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THE STUDIES ON WATERLOGGING DAMAGE IN JIANGHAN PLAIN USING DEM ①

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ABSTRACT: The waterlogging damage is the pit to agriculture in plain and lake region. This damage is related to the groundwater, ancient lakes, soil, land use and negative landforms, the conventional technique is adopted to the study of this damage. In this paper, we suggest a new technical method, the technique is based on DEM, to study this problem. The DEM is developed on the ECLIPSE MV/ 10000 AOS/ VS system, and the estimation model of waterlogging loss is built on the historical data of the test region in Jianghan Plain. and then, the rice waterlogging loss of test region is estimated by them.

KEY WORDS: waterlogging, agroecology, rice, loss estimation, DEM

I. PRINCIPLES AND METHOD

Waterlogging damage is the main obstacle factor of agriculture in plain and lake region. The research of waterlogging damage is usually depended on the ground conventional investigation. There is not report on the application of remote sensing to this research with the support of DEM yet. In this paper, the DEM applied to study of the damage in Jianghan Plain is developed in principles and method, and demonstrated in the case of Nantao drainage area, Honghu City in Jianhan Plain.

II. PRINCIPLES AND METHOD

Waterlogging damage is a disastrous phenomenon which influence the crop growth

①Support by nation natural science fund.

and maybe kill the crop sometimes. It is the resulted from ground surface with retarding water for a long time or from the high level of groundwater, the latter causes the sustaining saturation of soil water, and then destroy the equilibrium among the water, thermal energy and air in the soil, and decrease the fertility of soil. The waterlogging damage in Jianghan Plain is the coupling result between the dynamic of the surface water and groundwater dynamic in some situation, which is caused by the human activities, climate, soil, vegetation, landforms and hydrology in this human ecosystem[1-2]. As recognizing sign of waterlogging field, following indexes are very useful.

1. Waterlogging damage in Jianghan Plain

1.1 Groundwater

Groundwater is the main factor caused the damage. According to the complex effect of groundwater on agroecosystem in Jianghan Plain, the standard of waterlogging damage can be divided into six degrees: (1) Nonwatelogging, the buried depth of groundwater is more than 0.6 m; (2) Marginal waterlogging, the groundwater level is 0.3 – 0.6 m; (3) Slight waterlogging, the groundwater level is 0.2 – 0.3 m; (4) Mid waterlogging, the groundwater level is 0.1 – 0.3 m; (5) Hard waterlogging, the groundwater level is within 0.1 m; (6) Very hard waterlogging, the still water is on the ground surface.

1.2 The ancient lake

The Jianghan Plain is an alluvial plain which is taken shape over a structural basin by silt and sand come from the Changjing River. The ancient lakes represent the negative landforms in history. In the region, the groundwater level is relative higher than other region, and the waterlogging damage is taken place usually.

1.3 Soil

The undeveloped paddy (rice) soil and marsh paddy soil are the typical soils in waterlogging field. Because of scant permeability in these soil, the soil texture is very sticky, the sticky particle (with the size < 0.001 mm) in tilling layer or plough sole is more than 30%, and the physical sticky particle (with the size < 0.01 mm) more than 70%, and the content of organic matter more than 3%, and poisonous substance and gas are accumulated, so that the very hard waterlogging damage is taken place where usually[3].

1.4 Land use

Because the tillable period is short in waterlogging field, most of the hard waterlogging field is used as the single cropping of rice, and little slight waterlogging field is used as the double cropping rice.

1.5 Negative Landform

The negative landform is related closely to groundwater level, and is the key to form the particular paddy soil. It can be recognized from the topographic map, and represented clearly in the DEM.

The waterlogging field is closely related to above factors (Table 1), and these factors can be interpreted from the remote sensing images①, so the waterlogging field can be also interpreted from this images. In the spatial distribution, these factors are the representation of ground surface pattern in certain elevation. So it is possible to research the waterlogging damage with DEM.

Table 1 The relevant analysis of waterlogging field and other interpreted signs

	Groundwater	Ancient lake	Soil	Land use	Negative landform	DEM data	Compound data
Relevant coefficient	0.90 − 1.00	0.70 − 0.90	0.60 − 0.70	0.60 − 0.70	0.70 − 0.90	0.80 − 0.95	0.90 − 1.00
Confidence level	* * *	* *	*	*	* *	* *	* * *

2. The DEM development environments and steps

The DEM development environments and steps in this study are as following:

2.1 Hardware

- MV/ 10000 computer
- 6290 hard diskette driver system, 592 M bit
- GDC 1000 colour display terminal andGR−2412 colour graphic display terminal
- CD 460 Chinese word terminal
- XP−1100 plan plotter
- ECP−42 colour electrostatic plotter
- 5828 line printer
- DH 7500 digitizer

2.2 Software

- AOS/ VS operating system
- GKS graphical kernal system
- DG/ SQL data base management system
- MAPCAD computer aided design system

2.3 The DEM development process

Six imagery maps with scale of 1:10,000 are selected for the test region and LINE and LABEL data input models are selected to input the elevation points. The settlement factors is input with the support of Chinese word terminal. All the files are connected to a compound file which is put together through the coordinate transformation. The compound graph then be rasterized with 10 cm × 10 cm network, and transformed to the curve model

① Yu Guangming, 1991. The application of remote sensing to the study of waterlogging field.

with regular dot array. This model is Changed code to transport to the plotter. which produces the mic-contour map and stereo perspective drawing.

III. THE WATERLOGGING MECHANISM AND THE ESTIMATED MODEL

The process of waterlogging damage is that the change of groundwater level cause the change of agroecological environment, and then result in variation of crop physiology and morphology, the product of crop, at last, decrease. The condition of crop growth is the complex representation of waterlogging damage degree, which can be estimated from the physiological features of crop such as the color of root system, the height of plant, the index of leaf area, the root length, the weight of plant and so on. These features influence immediately the economic features such as the grains of a rice, the thousand-grain weight, the empty - shell rate, the theoretical product and actual product, and is related closely to two characteristic indexes of waterlogging fields, the groundwater level and the seepage of the field[4].

The main crop in Jianghan Plain is rice. Based on the measured data, the relationship between the decrease rate of rice product (Y) and the buried depth of groundwater (X) is received as following:

$$\ln Y = 1.149757 - 1.286999 \ln X$$

That is,

$$Y = AX^{-B} = e^{1.149757} X^{-1.286999} = 3.1574256 X^{1.28699} \qquad (1)$$

This equation is past through the examination (Table 2).

Table 2 The test for equation (1)

Error source	Square sum	Free variable	Variance	F test	Confidence level
Regressive (factor x)	$U = blxy$ $= 13.772796$	1	$S_u^2 = u / 1$ $= 13.772796$	$F = u / [Q / (N-2)]$	
Residual (random factor)	$Q = lyy - blxy$ $= 10.86896$	$N-2 = 10$	$S_Q^2 = Q / (N-2)$ $= 1.08696$	$= 12.670932$	$\alpha = 0.01^{**}$
Total	$lyy = \sum y^2 - 1/N(\sum y)^2$ $= 24.641756$	$N-1 = 11$		$> F_{1.10}^{0.01} = 10.04$	

Note that non-waterlogging damage is taken place when the groundwater level is under 0.7 m. and the maximum loss of waterlogging rice is not more than 100%, the equation (1) can be remedied under following critical conditions:

1° $x > 0.7, y \to 0$

2° $y_{max} = 100$

The equation (1) is solved by successive substitution method under above condition, then there are

$$y = \begin{cases} 100 & (-\infty, 0] \\ 3.1574256(x + 0.066)^{-1.28699} - 4.4330714 & [0, 0.7] \\ 0 & [0.7, \infty) \end{cases} \quad (2)$$

These are the loss estimation models for waterlogging rice in Jianghan Plain.

IV. LOSS ESTIMATION OF WATERLOGGING RICE

1. Test Region

The test region is located in the North of Honghu City, the part of Natao drainage area. Its coordinate is between 113° 30′ 0″ —113° 38′ 5″ E, 30° 00′ —30° 30′ N, and the total area is 106.77 km^2. In this region, the ground surface is low and plane, and there are many rivers and lakes. Most of its elevation is between 21–25 m. The production line of this region is 21.60 m, which is the upper limitation of groundwater level.

2. The Steps of Loss Estimation

(1) The area–elevation data of test region is calculated with the support of DEM, and the waterlogging interval of elevation is determined in comparison to the investigation of ground truth. The result is shown Table 3.

Table 3 The relationship between the elevation and area in the test region

Elevation (m)	Area (km^2)	Take part of total (%)
< 21.6	36.81	34.61
21.6–21.7	4.98	4.53
21.7–21.8	4.43	4.15
21.8–21.9	3.68	3.43
21.9–22.0	3.38	3.14
22.0–22.1	3.26	3.05
> 22.1	43.46	44.40

(2) The relevant test is performed with the index stated in Section 2, and the corre-

sponding weights w_i are determined to different height.

(3) The rate of product decrease of different elevation y_i is calculated in terms of w_i as following:

$$y_i = w_i y \quad (3)$$

where y is calculated by equation (2).

(4) The product decrease P is calculated as following:

$$P = \frac{1}{2} \times 1100 \times 1500 \times s \cdot y_i = 8.25 \times 10^5 \times s \cdot y_i \quad (4)$$

Where S is the area of corresponding elevation.

3. The Result

According to above steps, we calculated the corresponding indexes of elevation interval of waterlogging damage, and then regulated them in terms of waterlogging standard. The result is shown in Table 4. This result is taken from a supposition that all the elevation interval of waterlogging damage are planted the rice. So that the actual estimation must consider the corresponding ground truth to regulate the value.

Table 4 The waterlogging loss estimation of rice in the test region

Condition of disaster	Area (km^2)	Product decrease rate (%)	Product decrease (ten thousand kg)
Non	40.46	0	0
Marginal	13.32	15	164.775
Slight	4.80	30	118.800
Mid	4.98	45	184.875
Hard	5.19	70	294.525
Very hard	31.34	—	—

V. CONCLUSIONS

Based on the study of test region, the role of DEM for research of waterlogging damage is demonstrated in principles and method. The conclusion are as following:

(1) The waterlogging damage is closely related to the groundwater level, ancient lake, soil, land use, negative landform, and then its area can be interpreted from the remote sensing image, and its condition of disaster and loss can be estimated using the DEM.

(2) The result shows that DEM application to the study of rice waterlogging damage is

possible, but the actual estimation must be combined with investigation of the ground truth.

(3) This model of test region is fit to all the Jianghan Plain for estimation of rice waterlogging damage.

REFERENCES

[1] Yu Guangming, The researches on flood and waterlogging damage using remote sensing in Jianghan Plain: Foundation Studies. Technical Papers of FIG PC′ 91 Meeting and International Symposium, Vol. 2, pp.604—613, Beijing 1991.

[2] The application of remote sensing to the study of flood and waterlogging damage in Jianghan Plain, Remote Sensing Researches of Geological Disasters, Beijing 1991.

[3] Researches on the waterlogging mechanism in Jianghan Plain (to be published), 1991.

[4] Researches on the ecological characters of waterlogging field in Jianghan Plain (to be Published), 1991.