

SUPPLEMENTARY INFORMATION

Climate warming and crop management: A comprehensive analysis of the changes on double rice cropping systems in Southern China

Change of observed rice phenology and thermal requirements between the 1980s and 2010s

Changes in observed rice phenology for early rice and late rice and thermal requirements for different double rice cropping systems in Southern China from the 1980s to the 2010s were shown in Figure S1. The dates of transplanting for early rice were advanced by 2.2 days on average at most stations. In contrast, the dates of heading and maturity were delayed by 2.1 and 0.7 days on average in the 2010s compared with the 1980s, resulting in an increase in the stages from transplanting to heading (TTH) and transplanting to maturity (TTM). Overall, the dates of transplanting, heading, and maturity for late rice were delayed. The transplanting dates were delayed by 2.2 days on average, while the heading and maturity dates were less postponed, resulting in the shortening of TTH and TTM stages for late rice by 1.1 and 1.7 days, respectively. For the entire double-cropping rice system (the calculation method was shown in Table. S1, the growth period of late rice was shortened. Still, due to the delay of its transplanting period, the farming seasons from early rice maturity to late rice transplanting were prolonged, which led to the extension of each double rice cropping system. Under the impact of crop management, the accumulated temperature above 10 °C in the growth period of double rice cropping systems also increased, especially in MDR and LDR ($P < 0.05$). In the 1980s, the accumulated temperature above 10 °C of EDR, MDR, and LDR were 4002-4800, 4464-5507, 5071-5719 °C day, respectively, and increased by 157, 203 and 437 °C days on average in the 2010s (Figure S2B).

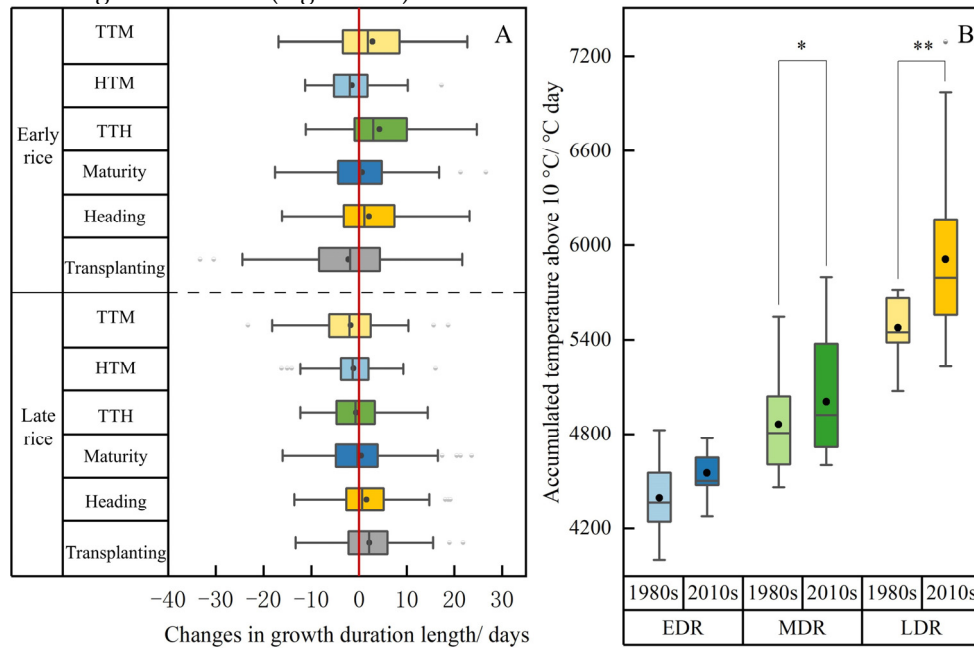


Figure S1. Observed phenological stages (A) and thermal requirements of double rice cropping systems (B) in Southern China from 1981 to 2010. TTH: transplanting to heading; HTM: heading to maturity; TTM: transplanting to maturity; EDR: Early-maturity double rice; MDR: Medium-maturity double rice; LDR: Late-maturity double rice; *: $p < 0.05$; **: $p < 0.01$.

Table S1. Definition of indicators for the distribution of rice cropping systems

Double rice cropping system	Cropping pattern
Early-maturity double rice	Early-maturity early rice + early-maturity late rice+ busy farming seasons
	Early-maturity early rice + medium-maturity late rice+ busy farming seasons
	Medium-maturity early rice + early-maturity late rice+ busy farming seasons
Medium- maturity double rice	Medium-maturity early rice + medium-maturity late rice+ busy farming seasons
	Medium-maturity early rice + late-maturity late rice+ busy farming seasons
	Late-maturity early rice + medium-maturity late rice+ busy farming seasons
Late-maturity double rice	Late-maturity early rice + late-maturity late rice+ busy farming seasons

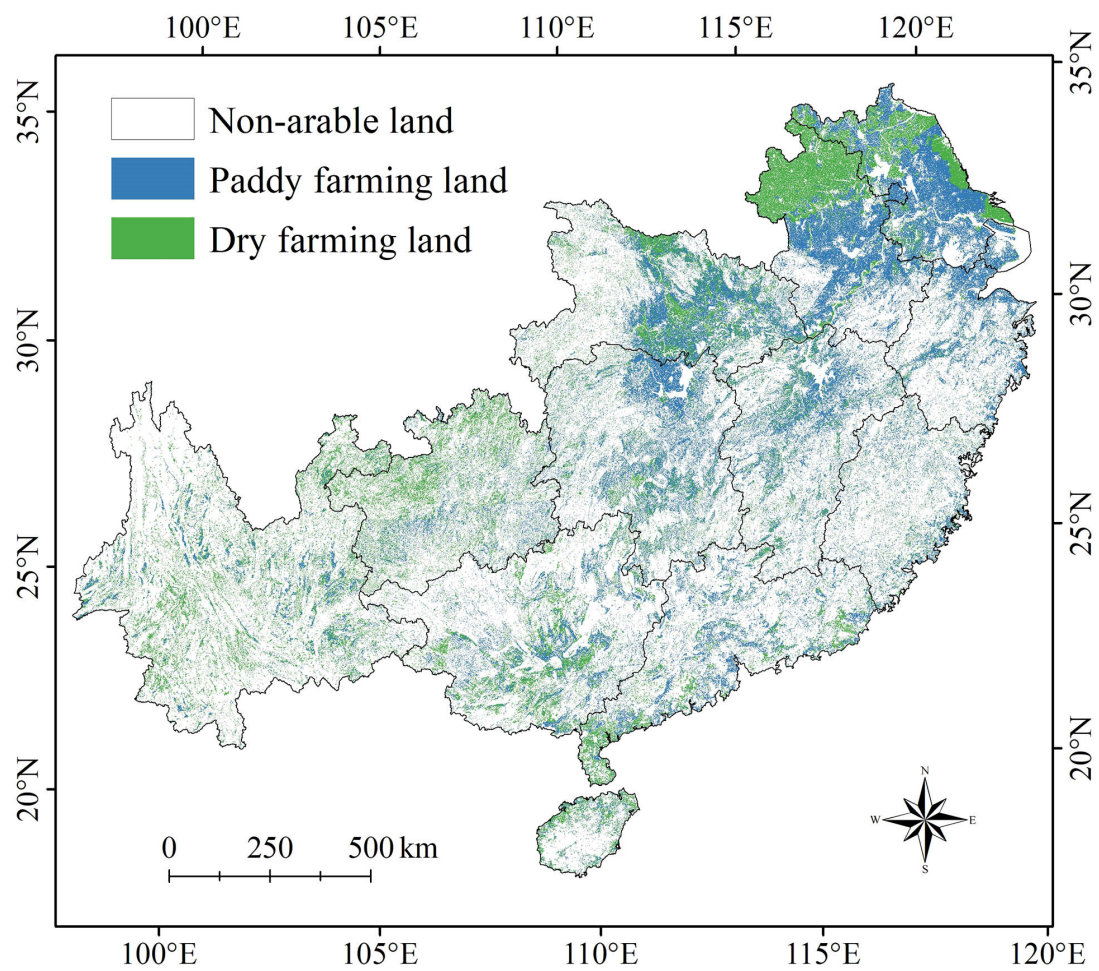


Figure S2. The distribution of the land use system in Southern China.

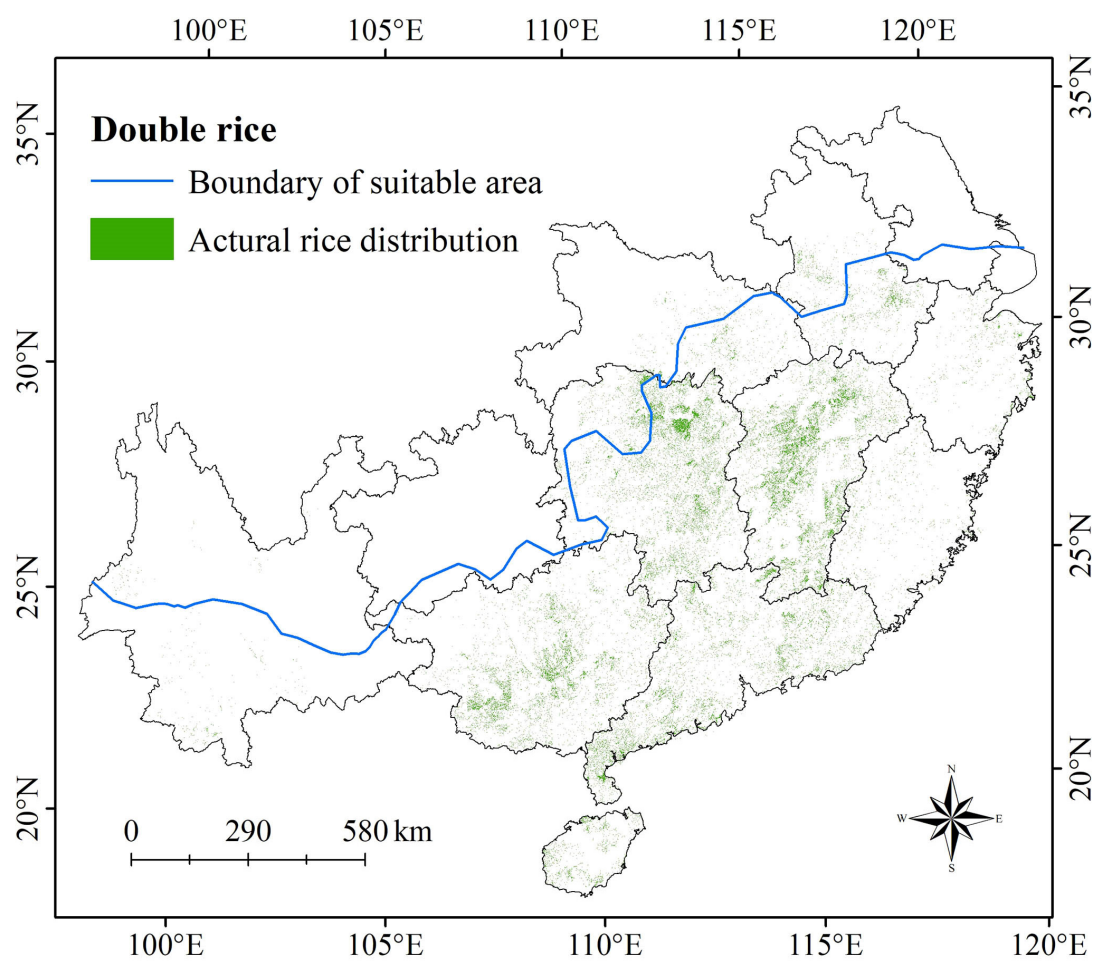


Figure S3. The actual distribution of double rice in Southern China in 2020.

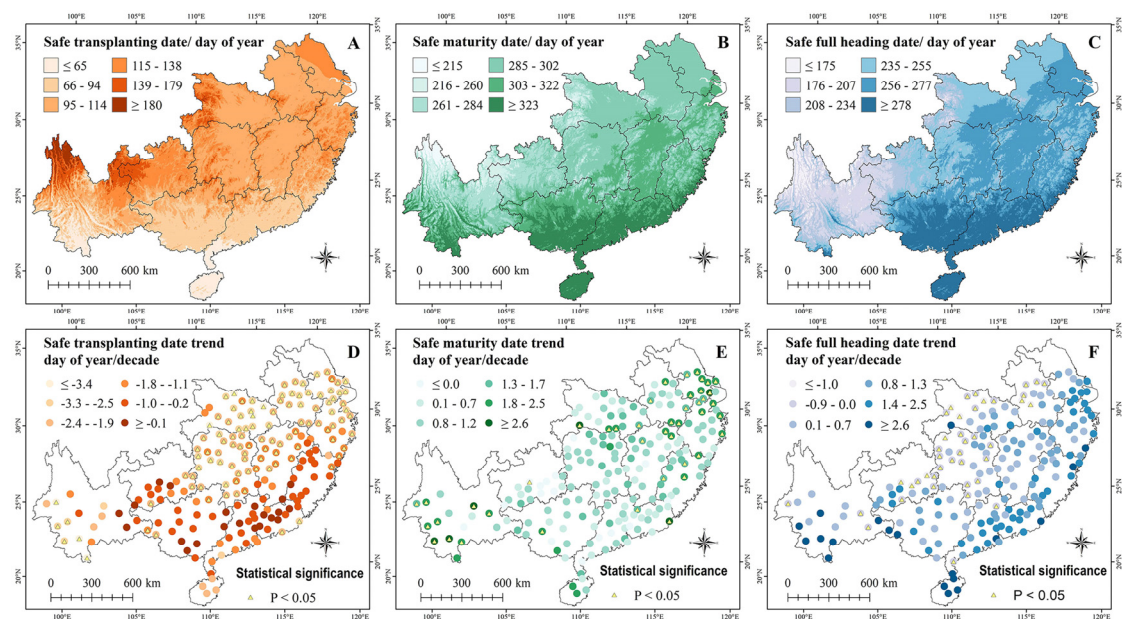


Figure S4. Thermal conditions of double rice in Southern China from 1961 to 2020. A, D: Safe transplanting date; B, E: Safe maturity date; C, F: Safe full heading date; A-C: Average value; D-F: Linear time trend and statistical significance.

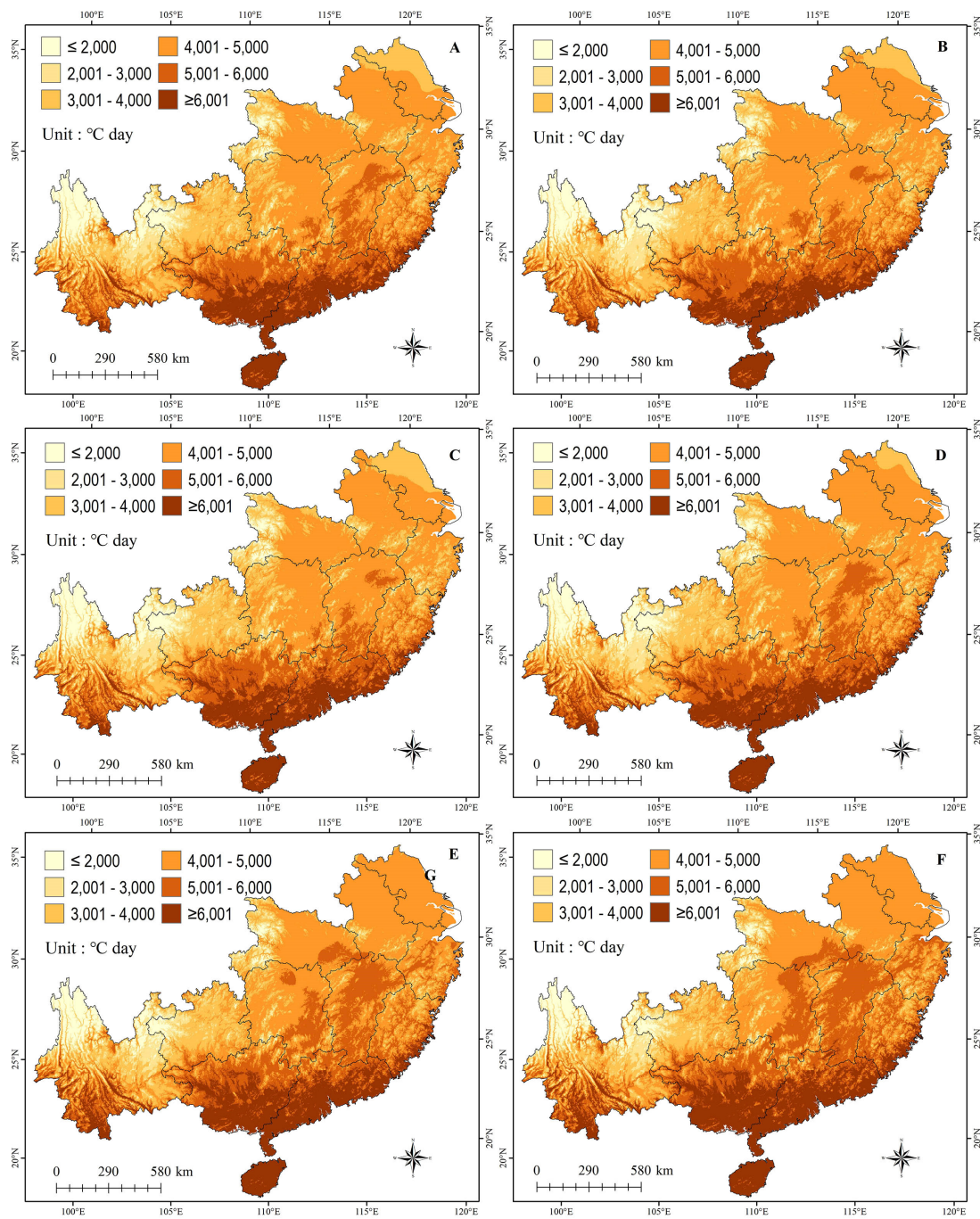


Figure S5. The accumulated temperature during potential growth period in Southern China from 1961 to 2020. A: 1961-1970; B: 1971-1980; C: 1981-1990; D: 1991-2000; E: 2001-2010; F: 2011-2020.

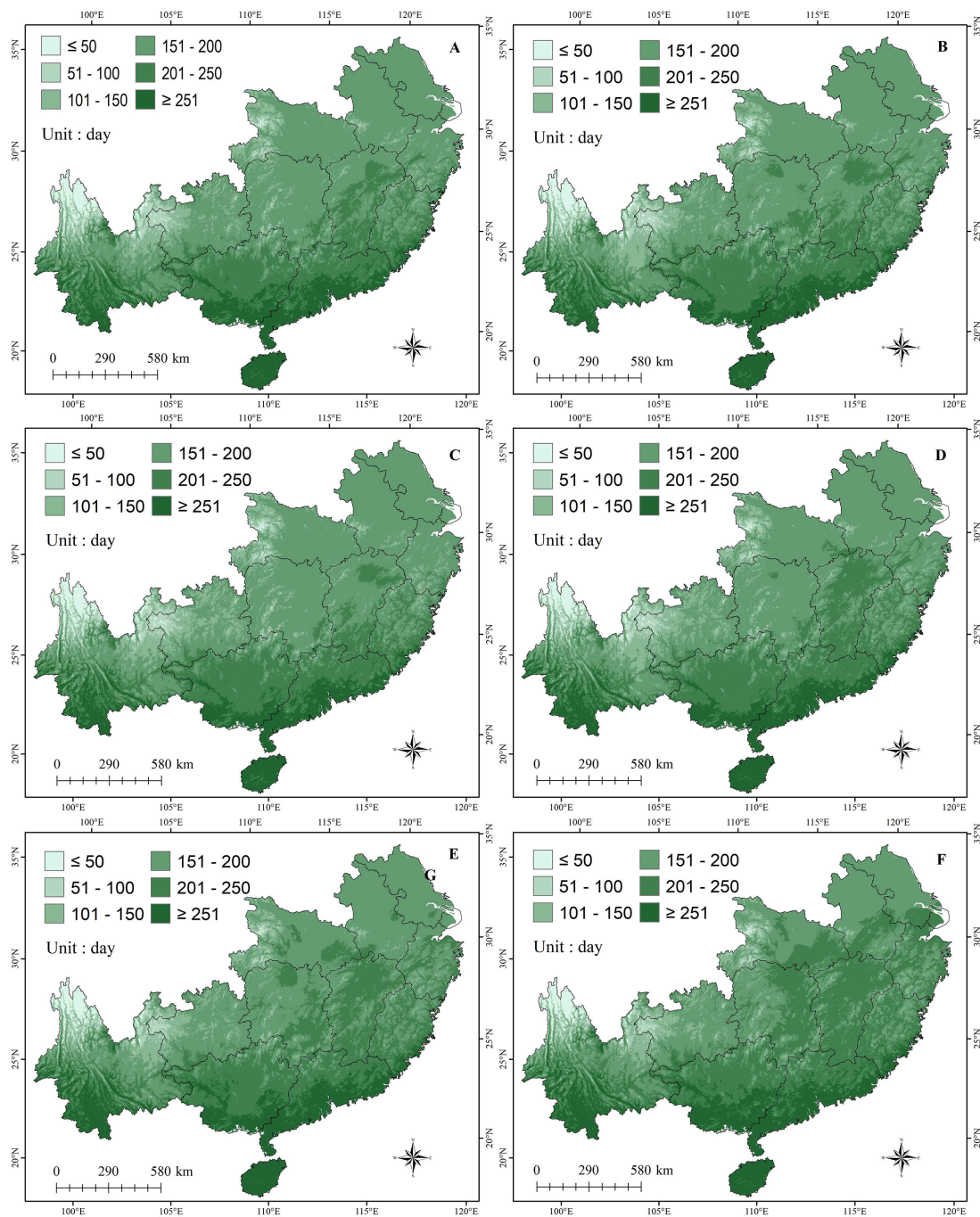


Figure S6. Potential growth period of double rice cropping systems in Southern China from 1961 to 2020. A: 1961-1970; B: 1971-1980; C: 1981-1990; D: 1991-2000; E: 2001-2010; F: 2011-2020.

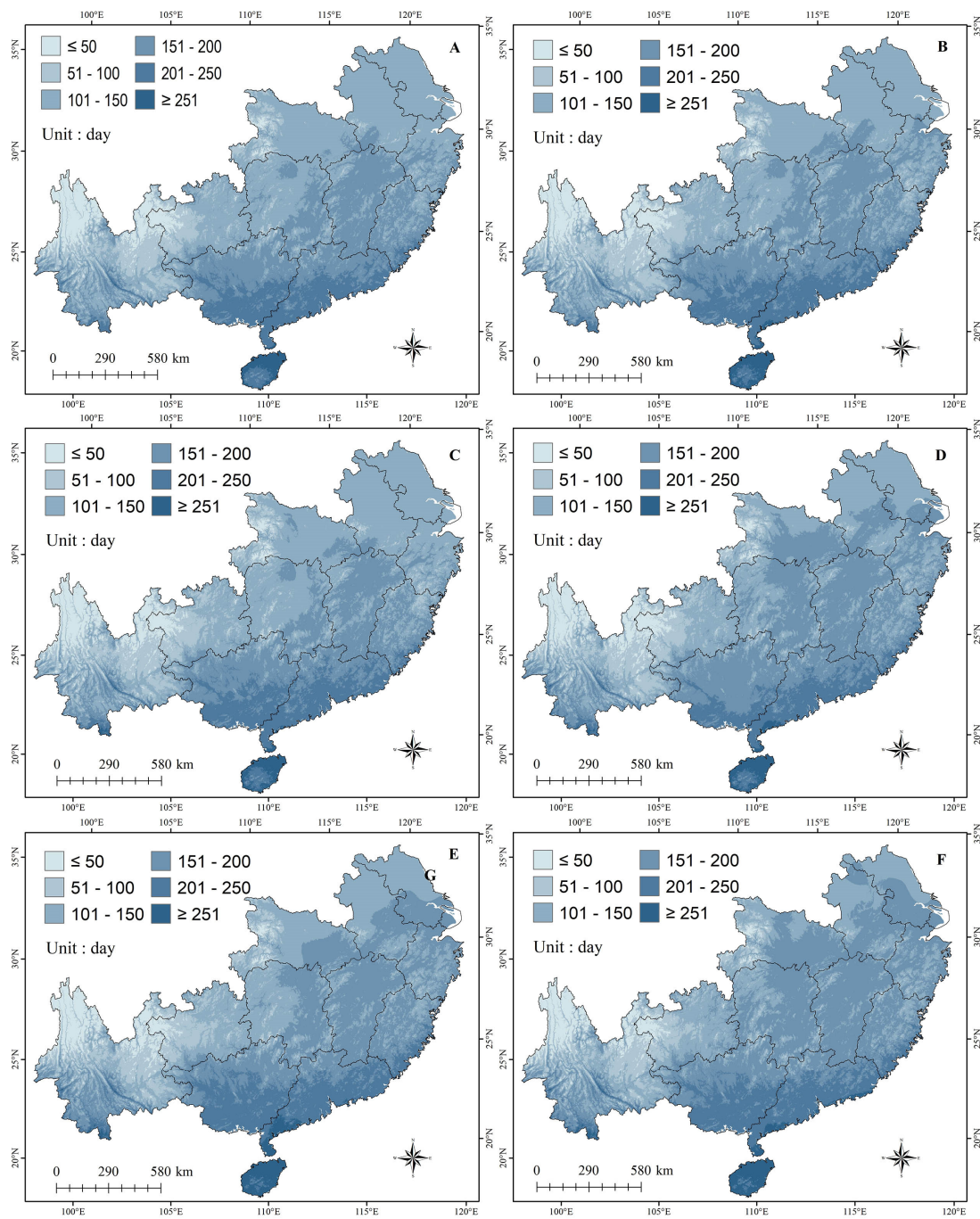


Figure S7. Safe heading days of double rice cropping systems in Southern China from 1961 to 2020. A: 1961-1970; B: 1971-1980; C: 1981-1990; D: 1991-2000; E: 2001-2010; F: 2011-2020.

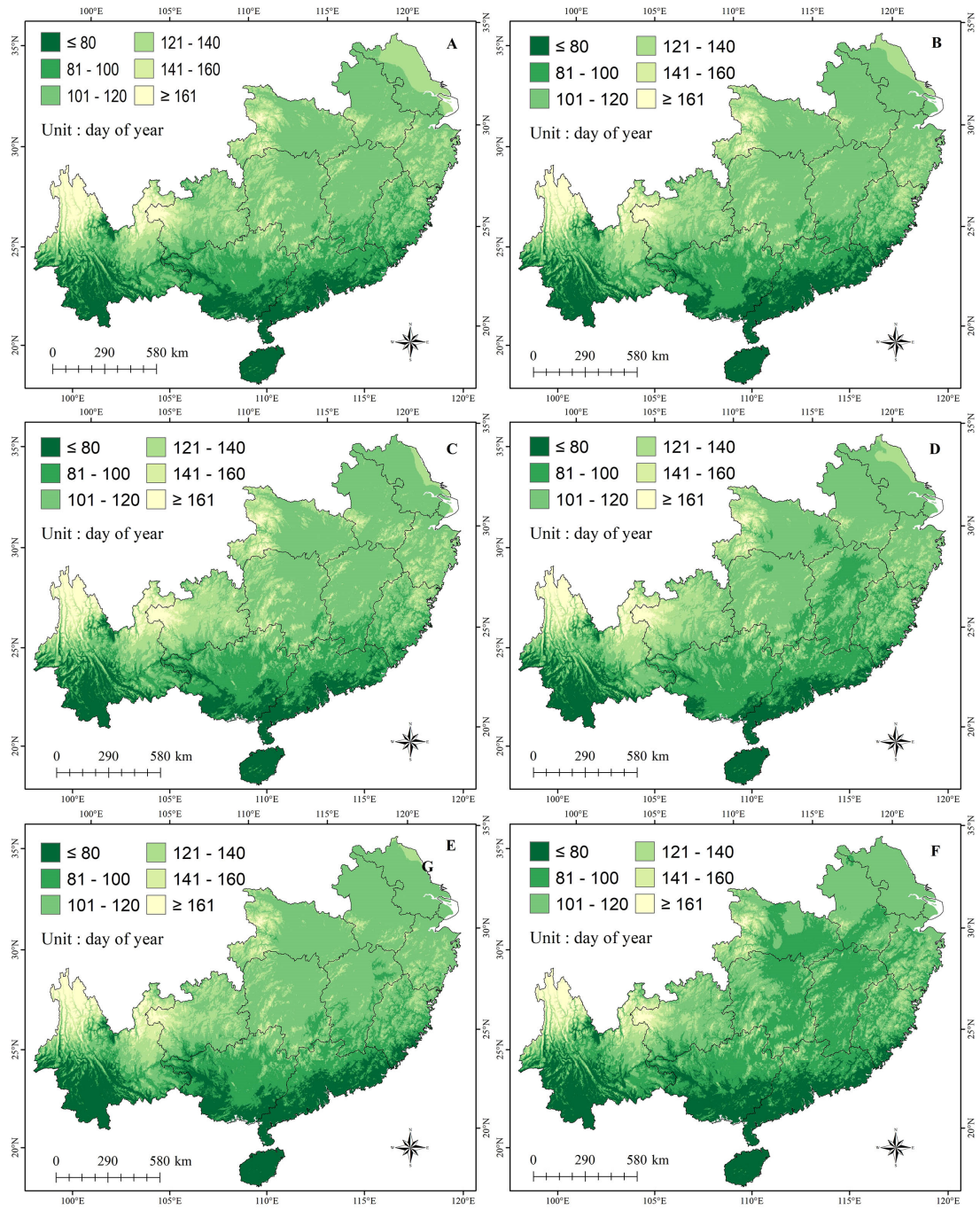


Figure S8. Safe transplanting date of double rice in Southern China from 1961 to 2020. A: 1961-1970; B: 1971-1980; C: 1981-1990; D: 1991-2000; E: 2001-2010; F: 2011-2020.

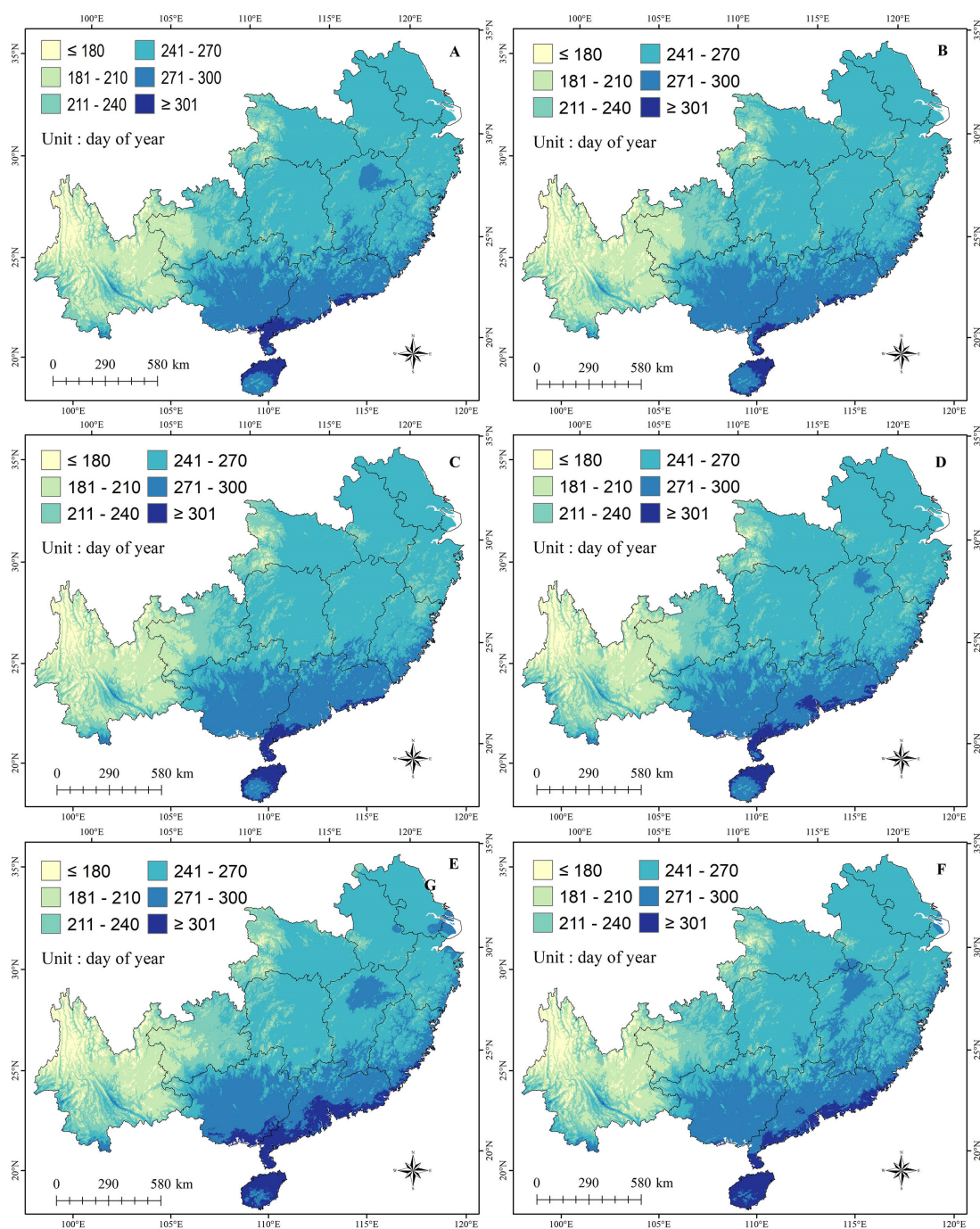


Figure S9. Safe full heading date of double rice in Southern China from 1961 to 2020. A: 1961-1970; B: 1971-1980; C: 1981-1990; D: 1991-2000; E: 2001-2010; F: 2011-2020.

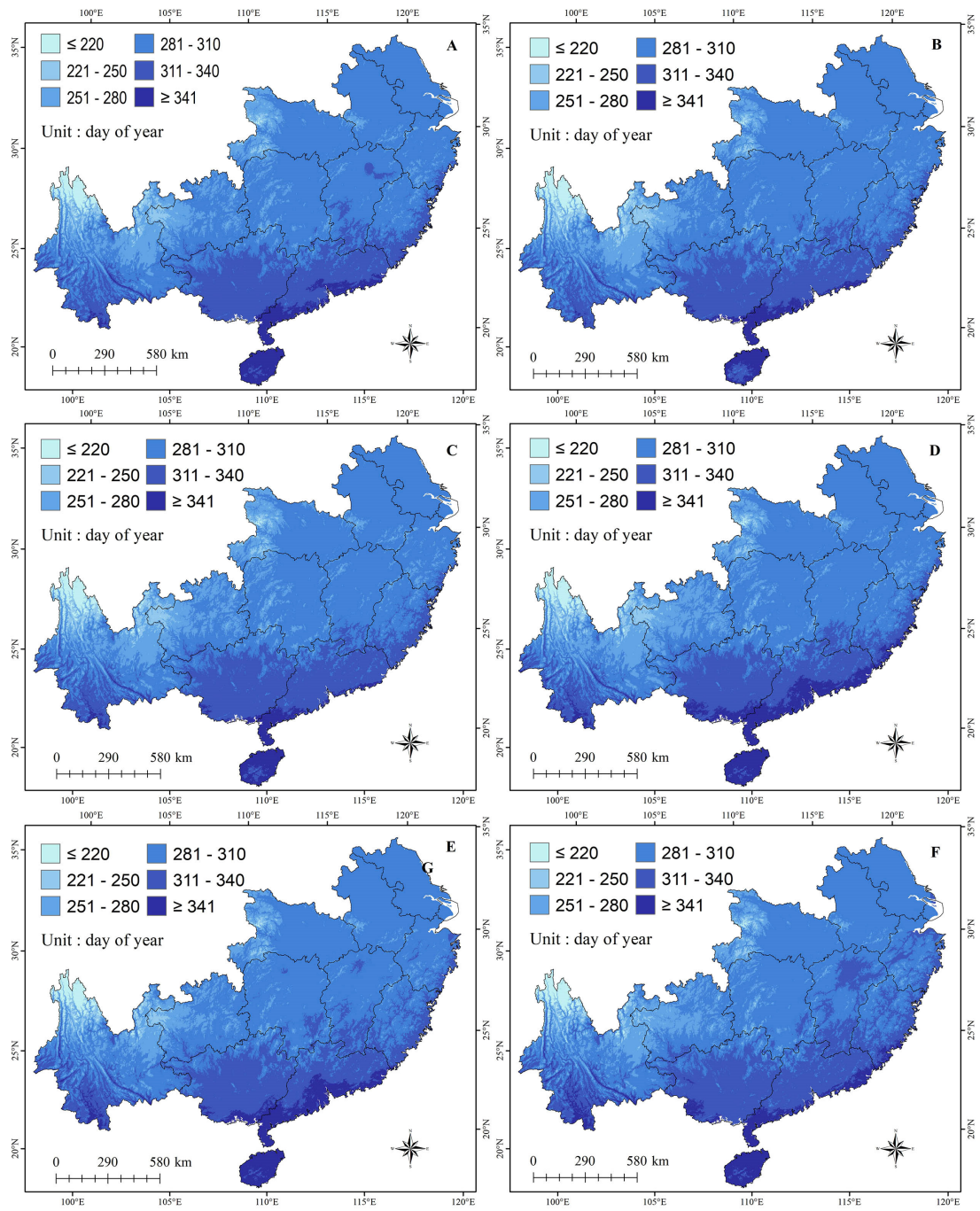


Figure S10. Safe maturity date of double rice in Southern China from 1961 to 2020. A: 1961-1970; B: 1971-1980; C: 1981-1990; D: 1991-2000; E: 2001-2010; F: 2011-2020.