

Monitoring Actual Irrigated Cropland Area in the Hexi Corridor Based on Blue/Green Evapotranspiration using Remote Sensing Observations

Bingkui Wei^{a,b}, Chaolei Zheng^a, Li Jia^a

^aState Key Laboratory of Remote Sensing and Digital Earth, Aerospace Information Research Institute, Chinese Academy of Sciences
^bUniversity of Chinese Academy of Sciences, China

ABSTRACT

Agricultural irrigation accounts for over 50% of China's total annual water use, intensifying water scarcity in arid regions like the Hexi Corridor in northwestern China. Due to minimal precipitation, agriculture in the Hexi Corridor relies heavily on irrigation, leading to ecosystem stress and water-use conflicts. This study presents a remote sensing-based approach to accurately monitor actual irrigated cropland area and irrigation water use by partitioning evapotranspiration (ET) into blue ET (BET) and green ET (GET) using the ETMonitor and CHIRPS datasets. Two water-energy-coupled models—Budyko (BD74) and Fu model (Fu81) were used, with the Fu81 parameter calibrated per Zhou et al. (2025). Irrigated areas were identified through BET-based thresholding and validated against statistical data and existing products. Fu81 outperformed BD74, achieving an R^2 of 0.83 and 86% spatial accuracy. Results show a continuous expansion of irrigated cropland from 2001 to 2021, while irrigation water use remained relatively stable, indicating improved water-use efficiency. This approach provides a reliable scientific basis for sustainable irrigation water management in arid agricultural regions.

INTRODUCTION

- China's agriculture uses 62.2% of total water, with only 0.576 irrigation efficiency.
- Northwest inland basins face severe water waste.
- Hexi Corridor is a major grain-producing region in arid northwest China, with scarce rainfall, average temperatures of 6.6–9.5°C, and limited surface water.
- Agriculture in the Hexi Corridor is heavily dependent on irrigation, leading to growing water stress.
- Accurate irrigation mapping is vital for water management and drought prevention.

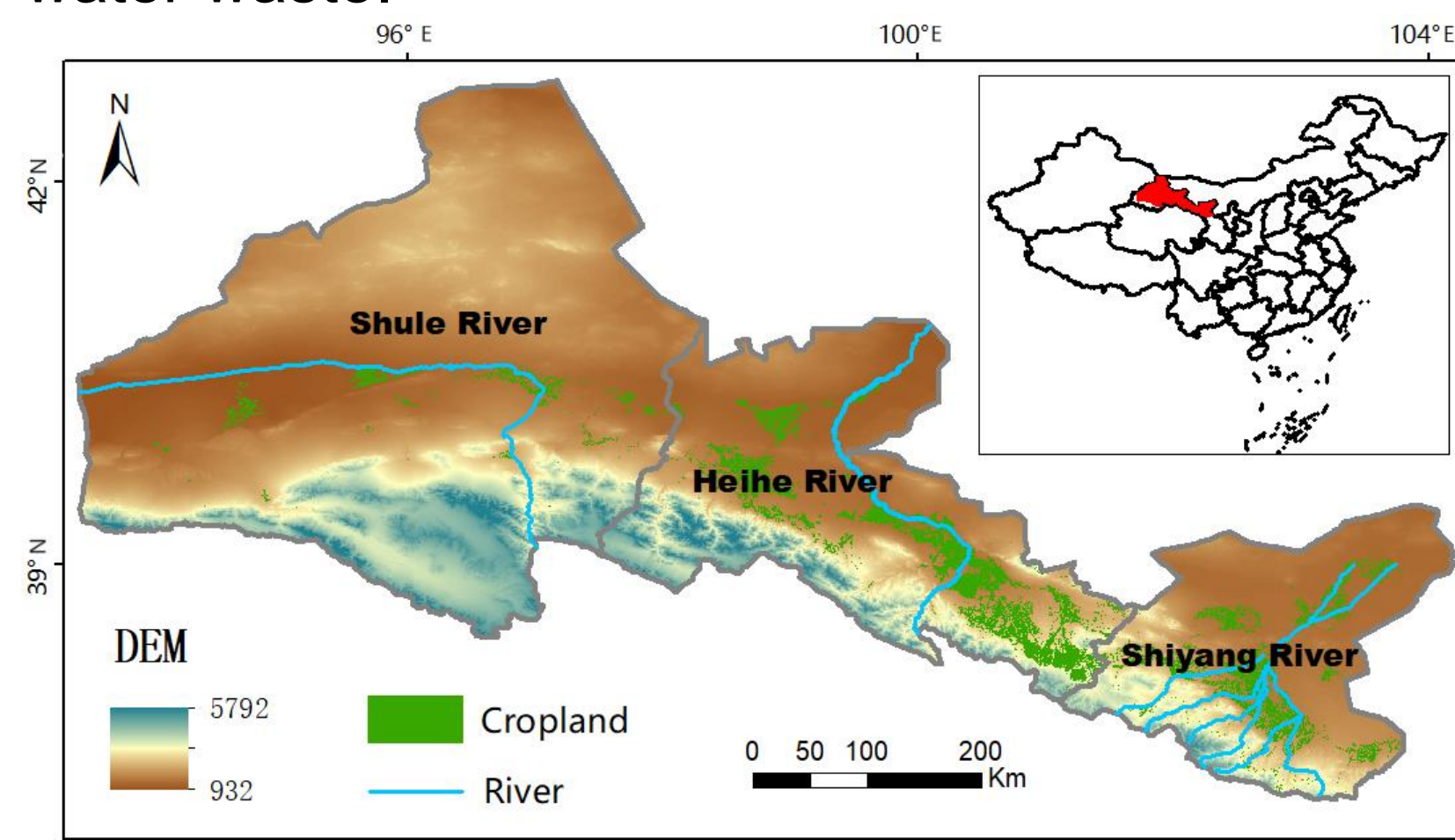


Fig.1. Overview Map of the Hexi Corridor

OBJECTIVES

- To extract and compare actual irrigated areas using blue/green ET decomposition derived from Budyko model (BD74) and Fu model (Fu81)
- To analyze the spatiotemporal variations of irrigated cropland in the Hexi Corridor from 2001 to 2021
- To estimate annual irrigation water use based on extracted irrigated areas and regional irrigation quotas, and explore its interannual trends and driving factors such as climate, irrigation policies, and water-saving technologies.

METHODS

Budyko hypothesis

In a closed basin, precipitation is the only source of water input, which eventually exits the system either as surface runoff or evapotranspiration. The portion lost through evapotranspiration essentially represents green water evapotranspiration (GET).

Estimation of GET

Budyko model:

$$\phi = \frac{ET_p}{P} \quad (1)$$

$$GET = P \sqrt{(1 - e^{-\phi}) * \phi \tanh \frac{1}{\phi}} \quad (2)$$

Fu model:

$$\frac{GET}{P} = 1 + \frac{ET_p}{P} - \left[1 + \left(\frac{ET_p}{P} \right)^\omega \right]^\frac{1}{\omega} \quad (3)$$

Due to the introduction of irrigation water sources, the ω value for irrigated croplands in each basin cannot be directly fitted. Therefore, the ω value of grasslands within the basin, which have similar physiological characteristics to the crops, is used as a proxy for that of the irrigated croplands.

Calculation of BET

$$BET = ET - GET \quad (4)$$

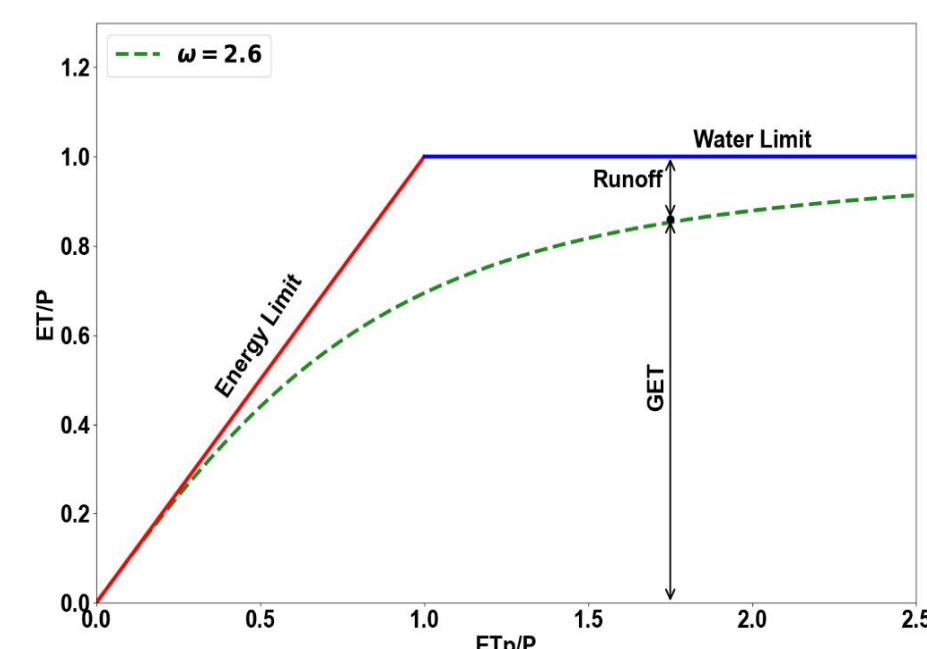


Fig.2. The Budyko curve

RESULTS

- This study compared the accuracy of the Fu81 and BD74 methods in estimating actual irrigated areas in the Hexi Corridor from both quantitative and spatial perspectives. The Fu81 model consistently outperformed BD74, with higher statistical accuracy ($R^2 = 0.833$, BIAS < 10, MAPE = 5.9%) and better spatial classification performance, achieving 86% accuracy, 4% higher than BD74. These improvements are attributed to Fu81's use of watershed-specific parameter optimization, which better captures regional heterogeneity in irrigation practices.
- From 2001 to 2021, the Hexi Corridor saw significant increases in actual irrigated area (77%) and irrigation cropland proportion (71%), with faster growth after 2013. Despite this expansion, irrigation water use declined and stabilized after 2013, indicating improved agricultural water use efficiency.

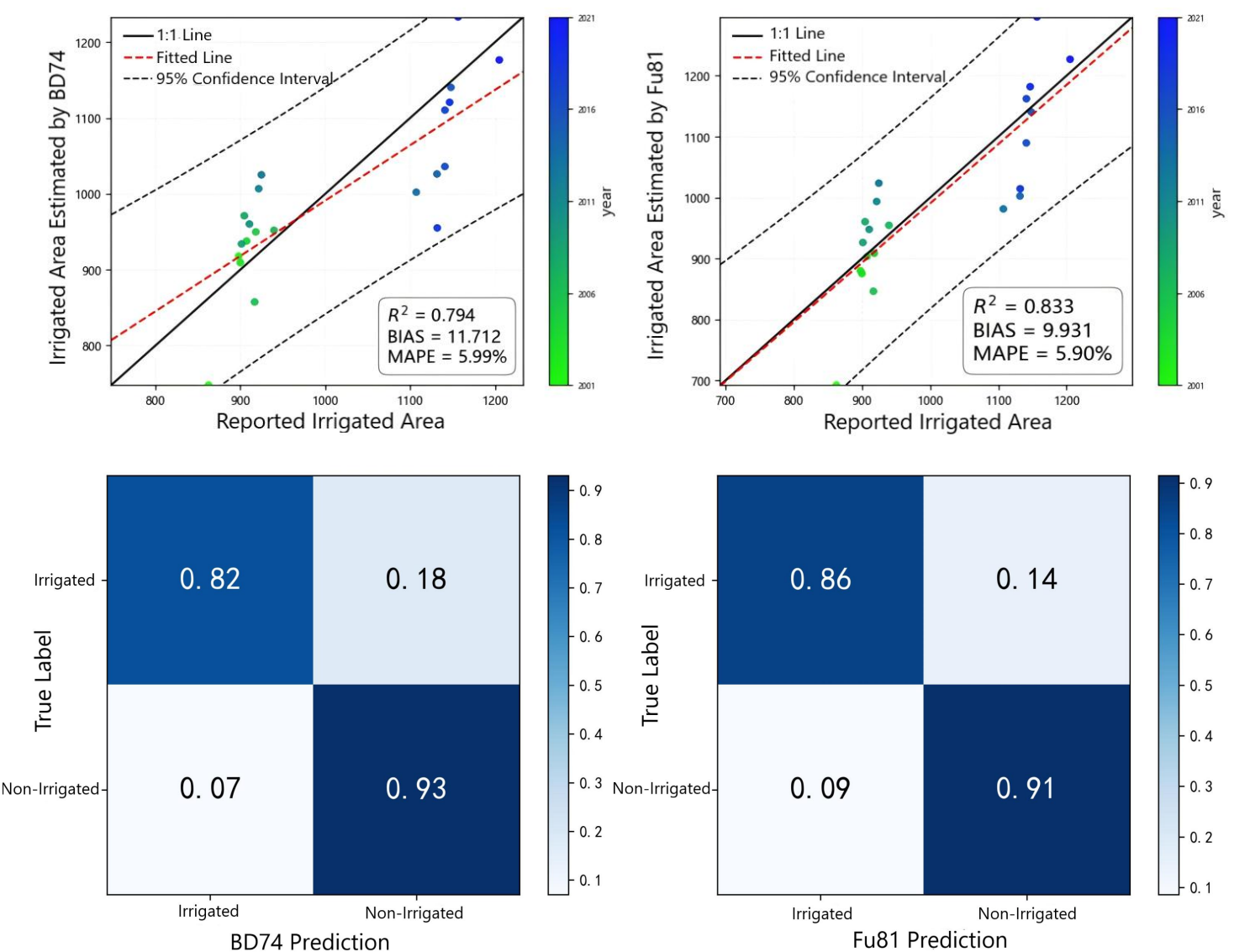


Fig.3. Accuracy Assessment Results

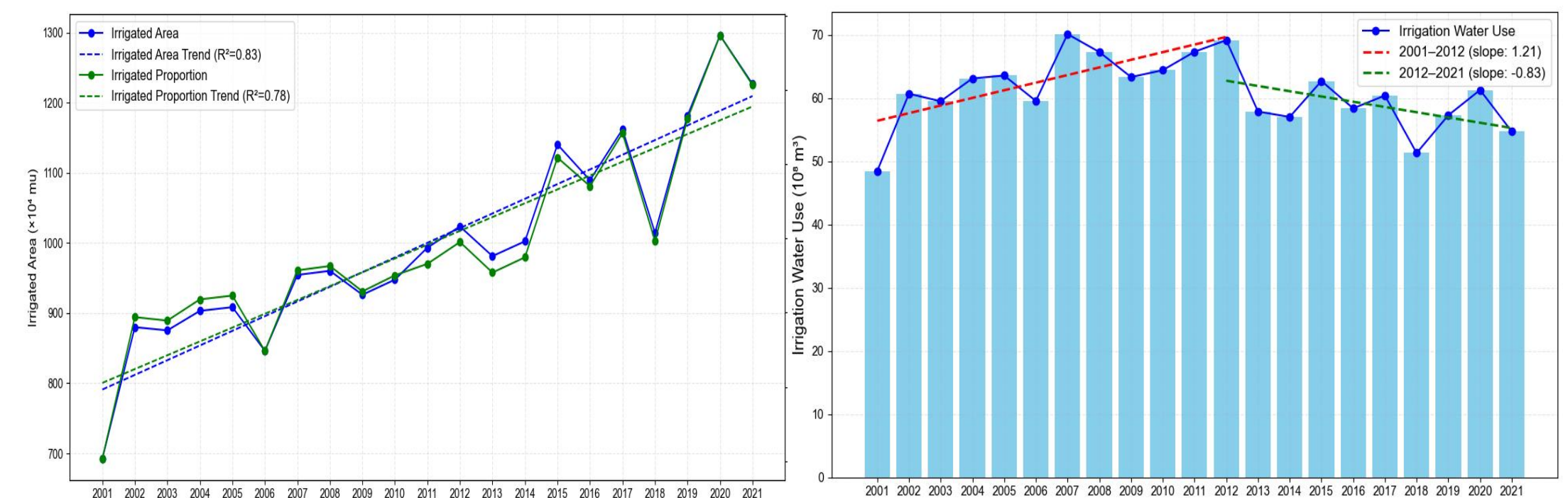


Fig.4. Interannual Trend Graph

- Based on irrigation information extracted using the Fu81 method, we found that 85% of croplands in the Hexi Corridor are dominated by blue water evapotranspiration, indicating a strong reliance on irrigation. The Shule River Basin has the highest blue water proportion, reaching 88.4%.

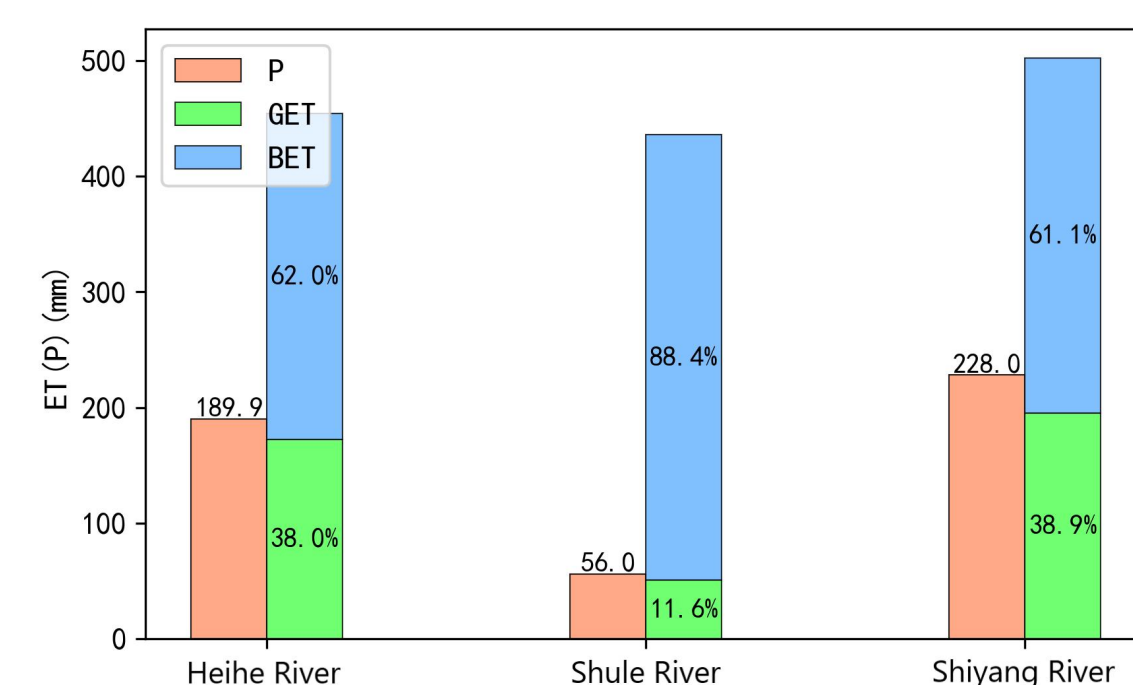


Fig.5. Annual Average Contribution of GET and BET to Total ET in Cropland Areas of each basin in the Hexi Corridor

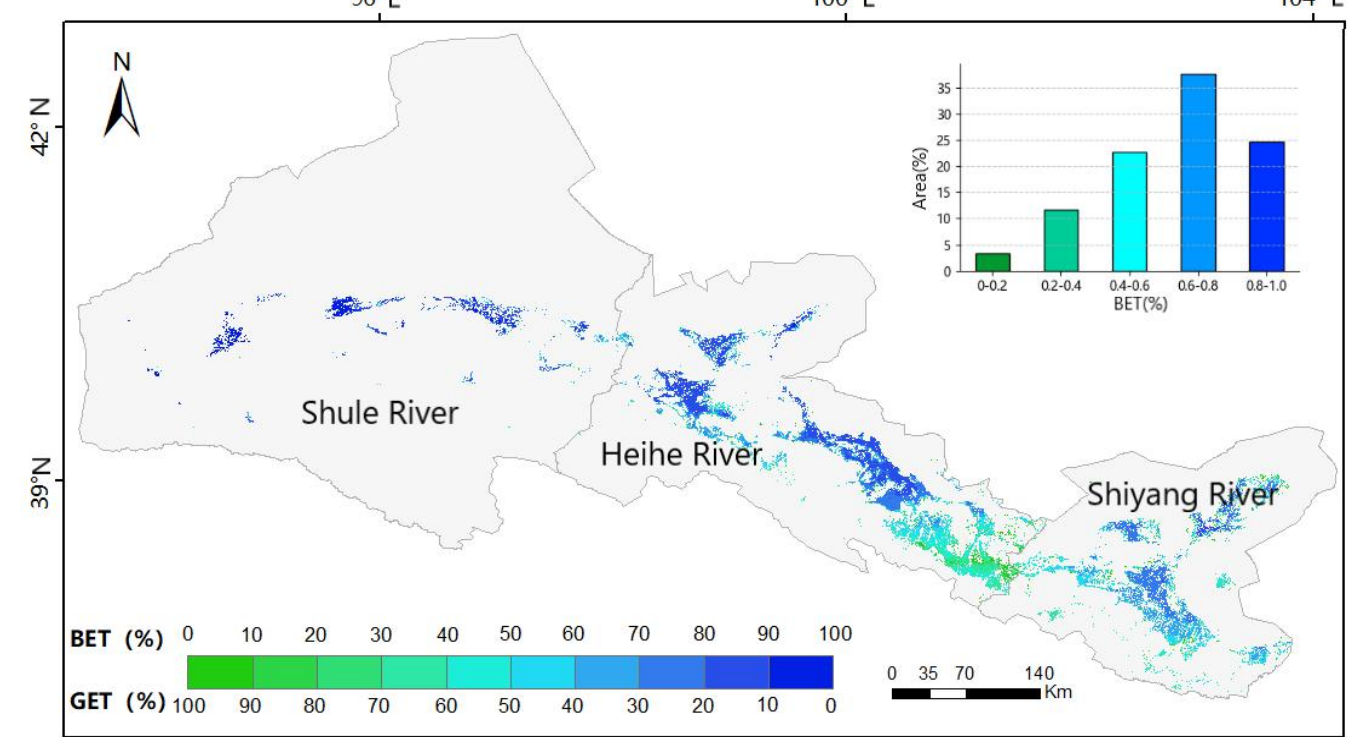


Fig.6. Average Annual Contribution of GET and BET to Total ET in Cultivated Areas of the Hexi Corridor

CONCLUSIONS

- Fu81 model shows higher accuracy:** By incorporating the watershed parameter ω , the Fu81 model achieved better performance than BD74, with an R^2 of 0.83 for area estimation and 86% spatial accuracy.
- Irrigated area expanded steadily (2001–2021):** Irrigated cropland in the Hexi Corridor increased by 200,000 mu per year, totaling a 77% growth over two decades.
- Blue water dominates agricultural ET:** Over 85% of cropland had blue water evapotranspiration shares above 50%, indicating strong reliance on irrigation sources.
- Improved irrigation efficiency since 2013:** Despite area expansion, total irrigation water use remained stable after 2013, suggesting improved efficiency through water-saving technologies and policies.

References

- [1] Zhou D, Zheng C, Jia L, et al. Partitioning Green and Blue Evapotranspiration by Improving Budyko Equation Using Remote Sensing Observations in an Arid/Semi-Arid Inland River Basin in China[J]. Remote Sens. 2025, 17, 612.
- [2] Afua Owusu, Stefanie Kagone, Mansoor Leh, et al. A framework for disaggregating remote-sensing cropland into rainfed and irrigated classes at continental scale. International Journal of Applied Earth Observation and Geoinformation[J], Volume 126. 2024, 103607, ISSN 1569-8432.
- [3] Budyko, M. I. The heat balance of the earth's surface[M]. Washington, D.C.: US Department of Commerce, 1958.
- [4] Fu, Baw-puh. On the Calculation of the Evaporation from Land Surface[J]. Chinese Journal of Atmospheric Sciences. 1981. 5 (1): 23–31.
- [5] Li D, Pan M, Cong Z, et al. Vegetation control on water and energy balance within the Budyko framework[J], Water Resources Research. 2013, 49.

Acknowledgement

This work was conducted as part of the Dragon 6 cooperation programme between the European Space Agency (ESA) and the Ministry of Science and Technology (MOST) of China. The authors acknowledge the support and coordination provided by the Dragon Programme Office