Supplementary Material

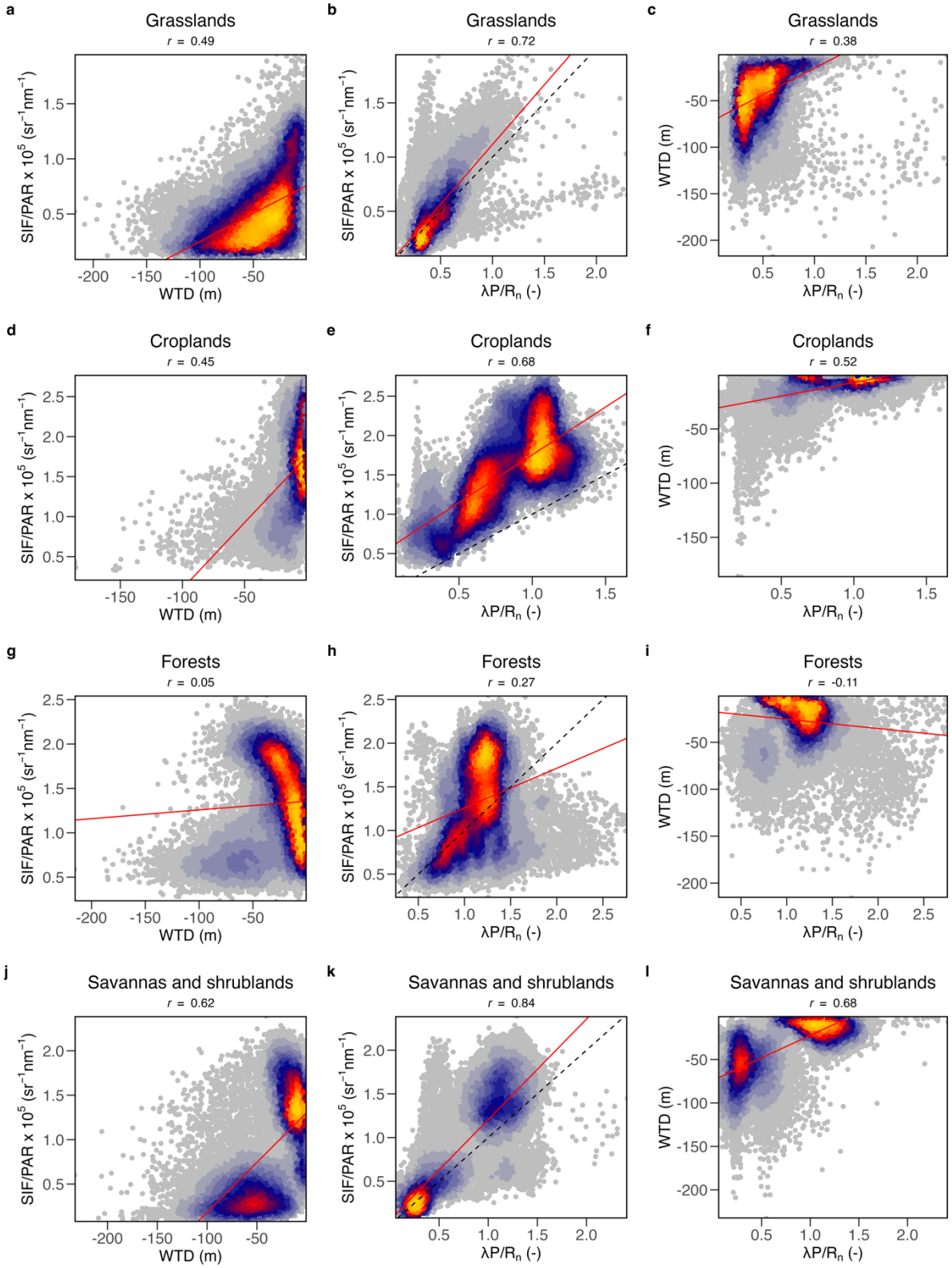
Groundwater rivals aridity in determining global photosynthesis

Francesco Giardina[1,2], Sonia I. Seneviratne[1], Jiangong Liu[2], Benjamin D. Stocker[3,4], Pierre Gentine[2,5]

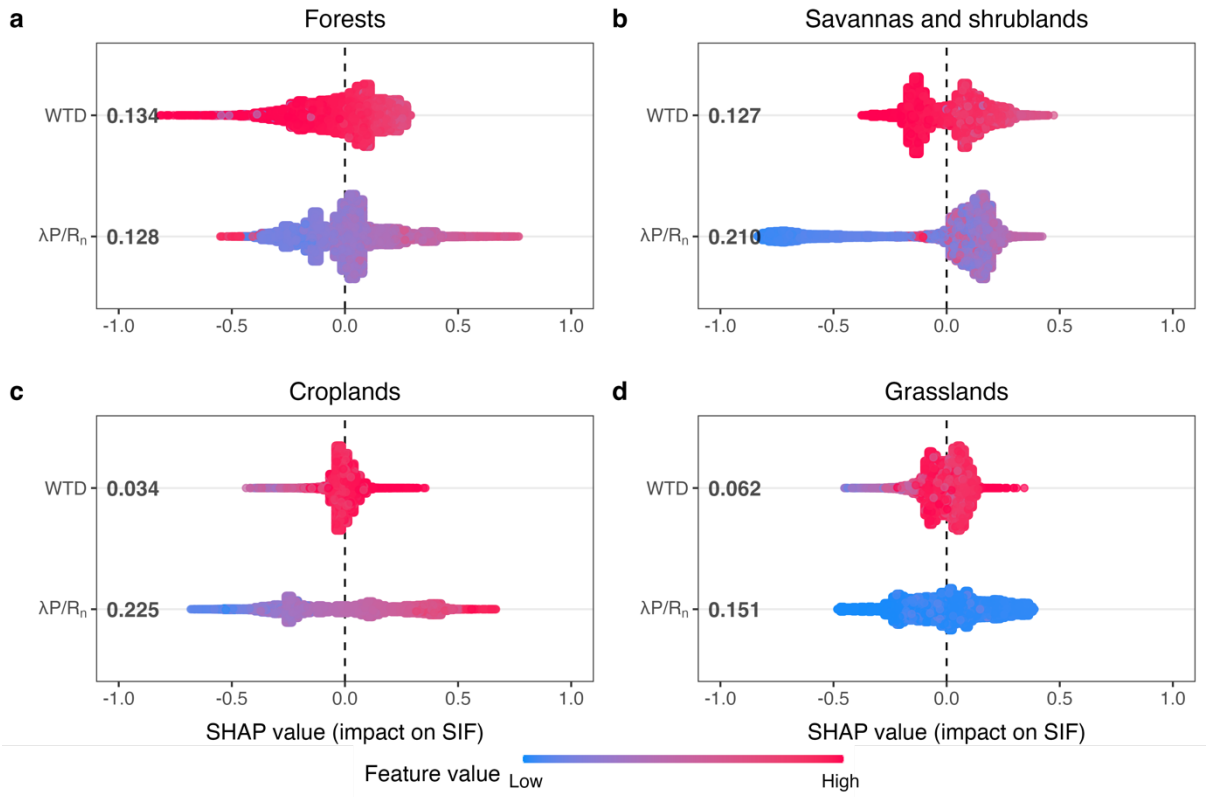
[1]Institute for Atmospheric and Climate Science, Department of Environmental Systems Science, ETH Zurich, CH-8092 Zürich, Switzerland
[2]Department of Earth and Environmental Engineering, Columbia University, New York, New York 10027, USA
[3]Institute of Geography, University of Bern, Hallerstrasse 12, 3012 Bern, Switzerland
[4]Oeschger Centre for Climate Change Research, University of Bern, Falkenplatz 16, 3012 Bern, Switzerland
[5]Center for Learning the Earth with Artificial intelligence and Physics (LEAP), Columbia University, New York, New York 10027, USA

Author for correspondence:
Francesco Giardina
Email: fgiardina@ethz.ch

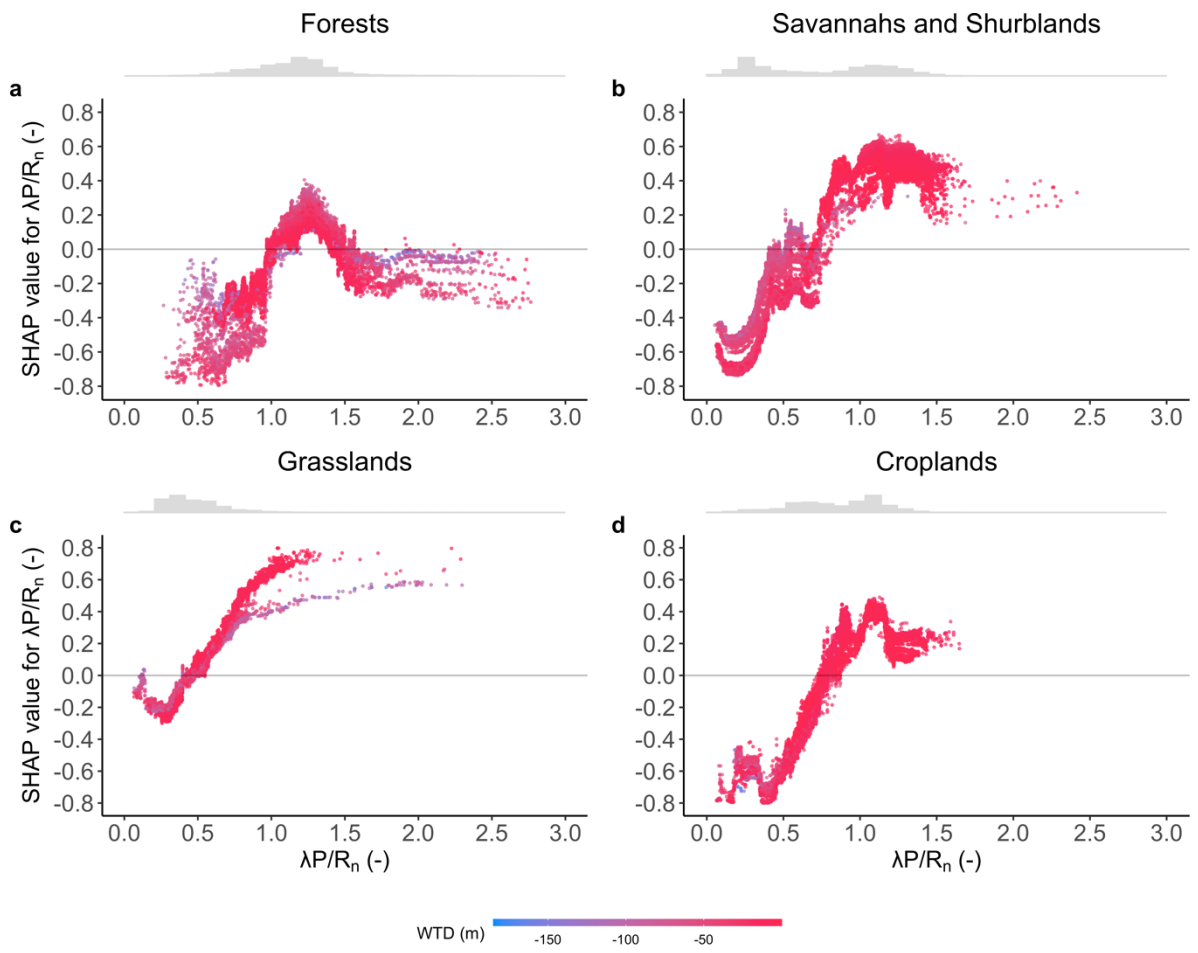
Supplementary Figures



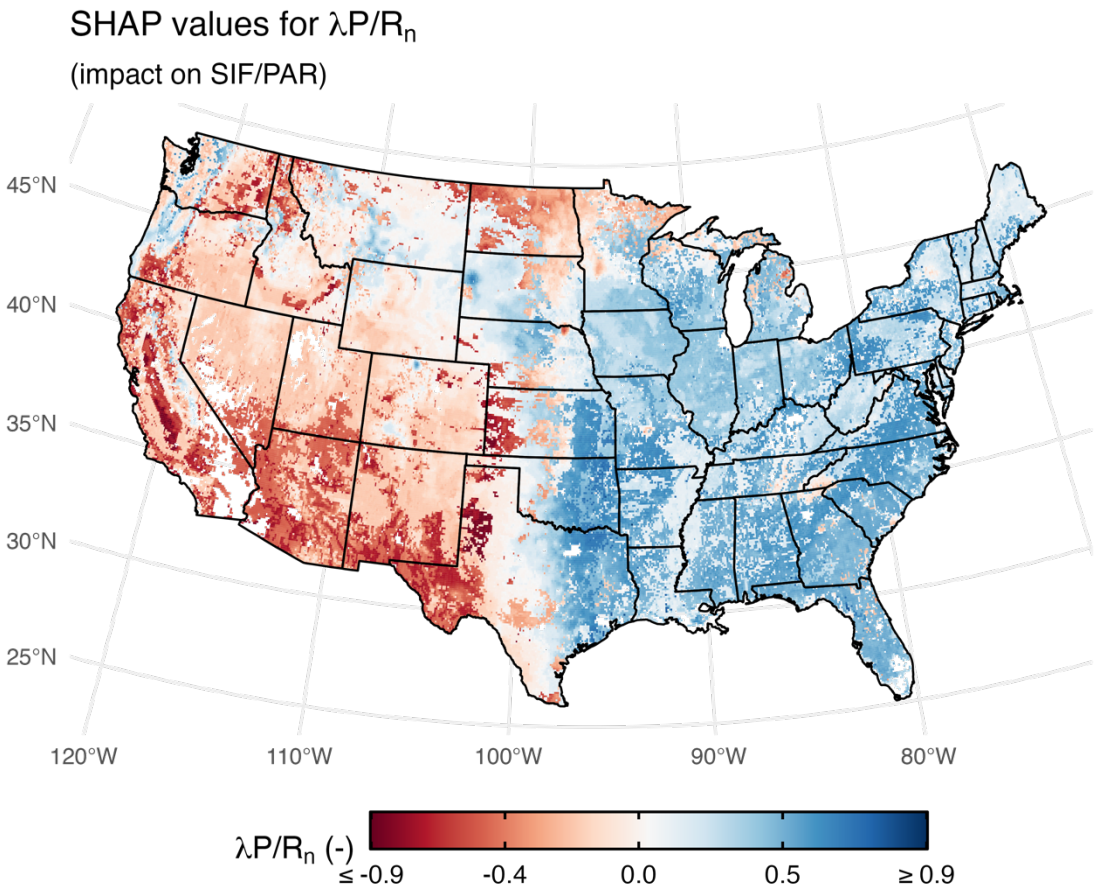
Supplementary Fig. 1 | Pearson correlation coefficients between features and with the target variable in the Extreme Gradient Boosting models for the USA. a-c, Grasslands. **d-f**, Croplands. **g-i**, Forests**. j-l**, Savannahs and shrublands. Red line: linear regression line between modelled and observed data. Dashed black line: y = x line.



Supplementary Fig. 2 | SHAP summary plots using global data. a-d, SHAP summary plots, which show the effect of different predictors on each model outcome. Each dot corresponds to the interannual mean of an individual pixel from global datasets. The average SHAP value, displayed to the left of each plot near the name of each predictor, represents the mean contribution of that predictor. The colour of a dot indicates the magnitude of each predictor at that location. The *x*-axis position of a dot represents the local SHAP value of the predictor, i.e. how a predictor affects the outcome of the model (i.e. SIF/PAR). Overlapping dots at an *x*-coordinate denote higher density, suggesting similar effects across multiple points. WTD: water table depth, P/R_n: moisture index. **a**, Forests (evergreen and deciduous, needle-leaved and broadleaved, and mixed forests). **b**, Savannahs and shrublands (savannahs and woody savannahs, open and closed shrublands). **c**, Croplands. **d**, Grasslands.



Supplementary Fig. 3 | SHAP dependence plots of $\lambda P/R_n$ versus its SHAP value along WTD gradients across plant functional types. SHAP dependence plot show how a specific predictor affects model outcomes while accounting for interaction effects between predictors. Each dot represents the long-term mean of an individual pixel from global datasets. The colour of a dot indicates the magnitude of the moisture index at that location. WTD: water table depth, $\lambda P/R_n$: moisture index. **a**, Forests (evergreen and deciduous, needle-leaved and broadleaved, and mixed forests). **b**, Savannahs and shrublands (savannahs and woody savannahs, open and closed shrublands). **c**, Grasslands. **d**, Croplands. Grey histograms on top of each panel depict marginal density plots for $\lambda P/R_n$.



Supplementary Fig. 4 | Spatial representation of SHAP values for P/R_n across the continental United States. SHAP values illustrate the effect of P/R_n on SIF/PAR. Positive SHAP values suggests that WTD has a positive impact on SIF/PAR (blue points), thus meaning that groundwater is supporting additional photosynthetic activity. Conversely, negative SHAP values indicate that the WTD value has a negative effect on SIF/PAR in that specific pixel (red points).

Supplementary Table 1 | Performance of Extreme Gradient Boosting (XGB) models

Plant functional types	R^2_{train}	R^2_{test}	$RMSE_{train}$	$RMSE_{test}$
USA				
Forests	0.55	0.49	0.32	0.34
Savannahs and shrublands	0.84	0.82	0.24	0.26
Grasslands	0.67	0.64	0.18	0.18
Croplands	0.69	0.66	0.27	0.29
World				
Forests	0.21	0.2	0.48	0.48
Savannahs and shrublands	0.32	0.31	0.47	0.47
Grasslands	0.27	0.27	0.35	0.35
Croplands	0.38	0.36	0.35	0.36