# Agricultural Carbon Sink and Agricultural Economic Development Investment: System Coupling Coordination Degree and Entropy Method Analysis—A Case Study of Shanxi Province

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**Abstract.** Agricultural carbon sink is an important initiative to promote China's "dual-carbon" plan in agricultural sector, based on studies that farmers in Shanxi province are seriously insufficient in the recognition of agricultural carbon sink, and a significant gap exists between regions in recognition and efficiency of carbon sink, cognitive level plays a decisive role in farmers' willingness to practice carbon sink. While the economic growth of agriculture and carbon sink efficiency exhibit a coupled coordination trend, agricultural economic growth and carbon sink efficiency are located in the "undercoordinated low-level equilibrium state" in this study. The information entropy of the coupling coordination and the coupling coordination model reveal 3 points: farmer's cognitive literacy needs to be effectively improved, Carbon sink promotion policy should be further improved and farmers' and agribusiness's interest are needed to be coordinated. Policy suggestions consist of setting up government-farmer-enterprise coordination channel, devising agricultural ecological compensation mechanism and perfecting policies system to achieve that carbon sink action synergizes with economic improvement.

**Keywords:** Agricultural Carbon Sinks, Agricultural Economic Development, Coupling Coordination.

## 1 Introduction

The Outline of the Implementation Plan on Reduction of Agricultural and Rural Emissions and Sequestration of Carbon confirms the green development principle for high-quality agricultural growth, and the plan will steer an effort for greening the agriculture in 14th Five-Year Plan period. Improving the agricultural carbon sink also solves the problem of pollution brought by the farm animal husbandry waste discharge and unutilized crop straw. For low-carbon agricultural model, such as standardized land building, eco-farms, grain-crop rotation system and green circular breeding, Shanxi's 11 grain producing-marketing balancing regions provided feasible paths. Though 80% and more livestock waste in Shanxi have been treated and used at present, the shortage of


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its public attention, imperfect technical publicity and irregular implementation of policies restrain the development of carbon sink, and enhancing publicity and technical services are quite necessary to beat these problems.

The potential of agricultural carbon sequestration is significant. Agricultural carbon sequestration is primarily achieved through carbon fixation and emission reduction in agricultural practices[1-2]. And fertilizers, plowing, and irrigation are the largest contributors to the total carbon source, and these three sources have substantial potential for carbon emission reduction[3]. Tillage reduces the stability of soil organic carbon and accelerates its decomposition[4].

Agricultural carbon sequestration and agricultural economic development are complementary. In terms of total carbon emissions, evaluations of agricultural low-carbon levels across provinces show that Shanxi's agricultural low-carbon level has consistently remained at Level II. Regarding the growth rate of carbon emissions, Energy-related agricultural carbon emissions increase more significantly than non-energy-related emissions[5-6]. However, due to the existence of high-input and energy-intensive agricultural production methods, the increase in output per unit area is not synchronized with the increase in straw volume[6]. The concept of harmonious coexistence between humans and nature, however, can bring more sustainable development and greater benefits to the people.

The influencing factors of agricultural carbon sequestration are complex and varied, as shown in Table 1.

**Table 1.** Summary of agricultural carbon sink efficiency

| Impact Factor | Refinement Analysis | Scholars Proposed |
|---|---|---|
| Technological innovation | Production efficiency and energy consumption reduction | Tian Yun et al., 2021 |
| Agriculture support finance | The financial support for agriculture helps agriculture to flourish, with obvious spatial differences | Han Jinyu et al., 202 1 |
| Agricultural industry cluster | Agricultural carbon emissions peaked and then declined | He Qing et al., 2021 |
| Farmers' awareness level | Rural population's ability to accept and utilize new technologies | Chen Yin'e et al., 2018 |

The current research focuses on the potential of agricultural carbon sequestration and its relationship with agricultural economic development, but lacks studies on the internal coupling coordination between Agricultural Carbon Sink and Agricultural Economic Development Investment. Therefore, this study will conduct a systematic coupling analysis based on primary survey data, and propose suggestions conducive to the development of agricultural carbon sequestration and agricultural economy, so as to enable them to play a greater role in rural revitalization.

## 2 Analysis Methods and Data Sources

This study based in Shanxi Province, a grain production-marketing equilibrium region in China with relatively high agricultural carbon sequestration capacity, reveals that recent efforts to establish high-standard farmland, develop eco-farms, and implement green cultivation techniques have promoted low-carbon agricultural development. Despite these, there remains need for weaker awareness of carbon sink and late adoption of carbon sequestration technology, which demands intensive policy regulation and scientific- tic-technological service as an optimal tool for improvement of agricultural sustainability.

### 2.1 Research Method

**Analysis Method.** The entropy method determines weights by calculating variability among sample data, ensuring objective evaluation results. Procedures:

①Data Standardization:

$$Z_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{n} x_{ij}^2}}$$

②Proportional Transformation:

$$P_{ij} = \frac{z_{ij}}{\sqrt{\sum_{i=1}^{n} z_{ij}}}$$

③Calculate Information Entropy and Information Utility Value:

$$e_{ij} = -\frac{1}{ln\, n}\sum_{i=1}^{n} ln(p_{ij})$$

$$d_{ij} = 1 - e_j$$

④Indicator Weight Values:

$$W_j = \frac{d_j}{\sum_{j=1}^{m} d_j}$$

The entropy method was applied to determine weights (0.311, 0.323, 0.251, 0.115) for agricultural economic development indicators—per capita cultivated area, labor input, total agricultural output value, and per capita rural income—with the comprehensive score representing development level.

**Coupling Degree Model.** The coupling degree model can measure system coupling degree and interdependency degree between elements or systems. But the coupling degree model can only reflect the coupling interaction degree of agricultural carbon sink efficiency and the interaction degree of economic development. They need not to be measured in terms of coordinated development degree. Coupling coordination degree model is used to measure the coordinated development level. Specific form is shown below.

$$S = \sqrt{W \times T}, S \in [0,1]$$

$$T = \alpha X_1 + \beta X_2 (\alpha + \beta = 1)$$

S denotes the coupling coordination degree between agricultural carbon sink efficiency and economic development, where T represents their comprehensive benefit index, and α/β (both set as 0.5 here) reflect each system's contribution. Higher S values indicate better synergistic development. Coupling coordination phases are classified in Table 2.

**Table 2.** Division of coupling/coordination stages

| Coupling/coordination | Value range | Stage |
|---|---|---|
| Coupling | $0< C \leq 0.3$ | Initial coupling |
| | $0.3< C \leq 0.5$ | Antagonistic |
| | $0.5< C \leq 0.8$ | Running-in phase |
| | $0.8< C \leq 1$ | Advanced Coupling |
| Coordination | $0\leq D \leq 0.3$ | Initial coordination |
| | $0.3< D \leq 0.5$ | Low-level coordination |
| | $0.5< D \leq 0.8$ | Intermediate coordination |
| | $0.8< D \leq 1$ | Advanced coordination |

### 2.2 Data Sources

The research is based on data obtained from the team's own survey, which are primary data.

## 3 Measurement Model

### 3.1 Construction of an Indicator System for Agricultural Economic Development

The construction of a composite indicator can decompose the level of agricultural economic development from an abstract level into a concrete, quantifiable, and operational structure based on its essential attributes and characteristics. This is a key step in analyzing the coupling coordination degree.

This study is based on the existing research results[1-6]and is organized as follows.By taking economic input and economic output as the first-level indicators of agricultural economic development, and using four indicators, including per capita operational area and labor input, as positive second-level indicators, a comprehensive indicator system for agricultural economic development is constructed. See Table 3 for details.

**Table 3.** Comprehensive indicator system for agricultural economic development

| Target layer | First level indicator | Secondary indicators | Indicator Description |
|---|---|---|---|
| Agricultural Economic Development | Economic investment | Per capita operating area | Cultivated land area |
| | | Labor Input | Number of people employed in the primary industry at the end of the year |
| | Economic Output | Total agricultural output | Total agricultural output |
| | | Per capita income of rural residents | Disposable income of rural residents |

Since the two data sets have different dimensions, raw data needs to be standardized before assigning values to the system indicators. Based on the fact that Analytical Hierarchy Process method (AHP), TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) are very subjective methods, this paper uses the Entropy Weight Method to assign values.

## 3.2 Construction of the Coupling Coordination Model

The obtained data were substituted in the model and the coupling degree between agricultural carbon sequestration efficiency and agricultural economic development was calculated. The calculation results are presented in Table 4. As can be seen from the Table 4, the coupling coordination degree varies considerably among various cities, with the general mean values in medium and high coupling coordination stage. Take for instance, the coupling coordination degree in Changzhi City changes dramatically, in which, 2015, 2022 and 2023 are in the early coordination stage, and other years are in the middle coordination stage. The starting point of Yangquan City is the smallest but the biggest in the rate of growth. In over ten years, Taiyuan City has moved from the middle coordination stage to the high coordination stage.

**Table 4.** Coupling degree between agricultural carbon sink efficiency and agricultural economic development

| | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Taiyuan** | 1.00 | 0.93 | 0.94 | 0.91 | 0.92 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| **Changzhi** | 0.89 | 0.99 | 0.30 | 0.99 | 1.00 | 0.89 | 0.32 | 0.86 | 0.85 | 0.85 | 0.35 |
| **Jinzhong** | 0.91 | 0.53 | 0.95 | 0.53 | 0.53 | 0.79 | 1.00 | 0.79 | 0.80 | 0.82 | 1.00 |
| **Datong** | 0.93 | 0.99 | 0.90 | 1.00 | 1.00 | 0.39 | 0.88 | 0.39 | 0.39 | 0.40 | 0.87 |
| **Yuncheng** | 0.77 | 0.96 | 0.95 | 0.93 | 0.93 | 0.92 | 0.97 | 0.89 | 0.82 | 0.82 | 0.82 |
| **Shuozhou** | 0.81 | 0.92 | 0.59 | 0.96 | 0.96 | 0.49 | 1.00 | 0.53 | 0.54 | 0.58 | 1.00 |
| **Xinzhou** | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 | 0.24 | 0.22 | 0.25 | 0.26 | 0.25 | 0.25 |
| **Linfen** | 0.94 | 0.84 | 0.72 | 0.83 | 0.57 | 1.00 | 0.93 | 0.99 | 0.97 | 0.96 | 0.95 |
| **Yangquan** | 0.48 | 0.49 | 0.75 | 0.49 | 0.49 | 0.85 | 0.38 | 0.93 | 0.95 | 0.97 | 0.41 |
| **Luliang** | 0.95 | 0.87 | 0.98 | 0.85 | 0.86 | 0.79 | 1.00 | 0.76 | 0.74 | 0.71 | 0.99 |
| **Jincheng** | 0.95 | 0.85 | 0.91 | 0.83 | 0.83 | 0.99 | 0.99 | 0.98 | 0.97 | 0.97 | 0.98 |

In general, the coupling degree and the coupling coordination degree of the agricultural carbon sequestration efficiency and the agricultural economic development of the Shanxi Province showed a rising-fall-rise-fall pattern and a continuously increasing trend at the end stage. The mean coupling degree is less fluctuated compared to the coordination degree and exhibits a small range of change from the beginning to the end time. The average coupling degree of the 11 cities reduced from 0. Mean coupling coordination degree rose from 0.56 in 2013 to 0.57, the two systems were all in medium coordination stage, which reflects the two systems are highly correlated. From mean coupling coordination degree and mean clustering coefficient, they reflect that two systems were always in high coupling stage. The significant variation from 2013 to 2023 indicates that the agricultural carbon sequestration efficiency may restrain the development of agricultural economy at the initial stage and the two subsystems develop with a synergistic pattern when they are strongly correlated (Table 4).

## 4 Suggestions

Stimulate public attention, provide stable income, encourage relatively high educated and young people participate the carbon sequestration production, set up a technology exchange base for large grain producers and livestock farm owners, improve the mechanism of carbon trade market, protect farmers carbon credit income. Accelerate the transformation, implement R&D of climate-change mitigation-oriented agricultural machinery, reward agrochemical companies to produce low-carbon products through incentive policies, reward high added value of carbon sinks agricultural materials, farmers' production cost. Encourage upgrading, give priority to collaboration, boost the role of carbon-sink agriculture for industrial upgrading, increase inter-province and region eco-environment collaboration and regional externality in spillover to raise the overall system carbon sequestration capability and let lagging regions achieve development overreaching by leapfrogging.

## 5 Conclusion

The formation of agricultural carbon sequestration in Shanxi exhibits gradient effect by spatial-temporal variations, in which technological improvement is still the main factor. The coupling coordination process of agricultural carbon sequestration efficiency and agricultural economies presents changing course of the bidirectional synergy, which is limited at first and then transitioned due to strengthened correlation, exhibiting threshold effect. It establishes an ecology-support-economic, economic protect-ecology circle where three important actors (government, companies, farmers) standardize management activities under ecological management and realize coordinated economic-ecological sustainable growth through rational resource utilization. Based on the above research conclusions, future research directions could focus on "The multi-agent collaborative optimization and ecological-economic coupling mechanism of agricultural carbon sequestration in Shanxi".

## References

1. Marland, Gregg, et al. "Managing soil organic carbon in agriculture: the net effect on greenhouse gas emissions." Tellus B: Chemical and Physical Meteorology 55.2 (2003): 613-621.
2. Kumar Sarangi, Prakash, et al. "Utilization of agricultural waste biomass and recycling toward circular bioeconomy." Environmental Science and Pollution Research. [J]. 30.4 (2023): 8526-8539.
3. Shang Jie, Yang Binjian. Estimation of Carbon Sources and Sinks in Crop Production and Dynamic Analysis of Influencing Factors on Net Carbon Sinks: A Case Study of Shandong [J]. Reform, 2019 (06): 123-134.
4. Lorenz, Klaus, and Rattan Lal. "Carbon sequestration in agricultural ecosystems." (2018): 978-3.
5. Tian Chengshi, Chen Yu. Estimation of Provincial Agricultural Carbon Emissions and Evaluation of Low-Carbon Levels in China—Application of Derived Indicators and TOPSIS Method [J]. Journal of Natural Resources, 2021 (02): 395-410.
6. Yang Guo, Chen Yao. Estimation of Agricultural Carbon Sinks in China and Coupling Analysis with Agricultural Economic Development [J]. China Population, Resources and Environment, 2016 (12): 171-176.