Study on Eco-climate Type Regionalization of Wheat Growing Areas in Yunnan Province

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Abstract In order to provide an objective and scientific theoretical basis for rational distribution of wheat growth in Yunnan Province, according to the relationship between Yunnan weather conditions and wheat growth adaptability, a study on eco-climate type regionalization of wheat growing areas in Yunnan was conducted using principal component analysis and GIS technology. The results show that Yunnan Province could be divided into four types, namely southern warm and humid wheat growing area, central semi-arid wheat growing area, central semi-humid wheat growing area and north-central cold wheat growing area.

Key words Wheat growing areas, Principal component analysis, Eco-climate types, Regionalization, Yunnan

As one of food crops growing in winter and spring in Yunnan Province, wheat has a planting area of 0.6 million hm^2 on average, and the maximum area reaches 0.733 million hm^2; it mainly distributes in Honghe, Wenshan, Qujing, Chuxiong, Dali, Licang, Baoshan, Yuxi, Lijiang, Kunming and so forth, its growth period corresponds with dry season of monsoon climate of Yunnan[1,3]. Limited by geographical, climatic and economic factors, lagging water infrastructure can not meet the basic demand of agricultural production for water during dry season in most mountain areas of Yunnan. Under the effects of monsoon climate and terrain, Yunnan has a variety of climate types[1]. With the improvement of urbanization rate of Yunnan, farmland will expend towards mountain areas[2], and climatic factors will affect wheat production more greatly. Therefore, based on the correlation between climatic factors (rainfall, temperature and sunshine duration) during the growth period and wheat farming, a study on eco-climate type regionalization of wheat growing areas in Yunnan is of great significance to rational distribution of wheat growth.

1 Data and methods

1.1 Data source Climatic data include average precipitation, temperature and sunshine hours of 125 counties in Yunnan from 1981 to 2010.

1.2 Selection of eco-climate factors Due to the effects of monsoon climate, wheat is sown from middle October to early November in most areas of Yunnan; wheat seedlings emerge from late October to early November; its tillering stage is from late November to early January; jointing and booting stage is from January to February; heading and flowering happen in March; seed filling and mature stage is from April to early May, and then it is harvested before middle May, so its growth period is 165 - 200 d[3]. Temporal and spatial distribution of rainfall, temperature (accumulated temperature) and sunshine hours during the growth period are key to the growth and development of wheat, so they are decisive factors of wheat yield[4,12,14]. In the eco-climate type regionalization of wheat growing areas in Yunnan, we chose 33 climatic factors closely related to wheat growth adaptability as regionalization indicators[1-4,12] (Table 1). Among them, rainfall from sowing period to tillering stage determines seedling quantity and tillering rate of wheat, so it is an initial factor influencing wheat yield; precipitation from jointing stage to seed filling stage determines water supply to wheat, so it affects number of productive ear and yield of wheat; accumulated temperature and its distribution in the growth period are heat conditions of wheat growth and development, and they influence wheat yield and quality; sunshine duration from February to April is a prerequisite for wheat growth and development, as well as an important factor influencing wheat yield and quality.

1.3 Regionalization methods and principles We used principal component analysis to establish the assessment model to judge wheat yield under the effects of eco-climate factors. Principal component analysis means that many variables are transformed into several composite indicators having major information of original variables, and there is no correlation between two any indicators[5-10]. In detail, original data were standardized firstly; secondly, their correlation matrix R was calculated; thirdly, eigenvalues, eigenvectors and contribution rate of R were calculated; fourthly, number of principal components was determined according to the contribution rate; fifthly, influencing factors with greater weight were chosen to explain comprehensive significance; finally, principal component values and comprehensive scores were calculated to carry out the regionalization[9].

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Table 1 Selected eco-climate factors and their codes for the eco-climate type regionalization of wheat growing areas in Yunnan

Index	Factors and their codes
Rainfall	Rainfall in sowing period x_1, rainfall in emergence period of seedlings x_2, rainfall in late emergence period of seedlings x_3, rainfall during tillering stage x_4, rainfall during middle and later tillering stage x_5, rainfall during late tillering stage x_6, rainfall during jointing and booting stage x_7, rainfall during late jointing stage x_8, rainfall during middle booting stage x_9, rainfall during late booting stage x_{10}, rainfall in heading and flowering period x_{11}, rainfall in heading period x_{12}, rainfall from heading to floweringx_{13}, rainfall in flowering period x_{14}, rainfall in seed filling period x_{15}, rainfall in early seed filling period x_{16}, rainfall in later seed filling period x_{17}, rainfall in mature period x_{18}, rainfall in early mature period x_{19}
Accumulated temperature	Accumulated temperature in sowing period x_{20}, accumulated temperature in emergence period of seedlings x_{21}, accumulated temperature during tillering stage x_{22}, accumulated temperature during jointing stage x_{23}, accumulated temperature in heading and flowering period x_{25}, accumulated temperature in seed filling period x_{27}, accumulated temperature in mature period x_{29}
Temperature	Temperature during later jointing and booting stage x_{24}, temperature in heading period x_{26}, temperature in later seed filling period x_{28}, temperature in early mature period x_{30}
Sunshine hours	Sunshine hours during booting stage x_{31}, sunshine hours in heading and flowering period x_{32}、sunshine hours during seed filling and mature stage x_{33}

1.3.1 R-type principal component analysis. R-type principal component analysis aims to study the internal relation of variables[6-7]. In the regionalization, according to the eco-climate types of wheat growing areas in Yunnan, we set up a matrix X_{pn} ($p=33$, $n=125$) containing 33 eco-climate factors of 125 counties. Matrix Y_{mn} composed of the first m principal components could reflect the information of factors in matrix X_{pn}[9-10].

1.3.2 Date processing and interpretation. Principal component analysis of matrix $x_{33\times125}$ was carried out using software SPSS. The indicators were rotated by varimax method. Scores of principal components were calculated using regression method.

2 Results and analysis

2.1 Standardization of original data Absolute values of load rate of factors in Table 2 reflect the correlation between factors and principal components, that is, the higher the load rate of a factor, the better the correlation with a principal component. When absolute value of load rate of a factor is $\geqslant 0.6$, the factor is significantly correlated with a principal component[8-14]. The first four principal components of $x_{33\times125}$ had a contribution rate of cumulative variances of 94.651% (Table 2), so we only calculated the first four principal components.

Table 2 Eigenvalues, contribution rate of variances and cumulative variances of the correlation matrix X_{pn}

Principal component	Eigenvalue	Contribution rate of variances//%	Contribution rate of cumulative variances//%
1	11.171	33.851	33.851
2	11.018	33.389	67.240
3	5.638	17.085	84.326
4	3.534	10.326	94.651

As shown in Table 3, for the first principal component, variables with a high load rate are x_{11}, x_{12}, x_{14}, x_9, x_7, x_{13}, x_8, x_{10}, x_{16}, x_{15} and x_{17}, which reflect rainfall and its distribution during several growth periods of wheat and affect wheat yield and quality. When load rate of a factor is positive, rainfall and its temporal distribution in dry season of winter in Yunnan is the fist factor influencing wheat yield, which is fully consistent with wheat cultivation practice of Yunnan. For the second principal component, variables with a high load rate are x_{18}, x_{19}, x_{15}, x_{17}, x_{25}, x_{20}, x_{21}, x_{26}, x_{22}, x_{24} and x_{23}, which can not only reflect heat conditions in each key growth period, but also show whether wheat has suffered low temperature injury in temperature-sensitive period. Load rates of these factors are positive, which is fully consistent with wheat cultivation practice of Yunnan. For the third principal component, variables with a high load rate include x_2, x_3, x_4, x_1, x_6 and x_5, which reflect rainfall and its distribution in early growth period of wheat. Positive load rate shows that rainfall has positive effects on wheat growth in early period. For the fourth principal component, variables with a high load rate are x_{31}, x_{32} and x_{33}, reflecting sunshine condition in middle and later stage of wheat growth and development. Positive load rate shows that there is enough sunshine in middle and later stage of wheat growth, and enough sunshine can improve photosynthetic efficiency of wheat and further affect wheat yield and quality, which is fully consistent with wheat cultivation practice of Yunnan.

2.2 Eco-climate type regionalization of wheat growing areas in Yunnan The contribution rates of principal components were used as weights to establish the comprehensive assessment model of principal components, and based on composite scores, Yunnan Province could be divided into four types of wheat growing areas (Fig. 1).

2.2.1 Northern cold wheat growing area. Northern cold wheat growing area, one of main producing areas of wheat and barley in Yunnan, is located in the center and north of Yunnan, including 30 counties and cities, such as Shangri-La, Deqin, Zhenxiong, Zhaotong and so forth. The area has a high altitude of about 1 800-3 600 m as well as yellow, purple and dark brown soil[19]. In growth period of wheat from spring to winter, the area has a low temperature, little rainfall and long frost period, so it is easy for wheat to be damaged due to low temperatures. Meanwhile, drought happens frequently, and there are many cloudy days and few sunshine hours. In this area, the growth period of wheat is long, about 170 d, so wheat species with strong resistance to cold

and drought can be planted here, and wheat (barley) and corn can be intercropped.

2.2.2 Central semi-arid wheat growing area. Central semi-arid wheat growing area is the main producing area of gain, including 48 counties and cities, such as Zhanyi, Xundian, Dayao and so on. There are many basins and hills in the region, with an altitude of 1 500 – 2 000 m, and yellow earth and paddy soil are common[19]. In growth period of wheat from spring to winter, the region has many features, such as warm climate, moderate heat, enough sunshine, little rainfall and short frost period. In the region, the growth period of wheat is about 165 d, and wheat is easy to suffer damage caused by drought.

Table 3 Eigenvectors of the correlation matrix V_{mp}

Factor	Principal component				Factor	Principal component			
	1	2	3	4		1	2	3	4
x_1	0.074	0.394	0.818	0.160	x_{18}	0.447	0.246	0.655	−0.461
x_2	0.092	0.364	0.894	0.093	x_{19}	0.555	0.191	0.537	−0.508
x_3	0.203	0.279	0.878	−0.006	x_{20}	0.028	0.965	0.194	−0.054
x_4	0.367	0.219	0.850	−0.105	x_{21}	0.024	0.965	0.214	−0.069
x_5	0.368	0.127	0.728	0.140	x_{22}	0.044	0.957	0.259	0.028
x_6	0.498	0.240	0.728	0.180	x_{23}	0.028	0.955	0.231	0.142
x_7	0.937	−0.048	0.741	−0.084	x_{24}	−0.014	0.957	0.204	0.181
x_8	0.928	−0.063	0.263	−0.093	x_{25}	−0.055	0.970	0.183	0.120
x_9	0.960	−0.049	0.223	−0.118	x_{26}	−0.020	0.962	0.174	0.139
x_{10}	0.942	−0.080	0.152	−0.084	x_{27}	−0.099	0.976	0.150	0.044
x_{11}	0.974	−0.097	0.215	−0.160	x_{28}	−0.104	0.976	0.143	0.040
x_{12}	0.970	−0.129	0.082	−0.100	x_{29}	−0.088	0.981	0.069	−0.055
x_{13}	0.967	−0.129	0.033	−0.152	x_{30}	−0.089	0.976	0.093	−0.038
x_{14}	0.949	−0.052	0.175	−0.193	x_{31}	−0.235	0.130	0.020	0.935
x_{15}	0.898	0.086	0.306	−0.245	x_{32}	−0.361	0.116	0.022	0.912
x_{16}	0.900	0.067	0.280	−0.265	x_{33}	−0.425	0.165	0.065	0.848
x_{17}	0.887	0.103	0.328	−0.223					

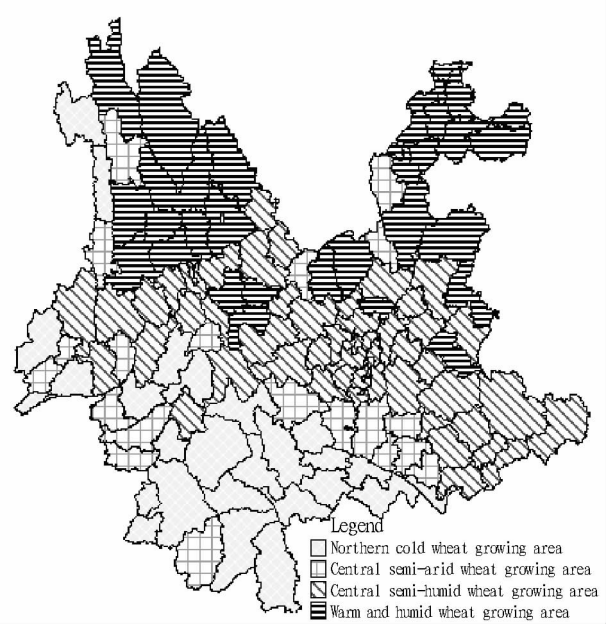

Fig. 1 Eco-climate regionalization chart of wheat growing areas in Yunnan

2.2.3 Central semi-humid wheat growing area. Central semi-humid wheat growing area, one of main producing areas of gain and cash crops in Yunnan, is situated in the west and central-south of Yunnan, covering 21 counties and cities, such as Pingbian, Shidian, Xinping and so forth. There are many small basins and valleys in this area, with an altitude of 1 000 – 1 500 m, and red soil and sand are main soil[19]. During growth period of wheat, the area has warm climate, rich heat, abundant sunshine, moderate rainfall and short frost period. The growth period of wheat is about 160 d in this area, so weak winter or spring wheat can be planted here, and wheat (barley) and other crops can be intercropped.

2.4 Warm and humid wheat growing area Warm and humid wheat growing area is in the south of Yunnan, including 26 counties and cities, such as Menglian, Yunxian and so forth, where cash crops are mainly planted in winter and spring instead of wheat. This region has a low altitude of below 1 000 m, and red soil and latosol are major soil[19]. During the growth period of wheat, the area has rich heat, enough rainfall and sunshine, so spring wheat and barley should be planted here, and wheat (barley) and cash crops can be intercropped.

3 Conclusions

Based on data of rainfall, temperature, accumulated temperature and sunshine hours of 125 counties and cities in Yunan Province during the growth period of wheat, the eco-climate type regionalization of wheat growing areas in Yunnan was carried out using principal component analysis. The results show that Yunnan Province could be divided into four types, namely southern warm and humid wheat growing area, central semi-arid wheat growing area, central semi-humid wheat growing area and north-central cold wheat growing area, which is consistent with many years of production practice. The eco-climate type regionalization results were not affected by personal factors and were shown in the form of a visual figure with the aid of GIS.

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est resources surges forward. Forest tenure transfer market is an important capital financing market promoting forestry development. As early as 2008, Dayi County has set up its own forest property right transaction market, whose responsibilities mainly include: (1) managing registration, transfer and mortgage of woods and forest land in the whole city; (2) collecting and issuing information about forest tenure transfer, forest tenure certificate mortgage, and market transaction; (3) promoting flow of forestry production factors; (4) conducting forest tenure value assessment service; (5) organizing training and providing forestry sci-tech service; (6) providing advisory service of laws, regulations and policies on forestry. The complete transaction process is shown in Fig. 1. In addition, Dayi County should establish perfect application platform and promote policy financial cooperation. For example, Dayi County government takes the lead in signing cooperation agreement with State Development Bank and Agricultural Development Bank, then entrusts other local financial institutions to grant loans to middle and small undertakings and forest farmers.

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