Damping Effect of Yellow River Basin Land and Water Resources about Agricultural Production

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Abstract: We study the influence of water and land resource constraints on the growth rate of agricultural output in the Yellow River Basin using the damping effect research method with 15 years of panel data from 2004 to 2018, and calculate the damping effect of water resources and land resources in the Yellow River Basin as 2.76% and 12.19% respectively. The results show that through the study of the provinces in the Yellow River Basin, the results show that the damping effect of water and land resources have significant variability in each province, and the damping effect of water resources is significantly negative in the upper reaches of the Yellow River, while it is significantly positive in the middle and lower reaches; and The damping effect of land resources is significantly positive only in Qinghai, Inner Mongolia, and the middle and upper reaches of Shanxi. In order to balance resource constraints with the stable growth of agricultural production, the quality of water and land resources should be improved and the utilization rate of resources should be improved.

1. Introduction

Agriculture is the foundation of the national economy, water and land resources are important inputs. Water resources are affected by climate change and various factors, and the amount of water resources within a given area can change. While the total land area remains constant, the effective area of land use changes as technology advances [1]. However, how and by what means this change in input factors affects agricultural economic growth is still a pressing research issue that needs to be addressed.

The Yellow River Basin is rich in energy resources as well as natural resources and is an important agricultural production area in China. Promoting ecological protection and agricultural development in the Yellow River Basin has a key role to play in the decisive victory in the battle against poverty. However, there are still many challenges to promoting agricultural development in the Yellow River Basin, which has a fragile ecological environment and wide differences in natural resource endowment and economic development between individual provinces[2-4]. In order to clarify the bottlenecks and countermeasures for agricultural development in the Yellow River Basin, this paper examines the following questions: How do the inputs of water and land resources in the Yellow River Basin change? How do changes in these input factors affect changes in agricultural output in the Yellow River Basin?

2. Literature Review

The relationship between resources and environment and economic growth has been the subject of much research by scholars at home and abroad. In economics, the link between the natural environment and economic growth was first explored using the environmental Kuznets curve (EKC), and this curve reveals the trend of environmental quality in line with GDP development, i.e. environmental quality first declines with income growth, and then increases with income growth when income levels reach a certain level, eventually showing an “inverted U” curve.

Research by domestic and international scholars on the relationship between natural resources and economic growth in China can be broadly classified into the following three categories. The first category is the decoupling theory, which is used to study the relationship between natural

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resources and economic growth. The point at which relative decoupling changes to absolute decoupling corresponds to the apex of the environmental Kuznets 'inverted U' curve, where the relationship between economic growth and environmental stress changes from a positive to a negative correlation. Huang Huan et al. (2019) calculated the decoupling effect of economic growth and environmental pollution in the Yangtze River Economic Zone from 2006-2017 using decoupling analysis, and explored the mechanism of the role of environmental regulation on the decoupling state[5]. Ding Baogen et al. (2019) used decoupling analysis to calculate the carbon emission coefficient of arable land resource use in China from 2000-2018[6]. Zhou Yannan et al. (2020) decomposed the carbon emissions of each province and region based on LMDI in terms of economic scale growth, structural transformation and technological upgrading [7]. Huang Xin et al. (2020) calculated the decoupling coefficient between land use carbon emissions and green GDP in Gansu Province from 2000-2017 [8]. The second category is the construction of a coupled model of natural resources and economic growth. Jiao Niantao et al. (2020) used a coupling coordination degree model and spatial regression analysis to evaluate the coupling coordination degree between tourism economy and ecological environment in the Yellow River Basin in the last decade [9]. Zhang Ke-yun et al. (2020) analysed the trend of regional economic variability in the Yellow River Basin in the last decade based on the Thiel index decomposition method, deviation-share analysis method and GIS analysis techniques [10]. The third category is the damping effect, which is used to explain the constraining effect of natural resources on economic growth.Nordhuas was the first to propose the “growth damping” or “tail effect” of natural resources, and Romer (2001) developed a model of economic growth under environmental constraints, and defined the difference between economic growth in the presence and absence of natural resource constraints as growthdrag. Wan Yongkun et al. (2012) measured the damping effect of water and land resources in Beijing, and the results showed that the damping effect of water and land resources fluctuates around economic growth[11]. Tang Xiaocheng (2016) measured the damping effect of energy, land and water resources on economic growth in Shandong Province from 1979 to 2012 as 1.07%, 0.78% and 0.16%, respectively [12]. Shen et al. (2019) found that the damping effect of water resources significantly decreased and leveled off during the study period [13]. Li Minghui et al. (2019) calculated the damping effect of water resources on food production in Shandong Province from 2001 to 2016 as 0.022%, and it showed a decreasing convergence trend [14].

The economy of the Yellow River Basin is growing rapidly, but at the same time, resource consumption is also growing in parallel and environmental pollution is becoming increasingly serious. But how much of a constraint are resource and environmental factors on the growth of the Yellow River Basin? How can the constraining effect of the Yellow River Basin's resources and environment on economic growth be mitigated? This paper constructs the damping effect function of water and land resources on agricultural production through the improved C-D production function, selects the panel data of nine provinces in the Yellow River Basin for a total of 15 years from 2004 to 2018, calculates the time and spatial distribution of the damping effect of water and land resources in the Yellow River Basin, analyses the bottlenecks and causes of agricultural production in the Yellow River Basin, and gives corresponding policy recommendations in this regard.

3. Research Methodology

3.1 Model Construction

In this research, we consider the impact of technological progress, refer to Romer's deformed production function, introduce water resources $S_i(t)$ and land resources $T_i(t)$, take capital, water resources, land resources and labour as input factors, and take agricultural output value as output, and construct a model of water and land resources on agricultural production function.

$$Y_i(t) = K_i(t)^{\alpha} S_i(t)^{\beta} T_i(t)^{\gamma} [A_i(t) L_i(t)]^{1-\alpha-\beta-\gamma} \quad (1)$$

In which, $Y_i(t)$ denotes the agricultural output of region i in year t; $K_i(t), S_i(t), T_i(t), A_i(t)$ and $L_i(t)$ denotes the capital input, water resource input, land resource input, technical progress and labour input of region i in year t, respectively. α, β, γ denote the capital output elasticity, water resource output elasticity, and land resource output elasticity, respectively, and should satisfy $0 < \alpha, \beta, \gamma < 1, \alpha + \beta + \gamma < 1$. from the analysis of economic implications. Taking the logarithm of both sides of the formula (1), we can obtain

$$ln Y_i(t) = \alpha ln K_i(t) + \beta \ln S_i(t) + \gamma \ln T_i(t) + (1 - \alpha - \beta - \gamma)[ln A_i(t) + ln L_i(t)] \quad (2)$$

The derivative of the logarithm of a variable with respect to time t is the growth rate of that variable, and by taking the derivative of both sides of the formula (2) with respect to time t, we get

$$g_{Y_i}(t) = \alpha g_{K_i}(t) + \beta g_{S_i}(t) + \gamma g_{T_i}(t) + (1 - \alpha - \beta - \gamma)\left[g_{A_i}(t) + g_{L_i}(t)\right] \quad (3)$$

When economic growth is on the equilibrium path, according to the Solow model, the rate of economic growth should be in line with the rate of capital growth, and this conclusion holds true for agricultural output as well, i.e. $g_{Y_i}(t) = g_{K_i}(t)$. Then when on the equilibrium growth path, the growth rate per unit of agricultural output is

$$g_{Y_i}(t)^p = \frac{\beta n_i + \gamma n_i + (1 - \alpha - \beta - \gamma)\left[g_{A_i}(t) + n_i\right]}{1 - \alpha} \quad (4)$$

3.2 Damping Effect of Water and Land Resources

Drawing on existing research, the damping efect of water and land resources on the growth of agricultural output $Drag_S, Drag_T$ is defined as the difference between the growth of agricultural output assuming no water and land resource constraints and the growth of agricultural output in the presence of water and land resource constraints. Therefore, the damping effect of water resources on the growth of agricultural output is

$$\begin{aligned} Drag_S &= g_{Y_i}(t)^p - g_{S_i}(t)^z \\ &= \frac{\beta n_i + \gamma n_i + (1 - \alpha - \beta - \gamma)\left[g_{A_i}(t) + n_i\right]}{1 - \alpha} - \frac{\beta g_{S_i}(t) + \gamma n_i + (1 - \alpha - \beta - \gamma)\left[g_{A_i}(t) + n_i\right]}{1 - \alpha} \\ &= \frac{\beta\left(n_i - g_{S_i}(t)\right)}{1 - \alpha} \end{aligned} \quad (5)$$

Similarly, the damping effect of land resources on the growth of agricultural output is

$$\begin{aligned} Drag_T &= g_{Y_i}(t)^p - g_{T_i}(t)^z \\ &= \frac{\beta n_i + \gamma n_i + (1 - \alpha - \beta - \gamma)\left[g_{A_i}(t) + n_i\right]}{1 - \alpha} - \frac{\beta n_i + \gamma g_{T_i}(t) + (1 - \alpha - \beta - \gamma)\left[g_{A_i}(t) + n_i\right]}{1 - \alpha} \\ &= \frac{\gamma\left(n_i - g_{T_i}(t)\right)}{1 - \alpha} \end{aligned} \quad (6)$$

If the damping effect of water and land resources is greater than 0, it means that the quantity of water and land resources has a hindering effect on the growth of agricultural output value, and the larger the absolute value, the more significant the hindering effect; on the contrary, if the damping effect of water and land resources is less than 0, it means that the quantity of water and land resources has no significant hindering effect on the growth of agricultural output value.

4. Empirical Analysis

4.1 Data Sources

The data used in this study were obtained from the China Statistical Yearbook (2004-2018) and the statistical yearbooks of the Yellow River Basin provinces (2004-2018). In order to better study the damping effect of total water and land resources on the growth of agricultural output value, some missing data were processed and converted, and the missing values were interpolated to make up for the missing values. Dependent variable is

Agricultural output Y_i, independent variables are Capital inputs K_i, Water resources inputs S_i, Land resource inputs T_i and Labour input L_i.

4.2 Damping Effect of Land and Water Resources in the Yellow River Basin

A regression of the Yellow River Basin production function model as a whole gives the capital output elasticity, water output elasticity and land resource output elasticity for the Yellow River Basin over the last 15 years. Ridge regression of the model using stata15.1 software (to attenuate the effects of multicollinearity) gave the results shown in Table 1.

Table 1 Regression Coefficients For the Yellow River Basin and the Provinces

Variables	Yellow River Basin	Shanxi	Shaanxi	Sichuan	Gansu	Henan	Inner Mongolia	Ningxia	Qinghai	Shandong
lnk	0.573***	0.003	0.570***	0.676***	-0.126	-0.077	-0.196	-0.377*	0.835	0.281***
	(0.01)	(0.065)	(0.026)	(0.012)	(0.079)	(0.074)	(0.118)	(0.045)	(0.746)	(0.062)
lns	-0.678*	0.758***	-1.213***	-0.166***	1.829*	-0.029	-2.772**	2.927***	0.350	-0.394
	(0.091)	(0.212)	(0.047)	(0.019)	(0.899)	(0.191)	(1.169)	(0.066)	(1.750)	(0.311)
lnt	-1.877***	0.923***	0.595	0.922***	2.224***	2.568***	2.483**	0.334***	-1.228	2.130***
	(0.0271)	(0.261)	(0.221)	(0.165)	(0.214)	(0.168)	(1.031)	(0.109)	(0.514)	(0.127)
Observations	15	15	15	15	15	15	15	15	15	15
R-squared	0.967	0.952	0.023	0.413	0.91	0.981	0.765	0.989	0.578	0.985

Note: ***, ** and * denote significance levels of 1%, 5% and 10% respectively. Standard errors after clustering to provincial administrative regions are shown in parentheses.

According to the analysis , land resource input has the greatest impact on agricultural production, followed by capital input, and water resource input has the least impact on agricultural production. The capital elasticity coefficient, water resource elasticity coefficient, land resource elasticity coefficient and water and land resource damping effect for a total of 15 years from 2004 to 2018 were calculated as shown in Table 2. It can be seen that the capital elasticity coefficient of agricultural production in the Yellow River Basin from 2004 to 2018 is 0.573, the water resource elasticity coefficient is -0.678, the land resource elasticity coefficient is -1.877, the water resource damping effect is 2.76% and the land resource damping effect is 12.19%.

Table 2 Damping Effect Of Water and Land Resources in the Yellow River Basin

Region	Water resources	Growth rate of land resources	Growth rate of labour force	Growth rate of agricultural output	Damping effect of water resources	Damping effect of land resources
Yellow River Basin	-0.03%	1.01%	-1.77%	4.61%	2.76%	12.19%
Shanxi	1.97%	2.41%	0.10%	3.71%	-1.42%	-2.14%
Shaanxi	0.99%	-0.12%	-1.54%	5.53%	7.15%	-1.97%
Sichuan	1.85%	1.14%	-2.33%	4.18%	1.97%	-12.64%
Gansu	-0.58%	2.07%	-0.37%	5.47%	0.34%	-4.82%
Henan	-0.27%	0.65%	-2.14%	4.85%	0.05%	-6.65%
Inner Mongolia	-0.45%	1.39%	0.37%	5.73%	-1.89%	-2.12%
Ningxia	-1.35%	1.83%	0.10%	5.99%	3.09%	-0.42%
Qinghai	-0.88%	1.23%	-2.16%	5.32%	-2.73%	25.23%
Shandong	-1.03%	0.67%	-2.61%	4.19%	0.87%	-9.74%

4.3 Time Series Evolution

In order to explore the magnitude of the constraining effect of water and land natural resources on agricultural production in the Yellow River Basin, we calculated the damping effect of water and land resources and the growth rate of agricultural output value in the Yellow River Basin for each year from 2005-2018. As can be seen from Table 3, the growth rates of agricultural output value from 2005-2018 are all positive and all fluctuate within 3% to 6%, indicating a stable trend of agricultural output value growth. A cross-sectional comparison shows that the absolute value of the land resource damping effect is significantly larger than that of the water resource damping effect, which indicates that the land resource constraint has a more significant impact on agricultural production in the Yellow River Basin than the water resource constraint. A vertical comparison shows that the highest value of the damping effect for water resources occurred in 2006 and the lowest value occurred in 2007, indicating that the impact of water resources on agricultural production in the Yellow River Basin changed dramatically between 2006 and 2007; the damping effect of land resources was positive overall, with a negative value only in 2013, indicating that there was no significant The damping effect of land resources on agricultural production in the Yellow River Basin was not significant in 2013.

Table 3 Damping Effect Of Water and Land Resources in the Yellow River Basin

Year	Drag s	Drag t	gy
2005	2.12%	15.04%	6.039%
2006	12.27%	16.72%	5.765%
2007	-3.91%	14.54%	3.306%
2008	3.85%	17.33%	5.861%
2009	4.58%	10.22%	4.081%
2010	0.01%	11.22%	4.801%
2011	4.34%	11.49%	4.686%
2012	6.78%	13.11%	4.971%
2013	2.89%	-9.68%	4.529%
2014	-2.49%	15.27%	4.199%
2015	5.65%	13.15%	4.505%
2016	-0.11%	14.13%	4.231%
2017	0.45%	11.01%	4.099%
2018	2.82%	17.69%	3.492%

In order to analyse more visually the relationship between the damping effect of water and land resources and the growth rate of agricultural output value in the Yellow River Basin over time from 2005 to 2018, the line graphs of the damping effect of water resources, the damping effect of land resources and the growth rate of agricultural output value over time are plotted in Figure 1 and Figure 2 respectively.

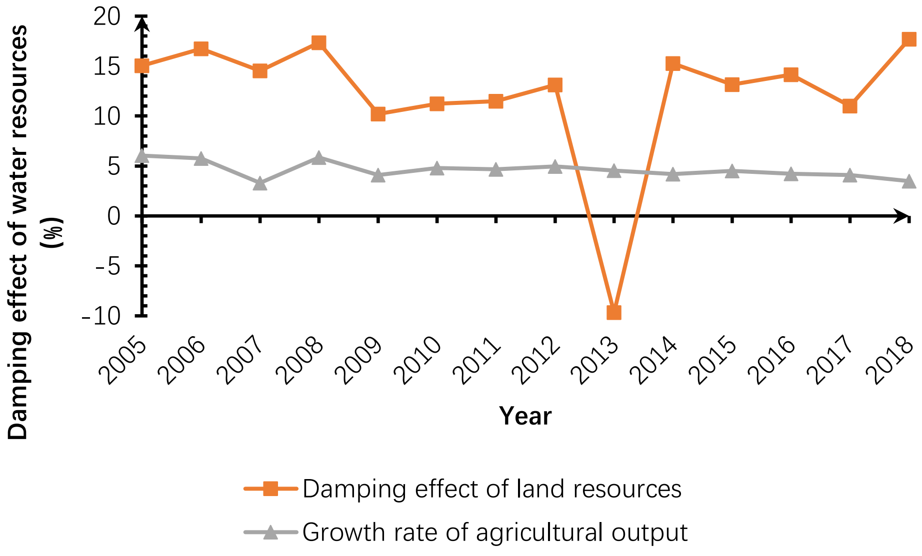

Fig.1 Trend of Water Resources Damping Effect in the Yellow River Basin

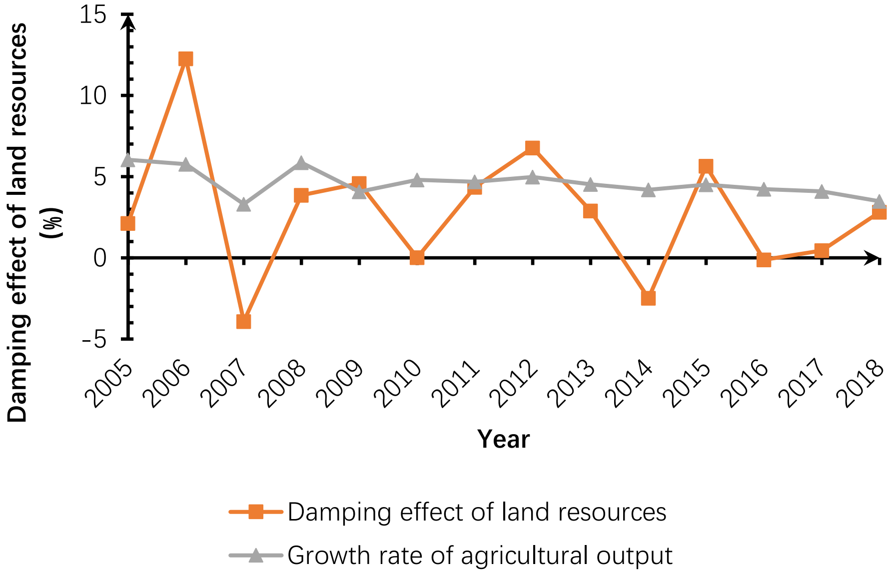

Fig.2 Trend of the Damping Effect of Land Resources in the Yellow River Basin

The above graph shows that the overall damping effect of water resources fluctuates around the growth rate of agricultural output, and the overall damping effect is greater than 0. Similarly, the overall damping effect of land resources fluctuates above the growth rate of agricultural output, and is positive except for 2013, indicating that land resources play an obvious role in constraining agricultural production. Analysing the above results, it can be seen that as the agricultural economy in the Yellow River Basin continues to grow, the damping effect of the constraints on natural resources, especially water and land resources, becomes more apparent, with the growth rate of agricultural output shrinking from 6.039% (2005) to 3.492% (2018); and the resource constraints in turn lead to technological changes to improve the efficiency of resource use, with the indirect effect of the number of people engaged in agricultural production is decreasing year by year. The indirect effect of this is that the number of people engaged in agricultural production is decreasing year by year, while water and land inputs are fluctuating upwards, resulting in the growth rate of the labour force always being smaller than the growth rate of water and land resources, so that water and land resources no longer play a constraining role. As water and land resources become less constraining, the damping effect fluctuates up and down, while the growth rate of agricultural output tends to decline slowly.

4.4 Spatial Characteristics

In order to explore the spatial constraining effect of water and land resources on the growth of agricultural output value in the Yellow River Basin, the damping effect of water and land resources in the Yellow River Basin by province from 2005 to 2018 were calculated according to Equation (5) and Equation (6) and related data as shown in Table 4. The average growth rate of agricultural output in all provinces of the Yellow River Basin was positive, indicating that agricultural production in the Yellow River Basin showed an overall increase during the study period. In order to visualise the relationship between the damping effect of water and land resources and the growth rate of agricultural output for each province in the Yellow River Basin, a bar chart is shown in Figure 3.

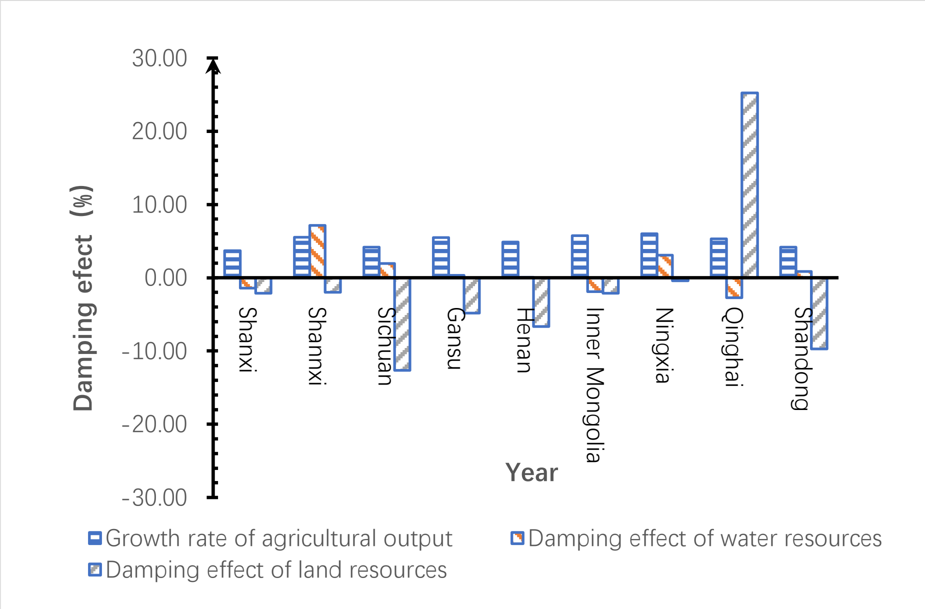

Fig.3 Water and Land Resource Damping Effects by Province

According to the Figure 3, it can be found that the variation of water and land resource damping effect in the Yellow River Basin is obvious, and the damping effect vary from province to province. Among them, Qinghai Province has the highest damping effect for land resources at 25.23%. This may be related to the quality of land resources in Qinghai Province, which is limited by its topography, the low quality of land resources and the scarcity of land area suitable for agricultural production, which plays an obvious constraining role in the growth of agricultural output. Sichuan Province, on the other hand, has the lowest land resource damping effect at -12.64%. With a large land area and excellent natural climatic conditions, Sichuan Province is well endowed for agricultural production, and land resources have a less constraining effect on the growth of agricultural output.

Meanwhile, Shaanxi Province has the highest damping effect for water resources, at 7.15%. Shaanxi Province is located in the lower reaches of the Yellow River Basin, where water resources are scarce, limiting the growth of agricultural output. Qinghai Province, on the other hand, has the lowest water resource damping effect at -2.73%. The Yellow River originates in the Bayan Kra Mountains in Qinghai Province, China, and as the source, its water resources are more abundant and have less constraining effect on the growth of agricultural output.

In addition, the damping effect of water and land resources in Inner Mongolia Autonomous Region and Shanxi Province are both less than 0, indicating that the growth of agricultural output in both regions is less affected by water and land resources, but the growth rate of agricultural output in Shanxi Province is lower than the average of the Yellow River basin, which may be due to the low input of other factors.

5. Policy Recommendations

In order to respond to the strategy of ecological protection and high-quality development in the Yellow River Basin, to improve the efficient use of natural resources such as water and land in the Yellow River Basin, to promote efficient, green and distinctive agricultural production in the Yellow River Basin, and to achieve synergistic development of agriculture and resources and environment in the Yellow River Basin provinces, this paper puts forward the following policy recommendations.

(1) Improve the efficiency of water and land resource use, and ensure the coordination of water and land resources with agricultural economic development. Implement agricultural water price reform in all regions, leverage the regulation of water prices and realise innovative water rights trading policies.

(2) Improve the quality of people employed in agriculture and optimise the structure of the workforce. Increase financial investment in the middle and upper reaches of the Yellow River Basin, establish special assistance schemes.

(3) Accelerate technological innovation in agricultural production. Increase investment in scientific research and innovation in the field of agriculture to optimise current agricultural production technology. At the same time, strengthen the information technology of agricultural production, promote the integration of agriculture with advanced technologies such as the Internet, and realise “smart agriculture”.Eventually realise the specialisation, scale and specialisation of agricultural production in the Yellow River Basin.

(4) Strengthen provincial cooperation in the Yellow River Basin, build a network of linkages for the development of the Yellow River Basin. Extensive exchanges and assistance between neighbouring provinces will be carried out to share knowledge and solve problems.

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