

# Analysis of Spatiotemporal Changes in Integrated Land Productivity in Chongqing from 1997 to 2023

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**Abstract** [Objectives] Integrated land productivity can reflect the comprehensive utilization of land and the overall output level, which is the most basic and commonly used indicator in assessing land use efficiency. This thesis aims to analyze the spatial and temporal changes of integrated land productivity in Chongqing from 1997 to 2023 in order to assess its land use efficiency. [Methods] This study measured the integrated land productivity of Chongqing Municipality, the only municipality directly under the central government in the western part of China, over the past 26 years (1997–2023) through relevant surveys and statistical data, and analyzed in depth the integrated land productivity of the 38 districts and counties under the jurisdiction of Chongqing, as well as the functional sub-districts of the "one district and two clusters" and the "one district and two clusters" in Chongqing. It also analyzes the characteristics of spatial and temporal differences in land productivity in 38 districts and counties under the jurisdiction of Chongqing and "one district and two clusters". [Results] The results of the study show that over the past 26 years, the integrated land productivity of Chongqing has shown an annual growth trend, and the integrated land productivity of the 38 districts and counties and the functional subregions of "one district and two clusters" has also increased significantly, but the average annual growth rate of the integrated land productivity varies among different regions. From the perspective of spatial differences, there are significant differences in land productivity among the 38 districts and counties of Chongqing and the functional subregions of "one district and two clusters", which are mainly due to the different natural conditions, economic development levels and functional positioning of each region. [Conclusions] Based on the results of the study and the actual situation of Chongqing, this paper puts forward the leading measures to improve the integrated land productivity, with a view to providing a reference basis for Chongqing to improve the efficiency of land use and promote the sustainable use of land resources.

**Key words** Integrated land productivity, Spatial and temporal changes, Chongqing

## 1 Introduction

Land productivity, as a key indicator of production or output value per unit of land area, not only intuitively demonstrates the technical level of land use, but also profoundly reflects its economic effectiveness<sup>[1]</sup>. Among the many dimensions of assessing land productivity, Integrated Land Productivity (ILP) is particularly compelling, which comprehensively reflects the comprehensive utilization efficiency and overall output level of land<sup>[1]</sup>. With the continuous growth of China's population base and the accelerated pace of urbanization, the contradiction between land resources and population growth has become more and more acute, therefore, improving the integrated land productivity has become a core strategic direction to ensure the sustainable use of land resources.

Chongqing, as a municipality directly under the central government in the western region, has undergone radical changes in its urban landscape and economic pattern since its direct administration in 1997. The rapid advance of urbanization and the booming economy have brought about a surge in population, and at the

same time, the demand and pressure for land use have been increasing day by day. However, it is worth noting that there is a lack of systematic research on the spatial and temporal changes of integrated land productivity in Chongqing, which undoubtedly restricts our ability to formulate regional integrated land productivity enhancement strategies according to local conditions<sup>[2]</sup>. In view of this, the author aims to analyze the spatial and temporal characteristics of the integrated land productivity in Chongqing over the past 26 years (*i. e.*, 1997–2023) since the administration of Chongqing in 1997, based on detailed survey data and statistics, and to conduct a detailed study on the spatial and spatial differences in the integrated land productivity of the various regions of Chongqing, taking into account the functional division of "one region and two clusters". The spatial variation of land productivity in each region of Chongqing is also examined in detail. Through this study, we expect to provide a scientific basis for the formulation of the new round of land use master plan in Chongqing, thus promote the improvement of land use efficiency and ensure the sustainable utilization of land resources.

## 2 General information about the study area

Chongqing, located in southwest China, is a vast area with a total area of 82 400 km<sup>2</sup>, spanning from 105°11' to 110°11' east longitude and 28°10' to 32°13' north latitude. The region's topography is intricate, dominated by mountains and hills, constituting

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its unique mountainous urban landscape. Climatically, Chongqing has a humid subtropical monsoon climate, with average annual temperatures stabilizing between 16 and 18 °C and average annual precipitation between 1 000 and 1 350 mm, which brings abundant water resources and suitable climatic conditions to the land.

As the only municipality directly under the central government in western China, Chongqing, with 38 districts and counties under its jurisdiction, is an important hub for the economic development of the upper reaches of the Yangtze River, as well as a center for the convergence of multiple elements such as politics, economy and culture. In the 2020 Chongqing Municipal Government Work Report, the strategy of promoting the coordinated development of "one district and two clusters" was proposed, aiming to further optimize the functional layout of the city and promote balanced regional development.

Among them, "one district" refers to Chongqing's main city metropolitan area, including 9 districts in the central city (Yuzhong District, Dadukou District, Jiangbei District, Shapingba District, Jiulongpo District, Nanan District, Beibei District, Yubei District, Banan District) and 12 districts in the main city's new area (Jiangjin District, Hechuan District, Yongchuan District, Nanchuan District, Qijiang District, Tongnan District, Tongliang District, Dazu District, Rongchang District, Daju District, Tongliang District, Tongliang District). Dazu District, Rongchang District, Bishan District, Fuling District, Changshou District). The "two clusters" refer to the town clusters of the Three Gorges Reservoir Area in northeast Chongqing and the Wuling Mountain Area in southeast Chongqing, with the former covering 11 districts and counties (Wanzhou District, Liangping District, Chengkou County, Fengdu County, Dianjiang County, Zhong County, Kaizhou District, Yunyang County, Fengjie County, Wushan County, Wuxi County), and the latter containing 6 districts and counties (Qianjiang District, Shizhu County, Xiushan County, Youyang County, Pengshui County, and Wulong District).

This paper will analyze the spatial and temporal changes of the integrated land productivity in Chongqing based on the division of urban functional areas, in order to provide strong data support and theoretical reference for urban planning and regional development.

### 3 Research data and method

**3.1 Data sources** The data needed for this study include the total land area data and GDP data of 38 districts and counties in Chongqing from 1997 to 2023. All of the above data come from the Chongqing Statistical Yearbook and the statistical bulletins of each district and county. Among them, the total land area adopts the existing land survey data, and the total land area of Chongqing is 82 400 km<sup>2</sup>. When counting and analyzing the economic data, all the GDP data we mentioned are calculated based on the price level of the current year. This practice ensures the timeliness and accuracy of the data, enabling us to have a more intuitive understanding of the economic growth and

changes in each year.

**3.2 Research Methods** Integrated Land Productivity (ILP) is an important indicator reflecting the comprehensive utilization of land and the overall level of output, which is generally expressed as the ratio of gross domestic product (GDP) to the total land area<sup>[4]</sup>. Its calculation formula is as follows:

$$ILP = \frac{GDP}{TLA} \quad (1)$$

where *ILP* is the integrated land productivity, *GDP* is the Gross Domestic Product, *TLA* is the total land area.

When analyzing the time change of land productivity, we need to introduce an important indicator, namely "Average annual growth rate"<sup>[5]</sup>. This indicator can help us measure the average annual growth rate of land productivity, more accurately understand the growth rate of land productivity in Chongqing in different periods, and further analyze the trend of land use efficiency. Its calculation formula is:

$$AAGR_i = \left( n \sqrt[n]{\frac{ILP_i}{ILP_0}} - 1 \right) \times 100\%; \quad (i = 1, 2, 3, \dots, n) \quad (2)$$

where *AAGR<sub>i</sub>* denotes the average annual increase in the combined land productivity; *ILP<sub>0</sub>* denotes the combined land productivity in the initial year, *ILP<sub>i</sub>* denotes the combined land productivity in the final year, and *n* denotes the number of intervening years between the initial and final years.

## 4 Results analysis

**4.1 Measurement of integrated land productivity** Using the research methodology, the integrated land productivity of each region and county in Chongqing was calculated from 1997 to 2023 (Table 1). At the same time, for the strategy of "one region and two clusters", the integrated land productivity of each region was also calculated. Based on these data, the spatial and temporal evolution of integrated land productivity in Chongqing over the past 26 years was systematically analyzed, providing important support for land use efficiency and production potential, and for the formulation of land policies and economic development strategies.

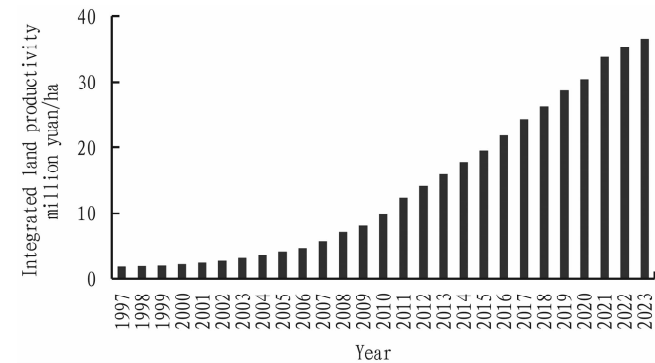
**4.2 Analysis of time change** On the basis of measuring the integrated land productivity of Chongqing in the past 26 years, the land change characteristics from 1997 to 2023 are analyzed from the time dimension. As shown in Fig. 1, in the past 26 years, the integrated land productivity of Chongqing has shown yearly growth, from 18 500 yuan/ha in 1997 to 365 800 yuan/ha in 2023, an increase of nearly 20 times. Since becoming a directly under the central government in 1997, Chongqing's economy has flourished; with the country's Western Development Strategy beginning in 2001, Chongqing's economic growth has been even more rapid. Since then, at five-year intervals, Chongqing's integrated land productivity has grown exponentially, with an average annual increase of 12.16%. This growth is a reflection of the rapid economic development of Chongqing over the past 26 years.

**Table 1** Integrated land productivity of various districts and counties and functional areas in Chongqing from 1997 to 2023 10<sup>5</sup> yuan/ha

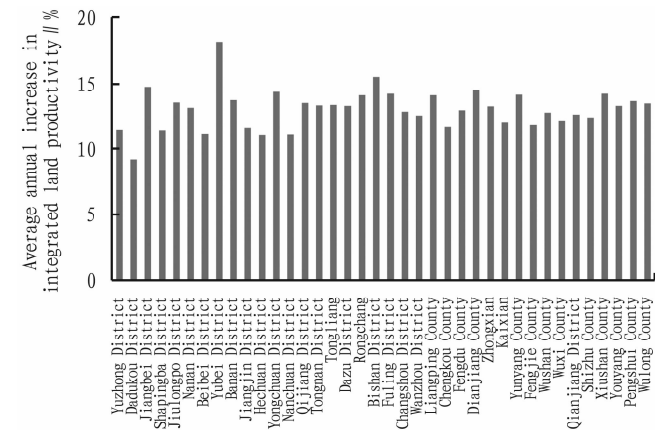
Administrative district	1997	2001	2005	2010	2015	2020	2023	Average annual increase// %
Chongqing	1.85	2.44	4.18	9.79	19.47	30.39	36.58	12.16
Yuzhong District	417.38	566.41	1 093.91	2 513.76	4 122.95	5 845.42	7 019.36	11.47
Dadukou District	35.63	46.01	74.22	188.53	155.32	259.12	352.72	9.22
Jiangbei District	22.04	26.29	62.49	182.89	311.28	600.27	789.86	14.76
Shapingba District	17.19	24.01	42.62	109.54	180.38	256.04	287.73	11.45
Jiulongpo District	15.87	26.85	61.04	133.09	232.31	354.90	432.19	13.55
Nanan District	15.23	22.05	41.43	125.89	258.88	309.89	375.41	13.12
Beibei District	6.72	7.63	10.62	30.78	57.00	84.29	103.79	11.10
Yubei District	2.20	3.35	10.01	39.51	82.19	138.40	168.22	18.16
Banan District	2.11	2.89	5.51	16.87	31.14	47.42	59.95	13.74
Jiangjin District	2.49	2.77	4.14	9.41	18.81	34.48	43.56	11.63
Hechuan District	2.96	3.65	5.57	10.43	20.32	41.49	44.81	11.01
Yongchuan District	2.47	4.00	7.19	19.07	36.19	64.24	81.31	14.39
Nanchuan District	1.10	1.34	2.39	5.52	7.16	13.86	16.67	11.03
Qijiang District	1.41	1.94	3.63	7.88	14.36	25.98	37.85	13.50
Tongnan District	1.46	2.24	3.85	7.38	16.77	30.02	37.63	13.32
Tongliang	2.24	3.33	5.39	11.18	22.98	49.33	58.24	13.35
Dazu District	2.37	3.37	5.36	12.89	24.32	48.78	60.61	13.27
Rongchang	2.62	3.14	5.43	14.88	30.63	65.90	80.75	14.09
Bishan District	2.52	3.83	7.22	16.69	41.64	81.65	107.43	15.52
Fuling District	1.74	2.60	4.59	14.75	27.60	41.58	55.28	14.23
Changshou District	2.91	3.89	6.11	16.06	30.20	51.44	67.18	12.84
Wanzhou District	1.59	2.12	3.86	14.47	23.96	28.08	34.12	12.52
Liangping County	1.02	1.39	2.58	5.88	12.82	26.07	31.42	14.10
Chengkou County	0.11	0.15	0.31	0.76	1.29	1.68	2.02	11.70
Fengdu County	0.59	0.79	1.27	2.66	5.17	11.56	13.98	12.93
Dianjiang County	1.10	1.91	3.35	7.50	15.80	29.34	37.48	14.53
Zhongxian	0.97	1.14	2.01	5.00	10.17	19.55	24.68	13.25
Kaixian	0.90	1.05	1.78	3.77	8.23	13.51	17.33	12.05
Yunyang County	0.53	0.67	1.20	2.35	5.15	12.68	16.55	14.13
Fengjie County	0.55	0.59	1.10	2.51	4.83	7.89	10.20	11.85
Wushan County	0.36	0.46	0.69	1.70	3.03	6.38	8.23	12.76
Wuxi County	0.16	0.22	0.37	0.93	1.82	2.73	3.24	12.15
Qianjiang District	0.57	0.84	1.52	4.17	8.43	10.21	12.50	12.61
Shizhu County	0.36	0.44	0.84	2.15	4.29	5.68	7.50	12.39
Xiushan County	0.47	0.59	1.12	3.10	5.63	12.28	15.08	14.24
Youyang County	0.18	0.24	0.39	1.12	2.26	3.89	4.72	13.28
Pengshui County	0.28	0.38	0.75	1.70	2.97	6.28	7.81	13.65
Wulong County	0.35	0.55	1.03	2.50	4.55	7.76	9.43	13.47
Chongqing	1.85	2.44	4.18	9.79	19.47	30.39	36.58	12.16
Center City	8.63	11.98	24.12	65.73	116.92	179.59	220.32	13.27
Main City New Area	2.10	2.82	4.72	11.36	22.02	40.59	51.57	13.11
Three Gorges Reservoir Area in northeast Chongqing	0.67	0.87	1.53	4.01	7.66	12.81	16.02	12.97
Wuling Mountain Area in southeast Chongqing	0.34	0.46	0.85	2.21	4.21	7.00	8.66	13.30

**NOTE** Due to space limitations, only some representative years of combined land productivity are shown here.

The average annual increase in the integrated land productivity of Chongqing districts and counties is shown in Fig. 2. The change trend of the integrated land productivity of Chongqing's 38 districts and counties in 1997–2023 is basically synchronized with that of Chongqing as a whole, showing a yearly increase. Specifically, over the past 26 years, Yubei District, Bishan District and Jiangbei District are the districts and counties with the largest increase in integrated land productivity, with their average annual increases of 18.16%, 15.52% and 14.76%, respectively. At the same time, there are also some districts and counties with relatively small increases in integrated land productivity, including Dadukou District with an average annual increase of 9.22%, and Hechuan and Nanchuan Districts with average annual increases of 11.01% and 11.03%, respectively, and the utilization and management of land resources in these districts and counties need to be further strengthened in order to improve integrated land productivity. It is worth noting that, except for Dadukou District, the average annual increase in the integrated land productivity of all other districts and counties in Chongqing has remained above 10%, which indicates that the efficiency of land resource utilization in all districts and counties in Chongqing is relatively high overall.



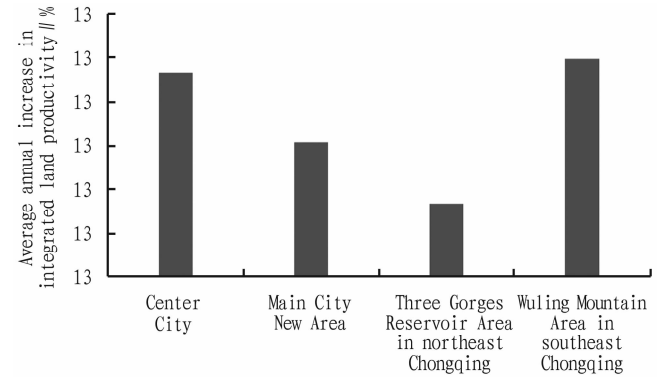
**Fig. 1** The change of integrated land productivity of Chongqing from 1997 to 2023



**Fig. 2** Comparison of the average annual growth rate of integrated land productivity in 38 Districts and Counties of Chongqing from 1997 to 2023

The average annual increase of land productivity in each region of Chongqing "one district and two clusters" is shown in Fig. 3, which reveals that the average annual increase of Wuling

Mountain District in southeast Chongqing is the highest in the past 26 years, reaching 13.3; the central urban area is in the second place, with 13.27; the average annual increase of land productivity in the main new area is 13.11; and the average annual increase of Three Gorges Reservoir Area in northeast Chongqing is the lowest, with 12.97. 13.11, ranking the third highest; the Three Gorges Reservoir Area in northeast Chongqing has the lowest average annual increase of 12.97.

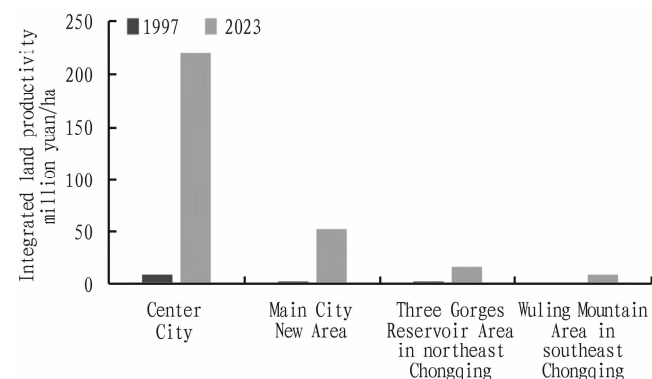


**Fig. 3** Comparison of the average annual growth rate of integrated land productivity in Chongqing's "One District, Two Groups" from 1997 to 2023

**4.3 Analysis of spatial difference patterns** Chongqing under the jurisdiction of 38 districts and counties, due to the differences in topography, climate and other natural conditions as well as the different levels of economic development and functional zoning of each district and county, there are obvious spatial differences in the integrated land productivity in each district and county. Chongqing main city metropolitan area (including the central city and the main city new area), to enhance the comprehensive carrying capacity of the central city, improve the professional service functions of important node cities<sup>[3]</sup>; northeast of the Three Gorges Reservoir Townships, highlighting the characteristics of the "reservoir area" "mountainous area", pay more attention to the integration and synergy of ecological and economic factors, and build a new township. The town cluster in the Three Gorges Reservoir Area in northeast Chongqing highlights the characteristics of "mountainous area" and "mountainous area", pays more attention to the integration and synergy of ecological and economic elements, and builds an advanced demonstration area of ecological priority and green development in the Three Gorges Reservoir Area of the Yangtze River Economic Belt<sup>[3]</sup>. The town cluster in Wuling Mountain District in southeast Chongqing highlights the characteristics of "landscape" and "folklore", promotes the development of ecological recreation, cultural tourism, processing of special resources and other industries, and builds a demonstration area for the integrated development of culture and tourism in the Wuling Mountain District. In response to the different characteristics and needs of each region, Chongqing has formulated different development strategies and plans to promote the economic development of each region and increase the comprehensive productivity of land.

As shown in Fig. 4, in terms of the spatial variability of integrated land productivity in sub-regions, when Chongqing was di-

rectly governed in 1997, the integrated land productivity of the nine central urban areas was 86 200 yuan per hectare, the integrated land productivity of the twelve new districts of the main city was 21 000 yuan per hectare, and that of the eleven districts and counties of the Three Gorges Reservoir Area in northeastern Chongqing was 0.67 million yuan per hectare, whereas that of the Wuling Mountains Area in southeastern Chongqing 6 districts and counties in the Wuling Mountain area in southeast Chongqing was only 0.34 million yuan/ha. After nearly 26 years of development, by 2023, the integrated land productivity of Chongqing's central city has reached as high as 2 203 200 yuan/ha, that of the main city's new districts is 515 700 yuan/ha, that of the Three Gorges Reservoir Area in northeast Chongqing is 160 200 yuan/ha, and that of the Wuling Mountain Area in southeast Chongqing is only 86 600 yuan/ha. It can be seen that there are obvious spatial differences in integrated land productivity between different functional subregions in Chongqing. This difference is mainly due to the different natural conditions, economic development level and functional orientation of each region. The central urban area and the new areas of the main city have higher integrated land productivity due to the concentration of their economic activities and urban functions, while the Three Gorges Reservoir Area in northeast Chongqing and the Wuling Mountain Area in southeast Chongqing have relatively lower integrated land productivity due to the complex topography, the relative scarcity of resources, and the relative lag in economic development. In the future development, Chongqing should further optimize the development strategy of each region, give full play to the characteristics and advantages of each region, and improve the integrated land productivity. At the same time, it is also necessary to strengthen resource integration and synergistic development, promote balanced development among regions, and realize the efficient use of land resources.



**Fig.4 Comparison of integrated land productivity of Chongqing's "One District, Two Groups" in 1997 and 2023**

## 5 Conclusions and Suggestions

**5.1 Conclusions** (i) As the only municipality directly under the central government in the western part of China, Chongqing has experienced rapid economic development in the past 26 years, especially after the country began to implement the strategy of developing the western part of the country in 2001, Chongqing's level of economic development has gone up to a new level, which makes

Chongqing's comprehensive growth rate of land (1997 – 2023) also grows exponentially, and the efficiency of land use is increasingly improved.

(ii) Over the past 26 years, Chongqing's integrated land productivity has shown a yearly growth trend. The 38 districts and counties under the jurisdiction of Chongqing as well as the "one district and two clusters" regions have also shown yearly growth in integrated land productivity, but there are significant differences in the average annual growth rate of integrated land productivity among districts and counties and regions.

(iii) From the perspective of spatial differences, the integrated land productivity in Chongqing shows obvious differences. Especially between the main urban areas of Chongqing and the town clusters in the Three Gorges Reservoir Area in northeast Chongqing and the town clusters in the Wuling Mountain Area in southeast Chongqing, the gap in the integrated land productivity can even be tens of times, reflecting the significant differences in the land use efficiency of the different areas of Chongqing.

**5.2 Suggestions for countermeasures** Based on the above research results and combined with the actual situation of Chongqing, the countermeasures to enhance the integrated land productivity of Chongqing are suggested as follows:

First of all, Chongqing should scientifically prepare a new round of land space planning, and determine the land use mode and development direction according to the characteristics and advantages of each region. This can maximize the characteristics and advantages of each region and achieve rational allocation and optimal use of resources. Secondly, there is a need to integrate urban and rural development and regional coordinated development. By rationally planning the layout of urban and rural development, synergistic development of urban and rural economy, society and ecology will be promoted, and the utilization of land resources will be improved. At the same time, investment efforts and policy support should be increased to promote the balanced development of different functional subdivisions and the coordinated development of regional economies. Finally, it is necessary to strengthen the construction of ecological civilization and implement an ecological and environmentally friendly land use strategy. In the process of land use, it is necessary to focus on ecological protection and environmental friendliness, promote green development, reduce damage to the ecological environment, and protect the integrity and stability of the ecosystem. These initiatives will help improve the efficiency of land resource utilization in Chongqing and promote sustainable economic and social development.

Through the implementation of the above measures, the integrated land productivity in Chongqing can be further improved, the rational utilization and optimal allocation of resources can be achieved, and the sustainable development of the economy and society can be promoted.

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for the exploration of innovative teaching approaches and methodologies that seamlessly incorporate modern information technology to enhance the evolution and enhancement of the educational framework in higher education institutions. This, in turn, aims to enhance the quality and efficacy of personnel development.

**4.4 Implementation plan** (i) Teaching objective of Molecular Biology and Experiment and positioning analysis of the case library. The team members engage in discussions to elucidate the teaching mode and positioning strategy of the case library in alignment with local industry characteristics and talent demands, based on the teaching objectives of Molecular Biology and Experiment. (ii) Acquisition, organization, and evaluation of local characteristic teaching resources. A comprehensive survey, systematic collection, classification, and in-depth analysis of local teaching resources relevant to the Molecular Biology and Experiment course will offer substantial material support for the design and development of the characteristic case library. (iii) Development, strategic planning, and content analysis of the characteristic case library. By adhering to the course outline of Molecular Biology and Experiment, the effective integration of teaching materials and local teaching resources that reflect local teaching resource characteristics is explored to create a teaching case with regional attributes. (iv) Dissemination and management mechanism of the case library. The creation of a script and operational plan for the case library is essential for studying the sharing and management mechanisms, ensuring the efficient utilization and broad dissemination of the case library.

#### 4.5 Implementation effect, application and promotion value of the case

**4.5.1 Implementation effect.** After two years of meticulous development, a total of 44 Molecular Biology and Experimental teaching cases have been finalized, with four cases thoughtfully crafted for each section.

**4.5.2 Application and promotion value.** The establishment of the Molecular Biology and Experiment case library serves as a valuable reference for developing aquaculture professional teaching resource libraries. It offers scientific guidance and practical examples for creating similar resources in other courses. The teaching

resource library created will be accessible across the province and potentially nationwide, offering high-quality educational materials to various regions and educational institutions. Teachers within the course groups have not only familiarized themselves with the development principles of the resource library but have also implemented them during the construction phase of Molecular Biology and Experiment. This integration has enhanced the teaching proficiency of educators and the overall development of the professional teaching team.

## 5 Conclusions

The training of aquaculture students plays a crucial role in developing advanced aquaculture professionals with essential skills such as independent thinking, scientific decision-making, and clinical practice abilities. This training aligns with the objective of nurturing "high-level and applied" fishery talents in China. Case teaching, recognized as an effective teaching approach, is instrumental in achieving this objective. However, the development of a case library for the Molecular Biology and Experiment course is still in its early stages, lacking well-established samples for reference. This research endeavors to establish a case library for Molecular Biology and Experiment to offer new insights for creating similar cases. Nevertheless, it is acknowledged that there are areas for improvement in the current case library. Collaboration with additional universities and enterprises is anticipated to enhance the quality and practicality of Molecular Biology and Experiment teaching, thereby fostering the growth of exceptional high-level applied talents in the aquaculture sector in China.

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