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50-year evapotranspiration declining and potential causations in subtropical Guangdong province, southern China

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ABSTRACT

Background: Evapotranspiration (ET) is an important flux term in the terrestrial hydrologic cycle system that integrated atmospheric and land surfaces, hydrological and biological processes. Any variations of the hydrological processes induced by climate change and forest management would be significantly reflected in ET component.
Methods: In this paper, we firstly calculated Guangdong's 50-year annual, humid- and dry-season ET jointly based on the water balance model and a physical-based ET model. Then, the separate contributions of climate change and reforestation on ET changes were evaluated by the double mass curve method.
Results: The time-series annual ET declined significantly ($p < 0.001$) during the past 50 years. The year 1980 showed to be an important change point. Both humid- and dry-season ET kept much stable during the former period 1956–1979, while decreased significantly ($p < 0.001$) during the later period 1980–2006. Climate change and reforestation contributed for about −34.02 and 31.03 mm/year for the annual ET variations, while about −28.18 and 27.25 mm/year for the dry seasons, and about −5.84 and 3.78 mm/year for the humid seasons, respectively.
Discussions and conclusions: By comparison, the positive contributions of reforestation on ET changes were completely offset by the negative contributions of climate changes. Climate changes were the key factors responsible for the reduction of Guangdong's ET. In particular, the regional ET in dry seasons was quite more sensitive to climate change and land cover changes, while much less sensitive in humid seasons. Our results also confirmed that land cover changes would have little impacts on the regional ET changes when P/PET > 1, but might cause greatly influences on ET when P/PET < 1. These conclusions indicate that afforestation might be actively encouraged in humid regions, but should be treated cautiously in non-humid regions or even be limited in arid regions. It will be directly useful for guiding government in future forest management.

1. Introduction

Recently, great emphasis has been given to two focuses in the fields of hydrology researches: (1) responses of hydrological processes to climate change (Bonell, 1998; Huntington, 2003; Neff et al., 2000; Shrestha et al., 2012) and (2) relations between hydrological processes and forest management (Legesse et al., 2003; Lu et al., 2013; Mango et al., 2011; Sun et al., 2006). The effects of climate change and forest management on hydrological processes are being pursued vigorously as a multi-disciplinary problem (Goyal, 2004). Nevertheless, the hydrologic responses to reforestation and deforestation are not well cognized at present (Sun et al., 2006). It has become the most important and controversial topic in the forest hydrology community (Lin and Wei, 2008; McVicar, 2007; Scott and Prinsloo, 2008). The general conclusion believed that forest removal or harvesting could increase surface runoff, while reforestation caused its reduction (Bradshaw et al., 2007; Bruijnzeel, 2004; Jackson et al., 2005; Oudin et al., 2008). But, some other results suggested limited or even no response (Antonio et al., 2008; Buttle and Metcalfe, 2000; Dyhr-Nielsen, 1986; Wilk et al., 2001), which was contrary to the traditional hypothesis. The inconsistent opinion about the relations between forest management and hydrological processes was found not only in small-scale watershed studies (Bruijnzeel, 2004; Jackson et al., 2005; Liu and Zhong, 1978; Ma, 1987), but also in large-scale watershed studies (Zhou et al., 2010).

Evapotranspiration component (ET), which consumes nearly 60–75% of precipitation inputs, is an important flux term in the terrestrial

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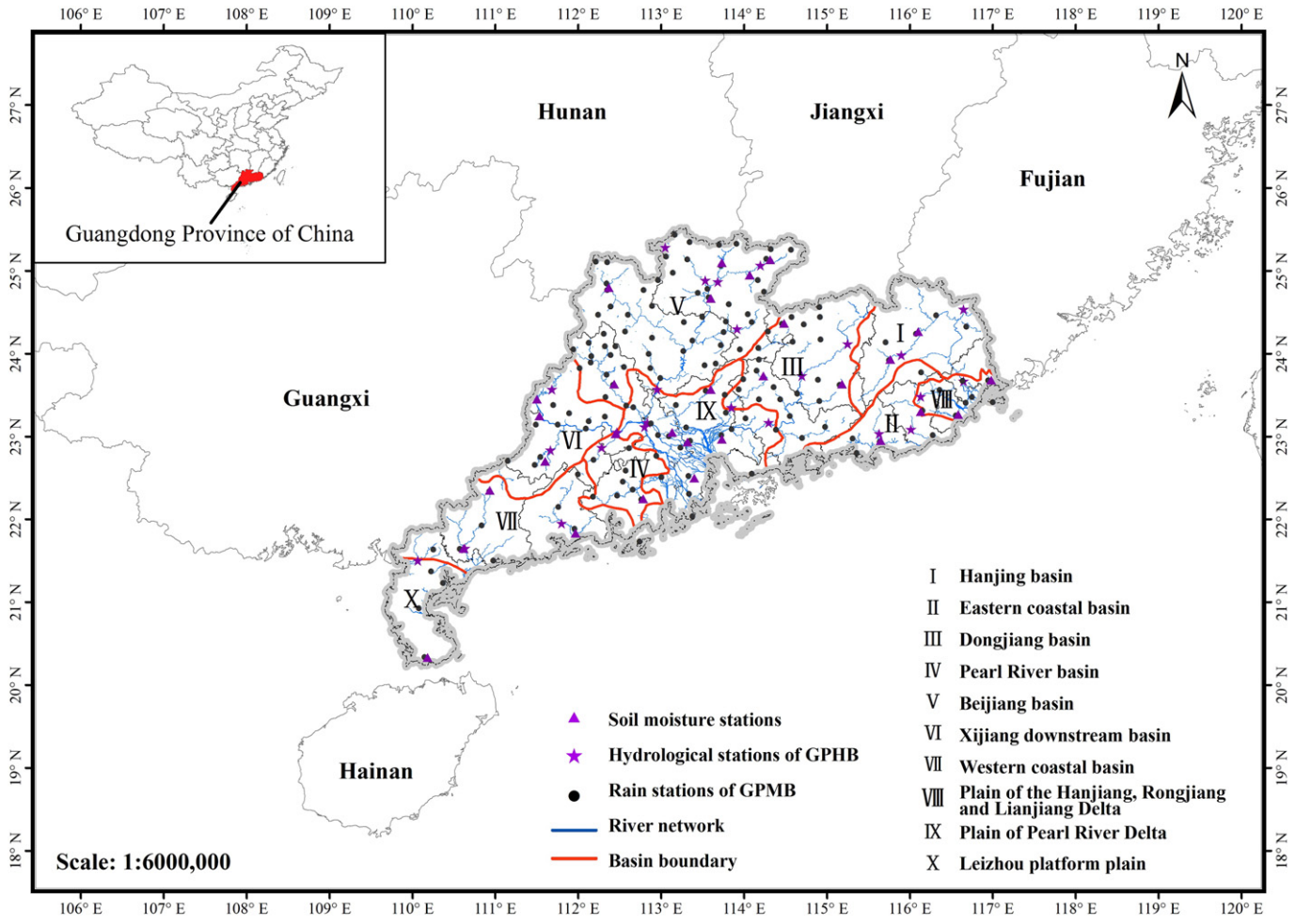

Fig. 1. Study area and observation stations.

hydrologic cycle system that integrated atmospheric and land surfaces, hydrology and biological processes (Chattopadhyay and Hulme, 1997; Penman, 1948). It is an effective indicator in describing regional hydrological system (Currie, 1991; Huo et al., 2013; Law et al., 2002; Zhou et al., 2008a, 2008b). Any variations of the hydrological processes induced by climate change and forest management will be significantly reflected in ET component (Bultot et al., 1988; Gleick, 1986; Goyal, 2004; Hillel, 1998; Huo et al., 2013; Zhang and Schilling, 2006). Hence, quantifying the regional-scale time-series ET is vital for understanding the interaction mechanizations between forest management and hydrological processes.

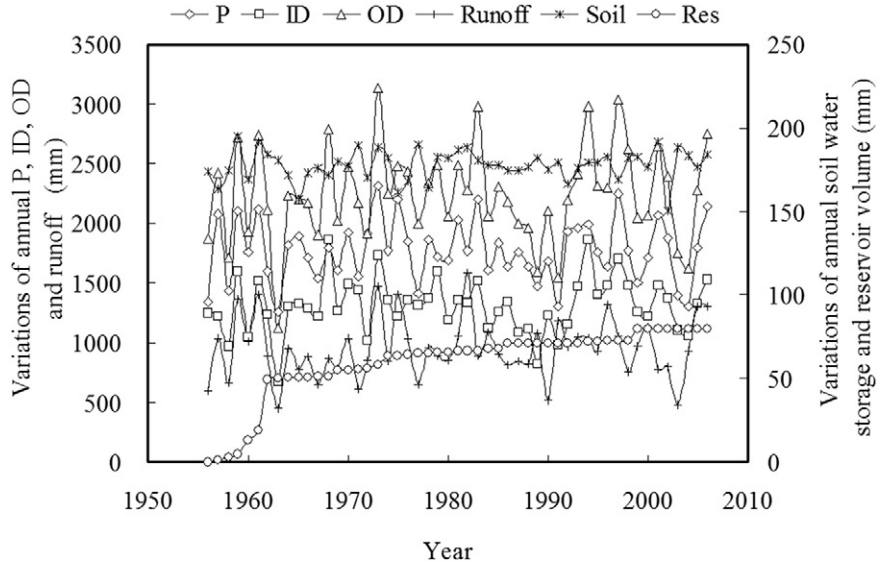

Fig. 2. Annual variations of the hydrological component.