Remote-sensing and modeling of the potential suitable sites for restoration in Dajiuhu sub-alpine wetland

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***Abstract*—In view of the data limitations for mountain wetland, we validated the application of high spatial resolution satellite imagery and DEM for mountain wetland conservation and restoration in this paper. Dajiuhu wetland, a rare sub-alpine wetland which is threatened by degradation and currently poorly understood, was select as the study area. Although there are scarce of basis data in Dajiuhu wetland, spatial patterns of the wetland vegetation could be obtained from the remote sensing interpretation, and the classification could achieve the plant formation level via integrating the high spatial resolution images with field survey. Total classification accuracy is about 83%. Despite of the widespread manmade drainage systems and the great changes on topography, hydrology, vegetations and land-cover, the potential suitable sites for wetland restoration could be modeled and located by the spatial analyzing to the result of satellite imagery classification and a high resolution (10m) DEM. Total area of the simulated potential lakes is 107.03hm^2, which is comparable with the original perennial lakes before 1950s. The research could provide basic data for the restoration of the Dajiuhu mountain wetland, and would be a useful tool to locate the potential suitable sites for wetland restoration.**

Keywords- remote sensing;sub-alpine wetland; restoration

I. INTRODUCITON

Mountains constitute a significant part of global ecological systems, with tremendous habitat and species diversity [1]. With a growing emphasis globally on water resource issues, mountain regions are regarded as the "water towers of the world". In mountain regions, wetlands may gestate from some river basins and closed basins, whose functions and services are of great importance to both people and nature for the conservation of biological diversity, hydro-ecological and socio-economic functions [2].

Notwithstanding the services that mountain wetlands provide, mountain wetlands are particularly sensitive and dynamic ecosystems [3]. They are particularly fragile and vulnerable to external pressures, and increasingly threatened by negative effects of climate change, increasing human activities such as reclamation, deforestation, intensification of agricultural practices, mining activities, hydropower generation installations and tourism and recreation activities.

At present, conservation and wise use of mountain wetland has received much attention [2]. However, mountain wetlands were commonly located in obscure areas with closed terrain, and inconvenient in transportations. There is hereby often scarce of basic data, such as boundary, area, land-cover, vegetation species, landscape patterns, etc, to make scientific layouts for mountain wetlands sustainability. Thus the data limitations and incomplete information have already been restrictive factors for the conservation and use of mountain wetlands in some regions.

Dajiuhu wetland, a sub-alpine wetland in Shennongjia Mountains, is just a mountain wetland which is facing the threat of extermination and currently poorly understood. Aiming at the data limitations and difficulties in carrying out wetland restorations, in this paper, high spatial resolution satellite images and DEM were applied for wetland classification, restoration simulation and the exploration of the potential of coupling high resolution satellite images and DEM for mountain wetlands sustainability.

II. STUDY AREA

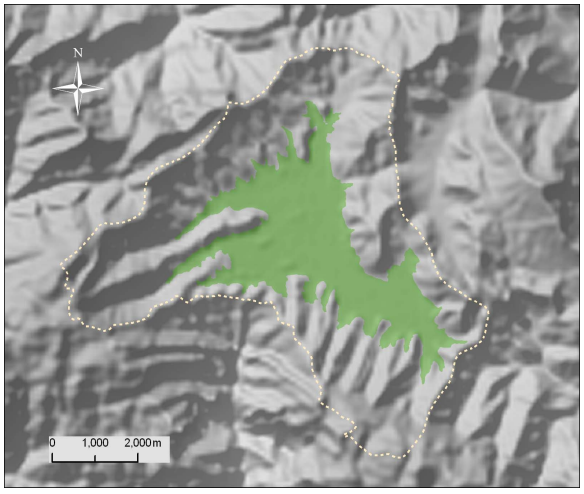

Figure 1. Dajiuhu sub-alpine wetland

The study area, Dajiuhu wetland is a sub-alpine wetland located in the Shennongjia Mountains of Central China, at approximately 31° 26′ -31° 32′ N and 109° 56′ -110°

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3′ E. It is a closed basin with a doline at its lowest position. Lowland area of the basin is about 1178.62 hm^2, and the whole drainage area of the basin is approximately 4323 hm^2.

As Shennongjia Mt. is one of the focus areas of global biodiversity research, Dajiuhu wetland acts as a key area maintaining ecological security for local regions. Peat swamp has formed during the geological period of the wetland, which is extremely rare and particular at the north-subtropical alpine region in China. History of the peat swamp in this wetland could be ascended to former Holocene, and thus could provide critical information to global change and wetland evolvement. Being a buffer area of the Shonnongjia Biosphere Reserves which has been accepted by the International Man and Biosphere Reserve Network of UNESCO, Dajiuhu wetland is also a National Geopark, a National Wetland Park, and a demonstration area of the Natural Forest Protection Program in China.

However, Socio-economic and environmental changes have impacted heavily on land use in this region. Because of the rapid extending of crop-planting, off-season culture, herb-planting and stockbreading in this wetland, some parts of the wetland have been drained and reclaimed to farmland since 1980s. As shown in fig.2, manmade drainage systems are widespread in the wetland. At present, environmental degradation poses a serious menace to the long term sustainability of wetland, and it makes the Dajiuhu wetland a threatened wetland that deserves much attention.

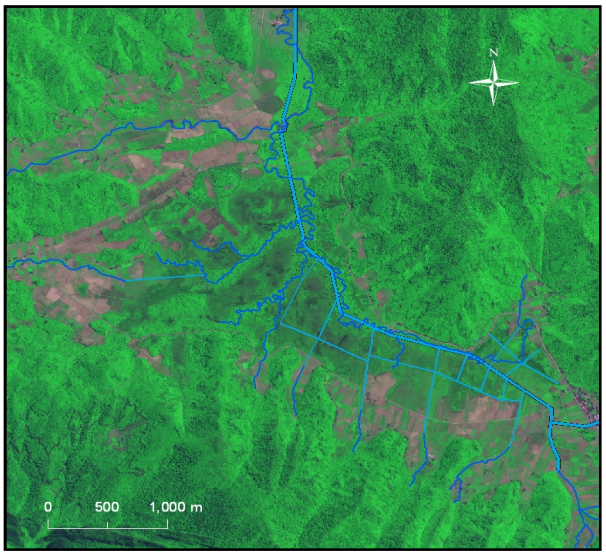

Figure 2. Drainage system of Dajiuhu wetland

III. MOUNTAIN WETLAND REMOTE SENSING

As landscape level patterns of wetland are very important to take into consideration when proposing a restoration or mitigation project [4], spatial patterns of wetland vegetation should be monitored and understood. Although field investigation could provide accurate information of vegetation types, it is time-consuming and difficult to cover all the study area based on liner-route sampling in field survey.

A. data

In order to get the information of wetland types and its spatial patterns, besides field survey, fine-resolution satellite image was applied in this study. It was reported that moderate spectral and spatial resolution satellite images such as Landat Thematic Mapper (TM) were not sufficient to discern mixed community types [5]. In wetlands, the community type is diversified, and it thus needs higher resolution images on the classification. Fortunately, higher-resolution satellite-based imagery is now commercially available. A QuickBird image captured in June 14, 2005 was purchased. It was radiometrically and geometrically preprocessed to orthoready standard level, consisting of four multi-spectral bands of 2.8m spatial resolution and a panchromatic band of 0.61m spatial resolution. Pan and multi-spectra bands of QuickBird were fused at first. Then the image was geometrically corrected by control points that we surveyed using GPS dual-frequency measurements in field. And then, it was reprojected to Universal Transverse Mercator (UTM) coordinate system.

B. vegetation classification

According to our field survey, Dajiuhu wetland has a high level of plant diversity. The dominant families of higher plant existing in the wetland are mainly made up of Cyperus, Gramineae, polygonaceae, Juncaceae, Rosaceae, etc. Based on the classification system in the monograph of "Vegetation of China", the wetland plant species could be classified into four vegetation type groups, then seven vegetation types, and then twenty formations. The four vegetation type groups are broadleaf forest, shrub-grassland, swamp, and aquatic vegetation. Then the four groups could be separated to seven vegetation types that are deciduous broad-leaved forest, shrub, herbosa, swamp, marsh, submersed vegetation, and emergent vegetation.

C. Remote Sensing Interpretation

As we known, there are often the phenomena of different object with the same spectra characteristics and same object with different spectrum in vegetation remote sensing, especially for fine spatial resolution satellite images [7]. At the same time, the species in Dajiuhu wetland are very plentiful and complex. Thus methods of automatic classification are difficult to reach the formation level in the wetland vegetation remote sensing. Despite of this, as we found in Dajiuhu wetland, the different vegetation formations are commonly distributed in different wetland environments with different tones, texture features and shapes. It is thus possible to distinguish the wetland vegetations to plant formations level using visual interpretation. For every plant formation that judged from field survey, corresponding imagery interpretation key was then established. Hereafter, spatial information of wetland vegetation formations was achieved through remote sensing interpretation.

As shown in fig.3, twenty vegetation formations were identified from the QuickBird image. By checking the classification accuracy with field work, the total accuracy turned out to be about 83.2%.

IV. MODELING THE POTENTIAL RESTORATION SITES

Before 1950s, Dajiuhu wetland had almost kept natural state, with many small perennial lakes in it. According to some descriptions from indigenous people, the area of wetland was about 700hm^2, and lakes are not less than 150hm2 at that time. But now, from remote sensing and image interpretation, it could be found that the area of wetland is about 370 hm2, and the lakes are not more than 20 hm2. Fortunately, in recent, being cognizant of the severe situation on rapid wetland degradation, local governments are eager to carry out projects of wetland restoration, and rebuild perennial lakes in the wetland.

As the historic record in Dajiuhu wetland are very limited, original spatial distribution of wetland before 1950s are could hardly be located. Moreover, former hydrology and topography have been changed greatly in recent years. Accordingly, it is not to restore the wetland to the original appearance, and the potential sites suitable for restoration are not uniform in all places with the degraded area. Locating potential sites for wetland restoration needs consideration of geomorphology, hydrology, land-use, soil, etc [4]. However, such basic data are absent or very limited in this area. Under the condition of that, an approach based on the combining of QuickBird images and DEM was used for selecting the potential sites in this study.

Usually, the potential sites for wetland restoration would be more easily of water residence, especially for lakes restoration. At the same time, the restoration project should not bring forward much destruction to the present wetland. Considering that water pathway and residence time were mainly determined by geomorphology [8], DEM was used to find out the locations which easily be restored to lakes. DEM used in this study is a high resolution (10m) DEM which mapped by Institute of Geodesy & Geophysics, Chinese Academy of Sciences.

As the topographic index is an important indicator of the spatial distribution of areas with high water content [9], it was thus select as a factor to locate the potential restoration sites. Topographic index was expressed as

$$\ln(a / \tan \beta) \qquad (1)$$

While 'α' is the drainage area per unit contour length, 'β' is the local slope. The present manmade channels, trenches, and ditches are widespread in the Dajiuhu area. Because of the huge drainage effects of the manmade drainages, water pathways and water residence time were shortened greatly. Hereafter, the present drainages system would be reconstructed or filled and leveled up in the process of wetland restoration. Accordingly, DEM that be used to compute the topographic index was rectified in the first step. Then through the calculation of topographic index, spatial information of the potential soil saturation was achieved. Classifying the topographic index and overlaying the map of topographic index with the result of wetland classification from QuickBird, the relationship between potential soil saturation and the present wetland distribution could be raveled. Through analyzing the above relationship and the wetland former state before 1950s, the potential restoration sites could be located, which will not invade or occupy the most important core areas of wetland preservation, and easily be transformed from farmland or degraded areas to wetland. As shown by fig.4, the simulated potential restoration sites of perennial lakes consist of many small lakes. The total area of the modeled lakes is 107.03hm^2, which is a rational result compared with the former lakes area of 150hm^2 before 1950s.

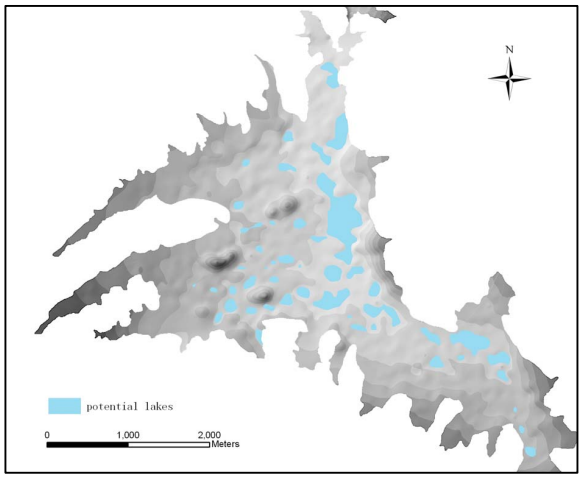

Figure 4. Potential suitable sites for restoration of perennial lakes

V. DISCUSS AND CONCLUSION

In this paper, we validated the application of high spatial resolution satellite imagery and DEM for mountain wetland conservation and restoration. Dajiuhu wetland, a rare sub-alpine wetland which is threatened by degradation and currently poorly understood, was select as the example. QuickBird imagery was processed and interpreted to classify the wetland vegetations. Assisted by detailed field survey, the classification result could reach to the plant formation level with an acceptable accuracy. Hereafter, combined with the result of wetland remote sensing, a geomorphological method based on topographic index was developed to model the potential fit areas for wetland restoration. Through spatial analysis such as correlation analysis and overlying analysis, the potential sites for restoration could be located, which will not invade or occupy the most important core areas of wetland preservation, and easily be transformed from farmland or degraded areas to wetland. The area of simulated potential lakes is comparable with the original perennial lakes before 1950s.

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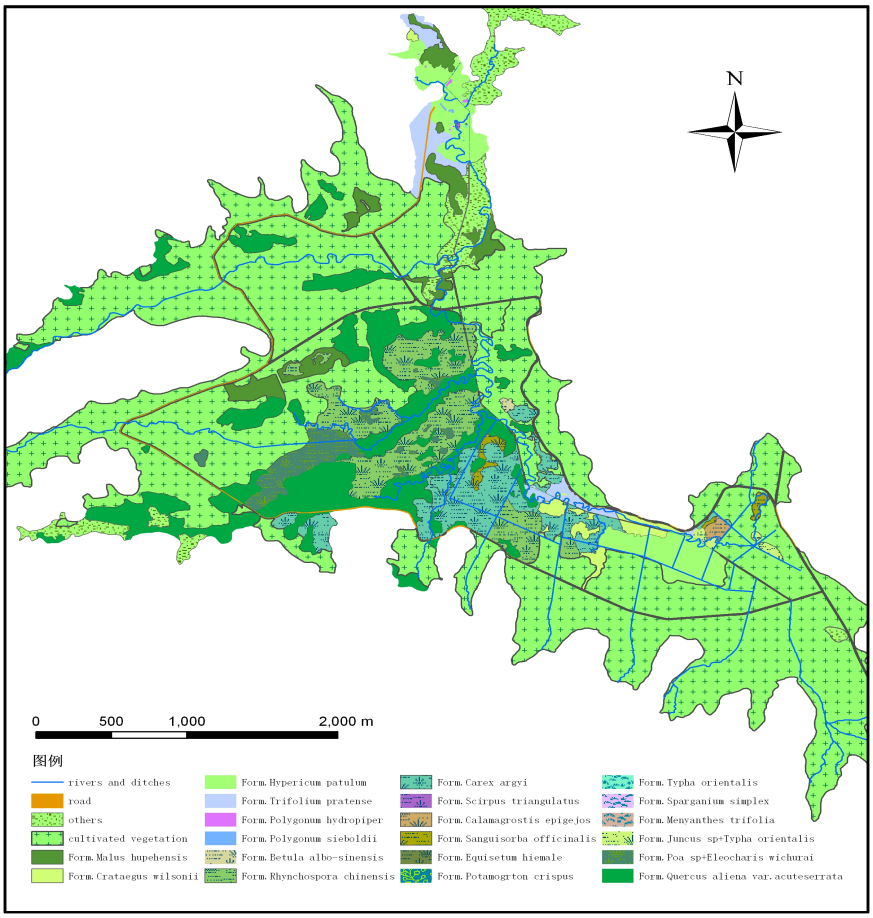

Figure 3. Vegetation formations of Dajiuhu wetland