Comprehensive Assessment of the availability of selenium resources in Wucheng based on the analytic hierarchy process

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Abstract. In this study, selenium content, soil nutrient elements and environmental quality are considered comprehensively as the main factor, weight of each index is calculated by analytic hierarchy process and Yaahp software, and spatial distribution of evaluation results is reflected by Geographical Information System. Wucheng district is taken as a case area and classified into some regions for selenium utilization. The southern mountainous and hilly area is suitable for the development of selenium-rich ecological tourism, the northern alluvial plain is suitable for the development of selenium-rich agriculture, Zone III-IV are not suitable for natural selenium-rich agriculture, Zone V is forbidden to farm because of the pollution of heavy metals.

1. Introduction

Selenium (Se) is one of the trace elements for humans and animals because of its effects in oxidation resistance, cancer prevention and cardiovascular disease\cite{1}. Previous studies focused more on how to replenish selenium and synthetic products of selenium\cite{2}. The development of selenium-rich soil resources was neglected. The key to overcoming selenium deficiency was Se-enriched products.

Soil provides essential nutrients and minerals for plant growth, including selenium, nutrient element, even heavy metals. Se-rich soil with abundant nutrient and clean environment would be the best choice for the development of selenium-rich agriculture. The evaluation of selenium-rich soil resources will be the basis for the development of natural selenium-rich industry

AHP was usually applied to multilevel analysis such as site selection, impact elements with different purposes \cite{3}. The AHP approach was also adopted for agricultural management practices\cite{4}. Therefore, AHP could be a feasible method to evaluate the availability of selenium resources and Se-enriched division.

This study planned to establish a comprehensive evaluation methodology of selenium resources considering selenium, soil nutrients and environmental quality. Based on the AHP and the geographic information system, the availability of selenium resources of Wucheng would be comprehensively evaluated, which provided a good place for development of selenium-rich industry.

2. Assessment methods and procedures

2.1. Index for assessment of selenium

The general steps of AHP are to establish the structure of indexes, and calculate the weight of each index through constructing the judgment matrix\cite{5}. The target layer was the availability of selenium or the possibility of developing Se-rich industry. To establish criteria layer, we consider selenium, environmental quality, and soil fertility. Environment quality should be chosen as an index, which
affects the safety of agricultural products. High soil fertility promotes plants growth and it was considered necessary and meaningful to promote the absorption of selenium in crops[6].

Selenium content will be the main indicator. In the criteria layer of soil fertility, the content of organic matter, nitrogen, phosphorus, potassium, boron and molybdenum were selected as indexes. pH and the content of heavy metals were identified as indicators of the environment quality layer. pH and heavy metals are the main risk control indicators in farmland environmental quality standard [7].

2.2. Weight determination
Pairwise comparisons are classically carried out by asking experts and scholars according to 9-point scales respectively. Then, the importance of each index was transformed into numerical value and the judgment matrix was constructed. Weight determination was calculated using Yaahp software[8].

2.3. Standardization of evaluation data
The evaluation data needed to be standardization. The min-max normalization method was adopted to eliminate the effects of different orders of magnitude. Index of selenium resources and soil fertility were standardized through formula (1) as the positive indicator. The concentrations of heavy metals were standardized using formula (2). When the selenium content exceeds 3 mg/kg, the selenium content was standardized by formula (3).

\[
R_i = \frac{X_i - X_{\text{min}}}{X_{\text{max}} - X_{\text{min}}} \times 100
\]

\[
R_i = \frac{X_{\text{max}} - X_i}{X_{\text{max}} - X_{\text{min}}} \times 100
\]

\[
R_i = \frac{0.375/X_{\text{min}} - X_i}{X_{\text{max}} - X_{\text{min}}} \times 100
\]

i is the sample number; Ri is the calculation f; Xi is the ith measured value, Xmax is the maximum value in data, Xmin is the minimum value.

Total points (S) was calculated in each units according to the weights and the Ri of each factor, which was calculated using formula (4). Classing grades was reflected as a map operated by Arcgis 10.2.

\[
S = W_i \sum R_i
\]

i is the sample number; S is the total points; Wi is the weight of each factor; Ri is non-dimensionalized value.

2.4. Comprehensive evaluation
The availability of selenium resources is divided into five levels (Table 1). In grade I, the soil must be rich in selenium, clean and nutrient-rich. Contaminated soil was directly assigned into rank V. Zone II suitable for the development of selenium industry because of its high selenium content and good soil environment. Zone III was allowed to develop selenium-rich industry, whereas the content of selenium and nutrient element was poor. Zone IV was not suitable for the development of selenium-rich industry due to the lack of selenium.

Table 1. The rating table for the availability of selenium.

| Classification | S     | Features                           |
|---------------|-------|------------------------------------|
| I             | ≥65   | Priority development zone for selenium |
| II            | 35-65 | Relative suitable for development zone for selenium |
| III           | 25-35 | Suitable for development zone for selenium |
| IV            | 15-25 | Not suitable for development of selenium-rich agriculture |
| V             | <15   | Forbid the development of agriculture |

3. Evaluation of selenium resource availability of Wucheng

3.1. Study area
Wucheng was taken as a research area, which located in Jinhua city, Zhejiang province, China, which lied between the north latitude 28°44’ - 29°15’ and the east longitude 119°18’ - 119°46’ with an area of 1073 km².
3.2 Sample collection and analysis
2079 topsoil samples (0-20 cm) were collected over the entire area using stainless steel shovels. All topsoil samples were sieved through a 100-mesh sieve after air-dried at room temperature. The content of selenium, heavy metals and nutrient elements were analyzed for all samples.

3.3 Questionnaire survey
We invited experts in the field of selenium and soil environment to score the importance of the evaluation index. According to the scoring results, the weight matrix of each index was established.

3.4 Calculation of weights
The relative importance of each index were shown in Table 2. The results of the environment quality and soil fertility layer was derived by the same method. Then the weights of each factors were calculated by the Yaahp software according to the judgment matrix.

| Table 2. Results of important factor in criterion layer |
|--------------------------------------------------------|
| Selenium resources | Environmental quality | Soil fertility |
| Selenium resources | 1 | 3 | 7 |
| Environmental quality | 1/3 | 1 | 6 |
| Soil fertility | 1/7 | 1/6 | 1 |

According to the results of Yaahp, the weights of each factor were accepted as shown in Table 3. This evaluation system consists of 3 criteria layers and 16 indexes layers.

| Table 3. Weight of each factor of availability evaluation system of selenium resources |
|-----------------------------------------------|
| Criterion layer | Weight | Index layer | Weight | Total weight |
| Selenium resources | 0.641 | Se | 0.641 | 0.641 |
| | | pH | 0.083 | 0.024 |
| | | Cd | 0.252 | 0.074 |
| | | Hg | 0.076 | 0.022 |
| | | Pb | 0.099 | 0.029 |
| Environmental quality | 0.292 | As | 0.148 | 0.043 |
| | | Ni | 0.098 | 0.029 |
| | | Cu | 0.090 | 0.026 |
| | | Zn | 0.077 | 0.022 |
| | | Cr | 0.077 | 0.022 |
| | | TOC | 0.542 | 0.036 |
| | | N | 0.111 | 0.007 |
| | | P | 0.111 | 0.007 |
| | | K | 0.111 | 0.007 |
| | | B | 0.063 | 0.004 |
| | | Mo | 0.063 | 0.004 |
| Soil fertility | 0.067 | |

3.5 Evaluation results and suggestions
The evaluation results of selenium resource availability in Wucheng District are shown in Fig.1. Zone I was the most suitable for developing selenium-rich ecotourism, which was 361.1 km², mainly distributed in Southern valley districts. Zone II occupied the largest area in Wucheng (635.4 km²), accounted for 60.6% of total area, distributed in the northern alluvial plain. It was priority development zone for selenium because of the high content of selenium, with clean and fertile land. Zone III was 38.0 km², which was suitable for development zone for selenium through applying exogenous selenium fertilizer because of the lack of selenium. Zone IV and V covered 6.9 km² and 7.7 km², respectively. The selenium and soil fertility were relatively low in the soils of Zone IV and V, which was not suitable for the development of selenium-rich industry. The land of Zone V was impoverished and polluted.
4. Conclusions

The evaluation method and process of selenium resources were established, which provided scientific support for the development of selenium-rich agriculture. Wucheng in Zhejiang province, China was evaluated in to 5 levels by considering selenium, soil nutrient and environment quality. Zone I is suitable to develop selenium-rich tourism, which accounts for 34.4% of the total area. Zone II is suitable to develop selenium-rich agriculture. Selenium-rich brands can be built in these areas. Zone III and IV are not suitable for developing natural selenium-rich agriculture. Zone V accounts for 0.7% of the total area and it is forbidden to develop agriculture due to the pollution of soil exceeding the national standard. Therefore, Wucheng is suitable for developing selenium-rich agriculture with abundant selenium resources, sufficient soil fertility and safe soil environment.

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