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Assessing the impacts of extreme agricultural droughts in China under climate and socioeconomic changes

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Supporting Information for

Assessing the impacts of extreme agricultural droughts in

China under climate and socioeconomic changes

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Fig.S1. The changing agricultural environment. (a) Ratio of food production in northern China to food production in southern China during 1960–2013. (b) Changes in planting areas for food (kha) in northern and southern China during 1950–2010. (c) Changes in irrigated areas in northern and southern China during 1950–2011. Widespread investment in groundwater extraction for irrigation started in the late 1960s and resulted in rapid expansion of irrigation area in the north. Construction of irrigation systems slowed after the Chinese Economic Reform in 1978 because of increasing investment demands from industry and other fields, but accelerated again after the enactment of the Water Law in 1988. Brown bars show cumulative groundwater storage loss under the northern China plains during 1996–2011. (d) Changes in the number of wells used for irrigation during 1960–2010.

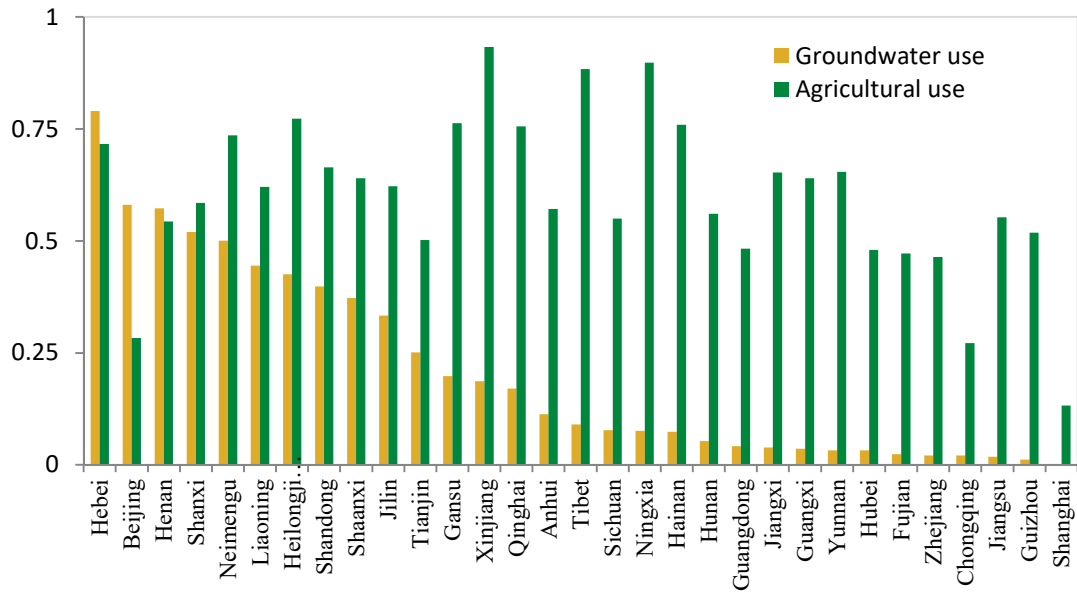


Fig.S2. The average fraction of water drawn from groundwater sources (orange) and fraction of groundwater assigned to agricultural use (green) compared with the total water use in the provinces of Mainland China, 2011.

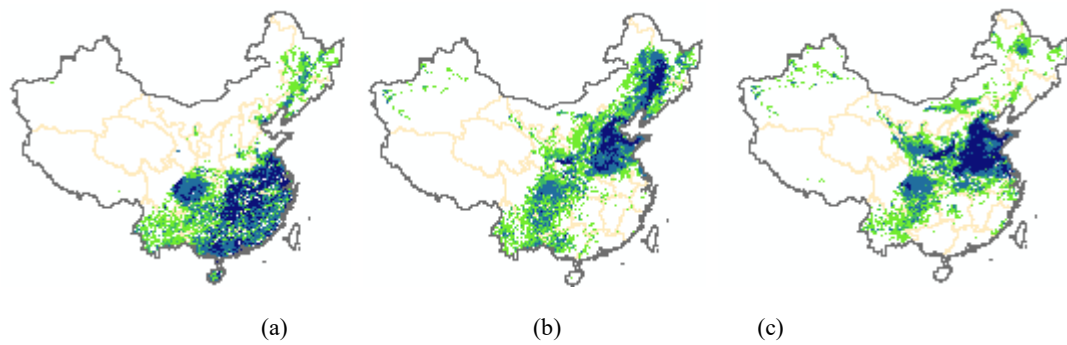


Fig.S3. Spatial distributions of harvest area for (a) rice, (b) maize, and (c) wheat in Mainland China during 2000

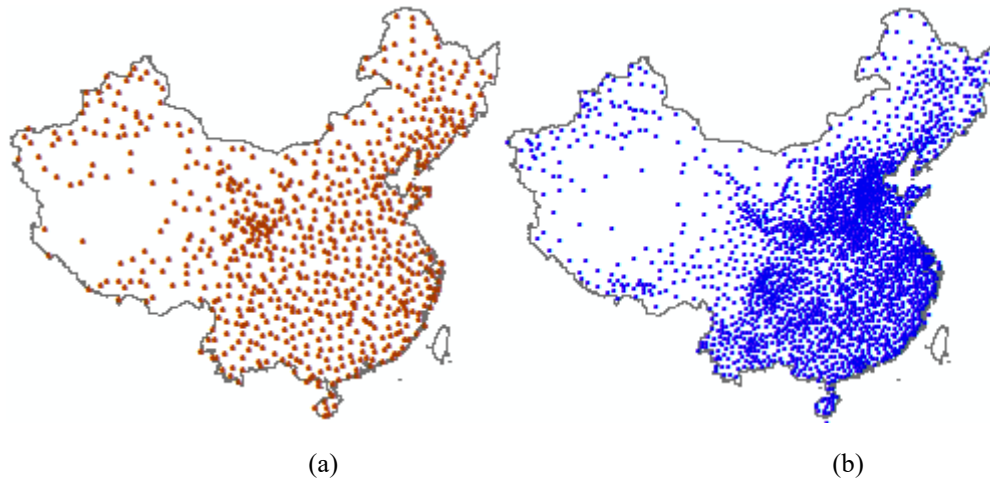
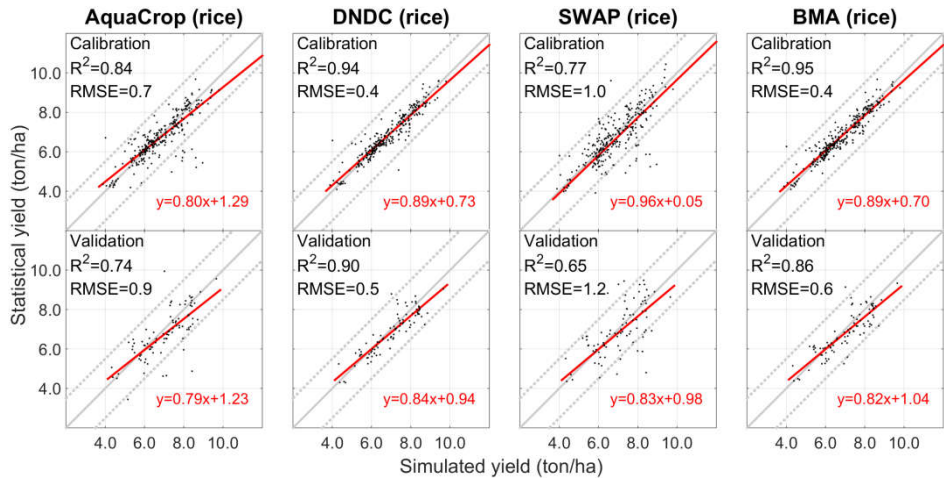
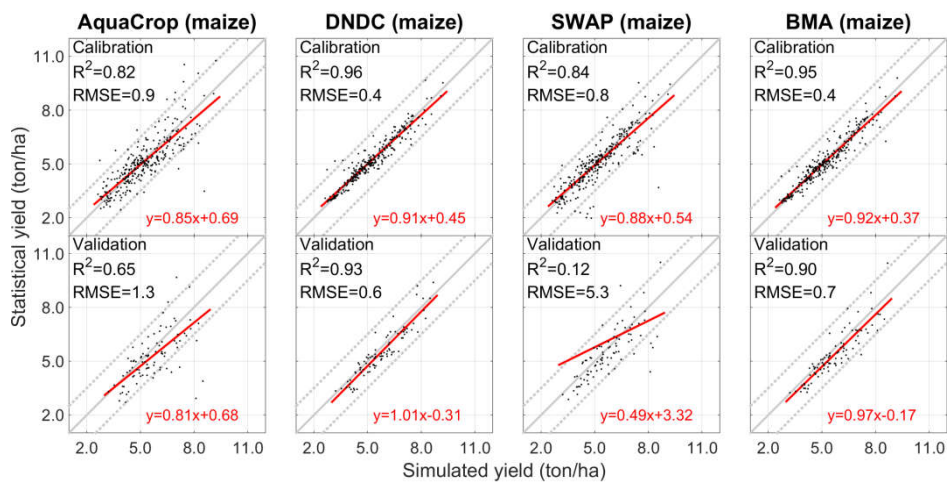


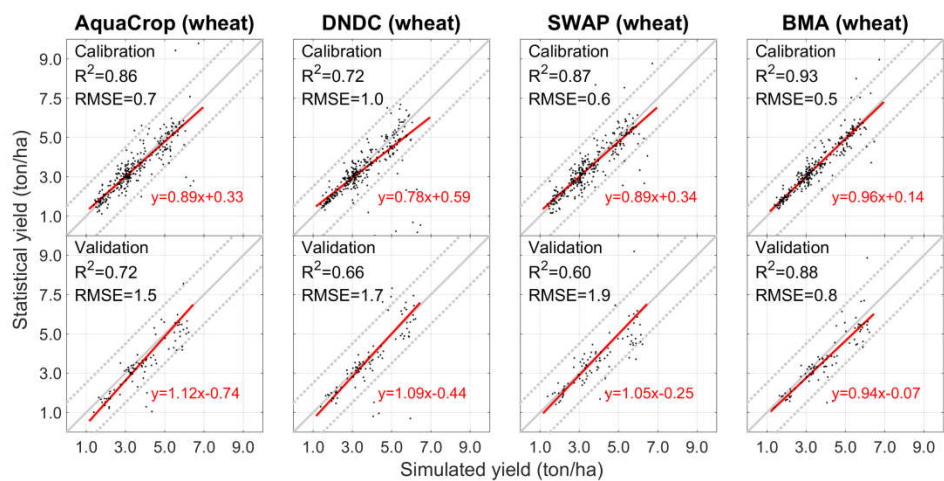
Fig.S4. Locations of (a) the meteorological stations where data used in this work was recorded and (b) the centroid points of the 2403 counties in Mainland China for the crop models



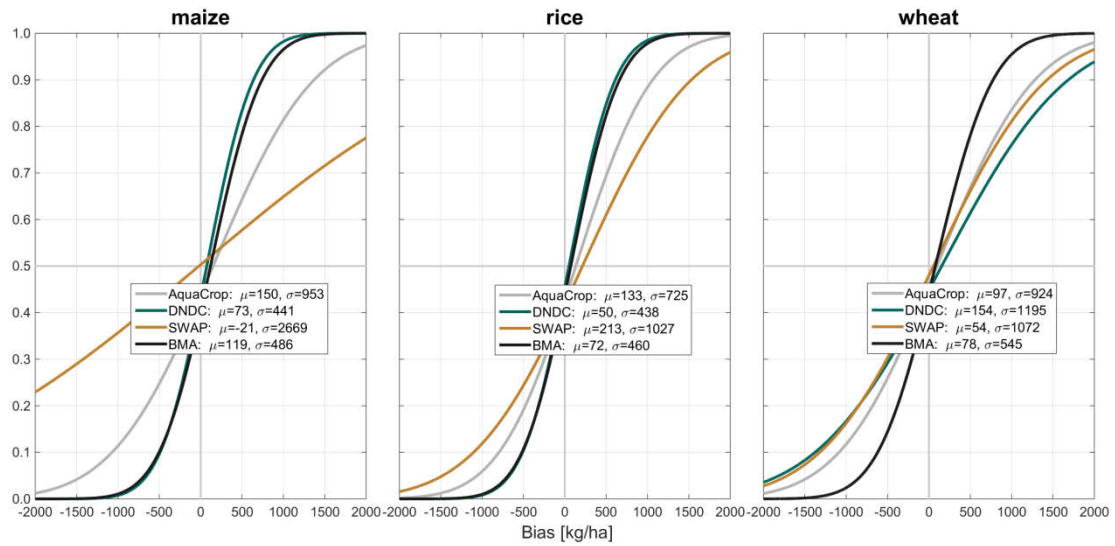
(a)



(b)



(c)



(d) Cumulative probability of bias (ton/ha) in each crop model

Fig.S5 Calibration and validation of the three crop models for the three major crops. (a) Rice, (b) Maize, and (c) Wheat. Calibration is conducted by training simulated provincial-level yields (vertical axis) against observed yields (horizontal axis) for 1998–2007. Validation is conducted by comparing simulated provincial-level yields after calibration against observed yields for 2008–2010. (d) Cumulative distributions of yield bias for simulated rice, maize, and wheat yields from each crop model during the validation period (2008–2010).

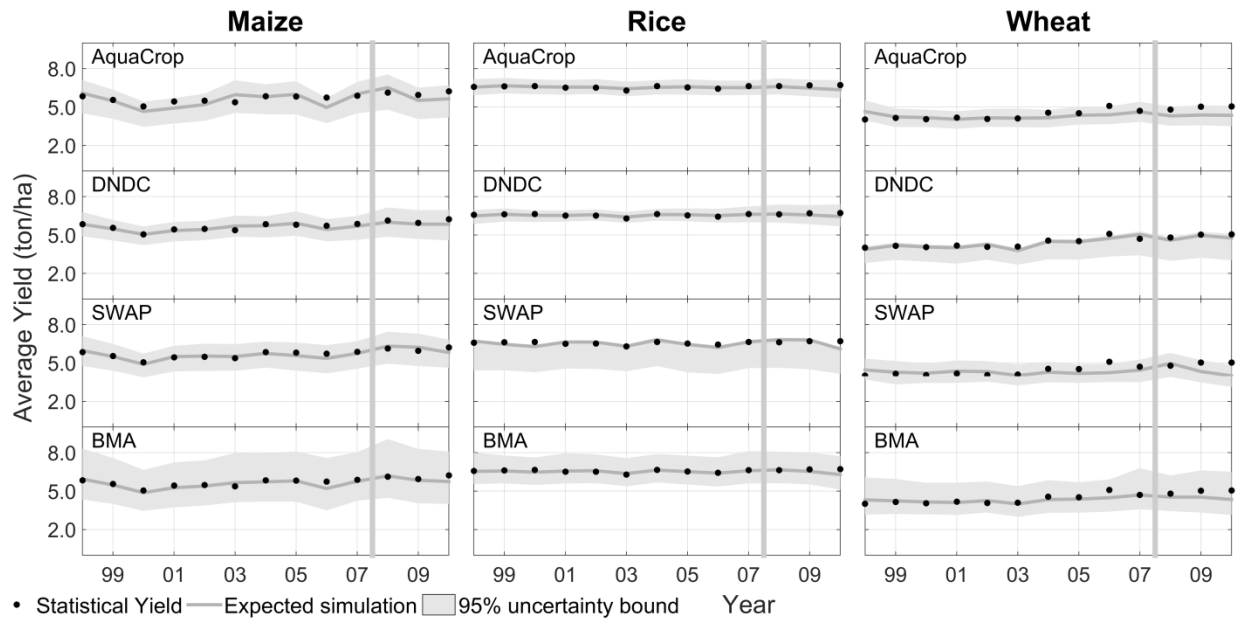


Fig.S6 Time series of national average simulated (line) and recorded (dots) yields of rice, maize, and wheat from the calibration (1998-2007) and validation (2008–2010).

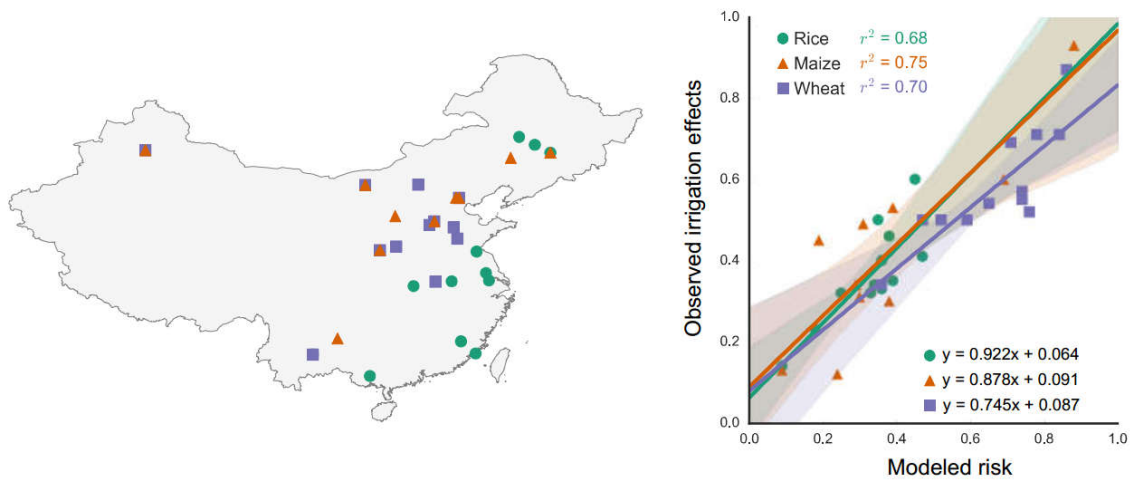


Fig.S7. (a) Locations of field studies measuring irrigation effectiveness for rice, maize, and wheat yields in Mainland China, and (b) relationships between measured irrigation effects and simulated drought risks for the corresponding crop in the counties containing the study locations. The modeled risk values for these locations are taken from the rainfed risk maps shown in Fig.S8a (for rice), c (for maize), and e (for wheat). Drought risk as defined in this work is a theoretical value of cumulative yield losses and probabilities that cannot be directly verified using experimental data. If local irrigation experiments are sufficiently long, however, the average differences between irrigated and rain-fed yields should approach agricultural drought risk (accumulation of the damage-probability curves). Although there are no perfect irrigation experiments, the evident relationship between these two variables across a wide selection of experiments covering all three crops provides a compelling independent validation of the model utility.

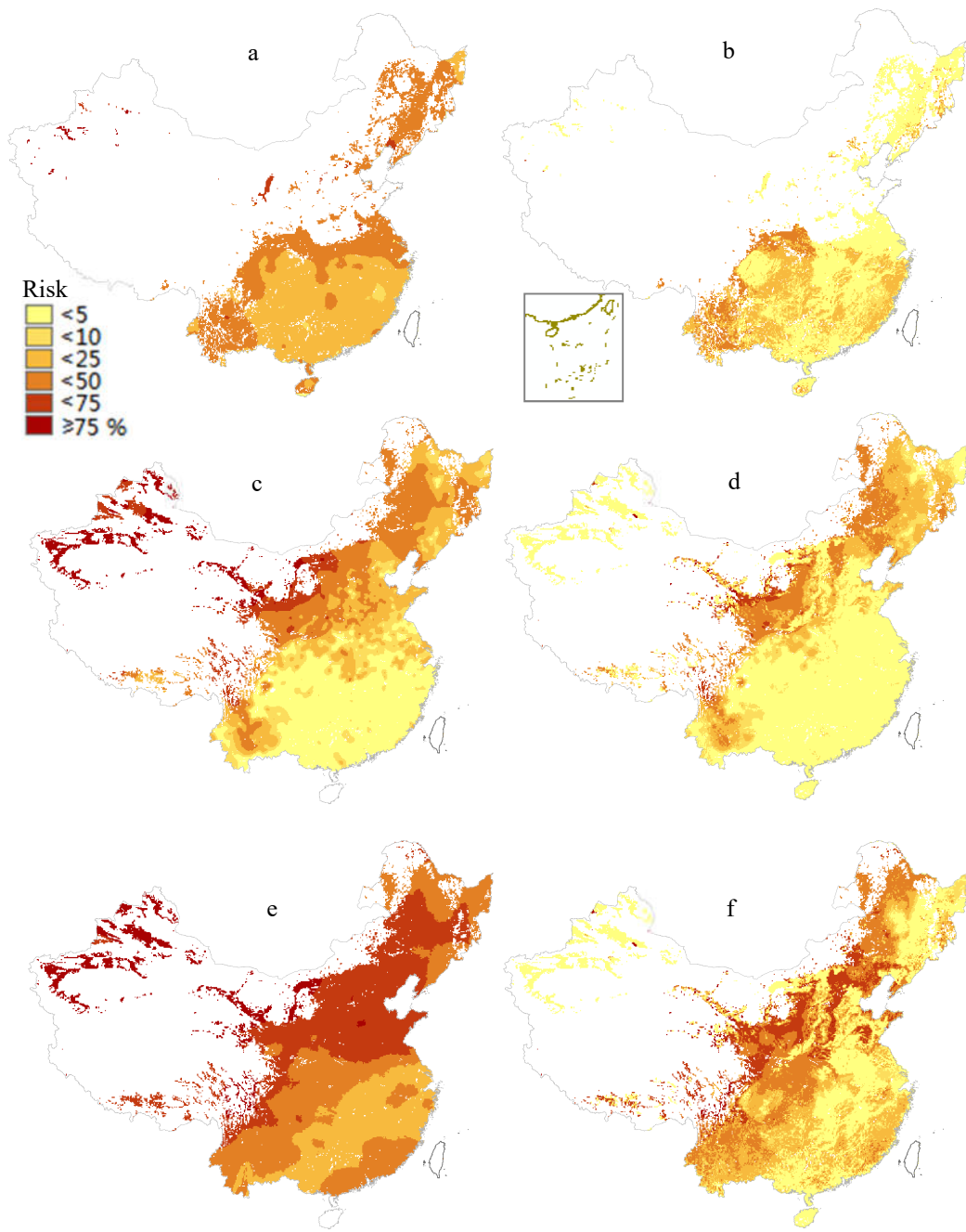


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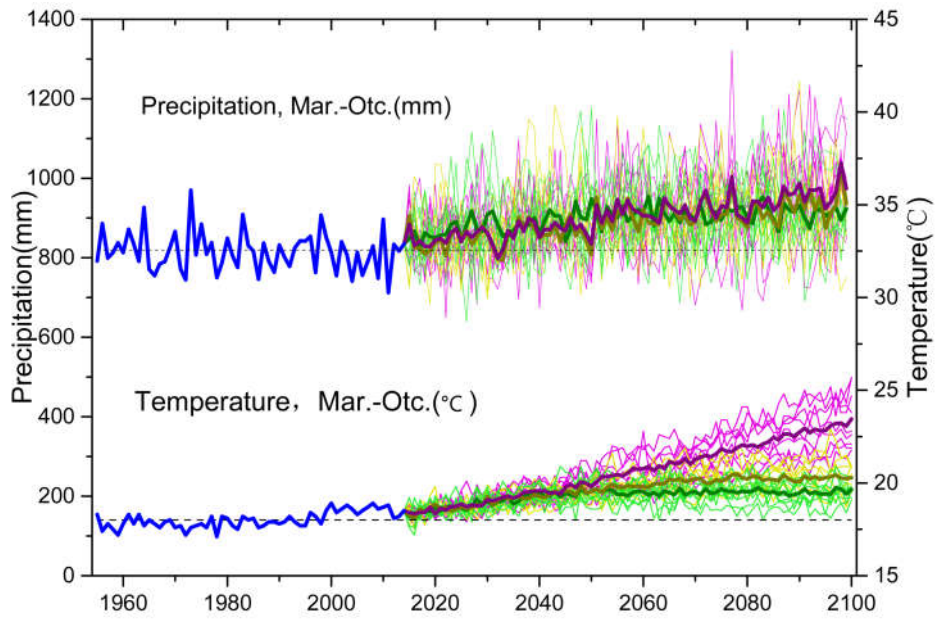


Fig.S9.The projected national average precipitation and temperature changes in crop growing seasons (from March to October) during 2015–2100 under RCP2.6 (green lines), RCP4.5 (yellow lines), and RCP8.5 (purple lines)based on the outputs of nine different climate models; thicker lines indicate average values for different scenarios).