A Method for Alpine Wetland Delination and Features of Border: Zoigê Plateau, China

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Abstract: Accurate wetland delineation is the basis of wetland definition and mapping, and is of great importance for wetland management and research. The Zoigê Plateau on the Qinghai-Tibet Plateau was used as a research site for research on alpine wetland delination. Several studies have analyzed the spatiotemporal pattern and dynamics of these alpine wetlands, but none have addressed the issues of wetland boundaries. The objective of this work was to discriminate the upper boundaries of alpine wetlands by coupling ecological methods and satellite observations. The combination of Landsat 8 images and supervised classification was an effective method for rapid identification of alpine wetlands in the Zoigê Plateau. Wet meadow was relatively stable compared with hydric soils and wetland hydrology and could be used as a primary indicator for discriminating the upper boundaries of alpine wetlands. A slope of less than 4.5° could be used as the threshold value for wetland delineation. The normalized difference vegetation index (NDVI) in 434 field sites showed that a threshold value of 0.3 could distinguish grasslands from emergent marsh and wet meadow in September. The median normalized difference water index (NDWI) of emergent marsh remained more stable than that of wet meadow and grasslands during the period from September until July of the following year. The index of mean density in wet meadow zones was higher than the emergent and upland zones. Over twice the number of species occurred in the wet meadow zone compared with the emergent zone, and close to the value of upland zone. Alpine wetlands in the three reserves in 2014 covered 1175.19 km² with a classification accuracy of 75.6%. The combination of ecological methods and remote sensing technology will play an important role in wetland delineation at medium and small scales. The correct differentiation between wet meadow and grasslands is the key to improving the accuracy of future wetland delineation.

Keywords: alpine wetland delination; ecological methods; remote sensing; Zoigê Plateau


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Wetlands are complex natural systems which are formed from the interaction of terrestrial and aquatic ecosystems. They cover 6% of the world’s land surface area (Mitsch and Gosselink, 2007). The effects of climate change and human activities on wetlands have attracted the attention of the international community (Woodward et al., 2014). In the past three centuries, as much as 87% of global natural wetlands may have been lost (Davidson, 2014). Accurate wetland delineation forms the basis of wetland definition and mapping, and is of great importance for wetland management and research. The first manual of wetland delineation in the world is known as the 1987 Manual (Environmental Laboratory, 1987). The 1987 Manual has been subsequently improved and supplemented (Tiner, 2006) and is widely used in the United States (Berkowitz, 2011). Another method of wetland identification commonly used by the U.S. Fish and Wildlife Service’s National Wetland Inventory Program (NWI) relies on remote sensing and photo interpretation (Wu et al., 2014).

In recent years, new methods and ideas have been applied to wetland delineation and mapping (Amler et al., 2015; Lee et al., 2015; Thomas et al., 2015). The outer borders of wetlands are indicated by the absence of hydromorphic soils and/or hydrophytes and/or specific woody species that are able to grow in periodically or permanently flooded or waterlogged soils (Junk et al., 2014). A Landsat Enhanced Thematic Mapper Plus (ETM+) band 5 (mid-infrared wavelength) to band 2 (visible green wavelength) ratio was used to better capture the total flooded wetland extent in the Sacramento San Joaquin Delta (Quinn and Epshtein, 2014). Object-based methods and high resolution multispectral WorldView-2 satellite image data were capable of delineating the wetland regions of Penang Island in Malaysia (Hassan et al., 2014). However, because wetlands are so complex it is hard to obtain a consensus on wetland definition and boundaries. The wetland boundaries extracted by geographers may not be accredited by ecologists. Studies discussing the value of community ecology do not mentioned that the application of remote sensing technology and community surveys may add consistency to some aspects of wetland boundary definition. It is necessary for geographers and ecologists to work together in the future to determine common wetland boundaries.

The Qinghai-Tibet Plateau is the third pole of the world, and its widespread alpine wetlands are sensitive to global climate change and human disturbance (Bai et al., 2013). The Zoigê Plateau is located in the northeastern corner of the Qinghai-Tibet Plateau, and is an ideal natural laboratory for research on alpine wetland delineation because of the characteristics of the basin topography, the moisture gradient and vegetation evolution. A number of studies have analyzed the spatiotemporal pattern and dynamics of alpine wetlands in the Zoigê Plateau (Chen et al., 2010; Deng et al., 2010; Li et al., 2011; Ye et al., 2011; Bai et al., 2013; Xue et al., 2014; Kang et al., 2016), however, they have not addressed the issues of wetland boundaries. The accurate delineation of alpine wetlands is an important basis for remote sensing mapping and monitoring, scientific research and conservation management of alpine wetlands in the Zoigê Plateau. The objective of this work was to discriminate the upper boundaries of alpine wetlands by coupling ecological methods and satellite observations.

The Zoigê Plateau (31°50′N–34°50′N, 100°45′E–103°38′E) belongs administratively to the counties of Zoigê, Hongyuan and Aba in Sichuan Province, and the counties of Maqu and Luqu in Gansu Province (Fig. 1).

The average altitude of this plateau is 3400 m and marsh soil, peat soil and meadow soil occur widely. It has the alpine cold climate of the plateau region, with an average annual temperature of 0.6℃–1.2℃, which reduces slightly from the south to the north and from the west to the east. The climate is characterized by two distinct seasons: in winter (from November to April), it is cold and dry, with little precipitation and strong sunshine, whereas in summer (from May to October), the climate is wet. The annual average precipitation is 600–800 mm, and the annual average evaporation is higher than precipitation. Climate warming (at a rate of 0.70℃ per decade) and increasing intensity of land use have caused rapid degradation of the Zoigê Plateau, mainly to grasslands and wetlands (Bai et al., 2013). Almost all the rivers in this region belong to the Yellow River system, including its main tributaries, the Heihe and Baihe rivers. Grasslands, emergent marsh and wet