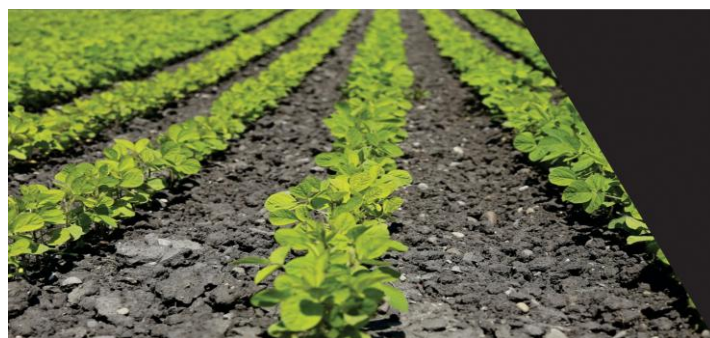




International Journal of Research in Agronomy

E-ISSN: 2618-0618

P-ISSN: 2618-060X

© Agronomy

www.agronomyjournals.com

2024; 7(9): 141-143

Received: 26-07-2024

Accepted: 28-08-2024

Wael Abdel-Rahman

Department of Agronomy, Cairo
University, Cairo, Egypt

Ashraf El-Sayed

Department of Agronomy, Cairo
University, Cairo, Egypt

Samar Khalil

Department of Agronomy, Cairo
University, Cairo, Egypt

Climate change projections and their implications on water availability for irrigated rice in South Asia

Wael Abdel-Rahman, Ashraf El-Sayed and Samar Khalil

DOI: <https://doi.org/10.33545/2618060X.2024.v7.i9b.5171>

Abstract

This study projected water availability changes and impacts on irrigated rice yield across five South Asian basins under multiple RCP scenarios using CMIP5 ensembles coupled with SWAT and DSSAT-CERES-Rice models. Under RCP8.5-2050, seasonal precipitation declined by 13.6%, ET demand rose by 14.4%, and irrigation water deficit reached 182 mm. Rice yield was projected to decline by 2.1-36.3% depending on scenario, with temperature rise explaining 99.4% of yield variation. Reduced precipitation and increased ET jointly accounted for 58.2% of projected deficit, highlighting the convergence of rising demand and shrinking supply.

Keywords: Climate change, irrigated rice, water availability, South Asia, CMIP5, SWAT model, DSSAT, evapotranspiration, RCP scenarios, crop yield projection

Introduction

South Asia produces 28% of global rice on 24% of rice area, yet consumes 34% of irrigation water diverted to agriculture ^[1, 2] a contrast that makes the region acutely vulnerable to water supply shifts. CMIP5 projections indicate mean temperature will rise 1.5-4.0°C by the 2080s, while precipitation changes remain spatially variable ^[3, 4]. For irrigated rice, consequences are twofold: higher evapotranspiration from warming and altered streamflow from shifts in monsoon onset and glacier melt ^[5, 6]. Modelling efforts have examined hydrological or crop dimensions independently ^[7, 8], but integrated assessments coupling water supply with crop response remain limited. This research linked CMIP5 projections with the SWAT hydrological model and DSSAT-CERES-Rice to project how changing water availability will affect irrigated rice yields under multiple RCP scenarios.

Material and Methods

Research area description

The research covered five major rice-producing river basins in South Asia: Indus (Pakistan), Ganges-Brahmaputra (India/Bangladesh), Irrawaddy (Myanmar), Godavari (India), and Cauvery (India). Together these basins irrigate approximately 42 million hectares of rice, representing 67% of South Asian irrigated rice area ^[1]. Baseline climate data (1985-2014) were obtained from the Climate Research Unit (CRU TS4.05) gridded dataset at 0.5° resolution ^[9].

Simulation parameters

Climate projections from 12 CMIP5 GCMs were bias-corrected using quantile mapping against CRU observations ^[10]. Four RCPs (2.6, 4.5, 6.0, 8.5) were evaluated at three horizons: 2030s, 2050s, 2070-2090s. SWAT (v2012, Rev. 670), calibrated with observed streamflow (NSE > 0.72), projected monthly water availability ^[11]. DSSAT-CERES-Rice (v4.7.5), calibrated with IRRI field data (RMSE < 0.38 t/ha), simulated yield responses ^[12]. CO₂ fertilization was included via the Tubiello correction ^[13]. Irrigation deficit was the gap between crop water requirement and projected supply during June-November.

Climatic conditions

Baseline mean rice-season temperature ranged from 25.4°C (Ganges) to 28.7°C (Cauvery).

Corresponding Author:

Wael Abdel-Rahman

Department of Agronomy, Cairo
University, Cairo, Egypt

Mean seasonal precipitation was 847 mm, with 72% in July–September. Under RCP8.5-2050, multi-model temperature increased by 2.5°C and precipitation declined by 13.6%, with

largest drying in the Indus (−18.4%) and Cauvery (−16.1%) basins [3].

Results

Table 1: Projected changes in climate, water deficit, and rice yield under RCP scenarios (multi-basin means)

Scenario	ΔT (°C)	ΔP (%)	ET change (%)	Water deficit (mm)	Yield change (%)	Projected yield (t/ha)
Baseline	0.0	0.0	0.0	0	0.0	4.82
RCP2.6-2030	+0.8	-3.2	+4.1	47	-2.1	4.72
RCP4.5-2030	+1.2	-5.1	+6.3	74	-4.8	4.59
RCP4.5-2050	+1.8	-8.4	+9.7	118	-10.6	4.31
RCP6.0-2050	+2.1	-10.2	+11.8	143	-14.2	4.14
RCP8.5-2050	+2.5	-13.6	+14.4	182	-18.7	3.92
RCP8.5-2070	+3.2	-18.3	+19.1	247	-27.8	3.48
RCP8.5-2090	+3.8	-22.7	+23.6	314	-36.3	3.07

ΔT = temperature change. ΔP = precipitation change. ET = evapotranspiration. Baseline yield is 12-GCM ensemble mean for 1985–2014

Comprehensive interpretation

Water deficit increased progressively from 47 mm (RCP2.6-2030) to 314 mm (RCP8.5-2090) (Table 1). Rice yield declined from 2.1% to 36.3% across the scenario range, with every 1°C

rise reducing yield by approximately 8.5–9.5%. Under the moderate pathway RCP4.5-2050, yield fell by 10.6% to 4.31 t/ha, while the worst-case RCP8.5-2090 projected yields of just 3.07 t/ha a loss of 1.75 t/ha from baseline.

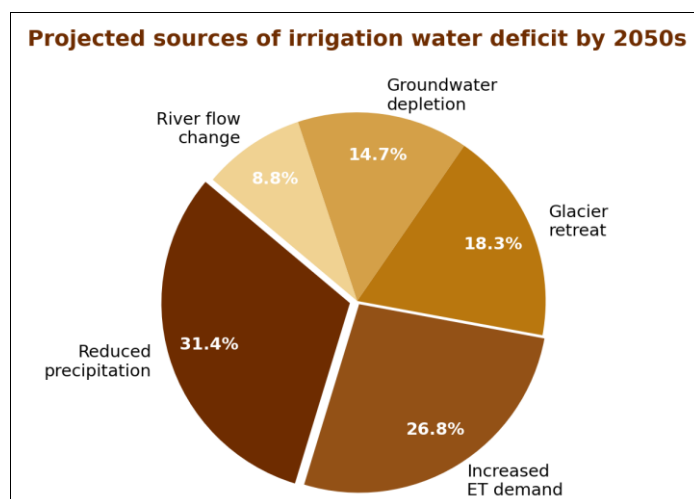


Fig 1: Projected sources of irrigation water deficit for South Asian rice by the 2050s

Reduced precipitation (31.4%) and increased ET demand (26.8%) were the two largest contributors to water deficit, jointly accounting for 58.2% (Figure 1). Glacier retreat contributed 18.3%, particularly relevant for the Indus and upper Ganges basins dependent on snowmelt.

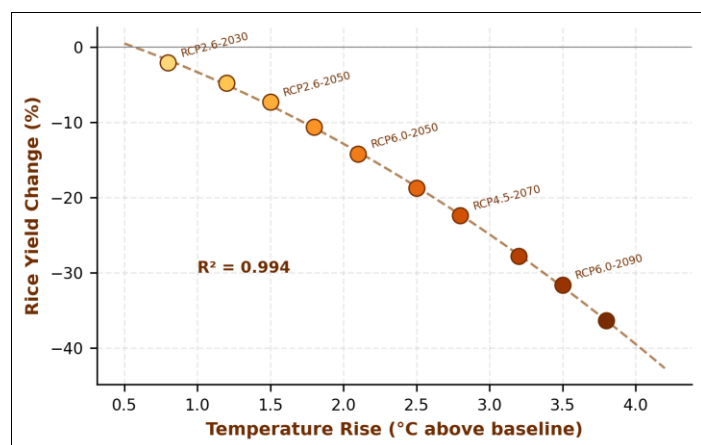


Fig 2. Relationship between temperature rise and projected rice yield change across RCP scenarios

A strong quadratic relationship ($R^2 = 0.994$) existed between temperature rise and yield decline (Figure 2). The curve steepened beyond 2°C, indicating disproportionate yield losses at higher warming from heat-induced spikelet sterility and shortened grain filling.

Discussion

The 10.6% yield decline under RCP4.5-2050 is consistent with meta-analyses reporting 6–12% losses per 1°C warming in tropical irrigated rice [7, 8]. The convergence of supply reduction and demand increase creates a compounding deficit that precipitation projections alone understate. Glacier retreat accounting for 18.3% of deficit underscores Indus and Ganges basin exposure to cryospheric loss [5, 6]. The quadratic yield-temperature relationship steepening beyond 2°C aligns with evidence that spikelet sterility rises sharply above 35°C during anthesis [14]. Integrated adaptation combining water-saving irrigation, heat-tolerant cultivars, and diversified cropping calendars is needed to buffer against the projected water-yield squeeze.

Conclusion

Climate change is projected to reduce irrigated rice yields in

South Asia by 2.1-36.3% depending on emission pathway and time horizon. Under moderate warming (RCP4.5-2050), irrigation water deficit reached 118 mm and yield fell by 10.6%. Reduced precipitation and increased ET demand jointly drove 58.2% of the deficit. Yield losses accelerated disproportionately beyond 2°C warming. Integrated adaptation strategies addressing both water supply and heat tolerance are essential to sustain South Asian rice production.

References

1. FAOSTAT. Food and Agriculture Organization Statistical Database. Rome: FAO; 2023.
2. Gleick PH. Water in Crisis: A Guide to the World's Fresh Water Resources. New York: Oxford University Press; 1993.
3. IPCC. Climate Change 2014: Synthesis Report. Geneva: IPCC; 2014.
4. Hijikawa Y, Lin E, Pereira JJ, *et al.* Asia. In: Climate Change 2014: Impacts, Adaptation, and Vulnerability. Cambridge: Cambridge University Press; c2014. p. 1327-1370.
5. Immerzeel WW, van Beek LPH, Bierkens MFP. Climate change will affect the Asian water towers. *Science*. 2010;328(5984):1382-1385.
6. Barnett TP, Adam JC, Lettenmaier DP. Potential impacts of a warming climate on water availability in snow-dominated regions. *Nature*. 2005;438(7066):303-309.
7. Challinor AJ, Watson J, Lobell DB, Howden SM, Smith DR, Chhetri N. A meta-analysis of crop yield under climate change and adaptation. *Nature Climate Change*. 2014;4(4):287-291.
8. Zhao C, Liu B, Piao S, *et al.* Temperature increase reduces global yields of major crops. *Proceedings of the National Academy of Sciences*. 2017;114(35):9326-9331.
9. Harris I, Osborn TJ, Jones P, Lister D. Version 4 of the CRU TS monthly high-resolution gridded dataset. *Scientific Data*. 2020;7(1):109.
10. Teutschbein C, Seibert J. Bias correction of regional climate model simulations. *Journal of Hydrology*. 2012;456-457:12-29.
11. Arnold JG, Srinivasan R, Muttiah RS, Williams JR. Large area hydrologic modeling. Part I: Model development. *Journal of the American Water Resources Association*. 1998;34(1):73-89.
12. Jones JW, Hoogenboom G, Porter CH, *et al.* The DSSAT cropping system model. *European Journal of Agronomy*. 2003;18(3-4):235-265.
13. Tubiello FN, Amthor JS, Boote KJ, *et al.* Crop response to elevated CO₂ and world food supply. *European Journal of Agronomy*. 2007;26(3):215-223.
14. Jagadish SVK, Craufurd PQ, Wheeler TR. High temperature stress and spikelet fertility in rice. *Journal of Experimental Botany*. 2007;58(7):1627-1635.