

## Article Supplementary information

**Table S1**

Optimal algorithms for modeling GPP in forest ecosystems with different combinations of temporal scales and indicators.

FLAML	Daily	8-day	16-day	Monthly
FLAML00	extra_tree	extra_tree	extra_tree	extra_tree
FLAML01	extra_tree	extra_tree	extra_tree	extra_tree
FLAML02	extra_tree	extra_tree	extra_tree	extra_tree
FLAML03	extra_tree	extra_tree	xgb_limitdepth	extra_tree
FLAML04	rf	rf	extra_tree	extra_tree
FLAML05	extra_tree	extra_tree	extra_tree	extra_tree
FLAML06	extra_tree	extra_tree	extra_tree	extra_tree
FLAML07	extra_tree	rf	extra_tree	extra_tree
FLAML08	extra_tree	extra_tree	extra_tree	extra_tree
FLAML10	extra_tree	extra_tree	extra_tree	extra_tree
FLAML11	lgbm	extra_tree	extra_tree	extra_tree
FLAML12	extra_tree	extra_tree	extra_tree	extra_tree
FLAML13	extra_tree	extra_tree	extra_tree	extra_tree
FLAML14	lgbm	extra_tree	extra_tree	extra_tree
FLAML15	extra_tree	extra_tree	extra_tree	extra_tree
FLAML16	extra_tree	extra_tree	extra_tree	extra_tree
FLAML17	rf	rf	rf	extra_tree
FLAML18	extra_tree	extra_tree	extra_tree	extra_tree

**Table S2**

R<sup>2</sup>, SD, RMSE for ALF station.

FLAML	R <sup>2</sup>	SD	RMSE	nuRMSE	TSS
FLAML00	0.70	0.934	1.108	0.540	0.9167
FLAML01	0.64	0.939	1.203	0.587	0.9063
FLAML02	0.66	0.957	1.177	0.574	0.9153
FLAML03	0.67	1.051	1.164	0.567	0.9225
FLAML04	0.66	0.989	1.172	0.575	0.9146
FLAML05	0.65	1.077	1.184	0.576	0.9195
FLAML06	0.66	0.940	1.172	0.574	0.9072
FLAML07	0.65	0.930	1.199	0.586	0.9005
FLAML08	0.66	0.972	1.177	0.576	0.9117
FLAML10	0.66	0.973	1.167	0.570	0.9146
FLAML11	0.64	0.948	1.219	0.598	0.9001
FLAML12	0.59	1.042	1.296	0.635	0.9046
FLAML13	0.63	1.057	1.223	0.597	0.9121
FLAML14	0.59	1.066	1.295	0.637	0.8896
FLAML15	0.56	1.114	1.350	0.663	0.8972
FLAML16	0.64	0.982	1.219	0.596	0.9096
FLAML17	0.62	0.982	1.248	0.612	0.9051
FLAML18	0.57	1.034	1.333	0.654	0.9014
Flux(average)	0.66	0.976	1.173	0.573	
ERA5(average)	0.61	1.022	1.261	0.618	
Forest(average)	0.64	0.999	1.217	0.595	

**Table S3**R<sup>2</sup>, SD, RMSE for CBF station.

FLAML	R <sup>2</sup>	SD	RMSE	nuRMSE	TSS
FLAML00	0.94	0.827	1.073	0.249	0.9533
FLAML01	0.92	0.779	1.226	0.285	0.9296
FLAML02	0.92	0.781	1.211	0.281	0.9302
FLAML03	0.92	0.833	1.162	0.269	0.9456
FLAML04	0.92	0.852	1.174	0.273	0.9525
FLAML05	0.92	0.799	1.210	0.281	0.9359
FLAML06	0.94	0.845	1.062	0.246	0.9560
FLAML07	0.93	0.844	1.124	0.261	0.9547
FLAML08	0.93	0.819	1.135	0.263	0.9480
FLAML10	0.94	0.846	1.041	0.241	0.9591
FLAML11	0.92	0.808	1.181	0.274	0.9425
FLAML12	0.92	0.788	1.174	0.273	0.9333
FLAML13	0.93	0.803	1.135	0.263	0.9416
FLAML14	0.92	0.807	1.180	0.274	0.9413
FLAML15	0.92	0.781	1.217	0.282	0.9263
FLAML16	0.93	0.821	1.121	0.260	0.9467
FLAML17	0.94	0.938	1.031	0.239	0.9819
FLAML18	0.93	0.817	1.149	0.267	0.9458
Flux(average)	0.93	0.820	1.153	0.268	
ERA5(average)	0.93	0.823	1.137	0.264	
Forest(average)	0.93	0.822	1.145	0.266	

**Table S4**R<sup>2</sup>, SD, RMSE for QYF station.

FLAML	R <sup>2</sup>	SD	RMSE	nuRMSE	TSS
FLAML00	0.91	0.917	0.676	0.297	0.9705
FLAML01	0.93	0.927	0.617	0.270	0.9754
FLAML02	0.92	0.937	0.655	0.287	0.9739
FLAML03	0.90	0.918	0.697	0.307	0.9691
FLAML04	0.93	0.932	0.609	0.266	0.9771
FLAML05	0.92	0.931	0.653	0.286	0.9741
FLAML06	0.90	0.910	0.698	0.307	0.9682
FLAML07	0.92	0.926	0.636	0.279	0.9751
FLAML08	0.91	0.938	0.673	0.296	0.9737
FLAML10	0.89	0.925	0.731	0.319	0.9676
FLAML11	0.90	0.923	0.720	0.314	0.9681
FLAML12	0.90	0.938	0.730	0.320	0.9695
FLAML13	0.89	0.918	0.734	0.321	0.9666
FLAML14	0.90	0.928	0.693	0.301	0.9710
FLAML15	0.90	0.928	0.722	0.316	0.9693
FLAML16	0.89	0.920	0.746	0.326	0.9658
FLAML17	0.91	0.939	0.678	0.296	0.9742
FLAML18	0.90	0.942	0.720	0.315	0.9708
Flux(average)	0.92	0.926	0.657	0.288	
ERA5(average)	0.90	0.929	0.719	0.314	
Forest(average)	0.91	0.928	0.688	0.301	

**Table S5**

Annual Observed GPP for forest stations.

FLAML	ALF	BNF	CBF	DHF	HZF	MEF	QYF
2003		2465.49	1454.80	1460.63			1704.82
2004		2598.21	1376.82	1418.54			1882.95
2005		2550.77	1192.84	1254.00			1646.81
2006		2535.49	1642.28	1460.02			1843.38
2007		2610.95	1567.89	1552.94			1847.33
2008		2415.08	1518.81	1387.86			1756.77
2009	2113.10	2146.42	1622.47	1354.39			1852.84
2010	2204.39	2243.15	1331.03	1422.73			1926.25
2011	2231.40	2826.87					
2012	2087.80	2664.65					
2013	1888.94	2860.98					
2014		2405.34			764.73		
2015		2548.65			831.30		
2016					858.41	1413.72	
2017					824.89	1466.58	
2018					845.04	1421.83	
Average	2105.12	2528.62	1463.37	1413.89	824.87	1434.04	1807.64

**Table S6**

Optimal algorithms for modeling GPP in grass ecosystems with different combinations of temporal resolution and indicators.

FLAML	Daily	8-day	16-day	Monthly
FLAML00	extra_tree	extra_tree	extra_tree	extra_tree
FLAML01	extra_tree	extra_tree	extra_tree	extra_tree
FLAML02	extra_tree	extra_tree	extra_tree	xgboost
FLAML03	extra_tree	extra_tree	extra_tree	extra_tree
FLAML04	xgboost	extra_tree	extra_tree	extra_tree
FLAML05	extra_tree	extra_tree	extra_tree	extra_tree
FLAML06	extra_tree	extra_tree	rf	rf
FLAML07	lgbm	xgboost	lgbm	extra_tree
FLAML08	extra_tree	rf	lgbm	rf
FLAML10	extra_tree	extra_tree	extra_tree	extra_tree
FLAML11	lgbm	extra_tree	extra_tree	extra_tree
FLAML12	extra_tree	extra_tree	extra_tree	extra_tree
FLAML13	extra_tree	extra_tree	rf	extra_tree
FLAML14	extra_tree	extra_tree	extra_tree	extra_tree
FLAML15	extra_tree	extra_tree	extra_tree	extra_tree
FLAML16	extra_tree	xgboost	rf	extra_tree
FLAML17	extra_tree	lgbm	lgbm	rf
FLAML18	extra_tree	lgbm	lgbm	rf

**Table S7**R<sup>2</sup>, SD, RMSE for DXG alpine meadows station.

FLAML	R <sup>2</sup>	SD	RMSE	nuRMSE	TSS
FLAML00	0.83	0.865	0.298	0.412	0.9379
FLAML01	0.81	0.880	0.316	0.437	0.9316
FLAML02	0.85	0.907	0.282	0.390	0.9539
FLAML03	0.82	0.921	0.303	0.420	0.9471
FLAML04	0.62	1.077	0.414	0.571	0.9009
FLAML05	0.84	0.957	0.287	0.398	0.9567
FLAML06	0.74	1.049	0.365	0.504	0.9352
FLAML07	0.65	1.101	0.421	0.582	0.9156
FLAML08	0.73	1.125	0.370	0.511	0.9323
FLAML10	0.83	0.866	0.294	0.407	0.9386
FLAML11	0.79	0.864	0.322	0.446	0.9221
FLAML12	0.87	0.906	0.258	0.357	0.9587
FLAML13	0.79	0.935	0.332	0.460	0.9403
FLAML14	0.79	0.912	0.328	0.454	0.9368
FLAML15	0.85	0.952	0.278	0.385	0.9588
FLAML16	0.75	1.011	0.355	0.492	0.9395
FLAML17	0.66	1.076	0.418	0.579	0.9185
FLAML18	0.75	1.087	0.360	0.499	0.9389
Flux(average)	0.77	0.987	0.339	0.469	
ERA5(average)	0.79	0.957	0.327	0.453	
Forest(average)	0.78	0.972	0.333	0.461	

**Table S8**R<sup>2</sup>, SD, RMSE for DLG grassland station.

FLAML	R <sup>2</sup>	SD	RMSE	nuRMSE	TSS
FLAML00	0.82	0.824	0.806	0.427	0.9388
FLAML01	0.84	0.853	0.753	0.398	0.9518
FLAML02	0.83	0.826	0.779	0.412	0.9403
FLAML03	0.81	0.825	0.814	0.431	0.9384
FLAML04	0.79	0.809	0.854	0.452	0.9265
FLAML05	0.79	0.793	0.858	0.454	0.9237
FLAML06	0.84	0.856	0.747	0.395	0.9516
FLAML07	0.85	0.880	0.724	0.382	0.9577
FLAML08	0.85	0.870	0.726	0.383	0.9557
FLAML10	0.82	0.832	0.805	0.426	0.9407
FLAML11	0.83	0.840	0.778	0.411	0.9462
FLAML12	0.83	0.830	0.767	0.405	0.9427
FLAML13	0.83	0.845	0.785	0.415	0.9449
FLAML14	0.82	0.834	0.803	0.424	0.9407
FLAML15	0.82	0.812	0.809	0.428	0.9329
FLAML16	0.84	0.864	0.764	0.404	0.9528
FLAML17	0.86	0.880	0.693	0.366	0.9606
FLAML18	0.84	0.855	0.749	0.396	0.9501
Flux(average)	0.83	0.837	0.785	0.415	
ERA5(average)	0.83	0.844	0.773	0.408	
Forest(average)	0.83	0.840	0.779	0.412	

**Table S9**R<sup>2</sup>, SD, RMSE for HBG\_S01 alpine scrub station.

FLAML	R <sup>2</sup>	SD	RMSE	nuRMSE	TSS
FLAML00	0.79	1.038	1.118	0.455	0.9503
FLAML01	0.78	1.065	1.144	0.465	0.9465
FLAML02	0.82	1.014	1.042	0.424	0.9558
FLAML03	0.80	0.999	1.100	0.448	0.9507
FLAML04	0.80	0.996	1.098	0.446	0.9503
FLAML05	0.83	0.976	1.002	0.408	0.9572
FLAML06	0.78	1.068	1.144	0.465	0.9484
FLAML07	0.78	1.096	1.161	0.472	0.9458
FLAML08	0.81	1.062	1.075	0.437	0.9534
FLAML10	0.77	1.057	1.177	0.479	0.9456
FLAML11	0.76	1.082	1.209	0.491	0.9415
FLAML12	0.79	1.060	1.119	0.455	0.9498
FLAML13	0.78	1.017	1.154	0.469	0.9467
FLAML14	0.79	1.029	1.134	0.461	0.9488
FLAML15	0.81	1.010	1.076	0.438	0.9529
FLAML16	0.76	1.084	1.210	0.492	0.9425
FLAML17	0.75	1.110	1.227	0.499	0.9394
FLAML18	0.80	1.059	1.107	0.450	0.9517
Flux(average)	0.80	1.035	1.098	0.447	
ERA5(average)	0.78	1.057	1.157	0.471	
Forest(average)	0.79	1.046	1.128	0.459	

**Table S10**

Annual GPP for grass stations.

FLAML	DLG	DMG	DXG	HBG_G01	HBG_S01	NMG	XLG
2003			222.67		500.05		
2004			172.16		552.49	356.04	
2005			124.36		583.03	93.27	
2006	690.16		188.13		958.56	385.63	282.73
2007	398.08		280.00		1000.05	360.54	464.25
2008	722.04		158.09		1004.61	467.04	574.42
2009	447.64		183.96		1035.98	155.60	321.30
2010	577.13		222.67		1071.99	549.31	337.72
2011	780.13				463.84		611.31
2012	752.98				467.26		754.28
2013	848.84				484.04		838.33
2014	663.70						553.47
2015	713.23	110.40		942.6199			
2016		237.39		940.1182			
2017		146.02		933.3493			
2018		397.67		974.3658			
2019				1028.5			
2020				961.4318			
Average	659.39	222.87	189.91	963.398	738.35	338.20	526.42

**Table S11**

Optimal algorithms for modeling GPP in cropland ecosystems with different combinations of temporal scales and indicators

FLAML	Daily	8-day	16-day	Monthly
FLAML00	extra_tree	extra_tree	extra_tree	extra_tree
FLAML01	extra_tree	extra_tree	extra_tree	extra_tree
FLAML02	extra_tree	extra_tree	extra_tree	rf
FLAML03	extra_tree	extra_tree	extra_tree	extra_tree
FLAML04	extra_tree	extra_tree	extra_tree	extra_tree
FLAML05	extra_tree	extra_tree	rf	extra_tree
FLAML06	extra_tree	extra_tree	extra_tree	extra_tree
FLAML07	extra_tree	extra_tree	extra_tree	extra_tree
FLAML08	extra_tree	extra_tree	extra_tree	extra_tree
FLAML10	extra_tree	extra_tree	extra_tree	extra_tree
FLAML11	extra_tree	extra_tree	lgbm	extra_tree
FLAML12	rf	rf	lgbm	rf
FLAML13	extra_tree	extra_tree	extra_tree	rf
FLAML14	extra_tree	extra_tree	extra_tree	extra_tree
FLAML15	rf	extra_tree	extra_tree	extra_tree
FLAML16	extra_tree	extra_tree	extra_tree	extra_tree
FLAML17	extra_tree	extra_tree	extra_tree	lgbm
FLAML18	rf	extra_tree	xgb_limitdepth	lgbm

**Table S12**

R<sup>2</sup>, SD, RMSE for JZA station (single cropping farmland station).

FLAML	R <sup>2</sup>	SD	RMSE	nuRMSE	TSS
FLAML00	0.88	0.948	1.628	0.348	0.9614
FLAML01	0.87	0.878	1.703	0.365	0.9441
FLAML02	0.88	0.913	1.580	0.338	0.9607
FLAML03	0.86	0.954	1.711	0.367	0.9599
FLAML04	0.86	0.888	1.723	0.369	0.9429
FLAML05	0.87	0.938	1.699	0.364	0.9536
FLAML06	0.85	0.971	1.769	0.379	0.9565
FLAML07	0.87	0.896	1.667	0.356	0.9470
FLAML08	0.86	0.960	1.755	0.376	0.9557
FLAML10	0.85	0.979	1.778	0.382	0.9621
FLAML11	0.86	0.921	1.711	0.366	0.9517
FLAML12	0.87	0.933	1.693	0.363	0.9576
FLAML13	0.84	0.997	1.841	0.396	0.9579
FLAML14	0.86	0.915	1.756	0.376	0.9468
FLAML15	0.86	0.942	1.721	0.369	0.9607
FLAML16	0.85	0.999	1.818	0.390	0.9600
FLAML17	0.85	0.932	1.776	0.380	0.9462
FLAML18	0.87	0.961	1.706	0.365	0.9623
Flux(average)	0.87	0.927	1.693	0.362	
ERA5(average)	0.86	0.953	1.756	0.376	
Forest(average)	0.86	0.940	1.724	0.369	

**Table S13**R<sup>2</sup>, SD, RMSE for YCA station (double cropping farmland station).

FLAML	R <sup>2</sup>	SD	RMSE	nuRMSE	TSS
FLAML00	0.88	0.855	2.082	0.344	0.9468
FLAML01	0.88	0.830	2.089	0.344	0.9405
FLAML02	0.87	0.820	2.183	0.360	0.9318
FLAML03	0.85	0.807	2.328	0.385	0.9208
FLAML04	0.86	0.805	2.303	0.380	0.9239
FLAML05	0.85	0.794	2.343	0.387	0.9166
FLAML06	0.86	0.820	2.285	0.377	0.9286
FLAML07	0.87	0.829	2.190	0.361	0.9368
FLAML08	0.88	0.809	2.140	0.352	0.9306
FLAML10	0.78	0.694	2.825	0.466	0.8404
FLAML11	0.85	0.783	2.358	0.389	0.9120
FLAML12	0.84	0.741	2.458	0.405	0.8864
FLAML13	0.78	0.723	2.863	0.472	0.8575
FLAML14	0.84	0.782	2.442	0.403	0.9080
FLAML15	0.78	0.700	2.809	0.465	0.8433
FLAML16	0.79	0.724	2.739	0.451	0.8636
FLAML17	0.86	0.788	2.287	0.377	0.9164
FLAML18	0.83	0.773	2.466	0.407	0.9035
Flux(average)	0.87	0.819	2.216	0.366	
ERA5(average)	0.82	0.745	2.583	0.426	
Forest(average)	0.84	0.782	2.400	0.396	

**Table S14**

Annual GPP for cropland stations.

Year	GCA	JRA	JZA	LCA	SYA	YCA
2003						1660.44
2004						1608.06
2005			932.05			1851.30
2006			1253.66			2261.62
2007			1198.56			2589.95
2008			1011.93			2105.58
2009			2143.05			2435.54
2010			930.78			2065.19
2011			1101.77			
2012			943.38		1281.01	
2013			995.96	64.56	1443.65	
2014			1361.07	1810.49	1296.93	
2015		2048.21		1563.24		
2016		1659.92		1817.80		
2017		1097.61		2164.50		
2018		1297.92				
2019		3407.58				
2020	2072.08	3245.50				
2021	1817.55					
2022	1870.31					
Average	1919.98	2126.12	1187.22	1484.12	1340.53	2072.21