Land management for sustainable water yield under future climate conditions in semiarid regions with over-utilized water resources: A case study of Xiong'an New Area

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1 Introduction

With the increasing demand of water resources for economic increase and population growth, the water resources have been over-exploited and over-utilized in many regions of the world, especially in semiarid regions. **Sustainable water availability** (i.e. water yield), which is largely determined by climate and land use, is vital for the ecological conservation and social development in the semiarid regions

- limited capability of hydrological modelling in the arid region
- difficulties in predicting the impacts of climate change on ecosystem water use and impacts of land use/cover changes on regional water availability under changing environment across different space and time scale

2 Methods

- The **Xiong'an New Area** (XNA) is chosen as a case study area. The XNA, a typical semiarid region located in North China, is now in the dilemma of water shortage and more water demand to increase the vegetation coverage from 10% to 40% by 2035.

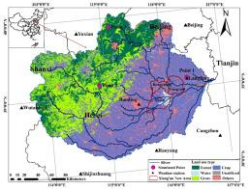

Figure 1. The location and land use characteristics of Daqing river basin.

- The **WAVES model** with a coupled water-carbon-energy structure is chosen because it can simulate ecosystem water use well and is applicable for the semiarid regions with over-utilized water resources.
- **Six scenarios** with different land use types and climate forcing data were designed to investigate the individual and combined impacts of land use change and climate change on vegetation dynamics and water budgets in the XNA.

Table 1. A summary of the six scenarios considered in this study

No.	Climate	Land use	Descriptions
S0	Observed	Cropland	the baseline real scenario
S1	Observed	Grassland	quantify individual impacts of land use change
S2	Observed	Forestland	
S3	Projected	Cropland	quantify individual impacts of climate change
S4	Projected	Grassland	two optional land use management scenarios to assess whether both sustainable water use and vegetation cover increase can be achieved
S5	Projected	Forestland	

3 Results

The future climate change of the XNA

Projected P and Ta indicated that XNA will become warmer and wetter.

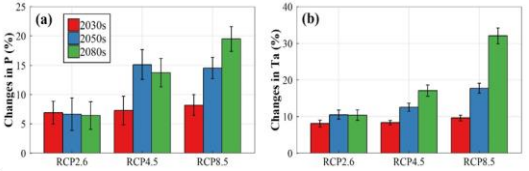

Figure 2. The average annual changes in (a) precipitation (P), (b) daily mean temperature (Ta) for three future periods under different emission scenarios.

Model calibration and validation

The WAVES model was capable to reproduced both LAI and ET dynamics satisfactorily in the study area.

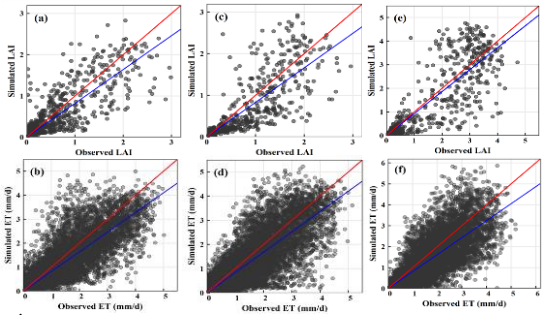

Figure 3. Scatter plots comparing observed and simulated 15-days LAI and daily ET of (a) and (b) cropland; (c) and (d) grassland, and (e) and (f) forestland, respectively.

Impacts of land use change during historical period

The cropland generated the more water yield (i.e. runoff) than grassland and forestland under the historical climatic condition.

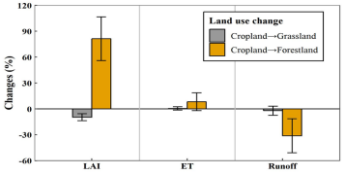

Figure 4. Estimated impacts of land use change on the LAI, ET and runoff under historical climatic conditions (i.e., 1982-2014. The bars and error bars represent mean and standard deviation of estimated annual changes (n = 33), respectively.

Impacts of future climate change

LAI was predicted to decrease under projected climate;
More water use and water yield were estimated in cropland due to increased precipitation and suppressed vegetation growth caused by warming.

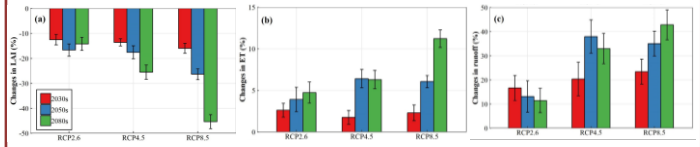

Figure 5. Estimated impacts of climate change on the LAI, ET and runoff for three future periods under three RCPs. The bars and error bars represent assemble mean values and standard errors of all assembled climate change scenarios (n = 18), respectively.

Combined impacts of land use change and climate change for two land management scenarios

Land conversion from cropland to grassland

The changes in LAI, ET and runoff in grassland were the same trend with those in cropland in future periods.

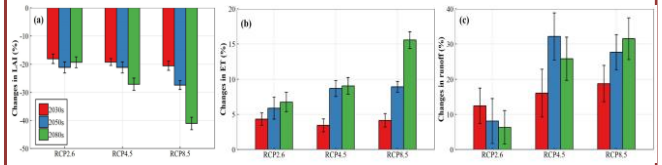

Figure 6. Estimated combined impacts of land use change (alternation of cropland to grassland) and climate change on the LAI, ET and runoff for three future periods under three RCPs.

Land use conversion from cropland to native forest

More than 20% (76 mm a^{-1}) water use increments were estimated in forestland in future periods under three RCPs, but more than 10% (12 mm a^{-1}) water yield increments were estimated in 2050s and 2080s under RCP4.5 and RCP8.5 due to greater increases in precipitation.s

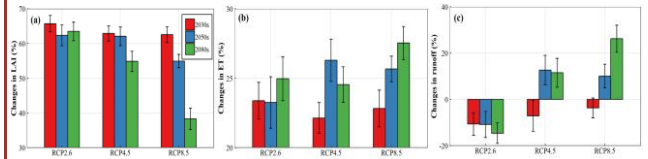

Figure 7. Estimated combined impacts of land use change (alternation of cropland to forestland) and climate change on the LAI, ET and runoff for three future periods under three RCPs.

4 Conclusion

- For the purpose of land management, it is recommended to plant crop or grass in the near-future and to plant forest in the mid-future and far-future to expand vegetation coverage in the XNA.
- This study highlights land management, especially afforestation should carefully consider future climate condition for sustaining water yield in the semiarid regions with over-utilized water resources.

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