Application of analytic hierarchy process on the study of soil salinization in the Northern Yinchuan Plain, China

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Abstract. The Northern Yinchuan Plain is a productive agricultural area of northwest China, which is under threat due to soil salinization. According to the formation and restoring history of soil salinization, the analytic hierarchy process (AHP) was adopted for analyzing the causes of soil salinization and efficiency of various restoring measures. The calculated results of the relative weights of the indicators showed that semi-arid climate and parent material of soil are dominant factors of soil salinization, which account for40.1% and 21.4% respectively. Furthermore, afforestation and planting salt-tolerant plants and improving drainage system were better than other measures, the values were 38.4% and 29.9% respectively. The study showed that AHP method could provide meaningful references for preventing and improving soil salinization in the study area.

Introduction

Soil salinization of irrigated lands is a crucial worldwide environmental problem and has negatively influence on the development of sustainable agriculture, especially in arid and semi-arid regions [1]. The Northern Yinchuan Plain is a significant food production base located in the Ningxia, Northwest China. However, soil salinization is one of the most significant problems that affect the agricultural production of the area, which has been restricting the Northern Yinchuan Plain in social and economic development [2].

The formation of soil salinization is a complex ecological and environmental problem including various natural and anthropogenic factors. It is difficult to use single one factor to trace out the formation of soil salinization. The AHP could decompose complicated problems into hierarchies and combines quantitative analysis with qualitative analysis. AHP has been widely applied in the environment assessment. Tang establish the river health assessment model based on AHP [3], Zhou used AHP analyze the cause of alpine grassland degradation [4]. In this study, AHP method is employed to analyze the causes of soil salinization and efficiency of various restoring measures oil salinization in the Northern Yinchuan Plain.

Method

Study area. The study area is located in the upper reaches of the Yellow River in the northern Yinchuan plain. It ranges within latitudes 38°26′60″—39°14′09″N and longitudes 105°57′40″—106°52′52″E.The mean annual precipitation for the period of 1990-2000 is only 180.13mm,but evaporation reaches 1791.76mm,which is in agreement with semi-arid climate (Fig.1).

The study area is a traditional agricultural region, and the Yellow River is the main source for irrigation. Due to natural and human activities [5], the study area is under threat of soil salinization. The saline land was about 75.3% of the total area, the slight, moderate and severe salinization area accounting for 30.7%、24.1% and 20.5% respectively [6]. The soil salinization has been restricting the Northern Yinchuan Plain in social and economic development.

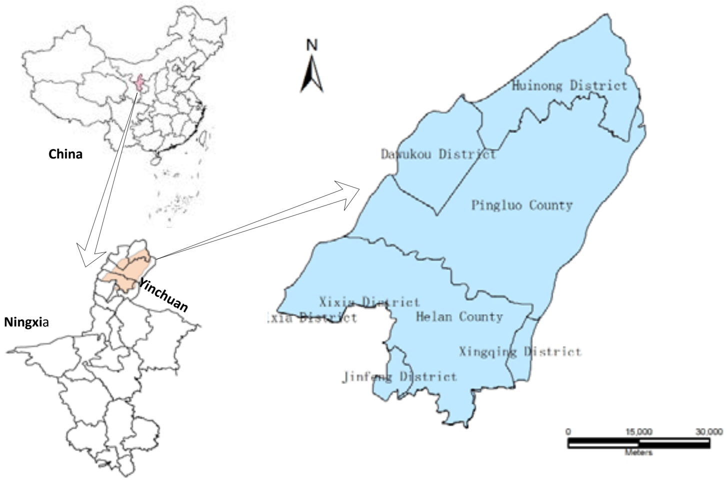

Fig.1 Location of the study area

Method. In this study, AHP was employed to analyze the causes of salinization and assess the efficiency of the measures on preventing soil salinization. AHP is a multicriteria decision making procedure for representing the elements of a problem hierarchically and ranking a set of alternatives or selecting the optimal alternatives by means of a series of pair-wise comparisons [7].

*Step 1*Structure a hierarchical model and identify the indicators. There are three layers included in the hierarchical model: the topmost layer is the goal of prevention and improvement of salinization, the second layer is the causes leading to salinization; the last layer is the corresponding measures (Fig.2).

According to numerous achievements on soil salinization in Northern Yinchuan Plain and semi-arid region [2, 5, 8], generally, semi-arid climate (F1) is a natural force inducing soil salinization; The parent material of soil (F2) provides salt resources for salinization; terrain and geomorphology (F3) have significant influence on the distribution of salinization; shallow groundwater table depth (F4) is main factor of soil salinization in the study area. In addition, groundwater with high salinity (F5) could accelerate salinization under intense evaporation. Furthermore, there are also many anthropogenic factors, which include unreasonable irrigation methods (F6), the poor drainage system (F7) and irrational cultivated practices (F8). According to the causes above, the measures for preventing salinization are summarized in the present study (Fig.2).

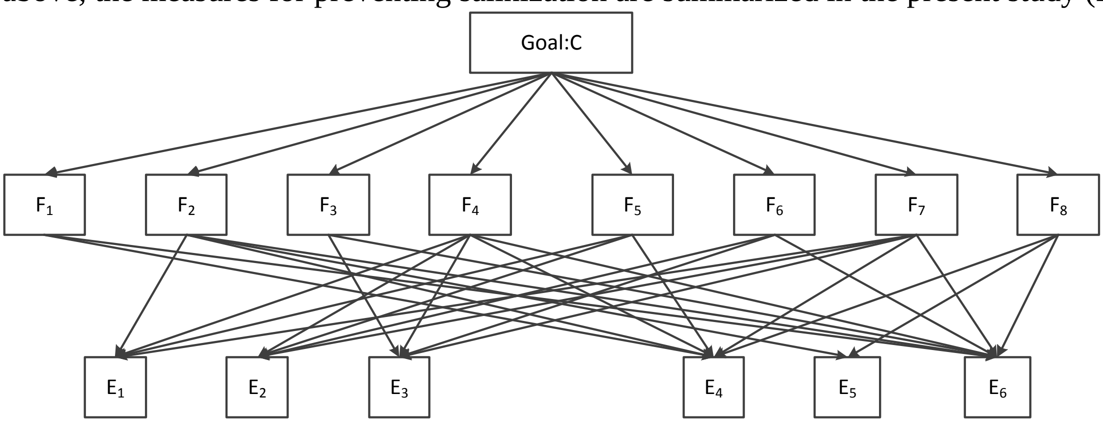

Fig.2 Structure of hierarchical model

Step 2 Construct pair-wise comparison matrix and weight the indicators. Based on the analysis of the causes above, the pair-wise comparison matrix combining 9-point scale developed by Saaty could be constructed. The matrix and the weights of second layer are shown in Table 1.

*Step 3*Check consistency of evaluation. To verify the judgments expressed by the decision maker, Saaty has proposed the following consistency ratio (CR) [9].The value is a measure of how much variation is allowed and must be less than 0.1:

Table 1 the matrix and weights for second layer

Causes	F1	F2	F3	F4	F5	F6	F7	F8	Weight
F1	1	5	9	5	3	7	7	9	0.4073
F2	1/5	1	7	3	3	5	5	7	0.2139
F3	1/9	1/7	1	1/5	1/5	1/3	1/2	1/2	0.0231
F4	1/5	1/3	5	1	1/2	2	2	5	0.0896
F5	1/3	1/3	5	2	1	5	5	3	0.1410
F6	1/7	1/5	3	1/2	1/5	1	2	3	0.0547
F7	1/7	1/5	2	1/2	1/5	1/2	1	2	0.0406
F8	1/9	1/7	2	1/5	1/3	1/3	1/2	1	0.0298

Consistency check: λ_{max}=8.5720, CI=0.0817, RI=1.41, CR=0.058<0.1

*Step 4*Hierarchy general ranking. The general ranking is concluded by the elevated value of single indicator multiply its weight.

Results and Discussion

According to the procedure above, the total arrangement of hierarchy and weight of third layer are shown in Table 3 and the most effective measures of soil salinization will be realized.

Table 3Hierarchy general ranking of indicators of third layer

E1	E2	E3	E4	E5	E6
0.2995	0.0830	0.0487	0.3845	0.0136	0.1708

The semi-arid climate (F1) and parent material of soil (F2) are considered as the main objective bases for soil salinization, which account for 40.7% and 21.4% respectively. Groundwater with high salinity (F5) and shallow groundwater table depth (F4) are the main factors influencing soil salinization holding 14.1% and 9% respectively. Moreover, unreasonable irrigation methods (F6), the poor drainage system (F7) and irrational cultivated practices (F8) are factors accelerating soil salinization (Fig.3).

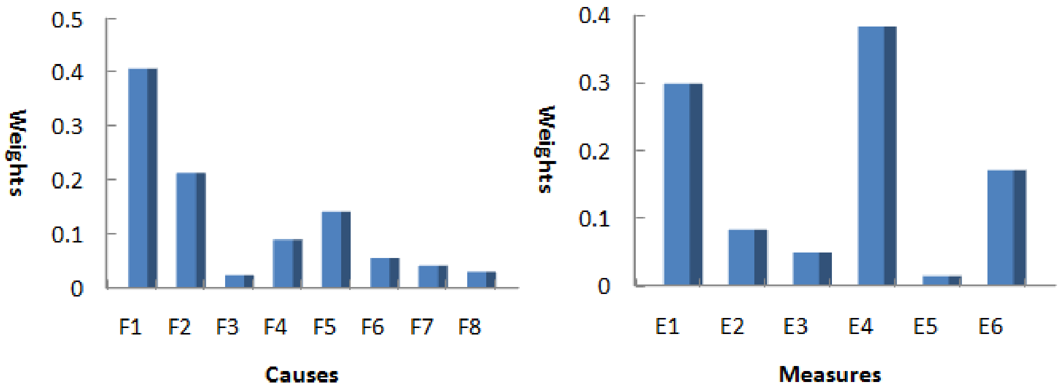

Fig.3 The distribution of integrated weights of various causes and restoring measures

The comparison of the efficiency of the various measures is shown in Fig.2. The measures of afforestation and planting salt-tolerant plants (E4) and improving drainage system (E1) are essential for preventing soil salinization, which occupies 38.4% and 29.9% respectively. Adoption of reasonable planting patterns (E6) and controlling seepage from canal (E2) are also effective, which possess 17% and 8.3% respectively. Additionally, land leveling (E3) and Chemical improvement (E5) are also playing irreplaceable role on soil salinization prevention.

Many experts agreed that the shallow groundwater table depth is the crucial factor influencing soil salinization. However, improving drainage system (E1) is not the most effective measure according to Fig.2. It could be interpreted by the measure of planting salt-tolerant plants (E4) and controlling seepage from canal (E2) can decline the groundwater level effectively. Therefore, the weight of improving drainage system (E1) is not the largest. The results indicate that soil salinization of the Northern Yinchuan Plain will be improved by taking comprehensive measures and the water-salts balance will be realized ultimately.

Conclusion

In this study, AHP technique is employed to assess the efficiency of various measures on preventing soil salinization in the Northern Yinchuan Plain. The method is comparatively objective and comprehensive. Furthermore, the application of AHP on the soil salinization in the study area could transform the qualitative indicator (such as the causes and measures of salinization) into quantitative indicator. According to results, afforestation and planting salt-tolerant plants and improving drainage system were better than other measures on preventing soil salinization. Therefore, the calculated results can provide basis and reference for preventing soil salinization.

Acknowledgements

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