A SYNTHETIC METHOD FOR INFORMATION EXTRACTION OF SALINITY OF SOIL

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ABSTRACT

High-reliability results of soil salinity in two test areas , Yanggao and Changling , one obtained through synthetic analysis of remote sensing data and non-remote-sensing data such as local hydrology and geomorphology . A mathematical model and GIS framework are applied in this study . By modifying its non-remote-sensing factors and parameters , the procedure advanced in the study can be used for other thematic analysis .

KEY WORDS: Salinity, Feature, Probability, Model Analysis, GIS

The combination of remote sensing method with GIS to solve complex problems is becoming increasingly popular . GIS as a tool can be used for various themes by inputing necessary information sources and model-analyzing .

In resent years , methods for the study of soil salinization have greatly developed from geographical analysis alone to the application of remote sensing analysis ; from visual interpretation of satellite image to its computer processing ; from single source , satellite image , to the combination of remote sensing data with non-remote -sensing data. In this paper , all the steps of the work are integrated by means of GIS , then the analysis of multi-source are modeled for the quantitative evaluation of salinity in various areas . The synthetic analysis shows the great significance of local geomorphology , hydrology , hydrogeology , and relation with soil salinization . It also indicates that it is necessary to modify model parameters for different areas . The paper is a brief report of previous and the latest work.

CHARACTERRISTICS OF THE STUDY AREAS

To generalize the work , it is essential to choose test areas in different geographical environment . Two typical salinized areas , Yanggao , Shanxi Province and Changling , Jilin Province in China , are selected in this paper , the former is a test area from which method , models and experiences are obtained , while the latter is a verifiable area through which the study methods are verified and amplified .

Yanggao Region

It is situated near 40°20'N , 113°50'E , has a temperate semiarid monsoon climate . Meadow soil and salinized meadow soil predominate in this area . Field investigation shows that vegetation species and their growing status are highly relative to soil salinity . Generally speaking , well-growing wheat often densely covers non-salinized areas and shoal bank , where there is enough water and a low mineralization rate ; sparse sorghum , foxtail millet , white yam , watermelon and soybean predominate in moderately salinized and slightly salinized areas where vegetation cover decreases with the increase of soil salinity; while the areas of saline soil are often bare ground .

This area is of many types of salinized soils . Its salinity is greatly influenced by ground water , so it is called salinized soil of ground-water-type. The study shows that slighter salinity of soil is often associated with deeper ground water and lower mineralization rate ; higher salinity of soil , in turn , is the result of shallower ground water and higher mineralization rate . This pattern is much more evident in June and July when salinization reaches the heights.

Changling Region

It is situated near 44°20'N , 123°30'E , also has temperate semiarid monsoon climate . Due to lack of rivers , it is a poorly drained area . As a result of shallower ground water , stronger evaporation and higher mineralization rate , soil of various salinity can be found in this area . As an agricultural region , climate , geomorphology , ground water hydrology , parent material as well as human activity can all affect soil salinization ; however , ground water and local geomorphology , esp. the latter whose effect is much more pronouncing in this area than in Yanggao , are the leading factors . Salts can be deposited on the surface of lowland and poor ground water runoff areas . The effect of micromorphology is also quite prominent in areas of lower relief . Some depressions are the region of highly concentrated salt and water where the highest salinity is not in the center but at the edge.

WORKING SYSTEM

The framework of GIS (Fig.1) is adopted to simplify and generalize the work . Data input section includes the input of remote sensing data , non-remote-sensing data and parameter tables , such as reading Landsat TM data tape , choosing subarea and storing them in form of grid ; digitizing the maps of ground water and geomorphology , changing the format from vector to raster ; coloring , displaying of image patches and input of parameters determined by experts . Pre-processing section has a variety of functions , for choice e.g. feature selecting of remote sensing data , geometry correction , layer overlaying , statistically analyzing of some known areas, etc. In model analysis , the necessary data before or after pre-processing are operated and the results are displayed in form of statistical tables or images . If the results are not satisfactory enough , parameter tables will be modified and operated again until the reasonable results are obtained . Finally , hard copy results of images or tables are outputed .

This framework helps to systematize the analysis processes , by means of which rapid processing , timely renewal of data and dynamically monitoring can be realized .

The whole flow is accomplished with VAX11/750 computer and peripheral equipments of image and graphic processing .

MAIN PROCEDURE

Routine Work

To evaluate the accuracy of the synthetic analysis , routine work such as ground data collection , field investigation and visual interpretation , accordingly the precise classification of soil salinity , should be completed before computer work , and the area of every salinity class , in the test region , should be worked out . Soil are classified according to the salt content in surface horizon , soils with a salinity of greater than 1% and 0.6-1% are saline soils and highly salinized soils , respectively , 0.4-0.6% is moderately salinized soils , 0.1-0.4% is slightly salinized soils and less than 0.1% is non-salinized soils . The routine work , on which the computer processing is based , should be done cautiously . To determine salt content and salinization types , soil sample analysis may be needed .

Features Selection

To decrease the amount of remote sensing data , separate the effects of soil and vegetation , and sharpen the characteristics of salinized soils , this study tried many ways of the feature selection . Slightly salinized soils and moderately salinized soils are very difficult to discriminate because they are often distributed criss-cross . After a number of comparisons and experiments , Kauth-Thomas transformation appears to be the best way for soil analysis . Data are reduced from 7 TM bands to 3 bands , i.e. brightness component , greenness component and wetness component . Greenness component extracts the influence of vegetation cover and helps to apply the relationship between vegetation and salinity . Obviously , the plan of soils view combinated from brightness component and wetness component carries the main information of soil salinization . In the two-dimentional space different salinized soils , esp. moderately salinized soil or slightly salinized soil , can be determined by their location. Having been processed , the color compounding image of three components is much more effective in salinity analysis than false color image of TM Bands 4 , 3, 2 and color image of the first 3 principle components after K-L transformation[3] .

Analyzing Model

Model analysis is based on classification of compounded multi-information . With expert experiences , it can be accomplished at its first run.

Soil salinization Model , based on soil genesis theory , can quantitatively analyze salinized soils . Satellite remote sensing data still used as the main information source , but they are no more than spectral information which only reflects the integrated characteristic of soil cover , soil types and other factors . It is necessary to combine the important ground information , such as geomorphology , hydrogeology and other non-remote-sensing data , with them to improve the reliability of result .

According to GIS method , all the data , including remote sensing data and non-remote-sensing data , should be overlayed , in same scale and project , then stored in Geo-database . Image data are stored in raster form with different band in different layer , and map data in vector form with every map in an isolated layer . Then , vector data should be changed to raster form and overlayed with other data layer . All the layers should be registered before model analysis .

If the grid element of all layers is :

$$X = (x1 , x2, \ldots, xs, \ldots, xn)^T$$

s = 1 , 2 ,..., n . n is the number of dependent sources . According to generalized statistical pattern recognition theory , if wj is the grade of salinity , j = 1 , 2 ,..., m . m is the number of grade ; rs is the weight of the sth source , then the simplified membership function[1] is :

$$Fj(X)=(1-n)\ln[P(wj)]+\sum_{s=1}^{n}\{\ln[rs*P(wj/xs)]\}\quad[2]$$

if

$$F* = MAX[Fj(X)] \quad (j = 1 , 2 ,..., m)$$

then X is belong to w* grade

As remote sensing data are often recognized by means of statistics , during preprocessing the statistical mean vector and covarience matrix of every grade can be got . Accordingly , Function F can be simplified as

$$Fj(X) = Prs + \sum_{s=1}^{n-k} \{\ln[rs*P(wj/xs)]\}$$

where k is the number of remote sensing sources ; rs makes allowance for the weight of non-remote-sensing data alone , Prs is posterior probability of all remote sensing data . The function can be used not only for salinity analysis but also for generalized compounding analysis of remote sensing data and non-remote-sensing data .

Determination of Probability Parameter tables

As indicated above , the principal factors influencing soil salinization of different areas can be determined through field investigation . However , these factors work in a certain rang . In Changling , for example , soil with ground water depth less than 0.5 m are often highly salinized and saline soil , soil with ground water depth 1.5--2.5 m are often slightly salinized , while soil with ground water depth greater than 2.5 m are often non-salinized farmland . This pattern varies in different area . In Yanggao , for example , the ground water , deeper than 1 m , has a similar tendency to influence soil salinity , but it is classified in more detail . Soil with ground water depth 1.4-1.8 m are usually moderately salinized . Probability parameters , in different scope , of the two test areas are list below . Due to little differentiation of ground water mineralization in Changling , ground water depth and geomorphology appear to be the main factors .(tables 1.1,1.2,1.3)

As a comparative area , Yanggao has a much great differentiation of ground water mineralization rate , so it becomes more important factors than in Changling . According to local conditions , the probability parameters are modified(tables 2.1,2.2) .

Calculation and Adjustment

The results of operating the input data through the model should be compared with visually interpreted soil salinity map . If it is not identical enough , other non-remote-sensing data should be considered or the probability parameters adjusted . This step is essential because there are complex factors influencing soil salinization . Expert experiences are indispensable for the salinization analysis of different areas . The framework of GIS is convenient for adjusting information sources or model parameters .

RESULTS AND CONCLUTIONS

GIS way is applied in the experiment of this paper . Based on data collecting and typical field investigation , the synthetic computer analysis of soil salinity is realized . In this paper , the features of remote sensing data are extracted and statistically analyzed ; geographical conditions are taken into account ; after overlay of TM image and such thematic maps as hydrology map, geomorphology map, model calculation and parameter adjustment to different locality are made ; as a result , the confidence has been greatly improved .

With visual interpreted soil salinity map on the scale of 1:100,000 as reference , the relative validity of model analysis in Changling , where n = 4 , can reach 94.1% (table 3) and that in Yanggao , where n = 3 , is as high as 91.7% (table 4) .

As a method of Synthetic Analysis , the procedure proposed in this paper is effective not only in monitoring salinized soils but also in other themes with higher accuracy . GIS way contributes greatly to data renewal and modification as well as model adjustment . Undoubtedly , this method has a generalized significance .

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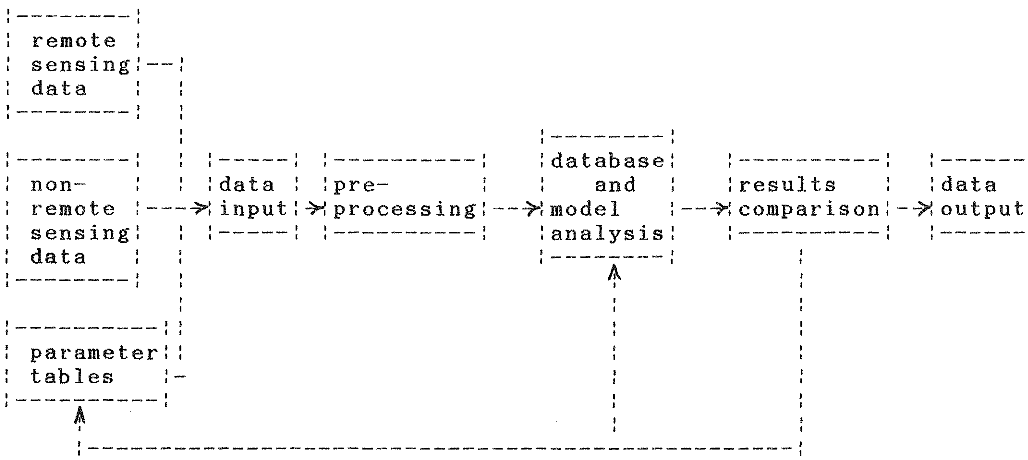

Fig. 1 Working framework

table 1.1 Probability Parameters of ground water depth at Changling

serial number	depth (m)	water (%)	non-salinized (%)	slightly salinized (%)	mid-salinized (%)	highly salinized (%)	saline soil (%)
1	0	100					
2	<0.5	5			5-15	35-45	45-55
3	0.5-1				10	65-75	15-25
4	1-1.5			5	45-55	15-25	20-30
5	1.5-2.5		5-15	75-85	5-15		
6	>2.5		85-95	5-15			

table 1.2 Probability parameters of geomorphology types at Changling

serial number	types	water (%)	non-salinized (%)	slightly salinized (%)	mid-salinized (%)	highly salinized (%)	saline soil (%)
1	water	100					
2	hollow	5		5	10-15	65-75	5
3	lower plain				5-15	15-25	65-75
4	slight sloped plain			65-75	10-20	5-15	5
5	plain		60-70	25-35			
6	dune		100				

table 1.3 probability parameters of ground water mineralization rate at Changling

serial number	rate (mg/l)	water (%)	non-salinized (%)	slightly salinized (%)	mid-salinized (%)	highly salinized (%)	saline soil (%)
1	<500		65-75	20-30	5		
2	500 - 1000		30-40	25-35	10-20	5-15	5-15

Table 2.1 Probability parameters of ground water depth at Yanggao

serial number	depth (m)	non-salinized (%)	slightly salinized (%)	mid-salinized (%)	highly salinized & saline soil (%)
1	1.0-1.4	0	10	20-30	60-70
2	1.4-1.8	0	20-30	60-70	10
3	1.8-2.0	15	60-70	10-20	5
4	2.0-2.4	50-60	30-40	5-15	0
5	> 2.4	70-80	20-30	0	0

table 2.2 Probability parameters of rate of ground water mineralization at Yanggao

serial number	rate (mg/l)	non-salinized (%)	slightly salinized (%)	mid-salinized (%)	highly salinized & saline soil (%)
1	<600	80-90	10-20	0	0
2	600-800	30-40	60-70	0	0
3	800-1000	5-15	70-80	10-20	0
4	1000-3000	0	0	70-80	20-30
5	3000-6000	0	0	20-30	70-80
6	>6000	0	0	10-20	80-90

table 3 . Results of different analysis , at Changling

proportion in total area	water (%)	non-salinized (%)	slightly salinized (%)	mid-salinized (%)	highly salinized (%)	saline soil (%)	village & city (%)	relative validity (%)
visual inter-pretation	2.95	40.4	5.33	11.43	20.32	17.53	2.03	100
only remote sensing	2.6	34.7	6.1	12.8	20.8	18.8	4.3	88.5
synthetic analysis	2.6	38.1	5.8	11.9	20.4	17.3	4.0	94.1

table 4 Results of different analysis , at Yanggao

proportion in total area	water (%)	non-salinized (%)	slightly salinized (%)	mid-salinized (%)	highly salinized (%)	saline soil (%)	relative validity (%)
visual inter-pretation	2.7	4.5	52.1	30.7	7.5	2.5	100
only remote sensing	3.2	4.0	48.0	30.4	11.2	2.8	90.6
synthetic analysis	3.2	4.0	48.3	30.9	10.5	2.8	91.7