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SUPPLEMENTARY MATERIAL

Research on an automated mapping method for rice aboveground biomass based on low-altitude remote sensing

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Figure S1. Photos of four sampling experiments. (a), (b), (c), and (d) are 23 July, 30 July, 23 August, and 7 September, respectively.

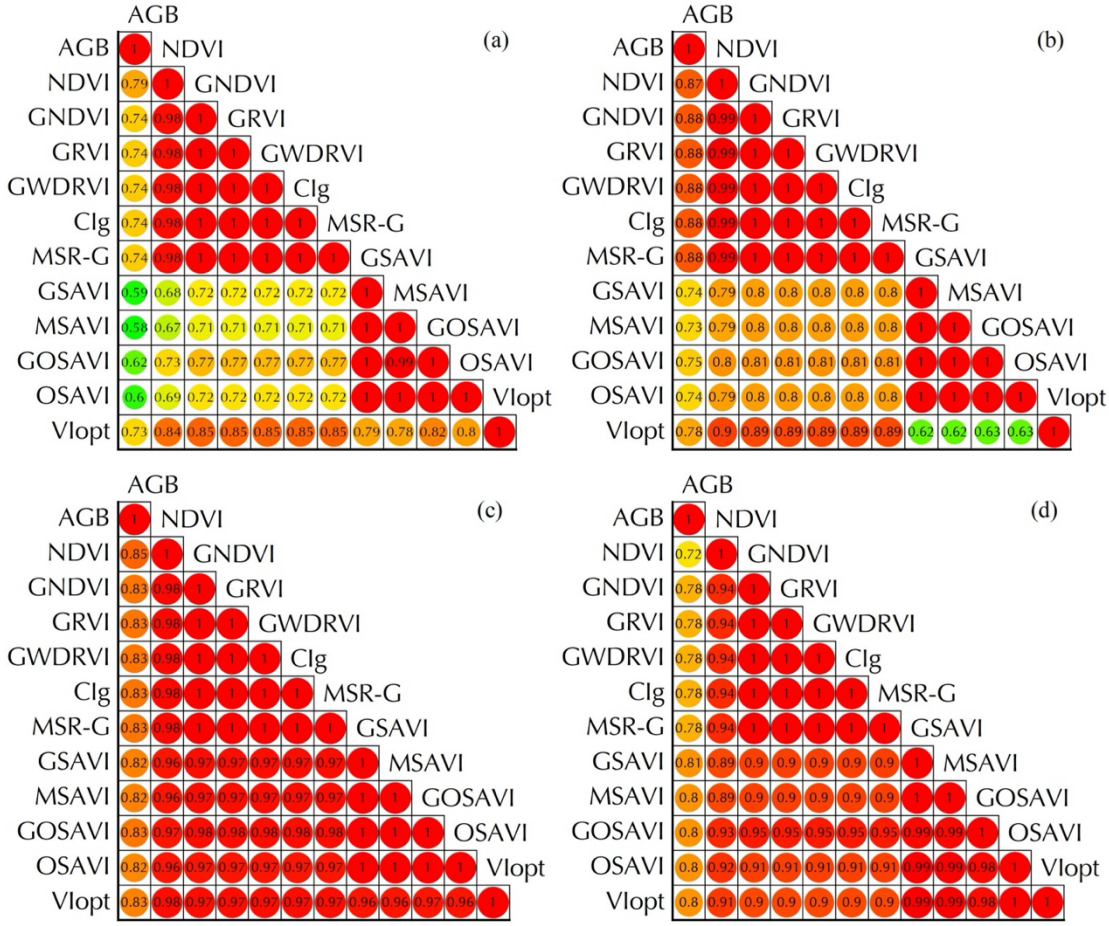

Figure S2. Autocorrelation Matrix Diagrams of Multispectral VIs. Including (a) Seedling Stage, (b) Tillering Stage, (c) Jointing Stage, and (d) Heading Stage.

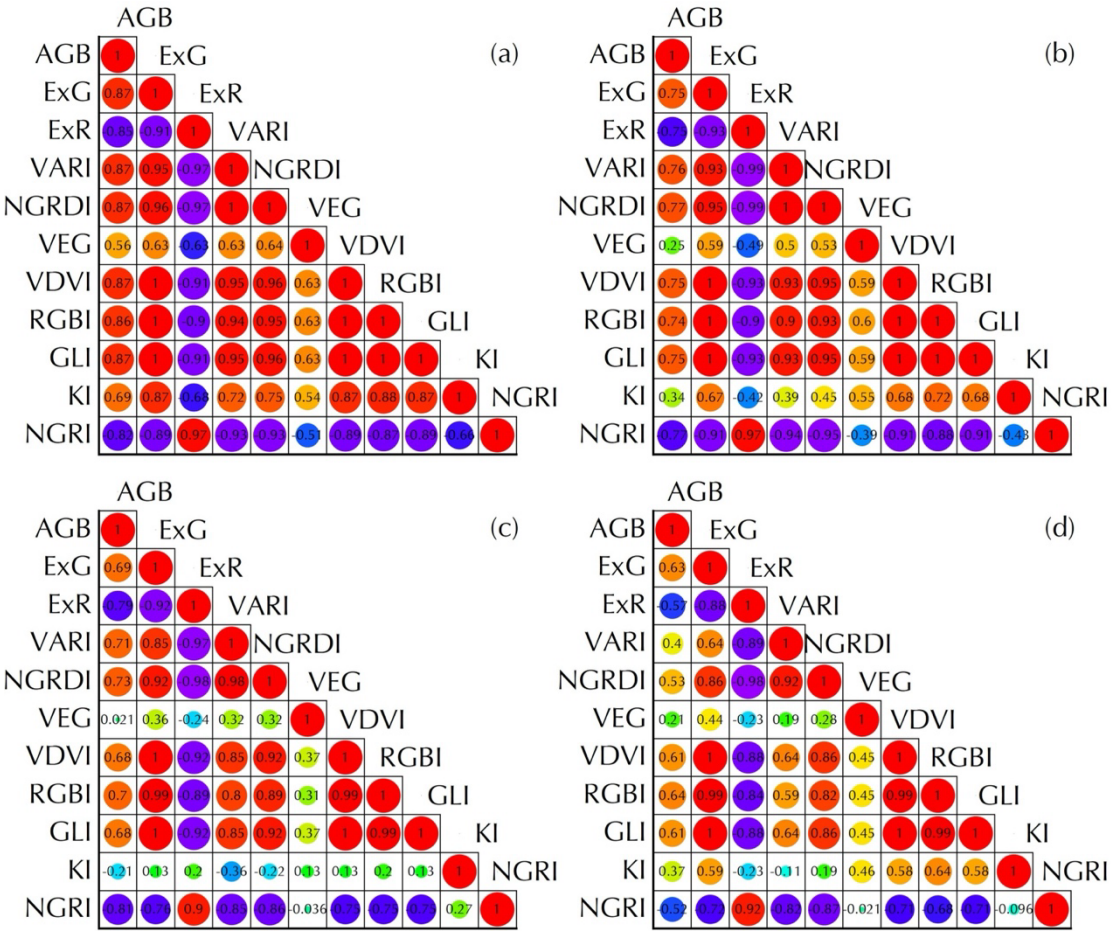

Figure S3. Autocorrelation Matrix Diagrams of RGB VIs. Including (a) Seedling Stage, (b) Tillering Stage, (c) Jointing Stage, and (d) Heading Stage.

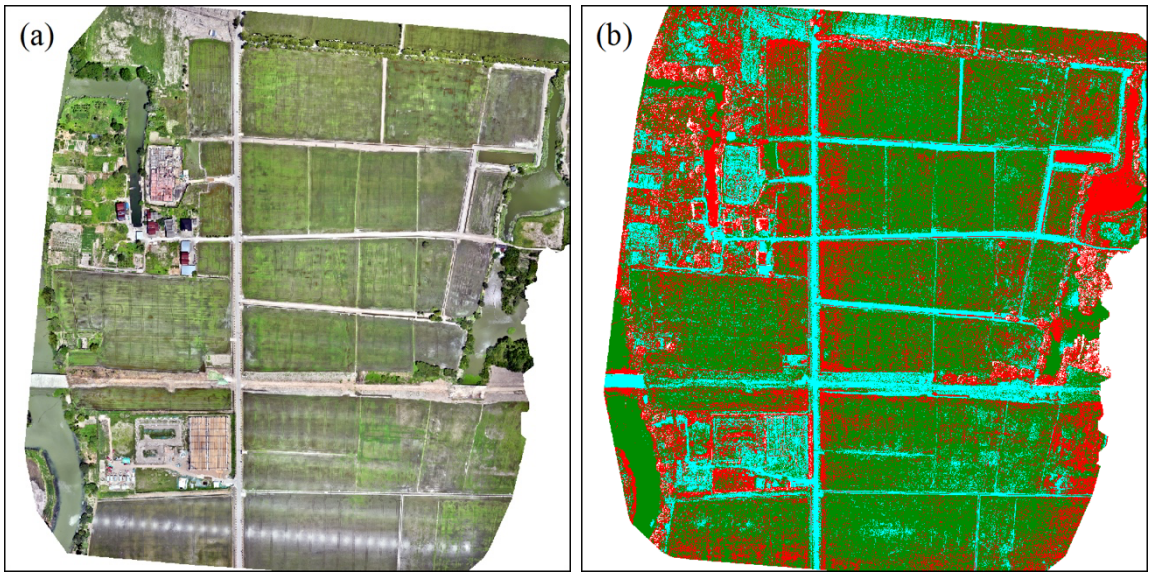

Figure S4. The clustering results based on the K-means method: (a) RGB image; (b) classification result.

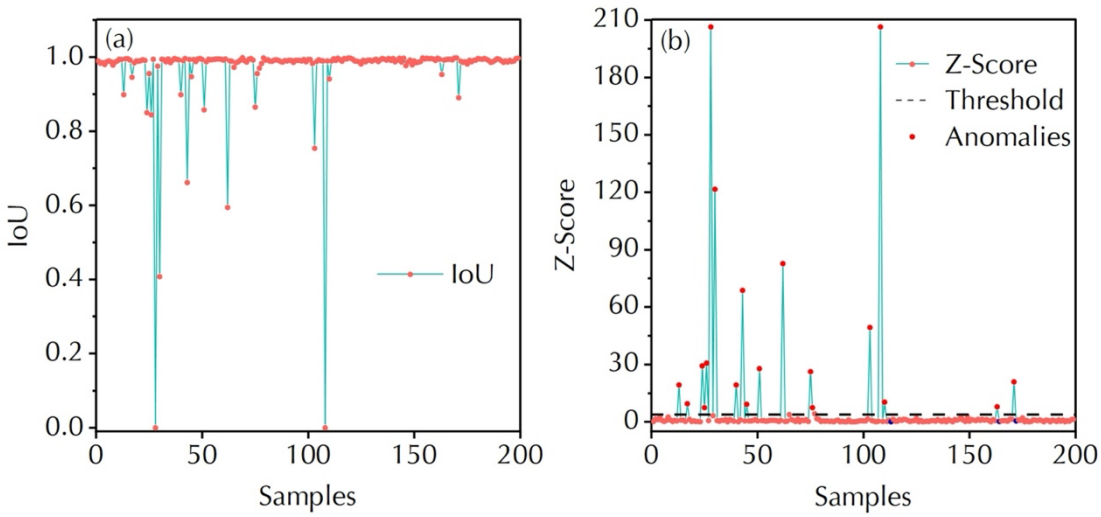

Figure S5. IoU Values and Outlier Detection for Image Segmentation Results. (a) IoU values of segmentation masks for 200 images; (b) outlier detection results based on the IoU values.

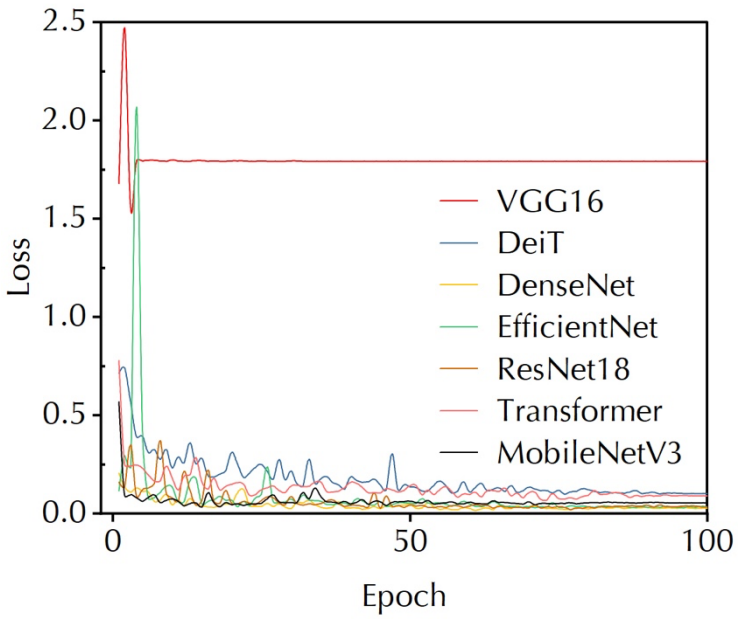

Figure S6. Loss Curves of Classification Models.

Table S1. RGB VIs and calculation method.

VI	Name	Equation
ExG	Excess Green Index	2G - R - B
GBD	Green-Blue Difference	G - B
EXR	Excess Red Index	1.4R - G
VEG	Vegetation Factor	$G / (R^{0.667} + B^{0.333})$
VDVI	Visible-Band Difference vegetation Index	(2G - R - B) / (2G + R + B)
NGD	Normalized Green Difference Index	(G - R) / (G + R)
NGRI	Normalized Green-Red Index	R / G
RGBI	Green-Blue-Red Ratio	G^2 / (R*B)
GLI	Green Leaf Index	(2G - R - B) / (2G + R + B)
KI	Kawashima Index	(R - B) / (R + B)

Table S2. Correlation between multispectral VIs and rice AGB.

Date	Correlation	VI Quantity	Name
Seedling	Monotonic Nonlinearity	29	NDVI, GNDVI, GRVI, GWDRVI, CIg, MSR-G, GSAVI, MSAVI, GOSAVI, GRDVI, MEVI, RDVI, WDRVI, SAVI, OSAVI, TNDVI, MSR, VIopt, NLI, MNLI, RVI, REDVI, RESAVI, REOSAVI, MRESAVI, RENDVI, RESR, MTCI, MRESR
	Complex Nonlinearity	2	NNIR, NDRE
	No Significant Association	19	DVI, EVI, GDVI, NGI, NREI, MDD, MNDI, MNDRE, MCARI
Tillering	Monotonic Nonlinearity	43	NDVI, DVI, EVI, GNDVI, GRVI, GDVI, GWDRVI, CIg, MSR-G, GSAVI, MSAVI, GOSAVI, GRDVI, NNIR, MEVI, MCARI, RDVI, WDRVI, SAVI, OSAVI, TNDVI, MSR, VIopt, MTCI, NLI, MNLI, RVI, NDRE, RERVI, REDVI, RERDVI, REWDVI, RESAVI, REOSAVI, MRESAVI, REVIopt, CIre, MSR-RE, RENDVI, RESR, DATT, MRESR, RETVI
	Complex Nonlinearity	0	
	No Significant Association	7	NGI, NREI, MDD, MNDI, MNDRE, MREDVI, NRI
Jointing	Monotonic Nonlinearity	45	NDVI, DVI, EVI, GNDVI, GRVI, GDVI, GWDRVI, CIg, MSR-G, GSAVI, MSAVI, GOSAVI, GRDVI, NNIR, MDD, MNDI, MEVI, MCARI, RDVI, WDRVI, SAVI, OSAVI, TNDVI, MSR, VIopt, MTCI, NLI, MNLI, RVI, NDRE, RERVI, REDVI, RERDVI, REWDVI, RESAVI, REOSAVI, MRESAVI, REVIopt, CIre, MSR-RE, RENDVI, RESR, DATT, MRESR, RETVI
	Complex Nonlinearity	0	
	No Significant Association	5	NGI, NREI, MNDRE, MREDVI, NRI
Heading	Monotonic Nonlinearity	14	NDVI, EVI, GNDVI, GRVI, GDVI, GWDRVI, CIg, MSR-G, GSAVI, MSAVI, GOSAVI, GRDVI, OSAVI, VIopt
	Complex Nonlinearity	3	RENDVI, RESR, MREDVI
	No Significant Association	33	DVI, NGI, NREI, NNIR, MDD, MNDI, MEVI, MNDRE, MCARI, RDVI, WDRVI, SAVI, TNDVI, MSR, MTCI, NLI, MNLI, RVI, NDRE, RERVI, REDVI, RERDVI, REWDVI, RESAVI, REOSAVI, MRESAVI, REVIopt, CIre, MSR-RE, DATT, NRI, MRESR, RETVI

Table S3. Multispectral VIs and calculation method.

VI	Name	Equation
NDVI	Normalized Difference Vegetation Index	$\frac{(\rho_{NIR}-\rho_R)}{(\rho_{NIR}+\rho_R)}$
GNDVI	Green Normalized Difference Vegetation Index	$\frac{(\rho_{NIR}-\rho_G)}{(\rho_{NIR}+\rho_G)}$
CIg	Green Chlorophyll Index	$\frac{\rho_{NIR}}{\rho_G}-1$
MSR-G	Modified Green Simple Ratio	$\frac{\left(\frac{\rho_{NIR}}{\rho_G}-1\right)}{\sqrt{\left(\frac{\rho_{NIR}}{\rho_G}+1\right)}}$
GSAVI	Green Soil Adjusted Vegetation Index	$\frac{1.5*(\rho_{NIR}-\rho_G)}{\rho_{NIR}+\rho_G+0.5}$
GRVI	Green Ratio Vegetation Index	$\frac{\rho_{NIR}}{\rho_G}$
GWDRVI	Green Wide Dynamic Range Vegetation Index	$\frac{(a*\rho_{NIR}-\rho_G)}{(a*\rho_{NIR}+\rho_G)}$ (a=0.12)
MSAVI	Modified Soil-adjusted Vegetation Index	$\frac{2*\rho_{NIR}+1-\sqrt{(2*\rho_{NIR}+1)^2-8*(\rho_{NIR}-\rho_R)}}{2}$
GOSAVI	Green Optimized Soil Adjusted Vegetation Index	$\frac{(1+0.16)(\rho_{NIR}-\rho_G)}{\rho_{NIR}+\rho_G+0.16}$
OSAVI	Optimized Soil Adjusted Vegetation Index	$\frac{(1+0.16)(\rho_{NIR}-\rho_R)}{\rho_{NIR}+\rho_R+0.16}$
VIopt	Optimal Vegetation Index	$\frac{1.45*(\rho_{NIR}+1)}{\rho_R+0.45}$

Table S4. Test set accuracy statistics of different models for AGB estimation. The table shows the mean and StD of 100 runs, with the dataset redivided in each iteration.

Period	Model	RMSE		R^2		RPD		RPIQ	
		Mean	StD	Mean	StD	Mean	StD	Mean	StD
Seedling	AdaBoost	2.066	0.446	0.709	0.126	1.984	0.432	2.751	0.796
	BayesianRidge	1.847	0.321	0.776	0.062	2.171	0.299	3.024	0.783
	ElasticNet	1.828	0.306	0.780	0.060	2.192	0.304	3.058	0.810
	ExtraTrees	1.778	0.336	0.792	0.058	2.276	0.416	3.156	0.832
	GPR	1.966	0.342	0.744	0.075	2.044	0.315	2.837	0.721
	GBR	2.041	0.361	0.718	0.106	1.977	0.352	2.743	0.741
	Huber	1.987	0.364	0.735	0.100	2.027	0.330	2.825	0.793
	KRR	2.270	0.551	0.664	0.112	1.814	0.373	2.509	0.667
	KNN	2.019	0.374	0.728	0.094	2.006	0.378	2.789	0.788
	Lasso	1.834	0.307	0.778	0.063	2.186	0.317	3.052	0.830
	LR	1.931	0.337	0.748	0.092	2.086	0.358	2.921	0.897
	MLR	2.107	1.006	0.663	0.377	2.127	0.706	2.953	1.214
	PLS	1.791	0.306	0.786	0.071	2.242	0.354	3.126	0.899
	RF	1.835	0.343	0.775	0.078	2.205	0.398	3.059	0.818
	Ridge	1.802	0.311	0.785	0.063	2.225	0.316	3.099	0.815
	SGDR	1.865	0.321	0.770	0.066	2.149	0.300	2.994	0.783
	SVR	1.949	0.322	0.750	0.067	2.052	0.274	2.855	0.717
	Theil-Sen	1.905	0.283	0.755	0.085	2.103	0.336	2.953	0.894
	XGBoost	2.070	0.387	0.713	0.105	1.954	0.350	2.706	0.723
Tillering	AdaBoost	3.416	0.889	0.681	0.193	1.944	0.460	2.204	0.935
	BayesianRidge	3.402	1.069	0.682	0.242	1.968	0.468	2.244	0.972
	ElasticNet	3.322	1.108	0.695	0.252	2.028	0.505	2.308	1.008
	ExtraTrees	2.934	0.634	0.773	0.092	2.232	0.486	2.538	1.070
	GPR	3.589	0.738	0.657	0.146	1.822	0.402	2.104	0.933
	GBR	3.478	0.817	0.673	0.175	1.893	0.411	2.141	0.883
	Huber	3.159	0.945	0.726	0.194	2.119	0.540	2.400	1.034
	KRR	3.899	1.026	0.602	0.172	1.723	0.475	1.924	0.826
	KNN	3.802	0.839	0.609	0.187	1.737	0.449	1.999	0.924
	Lasso	3.257	1.126	0.706	0.259	2.071	0.515	2.353	1.026
	LR	3.507	1.014	0.668	0.214	1.900	0.457	2.156	0.928
	MLR	4.058	1.714	0.526	0.432	1.766	0.608	1.987	0.997
	PLS	3.414	1.036	0.684	0.221	1.963	0.495	2.222	0.962
	RF	3.107	0.691	0.741	0.126	2.113	0.462	2.404	1.010
	Ridge	3.357	1.134	0.688	0.264	2.011	0.520	2.284	1.004
	SGDR	3.414	1.218	0.671	0.304	1.987	0.517	2.259	0.998
	SVR	3.234	1.212	0.701	0.284	2.125	0.601	2.402	1.080
	Theil-Sen	4.358	1.976	0.438	0.549	1.681	0.618	1.878	0.955
	XGBoost	3.255	0.722	0.717	0.132	2.023	0.475	2.292	1.008
Jointing	AdaBoost	11.995	2.011	0.516	0.156	1.488	0.224	2.089	0.540
	BayesianRidge	11.261	2.008	0.578	0.123	1.588	0.230	2.240	0.627

	ElasticNet	11.838	2.059	0.529	0.157	1.512	0.236	2.131	0.597
	ExtraTrees	10.868	2.636	0.597	0.135	1.651	0.318	2.214	0.692
	GPR	11.795	1.842	0.535	0.142	1.507	0.192	2.119	0.535
	GBR	12.153	2.081	0.500	0.182	1.473	0.236	2.054	0.492
	Huber	12.814	2.623	0.443	0.310	1.405	0.221	1.957	0.468
	KRR	16.809	4.127	0.047	0.392	1.092	0.234	1.532	0.458
	KNN	12.499	2.313	0.477	0.188	1.433	0.210	2.015	0.543
	Lasso	12.132	2.077	0.500	0.201	1.475	0.229	2.073	0.556
	LR	13.280	2.348	0.392	0.297	1.351	0.228	1.887	0.467
	MLR	14.120	3.745	0.305	0.362	1.319	0.336	1.846	0.615
	PLS	13.127	2.284	0.407	0.295	1.364	0.218	1.908	0.472
	RF	11.368	1.901	0.566	0.147	1.568	0.215	2.199	0.551
	Ridge	12.074	2.109	0.508	0.174	1.483	0.234	2.090	0.583
	SGDR	12.210	2.155	0.496	0.179	1.468	0.236	2.068	0.580
	SVR	11.381	2.268	0.575	0.111	1.577	0.225	2.228	0.644
	Theil-Sen	14.034	2.256	0.312	0.345	1.277	0.226	1.789	0.467
	XGBoost	12.216	2.186	0.497	0.170	1.467	0.237	2.054	0.530
Heading	AdaBoost	16.352	2.737	0.302	0.274	1.251	0.205	1.967	0.496
	BayesianRidge	15.213	2.194	0.407	0.166	1.332	0.166	2.094	0.494
	ElasticNet	16.380	2.548	0.305	0.231	1.243	0.184	1.954	0.497
	ExtraTrees	15.132	2.297	0.417	0.155	1.340	0.158	2.107	0.480
	GPR	19.526	2.598	0.044	0.145	1.031	0.074	1.617	0.326
	GBR	17.394	2.757	0.212	0.292	1.174	0.194	1.846	0.464
	Huber	20.866	5.663	-0.227	0.822	1.027	0.287	1.617	0.571
	KRR	21.096	4.758	-0.134	0.399	0.984	0.176	1.537	0.370
	KNN	21.381	2.888	-0.164	0.267	0.945	0.107	1.482	0.325
	Lasso	17.997	3.678	0.142	0.388	1.146	0.213	1.803	0.508
	LR	20.907	5.738	-0.227	0.831	1.021	0.271	1.608	0.547
	MLR	21.570	5.097	-0.249	0.601	0.977	0.249	1.534	0.490
	PLS	20.224	5.006	-0.117	0.662	1.038	0.236	1.636	0.515
	RF	15.983	2.556	0.342	0.218	1.274	0.183	2.006	0.490
	Ridge	16.815	2.811	0.265	0.261	1.214	0.192	1.909	0.499
	SGDR	17.207	3.107	0.226	0.301	1.191	0.200	1.873	0.505
	SVR	15.782	2.763	0.371	0.162	1.290	0.156	2.020	0.438
	Theil-Sen	20.762	4.842	-0.190	0.685	1.017	0.262	1.609	0.560
	XGBoost	17.482	2.885	0.210	0.271	1.169	0.188	1.838	0.466