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Pedodiversity analysis in Hainan Island

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Diversity indices and abundance distribution models are statistical tools which ecologists have applied for decades for analyzing the intrinsic regularities of various ecological entities. In this work, we have applied these techniques to use the notions such as pedodiversity (as an example of geodiversity in a broad sense), in order to detect the differences and similarities between both natural resources, biological and non-biological. The discussion has mainly been conducted through the study of landform based pedodiversity analysis applied to SOTER digital databases in Hainan Island, China. The main analytical methods include indices of richness S that are the number of the categories (SOTER units relating to different soils in this work), indices based on proportional abundance of categories H´ and E which are not only the number but also their relative abundance (in our case, the relative area occupied by each pedotaxa) is taken into account, models of the distribution of abundance of categories that provide the most complete description but also the least abridged and GIS mapping to show the spatial variation digitally.

Pedodiversity analysis in Hainan Island ZHANG Xuelei1, CHEN Jie1, ZHANG Ganlin1, TAN Manzhi1, J.J. Ib??_??kez2 (1. Institute of Soil Science, CAS, Nanjing 210008, China; 2. Centro de Ciencias Medioambientales, CSIC, Madrid 28006, Spain) 1 Introduction Measuring biodiversity has become a growing industry during the past years (Rosenzweig, 1995; Williams et al., 1996). However, measuring geodiversity (e.g. geological forms and structure, landforms, sedimentary deposits, minerals, rocks, fossils, soils and so on), has not achieved the same degree of development, even though its inventory and preservation are essential to know, to study and to interpret the geological history of the Earth, the processes that modeled it, and the past and present climates and landscapes, as well as the origin and evolution of life. Only recently, earth scientists have become involved with these problems in a similar way as the ecologists have followed. International and national forums begin now to be organized. Example are The European Association for the Conservation of the Geological Heritage (ProGEO) www.sgu.se/hotell/progep or www. sgu.se and the "Comisi?炸n de Patrimonio Geol?炸gico de la Sociedad Geol?炸gica de Espa??ka", etc. The last one makes an explicit reference to the interest of the study of geodiversity. The characterization and quantification of several aspects of geodiversity (e.g. geomorphic diversity, lithodiversity and pedodiversity) should be taken into account when estimating a territory´s ecological value because they are referred to as non-renewable natural resources that have profound qualitative and quantitative repercussions on the architecture of landscapes, ecosystems and biocenoses (Chen et al., 2001; McBratney, 1992; McBratney, 1995; Ib??_??kez et al., 1990; 1995a). At the same time, this may be one of the ways to explore, quantify and compare the complexity of abiotic landscape structures in different areas and environments (Ib??_??kez et al., 1995b; 1997; 1998). It is also reasonable to suppose that lithologic diversity and geomorphic diversity should be correlated in many instances. Certain methodologies and mathematical techniques from biological diversity are used in this work but with the discussion of their suitability and the implications of their use in pedodiversity problems. 2 Material and methods 2.1 Study area Hainan Island is the southernmost and tropical part of China. It covers 3.4 million ha and is one of the sparsely populated provinces of China with an estimated population of 7.24 million. Economic and ecological sound tropical agriculture is a pillar in the development of the regional economic strategy by the local governments. Some tropical crops, such as rubber and banana, are widely grown but with varying success. Hainan Island has a monsoon tropical climate, with annual mean temperature of 22-26oC. Annual average rainfall varies between 2,000 mm on the east coast to about 1,000 mm on the west coast. Seasonally Hainan suffers from typhoons that hit the island from the South China Sea. Cold air masses from continental China cause temperatures to fall below 3oC and damage crops. In some years the cold surge frequencies are lower, coinciding with El Nino, as do prolonged summer droughts. 2.2 Data Hainan has a wide array of tropical soil types at low and middle high altitude land, and other soil types at high elevations in the central mountains. A multiple scale GIS-based soil and terrain digital databases (SOTER) of Hainan have been developed provincially named HAISOTER databases at 1:250,000 scale (1998 to 2002). This includes the soil type of each SOTER unit plus the landform and other items. The dominant soil is defined as the soil that occupies the largest area of the unit. Each unit is numbered. This number is reported within each polygon and is the key to the legend of the digital map. The resultant soil database was stored in Excel format that can be used to do the indices calculation, analyze how our data conform to the abundance distribution models and show by GIS operations. 2.3 Analytical method The main analytical methods include indices of richness S that are the number of the categories (e.g. biological species, communities, pedotaxa, soilscapes, etc.) known to occur in a defined sampling area, indices based on proportional abundance of categories H´ and E which are not only the number but also their relative abundance (in our case, the relative area occupied by each pedotaxa) is taken into account, models of the distribution of abundance of categories that provide the most complete description but also the least abridged and GIS mapping to show the spatial variation digitally. 3 Results and discussion 3.1 Indices for quantitative pedodiversity analysis Similarly to studies of biological diversity, proportional abundance (Shannon Index) of taxonomic categories were used to estimate diversity in terms of richness (number of taxonomic categories SOTER units relating to certain soil types, SU) and evenness (distribution of taxonomic categories by areal abundance) (Shannon et al., 1948): H´ = -Σpi ln pi where H´ is Shannon Index, pi is estimated by means of ni/N where ni is the area covered by ith category (SU) and N is the total area studied. The relationship between the observed value of H´ and its maximum value (for a given richness occurs when all SUs are equiprobable) is used as a measure of evenness E (Pielou Evenness Index) (Pielou, 1969): E = H´/Hmax = H´/ln S where S is the richness or the number of categories and E takes values in the interval |0,1|. We calculate these indices by the number and the area of the related SUs, representing by H´1, H´2, E1, E2 and S1, S2 respectively. From Table 1 and Figure 1, we can draw some conclusions as follows: 1) The SUs relating to certain soil types richness (S values) were relatively variable amongst different landforms. SM had the lowest pedorichness when the landform LP had the greatest pedosphere richness. Other landforms were intermediate with respect to SU-soil richness. 2) Shannon´s index (H´ values) and Evenness index (E values) for different landforms were also marked. Obviously, the landform SM had the lowest values while the landform LP had the highest for Shannon indexing. The landform LV with E value larger than 0.9 has the SUs relating to soils best evenly distributed. 3) From Figure 1, we can see the good linear fitness of the indices H´1 and H´2 respectively calculated either by the number or the area of the related SUs. The r value is more than 0.95, indicating that it is acceptable to get the Shannon index by these two ways. 3.2 Models of the distribution for the abundance of soil related SUs The most popular models in Ecology (May, 1975; Magurran, 1988; Tokeshi, 1993) have been reported. Some of them fit our data some not. Here we introduce one model conforming to our data. Lognormal Model is a mixture of several other models like Geometric Series Model and Broken-stick Model. The segment of unit length is broken, at a randomly chosen point, into two parts. One part is chosen randomly and independently of its length, and it is broken again into two parts by choosing one of its points at random. One of the three resulting parts is chosen randomly and independently of its length, and it is also broken into two parts by choosing one of its points at random, and so on. Thus, the distribution of the lengths of all the parts tends to lognormal form (Kolmogorov, 1941). In Ecology this has the following interpretation: If we now assume that the species in a multispecies community have divided up some limiting resource among themselves in this manner, and that the abundance of each taxa is proportional to its share of the resource, then the taxa-abundance distribution is lognormal. This fragmentation process has been applied previously in soil sciences in connection with aggregates and particle-size distribution (Hatch, 1933). In this case, the density function is f (x) = exp where ?滋y and ?滓y are the random variable mean and standard deviation of y = logx. The parameter y is also used to characterize this distribution. Following May (1975) it holds that ?酌 = where ST is the total number of taxa. When this parameter equals one, it is called the canonical lognormal distribution. We use software Species Diversity and Richness (version 2.6, Henderson, 1998) to input our data for running the calculation of various diversity indices and fitting of common distributions. Each of the output windows has at a button which will present the estimate for each landform graphically. We first need to create the data set by using Microsoft Excel or many other spreadsheets, word processors, database programs etc. It is recommended that we organize large data sets using a spreadsheet program like Excel as this will give access to a wide range of sorting and editing procedures to ease the task. The software then gives us the observed and expected abundances of the SUs for the landform LP (LP is used here as an example). These are arranged in abundance classes and the upper column gives the upper bound of each class. The Chart tab shows a plot of the observed and ex pected frequency distributions arranged by class. The observed are plotted as a histogram and the expected as a curve (Figure 2). The results of a Chi-Squared test of the observed and expected observations are also given. The value of p = 0.613181 for landform LP then the distributions of the soil related SUs are significantly different at the 61.3181% level. These results can be copied onto the clipboard by selecting copy from the edit menu in the normal Windows manner. 3.3 Spatial analysis by GIS operations It is convenient to show the variation of SUs relating to certain soil types by using GIS Arcview (Zhang et al., 2001) in which we can do any needed spatial analysis and layout maps for possible users. The landform LP and its attached soils can be queried and mapped easily in Arcview environment (Figure 3). In its legend edit tool, we can obtain the results of what soils relating to the SUs for the landform LP. Some 465 out of all the 1443 SUs reach the conditions of both the landform LP and related soils (Cooperative research group, 2001). 4 Conclusions Diversity indices and abundance distribution models are statistical tools ecologists have applied for decades for analyzing the intrinsic regularities of various ecological entities. It would be interesting to use these techniques in pedological studies with the purpose of detecting the similarities and differences between both natural resources, biological and non-biological. In this paper we have applied them to specific pedological examples in Hainan Island of China supported by its provincial SOTER digital databases. We only present part of our work reflecting pedodiversity analysis for landforms. Actually we have conducted other related research including pedodiversity analysis for different parent materials, lithodiversity analysis for different landforms and soils, geomorphic diversity analysis for different parent materials and soils. All of these above-mentioned aspects of geodiversity analysis are equally important and interesting because the more geodiversities we consider the better we could do for eco-system and environmental conservation around us. Since results in ecological literature are usually interpreted in biological terms, our analysis may be relevant to offer some suggestions to the following questions to be solved in the future including the reasons for the similarities obtained between biotic and soil resources, ecological theory modification on some of its constructs once these similarities have been proven, and the implications for environmental management and assessment. 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关键词： Hainan Island; SOTER digital databases; pedodiversity; landforms; abundance distribution models; GIS spatial variation

