Research on the New Development Model of Low-carbon Agriculture in Liangshan Prefecture, Sichuan

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Abstract: In 2020, General Secretary Xi Jinping introduced the "dual carbon" imperative, encompassing the objectives of achieving a carbon peaking and carbon neutrality. This directive unequivocally signifies China's intent to shift its economic development paradigm towards a low-carbon trajectory. As agriculture is a substantial contributor to carbon emissions, the development of low-carbon agriculture has become a pivotal facet within the broader pursuit of a low-carbon economy. This study focuses its research on Liangshan Prefecture, located within the province of Sichuan, China. The research constructs a comprehensive evaluation index system for low-carbon agricultural development level in Liangshan Prefecture of Sichuan Province, which includes four first-level indicators of agricultural carbon emissions, agricultural carbon sink level, resource element input, and low-carbon agricultural economy, and twelve second-level indicators which are determined through the utilization of the entropy weight method. Based on the index data of Liangshan Prefecture in Sichuan Province from 2010 to 2019, the comprehensive score of low-carbon agricultural development level gradually increased from 0.22 in 2010 to 0.76 in 2019, indicating that the low-carbon agricultural development level of Liangshan Prefecture in 2019 entered the formative stages of a relatively high level. In order to further explore the model to promote the development level of low-carbon agriculture, this paper focus on the new model of agricultural and tourism integration, and employs economic indicators based on the entropy weight method that facilitate an evaluation of the prevailing state of tourism development within Liangshan Prefecture. Subsequent to this evaluation, the coupling coordination model reveals a noteworthy transformation in the integrated development level of low-carbon agriculture and tourism in Liangshan Prefecture during the period of 2010 to 2019. This transformation is characterized by an evolution from mild imbalance fluctuation to primary coordination stage. Importantly, there remains substantial potential for further enhancement in the future. Therefore, in light of these findings, the author proffers pertinent recommendations concerning the integrated development of low-carbon agriculture and tourism in the future from three aspects: harnessing inherent comprehensive capabilities, amplifying supportive measures, and expanding the reach of public awareness and engagement.

Keywords: low-carbon agriculture; agricultural tourism integration; entropy weight law; coupled coordination model

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1. Introduction

"To revive the nation, the countryside must be revitalized" The report of the 19th National Congress of the Communist Party of China in 2017 officially proposed the rural revitalization strategy, which is a new engine for rural construction and development in the new era, and by the end of 2020, China's poverty alleviation has achieved an important milestone. In 2021, the central government's "No. 1 Document" clearly pointed out that it is necessary to gradually achieve the goal of gradually achieving the goal of supporting poverty alleviation to comprehensively promoting the smooth transition of rural revitalization. This means that China will continue to work on rural revitalization to ensure that the achievements of poverty alleviation are consolidated and sustainable development[1][2]. Impoverished regions constitute a significant component of the extensive rural landscape. However, compared with other rural areas, these impoverished regions are characterized by a low level of productivity development, inadequate rural infrastructure, compounded material and spiritual poverty, limited access to natural resources, and underdeveloped government-led social management. Consequently, the progress in the rural revitalization process has been notably sluggish which stands as pivotal and challenging areas in the comprehensive execution of the rural revitalization strategy. The revitalization and advancement of these regions have consistently remained a prominent subject of both academic discourse and practical considerations.

The introduction of the "dual carbon" goal in 2020 underscores China's unwavering commitment to addressing climate change globally. It is dedicated to actively promoting carbon emission reduction and contributing to the global carbon emission reduction goal [3][4]. According to the environmental report of the United Nations Intergovernmental Panel on Climate Change (IPCC), agricultural carbon emissions are second only to the thermal power industry, ranking second in the global carbon emission industry, and the total carbon emissions of agriculture have long accounted for about 17% of global total greenhouse gas emissions, and have become one of the most serious sources of carbon emissions[5]. As China's grain production continues to rise and farmers' income growth decelerates,, the utilization of "high-carbon" crude agricultural production methods that heavily rely on production factor inputs are increasingly unsuitable for the healthy and sustainable development of agriculture. As a result, reducing agricultural carbon emissions and developing low-carbon agriculture have become widely discussed topics in all walks of life. In this context, this paper will discuss the new low-carbon agricultural development model for rural revitalization in Liangshan Prefecture, Sichuan Province based on the new background of "low-carbon economy + rural revitalization".

2. The development status of low-carbon agriculture and tourism in Liangshan Prefecture

In this paper, the entropy weight method was used to evaluate the development status of low-carbon agriculture and tourism in Liangshan Prefecture.

2.1 Steps of Entropy Weight Method Model Construction

(1) Standardized Processing of Raw Data

Standardized treatment mainly includes two aspects: dimensionless treatment and forward treatment [6]. In principle, depending on the meaning of the indicators, the units of the raw data we collate tend to be different. Therefore, in order to ensure that the analysis results are not influenced by the use of units, the author employ the range standardization method to process the data dimensionlessly. At the same time, to prevent the occurrence of meaningless statistical results, the author add 0.01 to the dimensionless data of each indicator. The dimensionless treatment formula for forward processing is:

$$x_{ij}^{'} = \frac{x_{ij} - x_{\min}}{x_{\max} - x_{\min}} + 0.01, \left(i = 1, \cdots m; \mathrm{j} = 1, \cdots n\right) \tag{1}$$

$$x_{ij}^{'} = \frac{x_{\max} \text{-} x_{ij}}{x_{\max} - x_{\min}} + 0.01, \left(i = 1, \cdots m; \mathrm{j} = 1, \cdots n\right) \tag{2}$$

Among them, Equation (1) is dimensionless treatment of metric data for positive attributes; Equation (2) is a dimensionless treatment of metric data for negative attributes. x_{mn} represents the original data value of the n th index in the m year, and $x_{\max}$ and $x_{\min}$ represent the maximum and minimum values of the indicator, respectively.

(2) Determination of Indicator Weights

After dimensionless processing of the original data, the entropy weight method is used to determine the index weight. Its calculation formula is:

$$P_{ij} = \frac{x_{ij}^{'}}{\sum_{i-1}^{m} x_{ij}^{'}} \tag{3}$$

$$E_j = -K \sum_{i=1}^{m} P_{ij} \ln(\mathrm{x}_{ij}^{'}) \tag{4}$$

$$d_j = 1 - E_j \tag{5}$$

$$w_j = \frac{d_j}{\sum_{j-1}^{n} d_j} \tag{6}$$

where K is a constant, related to the number of indicators, $K = \frac{1}{\ln(\mathrm{n})}$, P_{ij}、E_j、d_j、w_j represent the proportion of the j index of the i object, the entropy value, difference coefficient and weight of the j index, respectively.

2.2 Development status of low-carbon agriculture in Liangshan Prefecture

(1) Construction of Evaluation Index System

The most important thing in the construction of the evaluation index system is the selection of evaluation indicators. For the evaluation of the development status of low-carbon agriculture,

based on summarizing the existing research[7][8], the index system selected in this paper is mainly divided into the following four parts: agricultural carbon emissions; the level of carbon sinks in agriculture; resource element input; Economic indicators of low-carbon agriculture. Based on the principles of objectivity, scientific department, feasibility and measurability of the index system, the evaluation indicators of low-carbon agricultural development in Liangshan Prefecture selected in this paper are shown in Table 1[9].

Table 1 Evaluation Indicators of Low-carbon Agricultural Development in Liangshan Prefecture

The first layer of indicators	The second layer of indicators	Indicator units	Metric data source
Carbon emissions from agriculture (A1)	Consumption of Chemical Fertilizers (B1)	100 million tons	Direct access to statistical yearbooks
	Consumption of pesticide (B2)	100 million tons	Cultivated land area in Liangshan Prefecture / cultivated land area in Sichuan Province* pesticide use in Sichuan Province
	Consumption of agricultural diesel (B3)	100 million tons	Cultivated land area in Liangshan Prefecture / Cultivated land area in Sichuan Province * Agricultural diesel use in Sichuan Province
	Consumption of agricultural film (B4)	100 million tons	Cultivated land area in Liangshan Prefecture / Cultivated land area in Sichuan Province * Agricultural film usage in Sichuan Province
Agricultural carbon sink level (A2)	Forest cover (B5)	%	Statistical bulletins are obtained directly
	Arable land (B6)	10000 hectares	Direct access to statistical yearbooks
Resource Element Input(A3)	Number of employees in the primary sector (B7)	10000 people	Direct access to statistical yearbooks
	Total power of agricultural machinery (B8)	10000 kw	Direct access to statistical yearbooks
	Effective irrigation area (B9)	1000 hectares	Direct access to statistical yearbooks
Low Carbon Agricultural Economic Index (A4)	Agricultural GDP (B10)	100 million yuan	Direct access to statistical yearbooks
	Agricultural GDP as a percentage of total GDP (B11)	%	Agricultural GDP/Gross GDP
	Per capita disposable income of rural residents (B12)	yuan	Direct access to statistical yearbooks

Note: Organize and summarize by myself

(2) Evaluation of Low-carbon Agricultural Development Level in Liangshan Prefecture

Based on the formula of the entropy weight method and considering the practical temporal

context and data availability, the author has chosen the index data from 2010 to 2019 to evaluate the development level of low-carbon agriculture in Liangshan Prefecture. According to the China Statistical Yearbook, Sichuan Statistical Yearbook, Liangshan Prefecture Statistical Yearbook and Liangshan Prefecture Statistical Bulletin, the raw data the author have compiled are shown in Table 2. Then, according to the evaluation steps of the entropy weight method, we can finally obtain the weights of each index of low-carbon agriculture in Liangshan Prefecture, as shown in Table 3.

Table 2 Evaluation Data of Low-carbon Agricultural development level in Liangshan Prefecture from 2010 to 2019

Year	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	B11	B12
2010	13.83	0.54	3.69	1.00	42.38	35.13	147.02	212.05	127.82	282.79	36.06	4565.00
2011	14.23	0.55	3.84	1.08	42.38	35.24	150.82	242.27	134.54	323.74	32.37	5538.00
2012	14.64	0.54	4.07	1.13	43	35.45	185.60	273.80	154.97	362.80	32.32	6419.00
2013	13.32	0.53	4.12	1.14	43	35.58	182.74	294.19	158.88	384.36	31.65	7359.00
2014	13.61	0.31	2.47	0.69	43	35.71	183.94	310.52	160.25	409.74	31.18	8264.00
2015	13.68	0.51	4.04	1.14	43	58.05	188.26	327.98	164.15	447.48	34.03	9422.00
2016	13.80	0.50	4.03	1.14	43	57.87	192.13	339.70	167.66	482.94	34.40	10368.00
2017	13.73	0.48	4.02	1.13	43	57.90	191.15	351.79	170.95	513.02	34.64	11415.00
2018	13.69	0.44	4.04	1.04	43	57.95	196.32	353.35	186.43	535.81	34.42	12548.00
2019	12.93	0.51	5.21	1.37	47.12	57.95	197.28	360.43	187.48	600.23	35.94	13908.00

Table 3 Weights of Indicators at All Levels of Low-carbon Agricultural Development Level in Liangshan Prefecture From 2010 to 2019

The first layer of indicators	First-level metric weights	The second layer of indicators	Second-level metric weights	Comprehensive weighting of secondary indicators
A1	0.334621658	B1	0.231091602	0.077328255
		B2	0.279502165	0.093527478
		B3	0.240527144	0.080485592
		B4	0.248879089	0.083280334
A2	0.155841973	B5	0.381553881	0.059462109
		B6	0.618446119	0.096379863
A3	0.265834145	B7	0.347022744	0.092250495
		B8	0.334399718	0.088894863
		B9	0.318577538	0.084688787
A4	0.243702224	B10	0.326757765	0.079631594
		B11	0.343832649	0.083792781
		B12	0.329409586	0.080277849

After obtaining the weights w of the indicators at all levels(Table 3), the evaluation value of the development level of low-carbon agriculture in Liangshan Prefecture from 2010 to 2019 can be obtained according to the calculation formula $U_i=\sum_{j=1}^{n} w_j x_{ij}$ of the comprehensive evaluation function, as shown in Table 4.

Based on the existing research data on the development level of low-carbon agriculture, the author recognize that the evaluation criteria of low-carbon agricultural development level are shown in Table 5.

Table 4 Evaluation Values of Low-carbon Agricultural Development Level in Liangshan Prefecture From 2010 to 2019

Year	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Evaluation value of low-carbon agricultural development level(U1)	0.22	0.18	0.29	0.36	0.56	0.57	0.61	0.65	0.72	0.76

Table 5 Evaluation and Grading Standards for Low-carbon Agricultural Development Level

Comprehensive score	The level of low-carbon agricultural development	Corresponding phase
U<0.4	Low	Initial phase
0.4 <=U<0.6	Medium	Stages of development
0.6<=U<0.8	High	Formative stage
U≥0.8	Higher	Maturity stage

Based on Table 4 and Table 5, we can find:

Before 2013, the comprehensive evaluation score of low-carbon agricultural development level in Liangshan Prefecture was less than 0.4, indicating that the low-carbon agricultural development level of Liangshan Prefecture was in its infancy at this stage.

From 2014 to 2019, the comprehensive evaluation score of low-carbon agricultural development level in Liangshan Prefecture increased from 0.56 to 0.76, which fully indicates that the low-carbon agricultural development level of Liangshan Prefecture has shown a rising trend and entered the formation stage from the development stage.

2.3 Tourism development level in Liangshan Prefecture

The indicators selected in this paper to evaluate the tourism development level of Liangshan Prefecture are: the number of domestic tourists received (L1), the number of international tourists received (L2), the number of star-rated hotels (L3), the total tourism revenue (L4) and the proportion of total tourism revenue to GDP (L5). Based on the relevant statistical yearbooks, the author also selected data from 2010 to 2019 for analysis, as shown in Table 6. According to the entropy weight method, we can derive the weights of various evaluation indicators of tourism development level in Liangshan Prefecture and the evaluation values of development level over the years are shown in Table 7 and Table 8.

Table 6 Original Data of Tourism Development Level Evaluation Indicators in Liangshan Prefecture From 2010 to 2019

Year	L1(10,000 visitors)	L2(10,000 visitors)	L3(pcs)	L4(100 million yuan)	L5(%)
2010	13.83	0.54	3.69	1.00	42.38
2011	14.23	0.55	3.84	1.08	42.38
2012	14.64	0.54	4.07	1.13	43.00
2013	13.32	0.53	4.12	1.14	43.00
2014	13.61	0.31	2.47	0.69	43.00
2015	13.68	0.51	4.04	1.14	43.00
2016	13.80	0.50	4.03	1.14	43.00
2017	13.73	0.48	4.02	1.13	43.00

2018	13.69	0.44	4.04	1.04	43.00
2019	12.93	0.51	5.21	1.37	47.12

Note: In the process of data collection, there are individual data missing, in order not to affect the subsequent analysis, we have supplemented the data, and the resulting error of the analysis results is negligible.

Table 7 Weight of Indicators of Tourism Development Level in Liangshan Prefecture From 2010 to 2019

	L1	L2	L3	L4	L5
w	0.19	0.27	0.21	0.22	0.11

Table 8 Evaluation Value of Tourism Development Level in Liangshan Prefecture from 2010 to 2019

Year	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Evaluation value of tourism development level(U2)	0.57	0.66	0.73	0.59	0.10	0.60	0.60	0.56	0.49	0.78

3. New Model of Low-carbon Agricultural Development: Coordinated Development of Agriculture and Tourism

The coordinated development of agriculture and tourism can also be called the integrated development of agriculture and tourism, which is a new model for promoting rural economic development under the strategy of rural revitalization.[10-12] In recent years, with the development of society, the life pressure of urban residents has become more and more stressful, and people's desire to escape this high-pressure lifestyle for a short time has become stronger, which has derived a series of "back to basics" tourism methods, such as farmhouses, picking gardens and so on[13]. Liangshan Prefecture in Sichuan Province, as a typical area of deep poverty, has become the only way to explore a new model of rural economic development. As a hidden paradise in Sichuan, Liangshan Prefecture is the largest Yi nationality settlement in China, with magnificent natural scenery, unique ethnic customs and long history and culture, which make Liangshan full of infinite charm. Therefore, the new model of integrated development of agriculture and tourism is a new direction for Liangshan Prefecture to promote the low-carbon agricultural economy in Liangshan Prefecture in the future.

3.1 Construction of Coupling Coordination Model

The coupling coordination model is based on the coupling coordination degree to measure the interdependence between evaluation systems, the higher the coupling coordination, the higher the dependence between the two, and vice versa, the lower . Therefore, this paper opts for the coupling coordination model for the research on the integrated development status of low-carbon agriculture and tourism in Liangshan Prefecture.

In the process of constructing the coupling coordination model, the first step is to construct a comprehensive evaluation function, but based on the current situation of low-carbon agriculture development level and tourism development status in this paper, the author choose to skip the construction of the comprehensive evaluation function of low-carbon agriculture

and tourism, and directly enter the industrial coupling degree calculation step, the formula of coupling degree is:

$$C = \sqrt{\frac{U_1 U_2}{(U_1 + U_2)^2}} \tag{7}$$

The magnitude of the C value reflects the coupling degree of low-carbon agriculture and tourism in Liangshan Prefecture, and its value range is [0,1], the larger the value, the better the coupling degree. However, the degree of coupling does not reflect the degree of coordinated development between the two factors. Therefore, it becomes imperative to calculate the coupling coordination degree value to analyze the degree of coordinated development between the two. The coupling coordination is calculated as follows:

$$D = \sqrt{T \times C} = \sqrt{(\alpha U_1 + \beta U_2) \times C} \tag{8}$$

Among the formula above, D represents the coupling and coordination degree between low-carbon agriculture and tourism; T represents the comprehensive evaluation index of the fusion system. Under normal circumstances, the value range of D is [0,1], and the larger the value, the higher the degree of coordination. Based on the existing literature, the author believe that the classification criteria for coordinated development levels are shown in Table 9.

Table 9 Harmonized Classification Criteria for Development Levels

Coupling coordination	Hierarchical	Coupling coordination	Hierarchical
0.00—0.09	Extreme dysregulation	0.50—0.59	Barely coordinated
0.10—0.19	Severe dysregulation	0.60—0.69	Junior coordination
0.20—0.29	Moderate outrange	0.70—0.79	Intermediate coordination
0.30—0.39	Mild disorders	0.80—0.89	Well coordinated
0.40—0.49	On the verge of imbalance	0.90— 1.00	Quality coordination

3.2 Analysis of the Current Situation of Agricultural and Tourism Integration in Liangshan Prefecture

(1) The Model Outputs the Results

According to the measurement data of the development level of low-carbon agriculture and tourism in Liangshan Prefecture from 2010 to 2019, the evaluation results of the coupling and coordination degree of low-carbon agriculture and tourism in Liangshan Prefecture from 2010 to 2019 can be obtained by using relevant formulas. as shown in Table 10, and the change trend is illustrated in Figure 1.

Table 10 Evaluation Results of Coupling and Coordination of Low-carbon Agriculture and Tourism in Liangshan Prefecture from 2010 to 2019

	U1	U2	T	C	D	Coordination level
2010	0.22	0.57	0.39	0.45	0.42	On the verge of imbalance
2011	0.18	0.66	0.42	0.41	0.41	On the verge of imbalance
2012	0.29	0.73	0.51	0.45	0.48	On the verge of imbalance
2013	0.36	0.59	0.48	0.49	0.48	On the verge of imbalance
2014	0.56	0.10	0.33	0.36	0.35	Mild disorders

2015	0.57	0.60	0.58	0.50	0.54	Barely coordinated
2016	0.61	0.60	0.60	0.50	0.55	Barely coordinated
2017	0.65	0.56	0.61	0.50	0.55	Barely coordinated
2018	0.72	0.49	0.60	0.49	0.54	Barely coordinated
2019	0.76	0.78	0.77	0.50	0.62	Junior coordination

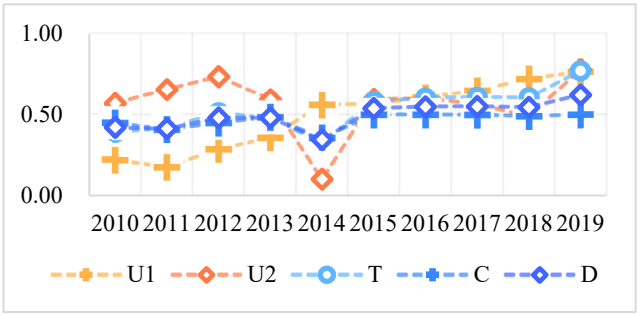

Figure 1 Changes in Coupling and Coordination between Low-carbon Agriculture and Tourism in Liangshan Prefecture from 2010 to 2019

(2) Analysis of the Results

From the perspective of T value, the integrated development of low-carbon agriculture and tourism shows a gradual growth trend after a short fluctuation on the whole. This indicates that the integration of low-carbon agriculture and tourism is gradually improving. However, it is important to note that there is still ample room for further growth at present.

From the C value, the coupling degree of low-carbon agriculture and tourism in Liangshan Prefecture from 2010 to 2019 was [0.36, 0.5]. This indicates a low level of coupling, with small fluctuations in magnitude. These findings strongly suggest that due to the influence of various factors, there are many problems in the integration of low-carbon agriculture and tourism. However, the overall trend in the coupling degree demonstrates significant potential for improvement, highlighting substantial room for further integration.

From the perspective of D value, the coordination degree of low-carbon agriculture and tourism in Liangzhou City was at [0.35, 0.62], which experienced a transition from a slight imbalance fluctuation to the primary coordination stage between 2010 and 2019. This shift signifies that with the proposal of strategic goals such as "poverty alleviation", "rural revitalization" and "low carbon", the level of integrated development of agriculture and tourism is getting higher and higher.

4. Conclusions

Under the background of rural revitalization strategy, poverty alleviation, "carbon peaking, carbon neutrality", green and sustainable development, this paper focuses on Liangshan Prefecture. Known as a hidden paradise in Sichuan, it is home to the largest Yi ethnic settlement in China, with its magnificent natural scenery, unique ethnic customs and long history and culture. By utilizing relevant data spanning from 2010 to 2019, this research

employs entropy weight method and coupling coordination model to quantitatively analyze the development status of low-carbon agriculture in Liangshan Prefecture and its integration with tourism. The analysis results are presented below:

First of all, in terms of the development status of low-carbon agriculture in Liangshan Prefecture, it is currently in the formative stage of low-carbon agricultural development;

Secondly, through the analysis of the integration and coordination degree of low-carbon agriculture and tourism, it can be concluded that there is an interdependent and mutually influencing relationship between low-carbon agriculture and tourism.

Finally, in terms of the integration of low-carbon agriculture and tourism, both sectors are currently in the stage of exploration and growth. However, the current level of integration between the two is in the initial coordination stage, indicating that there is still a long way to go to achieve the high-speed integration between low-carbon agriculture and tourism.

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