Spatial and temporal characteristics of rice potential productivity in main growing regions of China

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INTRODUCTION

Steady increase of rice production is very important for China's food security, while the impact of spatial and temporal differences in climatic factors on rice productivity in China is highly uncertain because of its vast area and marked variation. The main objectives of the present study were: (1) to predict the rice productivities of photosynthetic (PPS), photo-thermal (PPT) and climatic (PC) based on the model, (2) to analyze the spatial and temporal distribution characteristics of rice potential productivity in main rice production regions of China between two decades (1960s and 2000s), (3) to predict the yield increasing potential based on high yield target and actual yield of rice in 2000s in main rice production regions of China.

MATERIALS AND METHODS

Firstly, based on the software of ANUSPLIN and ARCGIS, the daily meteorological data from 1961 to 1970 (the 1960s) and from 1996 to 2005 (the 2000s) provided by 333 weather stations in main rice growing regions of China (Fig.1) were processed to obtain the daily meteorological surface data. Secondly, 41 types (Fig.1) of high yield targets, suitable sowing and harvest dates, and the dates of main growth and development stages were collected from the Rice High Yield Technical Specifications for the main rice growing regions of China, reported by the Department of Crop Farming Administration, Ministry of Agriculture, P.R. China (2009). In addition, the actual yields of rice in 2000s in main rice production regions of China were collected from the Agriculture Statistics Yearbook of China. Then, based on the model and the daily meteorological surface data, the annual PPS, PPT and PC were calculated, and the spatial and temporal distribution characteristics of above three potential productivities between two decades (1960s and 2000s) were analyzed based on the grid cell. Finally, the analysis was carried out on spatial distribution characteristics of yield increasing potential and percentage from high yield target to PPT, yield increasing potential from actual yield of 2000s to high yield target, and differences between PPT and PC of 2000s.

The algorithms for PPS (Y_Q), PPT (Y_{Ti}) and PC (Y_{Wi}) were calculated by Formula 1-3, respectively:

$$Y_Q=[\varepsilon \bullet \alpha \bullet c_L \bullet (1-\rho) \bullet \varphi \bullet (1-\omega) \bullet HI \bullet (1-\chi)^{-1} \bullet H^{-1} \bullet (1-S)^{-1}] \sum Q \quad (1)$$

$$Y_{Ti} = Y_{Qi} \bullet f_i(T) \quad (2)$$

$$Y_{Wi} = Y_{Ti} \bullet f_i(W) \quad (3)$$

where ε is the physiological radiation index; α is the absorption rate of PAR; ρ is the ineffective absorption rate; c_L is the correction index of daily LAI in rice growing period; φ is the light-energy conversion efficiency; ω is the respiration rate; χ is the water content of organic compounds; S is the mineral content of rice; H is the mass-energy conversion factor; HI is the harvest index; Q is the daily solar radiation on the ground ($J \cdot m^{-2} \cdot d^{-1}$).

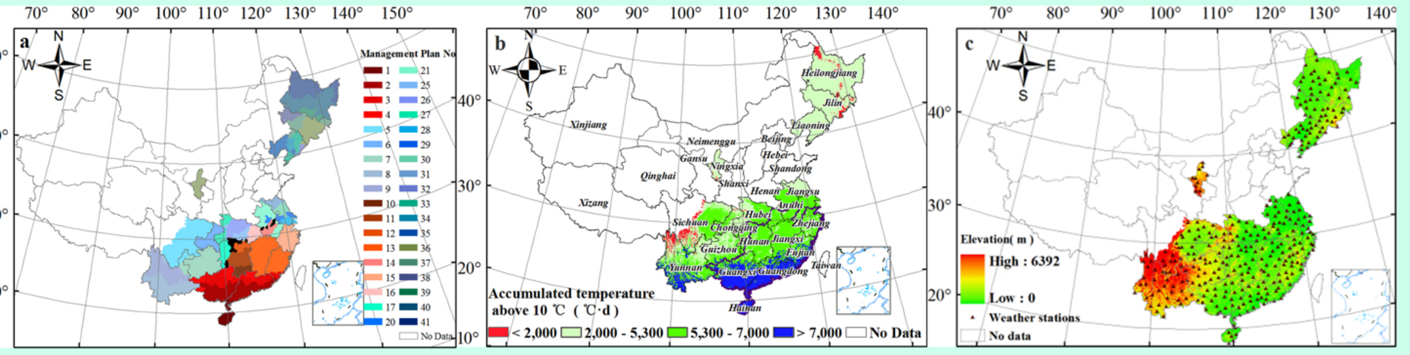

Fig.1 Distribution map of rice management plan type (a), annual accumulated temperature above 10℃ (b), and elevation and weather station (c) in main rice growing area of China.

RESULTS

The spatial distribution characteristics of rice PPS in both single- and double-cropping rice growing regions had the trend that rose gradually from north to south in different historical stages (Fig.2a & b). As compared with 1960s, the PPS of 2000s decreases by 5.40%, and the decreasing rates in Northeast and Southwest China were lower than those in Central and South China. Decreases in the PPS over the single- and double-cropping rice growing regions were 4.65% and 6.96%, respectively (Fig.2c).

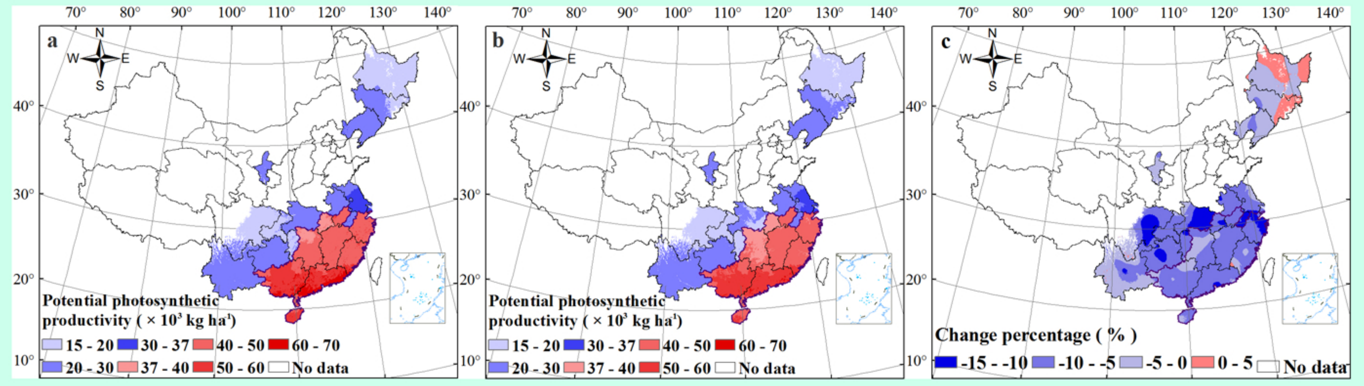

Fig.2 Spatial and temporal distribution of rice potential photosynthetic productivity in main rice growing regions of China (a. 1960s, b. 2000s, c. Change percentage between 1960s and 2000s).

In different historical stages, the spatial patterns of rice PPT in single-cropping rice growing region had the trend that increased gradually from north to south and from west to east, but in double-cropping rice growing region had the trend that increased gradually from north to south (Fig.3a & b). From 1960s to 2000s, the PPT increased in Northeast and Southwest China, while decreased in most areas of Middle and South China, with average decreases of 2.56% in main rice growing regions of China, and with average decreases of 1.17% and 5.46% over the single- and double-cropping rice growing regions, respectively (Fig.3c).

The spatial distributions of PC in both single- and double-cropping rice growing region had the trend that went up gradually from north to south in

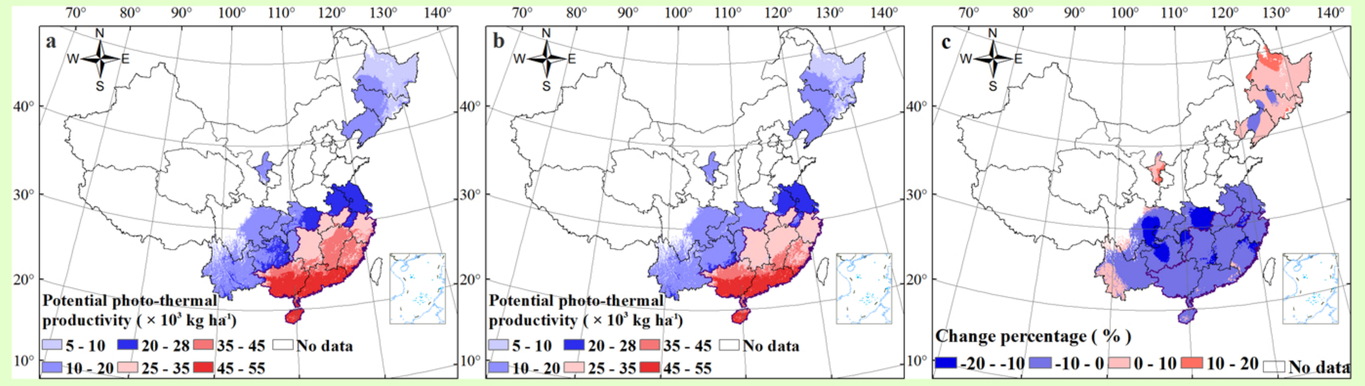

Fig.3 Spatial and temporal distribution of rice potential photo-thermal productivity in main rice growing regions of China (a. 1960s, b. 2000s, c. Change percentage between 1960s and 2000s).

two historical stages (Fig.4a & b). As compared with 1960s, the PC of 2000s decreased in most areas of China, while increased in part of Central and South China, with average decrease of 7.44% in main rice growing regions of China, and with average decreases of 8.13% and 6.04% over the single- and double-cropping rice growing regions, respectively (Fig.4c).

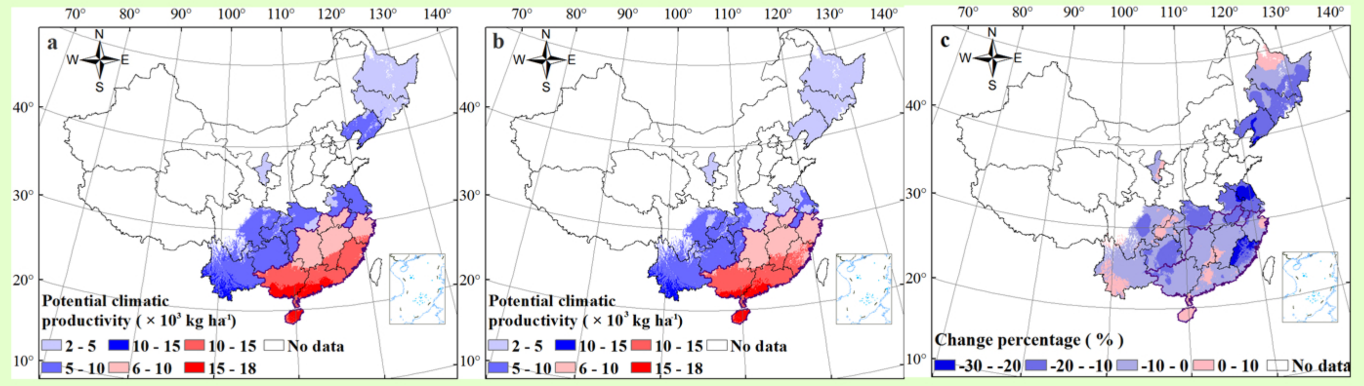

Fig.4 Spatial and temporal distribution of rice potential climatic productivity in main rice growing regions of China (a. 1960s, b. 2000s, c. Change percentage between 1960s and 2000s).

The yield increasing potential from the actual yield (2000s) to the high yield target ranged from 2×10^3 kg ha^{-1} to 6×10^3 kg ha^{-1} in most of the single-cropping rice growing region, and from 6×10^3 kg ha^{-1} to 12×10^3 kg ha^{-1} in the double-cropping rice growing region (Fig.5b). The yield increasing potential from the high yield target to the PPT (2000s) was less than 10×10^3 kg ha^{-1} in most areas of the single-cropping rice growing region, ranging from 10×10^3 kg ha^{-1} to 30×10^3 kg ha^{-1} in most areas of the double-cropping rice growing region, and from 30×10^3 kg ha^{-1} to 40×10^3 kg ha^{-1} in most areas of South China, such as Guangxi, Guangdong and Hai'nan Provinces (Fig.5c).

In addition, the differences from the PC to PPT in 2000s illustrated that the increasing potential contributed by irrigation were between 5×10^3 kg ha^{-1} and 20×10^3 kg ha^{-1} in the single-cropping rice growing region, and between 20×10^3 kg ha^{-1} and 40×10^3 kg ha^{-1} in the double-cropping rice growing region (Fig.5d). The differences from PC to PPT in 2000s indicated that making full use of rainfall and reasonable irrigation plan was favorable to exploring the rice potential productivity and ensuring the steady and high yield in rice. These results were helpful for further exploration of technical approaches to enhancing rice yields, and for quantitative decision support for guiding national rice production and food security in China.

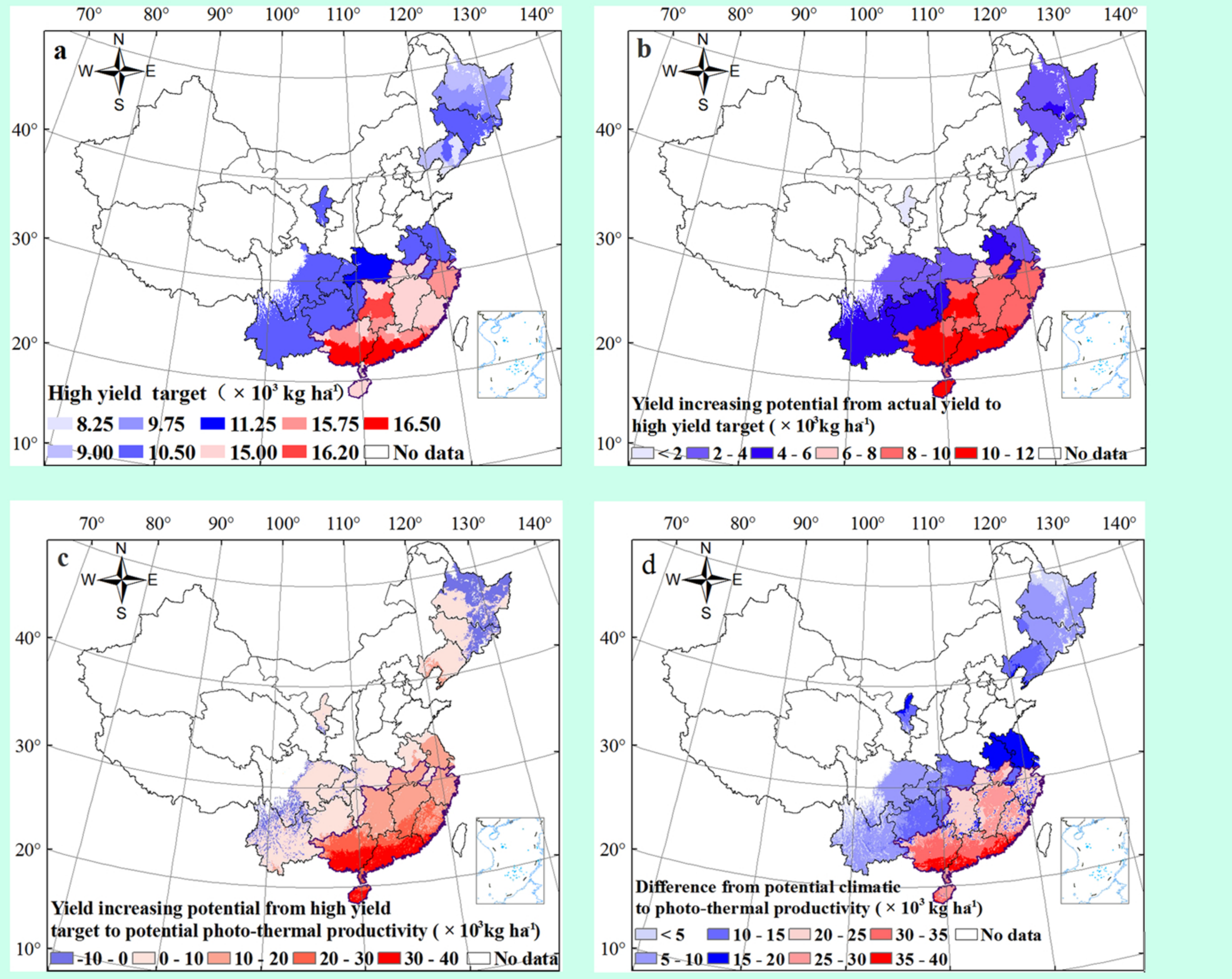

Fig.5 Spatial distribution of high yield target (a) and yield increasing potentials from actual yield of 2000s to high yield target (b), from high yield target to PPT of 2000s (c) and from PC to PPT of 2000s (d) in main rice growing regions of China.

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