AGRICULTURAL FLOOD LOSSES PREDICTION BASED ON DIGITAL ELEVATION MODEL

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Abstract: A new agricultural flood losses prediction method using digital elevation data combined with agricultural economic data is presented. The method is based on dynamically simulating the procedure of flood out. An example in Huangdunhu flood detention area, Jiangshu province of China has been given to describe how to use it to predict the incoming agricultural losses. Compared with prior methods, the method is more intuitive and accurate, and can be used to provide a scientific and effective reference for taking flood control and disaster mitigation measures.

Key words: Flood disaster, Agricultural losses prediction, DEM.

1. INTRODUCTION

The Huangdunhu flood detention area in Jiangsu province of China is a temporary flood detention area for Yi-River, Shu-River and Si-River. Its main function is to clip flood peak in order to keep the Luomahu reservoir safety. Huangdunhu covers an area of 335km^2 and contains 20,700 hm^2 of arable land, with a general ground elevation of 21 meters and its maximum flood detention capacity is 1.47 billion m^3 with average water depth of 5~7 meters. The flood disaster in this region is mainly caused by flood discharging of sluices located at Caodianzi and Shuangheqiao. Since the area is planning for flood detention, agricultural losses is the mainly losses when flood comes. How to forecast flood disaster caused by the discharging, built higher dam in time and diver flood to reduce agricultural losses is an import work for water management department and agricultural bureau of Jiangsu province.

2. BACKGROUND

The prior agricultural flood losses prediction methods mainly include two types: statistic data are used to deduct the incoming losses, and satellite images in inundated region are used to analysis the losses problem (Fen Ping, 1995). In the first type of method, the detailed losses statistic data in the flood area is very hard to acquire for short of time. Hence, only those losses data in typical areas are collected, then total losses statistic data are deducted from these typical data. Obviously, the result data is not accurate and the losses prediction is unfaithful. In the second type of method, the submerged areas can be clearly seen in the remote sensing satellite images, which can be an accurate guidance for the forecasting procedures. This type of methods has been widely used in recent years for its accuracy and convenience. (Badji M.S, 1997).

However, the flood flow directions, flood volume and total discharging time is different in each time, it is very difficult to find an accurate method to deduct incoming losses from the past flood losses data. Some scholars have tried different methods, such as the fuzzy theory and neural network (Huang C F, 1996; Wang Q J, 2001). Nevertheless, these results are not very satisfactory.

3. FLOOD AGRICULTURAL LOSSES PREDICTION BASED ON DEM

In order to accurately simulate the flood and forecast waterlogging losses, the paper used a method based on Grid DEM data. DEM, shorted for Digital Elevation Model. Grid DEM consists of a matrix data structure with the topographic elevation of each pixel stored in a matrix node. It is readily available and simple to use and using the DEM data is convenient to accurately simulate the whole inundating process, get the submerged region and access the submerged depth. Furthermore, based on these calculated flood data, it can accurately predicate the agricultural losses.

The whole losses forecasting process includes three steps:

Step 1: Fundamental data preparation.

Step 2: Inundating process simulation

Step 3: Agricultural flood losses prediction

3.1 Fundamental data preparation

Three types of critical data are needed to forecast the agricultural flood losses: the first type is the DEM data in research area. The second one is the vector data geographically matched with the DEM data, including the administrative divisions, road traffic, farmland plots, fish ponds block, economic crops block, orchards block, dams, sewers, culverts, and other location-based information. The last type of data is agriculture, forestry, animal husbandry, fishery, and other socio-economic data, matched with those vector data, as well as the submerged statistical losses data in the past years. The DEM data is used to simulate the whole inundating process, the vector format data is used to calculate the concrete inundated block, and socio-economic data is used to calculate the losses of submerged.

3.2 Inundating process simulation

Inundating process also including three steps:
Step 1: Preprocessing the DEM data.
Step 2: Specifying flow path and pooled start point.
Step 3: Specifying inundated region.

3.2.1 Preprocessing the Grid DEM data

The normal depression is a low-lying plain area with lower in center and higher around, in which water can be stored and may be drowned. In Grid DEM data, the elevation in the depression is less than the elevation of the spots around it. However there always exist some spots in the real Grid DEM data with these characters because of data precision during data acquisition. They are pseudo-depression, not real depression, and should be modified. Or else it will disturb the analysis processing of flood flow directions.

To eliminate the impact of pseudo-depression, threshold judgment is a simple and valid method. The value of threshold can be set to 1~2 grid's area in practice. When the area of the depression region is less than this threshold, it can be considered as a pseudo-depression region. Then the average elevation value of spots around this pseudo-depression region is used to replace the current elevation values in the pseudo-depression region in order to eliminate the impact of these pseudo-depression regions.

3.2.2 Specifying flood flow path and pooled start point

The flood will not be pooled immediately after discharging, but flow downstream region along the floodways, until it reaches relatively opened low areas when pooling began. In this process, the crops in the region of flowing path will subject to certain losses, but it is completely different with those subject to waterlogging, thus it is necessary to analyze the flood flow directions ,flow path according to surface topographic information and the pooled starting position.

Surface water is always along the steepest downward slope. Hence the simplest method for specifying flow directions is to assign flow from each spots in the grid DEM to one of its eight neighbors, either adjacent or diagonally, in the direction with steepest downward slope. This method, designated D8 (8 flow directions), was introduced by O'Callaghan and Mark (O'Callaghan, 1984) and has been widely used. In this method the finial flow direction can be decided according to the formulation 1:

$$\text{Direction} = (H - H1) - (H - H2) / 1.414 \qquad (1)$$

Where Direction represent the flow direction; H is the elevation of spot need to study; H1 is the lowest elevation spot of its eight neighbors in the vertical and heretical direction. H2 is the lowest elevation spot of its eight neighbors in the diagonal direction. If the Direction is negative, the flood will flow to the spot with H2 as its elevation, otherwise the flood will flow to the spot with H1 as its elevation. From the starting point, the similar calculation procedure should be taken for each spot along the flow direction, until the Direction is equal to zero.

In Huangdunhu detention area, because flooding disaster dues to the flood discharge in flood sluice, the starting point of runoff is the location of the sluice. Starting from this point, the flood flows from higher position to the lower position along to the elevation of terrain, which is the flood runoff. At the end point of flood runoff, the flood begins to pool, and then the point becomes the pooled start point of the total detention region.

3.2.3 Specifying inundated region

When inundate process begins, floods in low-lying areas begin pooling. As water continues to pool, the water level in the region gradually raises; eventually it ran across the brink of this low-lying region and flow to other low-lying areas, and then the water pools in the new regions once more. This process will repeat until no more water or no more regions accommodating for more water. Inundated simulation process requires large amounts of water mechanical model, which is a very complicated task, but for a plain region, we can use the following method to simplify the simulation process.

Starting from the pooling point, the flood diffuses to its 8 neighbors. The following code describes this diffusion procedure:

```
Do while no more water and no more area for water
    Presentwaterdepth = Presentwaterdepth + 1cm
    Push the present point into a stack
    Do
        Popup a point from the stack
        If the elevations of the point's 8 neighbors < Presentwaterdepth then
            Marks them with -999  'These points are submerged.
```

```
        Save them into a stack.
    Else
        Marks them with 999  'The point is a border point
    End if
    Loop until stack is empty.
Loop
```

When the simulation process begins, the program judges the submerged regions grids by grids until no more water or no more area for water. The storage capacity in submerged regions can be calculated by formulation 2.

$$SC = \sum_{1}^{N} waterdepth \times gridsize \qquad (2)$$

SC is the storage capacity. ***waterdepth*** is the depth of water in inundated grid. ***gridsize*** is grid size of DEM data. The inundated region contains ***N*** grids.

When the inundate calculation process finished, all of the grids with marks ***-999*** will form a connected region, which is a candidate submerged region. Water come together in the new area is a relative slow and the water level raise also slowly. Hence we should check weather the candidate submerged area contains another depression or not, and do the same simulation in the new area if flood runs across the low-lying area's border. The following code describes this procedure:

```
 'Check the candidate region
If there has no more depression then
   Accept the result
Else
   Presentwaterdepth = the elevation of the new depression start point
   Restore the submerge situation under the last water level.
   Do the inundating process in the new depression
End if
```

In the flood discharge process, the flood discharge time and the flood flow are identified, and then the total flood volume can be deducted. Next the submerged area can also be deducted by this method. Furthermore, the time arrived in a position can be calculated by the flood flow and the flood runoff.

3.3 Agricultural flood losses prediction

Agricultural losses prediction process includes three parts: pre-disaster evaluation, floods direct losses rate determination and agricultural losses prediction. Determining the pre-disaster value is relatively simple, only the farming season and the crops types factors are important, which are easy to acquire. Flood mainly causes two types of loss to the agriculture, the impact and the waterlogging, while the impact losses could be neglected in the plain area compared with the waterlogging losses. The disaster losses are also different in different land used situation even in the same waterlogging situation. For example: waterlogging in a short time with low water level gives little damage to the trees, however it will create a great damage to the fishery. Hence the floods direct losses rate is not only close related with land use factor but also related with flood area, submerged depth, submerged time and some other factors.

which farmland plots, fish ponds blocks, economic crops blocks, orchards blocks are drowned can be calculated by overlap analysis, a GIS method, in which several data layers are overlapped and new data layers or modification will make to the present layers. In practice, the drowned area in the DEM data are used to overlay with the farmland plots, the fish pond blocks and so on…, then new areas can be acquired, which means the drowned farmland plots, the drowned fish pond and so on…, and we also can get the submerged depth of a certain farmland block because the DEM data is geographically matched with these farmland.

The total flood agricultural loss can be get with the formulation 3

$$Loss = \sum_{1}^{N} LossRate \times Value \qquad (3)$$

Loss is the total agricultural losses in this flood. ***LossRate*** is the floods direct losses rate of the special type crops. ***Value*** is the pre-disaster value of crops. The inundated region contains ***N*** grids.

4. EXAMPLE

In order to make flood losses prediction process more convenient, we developed a prediction system on the basis of ArcGIS. The entire implement and use of this system includes three stages:

In the first stage: Its main target is to build a socio-economic database and accomplish a prediction system using the gathered socio-economic survey data, spatial geographic information and flood direct losses rate data, which shows in a tabulation style.

Figure 1 is the main interface of the prediction system, in which the DEM data and socio-economic survey data are represented in three-dimensional style.

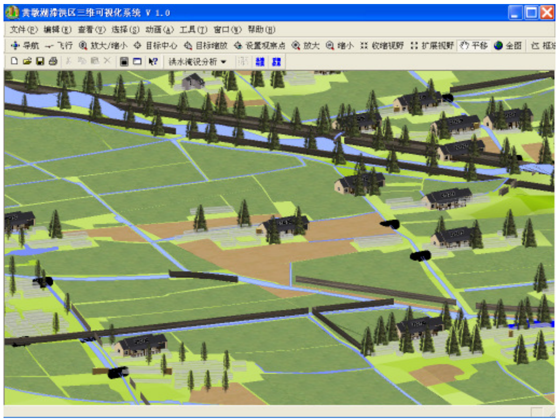

Figure.1 Main interface of the prediction system

In the second stage: The user can set the parameter of the flood out process (including flood flow, the volume of flood) and watch the inundating process and finally get the submerged information.

Figure 2 shows the finial inundated areas in a full map model. The inundated area shows in yellow color and different color depth represents different water depth. The original terrain color is kept if it is not submerged.

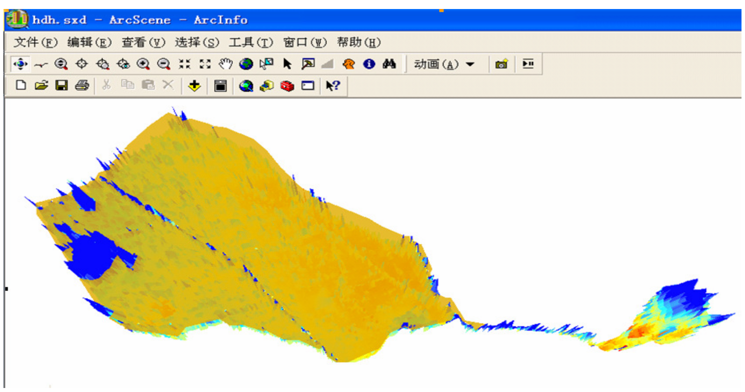

Fig.2 The inundated area

In the third stage: The total flood agricultural loss can be calculated by using formulation 3, in which the floods direct losses rate is selected automatically from the direct losses rate tables according to the water depth and water logging time.

Figure 3 shows one of the flood losses prediction tables. In this table, which is sorted by the family, the losses of different crops (rice, cotton, corn, kaoliang and so on…) are clearly shown.

编 号	户名	水稻(亩)	玉米(亩)	高粱(亩)	豆类(亩)	小麦(亩)	红薯(亩)	棉花(亩)	芝麻(亩)	花生(亩)
2603	0	738	0	0	0	0	0	0	0	0
2604	0	0	0	0	0	0	0	0	0	0
2605	0	0	0	0	0	0	0	0	0	0
2606	0	1107	0	0	0	0	0	0	0	0
2607	0	369	0	0	0	0	0	0	0	0
2608	0	369	0	0	0	0	0	0	0	0
2609	0	738	0	0	0	0	0	0	0	0
2610	0	369	0	0	0	0	0	0	0	0
2611	0	369	0	0	0	0	0	0	0	0
2612	0	0	0	0	0	0	0	0	0	0
2613	0	738	0	0	0	0	0	0	0	0
2614	0	738	0	0	0	0	0	0	0	0
2615	0	0	0	0	0	0	0	0	0	0
2616	0	738	0	0	0	0	0	0	0	0
小计		152403.9	0	0	0	863155.98	0	0	0	0

Fig.3 Flood losses prediction statistics

5. CONCLUSIONS

The paper describes an agricultural losses prediction method based on digital elevation data used in Jiangsu province of China. The most important characteristic of this method is its capability of dynamic simulation. It can be used to not only simulate the flood inundating process but also acquire the submerged depth and time under different simulated environments (e.g. flood flow speed, or discharging time). Based on these flood information, more accurate and intuitive losses information can be acquired, which provides great convenience to the water management department and agricultural bureau.

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