Research on the Comprehensive Evaluation of Alfalfa Management in Zuli River Basin

Rui Guo, Cui Wang, Xue Shang, Xuan Mi

Research on the comprehensive evaluation of alfalfa management in Zuli River basin

Rui Guo[1,2(✉)], Cui Yun Wang[2], Xue Ying Shang[2], Xuan Mi[2]

[1]School of Life Sciences, Lanzhou University, Lanzhou,Gansu,China

hdcygr@163.com

[2]School of Geography and Environment Engineering, Lanzhou City University, Lanzhou,Gansu,China

Abstract: Taken Alfalfa as an example, this study analyzed the impact of returning cultivated land to grassland in Zuli River basin. The entropy weight method was used to appraise the growth years for alfalfa. The results showed that the appropriate years for alfalfa in the northern of the basin is nine and sex for the southern of the basin. After the recommended planting years, the composite index significantly decreased. Then, the yield of alfalfa in Zuli river basin was expressed in map using multiple regression method.

Keywords: yield · GIS · multiple regression · entropy weight method

1 Introduction

Medicago Sativa is a good forage grass widely cultivated in the world, which has the largest planting area in China[1]. With the Characteristics of drought tolerance, cold resistance, salt resistance and barren resistance, alfalfa is a kind of ideal coarse fodder for livestock. With strong adaptability, high yield and rich nutrient, alfalfa not only plays an important role in Chinese traditional agriculture and animal husbandry, but also taken as the preferred species for the artificial grassland in the loess plateau[2]. Today in the construction of the western environment, alfalfa was used for returning farmland to grassland, optimizing the agricultural structure and so on[3].

People paid more attention to dried soil layer caused by long term cultivate alfalfa, although there are many advantages. The infiltration depth of rainfall is generally 100-300cm on the Loess Plateau area, while the soil evaporation transpiration depth is up to 800-1000cm, which resulting water deficit in the deep soil, and vegetation degradation [4].

In the recent ten years, with the increase of alfalfa planting area, the Chinese scholars have also studied the influence of Alfalfa on soil condition, the influence factors of alfalfa yield, the influence of Alfalfa on soil moisture and so on [5,6,7,8,9,10,11]. In this study, the effects of different rainfall and temperature conditions in the northern and southern part of the river basin, the influence of the soil condition, and the relationship between the planting time and the yield of alfalfa were analyzed to study a recommended management plan for Alfalfa in the basin. And the yield distribution of Alfalfa was simulated by GIS.

2 Experiments and Methods

2.1 Study on the suitable planting time of Alfalfa in Zuli River Basin

Data was collected from the literatures[2],[12].The entropy weight method was used. The principle of availability and identity was taken when choose the indicators. Select common indicators between two experimental points from the indicators obtained. The representative of soil condition was also taken into consideration（Table 1，Table 2）.

Table 1. The yields of alfalfa, soil moisture content, soil bulk density and potential mineralized nitrogen in Zhenyuan Experimental Station

Indicators / Planting years	Yields（$kg.hm^{-2}$）	Soil moisture content（0-1000cm）	Soil bulk density（0-200cm）	Potential mineralized nitrogen（0-200cm，kg/hm2)
3	7447.76	2232	1.343	
4	9839.95	1878.8	1.347	718.52
6	11500.54	1945.6	1.403	797.31
8	8982.13	1784.3	1.381	819.41
12	5051.38	1542.1	1.353	582.88
14	4066.64	1555	1.360	660.66
18	3291.01	1350.1	1.306	441.45
26	2476.04	1372.3	1.340	610.86

Data from:(Wan Sumei, 2008)

Table 2. The yields of alfalfa, soil moisture content, soil bulk density and potential mineralized nitrogen in Zhonglianchuan Experimental Station

Indicators / Planting years	Yields（kg/hm^2）	Soil moisture content（100-500cm）	Soil bulk density（0-40cm）	Available nitrogen(0-20cm)
3	1945	9.129	1.12	24.5
5	2794	8.78	1.165	22.7
9	4060	8.64	1.155	24.8
15	1577	5.88	1.18	25.2
21	1225	5.404	1.12	34.6
25	861	5.28	1.075	39.8

Data from: (Jiang Jinping, 2007)

2.2 Spatial distribution of Alafalfa Yield

All of the Alfalfa yield data are collected form the literature(Table 3).

The yield data in this study were derived from the experiment without fertilization and irrigation treatment, or control data in experiment. The ratio in the literature[2] was used to calculate the dry weight for only fresh weight.

Statistical analysis: the environmental factors which were significantly correlated with yield were selected to simulate the yield of Alfalfa in the watershed by the multiple regression model. Regression models of alfalfa production and regional environmental variables were created by stepwise regression method.

Based on the regression model, the grid computing module was used to simulate the spatial distribution of alfalfa yield in ArcGIS, then the yield distribution map of alfalfa was obtained.

Table 3. Data source of the yields of alfalfa and the location

Source	Longitude	Latitude	Yield
Co-variation of vegetation and soil quality during ecosystem restoration in the hilly region of the semiarid Loess Plateau [12]	104.04	36.02	1945
Effects of rainfall harvesting cultivation with ridges and furrows on emergence and grass yield of alfalfa in semiarid areas [13]	103.25	36.73	2011
Effects of irrigation amount and stage on water consumption characteristics and grain yield of alfalfa [14]	106.73	37.53	2420
Effects of nitrogen and phosphorus ratio on yield components and nutrient components of Alfalfa in dry land[15]	108.17	34.35	3185
Effect of N, P and K fertilization on yield and nutrient quality of alfalfa in Yellow River beach regions [16]	113.7	34.73	3412
The influence of fertilizer to the yield of *Medicago sative* L. [17]	116.68	36.73	4640

3 Results and Discussion

3.1 Study on the suitable planting time of Alfalfa in Zuli River Basin

Table 4. The weights for each indicators in Zhenyuan Experiment Station

Indicators	Yields	Soil moisture content	Soil bulk density	Available nitrogen
Weights	0.8317	0.0574	0.0014	0.1095

Table 5. The comprehensive ecaluation values for the different growing years' alfalfa

in Zhenyuan Experiment Station

Years	4	6	8	12	14	18	26
The comprehensive evaluation values	0.2159	0.2519	0.1977	0.1123	0.0914	0.0739	0.0569

According to the entropy method, the weights (wi) for each index in Zhenyuan experimental station were calculated and showed in Table 4. The sequence according to the weight is as follows: yields(0.8317), available nitrogen(0.1095), soil moisture content (0.0574), soil bulk density(0.0014). On the basis of the principle of entropy method, the result shows that the change of yield was the biggest, the influence on available nitrogen was the second, and the change range of soil bulk density was the least with the increase of planting years of alfalfa.

Then the comprehensive evaluation was applied to evaluate the growing years for alfalfa with the obtained weights. Table 5 is the comprehensive evaluation value of each year in Zhenyuan experimental station, which shows that: 6 years >8 years >12 years >14 years >18 years >26 years. The conclusion shows that the best growth time for alfalfa in this area was 6 years, 4 years is the next, followed by 8 years. After 8 years, the composite index decreased gradually with the increase of alfalfa growth.

Table 6. The weights for each indicators in Zhonglianchuan Experiment Station

Indicators	Yields	Soil moisture content	Soil bulk density	Available nitrogen
Weights	0.7122	0.155	0.0027	0.1301

Table 7. The comprehensive ecaluation values for the different growing years' alfalfa in Zhonglianchuan Experiment Station

Years	3	5	9	15	21	25
The comprehensive evaluation values	0.1561	0.2240	0.3252	0.1266	0.0986	0.0695

According to the entropy method, the weights (w_i) for each index in Zhonglianchuan experimental station were also calculated and showed in Table 6. The sequence according to the weight is as follows: yields(0.7122), soil moisture content (0.155), available nitrogen(0.1301),soil bulk density(0.0027). On the basis of the principle of entropy method, the result shows that the change of yield was the biggest, the influence on soil moisture content was the second, and the change range of soil bulk density was the least with the increase of planting years of alfalfa. That different from Zhenyuan experimental station where with more precipitation. This result shows that the effect of alfalfa's growth year on soil moisture in Zhonglianchuan is more than in Zhenyuan. Similarly, the change of soil bulk density was the smallest, showed that the effects of alfalfa's growth year on soil bulk density is the least, or a more long-term process than other factors.

Then the comprehensive evaluation was also applied to evaluate the growing years for alfalfa with the obtained weights. Table 7 is the comprehensive evaluation value of each year in Zhonglianchuan experimental station, which shows that: 9 years >5 years >3 years >15 years >21 years >25 years. The conclusion shows that the best growth time for alfalfa in this area was 9 years, 5 years is the next, followed by 3 years. After 15 years, the composite index decreased gradually with the increase of alfalfa growth.

3.2 Spatial distribution of Alafalfa Yield

Through correlation analysis found that the yield was significantly positive correlated with the mean annual rainfall, the mean temperature in July, average temperature ($p<0.05$)and average rainfall in July, rainfall in May to July($p<0.01$). And the correlation with other environmental factors did not reach a significant level(Table 8).

The abovementioned factors were used as independent factors to establish the multiple regression model of alfalfa production by the backward regression method. Regression models are as follows:

$$y=262.709+44.531x_6+0.781x_4 \quad (1)$$

Which x_6 is temperature in July， x_4 is precipitation in May, June and July. The regression model passed through F test ($p=0.018$),

Table 8. Correlation analyses between Alfalfa yield and meteorological

Environmental factors	Correlation coefficient(R)	*p*
Average precipitation (x_1)	0.835	0.038*
Precipitation in July (x_2)	0.944	0.005**
Precipitation in January (x_3)	0.648	0.164
Precipitation in May, June and July (x_4)	0.962	0.002**
Accumulative temperature (x_5)	0.867	0.025*
Temperature in July (x_6)	0.859	0.029*
Average temperature (x_7)	0.859	0.028*
Temperature in January (x_8)	0.774	0.071
Temperature in April (x_9)	0.589	0.218
Sunshine duration in May, June and July (x_{10})	0.238	0.650
Sunshine duration (x_{11})	-0.245	0.640
Frost free period (x_{12})	0.772	0.072

*Indicates significant correlation between Alfalfa yield and Corresponding Environmental factors(p<0.05).

** Indicates significant correlation between Alfalfa yield and Corresponding Environmental factors(p<0.01).

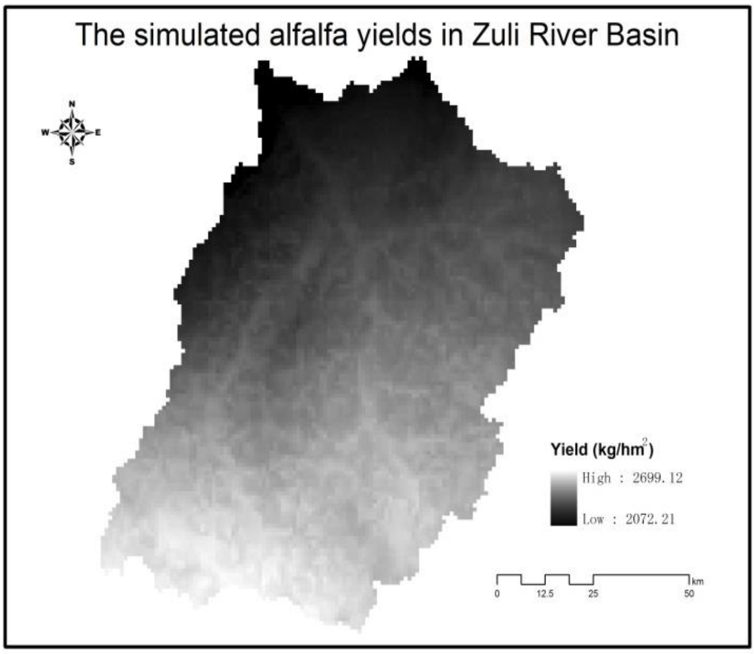

Fig.1. Potential yield distribution for Alfalfa

The raster calculate module in ArcGIS was used to calculate the Potential yield distribution(Fig.1) for Alfalfa basing formula (1) and two raster map layers(temperature in July and precipitation in May, June and July). The size of the grid is 30×30m.

The image shows that the yield of alfalfa in the south of the basin is the highest, which peaked out at 2699.12kg/hm^2. The yields were reduce further north, and have latitude belt distribution characteristics. The yield of alfalfa in the northwest of the basin is the lowest which was 2072.21kg/hm^2.

4 Conclusions

The entropy method which is an objective weighting method was adopted in the comprehensive evaluation of alfalfa growth years. Compared with other methods, it is possible to reduce the interference of human subjectivity to the evaluation process and fully tap the objective differences in each index in the evaluation system. Therefore, this method could more objective to reflect the influence of alfalfa growing period on soil and its own output. Judging from the weight of the entropy method, the weight of yield is much higher than the other three indicators both in the northern and southern parts of the basin, which reflects that the change between the yield was the largest in several indicators and played the largest role in the comprehensive evaluation.

The weight of soil bulk density was small in both two experimental stations, which shows the effect of alfalfa growth on soil bulk density was small compared with the other three indicators. This influence was slightly larger in the northern area with lower rainfall and temperatures than in the southern part of the region with relatively high rainfall and temperature. Although this effect is small, it can not ignore the effects of alfalfa growth on soil porosity.

The weight of soil moisture in Zhonglianchuan experimental station was larger than in Zhenyuan experimental station, illustrated that the effect of alfalfa growth on soil water content was higher in the northern area with less rainfall than in the southern part of the region with relatively high rainfall. According to the results of this study, the cropping years for planting alfalfa is suggested to be 9 years in the northern area, and 6 years in the southern area is appropriate, the longest is 8 years.

According to the correlation analysis of alfalfa yield and multiple environmental factors, the regression equation of yield between mean temperature in July and of rainfall in 5, 6, 7 three months was obtained. The yield of alfalfa in the basin is simulated based on the equation and map was expression in ArcGIS. The result reflects yield of alfalfa was between 2072kg/hm^2 and 2677kg/hm^2 under the artificial management, and decreased from south to north.

Acknowledgment

Financial support from Lanzhou City University's doctoral research fund（LZCU-BS2013-01）and Lanzhou City University's research fund for young teachers（LZCU-QN2017-20）are gratefully acknowledged.

References

1. Geng, H.Z.: Alfalfa in China (in Chinese). China Agriculture Press, Beijing(1995)
2. Wan S.M.: Study on Alfalfa Production Performance and Its Ecological Effects on Soil Environment in the Loess Plateau (in Chinese). Northwest Agriculture and Forestry University, Shanxi(2008)
3. Cao Y.H., Jia Z.K., Han Q.F.: Effect of alfalfa growth years on its yield and soil characteristics. Agricultural research in the arid areas. 26(3),104-108(2008)
4. Shangguan, Z.P., Zheng, S.X.: Ecological properties of soil water and effects on forest vegetation in the Loess Plateau. International Journal of Sustainable Development and World Ecology.13(4),307-314(2006)
5. Zhao, C., Feng, Z., Chen, G.: Soil water balance simulation of alfalfa (Medicago sativa L.) in the semiarid Chinese Loess Plateau. Agricultural Water Management. 69(2), 101-114(2004)

6. Yu, Y., Li, F.M., Wang, X.L.: Soil quality responses to alfalfa watered with a field micro-catchment technique in the Loess Plateau of China. Field Crops Research.95(1),64-74(2006)
7. Jia, Y., Li, F. M., Wang, X. L., Yang, S. M.: Soil water and alfalfa yields as affected by alternating ridges and furrows in rainfall harvest in a semiarid environment. Field Crops Research. 97(2),167-175(2006)
8. Jiang, H. M., Jiang, J. P., Jia, Y., Li, F. M., Xu, J. Z.:Soil carbon pool and effects of soil fertility in seeded alfalfa fields on the semi-arid Loess Plateau in China. Soil Biology and Biochemistry. 38(8),2350-2358(2006)
9. Su, Y.Z.: Soil carbon and nitrogen sequestration following the conversion of cropland to alfalfa forage land in northwest China. Soil and Tillage Research. 92(1),181-189(2007)
10. Wang, X. L., Sun, G. J., Jia, Y., Li, F. M., Xu, J. Z.: Crop yield and soil water restoration on 9-year-old alfalfa pasture in the semiarid Loess Plateau of China. Agricultural Water Management.95(3),190-198(2008)
11. Zhang, T., Wang, Y., Wang, X., Wang, Q., Han, J.: Organic carbon and nitrogen stocks in reed meadow soils converted to alfalfa fields. Soil and Tillage Research.105(1),143-148(2009)
12. Jiang. J. P.: Co-variation of vegetation and soil quality during ecosystem restoration in the hilly region of the semiarid Loess Plateau. Lanzhou University, Gansu(2007)
13. Yin, G. L., Yun, X. J., Shi, S. L., Wang, Q., Zhu, X. Q., Qiang-Dong, L. I.: Effects of rainfall harvesting cultivation with ridges and furrows on emergence and grass yield of alfalfa in semiarid areas. Journal of Gansu Agricultural University. 45(1), 111-115(2010)
14. Pei, X.Y., Song, N.P., Wang, L., Xie, B. X.: Effects of irrigation amount and stage on water consumption characteristics and grain yield of alfalfa. water saving irrigation. 1, 26-30(2010)
15. Jia, J., Han, Q.f., Zhou, F., Jia, Z.K., Wang, J.P., Yang, B.P.:Effects of nitrogen and phosphorus ratio on yield components and nutrient components of Alfalfa in dry land. Chinese Journal of Grassland Science.31(3),77-82(2009)
16. Hu, H.F., Xiao, J.S., Guo, X., Jie, X.L., Liu,S.L., Hua,D.L.,et al.: Effect of N, P and K fertilization on yield and nutrient quality of alfalfa in Yellow River beach regions. Journal of Hunan Agricultural University.35(2), 178-188(2009)
17. Fan, P., Tian, F., Gang, C.W.: The influence of fertilizer to the yield of Medicago sative L. Agricultural Research in the Arid Areas. 25(5), 31-34(2007)