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Water Use Efficiency of Grain Crops Dataset in Hebei Province of China (1995–2019)

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Abstract: Water scarcity is a crucial factor limiting crop yields in Hebei Province, which is a typical grain-producing region in China. Improving the efficiency of water use of grain crops on farmland is essential for ensuring regional food security and achieving sustainable agricultural development. Author base on dataset of the efficiency of water use of grain crops in Hebei Province of China (1995–2019) was developed by integrating data from the meteorological database of China, the United Nations Food and Agriculture Organization's (FAO) CROP database, field surveys, rural statistical yearbooks, and the super-efficiency SBM model, spatial econometric model, and GTWR model. The dataset contains the following: (1) data on boundaries of the study area; (2) data on the blue water, green water, and gray water footprints of grain crops in 1995, 2000, 2005, 2010, 2015, and 2019; (3) data on the trends of changes in the water footprints of food crops from 1995 to 2019; (4) efficiency of water use of grain crops at the county and regional scales in 1995, 2000, 2005, 2010, 2015, and 2019; (5) spatial effects, spillover effects, and spatial heterogeneity of the factors influencing the efficiency of water use of grain crops; and (6) the Theil coefficient and the rates of contribution of the four partitions. The dataset has been archived in .xlsx and .shp data formats, and consists of 65 data files with a total size of 4.09 MB (compressed into one file with a size of 2.36 MB).

Keywords: Hebei Province; SBM; water footprint; water use efficiency of grain crops; influential factors

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[2] Pan, P. P., Miao, J. X., Wang, X. X., *et al*. Water use efficiency of grain crops dataset in Hebei Province of China (1995–2019) [J/DB/OL]. *Digital Journal of Global Change Data Repository*, 2024. https://doi.org/10.3974/geodb.2024.02.04.V1. https://cstr.escience.org.cn/CSTR:20146.11.2024.02.04.V1.

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The dataset supporting this paper was published and is accessible through the *Digital Journal of Global Change Data Repository* at: https://doi.org/10.3974/geodb.2024.02.04.V1 or https://cstr.escience.org.cn/CSTR:20146.11.2024.02.04.V1.

1 Introduction

Water resources constitute the core element of food production, and the highly efficient use of water for grain crops on farmland in major food-producing areas that are also scarce in water has a direct impact on national food security and regional ecological security[1]. The National 14th Five-Year Plan for the Construction of a Water-saving Society in China notes that the shortage of water resources is an important bottleneck in the country's socio-economic development. In particular in the context of global changes and the increasing demand for food, agricultural water shortages in China are becoming increasingly severe[2]. Moreover, inefficient methods of irrigation for agricultural production, the serious pollution of major water bodies in the country, and unreasonable use of the available water resources have accentuated the problem of China's agro-ecological security[3]. Hebei Province is a traditional region of agricultural production in China that suffers from a serious shortage of water resources, because of which the sustained growth in its production of food crops comes at the expense of the large-scale exploitation of groundwater that has led to a continual decline in the water table. "Water for food" has gradually emerged as the feature of regional food production, and the high intensity of water use not only significantly disturbs the recycling of water resources, but also triggers a series of problems including ground subsidence, soil salinization, and water pollution[4]. This poses a serious threat to sustainable food production and the ecological environment[5].

Evaluating the efficiency of water use of grain crops, and identifying and regulating the factors influencing it provides an important foundation for optimizing the regional planting structure and efficiently managing the water resources. It can also help alleviate the conflict between the supply of agricultural water resources and the demand for them to ensure regional water and food security[6]. The indicators of water input used in prevalent studies in the area ignore the effective precipitation such that the output of the relevant models does not fully reflect the negative impacts of agricultural production on water resources and the water environment. The multi-perspective measurement of the efficiency of water use of grain crops and the evaluation of factors influencing it are essential for optimally using water resources[1]. In this study we consider wheat and maize, the two major grain crops grown in Hebei Province, as the objects of research, apply improved methods to measure the efficiency of water use and unexpected outputs, and introduce the water footprint, as an indicator that can comprehensively measure the water use and food output, to the SBM model (Slacks-based Measure of Super-efficiency Model)[7]. We then systematically construct a system of indicators that uses the blue water and green water footprints, planting area, application of discounted fertilizer, total power consumed by agricultural machinery, and agricultural labor as the input indicators, generates the agricultural GDP as the desired output indicator, and uses the gray water footprint as the non-desired output indicator. We use data from meteorological stations, rural statistical yearbooks, the FAO CROP database, and field surveys in a water footprint-based super-efficiency SBM model to calculate the multi-scale efficiency of water use of grain crops in Hebei Province by determining their blue, green, and gray water footprints from 1995 to 2019. Following this, we construct a system of indices of the factors influencing the efficiency of water use of grain crops by considering the actual situation in the study area, and use a spatial measurement model and the GTWR model (Geographically and Temporally Weighted Regression Model) to identify the key elements driving the efficiency of water use of grain crops and their spatial heterogeneity. This study provides a basis for subsequent research in the area as well as for decision-making to improve the efficiency of water use of grain crops in Hebei Province and other major grain-producing areas. This can in turn lead to the efficient use of agricultural water resources, and can ensure regional hydro-ecological security as well as the green and sustainable development of agriculture.

2 Metadata of the Dataset

The metadata for the dataset of the efficiency of water use of grain crops in Hebei Province of China (1995–2019)[8] are summarized in Table 1. They include the full name of the dataset, its short name, authors, year in which it was published, data format, data size, data files, data publisher, and data sharing policy, etc.

Table 1 Metadata summary of the Water use efficiency of grain crops dataset in Hebei Province of China (1995–2019)

Items	Description
Dataset full name	Water use efficiency of grain crops dataset in Hebei Province of China (1995–2019)
Dataset short name	WaterUseEfficiencySBM_Hebei_1995_2019
Authors	Pan, P. P. S-5072-2016, Hebei Normal University, panpeipei626@163.com Miao, J. X. Hebei Normal University, miao_jia_xin@163.com Wang, X. X. S-6861-2017, The Bureau of Natural Resources and Planning of Hebei Xiong'an New District Management Committee, Baoding, 18931179072@163.com Li, L. S., Hebei Normal University, lilinsi9360@163.com Wen, J. Y., Beijing Capital Planning and Design Engineering Consulting and Development Co. Beijing, wenjiayu329@163.com Wang, X. X., School of Ecology and Environmental Sciences, Ningxia University, wxy_whu@163.com
Geographical region	Hebei Province: 36°05′N–42°37′N, 113°11′E–119°45′E
Year	1995–2019
Data format	.xlsx, .shp
Data size	2.36 MB (after compression)
Data files	65 data files
Foundation	Hebei Provincial Social Science Foundation (HB20GL042)
Data computing environment	CROPWAT model; super-efficiency SBM model; spatial econometric model; ArcGIS
Data publisher	Global Change Research Data Publishing & Repository, http://www.geodoi.ac.cn
Address	No. 11A, Datun Road, Chaoyang District, Beijing 100101, China
Data sharing policy	(1) *Data* are openly available and can be free downloaded via the Internet; (2) End users are encouraged to use *Data* subject to citation; (3) Users, who are by definition also value-added service providers, are welcome to redistribute *Data* subject to written permission from the GCdataPR Editorial Office and the issuance of a *Data* redistribution license; and (4) If *Data* are used to compile new datasets, the 'ten per cent principal' should be followed such that *Data* records utilized should not surpass 10% of the new dataset contents, while sources should be clearly noted in suitable places in the new dataset[9]
Communication and searchable system	DOI, CSTR, Crossref, DCI, CSCD, CNKI, SciEngine, WDS/ISC, GEOSS

3 Methods of Data Development

Dataset development included the following work: (1) The green and blue water footprints of the grain crops were calculated based on the acquired meteorological data, data on the area of planting of food crops, and the demand for water in the growing period. The gray water footprint was calculated based on the application of discounted fertilizer to the grain crops. This yielded data on the blue, green, and gray water footprints of grain crops in the county units of Hebei Province in 1995, 2000, 2005, 2010, 2015, and 2019 as well as the trends of changes in them. (2) Statistical data and measurements of the water footprint were used in the super-efficiency SBM model to calculate the efficiency of water use of grain crops at the two scales of counties and subdivisions in Hebei Province in 1995, 2000, 2005, 2010, 2015, and 2019. (3) Regional differences in the efficiency of water use of grain crops were analyzed based on the Theil coefficient. Values of the Theil coefficient and the rates of contributions of the four major subregions in Hebei Province to it were obtained. (4) The causes and spatial effects of differences in the efficiency of water use of grain crops were examined based on the spatial econometric model, and the spatio-temporal geographical-weighted regression (GTWR) model was used to analyze the spatial distribution of the main factors in this regard.

3.1 Algorithmic

The above-mentioned dataset mainly uses methods to measure the water footprint, the super-efficiency SBM model, kernel density estimation, Thiel coefficient, spatial econometric model, and GTWR model[10]. The water footprint can describe the occupancy of water resources based on consumption[11], and includes blue, green, and gray water footprints. It is a more comprehensive method for measuring the occupancy of water resources than the traditional means of water measurement[12]. The super-efficiency SBM model was proposed by Tone based on the data envelopment analysis (DEA) model[13]. The dataset uses the super-efficiency SBM model based on the water footprint to measure the efficiency of water use of grain crops, and compensates for the lack of consideration of undesirable outputs in the DEA method that may lead to deviations in the results[14]. Kernel density estimation uses a continuous curve of density to represent the characteristics of distribution of efficiency[15]. The Theil coefficient is used to analyze differences in the efficiency of regional water use and their main sources[16]. These indicators are used to analyze the trends of change and regional differences in the efficiency of water use of grain crops in Hebei Province. Finally, the Spatial Dubin model (SDM model), spatial econometric model, and GTWR model are used to explore the spatial and spillover effects of the efficiency of water use of grain crops as well as the spatial-temporal characteristics of the distribution of the factors influencing it in the study area.

3.2 Technical Route

We used meteorological data, crop-related data, data on agricultural production and administrative divisions, the super-efficiency SBM model, spatial econometric model, and GTWR model from the above-mentioned dataset to calculate the efficiency of water use of grain crops in 139 county units of Hebei Province from 1995 to 2019. The steps are as follows (Figure 1).

(1) Basic data collection and collation

The basic data used in this study are provided in Table 2.

Data on administrative divisions: The 139 county units of Hebei considered in this study were based on the division of administrative regions in the province in 2015, in which the municipal districts were merged into one county unit. We used the literature[17] to divide Hebei Province into four regions: northwest Hebei (Zhangjiakou and Chengde), coastal areas (Cangzhou, Tangshan, and Qinhuangdao), areas surrounding Beijing and Tianjin (Baoding and Langfang), and south-central Hebei (Shijiazhuang, Hengshui, Xingtai, and Handan).

Meteorological data, coefficients of grain crops, and data on growth period: Meteorological data were obtained from the regional data center for resources and environmental science[1], and included the temperature, humidity, precipitation, wind speed, and hours of sunshine in cities in Hebei Province. Data on the coefficients and period of growth of the grain

[1] https://www.resdc.cn/Default.aspx.

crops were obtained by adjusting information obtained from the CROP database of the FAO by using data obtained from field surveys in various areas as well as past research, as shown in Table 3. This information was then used along with the CROPWAT model, developed by the FAO, to calculate the evapotranspiration of blue and green water (mm) during crop growth.

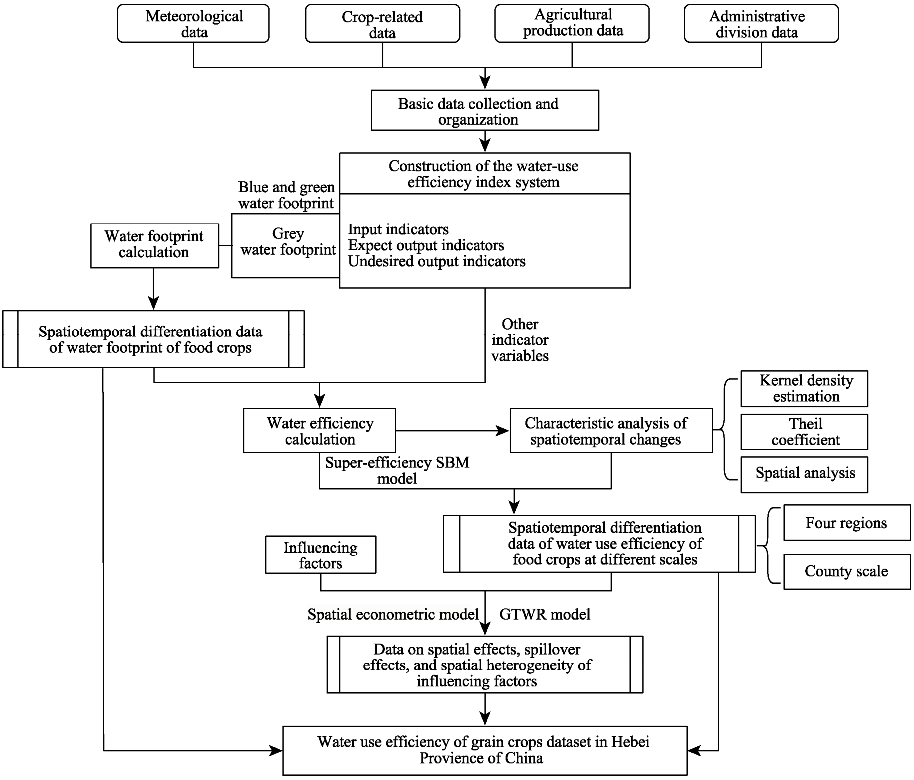

Figure 1 Technological roadmap of the dataset development

Table 2 Basic data information

Data source	Data type	Time (date)	Scale bar or resolution
National Catalogue Service For Geographic Information	Data on administrative divisions	2015	1:1 million
China Meteorological Administration	Meteorological data	1995, 2000, 2005, 2010, 2015, 2019	Municipal units
The UN FAO CROP database/field work	Grain crops coefficient and fertility period	Field work on July 7–8, 2021	County units
Hebei Province Rural Statistical Yearbook	Economic and social statistics	1995, 2000, 2005, 2010, 2015, 2019	County units

Table 3 Data on the coefficients of grain crops and their fertility period in Hebei Province

Grain crop	Fertility period	Grain crop coefficient			
		Initial	Development	Mid-season	Late season
Wheat	9.28–6.13	0.43	0.90	1.10	0.49
Maize	6.16–9.25	0.40	0.81	1.17	0.88

Statistical economic and social data: We obtained the relevant economic and social data from rural statistical yearbooks of Hebei Province to calculate the efficiency of water use of grain crops and determine the factors influencing it. Of the variables used to assess the efficiency of water use[10] (excluding the blue, green, and gray water footprints), the planting area was obtained from the statistical data, while data on the other variables could not be directly obtained were refer to the processing method of relevant research[18]. The variables used to identify the factors influencing the efficiency of water use are shown in Table 4, and included the annual precipitation, effective area of irrigation, area over which the crops were sown, their primary industrial output value, per capita net income of the rural residents in each county, urban population, total population, and the amount of chemical fertilizer applied to the grain crops.

Table 4 Factors influencing the efficiency of water use of grain crops

	Variable name	Variable code	Variable interpretation
Independent variables	Annual precipitation	AP	Annual precipitation (mm)
	Effective irrigation degree	EID	Effective irrigated area/area of crops sown (%)
	Agricultural farming structure	AFS	Maize sown area/area of grain crops sown (%)
	Industrial structure	IS	Agricultural output value/Primary industrial output value (%)
	Per capita net income of rural residents	CDI	Per capita net income of rural residents in all counties (Yuan)
	Urbanization level	UL	Urban population/total population (%)
	Density of agricultural machinery	AGM	Farm machinery production/area of crops sown (%)
	Fertilizer application intensity	FAI	Amount of chemical fertilizer used/area of crops sown (%)

(2) Calculation of water footprint of grain crops

The gray water footprint was calculated based on the wheat–maize rotation in the study area. We used past research to set the maximum allowable concentration and the rate of leaching of nitrogen fertilizer to 10 mg/L (national maximum) and 10%, respectively[17], and their minimum value (zero) was set to be that in nature.

(3) Calculation of efficiency of water use of grain crops

We considered the water used for irrigation and the effective precipitation, and set the gray water footprint as the index of the undesired output[7]. The water footprint was introduced to the super-efficiency SBM model to measure the efficiency of water use of the grain crops. The water footprint in the input index was calculated while the planting area was obtained from the statistical data. Because the other input indicators could not be directly obtained, we consulted past research[18], for them, and used the weight coefficient method to calculate the relevant data for the two crops.

(4) Analyzing the spatio-temporal variations in efficiency of water use of grain crops at different scales

We used kernel density estimation, the Theil coefficient, and GIS-based spatial analysis to analyze the spatio-temporal variations in the efficiency of water use of grain crops at different scales (provincial, regional, and county) in Hebei Province. Data on the administrative divisions of Hebei Province and the efficiency of water use of grain crops in each county were required for this.

(5) Analyzing causes and effects of spatial differences in efficiency of water use of grain crops

We used the actual status of grain planting in Hebei Province in combination with prevalent research[2,19–21] to identify eight indicators (Table 4) influencing the efficiency of water use of grain crops. We then examined the causes of spatial differences in the efficiency of water use and their spatial effects by using the spatial econometric model. Given that there are three types of spatial econometric models[22], we subjected them to tests of spatial autocorrelation and model tests to determine the optimal model for representing the efficiency of water use. The SDM model was finally chosen. This model required data on the administrative divisions and input indicators of Hebei Province, and the expected output and the undesired output of each indicator.

(6) Analyzing the spatio-temporal heterogeneity of influential factors

We analyzed the spatio-temporal heterogeneity of various factors influencing the efficiency of water use of crops in Hebei Province by using the spatio-temporal geographically weighted model of regression. The main process consisted of a multi-collinearity test, selection of influential factors, and the execution of the GTWR model. The required data included the administrative divisions of Hebei Province, efficiency of water use of grain crops, and the factors influencing it (Table 4).

4 Data Results and Validation

4.1 Data Composition

The dataset used to assess the efficiency of water use of grain crops in Hebei Province (1995–2019) consisted of six parts: (1) data on boundaries of the study area; (2) data on the blue water, green water, and gray water footprints of grain crops in 1995, 2000, 2005, 2010, 2015, and 2019; (3) data on the trends of changes in the water footprints of food crops from 1995 to 2019; (4) efficiency of water use of grain crops at the county and regional scales in 1995, 2000, 2005, 2010, 2015, and 2019; (5) spatial effects, spillover effects, and spatial heterogeneity of the factors influencing the efficiency of water use of grain crops; and (6) the Theil coefficient and the rates of contribution of the four partitions.

4.2 Data Results

(1) Spatio-temporal variations in water footprint of grain crops in Hebei Province

The blue, green, and gray water footprints represent the consumption of water for irrigation, precipitation water used for irrigation, and the emission of pollutants during crop growth, respectively. From 1995 to 2019, the total water footprint of grain crops in Hebei Province was influenced by an increase in the planting area, and exhibited an overall trend of increased with an annual growth rate of 1.03%. The change in the blue water footprint of the crops was relatively stable, their green and gray water footprints increased slightly, and the rate of growth of the latter was higher and began to decrease in 2000. On the whole, the proportion of blue and green water footprints of the crops decreased while the proportion of their gray water footprint increased significantly. Data on the spatial distribution of the blue, green, and gray water footprints of the grain crops in Hebei are shown in Figures 2–4. The high-value areas were concentrated in central and southern Hebei, and the coastal areas, while low-value areas were distributed in the northwest Hebei, and in areas northwest of Beijing and Tianjin. The overall pattern was low in the northwest and high in the southeast. This is because the spatial occupation of the main grain crops in Hebei Province gradually decreases from south to north. The distribution of planted wheat decreased from southwest to northeast, while that of planted corn exhibited a regular distribution of central > southern > northern[23]. In addition, the high-yield areas for grain crops consumed large amounts of blue and green water while emitting large volumes of pollutants, because of which their gray water footprint was large.

(2) Spatio-temporal heterogeneity of efficiency of water use of grain crops at different spatial scales

There were spatial differences in the efficiency of water use of the grain crops at the provincial, regional, and county scales in Hebei. The differences in the distributions of the efficiency of water use of grain crops was prominent at the provincial scale, and exhibited trends of decrease and increase in 1995–2000 and 2000–2015, respectively. By 2019, the

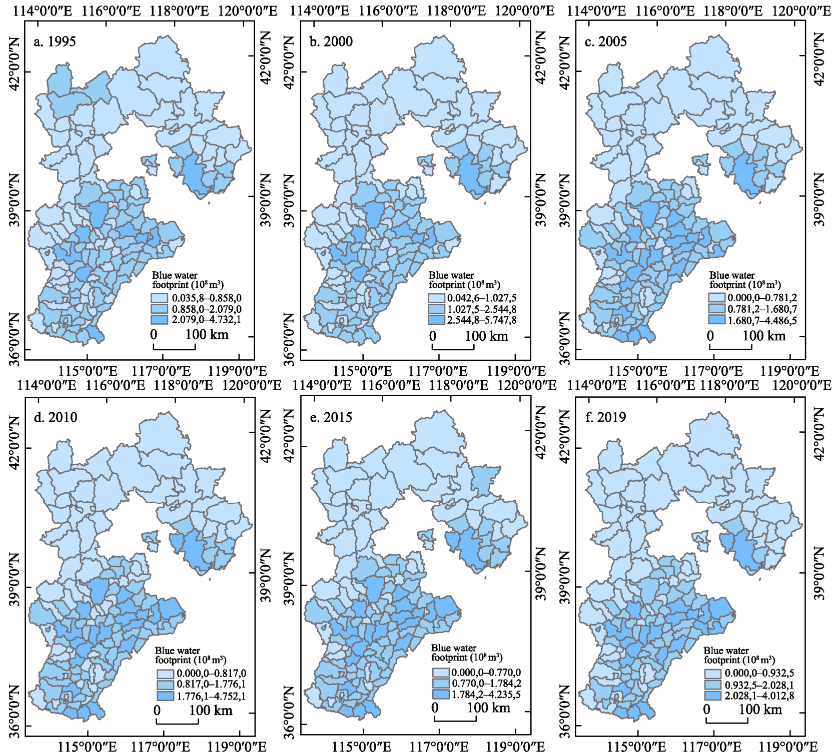

Figure 2 Maps of the blue water footprint of grain crops in Hebei Province (1995–2019)

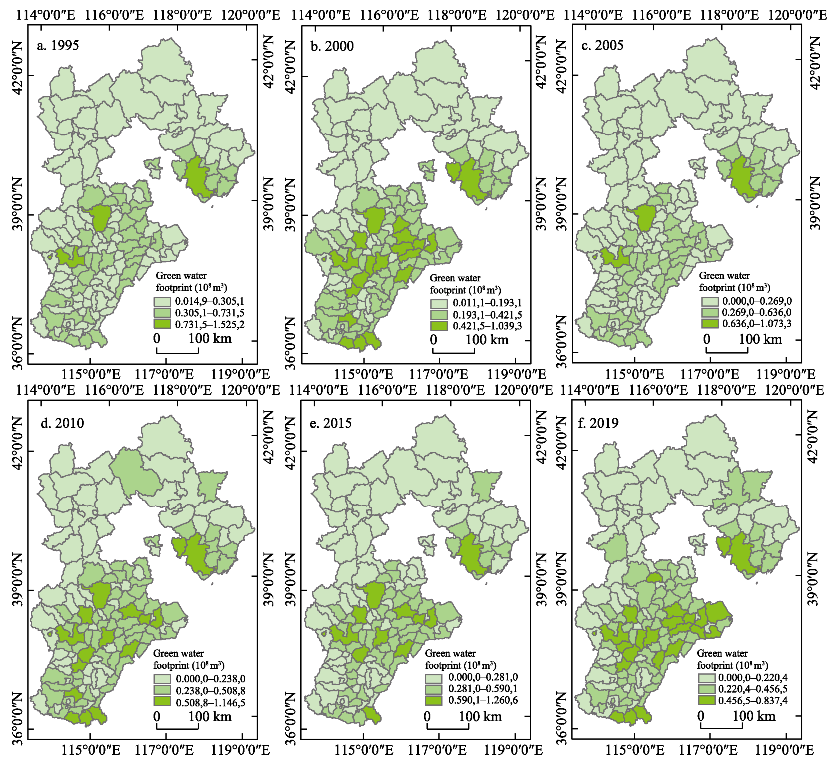

Figure 3 Maps of the green water footprint of grain crops in Hebei Province (1995–2019)

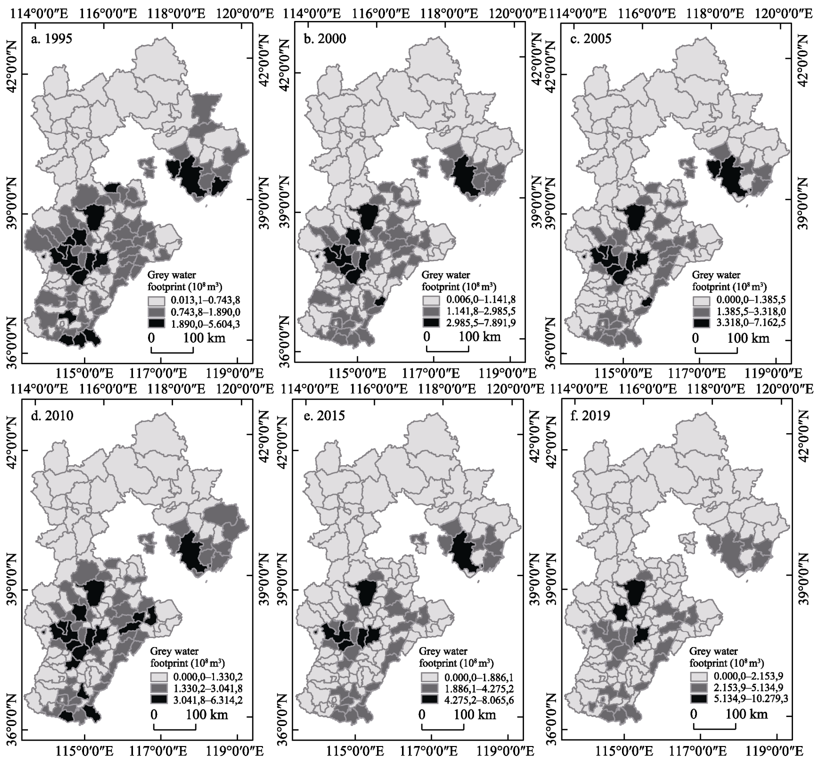

Figure 4 Maps of the gray water footprint of grain crops in Hebei Province (1995–2019)

efficiency of water use in most counties had decreased while the polarization of its regional efficiency had increased.

Figure 5 shows that the spatial pattern of the efficiency of water use of grain crops in the four major regions of Hebei changed significantly from 1995 to 2019. Northwest Hebei exhibited a downward trend, while the coastal areas, and areas surrounding Beijing and Tianjin as well as south-central Hebei exhibited a fluctuating downward trend. The range of change in each region was narrow from 2000 to 2015 and the spatial distribution was relatively stable, exhibiting a pattern of low in northwest Hebei and high in areas surrounding Beijing and Tianjin. The efficiency of water use in northwest Hebei significantly improved in 2019 while that of the other regions significantly decreased. It gradually decreased from north to south, which was consistent with its spatial distribution in 1995. An analysis of the regional Theil coefficient and the rates of contribution of the four regions[10] yielded clear regional differences in the overall efficiency of water use of grain crops in Hebei that mainly originated from within each region. Differences in the efficiency of water use of grain crops within south-central Hebei decreased from 1995 to 2019. This difference was large within northwest Hebei, the rate of contribution of which to the overall regional differences in the efficiency of water use increased. The coastal areas as well as areas surrounding Beijing and Tianjin made minor contributions to the difference in the efficiency of water use of grain crops, and the range of changes in efficiency within these regions was narrow.

Figure 6 shows that the efficiency of water use of food crops as well as its spatial pattern changed significantly at the county level, while its spatial distribution in plain areas was relatively stable. Zones with high and median efficiencies increased from 2000 to 2015, but the patterns of a significant expansion in low-value areas and a significant decrease in median-values areas were evident from 2015 to 2019. The high-value areas in the western and northern mountainous and hilly areas decreased. Overall, the range of spatial

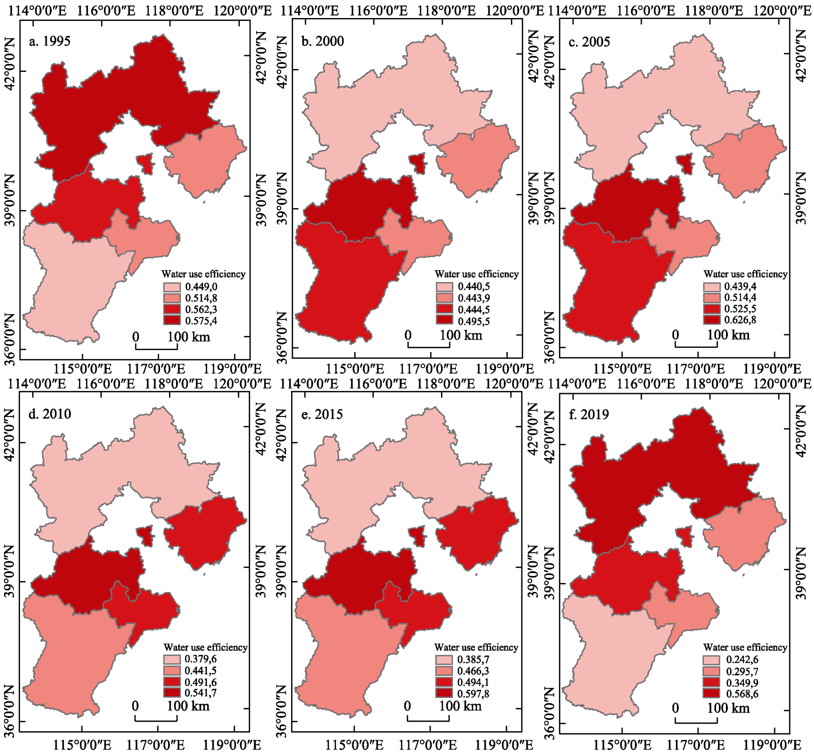

Figure 5 Maps of efficiency of water use of grain crops in the four regions of Hebei Province (1995–2019)

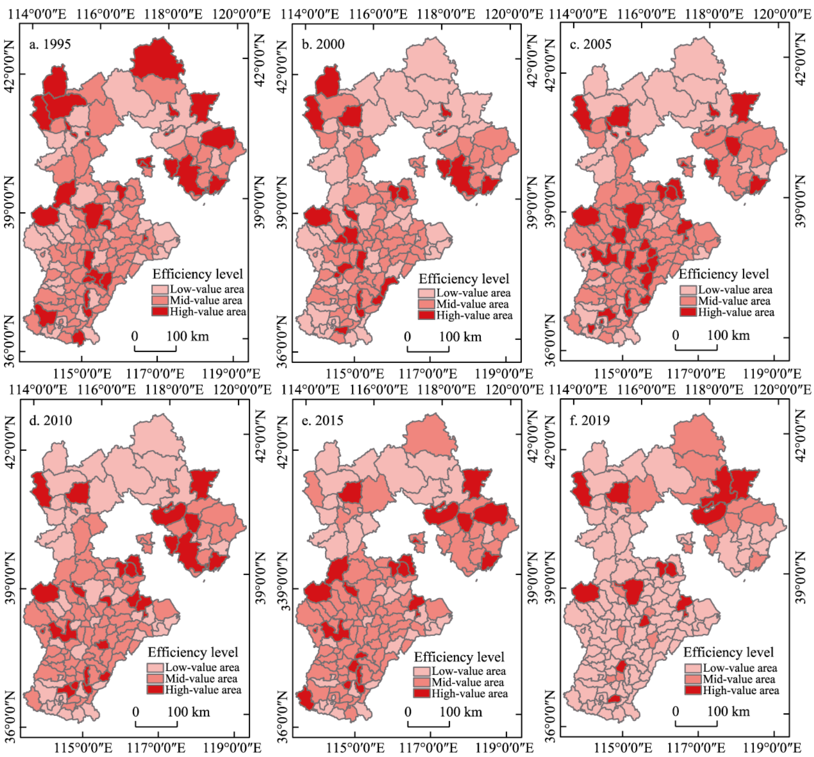

Figure 6 Maps of efficiency of water use of grain crops in Hebei Province (1995–2019)

distribution of low-value areas in Hebei Province expanded from 1995 to 2019 while that of high- and median-value areas decreased.

(3) Spatial heterogeneity of factors influencing the efficiency of water use grain crops at different scales

The factors influencing the efficiency of water use of food crops included those that had a direct impact (local effects) and others that had indirect spillover effects (effects on surrounding areas).Our results[10] show that CDI, UL, and AGM had positive effects and significant spillover effects, while EID and IS had a positive effect but insignificant spillover effects. Owing to the insufficient degree of optimization of AFS in Hebei, it had a negative effect on the efficiency of water use of grain crops. FAI had a negative effect and a prominent spillover effect, while AP had a minor influence on the efficiency of water use. We also analyzed the spatial differences among the influence of these factors on the efficiency of water use. EID and IS had a large influence on the efficiency of water use in the north but a minor influence in the south. The influence of UL decreased from the northeast to the southwest, while the area under the negative influence of AGM was mainly distributed in the northwest. The area under the negative influence of FAI and AFS was large, and had an opposite pattern of distribution. This suggests that reducing fertilizer use and optimizing the planting structure based on regional differences are important ways to improve the efficiency of water consumption of food crops.

4.3 Data Validation

There are three forms of Spatial econometric model that need to undergo data verification to select the most suitable model. We used[10] the SDM model with fixed spatio-temporal effects based on the test of significance of spatial autocorrelation, Lagrange Multiplier test, Likelihood Ration test, and Hausman test. The results showed that the model fit well and passed the significance test, which revealed the obvious spatial effect and spillover effect of the water use efficiency of grain crops in Hebei Province.

We analyzed the efficiency of water use of food crops and the factors influencing it based on statistical data. In practice, there is no specific location and observed value that can be used for comparative analysis. We verified the results in comparison with past work on the study area. The results showed that the efficiency of water consumption of grain crops in Hebei Province was generally poor, and exhibited a significant downward trend after 2015 that is in line with the results of related studies[24]. The parameter R^2 of the model of regression was adjusted to 0.948 after applying the GTWR model, and the outcome was consistent with that of certain past studies: That is, EID had a positive effect on the efficiency of water use of food crops[24–26], while AFS, AP, and FAI had a negative influence on it[3,24,25,27]. However, the results of some past studies were inconsistent with our conclusions. They have claimed that FAI has a positive effect on the efficiency of water use[28]. This is because these studies did not consider the unexpected output in this scenario, because of which their results do not reflect the actual efficiency of water use by crops. In addition, pollution due to nitrogen fertilizers is considered to be an index of pollution of water resources. Phosphate fertilizers and other options should be considered in future research to reduce pollution.

5 Discussion and Conclusion

Water shortage has and will continue to restrict sustainable regional grain production and the security of the ecological environment. Improving the efficiency of water use for food crops in major grain-producing areas that are also afflicted with water shortages is the key to alleviating the tension between the supply of water resources and the demand for them while ensuring food and ecological security[24]. In this study, we considered 139 county units of Hebei Province to calculate the efficiency of water consumption of grain crops under an improved multi-factor input–output framework, and analyzed the spatial effects of factors influencing this efficiency by integrating the model of spatial measurement with the GTWR model. The results showed that the total water footprint of grain crops in Hebei Province grew from 24.601 billion m^3 in 1995 to 31.494 billion m^3 in 2015, and the gray water footprint had the largest rate of annual growth in this period. The overall efficiency of water use of grain crops was poor, and exhibited a downward trend later in the study period. The difference in the efficiency of water use of grain crops in northwest Hebei was the largest, and made an increasing contribution to the overall difference in efficiency across the province. The factors influencing the efficiency of water use exhibited prominent spatial and spillover effects. UL and AGM had a positive effect on it as well as significant spillover effects, while EID and IS also had a positive effect but an insignificant spillover effect. FAI and AFS had a negative effect on the efficiency of water use, while the spillover effect of FAI was prominent.

We used the dataset to comprehensively evaluate the efficiency of water use of grain crops from multiple perspectives, and explored the spatial effects and spatial heterogeneity of the various factors influencing it. This provides basic data to support decision-making on the optimal use of water resources and making adjustments to the agricultural planting structure of farmland in Hebei Province as well as other major grain-producing areas that have limited water resources. The results showed that the planting structure and intensity of use of chemical fertilizers restrict improvements in the regional efficiency of water use, which means that it is important to appropriately alter the planting structure and promote green agriculture. However, we did not consider the actual impact of water-saving irrigation in this study. A field survey from 2022 to 2023 found the water-saving facilities in deep groundwater funnel areas of Hebei (Jizhou, Zaoqiang, Hengshui, Cangzhou, and Nangong) have been enabled, but cannot meet the demand of food crops irrigation. Therefore, the recognition degree and utilization rate of farmers in some areas for this are low, affect the improvement of water efficiency, the follow-up should be comprehensive evaluation of the actual impact of water-saving irrigation on effective irrigation area. Moreover, due to limitations in data acquisition, we were unable to analyze the efficiency of water use of a wider variety of grain crops. There is also a lack of research on the evolution of the efficiency of water use of grain crops over the long term at the county level. Future research in the area should seek to address these limitations.

Author Contributions

Pan, P. P., Wang, X. X. and Wang, X. Y. designed the algorithms of dataset. Pan, P. P., Miao, J. X., and Wen, J. Y. contributed to the data processing and analysis of water use efficiency for grain crops. Pan, P. P. and Wen, J. Y. designed the model and the algorithm. Wen, J. Y. and Li, L. S. did the data verification. Pan, P. P. and Miao, J. X. wrote the data paper.

Conflicts of Interest

The authors declare no conflicts of interest.

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