Evaluation of Land Resourses Using Geographic Information System

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COMMISION IV

ABSTRACT

The aim of land resource evaluation is to evaluate quality of every land unit according to vegetative productive potential of the land unit to inventory the quanlity, quantity and distribution of land resource and to determine the best way of use and management. It needs mult-types of data called factors which can be easily integrated with GIS.

This paper discribes the procedures of map digitalizing, factor selecting and model designing using Huangyan Land Resource Information System (HLRIS) which is based on the PC ARC/INFO Geographic Information System. A fuzzy-expert model is designed which possesses the advantages of fuzzy model and expert model and can be conveniently applied. In the HLRIS, transformation between vector data and raster data is covenient, so diverse basic data can exist in the system together. The application of the fuzzy-expert model to Huangyan district shows this model is very effective. Five grade land resource evaluated is provided to the administration for management dicision. It also provides the information of suitability of current landuse.

Keywords. GIS/LIS, Algorithm, Land Application

1. INTRODUCTION

Land is the natural integration on the earth surface with the effect of rock, terrain, climate, hydrology, living beings and vegetation. Reduction of the area under cultication causes much attention of the world. Land resources evaluation proved to be neccessary for the rational utilization of the limited cultivated area. Through hostory, the crude land evaluation was implemented instinctively by people two thousand years ago at the biginning of the use of land. But it is only several decades for scientific and systematic evaluation. New evaluation techniques are developed in order to meet the needs of rational utilization of the land resources with the progress of the resource survey and the planning of the land use (Fu Buojie, 1990). Various models were developed in this period such as expert model(EM), fuzzy model(FM) etc. with the development of computer technology especially the development of GIS. Land resource evaluation is now developing toward to the stage of integration, quantification and scientification(Zheng Zhixiang, 1986). Land Resource Information System(LRIS) is one type of GIS designed for the purpose of land evaluation, planning and management. Early GIS was mainly the LRIS. In the GIS, one can access the data base and use the models to evaluate conveniently.

In this paper, one fuzzy-expert model (FEM) was developed and a method to determine the subordinative function was also designed. All data used and result evaluated were captured, processed, managed and output in the HLRIS(Huanyan Land Resouce Information System). It is found that the application of this model in HLRIS to Huangyan district is very efficient and the results are almost identical to the real status of the land in Huangyan.

2. STUDY SITE AND DATA PROCESSING

The whole Huanyan county of Zhejiang Province was selected as study site. Huangyan County is about 80kms long in east-west direction and 20kms wide in south-north direction. The east of the county was adjacient to the ocean and the west of county is high moutain area. Deng River passes the whole area from the west to the east. Agriculture is one important industry in this region. Main crops produced are rice, fruit.

Huangyan orange is famous in the nation. As the development of industry, cultivated land is reduced rapidly in th recent years which causes a lot of problem in the region. It is neccessary to evaluate the land quality for the planning of efficeint land use in the region.

The evaluation of land quality was conducted in the HLRIS which was composed of PC ARC/INFO, TAS(Terrain Analysis System), RPS(Raster Data Processing System) and RDPS (Raster Data Plotting System). Various types of data can be easily processed and registered to a standard cordinate system.

Terrain map was digitalized into data base by ARC subsystem. By TAS, a digital elevation map (DEM) in the whole region was created from the digitalized terrain map. It also created, by TAS, the surface description data such as slope degree(SP), slope direction(SD), coarse degree of surface(CDS) etc. Other thematic maps such as soilmap, groundwater map, annual raining map and temperature accumlation map up 10^0c are also digitalized and registered to the same cordinate system. All these maps were transformed to raster data from vector data by the function of HLRIS and were put into the data base.

3. PRINCIPLES OF EVALUATION

Land resources are evaluated generally in terms of land factors such as soil, topography, meteorology, land use etc. In the process of evaluation, land area to be evaluated is divided into tiny units in which the changes of factors is little and can be omitted. Thus, the characteristics of these homogeneous units can be portrayed by factors.

If l stands for lth unit, f_i stands for ith factor, then the characteristic of lth unit can be described as:

$$LQ(l) = Q(f_1(l), f_2(l), \cdots, f_m(l))$$

$f_i(l)$ is the ith factor on the lth unit, m is the number of factors, Q is the function, $LQ(l)$ is the characteristic of the lth unit. If time is considered, the above equation was adapted to:

$$LQ(l,t) = Q(f_1(l,t), f_2(l,t), \cdots, f_m(l,t))$$

$LQ(l,t)$ is the characteristic of lth unit on time t. This equation demonstrates that the characteristic of land is determined by pertinent factors and changed with time and region.

4. MODELLING

Land evaluation is the process of assessing the land productivity and land use suitability. It is related closely to the land natural attributes and social, economic factors. No matter how complicated it is, it always abide by two theories.

A) Theory I: Land must be cultivated according to the most suitable use. Under this theory, land evaluation is conducted for purpose of land qualify and suitability to crops.

B) Theory II: Land must be used in the greatest productivity as long as the ecologic balance is not destroyed. Under this theory, it is deemed that if possible and profitable, the barren land may be ameliorated to be suitable to some crops considering social and economic factors.

Models created under these two theories have inner links, only starting points being different. If some social and economic factors must be considered and thier data can convieniently captured, models are generally designed under theory II. (Schultink, 1987) Generally, theory I is used most frequently in the land resource evaluation. In this paper, a new fuzzy-expert model was developed under theory I.

Providing factor assemblage $F = \{F_1, \cdots, F_m\}$, and result assemblage $V = \{v_{opt}\}$, (v_{opt} is the best class), the fuzzy relationship between them can be described by the matrix R.

$$R = (r_1, r_2, \cdots, r_m)_T$$

Among the matrix R, $r_i = \mu_R(f_i, v_{opt})(0 \le r_i \le 1)$, standing for the subordinative degree of land unit related to v_{opt} for factor f_i.

Let the factor fuzzy sub-assemblage is

$$A = \frac{a_1}{f_1} + \frac{a_2}{f_2} + \cdots + \frac{a_m}{f_m} \qquad (0 \le a_i \le 1)$$

written as $A = (a_1, a_2, \cdots, a_m)$. Among above equation, a_i leserbes the relative contribution of factor f_i comparing with ll factors.

upposing the result sub-assemblage

$$B = \frac{b_{opt}}{v_{opt}} \quad (0 \le b_{opt} \le 1) \quad \text{written to } B = (b_{opt})$$

b_{opt} is the subordinative digree to the best class of land unit.

Then the evaluation can be conducted by.

$$B = A \cdot R$$

that is: $(b_{opt}) = (a_1, a_2, \cdots, a_m) \odot \begin{bmatrix} r_1 \\ r_2 \\ \vdots \\ r_m \end{bmatrix} = \sum_{i=1}^{m} a_i r_i$

Thus, greater the value b_{opt}, closer to the best class the land unit, conversely, more depart from the best class.

Segmenting the value b_{opts} for all units. One can obtain a result map with N classes of land quality.

5. DETERMINATION OF SUBORDINATION FUNCTION

Fuzzy evaluation models need to determine the subordinative functions of factors to the results, so does the fuzzy-expert model developed in this paper. It is difficult to determine the subordinative function in the real application. In this paper, one method was developed to determine the subordinative functions according to the properties of the factors.

To the factor with continuous changing, it is assumed that there exists one range of values of factor in which values of factor are maxinum and correspond to the greatest subordinative degree of the factor to the best land class, that is, most closely to the best b_{opt}. Values of the factor changing from this range to the two sides correspond to the lower subordinative degrees. Further the distance from the range,smaller the subordinative degree. Thus the outlines of the subordinative function is that in some range, the function gets the maximam values, while changing from this range to two side the function reduces gradually(see fig.1). Therefore, the subordinative faction is designed as

$$\mu(x) = \begin{cases} \exp(-(\frac{x-a+b}{K_1})^2) & x \le a-b \\ 0 & a-b \le x < a+b \\ \exp(-(\frac{x-a+b}{K_2})^2) & x \ge a+b \end{cases}$$

$$K_1 = (c-a+b)/\sqrt{\ln 2}$$

$$K_2 = (d-a-b)/\sqrt{\ln 2}$$

The subordinative function can be completely determined by a, b, c, d four parameters. a describes the point best corresponding to the V_{opt}. b is the range magnitude. c, d are respectively the points on two side on which the value of function is 0.5. Fig.1 is illustrating chart of the construction of subordinative functions.

To factors with dispersive values, subordinative degree was accessed by tables. These tables were created by some training or expert knowledge.

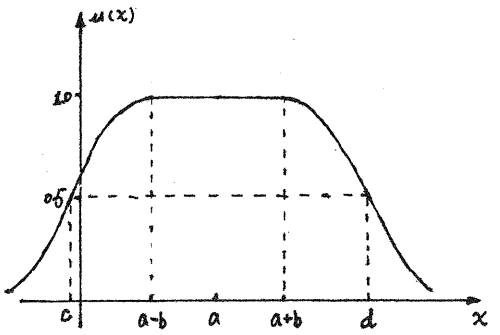

Fig.1. Curve of the subordinative function

6. RESULTS AND DISCUSSION

Land quality is closely related to land conditions which is reflected by land factors. Five factors were selected from a series of factors according to the magnitudes of their role in land. They are soil, groundwater, elevation, slope degree (SD) and coarse degree of surface (CDS). Except soil and groundwater, they are continuous factors. Their subordinative degrees (functions) and curves were trained and obtained (please see table 1, table 2, fig.2, fig.3, fig.4).

Table 1. Subordinative degree (SD) of factor soil

Code	*SD*	*Code*	*SD*
1	1.0000	8	0.2727
2	0.9091	9	0.2727
3	0.6818	10	0.1818
4	0.5000	11	0.1364
5	0.3636	12	0.1364
6	0.2727	13	0.0909
7	0.3182		

Table 2. Subordinative degree (SD) of factor groundwater

Code	*SD*	*Code*	*SD*
1	1.0000	9	0.3500
2	0.9000	10	0.3000
3	0.8000	11	0.2500
4	0.7500	12	0.2000
5	0.7000	13	0.1500
6	0.6000	14	0.1500
7	0.5500	15	0.1000
8	0.4500		

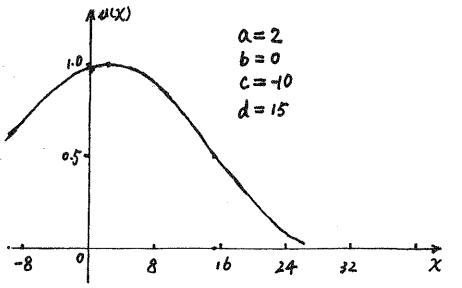

Fig.2 Subordinative function of slope degree

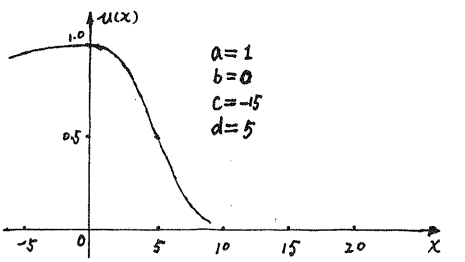

Fig.3 Subordinative function of coarse degree of surface

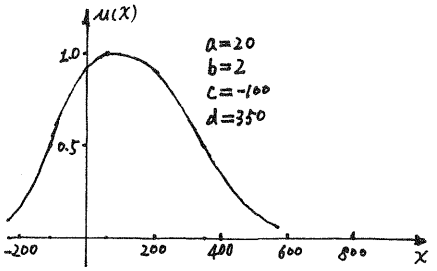

Fig.4 Subordinative function of elevation

Evaluation and analysis show that the result is very identical to the real situation of Huangyan district. The best land (1th grade land) is about 95.7 thousand acres which are almost distributed in the eastern plain and alluvial plains. Generally, it is rice soil with small slope and much abundant groundwater, suitable for the planting of rice, wheet and vegetable. 2th grade land is about 3.92 thousand acres which are mostly distributed on the two side of Deng River and the foots of the hills. Generally, it was wet soil or red soil with slow slope, suitable for planting of the orange, orchard and tea garden. 3th class land is about 50.6 thousand acres which are distributed in the western mountain area and the eastern coastal area. It is red soil with slope of 5–10 degree and solonchak which are suitable for the planting of forest and cotton respectively. 4th class land is about 11.1 thousand acres distributed in the west high mountain area suitable for forest and plasture. 5th class land is the worst land in Huangyan district. It is distributed in the highest mountain which have the highest elevation and the greatest slope. Generally it was the barren land.

7. CONCLUSIONS

The results from the use of GIS are promising. By utilizing the Terrain Analysis System, ARC Input System, Model Base and Raster Data Plotting System, one can easily digitize the thematic maps, create and analyze the DTM data, plot the result maps. GIS also provides the techniques to conveniently integrate diverse types of data.

The fuzzy-expert model (FEM) developed is efficient. It is on the base of fuzzy model and introduced some thought of expert model. FEM needs to determine only one subordinative function for one factor instead of several subordinative fuction for one factor in fuzzy model. The method of constructing subordinative function develpped here is practical and efficient. The results evaluated is much correspondent to the real status of land in Huangyan district. Furthermore, FEM can be applied to other evaluations such as crop suitability evaluation and land productivity evaluation.

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