Afforestation may aggravate the trade-off between water-related ecosystem services in degraded ecosystems

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Abstract

Land use change is a main factor of affecting water-related ecosystem services (WESs), critical for managing aquatic ecosystem. Nevertheless, how to establish the connection between realistic land management and optimizing WESs is unclear. To address this issue, we selected a typical ecologically vulnerable area, the Ussuri River Basin in China, as an analyzed domain to reveal the driving mechanism of WESs. Furthermore, four land scenarios were established to unfold the connection between land use and WESs. The results are as follows: from 2000 to 2018, cropland expansion led to increases of nitrogen export (+11.55%) and phosphorous export (+12.50%), along with increased food production (+127.27%) and water yield services (+1.41%). We found that the trade-offs occurred mainly within provisioning services (between water yield and food production) or regulating services (between water purification and soil retention). Regarding future scenarios, the traditional "Grain for Green" scenario failed to benefit ecosystems, not only increasing the trade-off intensity of ecosystem services, but leading to competitive relationships in WESs. As a result, afforestation may not be an optimal solution for the restoration of degraded ecosystems, especially in water-limited areas. The forestland buffer zone scenario was regarded as the optimal land practice, in which WESs were enhanced significantly and trade-offs were reduced between provisioning services, indicating that tree-planting near waters maintained both ecological benefits and fundamental grain outputs. These results highlighted importance of land management on WESs, offering a prospective evaluation of ecosystem service benefits under future development pathway.

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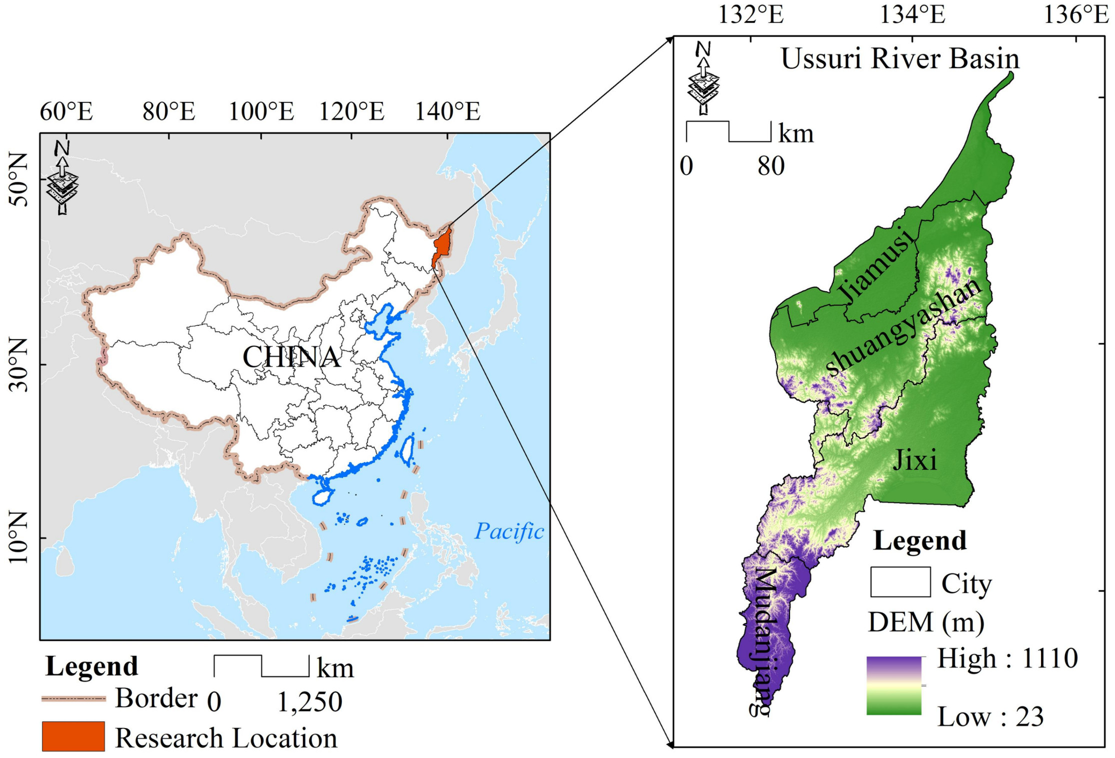

Fig. 1. Location and elevation of the study area.

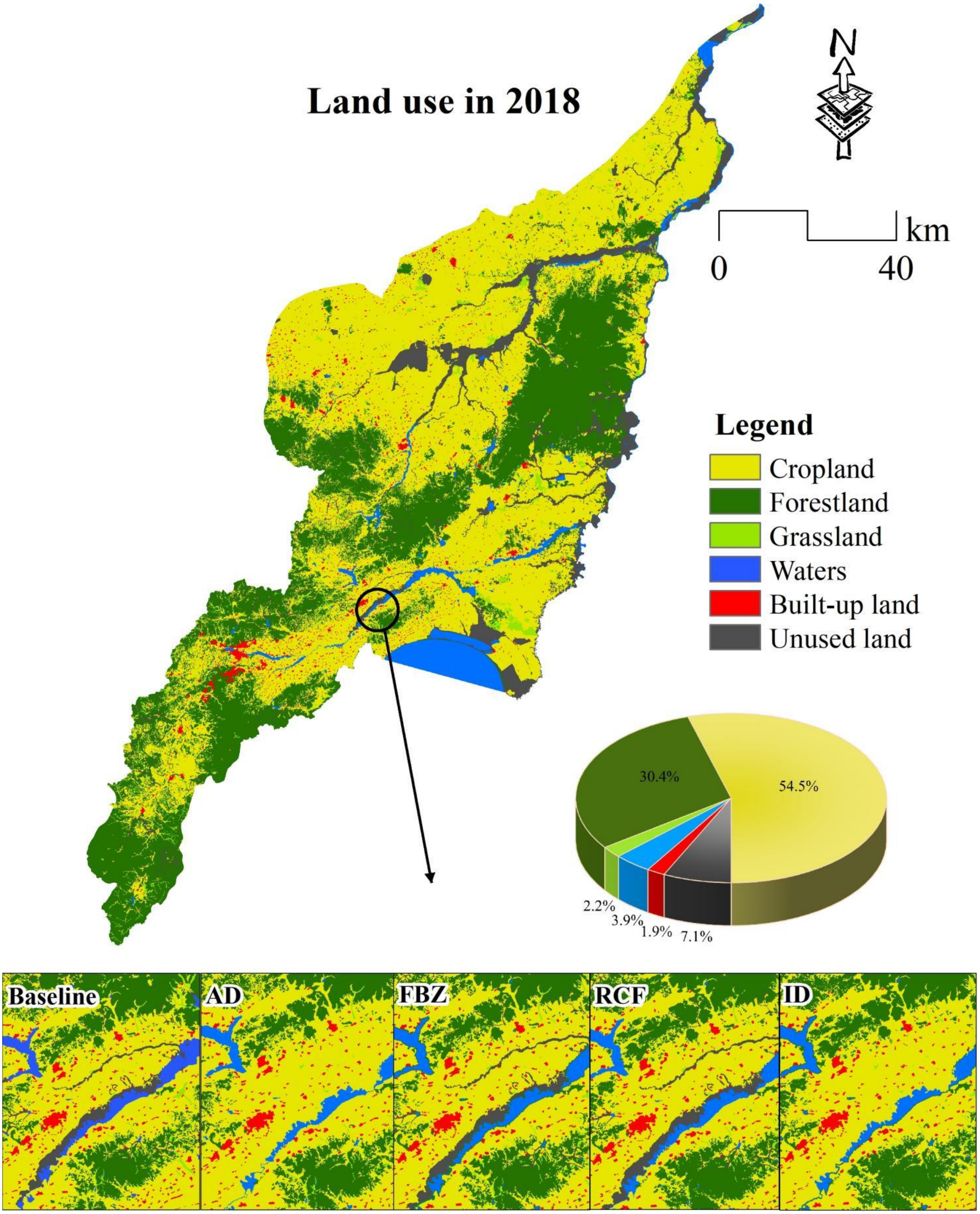

Fig. 2. Spatial distribution of land use types in the URB in 2018 and spatial details under different scenarios. (AD = agricultural development; FBZ = forestland buffer zone; RCF = Returning cropland to forestland; ID = integrated development).

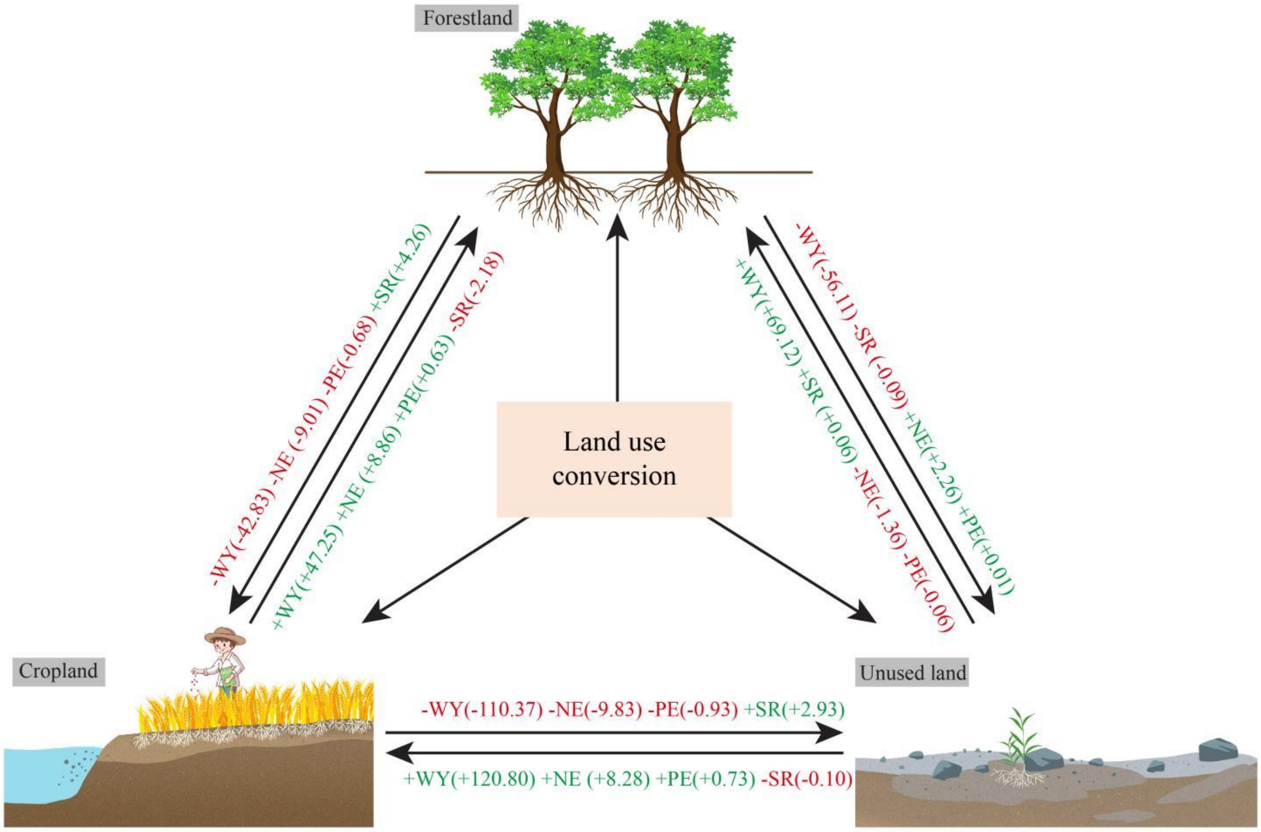

Fig. 3. Impact of three major land use types conversion on WESs from 2000 to 2018. Green color and red color represent the increase and decrease of the WESs, respectively. WY = water yield (mm), NE = nitrogen export (kg), PE = phosphorus export (kg), SR = soil retention (t). Food production is quantified at the watershed scale, whereas land use is quantified at the raster scale, so the impact of land use conversion on food production is not quantified in this study.

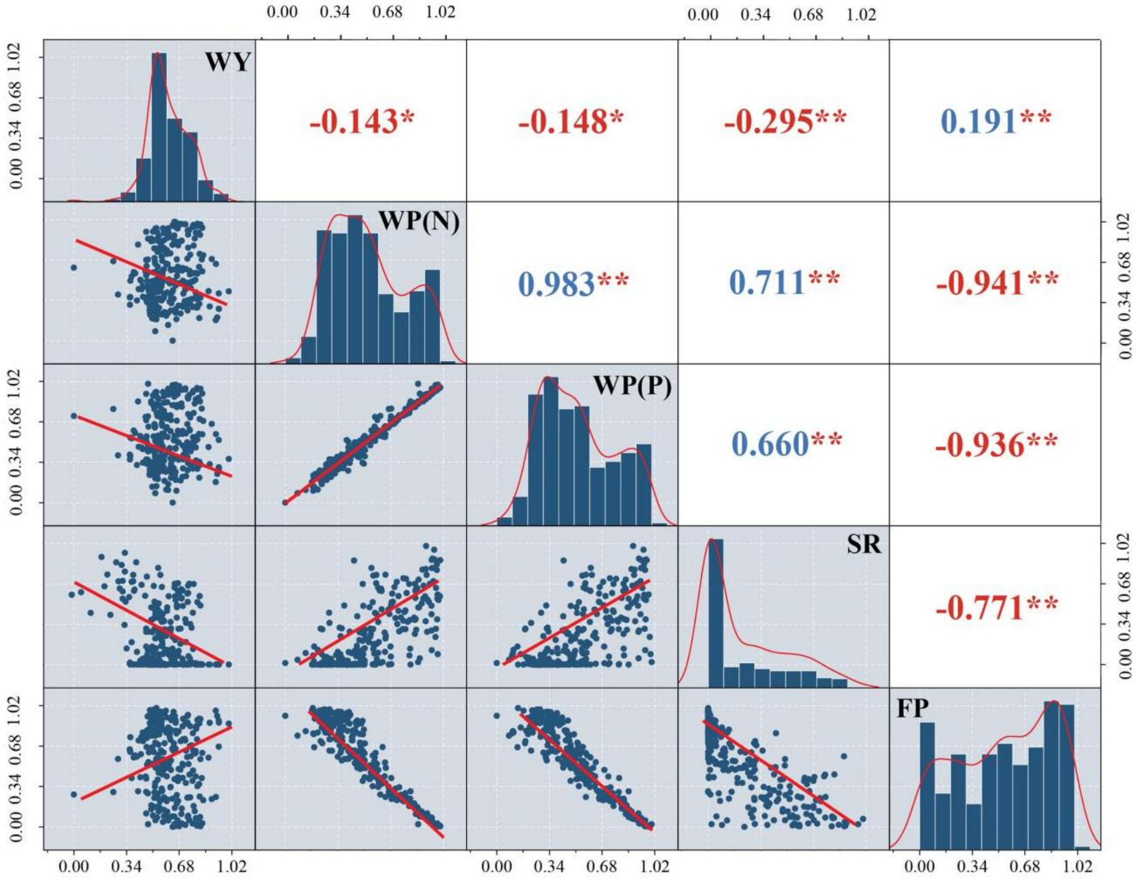

Fig. 4. Spearman correlation between different WESs in 2018. (*Correlation significant at $p < 0.05$, 2-tailed; **Correlation significant at $p < 0.01$, 2-tailed). WY = water yield. WP(N) = water purification (nitrogen). WP(P) = water purification (phosphorus). SR = soil retention. FP = food production. The red and blue values represent trade-offs and synergies between WESs, respectively.

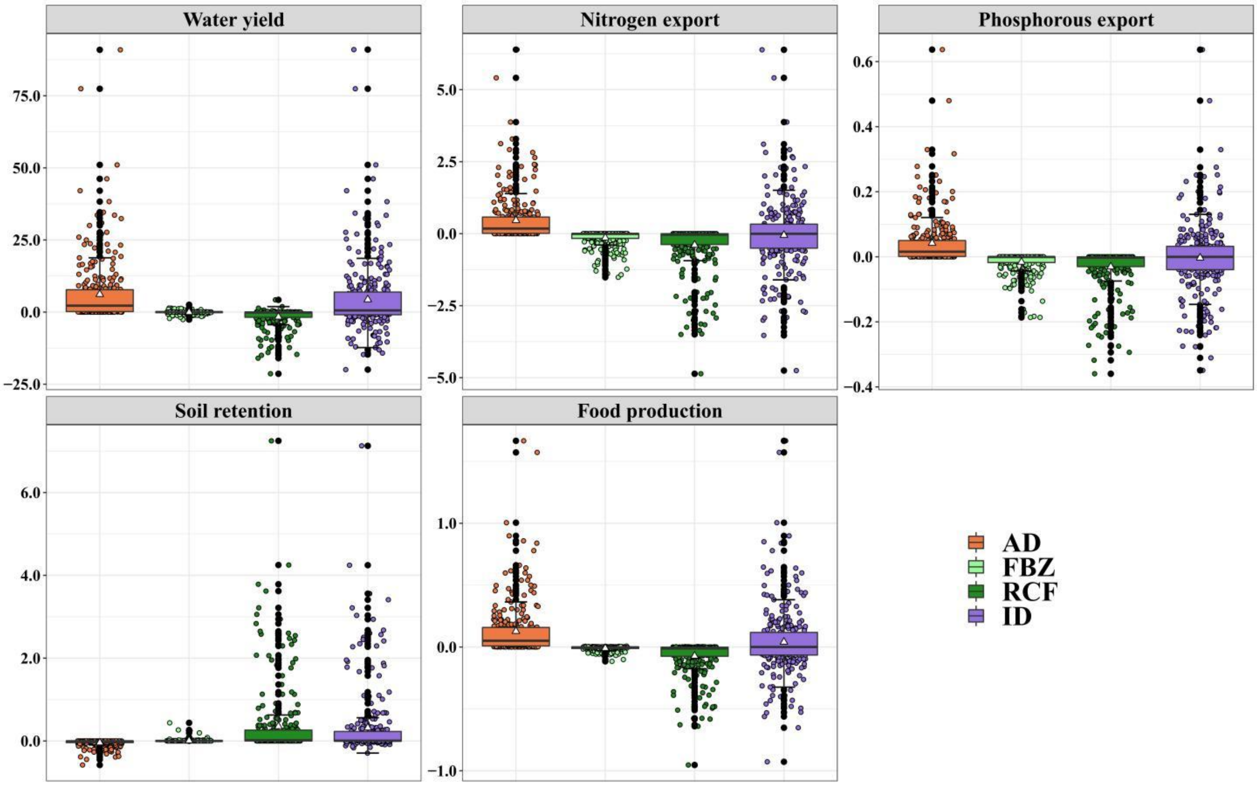

Fig. 5. Changes of WESs in sub-catchment scale under different scenarios. (Relative to baseline scenario. AD = agricultural development; FBZ = forestland buffer zone; RCF = returning cropland to forestland; ID = integrated development).

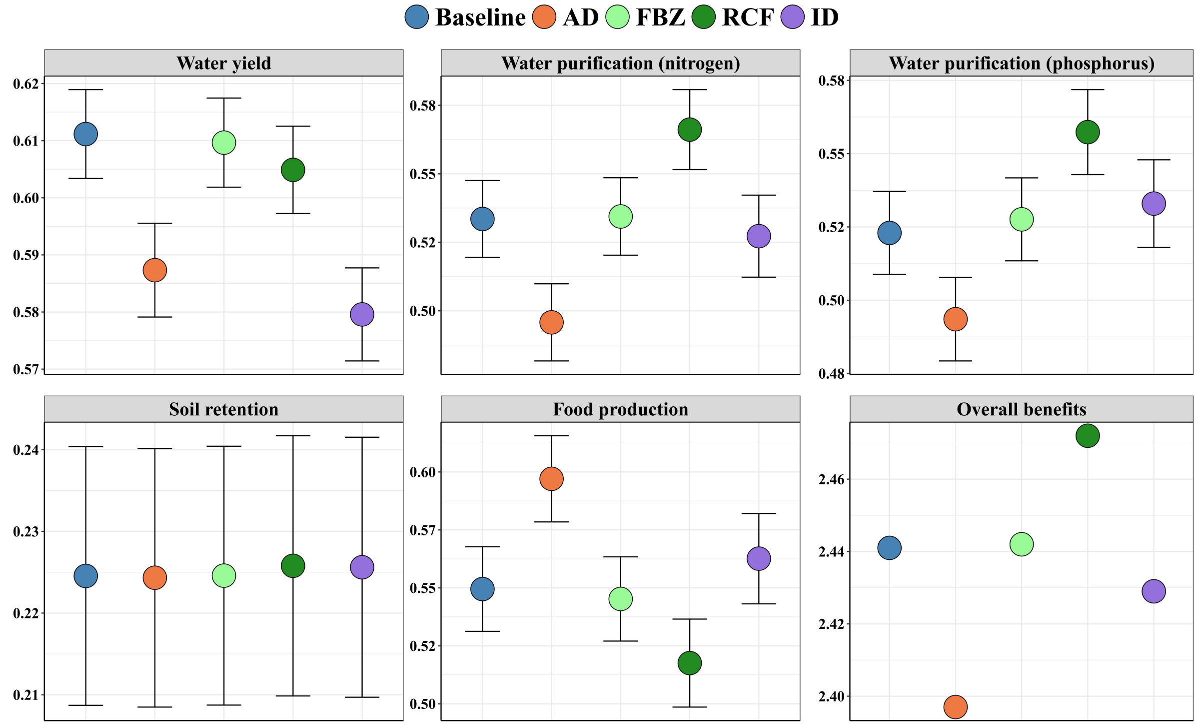

Fig. 6. Benefits for WESs under different scenarios. (AD = agricultural development; FBZ = forestland buffer zone; RCF = returning cropland to forestland; ID = integrated development).

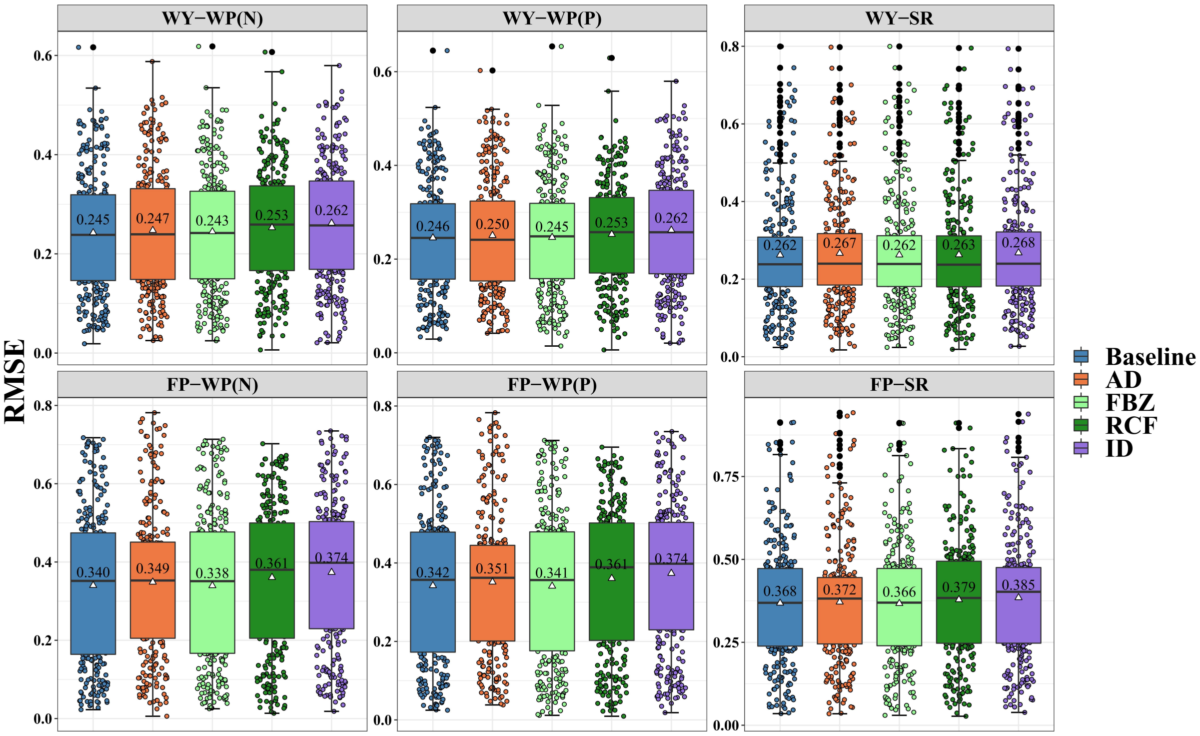

Fig. 7. Variation in RMSE between WESs in different scenarios. The white triangles and the numbers in the boxes represent the mean RMSE values for the different scenarios. (WY = water yield; WP (N) = water purification (nitrogen); WP (P) = water purification (phosphorus); SR = soil retention; FP = food production; AD = agricultural development; FBZ = forestland buffer zone; RCF = returning cropland to forestland; ID = integrated development).