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APPLICATION OF GIS IN ANALYZING ECOSYSTEM'S RELATIVE SENSITIVITY TO ACID DEPOSITION

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ABSTRACT: This paper describes an application of GIS technology in estimating ecosystem's relative sensitivity to acid deposition. East China is selected as the research area. Four variable layers, which are base rock, soil buffering ability, vegetation type and soil humidity, are used in the process. Five grades are separated in this research. The sensitivity mapping is also discussed in this paper.
DEY WORDS: acid deposition, sensitivity index, geographic information system

INTRODUCTION

With the rapid development of economy, the environmental problems becomes more concened in China. Among the environmental problems, acid rain is one that attracts more and more attention. According to the meteorological observations, the frequency of the rain with its pH less than 5.6 is over 50 percent in most part of east China.

Acid rain is a lay term for the recognized environmental problem caused by chemical reactions in the atmosphere of emissions of pollutants such as SO_X and NO_X with water and oxygen. The SO_X and NO_X are mainly generated by energy use, such as fossil fuels burning. The term, acid deposition, which covers wet and dry deposition onto ecosystems, is more commonly used in the academic field.

Several studies have shown that acid deposition has direct and indirect effects on the ecosystem, such as influencing the physical structure of soils, influencing the growth of plants, and even causing the forest decline in an area[1,2,3].

Geographic information system (GIS) is a new technology which integrates many disciplines of sciences: computer, geography, cartography and environmental science[4]. It is firstly developed from computer-assisted mapping, and at the early stage, it is short of the functions of geographic analysis and geographic modeling. With the development of computer science, cartography, and spatial analysis technology, GIS technology gradually matures. Now it has the functions of integrating spatial analysis and spatial modeling and can provide decision-making tool for resource management and environment management. In recent years, GIS technology shows the following development trends: (a) spatial data is more available to the public; (b) GIS software become more open and develops into multimedia technology; (c) there are more spatial modeling and decision-making tool in GIS system[5].

This paper describes the application of GIS technology in the estimation of the ecosystem's relative sensitivty to acid deposition in east China.

II. THE ESTIMATION AREA AND THE CRITICAL LOAD

1. The Estimation Area

The estimation area of this study covers seven provinces in east China: Zhejiang, Fujian, Jiangxi, Anhui, Hunan, Hubei, Jiangsu provinces, and Shanghai City. This area, which covers over one million square kilometers, and has a population of over 310 million, is one of the most economically developed ranges of the Changjiang (Yangtze) river. In this area, plain lakes are multitudinous, and elevation is usually under 50 meters.

The climate of this area spans two zones: the subtropical zone and the temperate zone. In summer, it is hot and humid, but in winter, it is cold and dry. The natural vegetation types, from south to north, are evergreen broadleaf to deciduous broadleaf.

2. The Critical Load

The critical load of an area is the maximum accepted level of acid deposition that will not ultimately change the structure and functions of a specific ecosystem. Under the critical load, the acid deposition will not have a long term and unrecoverable influences on the sensitive parts of a ecosystem.

The critical load varies with different ecosystems. It is an important criterion for assessing the emission cutoff plan. Based on the crtical load of an ecosystem, the decision makers can devise appropriate measures for emission cutoff by balancing the cost of control and economic development. The goal is that the environment should be protected and the economy should develop.

For a given ecosystem, the critical loads of the soil, surface water, and underground water are determined separately. Then the minimum of the three is taken as the ecosystem's critical load. At most times, it is hard to determine the critical load of an ecosystem. But since it is related to the system's sensitivity to acid deposition, we usually first estimate the sensitivity, and then determine the critical load.

III. ECOSYSTEM SENSITIVITY

In this study, four variables are used in estimating the sensitivity of a given ecosystem to acid deposition. They are: soil buffering ability, vegetation type, soil humidity and geologic base rock type.

The estimating process is as follows:

data collection and estimation zoning;

map digitization;

variable grading;

establishing the estimation formula;

sensitivity mapping.

1. Variables Influencing the Ecosystem Sensitivity

1.1 *Soil buffering ability*

The acid deposition buffering ability of soil is determined by many factors. It varies with the soil type, physical structure and chemical characteristics of the soil. The four variables commonly considered include: the soil's cation exchange capacity (CEC), base saturation (BS), pH, and the total exchange base (TEB).

The higher the CEC and TEB, the higher the soil's buffering ability to pH variation. Usually the soil with a TEB greater than 10 cmol/kg is considered to insensitive to the acid deposition, otherwise, it is considered to be sensitive.

In this study, the soil type is taken as the base for grading the soil buffering ability. A type of soil has specific range of BS and CEC. Therefore, grading the buffering ability by soil type is a simple and practical method in large area research.

1.2 *Vegetation type*

Vegetation type is another variable in determining the ecosystem sensitivity. Different vegetation types have different tolerant ability of acidity. Conifer forest is considered sensitive vegetation type to acidity increase, while broadleaf forest is considered insensitive to acidity. The sparse forest and shrub is considered to be just between sensitive and insensitive types. In some part of this study area, the farmers often use slaked lime in their fields. Slaked lime can buffer the effects of acid deposition. So the paddy field is considered an insensitive type in this study.

1.3 *Soil humidity*

Soil humidity has important effects on soil formation. The soil water quantity and flow direction influence soil particle dripping speed. In an area with a high ratio of precipitation to evaporation (P:PE), the soil humidity is high, the amount of water that pass through soil is large, and large amount of base cation in the soil is dripped away. So the buffering ability to acidity becomes low. Conversely, the lower the P: PE ratio, the lower the dripping speed, thus the higher the buffering ability.

1.4 *The sensitivity estimation model*

According to the above variables anaysis, the grading system used in this study is shown in Table 1.

Table 1 Relative sensitivity of ecosystem's variables to acid deposition

Soil	Low buffering ability	1
	High buffering ability	0
Base Rock	Sensitive	1
	Insensitive	0
Vegetation Type	Sensitive	2
	Sensitive-intermediate	1
	Insensitive	0
Humidity	Arid, semi arid	2
	Moist	1
	Very humid	0

This study use the following formula of simple addition to estimate the ecosystem sensitivity to acidity:

$$ESI = R_1 + R_2 + R_3 + R_4$$

here ESI is the sensitivity index;

R_1 is the sensitivity class value of the soil buffering ability;

R_2 is the sensitivity class value of the geologic base rock;

R_3 is the sensitivity class value of the vegetation type;

R_4 is the sensitivity class value of the humidity.

IV. SENSITIVITY MAP

The variable maps are digitized using PC. ARC/INFO software system. In order to estimate the combined effects of all variables layers, the four variable maps are converted to raster images. The study area covers 14 degrees in latitude and 15 degrees in longitude. We divide it into 14 × 15 grids of one degree by one degree. The one degree by one degree grid is further divided into 20 × 20 = 400 finer small rasiters. In this way, a raster image of 280 rows ×300 columns is got.

For every one grid of one degree by one degree, there is:

$$ESI = \sum_{K=1}^{4}(1/400 * \sum_{1=1}^{20}\sum_{j=1}^{20} Rij)$$

here Rji is the class value of variables, ESI is ecosystem sensitivity index.

The value of ESI ranges from 0 to 6. We reclassify the value into 5 grades:

$ESI \leqslant 2.0$,	$ESI = 1$
$ESI > 2$ and $ESI \leqslant 3.0$,	$ESI = 2$
$ESI > 3$ and $ESI \leqslant 4.0$,	$ESI = 3$
$ESI > 4$ and $ESI \leqslant 5.0$,	$ESI = 4$
$ESI > 5$ and $ESI \leqslant 6.0$,	$ESI = 5$

For every class value from 1 to 5, a different pattern or color is assigned. A value of 1 means insensitive, and a value of 5 means very sensitive. A value of 2,3, 4 means the sensitivity scales between insensitive and very sensitive. Thus the ecosystem sensitivity map is obtained.

V. CONCLUSION AND DISCUSSION

From the sensitivity map, the most sensitive part in the study area is Fujian and Zhejiang provinces. Most part of Fujian Province is in sensitive area, and a part of Jiangsu Province is in insensitive area. Large part of the less sensitive area is located north of the Changjiang River. This result coincides with the belt distribution of the climate, soil, and landuse type in the study area.

At this low resolution of one degree by one degree, the general rule of belt distribution can be found. This work will help the decision-making in the drafting of the emission control measures. If a finer resolution is used, more detailed sensitivity zones can be made out, which reflects the large geomorphologic features.

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