

# *Study on the Evaluation of Sustainable Agricultural and Rural Development*

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**Abstract.** Based on 84 prefecture-level cities in the Yellow River Basin from 2008 to 2022, this paper measures the SARD level in the Yellow River Basin by integrating AHP- entropy method, wavelet-genetic-support vector machine and wavelet-ant colony-support vector machine. Then, on the basis of referring to the relevant agricultural divisions, the spatial types of SARD in the study area are identified based on K-means clustering, and the obstacle factors that hinder SARD in the study area are distinguished by the obstacle degree model, and the factors that affect SARD in the study area and its driving mechanism are explored by the geographic detector. In order to promote the planning and guiding strategy of SARD in the study area.

**Keywords:** Sustainable Agriculture and Rural Development(sard), Spatial and Temporal Evolution, Spatial Type Identification, Planning Guidelines, Yellow River Basin

## 1. Introduction

Sustainable Agriculture and Rural Development (SARD) was first proposed in the 1991 FAO Den Bosch Declaration. It highlights the sustainability of agricultural and rural production, livelihoods, and household resilience, serving as a key approach to advancing rural revitalization. The Yellow River Basin is a major natural and economic region in China with abundant resources and great production potential. However, its SARD faces severe challenges: frequent natural disasters, water shortages, and intensive, irrational human activities have exacerbated human-land conflicts and increased governance difficulties, directly constraining sustainable development. Strengthening the governance and protection of the Yellow River Basin is essential for agricultural and rural sustainability, and is of great significance to safeguarding agricultural production and rural livelihoods. Foreign research and practice mainly focus on agro-ecosystem and environmental protection, focusing on improving the structure and function, and promoting the ecological and sustainable development of agriculture and rural areas. SARD's research focuses on food security, escape from poverty [1-5] and other basic livelihood issues, and its emphasis is on higher-level objectives such as human health [5], MFA [6], rural prosperity and livelihoods well-being [7], rural restoration and remediation [8-10], rural revitalization [11-13], and challenges, risk assessment, and future perspectives [14]. By formulating relevant policies and proposing optimization paths [15,16] to enhance the resilience and sustainability of agricultural development and diversify agricultural

systems, it becomes an important driving force to achieve the above goals. Taken together, these studies can reflect the state of agricultural and rural development more objectively and provide a scientific basis for the formulation of corresponding policies and planning measures. However, there are still some problems and challenges, such as fewer studies on the measurement of the spatial and temporal evolution of sustainable agriculture and rural development, fewer studies on valuable and targeted planning guidelines and optimization paths, a single research methodology, lack of qualitative and quantitative analyses, and insufficiently refined research scales and fewer combinations of SAD and SRD.

## **2. Regional overview and research methodology**

### **2.1. Overview of the study area**

Due to the merger of Laiwu City in Shandong Province into Jinan City in January 2019, combining with the definition of the flow range of the Yellow River basin by several scholars, and taking into account the integrity of the natural and administrative divisions, the 84 prefectural-level cities (states and leagues) involved in the Yellow River's main streams were finally included in the scope of the study area. With reference to the natural geographic factors such as topography, hydrology and so on. Now the Yellow River flows through nine provinces and autonomous regions.

### **2.2. Research methodology**

#### **2.2.1. Geo-probes**

Geographic probes are a group of statistical research methods aimed at revealing spatial differentiation and the driving forces behind it. In this study, factor probes were used to clarify the spatial variation of different factors on the level of sustainable agriculture and rural development (SARD) in the Yellow River Basin, and interaction probes were applied to analyze the changes in the explanatory power of different influencing factors on the level of SARD.

#### **2.2.2. Related algorithms**

Wavelet Transform (WT), originated in 1980s, it is an analysis and processing tool developed on the basis of localization of Fourier Transform, Wavelet Transform can make up for the difficulties of Fourier Transform. In the 1970s, John Holland in the United States proposed Genetic Algorithm (GA), which is based on simulating the evolution of organisms and genetics, so as to achieve the optimal solution. The principles of genetic algorithms include the construction of chromosomes and their coding, fitness, running parameters and genetic variants, the use of "0" and "1" conversions, and the application of uniform variation for the penalty factor C and the kernel function. Marco Dorigo in 1992 Ant Colony Optimization (ACO) algorithm was first proposed, which is based on the principle of estimating the range of parameter values, uniformly dividing the grid, and determining the value of its objective function, and performing the search for the shortest path, so that the probability of choosing that path is greater in the next time.

### **2.3. Indicator system**

This paper is based on two major subsystems, sustainable agricultural development and sustainable rural development, and eight sub-criteria layers, using Yaahp software to make the judgment matrix

of sub-criteria layers, consulting the experts in the related fields of sustainable agriculture and rural development, adopting the 9-level scaling method, and repeatedly adjusting and improving it by combining with the actual situation of the Yellow River Basin, and finally obtaining the values of weights of the eight sub-criteria layers(Table 1).

Table 1. Comprehensive weights of the SARD level evaluation index system

Standardized	Sub-criteria	AHP	Indicator layer	Combined
			D <sub>1</sub> ecological conservation	0.0007
			D <sub>2</sub> Agricultural film use	0.0002
	product quality	0.2168	D <sub>3</sub> Intensity of water consumption in agriculture	0.0003
			D <sub>4</sub> Cropland recovery index	0.0065
			D <sub>5</sub> Famous and Special Agricultural Products	0.0000
			D <sub>6</sub> geographically marked agricultural product	0.0038
			D <sub>7</sub> Agricultural labor productivity	0.0021
SAD			D <sub>8</sub> Agricultural land productivity	0.0042
	production efficiency	0.1194	D <sub>9</sub> Level of agricultural mechanization	0.0036
			D <sub>10</sub> Livestock output per laborer	0.0025
			D <sub>11</sub> Cash crop output per laborer	0.0051
			D <sub>12</sub> Value added of primary industry	0.0029
	Industry	0.1194	D <sub>13</sub> Primary sector output per capita	0.0013

Table 1. (continued)

			D <sub>14</sub> Agricultural value added to industrial	0.0051
	large-scale business operation	0.0443	D <sub>17</sub> National agricultural leading enterprises	0.0009
			D <sub>18</sub> State agricultural science and technology parks	0.0000
			D <sub>19</sub> Agricultural cooperatives	0.0008
			D <sub>20</sub> Level of agricultural socialization services	0.0019
SRD			D <sub>21</sub> Energy consumption dynamics index	0.0003
			D <sub>22</sub> Water resources per capita	0.0203
	Resource index	0.1281	D <sub>23</sub> Arable land per capita	0.0026
			D <sub>24</sub> Rural electricity consumption per capita	0.0062
			D <sub>25</sub> NDVI index	0.0006
			D <sub>26</sub> Engel's coefficient for rural inhabitants	0.0001
	quality of life	0.069	D <sub>27</sub> Farm household income diversification	0.0003
			D <sub>28</sub> Education coverage	0.0017
SRD			D <sub>29</sub> Medical personnel	0.0011
			D <sub>30</sub> Rural road density	0.0060
	Rural construction	0.064	D <sub>31</sub> urbanization rate	0.0008

Table 1. (continued)

		D <sub>32</sub> Road network density	0.0087
		D <sub>33</sub> Sewage treatment rate	0.0001
		D <sub>34</sub> forest cover	0.0025
		D <sub>35</sub> Effective irrigation of agricultural	0.0093
ecological conservation	0.2389	D <sub>36</sub> Soil erosion control area	0.0099
		D <sub>37</sub> Carbon emission factor	0.0008
		D <sub>38</sub> Environmental regulation	0.0029

### 3. Results and analysis

#### 3.1. SARD spatio-temporal patterns based on Wavelet-Genetic-Support Vector Machines

##### 3.1.1. SARD level

In the training test set, the maximum number of generations is set to 200. after the training of Genetic Algorithm-Support Vector Machine (GA-SVM), the mean square error (MSE) is obtained as 0.008, and the correlation coefficient with the curve of the true value is 0.97688. the optimal parameter penalization factor C and the kernel function g are 9.4318 and 0.01, respectively. compared with GA-SVM, the wavelet-GA-SVM performs better in terms of accuracy. In addition, the MSE obtained by Ant Colony Algorithm-Support Vector Machine Model (ACO-SVM) is 0.016 and the correlation coefficient with the actual value is 0.954. (figure 1).

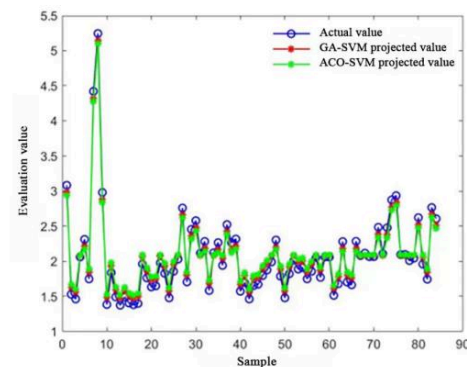


Figure 1. GA-SVM, ACO-SVM and actual value results

### 3.1.2. Guideline layer characteristics

The average value of sustainable agricultural development (SAD) is 1.067, with an average annual increment of -0.012, peaking in 2016. It scores highest in product quality and lowest in scale operation. Spatially, Qinghai has the highest SAD level, supported by scientific and technological innovation and a favorable grain output trend. The average value of sustainable rural development (SRD) is 0.985, with an average annual increment of 0.0080, peaking in 2016 and 2020. High scores in ecological conservation lifted the overall SRD level, and Shandong Province ranks highest spatially. As a major modern agricultural province, Shandong should leverage its resource endowments, enhance agricultural efficiency and competitiveness, rely on scientific and technological innovation, foster new drivers, and boost rural sustainable development. The composite SAD–SRD index shows a generally consistent trend with two peaks (2016, 2020) and two troughs, with scores around 1.3 and 1.1 respectively. Both indices have declined since 2020, presenting an overall pattern of "fluctuating rise followed by a slight decline".

### 3.1.3. Sub-criteria layer characteristics

From the comprehensive scores of SARD sub-criteria layers in the Yellow River Basin, the scores of the eight sub-criteria layers show different rates of upward and downward trends, with the highest and fastest growth rate of the ecological conservation score, the awareness of ecological environmental protection of the Yellow River Basin gradually improving under the support of national policies, the product quality and industrial efficiency changing with a larger magnitude, and the rest of the sub-criteria layers showing a stable trend of change. Overall, from 2008 to 2022, the comprehensive levels of each dimension in descending order are ecological conservation, product quality, production efficiency, resource index, industrial efficiency, quality of life, rural construction and large-scale operation.

## 3.2. SARD spatial type identification

In the 1930s, Hu Huanyong first studied China's agricultural zoning, dividing the country into nine agricultural regions, which laid the foundation for future scholars' studies. In the 1960s, Deng Jingzhong compiled the zoning of China's agricultural status quo and carried out related work; and in the 1980s, China's Comprehensive Agricultural Zoning divided the country into 10 first-class agricultural regions and 38 second-class agricultural zones. SARD in the Yellow River Basin is a complex systematic project, and a good ecological environment is the foundation for survival and development. This paper tries to make a scientific and reasonable spatial type zoning for the study area by combining the relevant policy and planning documents (figure2).

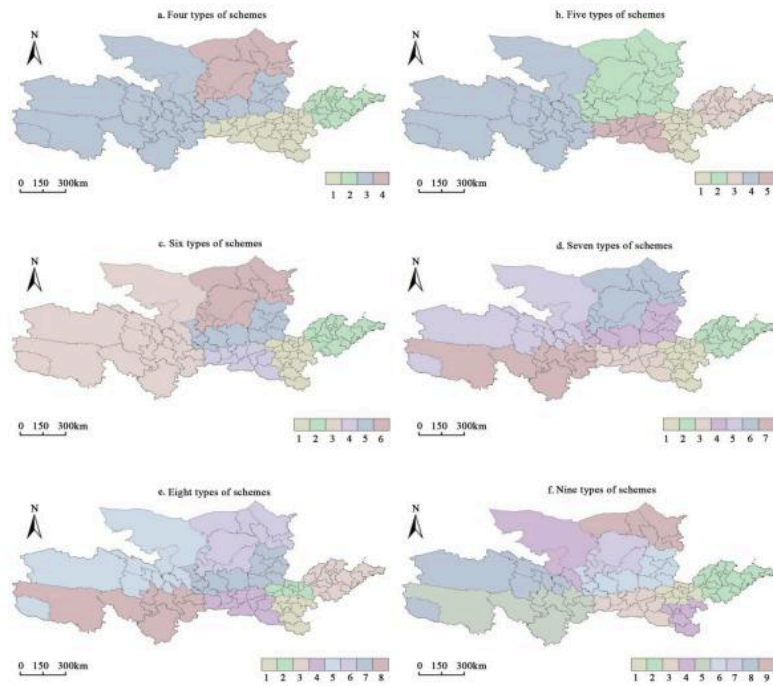


Figure 2. SARD level clustering scheme of prefecture-level cities

### 3.2.1. Overall level

From the time-series perspective, SARD levels across the six major regions of the Yellow River Basin generally trended "stable with fluctuating growth and a slight decline" from 2008 to 2022, with the most significant increase occurring between 2012 and 2016. The Shandong Hilly Area maintained the highest overall score, though its annual growth rate was  $-0.012$ . The Qinghai-Tibetan Plateau ranked second with the fastest growth at an annual increment of  $0.008$ , and overtook the Shandong Hilly Area to take first place in 2017. The Fenwei-Yuxi Hilly Area recorded an annual increase of  $0.001$ , with a  $0.1717$  score gap from the Qinghai-Tibetan Plateau. The remaining three regions scored below average. The Hetao Plain and Huanghuaihai Plain had similar overall levels, with annual changes of  $-0.003$  and  $-0.008$  respectively; the Huanghuaihai Plain had the slowest growth, while the Hetao Plain surpassed it in 2017. The Loess Plateau remained at the bottom with an annual change of  $-0.002$ . (Figure 3).

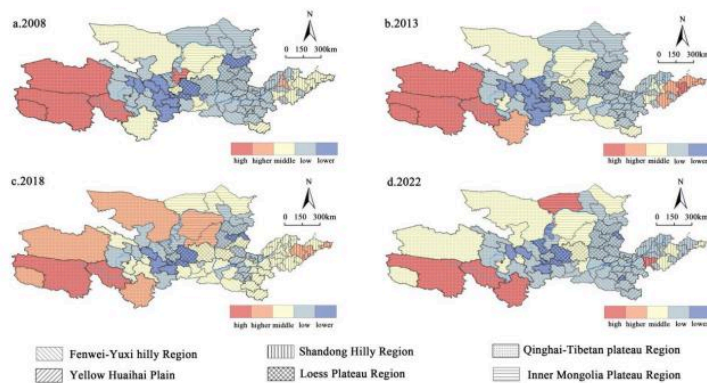


Figure 3. Evolution of spatial distribution of SARD levels

### 3.2.2. Sub-criteria level

In terms of the overall development trend, the SAD and SRD of the major sub-criteria layers showed a fluctuating trend with a slight decrease from 2008 to 2012, a steady increase from 2012 to 2016, and a slight decrease from 2016 to 2022. The scores of each sub-criteria stratum in the cities of Qinghai-Tibet Plateau and Shandong Hilly Areas are higher than the overall level of the study area; the scores of each sub-criteria stratum in Fenwei Plain-Yuxi Hilly Areas are the closest to the overall level of the study area; the scores of each sub-criteria stratum in the Yellow-Huai-Hai Plain Areas are much lower than the overall level; and the scores of the cities of Hetao Plain Areas and Loess Plateau Areas are closer to, and slightly lower than, the overall level.

## 4. Analysis of influencing factors and their driving mechanisms

### 4.1. Geodetic survey

Geoprobe is a spatial statistical analysis method to measure spatial heterogeneity, which is able to detect the spatial differentiation of geographic phenomena and reveal the spatial distribution relationship between its dependent and independent variables. Using the geoprobe model in combination with the research of related scholars, the influence factors of SARD in the Yellow River Basin are explored from both natural and economic and social levels. The systematic analysis and evaluation by integrating the natural and economic and social factors will help to accurately grasp the SARD driving mechanism and provide a scientific basis for sustainable agriculture and rural development. The data for the impact factors were obtained from the Center for Resource and Environmental Science and Data of the Chinese Academy of Sciences, the China Meteorological Background Dataset, and the statistical yearbooks of each province and city.

### 4.2. Driving mechanism

This paper analyzes the driving mechanisms of Sustainable Agriculture and Rural Development (SARD) in the Yellow River Basin from three dimensions: natural, economic and social. In the natural dimension, terrain, climate, soil, vegetation and water resources serve as fundamental driving factors, among which soil erosion and per capita water availability are the core elements. Regional natural differentiation has formed a differentiated agricultural layout: forestry and fruit industry in mountainous areas, animal husbandry on plateaus, and crop farming in plains. Climate, soil, vegetation and water resources further restrict crop growth, land productivity and ecological stability. In the economic and social dimensions, road density, per capita arable land area, proportion of the primary industry, population density and fixed-asset investment are the main driving forces leading to the spatial differentiation of SARD. This coupled natural-socioeconomic driving mechanism has effectively boosted farmers' income, improved agricultural efficiency and quality, and promoted the comprehensive advancement of rural revitalization.

## 5. Conclusions and responses

Based on relevant theories, the study proposes five pathways for rural sustainable development: first, restoring rural ecological environment through ecological agriculture, optimized land layout and efficient water utilization; second, upgrading rural industrial structure by exploiting agricultural multifunctionality and integrating farming, tourism, creativity and residence; third, strengthening rural cultural protection with an ecological catalyst approach, exploring local characteristics to build

an influential Yellow River cultural belt; fourth, improving rural governance under the concept of integrated governance, diversifying governance subjects and enhancing regulatory mechanisms; fifth, optimizing rural living environments in a people-oriented manner, improving infrastructure and public services to advance beautiful village construction and overall rural development.

## References

- [1] Godfray H C J, Beddington J R, Crute I R, et al. Food Security: The Challenge of Feeding 9 Billion People [J]. *Science*, 2010, 327(5967): 812-818.
- [2] Tilman D, Balzer C, Hill J, et al. From the Cover: Global food demand and the sustainable intensification of agriculture [J]. *Proc Natl Acad Sci*, 2011, 108(50): 20260-20264.
- [3] Foley J A, Ramankutty N, Brauman K A, et al. Solutions for a cultivated planet [J]. *Nature*, 2011, 478(7369): 337-342.
- [4] Irz X, Lin L, Thirtle C , et al. Agricultural Productivity Growth and Poverty Alleviation [J]. *Development Policy Review*, 2001, 19.
- [5] Welcha R M, Grahamb R D. A new paradigm for world agriculture: meeting human needs Productive, sustainable, nutritious [J]. *Field Crops Research*, 1999, 60(1-2): 1-10.
- [6] Wilson G A. The spatiality of multifunctional agriculture: A human geography perspective [J]. *Geoforum*, 2009, 40: 269-280.
- [7] Rivera M, Knickel K, Rios I D L, et al. Rethinking the connections between agricultural change and rural prosperity: A discussion of insights derived from case studies in seven countries [J]. *Journal of Rural Studies*, 2018, (59): 242-251.
- [8] Knickel K, Redman M, Darnhofer I, et al. Between aspirations and reality: Making farming, food systems and rural areas more resilient, sustainable and equitable [J]. *Journal of Rural Studies*, 2018, (59): 197-210.
- [9] Schouten M A H, Heide C M V D, Heijman W J M, et al. A resilience-based policy evaluation framework: Application to European rural development policies [J]. *Ecological Economics*, 2012, 81(3): 165-175.
- [10] Ankita R. Is Agrarian Resilience limited to Agriculture? Investigating the “farm” and “non-farm” processes of Agriculture Resilience in the rural [J]. *Journal of Rural Studies*, 2020, (12): 1-10.
- [11] Liu Y S, Li Y H. Revitalize the world’s countryside [J]. *Nature*, 2017, 548(7667): 275-277.
- [12] Yin X M, Chen J, Li J Z. Rural innovation system: Revitalize the countryside for a sustainable development [J]. *Journal of Rural Studies*, 2019, (10): 1-8.
- [13] Gao J L, Liu Y S, Chen J L. China’s initiatives towards rural land system reform [J]. *Land Use Policy*, 2020, 94.
- [14] Amruta S, Shivraj H N, Ajay V S, et al. Recent Advances in Nano-Enabled Seed Treatment Strategies for Sustainable Agriculture: Challenges, Risk Assessment, and Future Perspectives [J]. *Nano-Micro Letters*, 2023, 15(4): 159-195.
- [15] Claret C, Metzger M J, Kettunen M, et al. Understanding the integration of ecosystem services and natural capital in Scottish policy [J]. *Environmental Science and Policy*, 2018, (88): 32-38.
- [16] Malley Z J U, Taeb M , Matsumoto T . Agricultural productivity and environmental insecurity in the Usangu plain, Tanzania: policy implications for sustainability of agriculture [J]. *Environment Development & Sustainability*, 2009, 11(1): 175-195.