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National-scale paddy-upland rotation in Northern China promotes sustainable development of cultivated land

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ABSTRACT

As China requires more cultivated land to feed its increasing population, the sustainable development of cultivated land in its intensive agricultural production system has become a major issue for government and society. We firstly reviewed the progress of paddy-upland rotation (PUR) and conservation tillage, found that PUR was improve significantly soil properties, including redox potential of soil, the mineralization of soil organic matter, and the abundance of beneficial microorganisms, suggested that conservation tillage was an effective measurement for remedying the deficiency under the PUR. Meanwhile, we also systemically reviewed the statues of water resource infrastructure and policy level. Consequently, with current agriculture technology and the increasing capacity of adjusted artificial water resources, our results highlight the development of national-scale PUR as an effective adaptation strategy to protect and improve soil fertility and ensure agricultural security under climate change. In other words, from national strategy scale, national-scale PUR was a good choice in the major grain-producing areas of northern China in the coming 50–100 years. Lastly, further research in the few aspects was needed to better provide theoretical and technical support for promoting effectively the PUR.

1. Introduction

China requires more cultivated land to feed its increasing population by increasing the multiple cropping index (MCI) (Turner, 1978; Turner et al., 1997; Guo, 1997) and developing conserved land resources. The MCI is the ratio of annual cultivated area (the sum of cultivated areas and multiple cropping areas) and cultivated land, that of >55% cultivated land in China was more than 100% (Ding et al., 2013). Achieving sustainable cultivated land development in intensive agricultural production systems is vital for the Chinese government. However, drought (e.g., Li et al., 2003; He et al., 2011) and water shortage (e.g., Leontief, 1970; Miller and Blair, 2009) has seriously restricted land farming and grain production, such as north China plain. Consequently, water resource sustainability is required for sustainable development of cultivated land.

Water resources in China rank sixth in the world, but the regional distribution of water resources is very uneven (Zhao et al., 2015). Eighty percent of water resources are distributed south of the Yangtze River, especially in southwest China. However, 50% of cultivated land and 55% of conserved land resources are distributed in northwest, north, and northeast China. Therefore, the asynchronous spatial distribution between land and water resources is very obvious (Fig. 1a). In July 2014, two of the three main plains in China experienced a drought, especially the Huang-Huai Plain (Fig. 1b), during the summer maize tasseling/flowering stage. The water crisis and water conservation plan in China (Liu and Yang, 2012) has been examined, and policy recommendations including coordination, integrating social sciences, and enhancing international cooperation have been proposed (Liu and Yang, 2012). In 2013, Zhang suggested that food security issues stem from water resource security (Zhang, 2013). Consequently, optimizing spatial and temporal distribution of cultivated land and water resources was important to achieve sustainable cultivated land development.

Sustainable cultivated land development, in other words, that is ecological sustainability with preserving resource's quantity and quality, such as soil fertility and water sources. In past few decades, however, soil fertility declining (e.g., Liu et al., 1998), total quantity insufficiency of water resource (e.g., Leontief, 1970; Miller and Blair,

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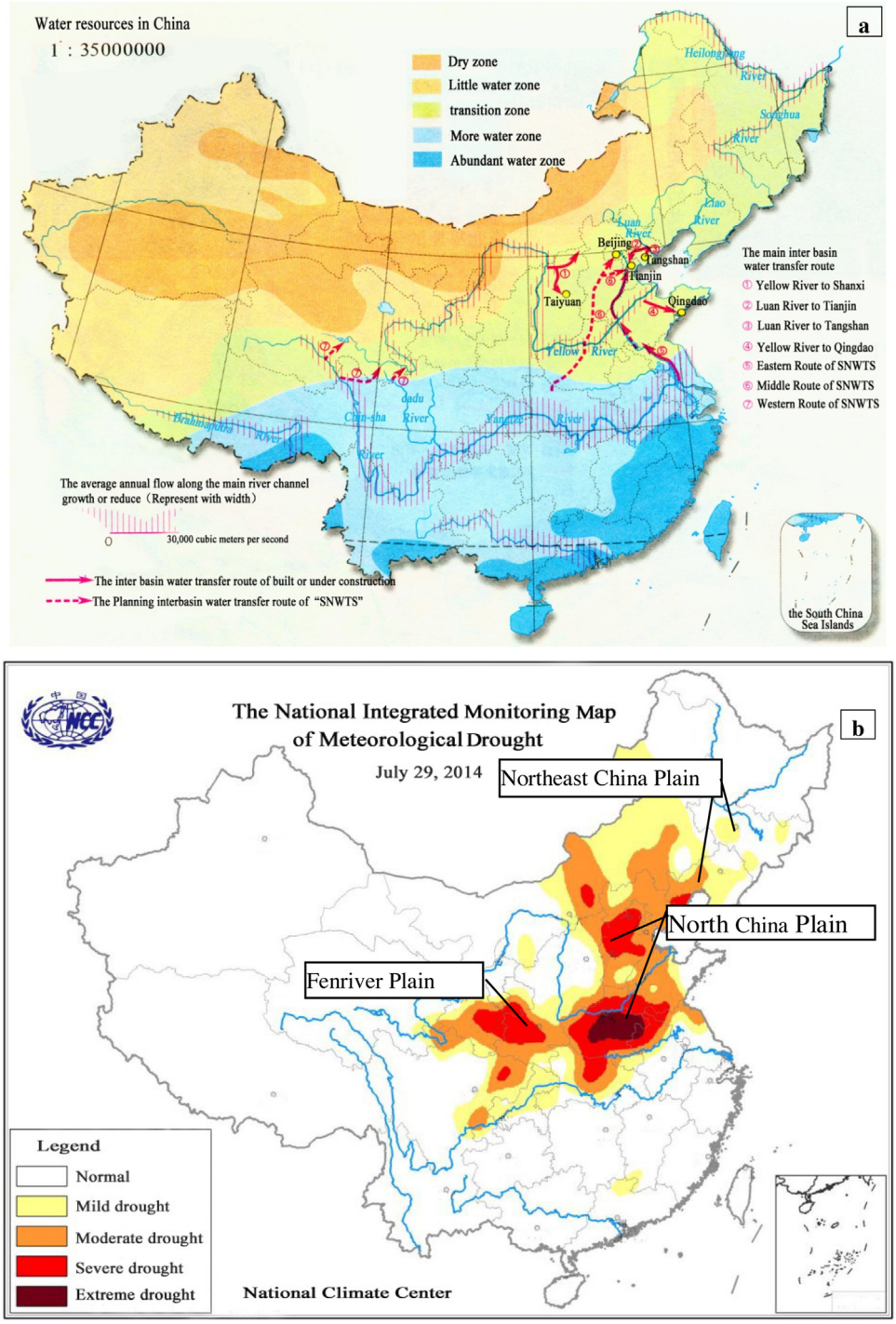

Fig. 1. Distribution of water resources and the main inter basin water transfer route (a); the national integrated monitoring map of meteorological drought on July 29 2014 (b).

2009) in Northern China and dated & unsound water source infrastructure (Liu and Wang, 2012) had badly restricted it. In this report, consequently, we firstly reviewed the progress of paddy-upland rotation (PUR) and conservation tillage, and introduced current water resource infrastructure, specially the south-to-north water transfer scheme, and policy level about water resource, above all of that were important in achieving a synergistic effect for sustainable cultivated land development. Lastly, we discussed the unresolved issues that remain to be addressed in further research for national-scale PUR.

2. Methods

We conducted a literature survey of peer-reviewed papers related to PUR and conservation tillage published before December 2014. To include as many studies as possible, we collected papers published in both English and Chinese from two databases, the Web of Science (in English) and the Chinese National Knowledge Infrastructure, the largest Chinese academic journal database. Twenty-seven papers (see the references in the supplemental material file) were collected in the conversation tillage according to the contents of two aspects: (1) yield, soil organic carbon and soil

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