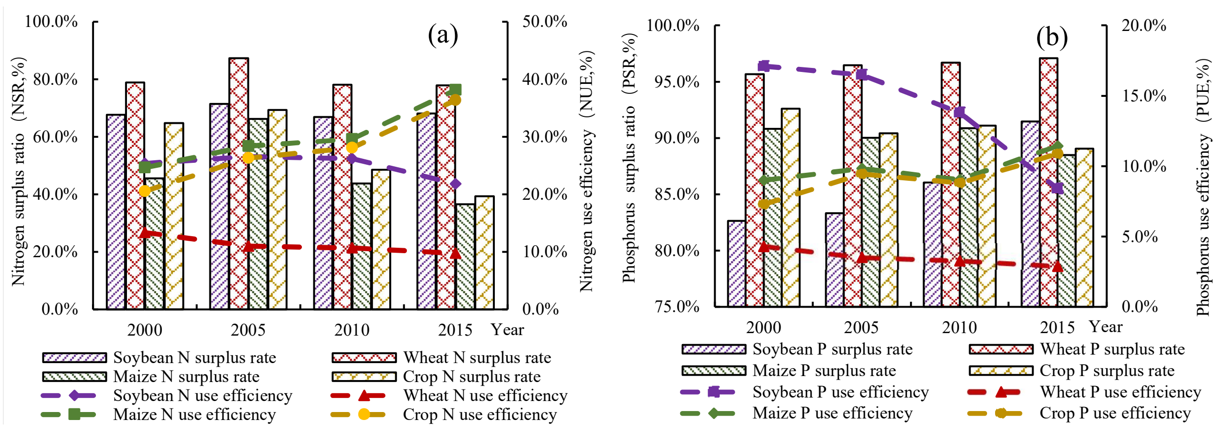
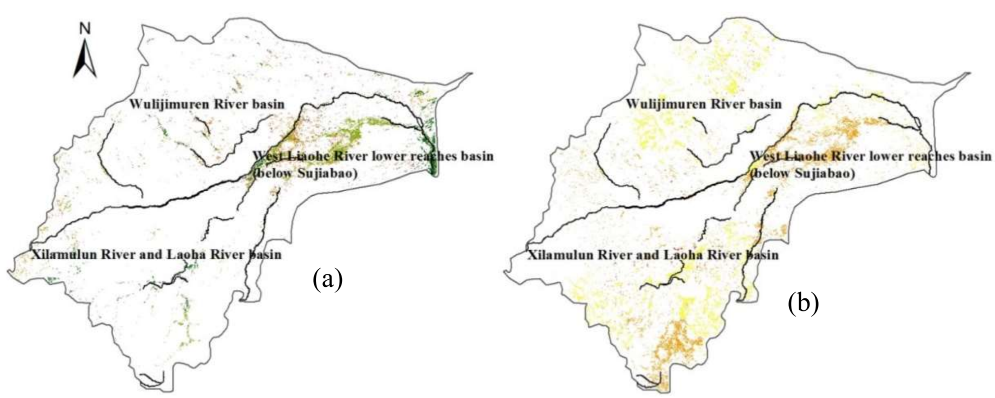


Figure 11. N,P use efficiency (a) and N,P surplus rate (b) in three crops and The West Liaohe River 's croplands during the 2000s–2015s.



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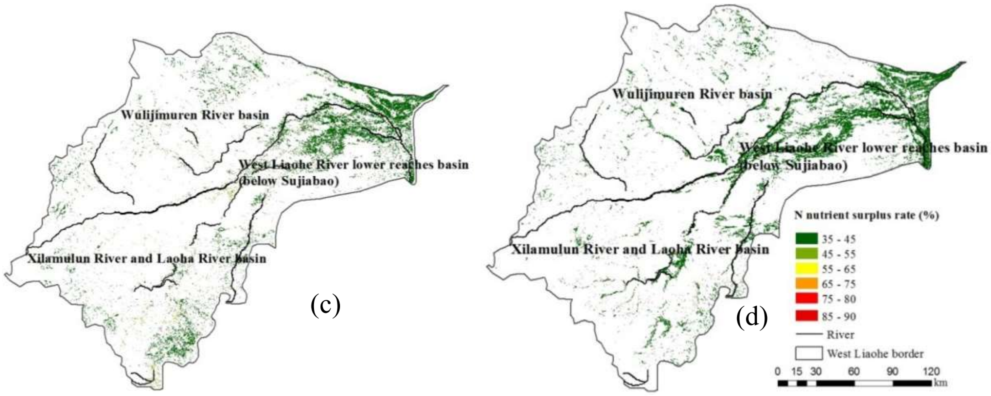

Figure 12. Spatial distribution of nitrogen nutrient surplus rate in 2000(a), 2005(b), 2010(c) and 2015(d).

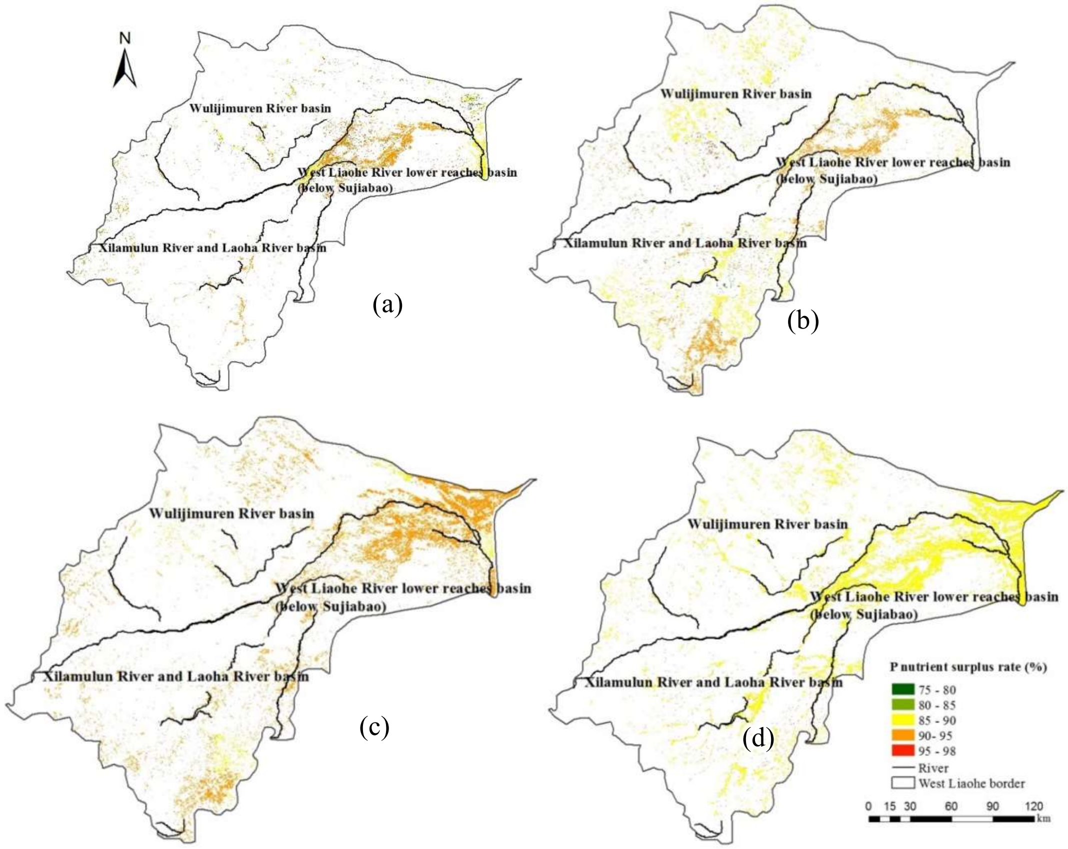

Figure 13. Spatial distribution of Phosphorus nutrient surplus rate in 2000(a), 2005(b), 2010(c) and 2015(d).

4. Discussion

4.1. Crop planting structure, Inner Mongolia agricultural policy, impact on farmland nutrients

Changes in maize and soybean planting patterns have a significant impact on farmland nutrient balance in the West Liaohe River Basin. There was a significant positive correlation between the proportion of the soybean planting area and the unit N surplus (R2=0.0.539, p<0.001), but a significant negative correlation with the unit P surplus (R2=0.506, p<0.001) (Figure.15a). There was a significant negative correlation between the proportion of the maize planting area and unit N surplus ($R2=0.8391$, $p<0.001$), and a significant positive correlation with unit P surplus ($R2=0.7867$, $p<0.001$) (Figure.15b).

From 2000 to 2015, the area planted to soybeans decreased from10. 6×104ha in 2000 to 1. 3×104ha in 2015, and the area ratio decreased by 19.04%. The maize planting area increased from 34. 5×104ha in 2000 to 143. 6×104ha in 2015, and the area ratio increased by 32.08%. The change in the area of the two crops together promoted the reduction of N surplus and the increase of P surplus in the farmland of the West Liaohe River Basin. It can be seen from the transfer of crop area, During the study period, soybeans in the West Liaohe River Basin were mainly converted into maize, accounting for 99.8% of the total soybean planting area. The conversion of soybean—>maize to some extent led to changes in the nutrient surplus per unit area of the West Liaohe River Basin. However, soybean—>maize conversion only accounted for 3.97% of the net change in maize acreage, and 93.23% of the newly added area of maize were mainly from land use types. Therefore, although the ratio of soybean area to the N, P surplus of the unit cultivated land area has a high correlation, the change of maize planting layout plays a decisive role in the change of nutrient surplus rate and use efficiency in the West Liaohe River Basin. At the same time, this point can also be seen from the spatial distribution changes of the main crops in the West Liaohe River Basin. The surplus areas of N, P nutrient surplus from 2000 to 2015 are mainly concentrated in the West Liaohe River lower reaches basin (below Sujiabao) (Figure.16a, b). This region is also a violently area of change in maize layout (Figure.16c).

In order to solve the problem of over-production of maize, Inner Mongolia introduced a series of measures to actively guide, on the one hand, speed up the destocking of maize, on the other hand, reduce the planting area of maize in non-dominant producing areas, increase soybeans, miscellaneous grains, etc. Planting area of dominant varieties. The sowing area of soybean and maize has a significant correlation with the nutrient surplus of the farmland. If the maize planting area is increased, the nitrogen unit surplus nutrient will decrease, and the phosphorus unit nutrient surplus will increase. If the soybean acreage is increased, the nitrogen unit surplus nutrient will increase, and the phosphorus unit surplus nutrient will decrease. Therefore, it is necessary to properly control the planting area of maize and soybean in the basin, adjust the balance of nitrogen and phosphorus nutrients, and reduce the risk of environmental pollution.

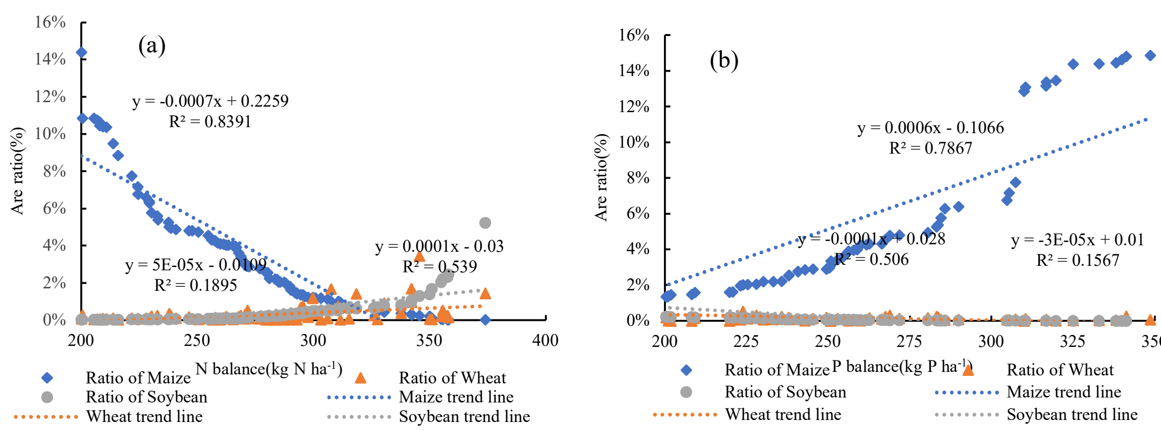

Figure15. Correlation between crop area ratio and N, P nutrient balance(a,b)

(in terms of county area).

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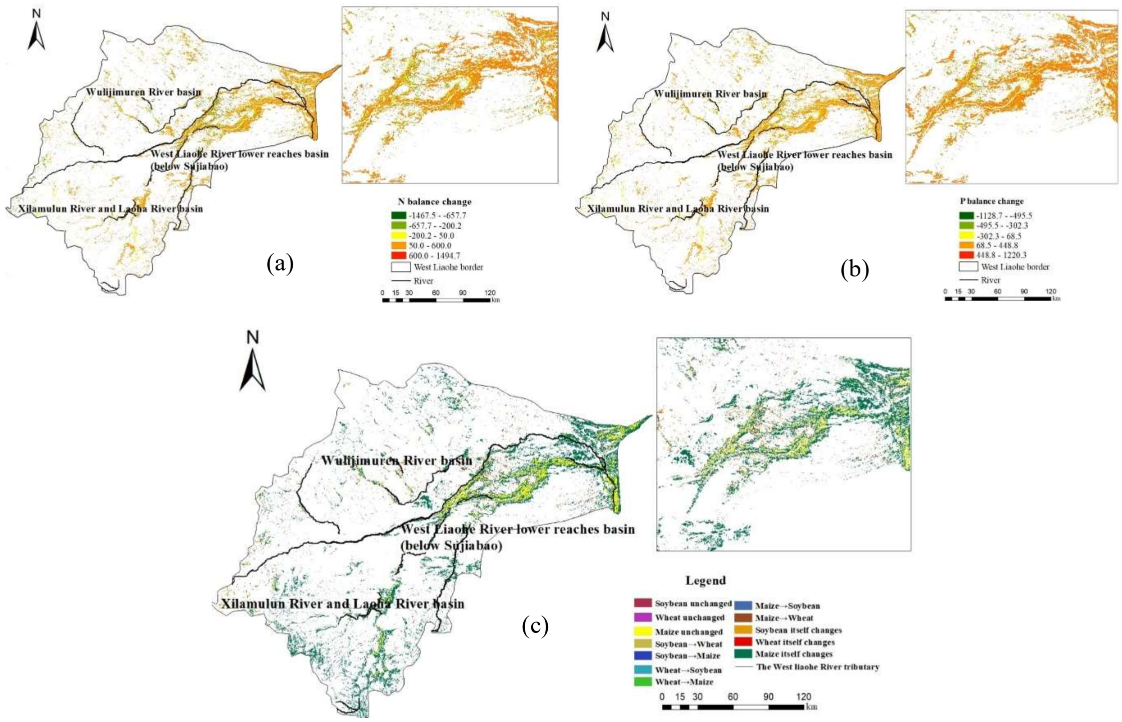

Figure16. Farmland nutrient change (a,b) and Crop change(c) in The West Liaohe River Basin from 2000 to 2015.

4.2. N,P nutrient surplus, agricultural production is the main source of non-point source pollution.

The N and P residuals per unit area of the West Liaohe River Basin are 225. 29~304. 21kg N ha^{-1} and 176. 25~282. 81Kg P ha^{-1}, respectively. Far exceeding the residual risk threshold of 180 kg N ha-1 and 35 kg P ha^{-1}, respectively, there is a risk of environmental pollution. Chemical fertilizer is the main source of the N, P nutrient input,the investigation found that the fertilization amount per unit area of farmland in the West Liaohe River Basin was as high as 417.93 kg · hm^{-2}, It greatly exceeds the safety limit of 225 kg · hm^{-2} set by developed countries to prevent chemical fertilizers from harming the environment [43]. From the N, P input component, fertilizer N, P nutrient inputs were three and four times the organic fertilizer N, P nutrient inputs, respectively. How to reduce N, P surplus, reduce the application of chemical fertilizer N, P are the key. The West Liaohe River Basin is an alternate farming and pastoral zone, and the combination of farming and pastoral is conducive to the improvement of N use efficiency. The manure produced by livestock and poultry breeding in the West Liaohe River Basin can be absorbed by farmland,we can reasonably set the ratio of organic fertilizer and chemical fertilizer, reduce the amount of chemical fertilizer application, and replace chemical fertilizer with organic fertilizer.

4.3. Further potential steps and research needs

By consulting relevant literature, the data show that in the past 15 years, there has been less research on the soil nutrient balance of farmland in Inner Mongolia, and most of them are soil experimental studies in small areas. Such research cannot highlight the differences in farmland nutrient balance between regions, also can not guide large areas Control of agricultural non-point source pollution. This paper, based on the long-term serial MOSDIS data in the West Liaohe River Basin, a GIS database of farmland nutrient balance was established to express the surplus of farmland nutrients in space. The research results can provide guidance for the adjustment of regional planting structure and the prevention

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and control of agricultural non-point source pollution. In the future, it will be necessary to continuously optimize the remote sensing interpretation model, improve the accuracy of crop interpretation. Set the ratio of organic fertilizer and chemical fertilizer use, reduce the amount of chemical fertilizer used, and find the best combination of organic fertilizer and chemical fertilizer use ratio. Optimize the crop planting pattern in the study area and determine the best crop planting structure.

5. Conclusions

In this paper,we established the GIS database of farmland nutrient balance, based on MODIS data, and regional and temporal changes on crop N and P balance in the West Liaohe River Basin from 2000 to 2015 were estimated. We found the Unit amounts of N input and output were increased in the West Liaohe River Basin, but the total N output decreased in 2015.The N balance decreased from 2000 to 2015. Compared with NUE, the N surplus rate (NSR) showed the reversed trend. P balance increased from 2000 to 2015. Compared with PUE, the P surplus (PSR) showed the reversed trend. Chemical Fertilizer is the primary source of nutrients. It is found that the West Liaohe River Basin is in a state of nutrient surplus for a long time. The N and P residuals per unit area of the West Liaohe River Basin are 225. 29~304. 21kg N ha^{-1} and 176. 25~282. 81Kg P ha^{-1}, respectively. Far exseeding the residual risk threshold of 180 kg N ha^{-1} [44]and 35 kg P ha^{-1} [45], respectively, and the nutrient use efficiency is low, there is a greater risk of agricultural non-point source pollution. From the trend of nutrient use efficiency and nutrient surplus rate in the West Liaohe River Basin, it can be concluded that the P pollution risk is higher than the N pollution risk. At the regional scale,The lower Liaohe River Basin (below the Sujiapu) was the region with the most violent changes in N and P nutrient balance, This region is also the region where the area of maize plantation fluctuates.

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