Dear Editor,

We are so appreciated for your letter on our manuscript “Reduction Assessment of Agricultural Non-Point Source Pollutant Loading”, Reference No: hess-2017-755. We are also extremely grateful to the editors’/reviewers’ comments on our manuscript and carefully considered every comment, and made cautious revision accordingly. Based on their suggestions, we have answered the questions in detail one by one. If you have any other questions about this paper, I would quite appreciate it if you could let me know them in the earliest possible time.

Most sincerely,

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Additive list

We have studied the valuable comments from you, the assistant editor and reviewers carefully, and tried our best to revise the manuscript. The point to point responds to the reviewer's comments are listed as following.

Reviewer's Responses to Questions

Generally, the manuscript addresses an important topic. The work in the manuscript is sufficient to be a publication. However, the writing needs to be improved in some sections of the manuscript. Please see specific comments below.

(1) Please write full words of abbreviations before using them. For example, NPS, SWAT in the abstract. The authors should check abbreviations throughout the manuscript.

Answer: Thanks for your very thoughtful suggestion.

We have made serious changes to the expression of abbreviations in the whole paper, such as NPS (Non-point source), SWAT (Soil and Water Assessment Tool), TN (Total Nitrogen), TP (Total Phosphorus), HTRW (Huntai River Watershed), environmental protection scenario (EPS), DEM (Digital Elevation Model), and BMPs (Best Management Practices scenarios).

The revised contents could be found in the file of "paper revised version (clean)".

(2) L16: "The study topics is mainly focus on", correct to "The study topic mainly focuses on". The purpose of the study is very general. I prefer specific objectives of the study.

Answer: Thanks for your very thoughtful suggestion.

We have revised the "The study topics is mainly focus on" to "The study topic mainly focuses on".

In order to make the article clear, we have revised the ""The study topic" to "The focus point". This section is the application scope of SWAT model, which was not the specific objectives of the study. The study objectives of the paper was "The model was used to quantify the spatial loading intensities of NPS nutrient TN (Total Nitrogen) and

TP (Total Phosphorus) to HTRW (Huntai River Watershed) under two scenarios (without & with buffer zones). The NPS pollutant loading decreased under the EPS, which showed that environmental protection measure could effectively cut down NPS pollutant loading in HTRW. SWAT was used to assess the reduction of agricultural NPS pollutant."

The revised contents could be found in the file of "paper revised version (clean)" & paper revised version (with track changes).

(3) L17-18: " SWAT model was constructed based on rainfall runoff and land use type": SWAT model also uses soil types and slope information.

Answer: Thanks for your very thoughtful suggestion.

We have improved SWAT model information, and have added the soil types and slope information to the SWAT. The revised contents could be found as the followed,

"SWAT model was constructed based on rainfall runoff, land use type, soil types and slope information.".

(4) L20: What do you mean by systematically analyzed? Can you describe what you did?

Answer: Thanks for your very thoughtful suggestion.

The systematically analysis contained three parts, which were (1) scenarios setting of SWAT; (2) modelling validation of SWAT in HTRW; (3) NPS pollutant loading calculation under status quo scenario & EPS.

The revised section was as followed,

Besides, the loadings and distribution traits of NPS pollutants were also systematically analyzed based on the model (scenarios setting, modelling validation, and pollutant loading calculation under status quo scenario & EPS).

(5) L24: What you mean by "scenario settings" in your study?

Answer: Thanks for your very thoughtful suggestion.

The "scenario settings" is the mean of "Land use types differences".

The revised contents could be found in the file of "paper revised version (clean)" & paper revised version (with track changes).

(6) In the Results and Discussion of the abstract, you should mention your results for calibration and validation before discussing about the results from scenarios.

Answer: Thanks for your very thoughtful suggestion. We added the following contents,

The E_{NS} (Nash-Sutcliffe efficiency coefficient) & R^2 (certainty coefficient) of stream & nutrients (TN & TP) in typical hydrological station were both greater than 0.6, and the $|Dv|$ (relative deviation) was less than 20%. The SWAT could be used in HTRW.

The revised contents could be found in the file of “paper revised version (clean)” & paper revised version (with track changes).

(7) Introduction, L53-54: "The concentrate…between different areas". Grammar is not right. Please rewrite.

Answer: Thanks for your very thoughtful suggestion.

We carefully devised the expression of the sentence. The revised contents were followed,

The NPS pollutant concentrate in water is dependent on the discharge intensity and pollutant treatment rate, therefore, which was difficult to make a fair comparison between different areas (Tucci 1998; Dingman 2002; de Oliveira et al.,2016).

(8) Materials and Methods. Section 2.1 about description of study area is too long. Please shorten it and only mention necessary information.

Answer: Thanks for your very thoughtful suggestion. We have shortened the length of Section 2.1. We only provided the necessary information of study area. The contents were been found as following,

The HTRW (40°27′~42°19′N, 121°57′~125°20′E) is in Liaoning province (Northeast China), and the watershed area is 2.73×104 km2, which takes about 1/5 of the area of Liaoning province (Fig 1). The HTRW is a tributary of Liaohe River Basin (The Liaohe River Basin is one of China's larger water systems) and is consist of Hunhe River, Taizi River, and Daliao River. The Hunhe River, Taizi River, and Daliao River watershed is HTRW’s sub-watershed. The HTRW has varied topography, low mountain is located in eastern part, and the other parts are alluvial plain. The elevation of northeast region is high. Loamy soils are mainly distributed in alluvial plain, and the average grade of lower HTRW is about 7%. HTRW area includes the cities of Fushun, Shenyang, Benxi, Liaoyang, Anshan, and Yingkou, most of Panjin city, some portions of Tieling city and a minor portion of Dandong city. The stream flow and nutrient were validated based on the five monitoring stations, Beikouqian, Dongling Bridge and Xingjiawopeng are located in Hunhe River, Xialinzi and Tangmazhai are in Taizi Rive. HTRW has temperate continental climate, the average annual temperature is 7°C, and precipitation is 748 mm.

(9) L141-L147 " For the calculation process … farmers status quo". I think these sentences should belong to the model setup section.

Answer: Thanks for your very thoughtful suggestion. We have put the " For the calculation process … farmers status quo" to the model setup section.

(10) The description about SWAT model is too long. Since we can find these information in many previous studies and in the manual of SWAT, there is no need to describe them in detail. Please shorten it and only choose the necessary information to describe.

Answer: Thanks for your very thoughtful suggestion. We have shortened the length of SWAT model description. We only provided the necessary information of SWAT model. We supplied some information of SWAT in the form of figure, such as Figure 1, and Figure 2.

(11) L184-185: " We used 30×30 grid data (elevation) as the basis for DEM operation". What did you do to prepare the DEM data?

Answer: Thanks for your very thoughtful suggestion.

We download the DEM data of HTRW from the SRTM (Shuttle Radar Topography Mission) data pack, the free data can be obtained on the website of http://srtm.csi.cgiar.org/SELECTION/inputCoord.asp. With GIS (Geographic Information System) platform, we obtained the DEM data of HTRW, as well as hydrological station & weather station distribution, by using the technology of DEM data projection transformation, splicing and cutting.

(12) L193-195 " The database of the underlying substrate was constructed based on the database of soil types using the soil properties & land development data as underlying substrate parameters". I don't understand what you want to say here. What are substrate parameters here?

Answer: Thanks for your very thoughtful suggestion.

The underlying substrate parameters means the data of topography characteristics, surface vegetation and soil types & distribution characteristics. These data were the basic to calculate NPS pollutant loading and distribution intensity changes.

(13) L204-205 "All the data were validated by the standard procedures used by the SWAT". Can you specify the standard procedures?

Answer: Thanks for your very thoughtful suggestion.

We added the related contents were as followed,

The SWAT uses the LH-OAT (Latin Hypercube One-factor-At-a-Time) sensitivity analysis method & SCE-UA (Shuffled Complex Evolution Algorithm) automatic calibration analysis method to determine the value of sensitive parameters.

The revised contents could be found in the file of "paper revised version (clean)" & paper revised version (with track changes).

(14) L228-229: Which period is used for calibration, and for validation?

Answer: Thanks for your very thoughtful suggestion.

We added the related contents were as followed,

The runoff, TN & TP loadings data used for calibration & validation were from 1992 to 2009, from 2006 to 2008, respectively.

In L287, to the stream flow, "For the simulation, 1990-1994 was the model preparation period, 1995-2001 was the model calibration period, and 2002-2009 was the model validation period." The contents could be found in the file of "paper revised version (clean)" (L296-L297).

In L304-306, to the nutrients, "Beikouqian, Xingjiawopeng, Xiaolinzi and Tangmazhai four hydrological stations had a continuous monthly water quality monitoring data from 2006 to 2007. Only the monthly data of TN & TP in Beikouqian were validated from 2008 to 2009 for the insufficient of water quality monitoring data.". Therefore, the 2006-2007 was the model calibration period, and 2008-2009 was the model validation period.

The revised contents could be found in the file of "paper revised version (clean)" & paper revised version (with track changes).

(15) L283-288: Your description on streamflow calibration is not clear about how you did for annual calibration and how you used the annual calibration to do monthly calibration. Did you use SWAT-CUP for this calibration?

Answer: Thanks for your very thoughtful suggestion.

We added the related contents were as followed,

(1) First, we dealt with the meteorological data and retained the 1990-2001 data series, then supplied the meteorological data simulation value from 1990 to 2001 by SWAT;

(2) We input into the runoff data of 1995-2001 to SWAT-CUP model to calibrate the runoff parameters;

(3) We took the (2) parameters into the database of SWAT, then extended the series of meteorological data to 1990-2009 and simulated runoff again.

(4) At last, we compared the runoff simulation values with monitoring value from 2002 to 2009.

The added contents could be found in the file of "paper revised version (clean)" & paper revised version (with track changes).

(16) Is the SWAT setup you used for calibration called the status quo scenario described in the Scenarios setting?

Answer: Thanks for your very thoughtful suggestion.

The scenarios setting for calibration was called the status quo scenario.

(17) L271-272: 29 smaller modeling units, are they sub-basins in SWAT? Or HRUs? Then after that you mentioned 184 HRUs. But with the number of soil types (26 types) and land use types (27 types), the number of HRUs (184) seems to be a very small number.

Answer: Thanks for your very thoughtful suggestion.

We added the related contents as followed,

To simulate the hydrological characteristics by SWAT, firstly, we divided the HTRW into a certain number of sub-basins according to DEM data, the sub-basins have the same characteristics of soil & land use; then we divided sub-basins into HRUs.

(18) I think the results are valuable, however, I don't feel they have been presented well to the reader.

Answer: Thanks for your very thoughtful suggestion.

In order to increase the readability of the paper, we reduced the number of pictures, and increased the number of tables to describe the reduction of agricultural NPS pollution loading. The spatial distribution of the mean annual TP and TN loading in the HTRW were 19, and 7 kg/ha, respectively. The region with a high NPS pollution loading is located in the middle and lower the HTRW, which included the urbanization and population density highly areas of Shenyang, Liaoyang and Anshan. Under the EPS, the TN and TP per unit area were 14, and 6 kg/ha, respectively. The output of NPS pollutant production, the loading intensities of TN & TP was reduced by 21.9%, 25.9% and 10.4% compared with the status quo scenario, respectively. The NPS pollution occurring within different sub-basins and regions located in the watersheds varied greatly, and the loading intensities of different pollutant types in the given sub-basin were slightly different. Land eco-restoration measures should be implemented to control agricultural NPS pollution from croplands. Therefore, SWAT simulation results provide a reference for the prevention of agricultural NPS pollution in agricultural watersheds.

(19) Conclusion

I feel that the conclusion is just repetition of the results and discussion. I don't think you should repeat the number of TN and TP loads under two scenarios. You should summarize what you learn from the results and discuss about them.

Answer: Thanks for your very thoughtful suggestion.

We have deleted the number of TN and TP loads under two scenarios. And summarized the contents that we learn from the results and discuss. We revised the contents as followed,

The NPS pollution is prone to cause in dry farmland, paddy, rural & urban areas. The SWAT model has been applied to study NPS in China by numerous research literature, they were mainly focuses on scenario simulation of NPS pollution and management in agricultural areas with rich hydrological and meteorological data. The basic monitoring data of HTRW were deficient, we selected the SWAT as the feasible method to access NPS pollutant loading in watershed level. We applied certain practices based on EPS to reduce the NPS pollutant loading in the Hunhe River, Taizi River and Daliao River watershed. The status quo scenario and EPS were used to calculate the output of NPS pollutant production. The output of NPS pollutant production, the loading intensities of TN & TP was reduced by 21.9%, 25.9% and 10.4% compared with the status quo scenario, respectively. In different regions of NPS pollutant loading in the HTRW changes greatly, and the pollutant loading intensity of different nutrients in the same region is slightly different. Land eco-restoration and land development mode adjustment measures should be practiced to reduce NPS pollutant loading of cultivated land.

The revised contents could be found in the file of “paper revised version (clean)” & paper revised version (with track changes).

We tried our best to improve the manuscript and made some changes in the manuscript. These changes will not influence the content and framework of the paper. And here we did not list the changes but marked in red in revised paper (Revision, changes marked).

We appreciate for Editors/Reviewers’ warm work earnestly, and hope that the correction will meet with approval.

Once again, thank you very much for your comments and suggestions.

Reduction Assessment of Agricultural Non-Point Source Pollutant Loading

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Abstract Non-point source (NPS) pollution has become a key impact element to watershed environment at present~~the largest threat to water quality ,in recent years~~. With the development of technology, application of models to control NPS pollution has become a very common practice for resource management and Pollutant reduction control in the watershed scale of China~~the management of soil and water resources on watershed scale in China~~. The Soil and Water Assessment Tool (SWAT) is a~~–~~ semi-conceptual model, ~~semi-distributed model, that~~which was ~~primarily~~ put forward ~~developed~~ to estimate pollutant production & the influences on water quantity-quality under different land development patterns in complex watersheds~~estimate the impacts of various land use and management practices on water, sediment, and agricultural chemical yields on water quantity and water quality in complex watersheds~~. Based on the overview of published papers with application of SWAT, the study topics is mainly focus on nutrients, sediments and related BMPs, impoundment and wetlands, hydrologic characteristics, climate change impact, and land-use change impacts. A SWAT model was constructed based on rainfall runoff and land use type. The migration-transformation processes of agricultural NPS pollutants were simulated and calculated based on the SWAT model. Besides, the loadings and distribution traits of NPS pollutants were also systematically analyzed based on the model. The model was used to quantify the spatial loading intensities of NPS Nutrient TN (Total Nitrogen) and TP (Total Phosphorus) to HTRW ~~NPS Nutrient (Total nitrogen TN and Total phosphorus TP) to Huntai River Watershed~~ (Huntai River basin~~HTRW, Liaoning province, China~~) under two scenarios (without and with buffer zones). The SWAT model was validated using actual

monitoring information. The SWAT model was calibrated and validated using actual monitoring data as well as the physical properties of the underlying substrate, hydrology, meteorology and pollutant sources in the HTRW. Scenario settings are mainly based on the changes of surface runoff and sediments, climate and land-use change from different spatial scales, and climatic/ physiographic zones. About 1 km within both banks of the trunk streams of the Huntai, Taizi and Daliao rivers, and 5 km surrounding the reservoirs were defined as buffer zones. Existing land use type within the buffer zone was changed to reflect the natural environment. The output of pollutant production under the "environmental protection" scenarios (EPS) was calculated based on the status quo scenario. Under the status quo scenario, the annual mean modulus of soil erosion in the HTRW was 811 kg/ha, and the output intensities of TN and TP were 19 and 7 kg/ha, respectively. For the unit area, the maximal loading intensities for TN and TP were 365.36 and 259.83 kg/ha, respectively. In terms of spatial distribution, TN and TP loading varied substantially. Under the EPS, the magnitude of N & P production from arable landthe magnitude of the nitrogen and phosphorus losses from cultivated land decreased to a certain degree, and the TN and TP pollution loading per unit area were reduced by 5 and 1 kg/ha annually, respectively. In comparison, the quantity of NPS pollutant production under the EPS was reduced by 21.9% compared with the status quo scenario, and the quantities of TP and TN decreased by 10.4% and 25.9%, respectively. These changes suggested a clear reduction in the export loading of agricultural NPS pollution. Loading intensities analysis showed that land use type is one key factor for controlling NPS pollution. The NPS pollution loading decreased under the EPS, which showed that environmental protection measure could effectively cut down NPS pollution loading in HTRW. SWAT was used to assess the reduction of agricultural NPS pollutant. However, SWAT model requires a large amount of data about the watershed being modeled; the data inaccuracy and local factors would impact the accuracy of the SWAT model. To determine the pollutant reduction under different land development patterns, and examine uncertainty of sensitivity parameters, the SWAT model in China has wide range of potential applicationFurther research is required to recognize the main factors that affect the accuracy of different NPS pollutants loading, examine uncertainty of sensitivity parameters, and extend the potential application range of SWAT in China.

Keywords Agricultural NPS Pollution Loading, Huntai River Watershed, Status Quo Scenario, Environmental Protection

1. Introduction

NPS pollution has become key influencing factor to improve surface water quality~~Non point source (NPS) pollution is increasingly recognized as a major contributor to surface water pollution in many watersheds (Lai et al., 2011)~~. There are many literatures have illustrated that underlying surface condition & precipitation characteristics~~demonstrated that soil characteristics, topography, and rainfall intensity~~ will impact the spatial distribution characteristics of NPS pollution nutrient loading (Robinson et al.,2005; Lindenschmidt et al.,2007). ~~Land use and landscape pattern influence the nature and extent of surface runoff and soil erosion (Liu et al.,2014).~~ The level of sediment and nutrient contribution from different parts of a watershed vary substantially (Niraula et al.,2013). The concentrate on NPS pollution is dependent on discharge it is highly variable and does not enable a fair comparison between different areas (Tucci 1998; Dingman 2002; de Oliveira et al.,2016). Loadings are considered better for comparing watersheds and for establishing the relationship between pollutants and land use (Quilb´e et al.,2006). At present, many researchers have preferred loadings over concentrations to convey their research (Yang et al., 2007; Ouyan et al.,2010; Outram et al., 2016). Land use types & underlying surface condition will influence the resources and nutrients distribution, and which will result in the reduction of NPS pollutant loading~~Land use and landscape pattern will influence the nature and extent of surface runoff and soil erosion, and which will result in changes in the NPS pollution loading~~ (Hundecha et al.,2004; Ahearn et al., 2005; Ouyang et al., 2013). In general, the spatial-temporal characteristic of NPS pollutant can be studied based on data statistics & model simulation~~the spatial distributions of NPS pollution can be quantified by monitoring or modeling methods~~ (Shen et al.,2013a). SWAT model can be determined NPS pollutant loading & supplied the decision-making program for watershed comprehensive development~~Watershed models can facilitate in identifying individual sources of NPS pollution and evaluating the decision schemes for watershed management~~ (Shen et al.,2011). Many documents have confirmed the combination of different land development patterns & landscape characteristics could reduce NPS pollution Many studies were focused on a reasonable land use and landscape pattern designed to reduce NPS pollution (Seppelt et al., 2002; Sadeghi et al.,2009).

Distributed physics & semi-conceptual models are effective means to calculate and assess theSpatially distributed hydrological models are useful tools to support the design and evaluation of NPS pollution spatial loading intensities. Many models have been developed to describe hydrological processes and NPS pollution through the physical laws of processes that occur in the natural land use type (Setegn et al.,2009; Oeurng et al., 2011). At the end of the 20th century, the SWAT model was developed by American scientists of USDA-ARSThe SWAT was developed by the United States Department of Agriculture-Agricultural Research Service (USDA-ARS) (Arnold et al.,1998). SWAT has been widely used in runoff simulation, the calculation of NPS pollution & implementation of best management practicesnon-point source pollution and the establishment of agricultural management measures. The SWAT was widely used in assessing the impact of NPS pollution under different land use types, for which was consisted by underlying surface, vegetation coverage, hydrometeorology, and agricultural production modules. The production changes of agricultural NPS nutrients based on diverse land development patterns have been studied & analyzed by SWAT modelThe SWAT includes approaches that describe how land cover, precipitation, temperature, and humidity affect different aspects of pollution loading of NPS nutrients and has been often applied as a tool to investigate the effects of land cover change. Several case studies of the impact of land use changes on pollution via NPS nutrients have been analyzed using this model (Ficklin et al.,2009; Shen et al., 2013b; Geng et al., 2015). which has been widely used to calculate & assess the distribution traits of NPS pollutant loading, as well as analyze the effects of land use and its spatiotemporal distribution pattern on NPS pollutant & soil loss in watershed scale The SWAT model has 701mathematical equations and 1013 intermediate variables, and the model has been widely used to simulate and evaluate the distribution traits of NPS pollutant loading, and analyze the effects of land use and its spatiotemporal distribution pattern on NPS pollutant and nutrient loss in small and large catchments in different regions of the world (Mapfumo et al.,2004; Gosain et al.,2005; Ouyang et al., 2009; Logsdon et al.,2013).

~~The articles related the SWAT model can be found in SWAT Literature Database (https://www.card.iastate.edu/swat_articles/).~~

The HTRW is the important tributary of Liaohe River Basin, which has been polluted seriously in recent years~~The Huntai River Watershed (HTRW) is a sub-basin of the Liaohe River Basin, which has historically been one of the most polluted basins in China in the last several decades~~. The main NPS pollution in Liaohe River is agricultural NPS pollution, and most NPS pollution happens in HTRW within Liaoning province (~~Department of Environmental Protection of~~ Liaoning Province DEP, 2011). Therefore, the HTRW face immense pressure due to water pollution. According to the twelfth five-year developmental plan, the annual mean growth of GDP in the Liaohe River watershed was greater than 13% and the urbanization rate was close to 75%. The policy of 'Revitalization of Old Industrial Bases in Northeast China' has caused significant changes in the land-use structure~~The urbanized area has been accelerating due to implementing the policy of 'Revitalization of Old Industrial Bases in Northeast China'. And the policy also has caused land use change considerably~~ (Liu et al.,2014). This accelerating urbanization alters the existing land use type in a way that results in more NPS pollution to local surface waters (Kuai et al.,2015). HTRW is the Basic product manufacturing base in China~~HTRW is one of the most important industrial and agricultural production bases in China~~.

The SWAT of the present study was used to quantify the spatial loading intensities of TN & TP to HTRW under different land use types, and assess the adaptability changes based on NPS pollutant loading reduction~~The SWAT of the present study was used to quantify the spatial loading intensities of TN and TP to HTRW under different land use types, and estimate the overall impacts based on the NPS pollution loading decrease~~. Nutrient losses were simulated in different scenarios-status quo scenario (without buffer zones) and "environmental protection" scenario (EPS, with buffer zones), using SWAT. The flow chart~~objectives~~ of this study were to: (1) elaborate the underlying surface (land use)~~analyze the land use~~ changes in the HTRW; (2) simulate the NPS pollution loading (TP and TN) of the HTRW under two scenarios; (3) contrast the different of NPS pollution loading in two scenarios, and assess the effect of reducing pollution loading under EPS. In this paper, the SWAT was used to estimate the agricultural NPS pollution loading of HTRW, and digital comparison analysis method was utilized to analyze the spatial distribution characteristics of pollution loading.

2. Materials ~~and~~ & ~~Methods~~methods

2.1. HTRW~~Study area~~

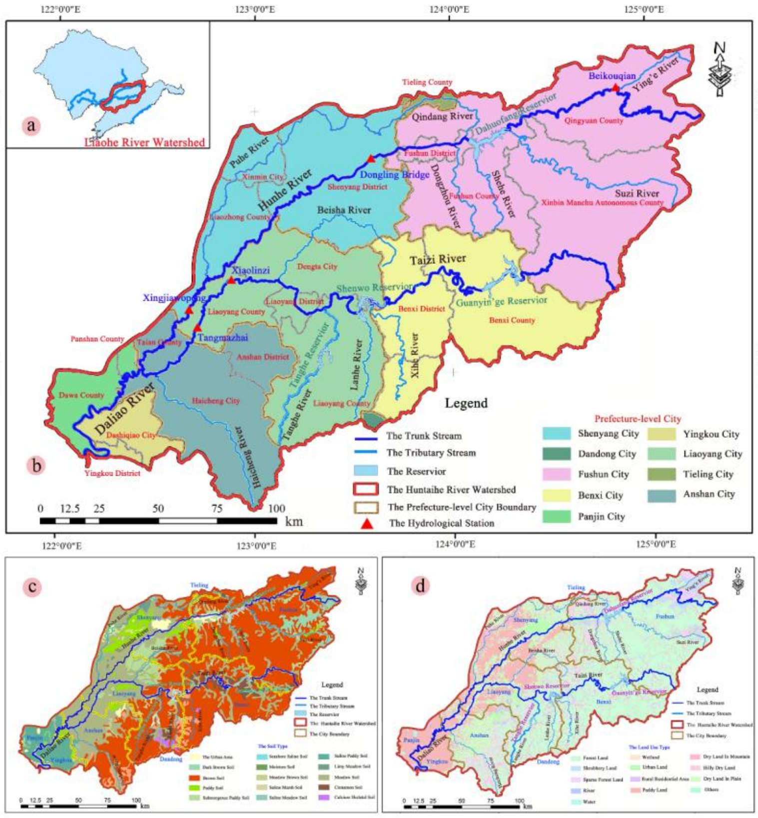
The HTRW (40°27′–42°19′N, 121°57′–125°20′E) is in Liaoning province (Northeast China)~~is located in east Liaoning province, Northeast China~~, and the watershed area~~and the area of the watershed~~ is 2.73×10^4 km^2, which takes about 1/5 of the area of Liaoning province~~18.45% of the area of Liaoning Province~~ (Fig 1). The HTRW is a tributary of Liaohe River Basin~~a sub-basin of the Liaohe River Basin~~ (The Liaohe River Basin is one of China's larger water systems~~The Liaohe River Basin is one of China's seven major water systems, which is in the northeast of China.~~) and is is consist of Hunhe River, and Daliao River~~made up of the Hunhe River (415 km), the Taizi River (413 km) and Daliao River (96 km)~~. The Hunhe River, Taizi River, and Daliao River watershed is HTRW's sub-watershed~~The Hunhe River watershed, Taizi River watershed, and Daliao River watershed is sub-basin of HTRW~~. The HTRW has varied topography, low mountain is located in eastern part, and the other parts are alluvial plain. The elevation of northeast region is high~~The terrain of the watershed declines from northeast to southwest, the eastern part of the watershed consists of low hills, while the middle and western parts are mainly alluvial plain~~. Loamy soils are mainly distributed in alluvial plain, and the average grade of lower HTRW is about 7%.~~The lower watershed primarily consists of loamy soils and the average slope is 8%.~~ HTRW area ~~The study area covers most of the central Liaoning Urban Agglomeration which is one of ten urban agglomerations in China, and~~ includes the cities of Fushun, Shenyang, Benxi, Liaoyang, Anshan, and Yingkou, most of Panjin city, some portions of Tieling city and a minor portion of Dandong city. The maxim runoff in the watershed is 76.32×10^8 m^3, primarily concentrated in June through September. The stream flow and nutrient ~~part of SWAT~~ was validated based on based on the five monitoring stations~~the five hydrological stations~~, Beikouqian, Dongling Bridge and Xingjiawopeng are located in Hunhe River, Xialinzi and Tangmazhai are in Taizi Rive. The total population of HTRW is 18.9 million people. The GDP is about 62% of Liaoning Province in 2012~~The study area had resident population of 1.89×10^7, and produced 62% of the total gross domestic product (GDP) of Liaoning Province in~~

2012.- HTRW has temperate continental climate, the average annual temperature is 7°C, and precipitation is 748 mmThe monsoon climate features of this watershed include an annual temperature ranging from 5~9°C and precipitation of approximately 748 mm.

The HTRW is in a conventional agricultural farming area, with a large area of farmland dominated by crop plants. The total area of farmland is 10 763 km^2 (account for 39.4% of the total area), including 4 086 km^2 of paddy field (dominated by rice) and 6 677 km^2 of dry farmland (including corn, soybean, vegetables and other crop plants). The upper reaches of the Hunhe and Taizi rivers have mountainous (69%), low hilly (6.1%) and plain land (24.9%). The economic output value of HTRW is dominated by agriculture.Agriculture is the main economic activity in HTRW. The farmland is mainly distributed in the floodplain area and valleys in riverine belts. Considering land patternBased on the land use, rainfall and source of pollutants, the HTRW faces a high risk of pollution from agriculture. Heavy use of fertilizers and soil erosion in the upper of HTRW has led to serious NPS pollution in HTRWThe massive application of fertilizers has caused the release of much N and P, resulting in serious NPS pollution in HTRW. For example, the Dahuofang reservoir of the Hunhe River and the water resources conservation area in its upper reaches are facing multiple threats, the agricultural NPS pollution is becoming increasingly serious and has not yet been controlled effectively (Shen et al., 2013c).

Fertilization in the HTRW is predominantly with nitrogen, followed by phosphorous and potassium. The heavy use of chemical fertilizers was mainly urea The types of fertilizer used in the watershed were mainly urea, diammonium phosphate and a small amount of potassium phosphate compound fertilizer. Atrazine and acetochlor were mainly used on dry farmland, and butachlor was mainly used in paddy fields. Based on the statistical data for 2006-2012, the quantity of fertilizers and pesticides applied in the watershed fluctuated annually. The upper reaches of the Huntai and Taizi rivers are dominated by mountains, the cultivation and harvesting of crops are conducted by hand, and therefore thorough statistics are not available. At present, weeds and pests in farmlands were mainly controlled by pesticides and herbicides. The upstream is rich in forest resources, the downstream has a large number of farmland, special landscape layout makes the HTRW become potential area for agricultural NPS pollution.

The upstream is rich in forest resources, and the downstream area is based largely on agricultural-pastoral industry, rendering the whole region to be the main recipient of pollutant emission.



a. The location of the HTRW.   b. The geographical zoning of HTRW.

c. The land use type of HTRW.   d. The soil type of HTRW.

Figure 1. Basic information on the HTRW. The figure has been supplied by www.geodata.cn, which is a national science and technology basic conditions platform and an earth system science data sharing platform. The figure information is public. The Liaoning province Water Resources Administrative Bureau granted permission for the basic information in the HTRW.

2.2. Model description

2.2.1. The Soil and Water Assessment Tool

SWAT is a semi-physical model developed to quantitatively calculate the response status of water quantity & quality to land use and management methods in the scale of watershedSWAT is a watershed-scale model developed to estimate the impacts of various land use and management practices on water quantity and water quality over a continuous long period (Gassman et al.,2007). SWAT is an effective to determine the long-term impact using monitoring data The model is proven to be efficient in using readily available data and in studying long-term impacts (Arnold et al.,2012). The basic data input for model running includes DEM/topography, soil type, vegetation status/ Land landscape, and best management practices scenariosThe model inputs consist of topography, soil properties, land use/cover type, weather/climate data, and land management scenarios. The calculation unit of watershed SWAT model is sub-watershed, and HRU (Hydrological Response Units), the unit delineation is based on the underlying surface status, vegetation coverage, soil classification, and land use (Neitsch, 2005).

The watershed is sub-divided into sub-watersheds and each sub-watershed is further divided into hydrological response units (HRU) based on topography, land use, and soil data (Neitsch, 2005).

The HRUs of SWAT are automatically divided according to soil conditions, DEM, geomorphological features, and land development (Douglas-Mankin et al., 2010)The HRUs in SWAT are defined as the lumped areas by the land use, slope and soil type in a sub watershed (Douglas-Mankin et al., 2010). For the calculation process is realized on HRU, therefore, we selected 0% land development, elevation/slope, and soil classification / attributes as the initial value on the scale of small key areaAs most of the equations are solved on the HRU level, 0% land use, slope and soil thresholds were chosen to define the HRU to capture small critical areas, therefore, 184 HRUs were delineated to determine NPS pollutant loading. A total of 184 HRUs were defined in the study watershed. In order to assess pollutant loss and ecological flow status, the flow curve, soil nutrient loss curve, and water-salt balance equation were applied during the period of model debuggingTo estimate water balance and nutrient simulation, the curve number method and Modified Universal Soil Loss Equation were applied during the build-up period. Meteorology data (sun radiation, atmospheric pressure, atmospheric temperature, precipitation and wind speed) were obtained from meteorological and hydrological stations of 12 cities located within HTRW.Weather data (daily precipitation, minimum and maximum temperature, solar radiation and wind speed) were obtained from 12 city weather stations located approximately within the watershed. The data of BMPs, such as crop sowing/harvest time, crop irrigation time, cultivation structure of cultivated land, fertilizer-use efficiency, and farmland planting plan were got from agriculture & environmental management department, or collected from the survey of farmers status quo. The farmland management information, such as the timing of manure and fertilizer application, crops harvest dates and land plantation structure were collected from detailed interviews with local farmers. Based on the above assessment results, we used QUAL2E (water quality model) to determine N & P yields loading, the route of sediment transport, and pollutant concentration of watershed outlet.The sediment, N and P yields from each sub-watershed were subsequently routed through the channels to the watershed outlet, using the QUAL2E (water quality model) program.

TThe SWAT is mainly used to assess the nutrient (N & P) production, migration, and transform.he SWAT model mainly simulates N and P cycling. These cycling processes occur simultaneously with the processes of the hydrological cycle and soil erosion. The N & P cycles simulation of SWAT was developed based on 5 different forms of N & 6 different forms of P, respectivelySWAT model's nitrogen and phosphorus cycles through five different pools of nitrogen (two inorganic forms: NH_4^+ and NO_3^-; three organic forms: fresh, stable and active) and six different pools of phosphorus (three inorganic forms: solution, active and stable; three organic forms: fresh, stable and active) in soil. The N & P cycles were consisted of the process of decomposition, mineralization, fixation, and conversionMineralization, decomposition, and immobilization are important processes in both N and P cycles. The NPS pollutant loading function is the basis of assessing N & P transport and transformationOrganic N and P transport with sediment is estimated using a loading function (McElroy, 1976; Williams et al.,1978; Zhang, 2005). Organic N & P losses calculation of SWAT was achieved by the integrated function of soil nutrient curve, NPS pollutant loading, soil properties change rate, and crop growth characteristicsDaily organic N and P runoff losses are calculated by loading functions based on the concentrations of these elements in the top soil layer, the sediment yield, and an enrichment ratio. The total amount of nitrate in lost soil was calculated by the product of water volume and nitrate concentration in water~~Nitrate concentration in mobile water is calculated and multiplied with mobile water volume to estimate total nitrate lost from the soil layer~~. Water volume is the consisted of surface runoff, groundwater runoff, and interflow/ subsurface flow~~Mobile water is the sum of runoff, lateral flow and percolation~~. The concentration of soluble P in water is calculated by topsoil P stocks, runoff variation, ratio of soluble P, and soil particle characteristics~~The soluble P removed in runoff is estimated using the P concentration in the top soil layer, runoff volume and the P soil partitioning coefficient~~.

Surface runoff from daily precipitation in HRU/Sub-watershed was calculated & assessed using the SCS-CN corresponding relationship curve and rainfall-runoff Coefficient (USDA Soil Conservation Service. National Engineering Handbook, 1972)~~Surface runoff from daily precipitation in each HRU was estimated using the Soil Conservation Service Curve Number (SCS-CN) method (USDA Soil Conservation Service. National Engineering Handbook, 1972)~~. With SCS-CN curve, saturated moisture, soil water profile/vertical distribution of soil moisture content, runoff module number of the underground water is determined, as well as the related parameters daily of precipitation.~~In the curve number method, daily precipitation is partitioned between surface runoff and initial and continued abstractions as a function of antecedent soil moisture condition.~~ The total discharge of runoff from sub-watershed/ HRUs is the sum of surface runoff flow, groundwater runoff flow, and interflow/ subsurface flow~~The total sub-watershed discharge computed by SWAT includes runoff from its HRUs and subsurface flow including lateral flow and return flow~~. Domestic water & irrigation water is direct consumptive water resources, the mainly water resources is surface runoff & groundwater runoff (Neitsch,2005).~~Water withdrawals for irrigation or urban use can be considered from different sources, such as aquifers or directly from the stream (Neitsch,2005)~~ The main routing of water circulation in SWAT is network-node diagram and natural-artificial dualistic water cycle mode. ~~. Channel routing in SWAT is represented by either the variable storage or Muskingum routing methods.~~ In the paper, we used a dualistic method for multi-layer and multi-function separation and interception of the rainfall and run off resources.~~For this study, the variable storage method was used.~~ Circulating flow of SWAT was varied with the dynamic changes of evaporation, infiltration, transport, and return flow (Arnold et al.,1998).Outflow from a channel is adjusted for transmission losses, evaporation, diversions, and return flow (Arnold et al.,1998). The HRUs of SWAT used soil erosion modulus, soil & water loss coefficient, and Universal Soil Loss Equation (MUSLE) to analyze erosion and sediment yield (Williams, 1975)Erosion and sediment yield from each HRU are estimated based on the Universal Soil Loss Equation (MUSLE) (Williams, 1975). Sediment is routed through channels using Bagnold's sediment transport equation (Bagnold, 1977). We used 2009 version of SWAT to calculate the correlation parameters. This study was carried out using the 2005 version of SWAT.

2.2.2. Model inputs

The data of DEM, geomorphology, underlying surface status, soil properties, land cover, meteorological & hydrological data (precipitation, evaporation, temperature, and atmospheric pressure, et al.) were input to achieve the operation of SWAT (Niraula et al.,2013).Data required in this study included Digital Elevation Model (DEM), soil properties, land use/cover, climate data such as precipitation, and minimum/maximum temperature, et al. (Niraula et al.,2013) Table 1 supplied the basic data information to be used in SWAT model. The database for the SWAT simulation is shown in Table 1. We used 30×30 grid data (elevation) as the basis for DEM operationDEM data were prepared using a digital map with a 30m grid (elevation). The DEM was selected as the topographical basis on which to construct the SWAT model, to extract the scope of the study area and to construct the topographical model. The stream network in the study area was extracted using 1:250 000 digital water system data (data source: www.geodata.com) as an ancillary model to construct the stream network model of the HTRW. We classified land use types into 27 categories.Land use data (1:100,000) were categorized into 27 types, The main type of land use of HTRW is forest (including orchard, 48.64%), dry land (24.38%), rice paddy (14.92%), urban land (vacant land, 7.78%) and unused land (uncultivated land, 1.85%) grassland (0.92%)The primary land use types in this area are paddy field (14.92%), dry land (24.38%), forest (including orchard, 48.64%), urban land (vacant land, 7.78%) and unused land (uncultivated land, 1.85%) grassland (0.92%). Soil types were categorized into 26 types, the primary soil types in this area are brown soil (54.1%), meadow soil (29.7%) and paddy soil (11.0%). The database of the underlying substrate was constructed based on the database of soil types using the land use data and soil data as underlying substrate parameters (Liu et al.,2015). The soil parameters were obtained from National earth system science data sharing infrastructure databaseNational earth system science data sharing infrastructure database was used to derive soil parameters. The watershed meteorological data (precipitation, evaporation, and temperature)(daily precipitation and minimum and maximum air temperature data) used in the present study include precipitation data for 1990-2009 collected by 76 rainfall stations and air temperature data for1990-2009 collected by 12 city meteorological stations. The missing meteorological information (rainfall, air temperature, relative humidity, mean wind velocity and solar radiation data) can be generated using the weather data generator simulation.The climate condition was then simulated using daily monitoring data from weather stations; weather data generator was used to supplement the missing records (missing rainfall, air temperature, relative humidity, mean wind velocity and solar radiation data) At least 3 sets monthly monitoring data . At least 3 data points per month for nitrate (NO_3), nitrite (NO_2), Ammonia (NH_3, NH_4), total nitrogen (TN), and total phosphorus (TP), were available in the time of 2006–2009were available for the period 2006–2009. Organic P and N were calculated by subtracting the sum of mineral components from the TP and TN, respectively (Neitsch,2005) We got the information of crop type, farming system, sowing time, fertilization time, and social economics from investigation and statistics department in HTRW. Other information, including crop farming, tillage, social economics, and the amount and timing of fertilizer application, was based on a statistics yearbook, as well as on field investigations in HTRW. All the data were validated by the standard procedures used by the SWAT.

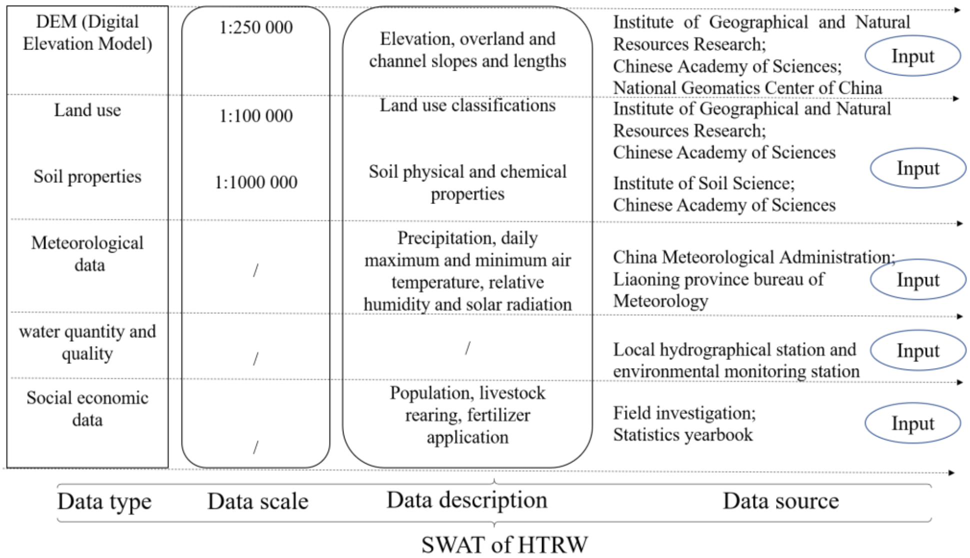


Figure 2. Data information in the HTRW.

Data type	Scale	Data description	Source
Digital Elevation Model (DEM)	1:250 000	Elevation, overland and channel slopes and lengths	Institute of Geographical and Natural Resources Research; Chinese Academy of Sciences; National Geomatics Center of China
Land use	1:100 000	Land use classifications	Institute of Geographical and Natural Resources Research; Chinese Academy of Sciences
Soil properties	1:1 000 000	Soil physical and chemical properties	Institute of Soil Science; Chinese Academy of Sciences
Weather data	——	Precipitation, daily maximum and minimum air temperature, relative humidity and solar radiation	China Meteorological Administration; Liaoning province bureau of Meteorology
water quantity and quality	——	——	Local hydrographical station and environmental monitoring station
Social economic data	——	Population, livestock rearing, fertilizer application	Field investigation; Statistics yearbook

The data information (type, scale, description, and source) of SWAT in HTRW are showed in Figure 2The details of the watershed features and the authority who issued the permission for information are listed in Table 1. We input the related meteorological, hydrological and soil data of SWAT got from China Meteorological Administration, China Hydrology, and Environmental & Ecological Science Data Center for West China.We obtained the major GIS input files and the related physical data from Institute of Geographical and Natural Resources Research, Institute of Soil Science and China Meteorological Administration (Shen et al., 2013b). The China Hydrology, water resources & water quality monitoring

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department of HTRW provided the automatic & regular monitoring hydrological dataThe periodic monitoring flow and water quality data were obtained from local government. All necessary permits were obtained for the input data. The Liaoning province Water Resources Administrative Bureau granted permission for the modelling of the pollutant production response to different land utilization scenarios in the HTRW.

2.2.3. Calibration and validation

The data of monthly scale were used to achieve the simulation of SWATWe used a monthly simulation step for the SWAT model. We used the code open SWAT-CUP module to calibrate parameters of SWAT in HTRW automatically (Abbaspour et al.,2007).We used the SWAT model calibration software SWAT-CUP 4.3.7 to perform auto-calibration in the HTRW (Abbaspour et al.,2007). SWAT-CUP is a public domain program, and thus can be copied and used freely. Sequential uncertainty fitting algorithm has higher calculation accuracy and simple application method, which was extensive used in the SWAT-CUP module (Wang et al.,2014; Yang et al.,2008)Among the model calibration methods available with SWAT-CUP, SUFI-2 has proven effective for calibrating and validating the SWAT model in different regions, with limited computational cost and high accuracy (Wang et al.,2014; Yang et al.,2008). By applicability of the SUFI-2 method, 28 parameters were modified using the Sequential Uncertainty Fitting version-2 program, which has been incorporated into SWAT cup software (Abbaspour et al.,2009). The E_{NS} can effectively avoid the uncertainty of hydrological sequence (precipitation, water flow, and evaporation), which was used to evaluate the run-off flow change of hydrological station in HTRWThe Nash-Sutcliffe coefficient was used as a criterion to evaluate the model performance, because it is the most common indicator in evaluating the hydrologic model (Nash, 1970).

The model for the present study was calibrated and tested using artificial parameter modification and automatic calibration. First, the runoff was calibrated, followed by N, P and other nutrients. The runoff was calibrated and tested using real data from the Xingjiawopeng, and Tangmazai hydrological station (Fig 1ure 4). The simulated values of N and P were calibrated using monitoring data from Beikouqian, Dongling bridge, Xingjiawopeng, Xiaolinzi, and Tangmazhai hydrological station. Various hydrologic and water quality parameters were adjusted under their change interval to fit with the monitored/observed data during calibration and validation (Figure 3)Various hydrologic and water quality parameters were changed within their ranges to get the best fit with the observed data during calibration and validation (Table 2). ESCO, GWQMN, and SURLAG were three key parameters in the process of calibration & validation of water flowESCO, GWQMN, and SURLAG were the three most sensitive parameters in the surface runoff simulation (Francos et al., 2003; Shen et al., 2010). For there was an explicit provision based on available water content in the soil profile, a change in the initial CN2 value would not greatly affect run off components. For nitrogen, the most sensitive parameters were NPERCO and SOL_NO3. For the phosphorus, SOL_LABP, PPERCO and PHOSKD were the most sensitive parameters. The initial concentration in the soil and the percolation coefficient were both identified to have a high degree of sensitivity for nutrients (Shen et al.,2014). The other sensitive parameters selected for calibration & validation in HTRW were showed in Figure 3Based on the sensitivity analysis, the most sensitive parameters were screened for calibration and validation in HTRW. In the HTRW, Liaoning Province government began to monthly monitoring of pollutant since 2006 the local government began periodic monitoring of nutrients with approximately monthly sampling since 2006. The runoff, TN & TP loadings data used for calibration & validation were from 1992 to 2009, from 2006 to 2008, respectively.The parameter calibration and validation were conducted using data for runoff from 1992 to 2009, TN and TP loadings from 2006 to 2008.

In the present study, the simulated effects were evaluated based on analysis and comparison using the runoff hydrograph, *Dv* (relative deviation), E_{NS} and R^2 (certainty coefficient)In the present study, the simulated effects were evaluated based on analysis and comparison using the runoff hydrograph, relative deviation (*Dv*), Nash-Sutcliffe efficiency coefficient (E_{NS}) and certainty coefficient (R^2). The runoff hydrograph and *Dv* were frequently used to simulate the entire deviation of water quantity; E_{NS} and R^2 were used to simulate the effects of the simulation (Yang et al.,2014). The *Dv*, E_{NS} and R^2 are calculated as

$$D_v = [(M - W)/W] \times 100\% \qquad (1)$$

Here, D_v was the relative deviation; *W* was the observed mean value; and *M* was the predicted mean value.

$$E_{NS} = 1 - [\sum_{i=1}^{n}(W_i - M_i)^2 / \sum_{i=1}^{n}(W_i - \overline{W})^2] \qquad (2)$$

Here, E_{NS} was the Nash-Sutcliffe efficiency coefficient; W_i was the observed value at time i; W_i was the simulated value at time i; and $\overline{W}$ was the observed mean value.

$$R^2 = \{[\sum_{i=1}^{n}(W_i - \overline{W})(M_i - \overline{M})]/[\sqrt{\sum_{i=1}^{n}(W_i - \overline{W})^2}\sqrt{\sum_{i=1}^{n}(M_i - \overline{M})^2}]\}^2 \qquad (3)$$

Here, R^2 was the certainty coefficient; W_i was the observed data at i^{th} period; M_i was the simulated data at i^{th} period~~W_i was the observed value at time i; M_i was the simulated value at time i~~; $\overline{W}$ was the observed mean value; and $\overline{M}$ was the predicted mean value.

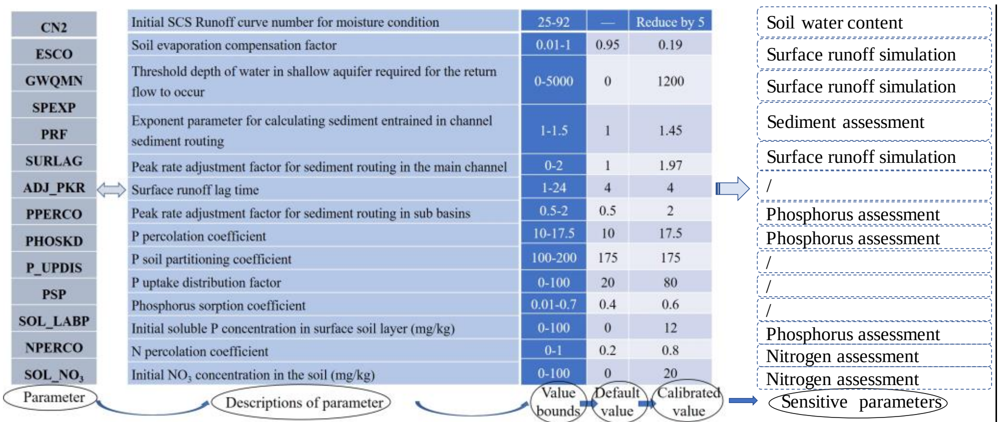


Figure 3. Parameters calibration of SWAT model in the HTRW

~~**Table 2.** Calibrated parameters of SWAT model in the HTRW Based.~~

~~Parameter~~	~~Descriptions~~	~~Value bounds~~	~~Default value~~	~~Calibrated value~~
~~CN2~~	~~Initial SCS Runoff curve number for moisture condition~~	~~25-92~~	~~—~~	~~Reduce by 5~~
~~ESCO~~	~~Soil evaporation compensation factor~~	~~0.01-1~~	~~0.95~~	~~0.19~~
~~GWQMN~~	~~Threshold depth of water in shallow aquifer required for the return flow to occur~~	~~0-5000~~	~~0~~	~~1200~~
~~SPEXP~~	~~Exponent parameter for calculating sediment entrained in channel sediment routing~~	~~1-1.5~~	~~1~~	~~1.45~~
~~PRF~~	~~Peak rate adjustment factor for sediment routing in the main channel~~	~~0-2~~	~~1~~	~~1.97~~
~~SURLAG~~	~~Surface runoff lag time~~	~~1-24~~	~~4~~	~~4~~
~~ADJ_PKR~~	~~Peak rate adjustment factor for sediment routing in the sub-basins(tributary)~~	~~0.5-2~~	~~0.5~~	~~2~~
~~PPERCO~~	~~Phosphorus percolation coefficient~~	~~10-17.5~~	~~10~~	~~17.5~~
~~PHOSKD~~	~~Phosphorus soil partitioning coefficient~~	~~100-200~~	~~175~~	~~175~~
~~P_UPDIS~~	~~Phosphorus uptake distribution factor~~	~~0-100~~	~~20~~	~~80~~
~~PSP~~	~~Phosphorus sorption coefficient~~	~~0.01-0.7~~	~~0.4~~	~~0.6~~
~~SOL_LABP~~	~~Initial soluble P concentration in surface soil layer (mg/kg)~~	~~0-100~~	~~0~~	~~12~~
~~NPERCO~~	~~Nitrogen percolation coefficient~~	~~0-1~~	~~0.2~~	~~0.8~~

SOL_NO3	Initial NO3 concentration in the soil (mg/kg)	0-100	0	20

The first four years (1990-1994) were regarded as domestication stage of SWAT to minimize the uncertainty of initial meteorology & underlying surface valueThe first four years (1990-1994) were used as a warm-up period to minimize uncertain initial conditions (e.g., soil moisture, ground residue, nutrient pool). We used manual method of parameter adjustment to calibrate the SWAT in HTRWA manual calibration technique was adopted. To determine the sensitivity of various parameters, we manually adjusted one parameter at a time according to the accuracy and change interval in Figure 3To identify the sensitive parameters for calibration, we used a manual one-at-a-time relative sensitivity analysis to the list of parameters synthetized from reviews. The SWAT models were calibrated for streamflow using data from the Institute of Geographical and Natural Resources Research. The observed streamflow was separated into surface runoff and base flow components with a base flow separation filter program (Arnold et al.,1998). To realize the matching between hydrographs base flow from model simulation and actual monitoring, the quantitative data analysis technology (E_{NS} & R^2) was used to calibrate SWATTo realize the matching between hydrographs base flow from model simulation and excess runoff with observed counterparts, quantitative measures (percent bias, determination coefficient, and Nash-Sutcliffe efficiency) were also used during calibration (Neitsch,2005). In order to calibrate the stream flowWhen the models were calibrated for flow, we subsequently calibrated runoff, and nutrients (TP and TN) with the same geographical and hydrological data. During calibration, we used LOADEST model to eliminate the uncertainties caused by the differences in sampling & testing methods of water quality (Yang et al.,2014).During calibration, we used LOADEST model to eliminate the uncertainties coming from measurement errors in water quality data (Yang et al.,2014).

2.3. Scenarios setting

To seek the relationship between agricultural NPS pollutant loading and land use types, comprehensive comparison method was used in different land use types under urbanizationTo highlight the interactions of the land use type and NPS nutrient pollution loading over a long period, comparative analysis approach was applied in different land use types under urbanization. In this study, two scenarios were established: status quo scenario, and “environmental protection” scenarios (EPS).

The status quo scenario was formulated based on the existing socio-economy developmental structure and environmental protection measures, and the land use type in the light of the existing developmental model and planning conditions. The BMPs information & land use data (cultivated land area, pesticide & fertilizer use utility amount, crop type) were obtained from Liaoning Province statistical yearbooks-2013 and field survey~~Land management data including crops growth characters, fertilizer and pesticide utility, came from Liaoning Province statistical yearbooks (2013) and field survey~~.

Considering the regional development prospects & eco-environment protection strategy in HTRW, The EPS was proposed~~established and based on related watershed ecological and environmental protection policies~~. 1 km within both banks of the Hunhe, Taizi and Daliao rivers and 5 km surrounding reservoirs are defined as buffer zones. In the buffer zones, existing land use types were changed to restore the natural environment (grassland and forest). The output of pollutant production is calculated based on the regional environmental protection. This scenario not only preserves the fundamental position of agriculture in the watershed, but also improve the ecosystem service value of the watershed by only slightly reducing the amount of fertilizers and pesticides used for agricultural production. The scenarios setting can provide scientific basis for further understanding characteristics of the nitrogen and phosphorus loadings and agricultural structure adjustment in HTRW.

2.4. Framework of the study

Hunhe River, Taizi River, and Daliao River sub catchment was delineated based on DEM & river system, and further divided by 29 small calculation module according to 184 HRUs, water resources zoning, and administrative zoning~~In the application of SWAT model, the HTRW is subdivided into 3 sub-catchments (Hunhe River, Taizi River, and Daliao River sub catchment) based on DEM and channel network, and further delineated by 29 smaller modeling units according to 184 HRUs, water resources zoning, and administrative zoning~~. According to the water network & the location of basin drainage, we used the monitored data calibrate & validate the stream flow and concentration changes of pollutants in HTRW~~According to the simulated water~~

~~routing through the stream network to the basin outlet, the stream flow and water quality parts of SWAT model were calibrated and validated based on observed data~~. And then the land development patterns in two scenarios were imported to SWAT model to simulate the TN and TP pollution loading~~And then the land use maps in two scenarios were input SWAT model to simulate the TN and TP pollution loading~~. Finally, the NPS pollution loading decrease was analyzed based on land use scenarios.

The primary source area of aquatic pollution is mainly distributed along both channels of the trunk stream of the Hunhe River, Taizi River, and Daliao River; the risk of NPS pollution is mainly related to the patterns of agricultural plantation and farmland utilization. The secondary source area of aquatic pollution is mainly distributed along the tributaries of HTRW. Therefore, this project paid special attention to the pollutant production in the agricultural lands adjacent to the water channels.

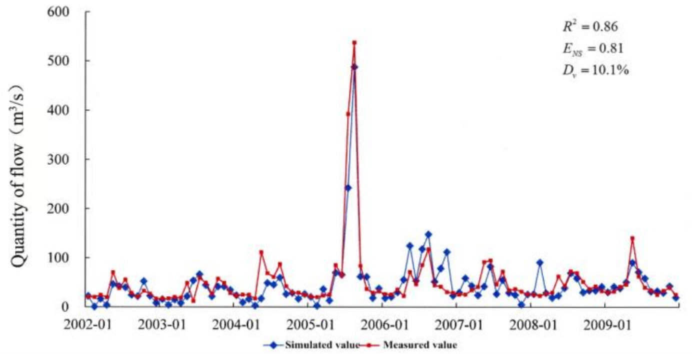
3. Results and Discussions

3.1 Model validation

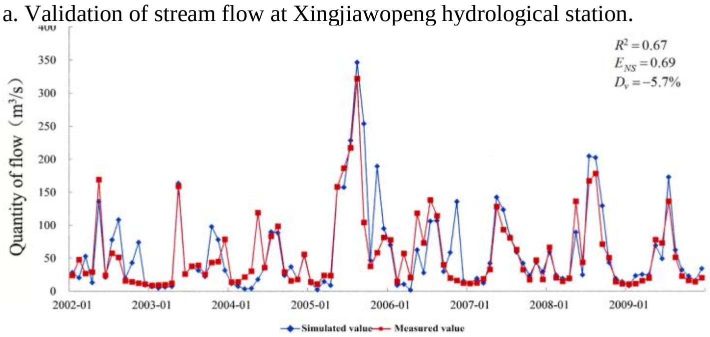
Stream flow. Because the HTRW lacks basic runoff data, the present study focused on calibrating and testing the runoff model. During annual calibration, the runoff curve data were first calibrated, and then the available water content in the soil and the soil evaporation compensation coefficient were modified until they matched the requirements for runoff. Finally, the monthly runoff curve was modified. For the simulation, 1990-1994 was the model preparation period, 1995-2001 was the model calibration period, and 2002-2009 was the model validation period.

According to the calibration results, E_{NS} and R^2 for Xingjiawopeng hydrological station and Tangmazhai hydrological station were both greater than 0.6, and the $|Dv|$ values for both stations were less than 20% during the model preparation period, suggesting that the parameters of the SWAT model were reliable after calibration, and thus the model can be used for further study. The monitoring value fitted very well with the simulation value obtained from hydrographic curve, most crest values observed were very similar~~The observed and simulated hydrological curves fit very well, most peaks observed are quite consistent~~. In the model calibration period, the matching curves for the simulated and measured values of monthly runoff at

Xingjiawopeng and Tangmazhai hydrological stations are shown in Fig 2 (a) and Fig 2(b). The runoffs at these two hydrological stations were well matched. However, the accuracy of the runoff in the second half of the year in 2002, 2005 and 2006 was poor, likely due to the length of the data series and specific stations selected. In terms of the standards for the simulation and evaluation of the hydrological model, the simulation effects at the monthly scale were much better.



a. Validation of stream flow at Xingjiawopeng hydrological station.

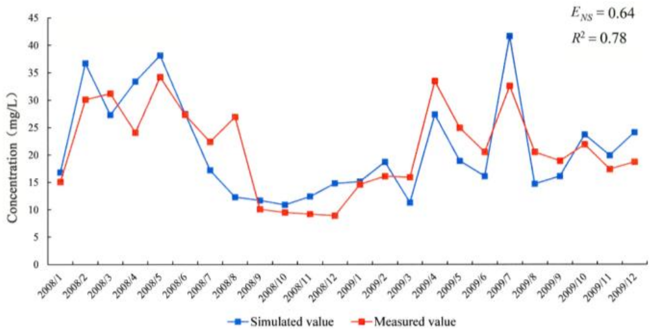


b. Validation of stream flow at Tangmazhai hydrological station.

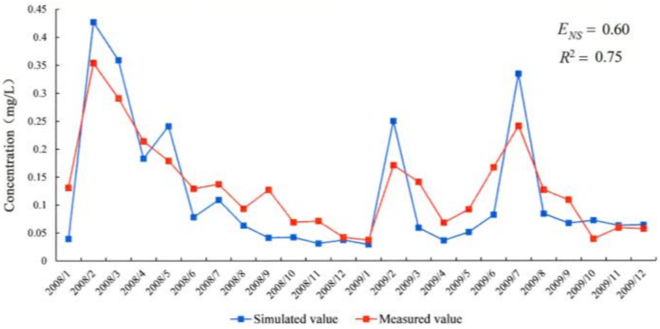
Fig 2. The goodness-of-fit results obtained of stream flow during the calibration and verification period.

Nutrients. The nutrients concentrations of water were simulated by SWAT. Based on the verification of the accuracy of the initial concentrations, the fertilization and cultivation measures for nutrients in the soil, the nitrate and soluble P loading can be simulated by adjusting the nitrogen permeability coefficient (NPERCO) and the phosphorous permeability coefficient (Lam et al., 2011). ~~With the calibrated parameters value, the extended simulation was conducted by running the well-calibrated SWAT models in the HTRW. Based on the verification of the accuracy of the initial concentrations, the fertilization and cultivation~~

measures for nutrients in the soil, the nitrate and soluble P loading can be simulated by adjusting the nitrogen permeability coefficient (NPERCO) and the phosphorous permeability coefficient (Lam et al., 2011). The SWAT model can simulate the concentrations of water nutrients including nitrates, organic nitrogen soluble phosphorus, and organic phosphorus. Beikouqian, Xingjiawopeng, Xiaolinzi and Tangmazhai four hydrological stations had a continuous monthly water quality monitoring data from 2006 to 2007. Only the monthly data of TN & TP in Beikouqian were validated from 2008 to 2009 for the insufficient water quality monitoring dataBeikouqian, Xingjiawopeng, Xiaolinzi and Tangmazhai four hydrological stations monitor water quality data continuously from 2006 to 2007, the observed data in four stations from 2008 to 2009 were compared with simulated data derived from SWAT model. Only the TN and TP of Beikouqian were validated on a monthly scale because of the limitations of the observed data. The Xingjiawopeng, Xiaolinzi and Tangmazhai Hydrological Stations only had the TN data in the study time. Therefore, Beikouqian was selected to show validation curves, the TN E_{NS} and R^2 were 0.64 and 0.78, and the TP E_{NS} and R^2 were 0.60 and 0.75, respectively (Fig 3ure 5(a), Fig 3ure 5(b)). The calculation values results of E_{NS} and R^2 of Xingjiawopeng, Xiaolinzi and Tangmazhai hydrological stations were 0.62 and 0.73, 0.61 and 0.72, as well as 0.62 and 0.77, respectively. The values of all R^2 were higher than 0.7, which confirmed the SWAT could be used for water quality simulation in HTRWThe values of all R^2 were above 0.7, which indicated the simulation of water quality in SWAT model was acceptable.



a. Validation of TN at Beikouqian hydrological station.



b. Validation of TP at Beikouqian hydrological station.

Figure 5. The nutrients validation in Beikouqian station~~**Fig 3.** The goodness-of-fit results obtained of nutrients during the calibration and verification period.~~

3.2. NPS pollution loading under status quo scenario

The output of NPS pollutant production was calculated using the pollutant loading approach based on the attributes of the regional calculation results and land use scenarios in HTRW. The output of N and P production in different calculation units were calculated based on the spatial changes of soil types, crops and residuals, as well as the differences in the coefficients of N and P losses under different land use types. The paddy fields, rural residential, urban development, and vegetation type maybe the important indicators for variability in NPS pollution, and that nutrition pollution was influenced by the integrated effects of different land uses (Cai et al., 2015; Lee et al.,2010). The annual throughputs of TN and TP production were 18 707 t and53 322 t, respectively (Table 3).

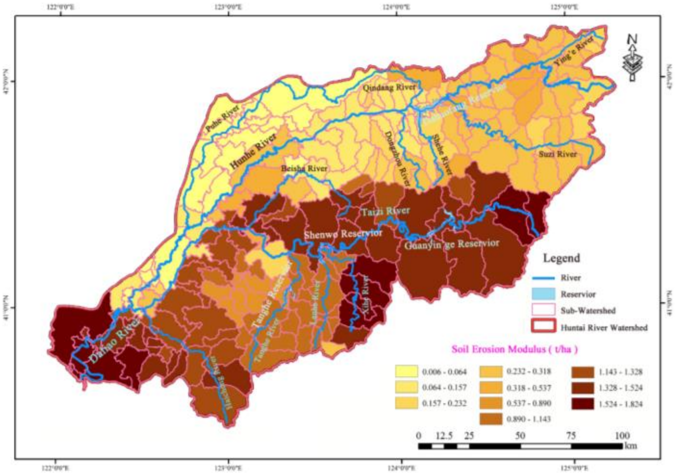
Table 3. The pollutant production in the HTRW under status quo scenario

Watershed	Area (km^2)	Run off (E+08 m^3)	Pollutant (t)			Pollutant loading (kg/ha)		
			Sediment	TP	TN	Sediment	TP	TN
Hunhe River	11 565	24.04	220 004	8 993	24 264	190	8	21
Taizi River	13 903	33.31	1 699 996	6 399	19 010	1 223	5	14
Daliao River	1 913	1.60	300 002	3 315	10 048	1 568	17	53
Total/Average	27 381	58.95	2 220 002	18 707	53 322	811	7	19

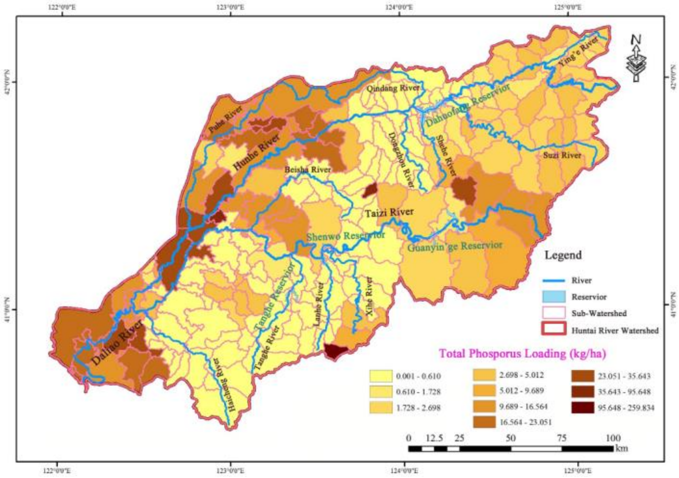
Source: China Hydrology; National earth system data sharing infrastructure~~Source: Chinese Academy of Sciences; National Geomatics Center of China~~; Field investigation of Liaoning province; Chemical fertilizer/Land area/Soil erosion statistics yearbook of Liaoning province; Liaoning province bureau of Meteorology.

3.2.1. Sediment

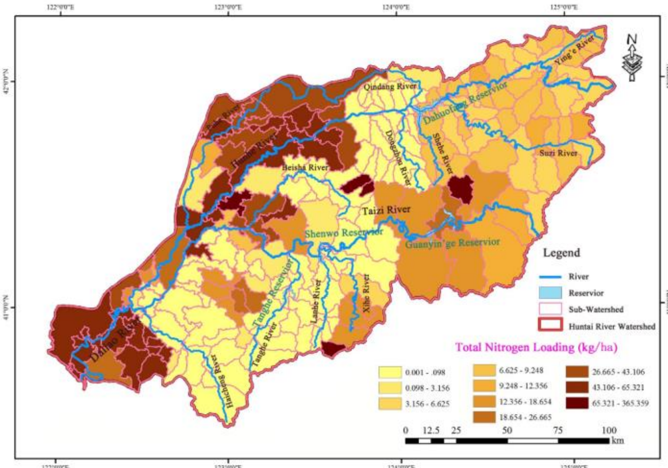
The sediment loading is the data basis to calculate the TN & TP loading, and which is affected by the type of land development and vegetation coverage (which was generally dominated by forest and farmland)The TN and TP loadings are closely linked with sediment loading, which is mainly affected by land use type (which was generally dominated by forest and farmland). Based on the simulation by the SWAT model, the annual output of sediment (silt) production in the watersheds of the Hunhe, Taizi and Daliao rivers was 22×10^4 t, 170×10^4 t and 30×10^4 t, respectively. The annual soil erosion modulus in the study area was 0.811 t/ha, and its spatial distribution is shown in Figure 46(a). The soil erosion (sediment) value varied widely in different regions, with the change interval from 0 to 1.824 t/ha.The amount of sediment (silt) yield was extremely different in sub-basin, with a range of 0–1.824 t/ha. Soil erosion in Daliao River watershed was very seriousThe soil erosion in the Daliao River watershed was the most severe (with up to 1.568 t/ha in some regions), followed by the Taizi River watershed (The amount was 1.223 t/ha in most regions) and Hunhe River watershed (Less than 0.19 t/ha in most regions). Yingkou and Dashiqiao has even topography, and incoming silt from the upper reaches is accumulated therein. The soil erosion modulus is therefore very high, which contributes greatly to the silt inputs to the HTRW (Tang et al.,2012). The soil erosion was affected by natural & human factors. The natural factors mainly included topography, underlying surface conditions and soil types, the human factors mainly consisted of vegetation coverage, precipitation type, land use, crop cultivation and cultivated land farming methods.The main factors affecting soil erosion included surface runoff, vegetation coverage rate and crop management, soil and water conservation practices and topographic factors (Ramos, 2006). Besides, the soil erosion modulus was relatively serious in agricultural land, particularly in dry land and paddy fields, based on a preliminary analysis. Moreover, mountainous area has great soil erosion (Hong et al.,2012). The HTRW had high forest coverage, which effectively prevented the soil erosionThe land use types were dominated by forest in HTRW, with relatively high vegetation coverage rate that prevented soil erosion. Daliao rivers had a large area of cultivated land, therefore, there was higher probability to cause soil erosionDaliao rivers was dominated by cultivated land, which was prone to soil erosion after rain scouring. Besides, the soil types are also the key influencing factors to cause soil erosion, therefore, the brown and paddy soils are prone to bring about the accumulation of sediment (Hong et al.,2012).~~The paddy soils, brown soils exported most sediment, which is much associated with the soil properties, indicating the strong penetration and low soil compaction (Hong et al.,2012). The soil types that are spatially distributed are a significant factor of high erosion.~~



a. The sediment.



b. The TP.



c. The TN.

Figure 46. NPS pollution loading distributions of HTRW under status quo scenario.

3.2.2. Total Phosphorus (TP)

With SWAT simulation results~~Based on the simulated results of the SWAT model~~, the annual output of TP production in the watersheds of the Hunhe, Taizi and Daliao rivers was 8 993 t, 6 399 t and 3 315 t, respectively, the watershed loading output intensity was 7 kg/ha. The TP loading had the same spatial distribution pattern with the sediment loading~~The distribution of the TP loading was nearly consistent with the distribution of the sediment yield~~. The TP loading ranged from 0 to 259.83 kg/ha~~. The TP primarily contained organic phosphorus, adsorbed inorganic phosphorus and dissolved phosphorus, which ranged from 0 to 120.70 kg/ha, 0 to 117.10 kg/ha and 0 to 27.32 kg/ha, respectively~~. Figure 6(b) showed the spatial variation of TP loading the HTRW~~Fig 4(b) illustrates the spatial distribution of the mean annual TP loading in the HTRW~~. The average annual water volume was affluent in Hunhe River, which prompted a large amount of P deposited in the downstream plain~~The average annual run-off was larger in Hunhe River, which enabled the large wet deposition of P~~. The changes in space of the TP loading was affected by topography~~The spatial distribution of the TP loading was affected by topography~~, precipitation, land use type, and silt losses. The TP loading output intensity of on the slope in the Daliao River watershed was higher than that in the Hunhe River watershed, and the Taizi River watershed was the lowest. Large amounts of fertilizer and pesticides have been applied to the farmland. Organophosphate pesticides accounted for 40% of the total pesticides. Therefore, the farmland has high TP concentrations, which was the same findings with Wang(2012)Therefore, the farmland has high TP concentrations. The results are consistent with previous studies, proving that soil erosion is a significant contributor to NPS pollution TP loading (Wang et al., 2012). The paddy fields and dry lands mainly distributed in Hunhe River downstream, therefore, the P loading in these plain area is higher (Li et al., 2010)The areas with high loading intensities of TP were concentrated in dry lands and paddy fields, with conventional tillage patterns and massive use of fertilizers, particularly in Hunhe River downstream (Li et al., 2010). Correspondingly, the cities and counties with a large proportion of farmland, such as Dashiqiao, Panshan and Dawa city in the Daliao River watershed, as well as the city of Haicheng and Taian county in the Hunhe River watershed, have higher TP loading output intensity. The regions with a large proportion of developed land, such as the city center of Fushun, Shenyang in Hunhe River watershed, the municipal districts of Liaoyang city and Benxi city at the Taizi River watershed, which have lower TP loading output intensities. Based on the land use type, the tributaries with a higher proportion of farmland have the highest TP output intensities, whereas the tributaries with substantial vegetation cover as forested land have relatively lower TP output intensities. For the paddy soils, brown soils exported most sediment, the higher loading intensities of these soils are associated with the historic fertilizer application and the long residence times of nutrients in soil (Hong et al.,2012). The output intensity of TP is closely related to soil characteristics and attributes.The output intensity of TP is much associated with the soil properties.

3.2.3. *TN* Total Nitrogen (*Total Nitrogen* TN)

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Upon simulation and calculation, the output of TN production in the watersheds of the Hunhe, Taizi and Daliao rivers was 24 264 t, 19 010 t and 10 048 t. The annual loading output intensity of TN in the watershed was 19 kg/ha. Figure 6(c) showed the spatial variation of TN loading the HTRWFig.4 (c) illustrates the spatial distribution of the mean annual TN loading in the HTRW. The TN loading varied interval from 0.001 to 365.36 kg/haThe TN loading varied greatly from one sub-basin to another, ranging from 0.001kg/ha to 365.36 kg/ha. The TN primarily contained Organic Nitrogen and Nitrate Nitrogen, which ranged from 0.15 kg/ha to 215.41 kg/ha, and 0.15 kg/ha to 166.89 kg/ha, respectively. The TN loading had the same spatial characteristics with TP loadingThe spatial distribution of TN loading is consistent with the spatial distribution of TP. The loading output intensity of TN in the Daliao River watershed was greater than that in the Hunhe River watershed, and the Taizi River watershed was the lowest. Large amounts of fertilizer were applied in the study area. Nitrate and organic N accounted a substantial portion of the fertilizer used in HTRW. Therefore, the loading output intensity of TN in the watershed was very high. The regions with a great proportion of farmland, such as the middle and lower reaches of the Hunhe River, the lower reaches of the Taizi River and the tributaries in the upper reaches of the Daliao River, have high output intensities of TN. The organic N contents in forested land was very low. Thus, the output intensity of TN in regions with high vegetation cover of forest, such as the mountainous area in the upper reaches of the Taizi and Hunhe rivers, was very low. The output loading intensity of TN in the municipal districts with high developed area was the lowest, such as the municipal districts of Fushun city and Shenyang city in the Hunhe River watershed, and the municipal districts of Benxi city, Liaoyang city and Shenyang city in the Taizi River watershed.

The loading intensity of TN and TP in the HTRW were characterized by its regional distribution. Although the counties of Qingyuan, Yibin and Benxi county, located in the upper reaches of the HTRW, had high output of water and silt, their loading intensities of pollution were not high. From the unit area perspective, the maximum loading intensities of TN and TP were 365.36 and 259.83 kg/ha, respectively. The regions with high loading intensities of TN and TP were mainly distributed in Taian, Haicheng, and Fushun city. The loading intensities of TP and TN near the Dahuofang, Tanghe, Shenwo and Tanghe reservoirs were not high, ranging from 0.006-9.584 kg/ha, and 0.08-19.485 kg/ha, respectively. Based on the topography and soil type distribution, the gradient in the upper stream of HTRW was usually high~~Based on the topography and soil type distribution, the gradient in the upper reaches of the watershed was usually high~~. The soil type is predominately brown soil and salted paddy soil, both of which are easily eroded. The topography in the lower reaches is usually even, as in the cities of Anshan, Haicheng, Yingkou and Panjin. The elevation is not high, and the soil type is usually predominately meadow soil and brown soil, both of which have a higher soil erosion rate, silt loss and loading intensity of pollutants. The regions with heavy loading intensities of TN and TP included Xinmin county, located in the middle and lower reaches of the HTRW, the municipal district of Shenyang city, Liaozhong county, Dengta city, Liaoyang county, the municipal district of Anshan city, Haicheng city and a portion of Dashiqiao city. Based on the land development pattern in the Taizi River~~Based on the land use type in the Taizi River watershed~~, dry fields and paddy fields were mainly distributed on the plain area of this watershed, which is therefore a core source of loading intensity. The spatial difference in the loading intensity between TN and TP were inconspicuous. soil types and land development status in the watershed, the upper stream of watershed have high vegetation coverage~~Based on~~

the topography, landform, soil types and land use conditions in the watershed, the upper reaches of the watershed have high vegetation coverage, less farmland and a low loading intensity of pollutants; the lower reaches of the watershed have more farmland, high rates of fertilizer application and a high soil erosion and pollution loading (Yin et al.,2011). To sum up, the spatial characteristics of TP loading was the result of comprehensive effect from precipitation/run off characteristics, soil properties, soil erosion and vegetation coverage. Consequently, the spatial distribution of sediment, TN and TP loadings is primarily related to the distribution of land and water, soil types and to the situation of local soil loss.Therefore, in order to effectively control TN loading and soil erosion in the HTRW, the BMPs, fallow measures of cultivated fields, watershed vegetation restoration and soil & water conservation in the upper stream, which were the most important measure that should be implemented. Therefore, conscientious fertilization practices and eco-friendly tillage patterns should be implemented to control NPS pollution from farmlands, and the implementation of Best Management Practices (BMPs) for different NPS pollutant types should be considered in specific sites (Shen et al.,2014).

3.3. NPS pollutant loading under EPSNPS pollution loading under environmental protection scenarios (EPS)

The prevalence of farmland within a watershed has long been an important question, and strong evidence exists of a correlation between land development mode and water environment protect & rehabilitation at the basin scaleThe prevalence of farmland within a watershed has long been an important question, and strong evidence exists of a correlation between land use and water quality at the basin scale. Numerous studies have used land use data and stepwise regression analysis to explore relationships between land use and water quality parameters and ecological integrity on a regional scale, including sub-basins, river riparian buffer zones, and specific monitoring sites (Uriarte et al., 2011; Schiff, 2007; King et al., 2005)~~Numerous studies have used land use data and stepwise regression analysis to explore relationships between land use and water quality parameters and biotic integrity at multiple spatial scales, including sub-basins, river riparian buffer zones, and specific monitoring sites (Gove et al., 2001; Mehaffey et al., 2005; Uriarte et al., 2011; Li et al., 2009; Sliva, 2001; Schiff, 2007; King et al., 2005)~~. The riparian buffer zones could effectively reduce the concentration levels of NO_3^- in water, which was 47% lower than the soil content (Venkatachalam et al.,2005)~~Study showed that the impact of riparian buffer zones was clearly observed in higher-order streams where the observed NO_3^- levels are 43.7% less than that of the upland (Venkatachalam et al.,2005)~~. The dry farmland caused a higher NPS pollutant loading, followed by paddy, rural and urban area, forest land, and shrub land~~The contribution rate of the NPS pollution loading coming from different land use types in descending order was dry farmland, paddy, rural and urban area, forest land, and shrub land~~. Under this developmental scenario, the area of farmland in the watershed was reduced; a modest area of farmland (29 500 ha, accounting for 2.74 % of the total farmland area) was converted to forestland (included shrub land, 14 753 ha), grassland (5 899 ha), wetland (8 848 ha); and NPS pollution from farmland decreased. The objective of water quality protection within the critical zoning of the watershed was realized. For the riparian buffers can be planted in various diverse vegetation, the N removal rate of 60m wide woody soil buffer zone was 16% and 38% higher than that of shrubbery and grassland, respectively (Aguiar et al.,2015). ~~Considering different vegetation types used in the buffers, 60-m-wide buffers composed of woody soils were more effective in N removal (99.9%) than areas with shrub (83.9%) or grass vegetation (61.6%) (Aguiar et al.,2015).~~ Urban & rural areas were considered as the same type of land use in SWAT~~Rural and urban were treated as one~~

category in SWAT model, about 1 kilometer within both banks of the tributaries of the Hunhe, Taizi and Daliao rivers and 5 kilometers surrounding reservoirs were defined as buffer zones, including 1946 km^2 of farmland, urban land, and rural residential land, which accounts for 7.1 % of the total area in the watershed. The woodland coverage rate was reduced by 1%, the loading intensity of sediment, TP and TN increased by 0.01~11.34, 0.15-2.83, and 0.40-14.00 kg/km^2, respectivelyFor every 1% reduction in forest area, the loading intensity increased by 0.01~11.34 t/km^2 for sediment, 0.15-2.83 kg/km^2 for TP and 0.40-14.00 kg/km^2 for TN. The output of pollutant production under EPS was calculated by transforming the existing land use type.

Based on the parameter quantification results of SWAT, the TN and TP losses from farmland was effectively reduced after the modification of the land use structure. TN and TP respective range of change was from 0 to 365.357 kg/ha, and from 0 to 259.834 kg/haThe TN and TP ranged from 0 kg/ha to 365.357 kg/ha, and 0 kg/ha to 259.834 kg/ha, respectively. The annual losses of TN and TP were reduced by 13 839 and 1 946 t/a, respectively. In comparison, the output of NPS pollutant production under the EPS was decreased by 21.9% compared with that under the status quo scenario, whereas the outputs of TP and TN were reduced by 10.4% and 25.9%, respectively. Under EPS, the average loading intensities of TN and TP were 14 and 6 kg/ha on a unit area basis, which were 14.3% and 26.3% less than the loading intensities under status quo scenario. The NPS pollution loading decline obviously in the EPS. The variation of TP and TN pollution loading between status quo and EPS was shown in Table 4. The amount change indicated that riparian buffer and land development pattern change could effectively reduce the NPS pollutant loading in the HTRW.The amount change indicated that riparian buffer and eco-restoration measures designed to natural land use property could reduce the watershed pollution loading.

Table 4. The variation of TP ~~and~~ & TN pollution loading between EPS and status quo scenario

Watershed	Pollutant loading of EPS (kg/ha)		Pollutant loading variation (kg/ha)		Farmland variation (ha)	Forestland variation (ha)	Grassland variation (ha)	Wetland variation (ha)	Pollutant annual variation(t/a)	
	TP	TN	TP	TN					TP	TN
Hunhe River	7	16	-1	-5	-12460	+6231	+2492	+3737	-838	-5743
Taizi River	4	10	-1	-4	-14979	+7491	+2995	+4493	-776	-5606
Daliao River	16	40	-1	-13	-2061	+1031	+412	+618	-332	-2490
Total/Average	6	14	-1	-5	-29500	+14753	+5899	+8848	-1946	-13839

"—" denotes a decrease compared to status quo scenario; "+" denotes an increase compared to status quo scenario.

4. Conclusions

The NPS pollution is prone to cause in dry farmland, paddy, rural & urban areas~~NPS pollution mainly came from dry farmland, paddy, rural and urban areas~~. The SWAT model has been applied to study NPS in China by numerous research literature, they were mainly focuses on scenario simulation of NPS pollution and management in agricultural areas with rich hydrological and meteorological data. The basic monitoring data of HTRW were deficient, we selected the SWAT as the feasible method to access NPS pollutant loading in watershed level.~~Considering the data shortage in the HTRW, the SWAT is an effective method for estimating NPS pollution loading in watershed scale.~~ We applied certain practices based on EPS to reduce the NPS pollutant loading in the Hunhe River, Taizi River and Daliao River watershed~~Certain practices based on EPS should be considered for the purpose of NPS pollution control in the Hunhe River, Taizi River and Daliao River watershed~~. The status quo scenario and EPS were used to calculate the output of NPS pollutant production. Under the status quo scenario, the soil erosion modulus in the HTRW was 0.811 t/ha, and the soil erosion in the Daliao River watershed was the most severe. The TP & TN annual loading in the HTRW was 19, and 7 kg/ha, respectively~~The spatial distribution of the mean annual TP and TN loading~~

~~in the HTRW were 19, and 7 kg/ha, respectively~~. In the middle and lower stream of HTRW has a higher NPS pollutant loading, which included the urbanization and population density highly region of Shenyang, Anshan and Liaoyang~~The region with a high NPS pollution loading is located in the middle and lower the HTRW, which included the urbanization and population density highly areas of Shenyang, Liaoyang and Anshan~~. Under the EPS, the TN and TP per unit area were 14, and 6 kg/ha, respectively. The output of NPS pollutant production, the loading intensities of TN and TP was reduced by 21.9%, 25.9% and 10.4% compared with the status quo scenario, respectively. In different regions of NPS pollutant loading in the HTRW changes greatly, and the pollutant loading intensity of different nutrients in the same region is slightly different. ~~The NPS pollution occurring within different sub-basins and regions located in the watersheds varied greatly, and the loading intensities of different pollutant types in the given sub-basin were slightly different.~~ Land eco-restoration and land development mode adjustment measures should be practiced to reduce NPS pollutant loading of cultivated land~~Land eco-restoration measures should be implemented to control agricultural NPS pollution from croplands. Therefore, SWAT simulation results provide a reference for the prevention of agricultural NPS pollution in agricultural watersheds~~.

In this study, the SWAT model can be used to simulate and calculate the source, and potential reduction of agricultural NPS pollutants based on different land use type. The reliability of SWAT evaluation results is decided by information completeness and the reasonable degree of parameter initialization~~The SWAT simulation accuracy depends on the completeness of data and the reasonable degree of parameter initialization~~. In HTRW some data were missing, such as the rainfall intensity, and water pollution, et al. The data inaccuracy and local factors has a certain impact on SWAT model accession result~~The data inaccuracy and local factors would~~

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impact the accuracy of the SWAT model. To determine the pollutant reduction under different land development patterns, and examine uncertainty of sensitivity parameters, SWAT model in China has wide range of potential application.Further research is required to recognize the main factors that affect the accuracy of different NPS pollutants loading, examine uncertainty of sensitivity parameters, and extend the potential application range of SWAT in China.

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