Soil Environmental Quality in Nan Ling Commodity Grain Base Based on Equal Intercept Transformation Radar Chart

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Research

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Abstract

Background: Nan Ling commodity grain base is a national high-standard farmland demonstration area. Scientific evaluation of soil environmental quality is of important significance to plan land resources rationally to improve the quality and efficiency of agricultural production.

Methods: This paper try to apply the equal intercept transformation radar chart –an improved radar chart– to the assessment of soil environmental quality. In the assessment, the area of equal intercept transformation radar chart is adopted to represents the soil environmental quality.

Different from the other assessment methods in common use, the equal intercept transformation radar chart method, as a visual graphic data analysis method, transforms data into graphics and therefore the data information can be retained and excavated more fully. Moreover, this advanced radar chart overcomes targetedly the main defect of the conventional radar chart that the evaluation result depends heavily on the order of arrangement of indicators.

Results: The results indicate that the soil environmental quality at depth of 0-60cm in low mountain area of Nan ling commodity grain base is the second grade while that in the hilly and plain area are both the first grade. The indicators of poor soil environmental quality in low mountain area are exogenous Cd and endogenous As, those in hilly area are exogenous Cd and endogenous As and Hg, and that in plain area is exogenous Cd.

Conclusion: It is proved through this special case study that the application of equal intercept transformation radar chart to the assessment of soil environmental quality is feasible and more intuitive, comprehensive and fine.

Background

Nan ling important commodity grain base，as an important component of Wan jiang Economic Belt，is a national high-standard farmland demonstration area and rich in high-quality rice and vegetables. The selection of planting patterns and stable and high yields of crops are largely controlled by the soil properties and quality of the base. Soil quality can be defined as the capacity of a specific type of soil to sustain plant and animal productivity, maintain environmental quality and support human health and habitation within natural or managed boundaries (Karlen et al, 1993). Soil quality integrates inherent and dynamic soil properties and is influenced by land use and management, which interacts with the soil system (Karlen et al, 2003). Soil environmental quality, as an important component of soil quality, reflects the level of harmful substances in the soil. The scientific, accurate and comprehensive assessment of soil environmental quality of study area has an important significance to plan land resources rationally, build high standard farmland, develop characteristic agriculture and improve the quality and efficiency of agricultural production (XiaoYan Li et al, 2019，Zahra Safadi et al, 2018).

Many methods and various models have been used for soil quality assessment (Sun et al., 2003; Nosrati, 2013; Zornoza et al., 2015; Mauricio et al., 2017). The commonly used methods of soil environment quality assessment include Single factor index method, Comprehensive index method, Fuzzy mathematics method, Multivariate statistical analysis and Artificial neural network method, etc.

The comprehensive index method has been successfully used to assess soil quality in many regions, at different scales and under different agricultural management practices (Obade and Lal, 2017; Yu et al., 2018; Qi et al., 2009; Nosrati, 2013; Fazel et al., 2014; Yu et al., 2018)

Helena Doležalová Weissmannová and Jiří Pavlovský (2017) provided a review about assessments of soil quality using various indices. The indices were divided into single indices and total comprehensive indices and the calculation formulae for every index with the classes of contamination or risk of soil indicated by the corresponding index value was presented respectively. This method can only provide the grade of soil quality, unable to display the difference of indicators' content，losing the uniqueness of data.

Yan Hu et al. (2016) applied the fuzzy mathematical method to the environmental risk assessment of soil at a petroleum-contaminated site in China，Distinguishing the primary environmental risk in the soil. This method considers the fuzziness of evaluation, but the determination of fuzzy weight is subjective, which directly affects the reliability of evaluation results.

Singh, S (2015) et al. performed the environmental risk assessment of heavy metal pollution using multivariate analysis in the soils of Varanasi environs, India，identifying the principal Contaminants. However, this method has shortcomings in classification and consistency check.

Yong Liu et al. (2016) assessed the soil quality basing support vector machine of the soil polluted by heavy metal in Tai Yuan city and provided a classification of the soil quality. These similar intelligent algorithm have a strong ability to build mapping relationships，but the models training and computation are complex.

Radar Chart, named for the chart like navigation radar, also known as Spider Chart, is a graphical method of data analysis. It draws the value of multiple related attributes by a certain method, then through the analysis of the painted charts, so as to achieve the purpose of comprehensive evaluation of the object. Radar Chart is mainly used in the evaluation of enterprise's financial condition, operation risk assessment and so on.

Du Aiwen (2007) applied the radar chart method to audit the economic benefits of two companies, obtained the evaluation results, and analyzed the reasons to provide the corresponding suggestions.

In the field of earth science and environmental quality, radar chart method has been rarely used，Zhang Qi et al. (2017) applied radar chart to distinguish basalt tectonic environment and trace mineral source area, analyzing its applicability and achieving certain effects，Zhang Xinyu (2014) compared and analyzed the environmental quality of different regions and different years using the radar chart method, and obtained the comprehensive environmental index. While in the assessment of soil environmental quality, the use of radar chart is still rare. Besides，There is a major weakness in traditional radar Chart method that the evaluation result varies wildly from one order of arrangement of indicators to another.

This paper used 1962 groups of soil samples collected from 1:5 million land quality geochemical survey, and selected Cd, Hg, As, Cu, Pb, Cr, Zn, Ni 8 indicators according to the People's Republic of China soil environmental quality standard (GB15618-1995, and GB15618-2008 referred) to explore the application of equal intercept transformation radar chart to assessment of the environmental quality of shallow soil in different landforms and depths of Nan ling commodity grain base. In the assessment, the equal intercept transformation radar chart area was used to represent the soil environmental quality level.

Different from the assessment methods of soil environment quality in common use, the equal intercept transformation Radar Chart, as a graphical analysis method, translates abstract figures into graphical figures, retaining numerical information faithfully and presenting it in a graphical form visually, which is more intuitive and clearer. Meanwhile, the area of equal intercept transformation radar chart is totally independent of the order of arrangement of indicators. And each set of sample data has only one corresponding equal intercept transformation radar chart, without losing its uniqueness, so that it is convenient to compare between different samples. In the process of assessment, each attribute of the chart represents one certain aspect of the environmental quality of the soil. Through the analysis and research of chart, expressing figures in the chart and describing the chart by figures, figures and the chart can be really combined and the information of figures can be more fully excavated, so that the assessment results are more comprehensive and finer (Lee AJT et al, 2016；Romain Chaumillon et al, 2017；Shun xi Li et al, 2017).

1 Survey Of Research Area

In this paper, the study area for Nan ling national important commodity grain base is located in the southeast of Anhui province with geographic coordinates of E117°30'57"-E118°31'30", N30°35'20"-N31°10'40" and a total area of about 880 km^2 (see Fig.1).

The research area belongs to the humid monsoon climate zone of north subtropical zone, which is rich in hydrothermal resources, especially in June and July. The research area belongs to the Yangtze River basin, and the rivers flowing through the area are mainly Qingyi River and Zhang River and its many tributaries. As the largest tributary of the middle and lower reaches of the Yangtze River, the Qingyi River flows from the south to the east of the study area, and it is the drainage datum of surface water and groundwater in the study area; The Zhang river originates in the area, and the general flow is from south to north; The two rivers are communicated by the Zifu river. In the northeast of the study area, the rivers and lakes are connected and the water is developed.

The study area is located in the transitional zone from the mountainous area of southern Anhui Province to the plain along the Yangtze River. In general, the southwest topography is the highest and gradually decreases to the northeast, forming the low mountain areas (I), hilly areas (II) and plain areas (III). The soil types in the study area are mainly acidic paddy soils.

The study area is an important part of the Wan jiang Economic Zone. Nan ling county in the area is the main grain-producing area in Anhui province, where rice and tea are abundant. Scientific evaluation of soil environmental quality is the inherent requirement of high standard farmland planning and construction in this area.

2 Evaluation Method

2.1Equal Intercept Transformation Radar Chart

Radar chart method–named for its radar like shape–is a kind of a visual graphic data analysis method. It can be applied to comprehensive evaluation of an object composed of several indicators. It realizes the visualization of data by transforming figures to graphics. The figures are expressed by graphics and graphics are described by figures, through the analysis and study of the radar chart, the data information is fully mined and comprehensive evaluation results of the object are obtained.

In the application process, the distances from the origin to the end of different axes should not vary too much. If the gaps between different indicators are too large, it needs to be scaled by a certain method so that the corresponding length of the line segments on the graph is in the same order of magnitude. The values represented by the coordinate ranges and unit lengths of different axial directions may be different to suit the actual values of different indicators.

The original radar chart method exists a major disadvantage that the evaluation result has strong relation with the order of arrangement of indicators. To response this problem，this paper introduce the equal intercept transformation radar chart.

Its basic process is: firstly, N rays drew with the same angle from the same origin as figure axis respectively represent the N indicators of the evaluation objects; secondly, a fixed length line segment was cut on the bisector of every two adjacent index axes, i.e. "equal intercept"; thirdly, With the coordinates of each index value, the N points are made on the corresponding axis; finally, the N points and N ends of intercepts are connected successively by line segments to form a 2N-side polygon, equal intercept transformation Radar Chart.

2.2Assessment process

This paper used 1962 groups of soil samples collected from 1:5 million land quality geochemical survey, and selected Cd, Hg, As, Cu, Pb, Cr, Zn, Ni eight indicators according to the People's Republic of China soil environmental quality standard (GB15618-1995, and GB15618-2008 referred) to explore the application of equal intercept transformation radar chart in assessment of the environmental quality of shallow soil in different landforms and depths of Nan ling commodity grain base.

The average values of each index of soil samples at different depths in different geomorphic areas of the study area were calculated respectively, and the equal intercept transformation radar charts were drawn accordingly. The standard values of soil environmental quality given by GB15618-1995 were also drawn on the charts. In the drawing，instead of directly using the data of each indicator's content，it was magnified properly to make the content of different indicator unified to the same order of magnitude.

Then these drawn radar charts were analyzed：Firstly, a single indicator analysis was carried out to separately calculate the environmental quality levels of the soil indicators at different depths in different geomorphological areas; Secondly, The area of each equal intercept transformation radar chart（which represents the comprehensive soil environmental quality）was calculated (see Formula 1) respectively and compared with that of standard radar chart. Thus, the soil environmental quality of each evaluation unit was classified according to GB15618-2008.

$$S = \sum_{1}^{n} A_i L \sin\frac{\theta}{2}$$

Formula 1

In the formula, *n* represents the number of indicators (*n*=8 in this paper); A_i represents value of *i* indicator/axis; L represents "equal intercept"(*L*=150 in this paper) ; 0 represents the angle between two adjacent axes(0=45°, constant) ; *S* represents area of radar chart.

The above calculation results are presented in the corresponding charts, which were analyzed to draw the conclusions.

3 Results And Analysis

The equal intercept transformation radar charts of soil environmental quality at different depths in the low mountain, hilly area and plain area of the study area are drawn respectively (shown Fig.2 to Fig.10).

3.1 Area analysis of radar chart

The equal intercept transformation area of the radar chart represents the soil environmental quality. The areas of the above equal intercept transformation radar charts are shown in the Tab.1

Tab. 1 The areas of the equal intercept transformation radar charts

	Low mountain	Hilly area	Plain area
0-20cm	153486.10	125736.07	128539.04
20-40cm	151161.69	124648.11	115603.52
40-60cm	149724.75	116579.18	111043.29
First level grades	128820		
Second level grades	205200		

The areas of the soil environmental quality equal intercept transformation radar charts of various geomorphic units at different depths were compared with the standard radar chart respectively，If certain one is less than the standard radar chart area of the first grade, the soil environmental quality level of the corresponding geomorphic unit and corresponding depth is the first grade，While if it is between the standard radar chart area of the first grade and that of the second grade, the soil environmental quality level of the corresponding geomorphic unit and corresponding depth is the second grade. According to this, the soil environmental quality level of each depth of each geomorphic unit can be obtained (see Tab.2).

Tab. 2 The soil environmental quality level of each depth of each geomorphic unit

	Low mountain	Hilly area	Plain area
0-20cm	Second level	First level	First level
20-40cm	Second level	First level	First level
40-60cm	Second level	First level	First level

As is shown in Tab.2，According to the table, the soil environmental quality of 0-60cm in low mountain area is the second grade, which can be described as "still clean" and generally pollution-free. The soil environmental quality of 0-60cm both in hilly area and plain area is the first grade, which is clean and pollution-free.

The areas of the soil environmental quality equal intercept transformation radar charts of different geomorphic units and different depths was drawn into a columnar map (shown Fig.11).

As can be seen from Fig.11，in space，there is not much difference in soil environmental quality between the hilly area and the plain area, which are both superior to that in the low mountain area. Specifically, the soil environmental quality of 0-20cm is ranked as hilly area > plain area > low mountain area and that of 20-60cm is ranked as plain area > hilly area > low mountain area.

In vertical, with the increase of depth, the soil environment quality in low mountain area, hilly area and plain area gradually increased. In the hilly area and plain area, the soil environment quality changed greatly, while that in the hilly area changed little. The soil environmental quality in hilly area increased significantly from 20-40cm to 40-60cm, while the increasement in plain area occurred from 0-20cm to 20-40cm.

3.2 Analysis of each factor

The soil environmental quality of 0-20cm is ranked as hilly area > plain area > low mountain area and that of 20-60cm is ranked as plain area > hilly area > low mountain area.

As is shown in Fig.2 to Fig.10,the indicators of poor soil environmental quality of shallow soil in low mountain area are Cd and As, those in hilly area are Cd, As and Hg and that in plain area is Cd.

At a depth of 0-20cm, the mining of gold and copper mines with high Cd in low mountain areas and the application of phosphate fertilizers with high Cd content have significantly increased the Cd content in the soil of low mountain area. In addition, the soil in the low mountain areas is mostly lime soil, of which the parent material is carbonate weathering, with a high As content. Therefore, the soil environmental quality in the low mountain area is the worst.

The plain area is flat and open with developed water system and deep soil layer, which is a large area of farmland. The long-term and large-scale application of phosphorus fertilizer with high Cd content makes the Cd content of farmland soil in plain area higher and the soil environment quality worse.

In comparison, the imported Cd in the soil in the hilly area is lower and the soil environmental quality is the best.

Below 20cm depth, as the depth increases, the soil particle size gradually decreases, and the clay mineral content in the soil gradually increases. The elements content mainly derived from the parent material of the soil gradually increase. For example, the endogenous Cd in low mountain soil increases with depth. The parent material of soil in hilly area is mostly weathered sand conglomerate, in which the content of As and Hg is high. With the increase of depth, the contents of As and Hg in hilly area soil increase. On the other hand, the exogenous elements are mainly adsorbed on the surface of clay minerals and soil organic matter. With the increase of depth, although the clay mineral content increases to some extent, the organic matter content decreases significantly, so the imported Cd content in the plain area soil decreases. Therefore, the soil environmental quality in the low mountain area is still the worst, while the soil environmental quality in the plain area surpasses that in the hilly area.

Beyond the above elements, the contents of Cu, Pb, Cr, Zn, Ni are generally low on the whole, which are stable or in a good trend vertically.

4 Conclusions

（1）The equal intercept transformation radar chart method was applied to the assessment of the shallow soil quality of Nan ling commodity grain base. The results are in line with the actual conditions in the study area, and the method is feasible and has unique advantages: The equal intercept transformation radar chart method can retain and excavate more data information by a more intuitive and efficient visual analysis process. Above all, the equal intercept transformation radar chart overcomes targetedly and effectively the main defect of the conventional radar chart that the evaluation result depends heavily on the order of arrangement of indicators.

(2)The soil environmental quality at depth of 0-60cm in low mountain area of commodity grain base is the second grade while that in the hilly and plain area are both the first grade. The soil environmental quality of 0-20cm is ranked as hilly area > plain area > low mountain area and that of 20-60cm is ranked as plain area > hilly area > low mountain area.

(3)The indicators of poor soil environmental quality of shallow soil in low mountain area are imported Cd from mining of gold and copper mines with high Cd in low mountain area and the application of phosphate fertilizers with high Cd content and endogenous As from parent material of the soil-carbonate weathering, that in hilly area are exogenous Cd and endogenous As and Hg from parent material of the soil-weathered sand conglomerate and that in plain areas is exogenous Cd from long-term and large-scale application of phosphorus fertilizer with high Cd content.

5 Innovations

(1)This paper applied the equal intercept transformation radar chart method to the assessment of soil environmental quality exploratively. Through a special case study, it was proved that the method is feasible and can fully retain and excavate the data information, and the visual analysis is more intuitive, efficient, comprehensive and fine. Most importantly, the equal intercept transformation radar chart overcomes targetedly and effectively the major weakness of the conventional radar chart that the evaluation result depends heavily on the order of arrangement of indicators.

(2)In the assessment, this paper try to introduced a new idea researchfully that let the area of equal intercept transformation radar chart represents the soil environmental quality. By calculating it, we can obtain the assessment of soil environmental quality.

(3)In the assessment, instead of directly using the data of each indicator's content, it was magnified properly to make the content of different indicator unified to the same order of magnitude, which is convenient for comparison and analysis.

6 Discussion

As a graphic data analysis method, the basic idea of radar chart is to draw multiple attribute values of the objects into radar charts according to certain methods, and by analyzing the drawn figures to achieve the purpose of comprehensive assessment of objects. The quality of soil environment is determined by the soil environmental indicators. Therefore, the application of radar chart to the assessment of soil environmental quality is applicable in theory. This research also confirmed this point. Compared with traditional methods, the radar chart method transforms data into graphics and through an intensive analysis of graphics, the data information can be retained and excavated more fully. Thus, the assessment is more intuitive, comprehensive and fine by combining figures and shapes.

However there is a major disadvantage in traditional radar chart method that the evaluation result has a strong relation with the order of arrangement of indicators. The application of equal intercept transformation radar chart can solve it effectively.

This paper analyzed the area of equal intercept transformation radar chart, based on which soil environmental quality was assessed. In the future research, we can analyze the other more attributes of equal intercept transformation radar chart, identify its meaning so as to excavate the data information more furtherly and to enrich the assessment continually.

Declarations

Ethics approval and consent to participate Not applicable

Consent for publication Not applicable

Availability of data and materials The datasets used or analysed during the current study are available from the corresponding author on reasonable request.

Competing interests: The authors declare that they have no competing interests.

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Authors' contributions MJY, YLT and HBD jointly completed field investigation and sampling; HBD was the major contributor in writing the manuscript conducting data analysis and research; GHZ conducted guidance and verification on the manuscript. All authors read and approved the final manuscript.

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Figures

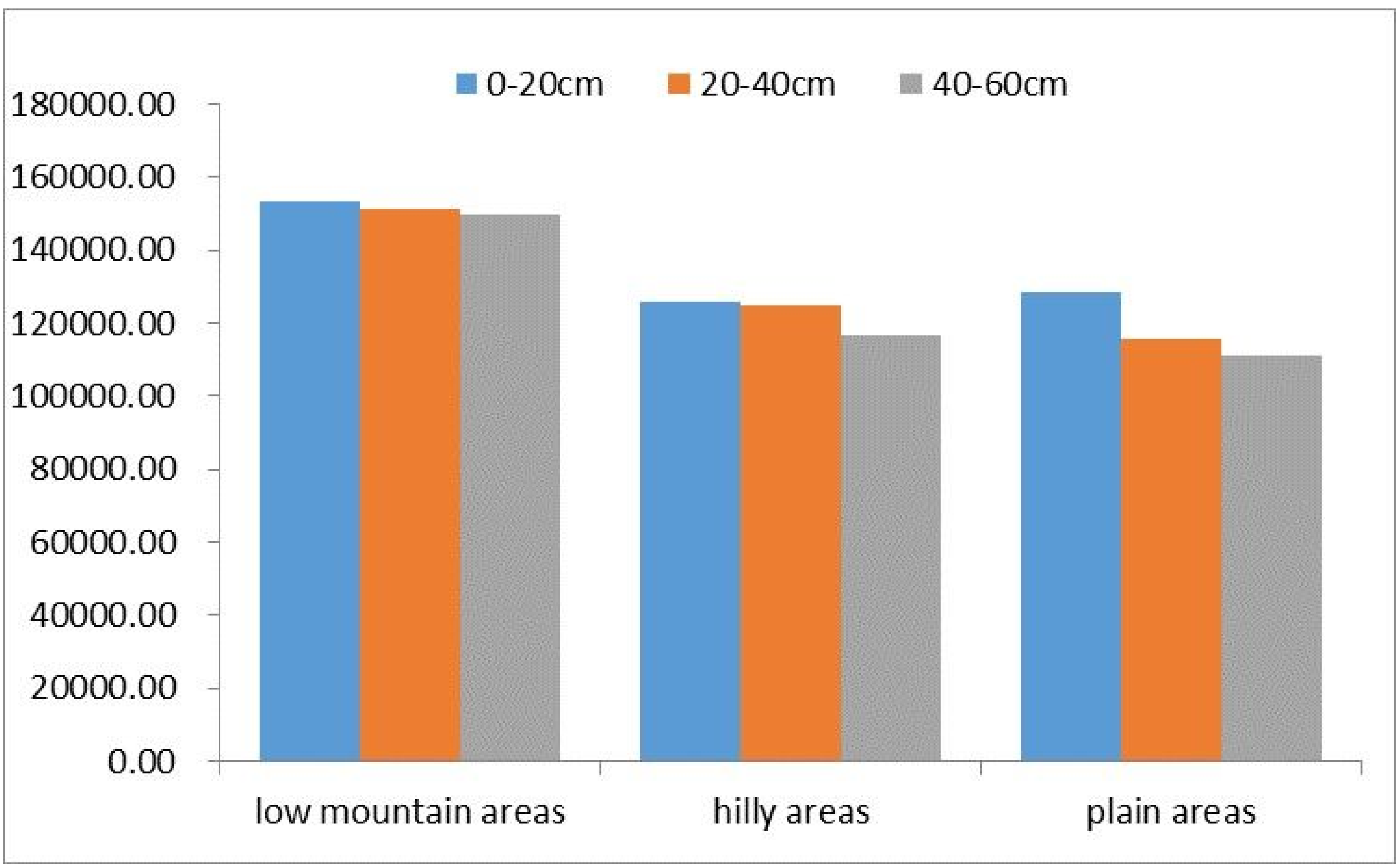

Figure 1

The soil environmental quality (represented by areas) of each depth of each geomorphic unit

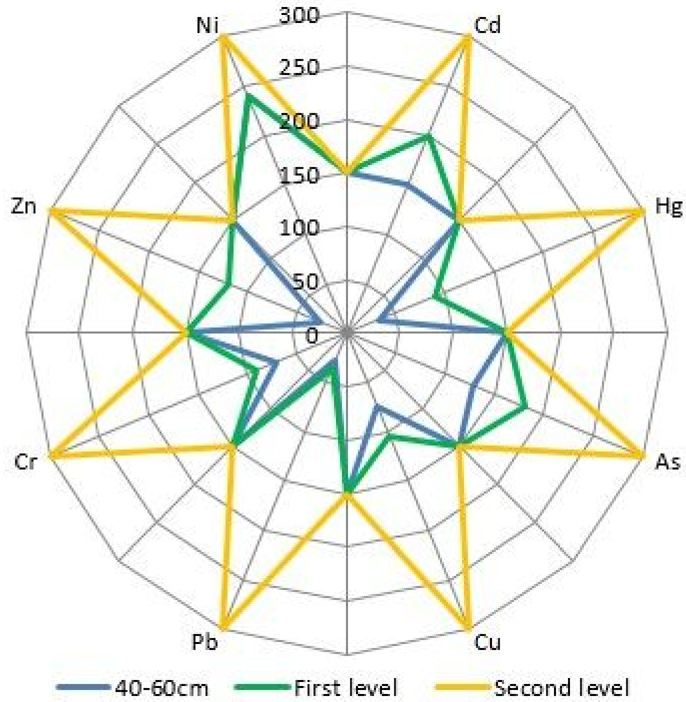

Figure 2

Environmental Quality Radar Map of 40-60cm Soil in Plain Areas

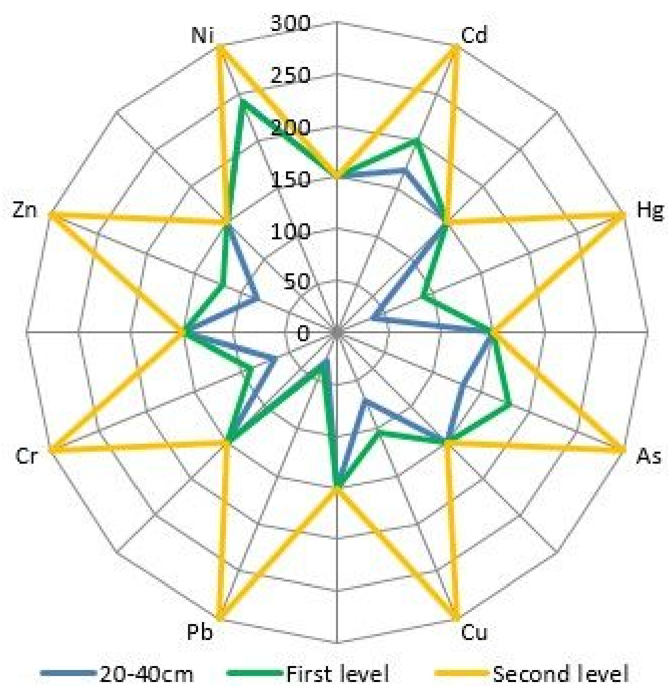

Figure 3

Environmental Quality Radar Map of 20-40cm Soil in Plain Areas

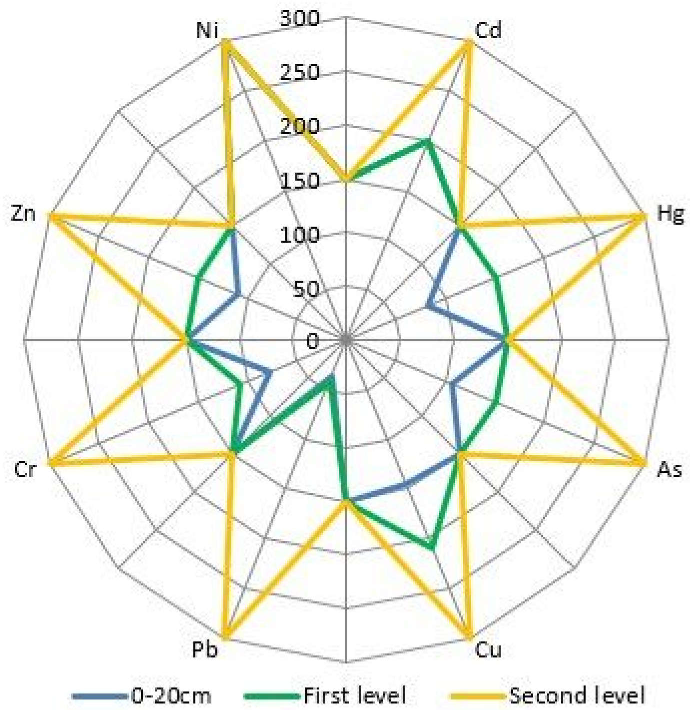

Figure 4

Environmental Quality Radar Map of 0-20cm Soil in Plain Areas

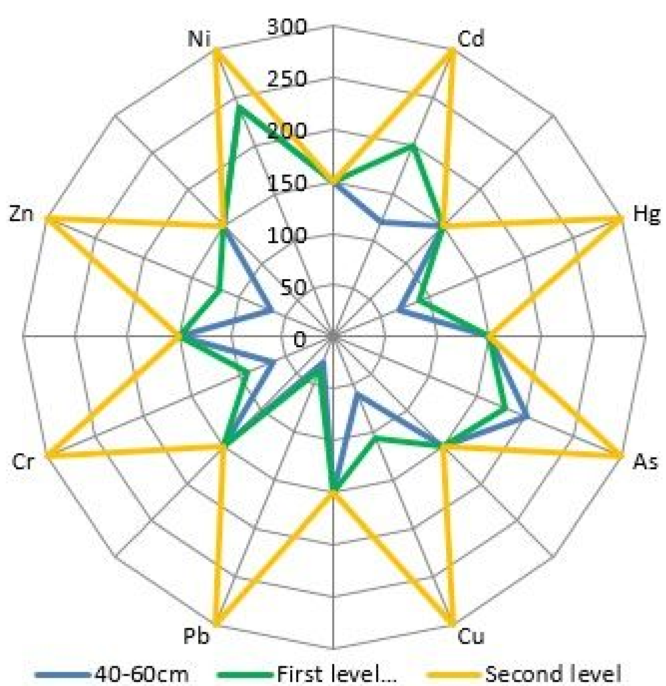

Figure 5

Environmental Quality Radar Map of 40-60cm Soil in Hilly Areas

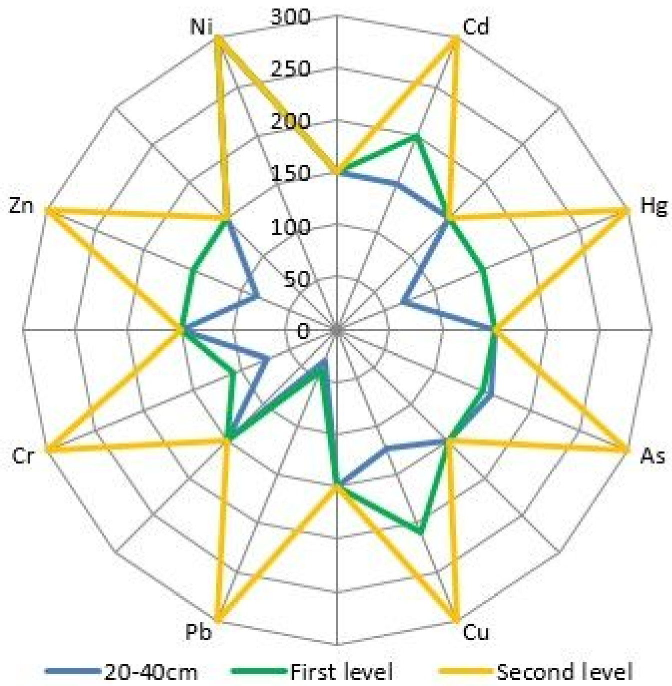

Figure 6

Environmental Quality Radar Map of 20-40cm Soil in Hilly Areas

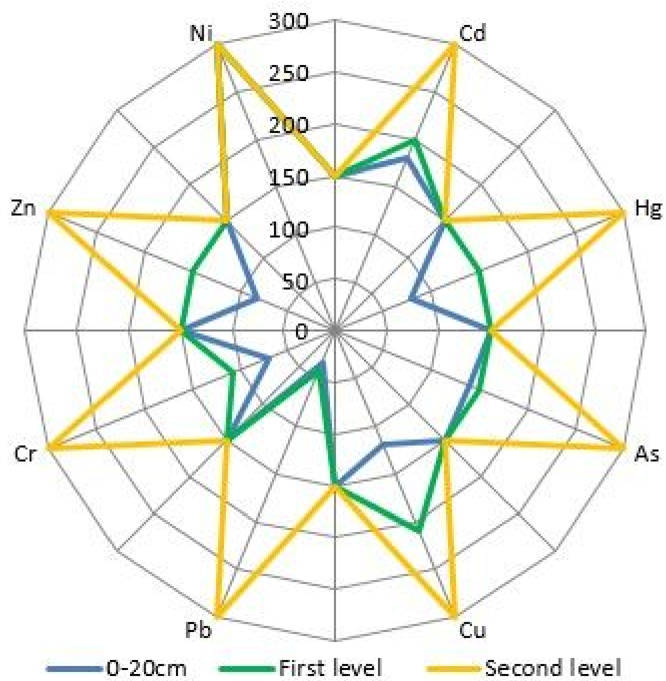

Figure 7

Environmental Quality Radar Map of 0-20cm Soil in Hilly Areas

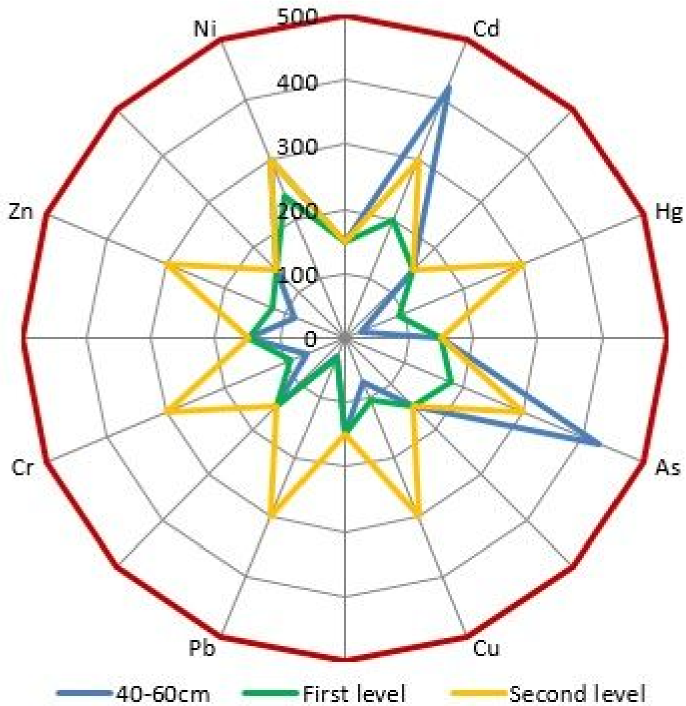

Figure 8

Environmental Quality Radar Map of 40-60cm Soil in Low Mountainous Areas

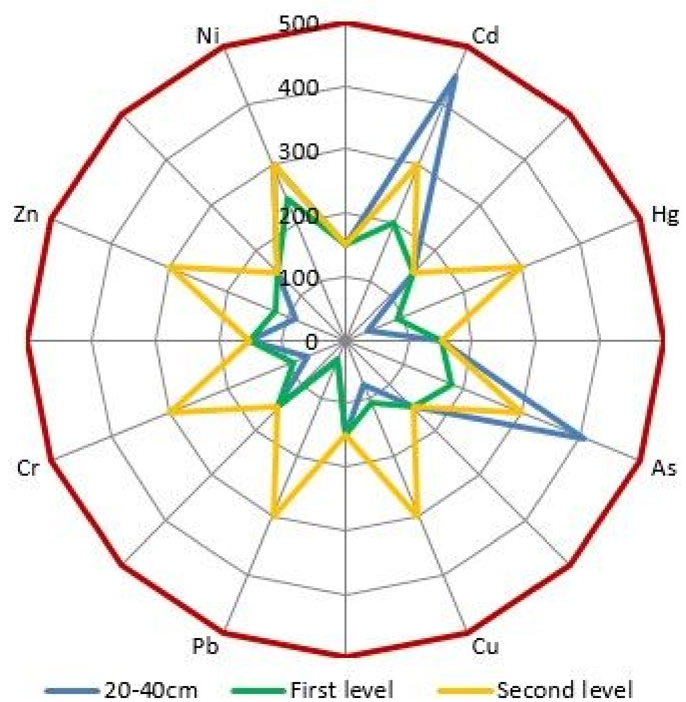

Figure 9

Environmental Quality Radar Map of 20-40cm Soil in Low Mountainous Areas

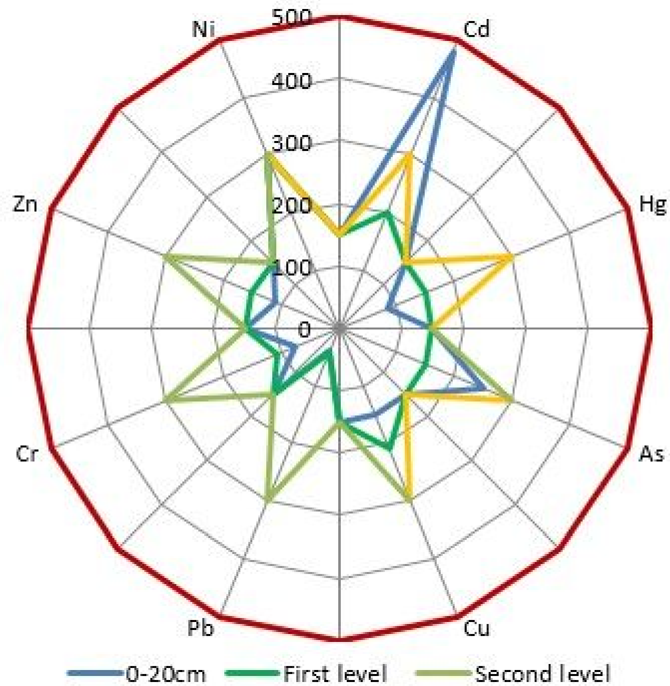

Figure 10

Environmental Quality Radar Map of 0-20cm Soil in Low Mountainous Areas

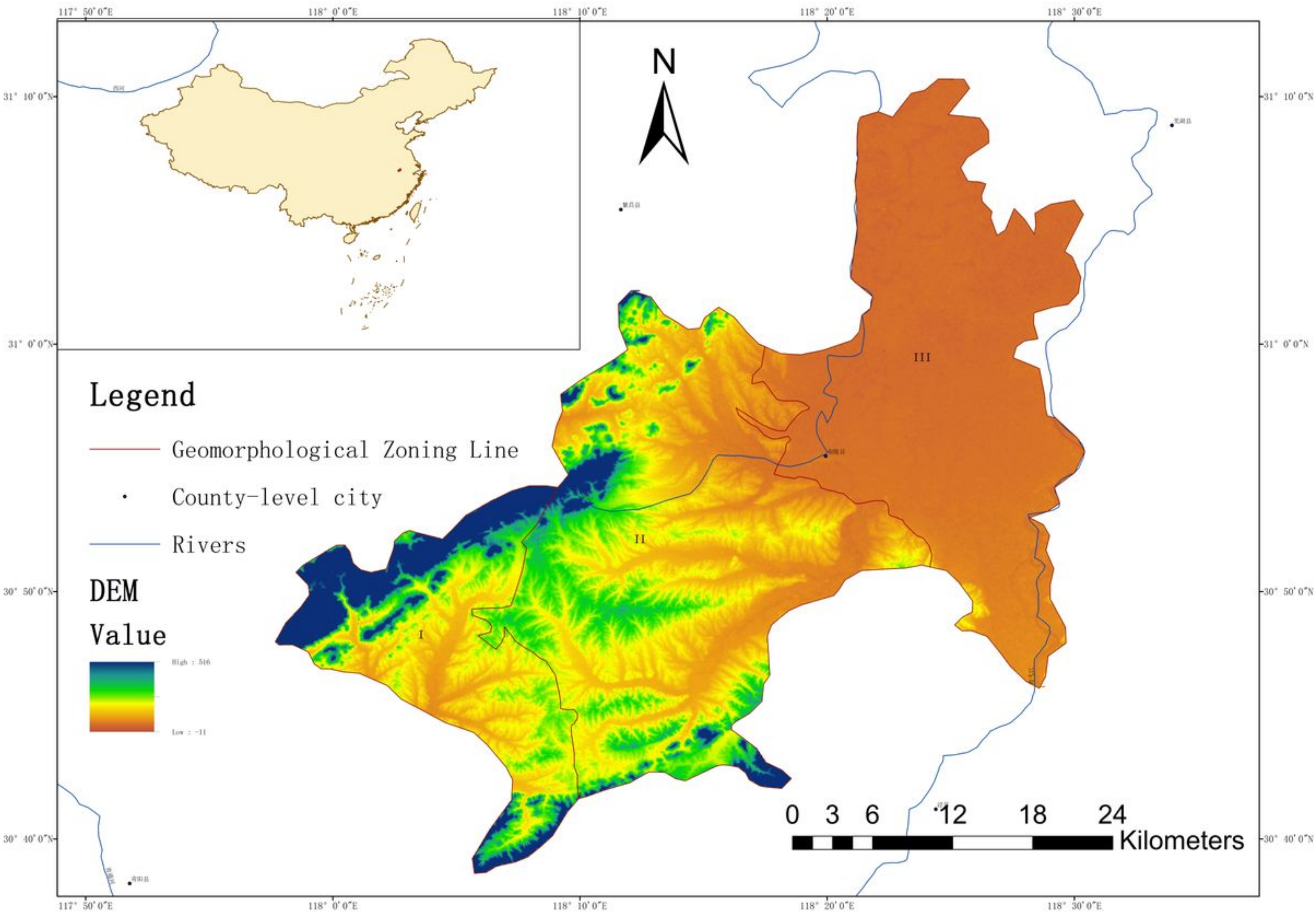

Figure 11

Topographic and geomorphological maps of Nan ling area. Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.