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Cost-effectiveness analysis of water-saving irrigation technologies based on climate change response: A case study of China☆

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ABSTRACT

This study provides a cost-effectiveness analysis of four water-saving irrigation techniques that are widely implemented in China to address the impacts of climate change: sprinkler irrigation, micro-irrigation, low-pressure pipe irrigation and channel lining. The aim is to thoroughly understand the economic feasibility of water-saving irrigation as an approach to coping with climate change. Based on the cost-effectiveness analysis, this study finds that water-saving irrigation is cost-effective in coping with climate change, and has benefits for climate change mitigation and adaptation, and for sustainable economic development. For the cost-effectiveness ratio of mitigation and adaptation, only that of channel lining is negative (for mitigation is −43.02 to −73.41 US\$/t, for grain yield increase −34.35 to −20.13 US\$/t, and for water saving −0.020 to −0.012 US\$/m^3). Sprinkler irrigation has the highest incremental cost for mitigation (476.03–691.64 US\$/t), because when sprinkler irrigation is used, there may be additional energy needs to meet water pressure requirements, which may increase greenhouse gas emissions compared to traditional irrigation. For mitigation, in districts where the pumping head for pressure is lower than the critical energy saving head, sprinkler irrigation should be avoided. Micro-irrigation has the highest incremental cost for adaptation followed by sprinkler irrigation and low-pressure pipe irrigation, but when considering the revenues from improved adaptation, all of the measures assessed are economically feasible. The results suggest that for mitigation and adaptation objectives, micro-irrigation performs best. From an economic perspective, channel lining is recommended. Therefore, a balanced development of channel lining and micro-irrigation according to different geographical conditions is recommended.

1. Introduction

Agriculture is one of the most vulnerable sectors to climate change (IPCC, 2007a). Water resources are essential to agriculture, but over the last 50 years, some parts of China (Figs. 1 and 2), including major grain producing areas, have experienced declining precipitation (Ren et al., 2005). In recent decades, an annual average of 12.64 million ha of farmland has been affected by drought, with an average disaster rate (i.e., the percentage of the total drought affected area that suffers disastrous loss) of 56.71%. In 2008, the grain loss caused by drought was about 16 million tons and financial losses were about 23 million Chinese yuan (CNY) (MWR, 2011). In addition, increasing demand for water from urban and industrial sectors places greater pressure on agricultural water use (Fedoroff et al., 2010). Previous studies have indicated that water-saving irrigation (WSI) contributes to water saving and also to the reduction of greenhouse gas emissions, which can ease the negative effects of climate change on agricultural production (Zou et al., 2012; Karimi et al., 2012). However, the cost and effectiveness of using WSI to cope with climate change remains unknown. To date, there have been limited comparisons with other adaptation and mitigation measures to inform identification of adaptation and mitigation strategies. A clear picture of the cost-effectiveness of WSI techniques in coping with climate change can also support identification of balanced responses to climate change and sustainable economic development.

Cost-effectiveness analysis (CEA) is a decision-making assistance tool that compares alternatives to achieve a goal with regard to their resource utilization (cost) and outcomes (effectiveness) (Bambha and Kim, 2004). CEA can be used to find the least cost means to achieve a goal, or to estimate the expected costs of achieving a particular outcome (Tietenberg and Lewis, 2011). It can also be used to compare the impacts and cost of various alternative means of achieving the same objective (Dhaliwal et al., 2012). The

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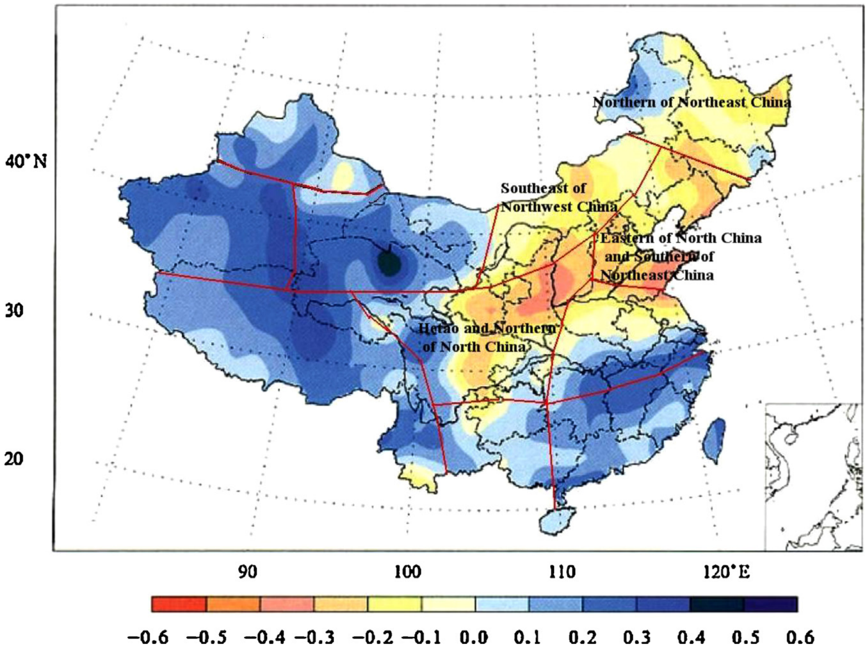

Fig. 1. Tendency of annual precipitation in China from 1956 to 2002 (Ren et al., 2005).

result of a CEA is expressed in a ratio (cost-effectiveness ratio, CER) between cost and outcome (Johannesson, 1995). CEA has been used for estimating the cost of mitigation in the electricity sector (Sims et al., 2003), and in dairy farms (Vellinga et al., 2011), buildings (Hoogwijk et al., 2010), agriculture (Wassmann and Pathak, 2007), transport (Metz et al., 2001) and the service sector (Hoogwijk et al., 2010). Despite this large body of literature, there are no specific studies addressing the cost-effectiveness of WSI for climate change adaptation and mitigation.

Compared to traditional irrigation practices, WSI techniques require higher capital investment. Revenue is a major driver for farmers who pursue agricultural production (Muhammad et al., 2007). Therefore, the cost and effectiveness are very important factors relevant to the willingness of farmers to adopt WSI (Tiwari and Dinar, 2000). In the context of climate change, sustainable development, mitigation and adaptation are integral parts of the response to climate change. For developing countries, mitigation is a long-term and arduous challenge, while adaptation is a present and urgent task. With global greenhouse gas concentrations rising, a successful response to climate change is a concern faced by the whole world (IPCC, 2007a,b).

In order to elucidate the relationships between the costs and effectiveness of WSI in the context of climate change adaptation and mitigation, CEA was applied to the four most widely

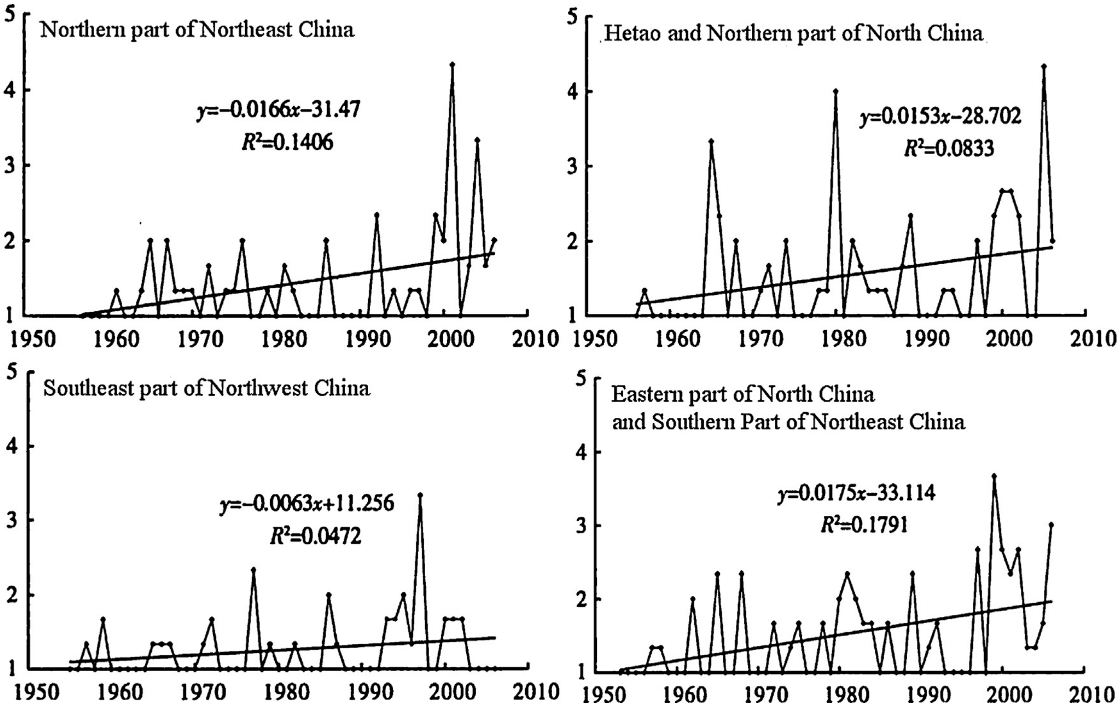

Fig. 2. Average drought grades and linear trend of four representative stations in China from 1956 to 2006 (Yang and Li, 2008).