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Impacts of the channel/barrier effect and three-dimensional climate—A case study of rice water requirement and irrigation quota in Yunnan, China

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ABSTRACT

Yunnan is a large rice-growing province in China that is situated in a low-latitude plateau area. In this province, the channel/barrier effect and three-dimensional climate play prominent roles and significantly influence the rice water requirement (ET_c) and irrigation quota (IQ), while the research about the influence mechanism and results is lacking. We estimated the rice ET_c and IQ of different hydrological years based on the experimental data from six areas of mid-season rice and the single crop efficient approach recommended by FAO-56. The contour maps were drawn with GIS, and the spatial distribution of the rice ET_c and IQ under the influence of the channel/barrier effect and three-dimensional climate were analyzed. The results showed that high water ET_c and IQ of rice were distributed in the hot, dry river valley area. The rice ET_c was the smallest in northwestern Yunnan, and the IQ was the smallest in southern Yunnan. The ET_c and IQ of rice were divided into several intervals by mountains and valleys, and varied largely among different channels and little within one channel. The three-dimensional climate results in the abrupt changes of ET_c and IQ, The leading meteorological factors causing the abrupt changes were different, and there were also complex correlations between these meteorological factors. Taken together, temperature and rainfall were the most critical elements in the three-dimensional climate. The results of this study illustrated the regularity and inherent mechanism of the rice ET_c and IQ under the influences of the channel/barrier effect and three-dimensional climate, providing certain references for the analyses and calculation of the rice ET_c and IQ in similar circumstances.

1. Introduction

At present, agricultural irrigation water accounts for more than 70% of the total water consumption in China. Rice is one of the most water-consuming crops in China. The annual water consumption of rice accounts for 51.1% of the total water consumption of crops (Mao, 2001). Due to the shortage of water resources and for the better allocation and utilization of water resources, many researchers inside and outside China have carried out tests on water requirements and irrigation quotas of rice (Mao, 2001; Watanabe et al., 2006; Tuong et al., 2005; Tabbal et al.,2002; Martini et al., 2013; Hou et al., 2016; Xu et al., 2017).

As a large rice-growing province in China, Yunnan has a long history of rice cultivation. In this province, rice is widely distributed (Katsura et al., 2008). Principally, mid-season rice is cultivated for one season. The traditional flood irrigation method is mainly used (Pan and Yao, 1992). To date, the results of experimental research on ET_c and IQ of rice in Yunnan are hardly useful as reference, for most of them were obtained based on meteorological data via analytical calculation and via modeling and forecasting (http://www.ynqi.gov.cn/). These results are valuable for reference to some extent, but the differences between them and the actual values need to be verified.

Yunnan is located in a low-latitude plateau region, with more than 94% of its area mountainous. Altitudes and climates vary widely across the province. There are large rivers featured with Longitudinal Range-Gorge Region (LRGR). In the near-surface layer, such landforms act as east-west barriers and north-south transmission channels towards the southeastern and southwestern monsoons in this region, forming a channel/barrier effect. Changes in climate and runoff also show significant characteristics due to this channel/barrier effect (Wang, 2005). Altitudes, mountains and valleys also affect solar radiation, humidity, wind speed, rainfall and temperature, with certain correlations among them. However, the topography and weather conditions of Yunnan make the correlations among these parameters very complex (Wang, 2005; Komuscu et al., 1998); thus, a complex and diverse three-dimensional climate eventually forms.

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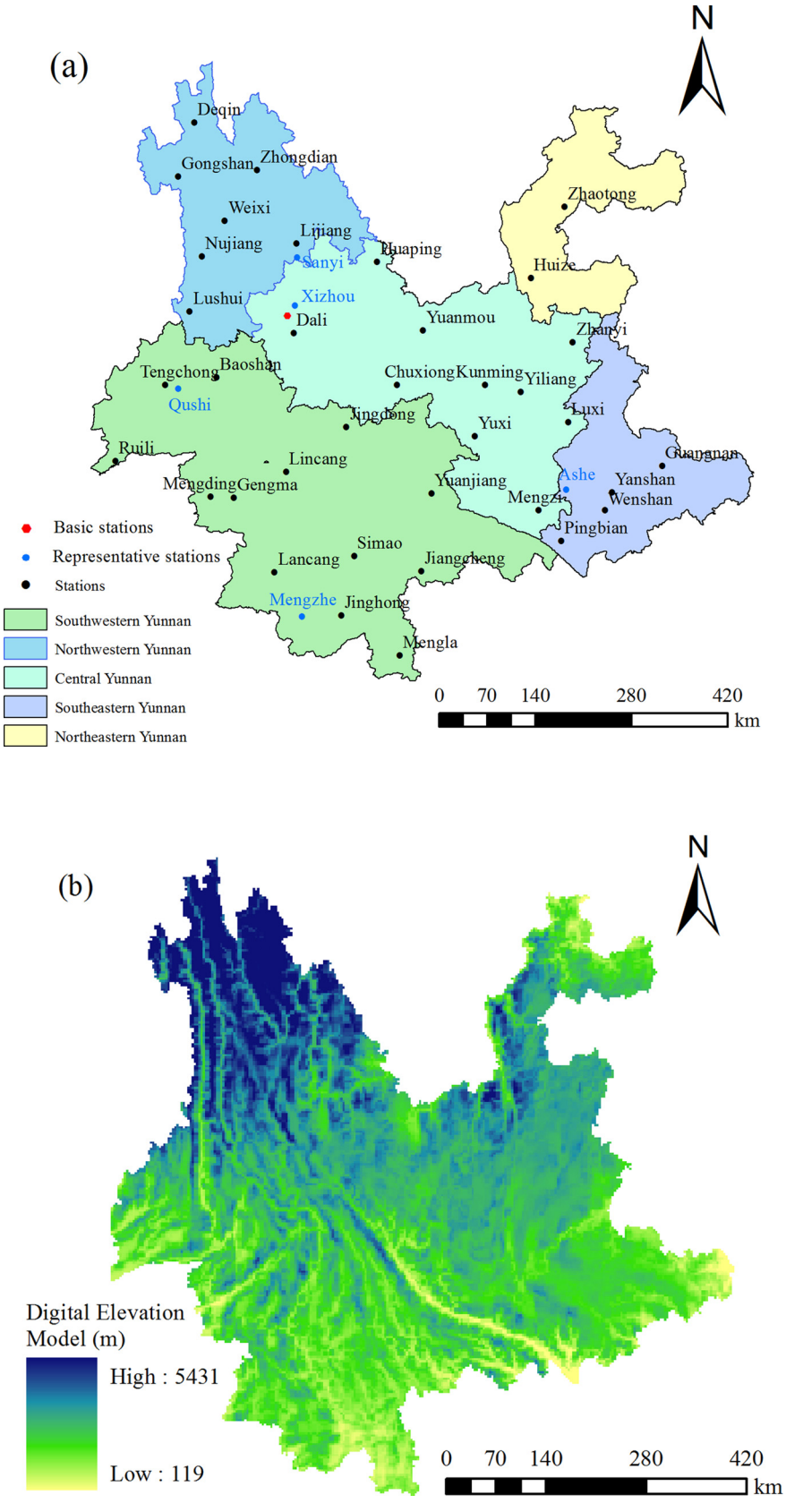

Fig. 1. Distribution of national meteorological stations, basic stations, representative stations (a) and digital elevation model of Yunnan (b).

Research has shown that climate change greatly influences the ET_c and IQ of rice (Yoo et al., 2012; Silva et al., 2007; Rodriguez Diaz et al., 2007; Ye et al., 2015; Thomas, 2008), and temperature is one of the most important influencing factors. Temperature can affect the growth and vegetation of rice (Nishiyama, 1976; De Datta, 1981; Oldeman et al., 1987) and further affect the length of the rice growth period