Regional Evaluation on Sustainable Development of Agriculture in Tibet Based on Cluster Analysis

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Abstract To understand the spatial difference of agricultural sustainability in Tibet, this paper establishes a comprehensive evaluation model of agricultural sustainability to calculate the score of agricultural sustainability of 7 areas in 2013 in Tibet. By using cluster analysis, this paper conducts the regional evaluation of Tibet's agricultural sustainability. The results show that 7 cities' regional difference of agricultural sustainability was obvious in 2013, the agricultural sustainability index value was 0.4232 – 0.6937, and the value was in the order of Nyingchi > Lhasa > Shannan > Ali > Shigatse > Qamdo > Nagqu. According to the agricultural sustainable development level, Tibet can be divided into three regions: the first type is the area with the highest level of sustainable development of agriculture, including Nyingchi and Lhasa; the second type is the area with the average level of sustainable development of agriculture, including Shigatse and Shannan; the third type is the area with the low level of sustainable development of agriculture, including Qamdo, Ali and Nagqu.

Key words Cluster analysis, Level of sustainable development of agriculture, Regional evaluation, Tibet

1 Introduction

Tibet is the source of rivers and "ecological barrier" for China and South Asia, and the sustainable development of agriculture in Tibet directly or indirectly affects the national sustainable development process. Adopting effective way to measure and evaluate the level of sustainable development of agriculture in Tibet, is of practical significance to further promoting the sustainable development of agriculture in Tibet. At present, Chinese scholars have done a lot of researches about the evaluation of sustainable development of agriculture. At the national level, Zhou Hailin[1] studies the relationship between agricultural environmental changes and agricultural activities or agricultural policies, and builds the indicator system that reflects the sustainable development of agriculture. Liu Fengqin[2] builds a dynamic evaluation indicator system for sustainable development of agriculture, and also brings forward the steps of building this evaluation indicator system model. Xu Xianghua and Yang Guijuan[3] establish the indicator system for sustainable development of agriculture consisting of five criteria layers (environmental resources, agricultural economy, rural society, agricultural science and technology, external environment). At the regional level, scholars have used different methods to build the evaluation indicator system for sustainable development of agriculture from different aspects. From agricultural production, agricultural economy, rural society, agricultural resources and environment, Kang Cuixia *et al.*[4] establish the evaluation indicator system for the sustainable development of agriculture in Shijiazhuang City, and do empirical research. Cui Herui uses factor analysis and cluster analysis, and Sun Yanling *et al.* use analytic hierarchy process[5–6] to evaluate the sustainable development of agriculture in Hebei Province and Sichuan Province, respectively. Yuan Jiuhe and Qi Chunjie[7] use entropy method to evaluate the agricultural sustainability in Hunan Province. Shan Shiying, Dai Xiaochun and Zhou Chengzao use different indicators to build the evaluation indicator system for the sustainable development of agriculture in Shandong Province and Hubei Province, respectively[8–9]. Based on the existing domestic research literature on sustainable development of agriculture, it is found that there are few studies on the evaluation of Tibet's agricultural sustainability, and the regional evaluation is even rare. In view of this, this paper uses cluster analysis to evaluate the level of sustainable development of agriculture in different regions of Tibet, in order to understand development status and regional differences, and provide the basis for improving the level of sustainable development of agriculture in Tibet.

2 Overview of the study area

Tibet (78°25' – 99°06'E, 26°44' – 36°32'N) is a region on the Tibetan Plateau in Asia. It is the traditional homeland of the Tibetan people as well as some other ethnic groups such as Monpa, Qiang and Lhoba peoples and is now also inhabited by considerable numbers of Han Chinese and Hui people. Tibet is the highest region on Earth, with an average elevation of 4900 m. The highest elevation in Tibet is Mount Everest, earth's highest mountain rising 8848 m above sea level. It has a total area of 1228400 km^2, including 830000 km^2 of natural grassland (67% of the total land area), 63200 km^2 of forest land (5% of the total land area), 2200 km^2 of arable land (0.18% of the total land area). It has adequate lighting and low average annual temperature. The temperature difference is small, and it has distinct wet and dry seasons.

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The main crops include highland barley, wheat, fava bean and rape, basically one crop a year. At the end of 2013, Tibet had a population of 3120400; per capita GDP reached 22128 yuan; per capita net income of farmers and herdsmen was 6578 yuan.

3 Research methods

3.1 Establishment of evaluation indicator system and data sources Based on related research results[10-16], according to the actual situation of Tibet, we establish the evaluation indicator system for the level of sustainable development of agriculture in Tibet. The indicator system is divided into three layers. The first layer is goal layer, and it is a composite indicator integrating all layers of data, reflecting the comprehensive level of sustainable development of agriculture in Tibet. The second layer is criteria layer, mainly including 3 sub-system layers (agricultural production and economy; rural population and society; agricultural resources and environment). The third layer is indicator layer, with 16 indicators to reflect the development of 3 criteria layers, respectively (Table 1). The indicator property is positive, and it plays a role in promoting sustainable development of agriculture. It is the other way around for negative indicators. The relevant data are from *Tibet Statistical Yearbook* (2014).

Table 1 Evaluation indicator system for Tibet's agricultural sustainability

Goal	Criteria	Weight in the criteria layer	Indicators	Data sources or calculation methods	Weight in the indicator layer	Indicator property
Level of sustainable development of agriculture	Agricultural economy and production sub-system	0.5478	Per capita agricultural GDP//yuan	Agricultural GDP/rural population	0.2108	Positive
			Per capita share of food//kg	Food production/population	0.1471	Positive
			Per capita net income of farmers and herdsmen//yuan	*Tibet Statistical Yearbook* (2014)	0.2108	Positive
			Land productivity//yuan/ha	Agricultural GDP/crop acreage	0.1317	Positive
			Agricultural labor productivity // yuan/person	Rural GSP/number of rural labor	0.2060	Positive
			Proportion of non-agricultural industries in rural areas//%	Agricultural GDP/rural GSP	0.0937	Positive
	Agricultural resources and environment sub-system	0.2388	Irrigation rate//%	*Tibet Statistical Yearbook* (2014)	0.1928	Positive
			Arable land per capita//mu	Arable land area/number of rural labor	0.2806	Positive
			Fertilizer use intensity//kg/ha	*Tibet Statistical Yearbook* (2014)	0.1669	Negative
			Pesticide use intensity//kg/ha	*Tibet Statistical Yearbook* (2014)	0.1669	Negative
			Total power of agricultural machinery per hectare//kW/ha	Total power of agricultural machinery/arable land area	0.1928	Positive
	Rural population and society sub-system	0.2134	Rural and urban residents' income ratio//%	Per capita net income of rural residents/disposable income of urban residents	0.1263	Positive
			Proportion of rural labor//%	Number of rural labor/total population	0.2004	Positive
			Population density//person/km^2	*Tibet Statistical Yearbook*	0.3909	Negative
			Engel coefficient//%	Food expenditure/personal consumption expenditure	0.1056	Negative
			Population growth rate//‰	*Tibet Statistical Yearbook*	0.1768	Negative

3.2 Weight determining Currently, the main methods of determining the weight include grey relational analysis, AHP, Delphi method and principal component analysis. In this paper, we use expert evaluation combined with AHP to determine the weight of 3 criteria layers and 16 indicators, respectively, as shown in Table 1.

3.3 Data normalization In order to eliminate the impact of different dimensions, there is a need to normalize the indicator data. The normalization formula is as follows:

$$X_i = (C_i - C_{i\min})/(C_{i\max} - C_{i\min}) \text{ (positive indicators)}$$

$$X_i = (C_i - C_{i\max})/(C_{i\min} - C_{i\max}) \text{ (negative indicators)}$$

where X_i is the normalized value of indicator i; C_i is the value of indicator i; $C_{i\max}$ and $C_{i\min}$ are the maximum and minimum value of indicator i.

3.4 Evaluation index and composite index calculation F is used to denote the agricultural sustainability index, the formula $F = \sum W_i \cdot X_i$ is used to calculate the evaluation value of criteria layer, and then the formula $F = F_1 + F_2 + F_3$ is used to calculate the composite index of sustainability. In the formula, W_i is the weight of evaluation indicator i; X_i is the normalized value.

3.5 Cluster analysis To further clarify the spatial distribution characteristics of Tibet's agricultural sustainability, we use cluster analysis for zoning. With evaluation value of various sub-systems in 7 cities and comprehensive evaluation value as new variable, we use DPS10.5 data processing system, chi-square distance and sum of squares of deviations for clustering.

Table 2 Evaluation indicator value of agricultural sustainability in different cities of Tibet in 2013

Indicators	Lhasa	Qamdo	Shannan	Shigatse	Nagqu	Ali	Nyingchi
Per capita agricultural GDP//yuan	12112	9522	5900	9832	8920	13218	15389
Per capita share of food//kg	379.51	298.43	455.04	540.96	30.14	63.43	483.13
Per capita net income of farmers and herdsmen//yuan	8265	5900	7099	6027	6398	6391	8612
Land productivity //yuan/ha	55122	61658	28608	39321	349474	221619	53701
Agricultural labor productivity//yuan	20421	13219	14526	12045	9156	16551	19749
Proportion of non-agricultural industries in rural areas//%	40.69	27.97	59.38	18.37	2.58	20.14	22.08
Irrigation rate//%	82.63	37.36	89.89	86.59	0.00	23.19	69.5
Arable land per capita//mu	3.30	2.32	3.09	3.75	0.38	0.89	4.3
Fertilizer consumption//kg/ha	525.00	171.00	208.00	201.00	19.00	223.00	243
Pesticide consumption//kg/ha	4.00	1.00	4.00	6.00	0	1.00	6.00
Total power of agricultural machinery//kW/ha	33022.15	14957.79	23183.58	21825.14	66390.94	64465.95	34914.84
Rural and urban residents' income ratio//%	0.39	0.34	0.37	0.30	0.31	0.26	0.484
Proportion of rural labor//%	29.79	46.24	40.68	46.92	41.14	48.94	36.574
Population density//person/km^2	18.08	6.27	4.73	4.24	1.06	0.32	1.63
Engel coefficient	0.45	0.59	0.50	0.55	0.53	0.58	0.56
Population growth rate//‰	17.00	2.60	9.80	7.80	11.50	5.90	13.8

4 Results and analysis

The normalized data are calculated based on the above steps to get 7 cities' 3 sub-systems and comprehensive agricultural sustainability (Table 3). Table 3 shows that except agricultural resources and environment sub-system, there are great differences in the subsystems and comprehensive agricultural sustainability between Tibet's 7 cities. From each sub-system, it is found that there are the greatest differences in sustainable development level of rural population and society between the regions, and the index value is in the range of 0.1773 –0.5592. The index is highest in Ali and lowest in Lhasa. The development level is in the descending order of Ali > Shigatse > Shannan > Nyingchi > Nagqu > Qamdo > Lhasa. It is followed by agricultural economy and production sub-system, with index value of 0.2771 –0.7881, and the index is in the order of Nyingchi > Shannan > Nagqu > Shigatse > Ali > Lhasa > Qamdo. Under the combined effect of three sub-systems, the agricultural sustainability varies in Tibet's different regions. Nyingchi has the highest level of development, with the composite sustainability index of 0.6937, followed by Lhasa; Nagqu has the lowest level of development, with the composite index of only 0.4232.

Table 3 Evaluation results of agricultural sustainability in Tibet's different regions

Regions	Agricultural economy and production sub-system	Agricultural resources and environment sub-system	Rural population and society sub-system	Agricultural sustainability
Lhasa	0.7001	0.5204	0.1773	0.5456
Qamdo	0.3013	0.5024	0.6518	0.4241
Shannan	0.4721	0.5892	0.6120	0.5299
Shigatse	0.3885	0.5597	0.6652	0.4884
Nagqu	0.2771	0.5600	0.6451	0.4232
Ali	0.2911	0.5385	0.7704	0.4525
Nyingchi	0.7881	0.5975	0.5592	0.6937

Clustering results (Fig. 1) show that Tibet's 7 cities can be divided into three categories: the first category includes Nyingchi and Lhasa; the second category includes Shigatse and Shannan; the third category includes Nagqu, Ali and Qamdo. The level of sustainable development of agriculture shows a decreasing trend from east to west, from south to north. For the first category of regions, they have high score in three sub-systems, and they are the regions with high level of sustainable development of agriculture in Tibet. Nyingchi are in the first three places in terms of scores of 9 indicators such as per capita agricultural GDP, per capita share of food, arable land per capita, per capita net income of farmers and herdsmen and rural per capita electricity consumption; except rural population and society sub-system with low level of sustainable development, the other two sub-systems have high score, so that the region's composite score of agricultural sustainability is ranked first. Lhasa, in the second place, has the highest agricultural labor productivity and Engel coefficient. In terms of 4 indicators such as per capita net income of farmers and herdsmen and proportion of non-agricultural industries in rural areas, it is ranked second; in terms of 3 other indicators, it is ranked third, indicating that this region has high level of agricultural economic development and high living standards. Overall, the 2 cities in the first category have good resource endowment and high resource use efficiency; the level of agricultural industrialization and investment comes out in front, the agricultural production ability is strong, and the level of rural economic development is high; the superior geographical location and convenient traffic conditions lay a good foundation for sustainable development of agriculture. For the second category of regions, they have high scores in agricultural resources and the environment sub-system, and rural society and population sub-system, and moderate scores in agricultural production and economic sub-system. Shigatse and Shannan in this category are Tibet's main agricultural areas which have a long history of agricultural development and abundant rural labor resources. The cultivated land resources are rich in the region, and the per capita arable land area is ranked fourth in Tibet. The irrigation and water conservancy facilities are relatively complete and crops can get timely irrigation, so they are ranked first and second respectively among the 7 cities in terms of effective arable land irrigation rate. However, the population is relatively concentrated, the natural growth rate of population is high, and both the land productivity and agricultural labor productivity are low, so their economic development level is lower than that of Nyingchi and Lhasa. The third category of regions, including Nagqu, Qamdo and Ali, are characterized by a large population, high birth rate and low education level of residents. There are few arable land resources, agricultural infrastructure is relatively backward, and the irrigation rate and ability to withstand disasters are lower than the average level of the region, leading to low agricultural productivity. There is single industrial structure, it is dominated by animal husbandry, and the production capacity is not high, resulting in single source of farmers' income, and low level of per capita agricultural GDP and per capita net income of farmers and herdsmen.

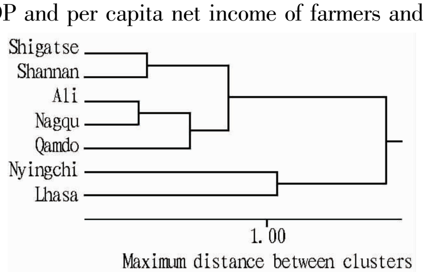

Fig. 1 Clustering results of Tibet's 7 cities in terms of agricultural sustainability

5 Conclusions and recommendations

5.1 Conclusions To understand the spatial difference of agricultural sustainability in Tibet, this paper establishes a comprehensive evaluation model of agricultural sustainability to calculate the score of agricultural sustainability of 7 areas in 2013 in Tibet. By using cluster analysis, this paper conducts the regional evaluation of Tibet's agricultural sustainability. The results show that 7 cities' regional difference of agricultural sustainability was obvious in 2013, the agricultural sustainability index value was 0.4232 – 0.6937, and the value was in the order of Nyingchi > Lhasa > Shannan > Ali > Shigatse > Qamdo > Nagqu. According to the agricultural sustainable development level, Tibet can be divided into three regions: the first type is the area with the highest level of sustainable development of agriculture, including Nyingchi and Lhasa; the second type is the area with the average level of sustainable development of agriculture, including Shigatse and Shannan; the third type is the area with the low level of sustainable development of agriculture, including Qamdo, Ali and Nagqu.

5.2 Recommendations

5.2.1 Developing the measures for sustainable agricultural development in accordance with local conditions. In order to promote the balanced sustainable development of agriculture in Tibet's regions, there is a need to find out the constraints on agricultural sustainability of each city, and develop appropriate measures to improve level of development and narrow regional disparities on this basis. For example, the constraints on sustainable development of agriculture in Lhasa mainly include too high population density and excessive application of chemical fertilizer, so it is necessary to control population growth and application of chemical fertilizer.

5.2.2 Effectively protecting ecological environment. As we all know, Tibet's agricultural ecosystem is vulnerable and difficult to repair. Therefore, we should pay special attention to the agricultural ecological environment protection. Firstly, it is necessary to adopt more stringent and effective measures to strengthen the protection of cultivated land resources. Secondly, it is necessary to scientifically control the use of pesticides and fertilizers in the process of agricultural production. The agricultural departments of Tibet should make special plans on bio-pesticide application and rational application of fertilizers as soon as possible, in order to reduce the ecological environment pollution caused by excessive use of pesticides and chemical fertilizer.

5.2.3 Adjusting industrial structure and improving comprehensive agricultural productivity. To increase comprehensive agricultural productivity, it is necessary to adjust the industrial structure according to regional resources characteristics and advantages. In Nagqu and Ali with limited arable land resources and poor land quality, the comparative advantage of farming resources is not obvious, and it is necessary to focus on the development of animal husbandry; in Shigatse and Shannan as the traditional agricultural areas, it is necessary to take advantage of rich land resources, human resources and relatively advanced agricultural technology to develop farming; in Lhasa with superior geographical location, it is necessary to vigorously develop suburban agriculture and combine farming with animal husbandry.

5.2.4 Increasing investment and strengthening the construction of agricultural infrastructure. It is necessary to vigorously build or renovate water conservancy facilities, and promote scientific irri-

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reading subjects, reading media and reading environment, the effect of reading behavior on entrepreneurial performance is different. Firstly, reading media can significantly increase survival years of entrepreneurial enterprises. Secondly, reading media can significantly increase possibility of survival for at least 8 years of entrepreneurial enterprises. Thirdly, reading media can significantly strengthen social reputation of entrepreneurial enterprises, and reading subjects can enhance social reputation of entrepreneurial enterprises to a certain extent.

From the above analysis, our conclusions mainly lie in following aspects: functions of reading subjects, reading media and reading environment are different. We divided entrepreneurial performance into survival performance and financial performance. Besides, we further analyzed influence of reading behavior on survival performance and financial performance. This will break the simple understanding of "reading behavior of entrepreneurs having certain positive effect on entrepreneurial performance", in hope of providing theoretical basis for fully understanding the effect of reading behavior on entrepreneurial performance of enterprises. It should be noted that our data were collected from some enterprises of Chongqing, which will reduce randomness of data to a certain extent and make our study have certain regional limitation. In future, it is expected to make further pertinent survey, to test universality of our conclusions. In addition, we mainly interviewed entrepreneur. In future, it is recommended to study entrepreneurial teams, and study their reading behavior and influence of different reading behavior on entrepreneurial performance, so as to provide guidance for entrepreneurial teams.

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gation technology, so as to enhance the effective irrigation rate and the ability of agricultural ecosystem to withstand disasters.

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