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Effects of Cropland Cover Changes on Regional Climate over Western China Based on Simulations with RegCM3

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Abstract

The impacts of land cover changes on regional climate in Shaan-Gan-Ning (SGN) in western China were simulated with RegCM3. Sensitivity experiments were conducted by replacing crop grids with different new land cover types in the key area of SGN, where the returning cropland to tree/grass project has been carried out since 1999. The modified new land cover types include desert, forest, shrub and grass. They represent degraded, improved, and maintained vegetation cover with natural canopy in the key area. Results from three individual case studies show that the land cover change causes changes in temperature and terrestrial water variables especially within the key area, while changes in precipitation are found for a larger area. The strongest changes appear where the cropland is degraded to bare soil, leading to increasing temperature and decreases in rainfall, evaporation and soil water. Opposite changes occur when cropland changed into forests, especially with strong increases in soil water. When cropland changed to grass and shrub land, the climatic changes are closer to those with forest cover. This shows the importance of improving and maintaining the vegetation in SGN for the ecosystem and regional climate.

Keywords: land cover change; RegCM3; regional climate

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1 Introduction

Numerous observation and simulation studies have shown that land cover changes have important consequences for regional climate and ecosystem [*Pielke*, 2005; *Gao et al.*, 2003]. Cropland as a special land type related to human activities has also significant impacts on regional climate in various areas worldwide, e.g., in China [*Zhang et al.*, 2010], India [*Douglas et al.*, 2009], and the USA [*Cooley et al.*, 2005].

In this study we focus on typical arid and semi-arid areas of western China, called the Shaan-Gan-Ning (SGN), which includes parts of the provinces of Shaanxi and Gansu, and Ningxia Hui autonomous region. The SGN is located at the transition zone from cropland/forest (to the east) to desert (north) and high land (west) areas, and is characterized by water shortages and desertification. Therefore, the Chinese Government has been funding the returning cropland to tree/grass project since 1999. *Shi and Wang* [2003] investigated possible changes in the regional climate

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through this project. They concluded that the afforestation and re-greening of deserted land in western China was beneficial to the eco-environment, and the large-scale land cover change in Northwest China may have the effect of adjusting the East Asian monsoon system and regional climates in other parts of China. Observation studies also show that the vegetation has effectively improved or stabilized after the project [*Li et al.*, 2010].

In order to further understand the effects of different cropland cover changes, numerical simulations have been conducted with the regional climate model RegCM3.

2 Regional climate model and experimental design

The model used in this study is the third generation of the Regional Climate Model (RegCM3), which was developed at the Adbus Salam International Center for Theoretical Physics (ICTP) based on RegCM2 of the U.S. National Center for Atmospheric Research. The detailed information of the model was introduced in *Pal et al.* [2007] and other related references. RegCM3 has been applied in numerous areas worldwide. In China, it has been used for climate simulations [*Bao et al.*, 2006; *Gao et al.*, 2012; *Zhang et al.*, 2005b], investigations of land cover and land use change impacts at different scales and regions, such as for the whole China [*Gao et al.*, 2007; *Yu and Xie*, 2012], North China [*Zhang et al.*, 2005a], and Sanjiangyuan region in the Qinghai-Tibetan Plateau [*Lian and Shu*, 2009], with very few studies focusing on the SGN.

The model has 18 vertical levels and a 30 km horizontal resolution. There are totally 65×85 grid points for the key area (34°–39°N, 104°–111°E) of SGN located at the center of the model domain. The land cover types of RegCM3 have been obtained from the Biosphere-Atmosphere Transfer Scheme [*Dickinson and Henderson-Sellers*, 1993].

Three case years are selected according to their vegetation and climate status. The year 1999, as the reference year, is characterized by low normalized difference vegetation index (NDVI) values. The years 2004 and 2007, with high NDVI values, have different temperature and rainfall conditions (Figures omitted). We hope to find common features of land cover change impacts on the regional climate under different vegetation and climate conditions. For each case, besides the control run (noted as CTL), four sensitivity experiments have been made by replacing the cropland grids of the key area with different land cover types, including desert (type 8 in BATS), deciduous broad tree (5), short grass (2) and deciduous shrub (17). In Table 1 the details of the experiment designs and principles are listed. Totally 15 simulations have been conducted for the numerical investigations.

Table 1 Simulation experiment names and designs

Simulation	Experiment description
CTL	Control simulation with land cover datasets of USGS
CtoDesert	Change the cropland grids into desert at the key area, degrading of LC
CtoTree	As CtoDesert, but replace cropland with forest, improving of LC
CtoGrass	As CtoDesert, but replace cropland into short grass, maintaining of LC
CtoShrub	As CtoDesert, but replace cropland into shrub, maintaining of LC

Figure 1 shows the land cover type distribution within the key area of SGN, in which crop (red grids) is majorly located in the middle and eastern part. There are totally 78 crop grids that will be converted to different types in the different sensitivity experiments.

The integration periods in all experiments are from February 1 to October 31, with the first month being the spin-up. Therefore, the analysis focuses on the period of March–October when crops are growing in the area.

3 Effects of cropland cover change

At first, the RegCM3-simulated climate features in the CTL experiments are evaluated. The used observed monthly temperature and precipitation data-