Characterize the spatial patterns of perennial waterlogged cropland using the micro-geomorphology structure in Jianghan Plain, middle reaches of the Yangtze River

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Abstract **Artificial micro-geomorphology would show increasing potential in understanding the interactions between natural environment and human activities. In this paper, we try to analyze the relationship between the spatial patterns of perennial waterlogged cropland and the micro-geomorphology structure in Jianghan Plain. The method is an integration of the identifying index of slope position and the calculation of topographic index. The result shows preferable agreement with the waterlogged area identified from remote sensing and soil map. It confirms that the geomorphological methods are effective to simulate the distribution of waterlogged croplands, even in an alluvial plain with complicated hydrogeology regimes.**

INTRODUCTION

Currently, activities that humans rearrange and utilize the land have been a more and more powerful geomorphic force, and artificial micro-geomorphology has played an increasing role in the distribution of some disasters. Compared with large scale geomorphological conformations, micro-geomorphology is of small space-scale, and more easily influenced by human activities. However, little has been done to associate geomorphology and natural disasters directly [1, 2]. In this paper, we try to analyze the relationship between the spatial patterns of perennial waterlogged cropland and the micro-geomorphology structure in Jianghan Plain.

As a kind of agricultural disaster, waterlogging phenomenon is widespread in the earth, especially in some cropping regions of floodplains. Waterlogging poses a serious threat to the world's productive agricultural land, and these threats have made vast expanses of land totally unsuitable for cultivation. In developing countries which depend heavily on agriculture, the menace of waterlogging is of more immense concern. In china, waterlogging is one of the most harmful disasters comparable with flood in the reaches of Yangtze River [3].

Because of the violent human activities to geomorphology, there are ferocious complex hydrological regimes in the waterlogging vulnerable areas. Besides, monitoring sites are often scarce in most waterlogging areas. Consequently, it is difficult to use hydrological modeling in this situation, and hardly any existing way is available currently to get a quantificational result. Considering that geomorphology determining topography and the nature of deposits, thus water pathways and residence times, and has a tight connection with human activities, it is assumed here that the spatio-temporal patterns of waterlogging fields could be simulated directly from the geomorphology. Therefore, the aim of this paper is to use the micro-geomorphology structure and some related indexes for the delineation and characterization of waterlogged cropland. Given the wide availability of DEM over the recent years, this method presents the advantage to be easy and possible over large areas integrated with remote-sensing or field surveys. .

STUDY AREA AND DATA

Jianghan Plain is an alluvial plain formed by the deposition of sediments over a long period of time by the Yangtze and Hanjiang Rivers. Elevations of the most areas in Jianghan Plain are below 50 m. However, the low-lying fluvial landforms, abundant rainfall, vast runoff from rivers, and inappropriate land use patterns in some regions of the plain often cause soil saturation and surface flooding. We select a small region as the sampling area in the Jianghan Plain. Location of the sampling area is shown in figure.1. It is one of the typical geomorphology units in the plain with a shape like dish. Perennial waterlogged croplands are widespread in the plain, and also occurred in this place.

Data used in this research mainly include observations and measurements from different sources: SRTM (Shuttle Radar Topography Mission) DEM, Landsat ETM+ images captured in 2000 and 2004, and soil map, in addition to ground observations.

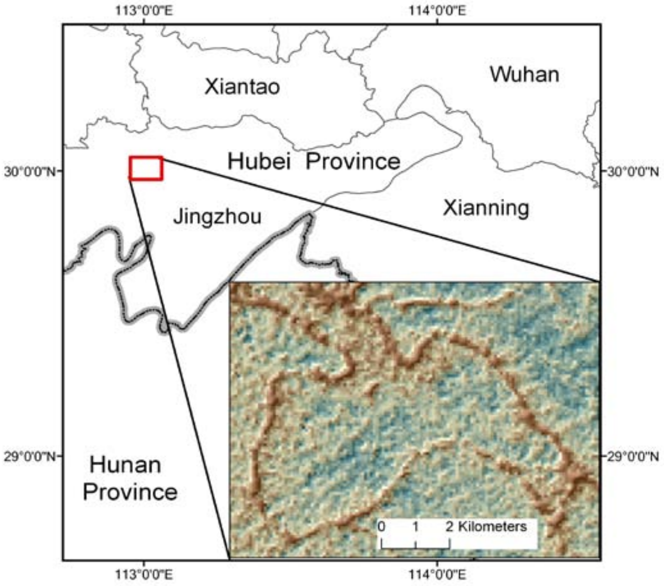

Figure 1. Location of the study area

METHODS

As far as the study methods are concerned, the waterlogging vulnerability is studied mainly by the following methods: numerical simulation from the hydrological and hydraulic modeling, socioeconomic method integrated with meteorological method, and comprehensive analysis of the cause of waterlogging. Those methods requires a lot of data which is lacking in most cases and it is difficult to study the waterlogging risk happened in a broad region. Moreover, waterlogging fields are always located in landscapes with little topographic relief, thus hydrologic modeling in low-lying, flat terrain poses significant difficulties due to a lack of significant topographic gradients.

Because geomorphology is the main factor that determines water pathways, predicting of the spatial distribution of areas with high water content would be through the way by using the geomorphology. Many researchers used the topographic index as an index of saturation. For example, Curie et al. (2007) attempted to predict the extent of waterlogged soils by using the topographic index. At present, there are many other studies of using indirect topographic/landform site factors for the indication of vegetation, soil, snowcover, wetland, etc. They all could show the potential of the quantitative, exclusively geomorphology-based methods for the delineation and characterization of waterlogged cropland.

The research could be made up of three parts: (1) monitoring the spatial patterns of waterlogged fields, (2) interpreting the geomorphology structure and extracting relevant factors, and (3) quantifying and modeling the effects of geomorphology to the distribution of waterlogged fields. The methods are an integration of geomorphology, remote sensing, GIS and geostatistical analysis.

A method is developed by integrating the local topography analysis and the overland flow simulation to extract the structures of artificial micro-geomorphology. Differences between the local elevation of each pixel and the average elevations of around pixels within different distances are calculated first in the local topography analysis process. Then the appropriate distances are evaluated to obtain the size of analysis window. Using the moving window statistics, potential pixels in the structure lines of artificial micro-geomorphology can be filtered from the whole study area. Afterwards, flow simulation was used to identify the real pixels in the structure lines out of the all the potential pixels.

Spatial patterns of waterlogged croplands are identified using remotely sensed images according to its ecological and thermodynamic characteristics. According to field surveys, the characteristics of waterlogged cropland not only show sub-surface physicochemical features, but also show ecological and thermodynamic appearances. We use the time series of indexes including land surface temperature and the Normalized Difference Vegetation Index (NDVI) extracted from Landsat ETM+ images to monitor the waterlogged cropland. The way to retrieve the Land Surface Temperature (LST) using single channel of Landsat scenes is described by Jimenez-Munoz and Sobrino [4]. NDVI are calculated from Landsat images using the formula of (band 4 - band 3) / (band 4 + band 3).

Parametrization of micro-geomorphology is the key step to characterize the spatial distribution of the waterlogged cropland. Terrain shape characteristics such as slope, peaks, topographic index, and profile curvature, etc could be easily derived from digital elevation models. However, in order to build up geomorphologic models, it is necessary to develop new geometric characteristics [5], and to integrate the existing factors into an effective way. In this paper, we mainly use the index of slope position and topographic index to model the distribution of waterlogged cropland.

Result and discussion

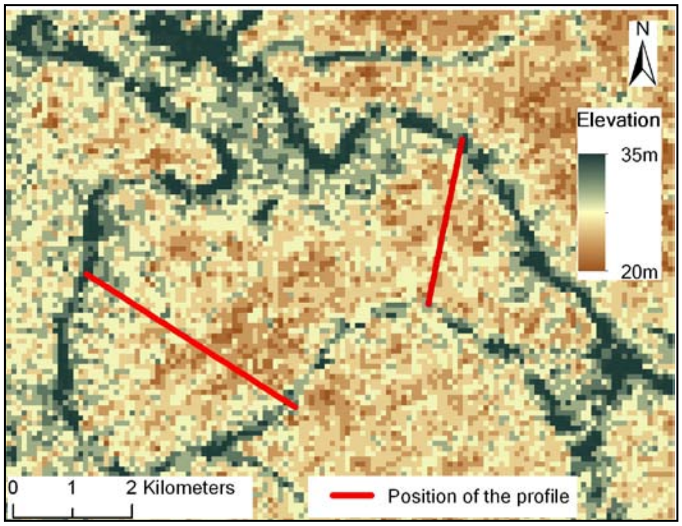

Figure 2. DEM of the study area

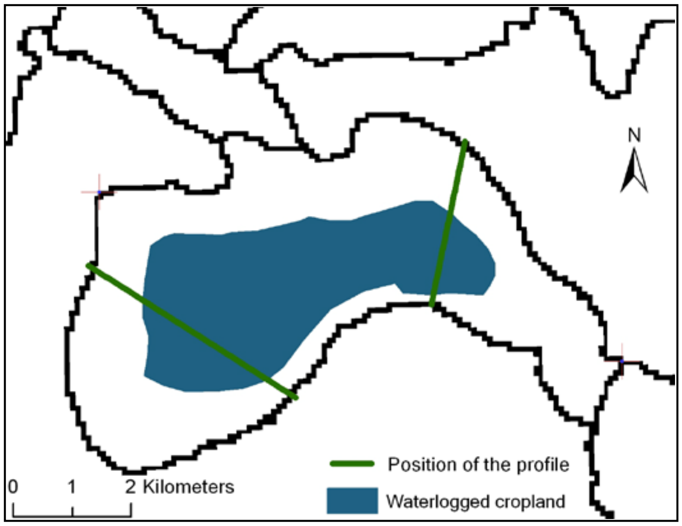

Figure 3. The extracted micro-topography structure and the area of the waterlogged cropland

The typical morphological structure of micro-topography in Jianghan Plain is characterized by enclosed embankments on the low-lying land. As shown in figure 2, this kind of morphological structure of micro-topography looks like a dish and divides the plain to hundreds of unit. In this sample area, the elevation ranges from 20m to 35m. Using the method of local topography analysis and the overland flow simulation, the skeleton lines of the enclosed micro-topography structure can be extracted automatically. Figure 3 shows the extracted micro-topography structure with dark line. Waterlogged cropland is extracted using remotely sensed imaged and soil map, and is demonstrated using cyan color in Fig.3. It can be found that the waterlogged cropland is located in the central area of the micro-topography unit.

Fig.4 and Fig.5 shows two profiles of the terrain and the locations of waterlogged cropland in the profiles. Red lines are the fitted quadratic polynomial lines. The positions of the profiles are shown in Fig. 2 and Fig.3. The sections between green lines are the ranges of waterlogged cropland areas in Fig.4 and Fig.5.

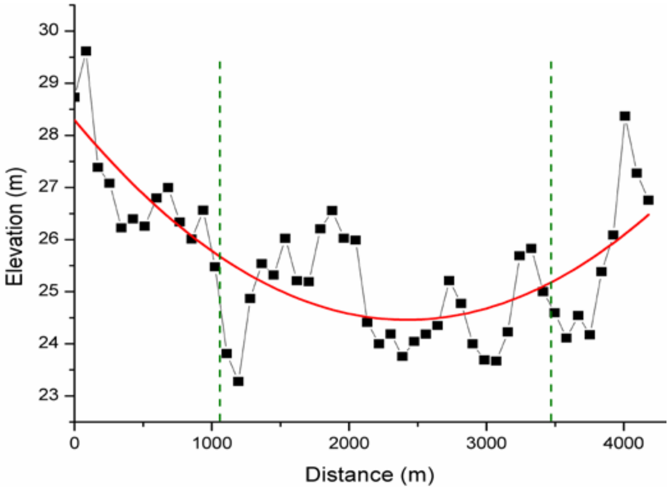

Figure 4. Profile of the terrain and the locations of waterlogged cropland in the profile 1.

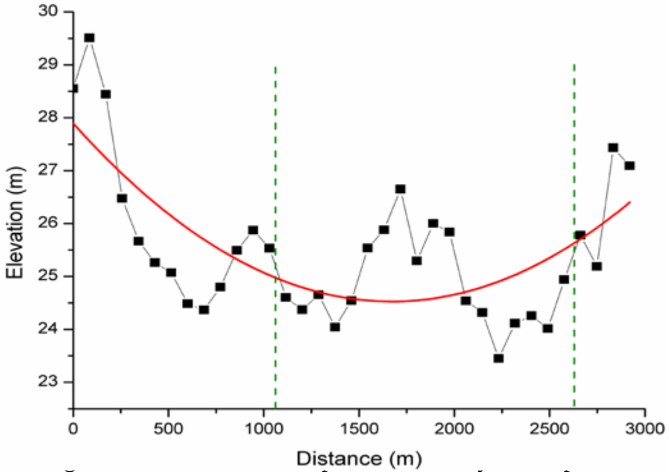

Figure 5. Profile of the terrain and the locations of waterlogged cropland in the profile 2.

It is evident that the waterlogged disaster occurred in the bottom of the pitch arcs of the fitted lines. Therefore, the potential waterlogged area can be identified according to the slope position in the enclosed structure. Topographic index is another way to simulate the distribution of the waterlogged cropland. We calculate the index using multiple-flow-directions algorithm. Afterwards, the two results are compared and integrated to the last simulation result. The simulated waterlogged cropland in the sampling area is shown in Fig.6.

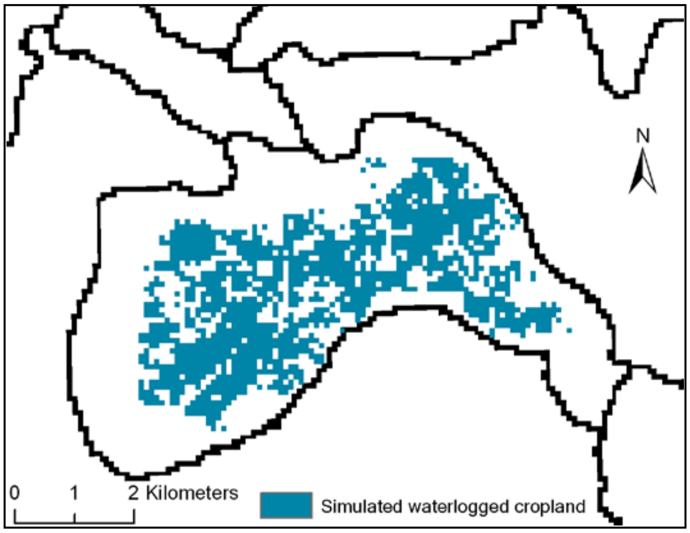

Figure 6. Simulation result of the waterlogged cropland.

CONCLUSION

The result shows acceptable agreement with the waterlogged area identified from remote sensing and soil map. It confirms that the geomorphological methods are effective to simulate the distribution of waterlogged croplands, and the artificial micro-geomorphology shapes the spatial patterns of the waterlogged soil. Even in an alluvial plain with complicated hydrogeology regimes, the micro-geomorphology is still one of the major driving factors for waterlogged croplands distribution, despite that waterlogged soil is essentially induced by high levels of groundwater. Geomorphology methods would be helpful for the estimation of the interactions among disaster spatial patterns, human activities and natural environment.

ACKNOWLEDGMENT

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