Distribution characteristics of the soils in Henan province of central China based on pedodiversity methodology

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Abstract. A newly developed pedodiversity methodology was used in analyzing the distribution character of the soils in Henan province of central China. The rare soil types and representative soil types were defined after three soil parameters (soil patch numbers, total area and spatial distribution diversity in 2km×2km grid scale) were calculated respectively. Results show that there are positive correlations between soil patch numbers, total area and spatial distribution diversity, the regression equations between spatial distribution diversity and total area is \(y=0.086\ln(x)-0.021\), \(R^2=0.992\) and \(y=0.106\ln(x)+0.161\), \(R^2=0.921\) between spatial distribution diversity and patch numbers. The value constituent pattern of soil spatial distribution diversity fits the normal distribution. More attention needs to be paid to protect the endangered rare soil types. The soil type quantity per km\(^2\) is always different under different local conditions.

1. Introduction
Soil is one of the most important natural resources and also the fundamental element in the terrestrial ecosystem. Soils are classified based on their different physical and chemical properties from the combined effects of soil formation factors such as climate, organism, landform, parent material and time, and current soil classification system for the soil types in China is divided into soil order, suborder, group, subgroup, family and soil series [1]. The spatial distribution feature of different soil types follow some similar rules like the regional distribution of biological specie [2]. The diversity concepts and methodologies widely used in the biology research field have been introduced into the soil science in the early 1990s [3], making pedodiversity become an important topic [2,4,5].

The rational and proper use of soil resources is an inevitable requirement of the sustainable development strategy. In the past years, the rapid development of urbanization has occupied many endemic soil types [6,7] something like those endangered plant and animal populations, and the original local ecosystem destroyed in the bio-ecosystems.

In this work, Henan province in central China was chosen for the calculation of pedodiversity index of soil families before the classical (such as the statistics of soil total area, soil patch numbers, richness and Pielou index) and a new [8] measurement methodology were combined to obtain a better evaluation of the discreteness feature of different soil distribution in the view of spatial distribution. The whole Henan province here is divided into 5 subareas (eastern, western, southern, northern and
central Henan) according to their different geography, climate, terrain and other factors, and several kinds of related index have been counted before the distribution pattern of pedodiversity in Henan province analyzed. The distribution pattern of typical soils and rare soils in Henan province has also been analyzed to provide a scientific basis and monitor for the rational use of soil resources.

2. Materials and methods

2.1. General situation of the selected case areas and data source

Henan province (110°21′-116°39′E, 31°23′-36°22′N) is located in the east-central China, also the middle and lower reaches of the Yellow River, the total land area is 167,000 km\(^2\) with a resident population of 94.02 million (2010), its terrain is higher in the west and lower in the east, most of which is under warm temperate while very few area belongs to subtropical monsoon climate conditions and it is also a very important province as the national agricultural base. There are 15 soil groups, 39 soil subgroups and 138 soil families. The digital soil vector data taken from the second national soil survey and administrative map of Henan province were used in this study and operated by PC software ArcGIS 9.3.

2.2. Research method

The following formula which modified from the Shannon entropy is used to better evaluate the spatial discreteness based on the classic pedodiversity methodology (such as richness and Pielou index):

\[
Y_h = \frac{-\sum_{i=1}^{S} p_i \ln p_i}{\ln S}
\]  

In evaluating the spatial distribution diversity of a soil family, \( S \) expresses the total amount of spatial grids, \( p_i \) expresses the area ratio of number \( i \) spatial grid to the total area of the soil family. In this case, diversity index \( Y_h \) expresses the spatial distribution diversity, which is the discreteness degree of this soil family showing the diversity pattern of spatial distribution. The index \( Y_h \) values from 0 to 1, when the relative abundance distribution is extremely uneven, \( Y_h \) values 0, but when each object in a uniform distribution, \( Y_h \) values 1. There is a direct relationship between the \( Y_h \) value and the grid size or object distribution feature, but a recent study [9] showed that the calculated results have similar trend in some certain similar scales. Figure 1 shows an artificial example of the spatial distribution of a soil family, the central numbers in the grid express the soil total area in the grid, the numbers in the lower right corner express the serial number of each grid, and the spatial distribution diversity index \( Y_h \) in this example amounts to 0.727.

![Figure 1. Artificial example of spatial distribution of soil family](image)

The total area and patch numbers of each soil family in Henan province have been counted by using the classic research methodology before the spatial distribution diversity of soil family in 2km×2km grid scale is calculated, by which the soil distribution characteristic of Henan province has been analyzed and some rare soil families and representative soil families have been selected and defined.
before their rare or representative degree and geographic location or other information analyzed briefly to provide an objective data support for the soil resources protection in Henan province. Finally, the distribution pattern of pedodiversity has been evaluated under the different climate, basin and terrain conditions in Henan province according to the geographical principle.

3. Results and discussion

3.1. Statistics and correlation analysis of soil area, patch numbers and spatial distribution diversity

There are 138 soil family types in Henan province and the total area of which is 161800km² (water, urban core area and soil families without any attributes are not included), the Pielou index is 0.810 and that is to say the soil constituent in Henan province is relatively uniform.

Regression analysis (Figure 2) has been made based on the data sets of soil area, patch numbers and spatial distribution diversity to explore the internal relationship between the classic soil information statistical methodology and the new pedodiversity research methodology. It can be found that there are three certain degrees of positive correlationship between the three data groups, for instance, the soil family area is generally increased linearly with the increase of soil patch numbers (Figure 2a); there is an exceptionally accurate logarithmic function relationship (Figure 2b) between the soil family area and soil spatial distribution diversity with the coefficient of determination ($R^2$) 0.992; and there is an obvious logarithmic function relationship (Figure 2c) between the soil patch numbers and soil spatial distribution diversity with the coefficient of determination 0.921.

The difference between maxima and minima of soil distribution diversity is 0.7165, that is to say there is a huge difference in the spatial distribution range between the most widely distributed soil family and the least widely distributed soil family. The statistics of Table 1 is about the distribution pattern of soil family spatial distribution diversity in Henan province which consistent with the normal distribution.

| Numerical range | Soil family numbers |
|-----------------|---------------------|
| 0.0–0.1         | 2                   |
| 0.1–0.2         | 7                   |
| 0.2–0.3         | 12                  |
| 0.3–0.4         | 22                  |
| 0.4–0.5         | 29                  |

| Numerical range | Soil family numbers |
|-----------------|---------------------|
| 0.5–0.6         | 30                  |
| 0.6–0.7         | 26                  |
| 0.7–0.8         | 10                  |
| 0.8–0.9         | 0                   |
| 0.9–1.0         | 0                   |

3.2. Evaluation of rare and representative soil families

The statistics of the total area and patch numbers are generally used in the classic evaluation of soil rare degree, which can only analyze the classification pattern macroscopically but cannot describe the spatial distribution pattern directly. The new pedodiversity research methodology (spatial distribution diversity) now can be used to analyze the distribution characteristics of each rare and representative...
soil family in Henan province according to their constituent and spatial distribution.

Figure 3. Distribution patterns of rare soil families, representative soil families and subareas in Henan province

Total area, patch numbers and spatial distribution diversity are selected as the main assessment index of rare and representative soil families, and 10 groups of minimum value and 10 groups of maximum value of these 3 assessment index are selected in the rare soil evaluation and representative soil evaluation respectively. The soil family Lithic Eutric Rougi Orthic Primosol, Carbonati Hapli Ustic Argosol, Carbonati Calcaric Ustic Argosol, Sandy Lithic Ochri Aquic Cambosol, Dark Ferri Udic Argosol, Shajiang Calcaric Ustic Argosol, Hapli Ferri Udic Argosol, and Hapli Stagnic Anthrosol have the minimum value of the above mentioned 3 assessment index, that is to say these 8 soil types have the smallest area, least patch number and least discreteness distribution pattern at the same time, so they are selected as the rare soil families in Henan province. For instance, the soil type Lithic Eutric Rougi Orthic Primosol has the minimum assessment index (2.4km$^2$, 1 and 0.0802 respectively) so that this soil type is the rarest one in Henan province. The soil family Loamy Hapli Aquic Cambosol, Sandy Hapli Udic Cambosol, Aandy Ferri Udic Argosol, Clay Siltigic Aquic Cambosol, Sandy loamy Hapli Aquic Cambosol, Ferri Udic Argosol, and Earth cumuli Shajiang Calci Aquic Vertosol have the maximum value of the 3 assessment index, that is to say these 7 soil types have the biggest area, highest patch number and most discreteness distribution pattern at the same time, so they are selected as the representative soil families in Henan province. For instance, the soil type Loamy Hapli Aquic Cambosol has almost the maximum assessment index (first, fourth and first position respectively) so that this soil type is the most representative one in Henan province. The distribution pattern of rare and representative soil families are shown (Figure 3) and it can be clearly found that the central and eastern Henan don’t have any rare soil families, while central, northwestern and furthest southern Henan have a little representative soil families.

3.3. Evaluation of soil constituent in subareas
The distribution pattern of different soil types is influenced by climate, terrain and water environment factors so that different regions have different soil constituent characteristics. Henan province is divided into 5 subareas according to their different locations before some types of related data (Table 2)
are calculated. The Pielou index sequence is eastern Henan < northern Henan < southern Henan < central Henan < western Henan and the difference between the maximum and minimum is 0.1738, that is to say the soil distribution patterns have greater difference among the different subareas in Henan province. The soil family number is divided by the total area of subarea, namely the soil type amount in per km\(^2\), and the sequence of which is southern Henan (0.0010) < eastern Henan (0.0013) < northern Henan (0.0026) < western Henan (0.0028) < central Henan (0.0044), that is the central Henan has the most soil types while southern Henan has the least in the almost same area size. The reason for this phenomenon is still not clear but it can be inferred that there are some relationship between the single composing of soil types and high discreteness of surface water spatial distribution [10]. In further research next, there should be hopefully some new findings with more data to be taken into account.

| Subarea          | Soil family numbers | Pielou index | Total area of subarea (km\(^2\)) |
|------------------|---------------------|--------------|----------------------------------|
| eastern Henan    | 37                  | 0.6385       | 28933.7                          |
| western Henan    | 93                  | 0.8123       | 33014.7                          |
| southern Henan   | 59                  | 0.7604       | 60435.0                          |
| northern Henan   | 72                  | 0.7479       | 27696.6                          |
| central Henan    | 67                  | 0.8024       | 15290.3                          |

4. Conclusions
Both the classic and a newly developed pedological methodology have been jointly applied to the distribution pattern evaluation of Henan soil. Results show that: (1) the soil distribution in Henan province is comparatively even; (2) there is a significant connection between soil area, patch numbers and spatial distribution diversity, for instance the soil family and spatial distribution diversity follow a perfect logarithmic function relationship with the coefficient of determination (R\(^2\)) 0.992; (3) The value constitution of soil family spatial distribution diversity fits the normal distribution; (4) there are 8 rare soil families and 7 representative soil families in Henan province and the rare soils need special protection; (5) the soil constituent is always different in different subareas; (6) the soil spatial distribution diversity performs better than traditional pedodiversity in evaluating the soil spatial distribution patterns.

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