calibrated models using gridded weather, management information, and representative genetic coefficients, achieving district-level correlations above 0.7 and relative RMSE below 25% for most major rice-growing districts, and demonstrating reasonable skill in reproducing yield anomalies in out-of-sample years-supporting their use for near-real-time yield estimation and risk assessment (Arumugam et al., 2020).

6 Applications of Rice Yield Formation Models

6.1 Decision support for irrigation and fertilization

Rice yield formation models are increasingly used to optimize coupled water-nitrogen management, balancing grain yield with resource efficiency and environmental impacts. Field experiments combined with regression modeling show that irrigation regime and nitrogen rate jointly determine grain yield, total water productivity, and nitrogen recovery efficiency, but that these objectives cannot be maximized simultaneously, motivating multi-objective decision tools based on water-nitrogen-yield response surfaces (Cao et al., 2020). Multi-objective quadratic models integrating water-nitrogen-yield and water-nitrogen-quality relationships further demonstrate that optimal irrigation and nitrogen combinations differ among management scenarios, and that excessive inputs can become counterproductive for both yield and grain quality.

Model-based seasonal and long-term scenario analyses allow irrigation and fertilization decisions to be tailored to local climate risk. Using CSM-CERES-Rice within DSSAT, one study quantified how early direct seeding, no-tillage, and moderate nitrogen rates simultaneously improved yield, irrigation efficiency, and reduced methane emissions over 35 years, providing concrete guidance on planting date, tillage, and N rate selection (Figure 3) (Darikandeh et al., 2025). Machine-learning decision models that couple ensemble yield prediction (e.g., extremely randomized trees) with swarm-intelligence optimization have also been proposed, enabling site-specific recommendations of N-P-K base fertilizer that increase average rice yields by more than 13% while reducing the need for extensive field experimentation (Gao et al., 2023).

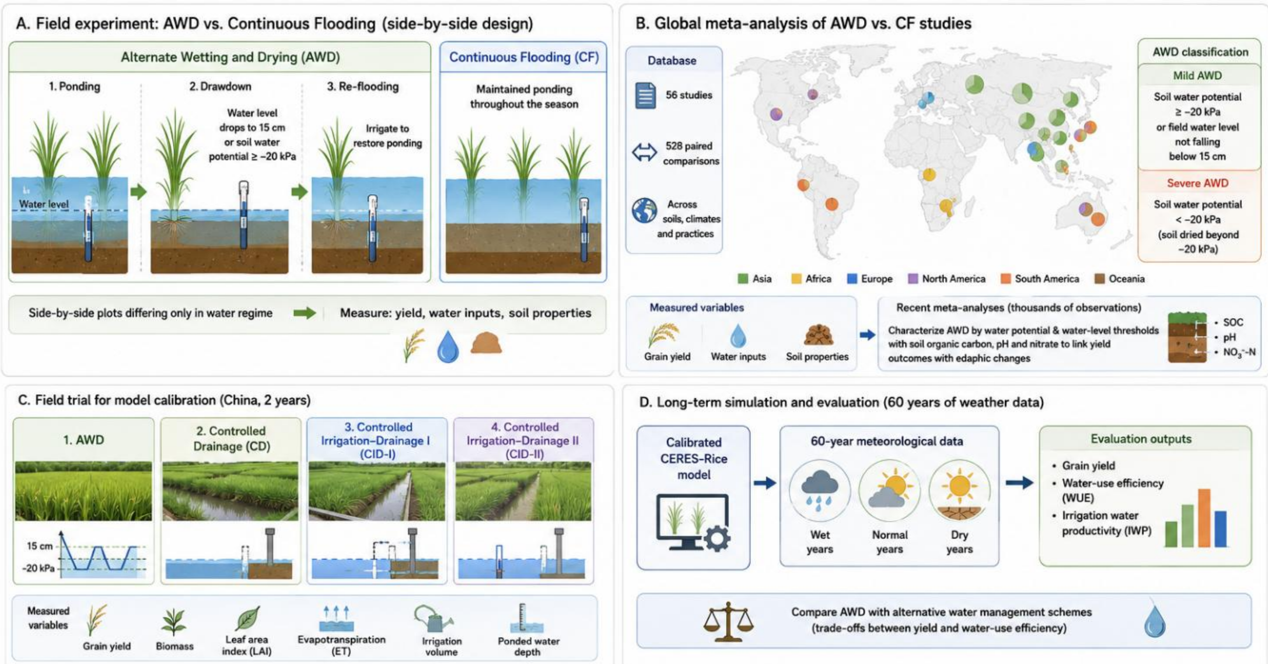

Figure 3 Experimental designs and analytical frameworks used to compare alternate wetting and drying (AWD) with continuous flooding (CF) in rice production systems

6.2 Climate change adaptation and risk assessment

Process-based crop models calibrated for local cultivars are widely applied to assess climate change impacts and identify adaptation levers. In Mediterranean Türkiye, DSSAT-CERES-Rice simulations under multiple GCMs and RCPs showed that irrigated yields could increase slightly in late-century, whereas rainfed yields declined by 15%-25% due to higher temperatures, shorter growth duration, and soil-moisture stress, illustrating how