# Modelling Effect of Climate Trend Change on Wheat Yield in North China by EPIC Model

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## 1. Introduction

Global climate change is likely to have great impact on regional and local crop yield. A variety of past studies show that there was a significant decadal climate change during the past 40 years in drought-prone North China [1]. Most areas in North China experienced precipitation decrease and faster temperature increase rate. More importantly, the solar radiation declined in most part of North China. It is of importance to understand how the changes of the climate components had impacted crop yield in North China in order to achieve better adaptive strategies. Environmental Policy Integrated Climate (EPIC) model is a field scale crop model capable of simulating daily crop growth and yield under various climate and environment conditions, and complex management scheme [2]. The model has been applied successfully world wide in a series of climate regions to simulate crop growth and yield, both in short and long terms.

The objectives of this study are: 1) to model the wheat yields (1961-2005) of both irrigated and rain-fed spring and winter wheat at 80 sites located in four agro-regions of North China by EPIC model, and 2) to analysis the influence of the changes of radiation, water stress, and temperature stress on wheat yields.

## 2. Study Area and Data

The 80 sites are spatially equally distributed in four agro-regions, the Northeast China (NE), the North China Plain (NP), the Northwest China (NW), and Xinjiang Autonomous Region (XJ) as displayed in Fig. 1. Each station was categorized into spring, denoted as S (triangle) or winter, denoted as W (circle) wheat according to the information obtained from the agro-meteorological dataset or its accumulated temperature. The stations were also divided into rain-fed, denoted as R (filled symbol) and irrigated, denoted as I (empty symbol) according to their past actual practice. As shown in Fig. 1, there are altogether eight combinations of agro-region, wheat type (spring or winter) and irrigation type, which are denoted as NE-S-R (32 sites), NP-W-I (14 sites), NW-S-I (8 sites), NW-S-R (8 sites), NW-W-I (4 sites), NW-W-R (3 sites), XJ-S-I (3 sites), and XJ-W-I (8 sites) respectively.

The climate data, which includes daily minimum temperature, maximum temperature, precipitation, solar radiation, relative air humidity and wind speed, were obtained from the Meteorology Bureau of China. The soil data were digitalized from the 1:1,000,000 soil map and profile tables. The planting and harvesting dates of each station were derived from the agro-meteorological dataset of China. Fertilizer data were obtained from county-level statistical data. Irrigation volume for each station was set according to agro-regions. The default crop parameters of spring and winter wheat were used, whilst the potential heat unit (PHU) of spring and winter wheat were set to 1700 and 2000 Celsius degree respectively according to the past study results [3].

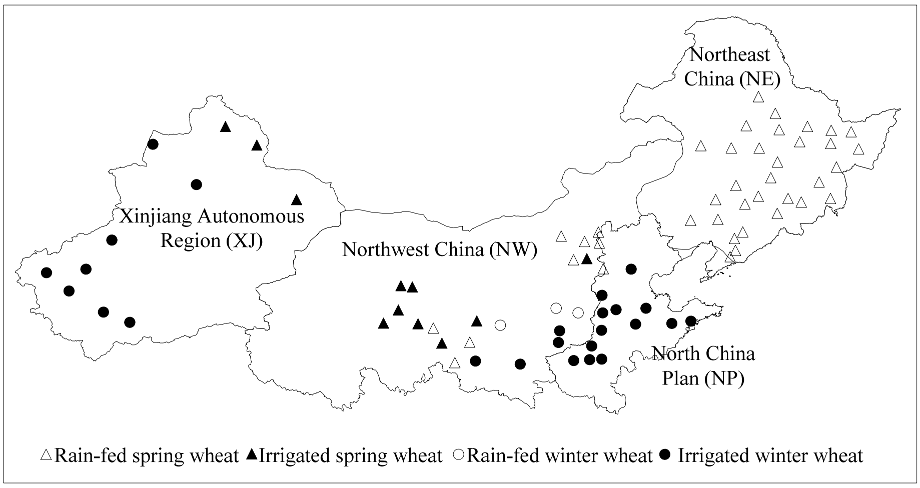


Fig.1 Map of rain-fed and irrigated spring and winter wheat sites in northern China.

## 3. Method

EPIC model was developed by a USDA modeling team in the early 1980s and the model has been keeping on very active evolving. The EPIC model can be subdivided into nine separate components defined as weather, hydrology, erosion, nutrients, soil temperature, plant growth, plant environment control, tillage and economic budgets. The model operates on a continuous basin using a daily time step and can perform long-term simulations for hundreds of years [4].

Since the goal of this study is to model the impact of climate on wheat yield, the daily time series for nutrition and aeration stress indices among different years remain unchanged. Thus we assume that, for a specific station, there are no changes on wheat types, fertilizing, tillage, or irrigation during the whole simulating periods. Other input data such as soil type, physical soil properties of the 15 layers also remains unchanged. The sole changing inputs are climate-related variables. Under the above assumption, the spring and winter wheat yields of 80 sites from 1961 to 2005 were simulated by inputting actual daily meteorological data.

There are numerous versions of EPIC and EPIC5300 was adopted for simulation in this study. Wheat yield is modeled in a daily time step: 1) calculating daily potential biomass which is mainly decided by radiation, temperature and relative humidity, 2) deriving a variety of daily stress indices regarding water, temperature, nutrition and aeration, 3) computing harvest index by selecting the stress index with minimum value among the above indices to represent the growth constrain of each day, and 4) aggregating the multiple of potential biomass and harvest index of the whole growing period as yield. The detailed equations can be found in the related reference [4].

$$WS_i = \sum_{l=1}^{M} u_{i,l} \Big/ E_{pi} \qquad (1)$$

$$TS_i = \sin\left(\frac{\Pi}{2}\left(\frac{TG_i - T_{bj}}{T_{oi} - T_{bj}}\right)\right),\ 0 \le TS_i \le 1 \qquad (2)$$

The changes of wheat yields are primarily the result the changes of radiation, water stress index (equation 1), and temperature stress index (equation 2), where *WS* is the water stress factor, *u* is the water use in layer *l*, and $\underline{E_p}$ is the potential plant water use on day *I*, and *TS* is the plant temperature stress factor, *TG* is the average daily soil surface temperature in ℃, $T_b$ is the base temperature for crop *j*, and $T_0$ is the optimal temperature for crop *j*.

## 3. Results and Validation

The average values of derived radiation, annual mean water stress index, and annual mean temperature index for each combination are given in Fig. 2, whilst the annual mean yields for each combination are illustrated in Fig. 3.

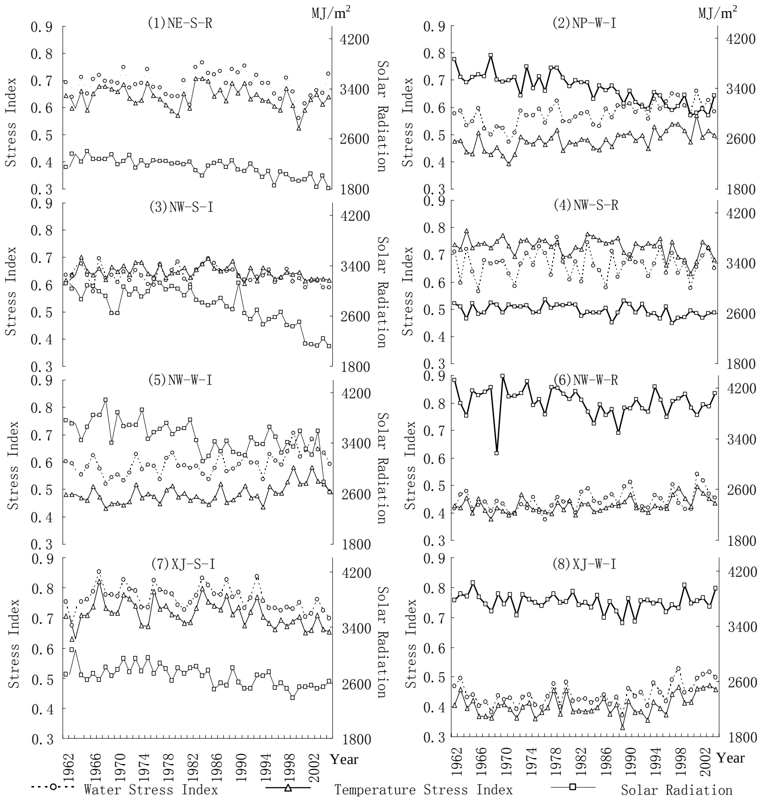

Fig. 2 Annual solar radiation and water and temperature stress index (1961-2005).

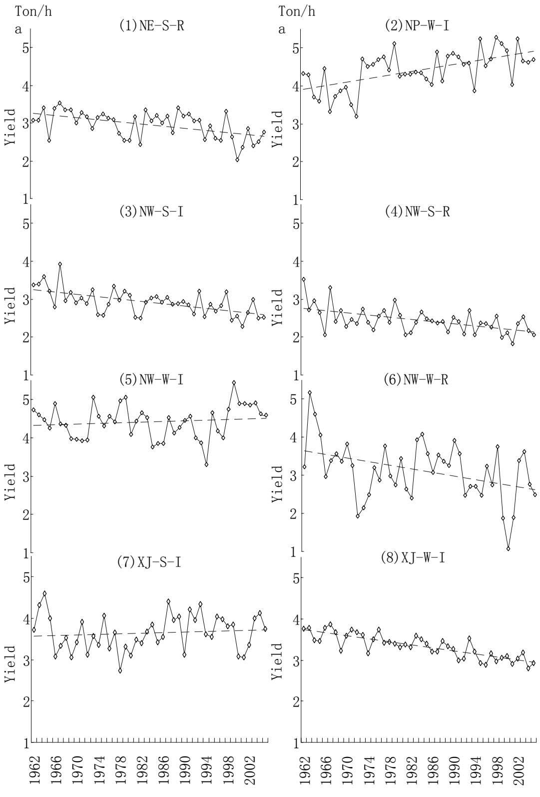

Fig. 3 Simulated annual wheat yields of the eight combinations.

The yields of most sites have statistically significant decrease during the 45 years simulation with actual climate input. The wheat yields of NE-S-R, NW-S-I, NW-S-R, NW-W-R and XJ-W-I show fluctuant declines. There are no significant changes for NW-W-I and XJ-S-I, whilst NP-W-I increased.

The simulated yield in the year of 1996 was compared to the actual county-level yield derived from year book. The actual yields of the county where the station locates are used as reference yields to draw scatter graph as shown in Fig. 4. The correlation between the simulated and actual yields is 0.775 with RMS of 0.599.

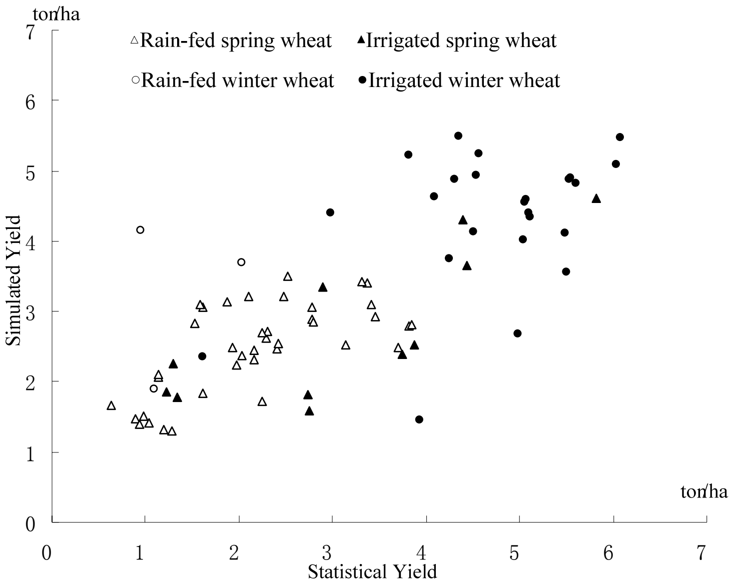

Fig. 4 Simulated yields of 80 stations and statistical county-level yields (1996).

## 4. Conclusions and Discussion

The spring and winter wheat yields of 80 sites in North China during the past 45 years from 1961 to 2005 were simulated by using actual climate conditions, while the other input, like soil, tillage etc, with relatively good accuracy. But uncertainties do exist. The sources for the modeling uncertainties may come from input data like soil data, management data, or crop parameters. Another source that may influence validation comes from the county-level statistical yield used in this study due to the lack of actual yield data of each site.

Solar radiation decrease would have played a very important role in the changes of yields of most North China during the past 45 years. As shown in Fig. 2, there are downward trends for radiation from 1961 to 2005, although the downward trends became much flat after early 1980s. Decline in solar radiation would have resulted in less potential biomass for wheat, which in turn would have led to yield decrease.

Water stress was more severe than temperature stress in rain-fed areas like NW-S-R. For irrigated areas, temperature stress was the major stress factor. Interestingly, the simulated irrigated winter wheat yield in North China Plain increased although the radiation decreased, which may imply that rapid temperature increasing would have played a very positive role for winter wheat growth.

The simulation in this study was carried out at site-specific level, which is unable to represent the real wheat planting areas. On the other hand, it is of great importance to understand the impact of future climate changes on wheat yield and phenology. Therefore, gird-based EPIC under the support of GIS system, together with future climate scenarios like future climate scenarios of GCMs or Regional Climate Model as input, will be implemented in the future study.

**Acknowledgement:** This work is supported by National Basic Research Program of China (2006CB400505) and National Science Fund Project (40601002).

## Reference

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