Supplementry Materials

Table S1. Empirical parametric models selected in this study to predict LAI. Model names were primarily identified by VIs and study regions. Here we used acronyms of states or countries to represent the study regions. For the equations using same VIs and regions, we further added the surname of the first author to distinguish the model.

Indices	Study sites	Crops	Empirical models	References	Model names
NDVI	Northeastern China	Corn	$0.051e^{4.5007NDVI}$	[1]	NDVI_CN_Yang
	Nebraska	Corn, soybean	$\frac{\ln\left(\frac{1}{1-\frac{NDVI-0.2064}{0.7298}}\right)}{0.6159}$	[2]	NDVI_Ne_Viña
	Canada	Corn, soybean	$11.266NDVI-4.007$	[3]	NDVI_CA_Kross
gNDVI	Canada	Corn, soybean	$13.96gNDVI-5.465$	[3]	gNDVI_CA_Kross
SR	Canada	Multiple crops	$-1.6\ln\left(\frac{14.5-SR}{13.5}\right)$	[4]	SR_CA_Chen
	Nebraska	Corn, soybean	$\frac{SR-0.5761}{3.788}$	[2]	SR_Ne_Viña
	Nebraska	Corn, soybean	$-0.0008SR^2+0.4SR+0.25$	[5]	SR_Ne_NR
	Canada	Corn, soybean	$-9.296e^{-0.163SR}+6.91$	[3]	SR_CA_Kross
RSR	Canada	Multiple crops	$\frac{RSR}{1.3}$	[4]	RSR_CA_Chen
EVI	Northeastern China	Corn	$5.1213EVI-0.6651$	[1]	EVI_CN_Yang
	Nebraska	Corn, soybean	$\frac{\ln\left(\frac{1}{1-\frac{EVI-0.1408}{0.7512}}\right)}{0.3789}$	[2]	EVI_Ne_Viña
GARVI	Nebraska	Corn, soybean	$\frac{\ln\left(\frac{1}{1-\frac{GARVI-0.3417}{0.5322}}\right)}{0.4727}$	[2]	GARVI_Ne_Viña
WDRVI	Nebraska	Corn, soybean	$\frac{\ln\left(\frac{1}{1-\frac{WDRVI+0.668}{1.4392}}\right)}{0.3418}$	[2]	WDRVI_Ne1_Viña WDRVI_Ne2_Viña
gWDRVI	Nebraska	Corn, soybean	$3WDRVI^2+3.9WDRVI-0.45$	[5]	gWDRVI_Ne_NR
Cl_{green}	Nebraska	Corn, soybean	$\frac{Clgreen-0.991}{1.6769}$	[2]	Cl_{green}_Ne_Viña
	Nebraska	Corn, soybean	$-0.018Clgreen^2+0.74Clgreen-0.54$	[5]	Cl_{green}_Ne_NR

Table S2. Physical-based parametric equations used in this study

Indices	Sites	Crop types	LAI retrieval formulas	References	Model Name
NDVI	Canada	Multiple crops (corn, soybean)	$-\frac{\ln(1.081(1-1.017NDVI))}{0.647}$	[6]	NDVI_CA_Liu
SR	Southern Spain	General dataset	$0.1626SR+0.3274$	[7]	SR_ES1_Liang
		Specific dataset	$0.1698SR+0.222$		SR_ES2_Liang
EVI	Canada	Multiple crops (corn, soybean)	$-\frac{\ln(1.102(1-0.91NDVI))}{0.273}$	[6]	EVI_CA_Liu
	Southern Spain	General dataset	$6.669EVI^{1.867}$	[7]	EVI_ES1_Liang
		Specific dataset	$6.42EVI^{2.007}$		EVI_ES2_Liang
RDVI	Canada	Multiple crops (corn, soybean)	$0.0918e^{6.002RDVI}$	[8]	RDVI_CA_Haboudane
	Southern Spain	General dataset	$12.8RDVI^{2.936}$	[7]	RDVI_ES1_Liang
		Specific dataset	$13.23RDVI^{2.007}$		RDVI_ES2_Liang
OSAVI	Canada	Multiple crops (corn, soybean)	$-\frac{\ln(1.128(1-1.058OSAVI))}{0.459}$	[6]	OSAVI_CA_Liu
	Southern Spain	General dataset	$0.08735e^{4.815OSAVI}$	[7]	OSAVI_ES1_Liang
		Specific dataset	$0.08625e^{4.767OSAVI}$		OSAVI_ES2_Liang
MSAVI	Canada	Multiple crops (corn, soybean)	$0.1663e^{4.2731MSAVI}$	[8]	MSAVI_CA_Haboudane
MTVI1	Southern Spain	General dataset	$4.695MTVI1^{1.425}$	[7]	MTVI1_ES1_Liang
		Specific dataset	$4.411MTVI1^{1.566}$		MTVI1_ES2_Liang
MTVI2	Canada	Multiple crops (corn, soybean)	$0.2227e^{3.6566MTVI2}$	[8]	MTVI2_CA_Haboudane
	Canada	Multiple crops (corn, soybean)	$-\frac{\ln(1.027(1-0.819MTVI2))}{0.245}$	[6]	MTVI2_CA_Liu
	Southern Spain	General dataset	$0.4325e^{2.745MTVI2}$	[7]	MTVI2_ES1_Liang
		Specific dataset	$0.4161e^{2.699MTVI2}$		MTVI2_ES2_Liang
SPVI	Southern Spain	General dataset	$11.76SPVI2^{1.383}$	[7]	SPVI_ES1_Liang
		Specific dataset	$11.68SPVI2^{1.471}$		SPVI_ES2_Liang

Table S3. Approaches used to measure LAI and remote sensing data used to develop empirical relationships

Study (reference)	LAI measurement approach	Remote sensing data used to develop models
Yang et al. [1]	LAI-2000*	Canopy reflectance using ASD FieldSpec Pro spectro-radiometer
Viña et al. [2]	Leaf area meter (Model LI-3100, Li-Cor)	Canopy reflectance using Ocean Optics USB2000 radiometer
Kross et al. [3]	Hemispherical photo interpretation	RapidEye satellite data
Chen et al. [4]	LAI-2000*	Landsat satellite data
Nguy-Robertson et al. [5]	Leaf area meter (Model LI-3100, Li-Cor)	Canopy reflectance using Ocean Optics USB2000 radiometer
Liu et al. [6]	LAI-2000*	PRO-SAIL radiative transfer model
Liang et al. [7]	LAI-2000*	PRO-SAIL radiative transfer model
Haboudane et al. [8]	LAI-2000*	PRO-SAIL radiative transfer model

*LAI-2000 canopy analyzer by LI-COR corporation. Studies used LAI-2000 either reported measured LAI as green LAI or LAI without specifying green or total plant LAI.

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Table S4. Statistical summary for **corn** at Mead and Bushland sites using **empirical approaches**. Top five methods are in bold.

Methods		Mead				Bushland			
Group	**Name**	**RMSE**	**MAE**	**R^2**	**Rank**	**RMSE**	**MAE**	**R^2**	**Rank**
Parametric methods	NDVI_Ne_Viña	1.2491	0.9484	0.8245	7	1.8278	1.3057	0.8938	18
	NDVI_CN_Yang	1.9791	1.5454	0.8263	27	2.2048	1.5885	0.8918	34
	NDVI_CA_Kross	1.2152	0.9868	0.8076	10	1.3059	1.1255	0.8709	13
	gNDVI_CA_Kross	1.2902	1.0598	0.8143	13	1.1099	0.9214	0.8708	8
	SR_CA_Chen	1.8825	1.4493	0.5290	36	2.4756	1.8069	0.5809	43
	SR_Ne_Viña	1.4324	1.1072	0.8098	17	2.0601	1.4605	0.8454	32
	SR_Ne_NR	**0.9141**	**0.6972**	**0.8113**	**3**	1.6588	1.1558	0.8485	17
	SR_CA_Kross	**1.0330**	**0.7827**	**0.8270**	**5**	**1.1493**	**0.9169**	**0.9135**	**5**
	RSR_CA_Kross	2.4831	2.0038	0.8238	34	0.9675	0.7235	0.8693	7
	EVI_Ne_Viña	2.9373	2.3132	0.7791	42	2.8918	2.5854	0.8298	45
	EVI_CN_Yang	2.8920	2.2878	0.8148	40	2.5333	1.8231	0.9000	38
	GARVI_Ne_Viña	2.3795	1.9390	0.7110	41	2.1712	1.8812	0.8820	39
	WDRVI_Ne1_Viña	2.0226	1.6160	0.8198	30	2.3776	1.8101	0.8757	41
	WDRVI_Ne2_Viña	**0.9652**	**0.7441**	**0.8185**	**1**	1.6441	1.1304	0.8805	14
	gWDRVI_Ne_NR	**0.9932**	**0.7561**	**0.8217**	**2**	1.5338	1.0371	0.8906	10
	Cl_{green}_Ne_Viña	1.0627	0.7856	0.8133	6	1.7444	1.2751	0.8752	19
	Cl_{green}_Ne_NR	**1.0148**	**0.7706**	**0.8231**	**4**	1.5466	1.0506	0.8916	11
Non-parametric methods	**SVM_Empirical**	1.7509	1.4416	0.7992	25	**0.9708**	**0.7309**	**0.9084**	**3**
	NN_Empirical	2.8218	2.2430	0.8136	39	**1.1928**	**0.9660**	**0.9279**	**4**
	RF_Empirical	1.2197	0.9021	0.7767	12	1.6732	1.2133	0.8019	20

Table S5. Statistical summary for **soybean** at Mead and Bushland sites using **empirical approaches**. Top five methods are in bold.

Methods		Mead				Bushland			
Group	**Name**	**RMSE**	**MAE**	**R^2**	**Rank**	**RMSE**	**MAE**	**R^2**	**Rank**
Parametric methods	NDVI_Ne_Viña	0.7389	0.5658	0.8330	9	1.4998	1.1971	0.8856	16
	NDVI_CN_Yang	1.1241	0.8248	0.8327	27	2.0161	1.6043	0.8820	34
	NDVI_CA_Kross	1.7071	1.4991	0.7588	37	0.9381	0.7342	0.8470	6
	gNDVI_CA_Kross	1.9403	1.7060	0.7722	39	**0.7957**	**0.6025**	**0.8545**	**5**
	SR_CA_Chen	2.3398	1.6977	0.2821	40	2.3003	1.8449	0.6097	41
	SR_Ne_Viña	0.7393	0.5789	0.8454	7	1.7255	1.3654	0.8659	28
	SR_Ne_NR	1.1396	0.9707	0.8451	26	1.1555	0.9027	0.8677	10
	SR_CA_Kross	1.6154	1.3744	0.8089	33	**0.7507**	**0.5872**	**0.8830**	**1**
	RSR_CA_Kross	2.7368	1.8060	0.8101	38	**0.8482**	**0.6534**	**0.8616**	**4**
	EVI_Ne_Viña	3.3030	2.8156	0.6880	45	3.4741	2.9409	0.8118	43
	EVI_CN_Yang	2.8888	2.1587	0.7271	42	2.4876	1.8483	0.8320	40
	GARVI_Ne_Viña	1.6220	1.1438	0.5797	36	1.6709	1.5377	0.8886	26
	WDRVI_Ne1_Viña	1.1150	0.8084	0.8409	23	2.1604	1.7935	0.8796	38
	WDRVI_Ne2_Viña	0.9408	0.7629	0.8409	18	1.2285	0.9476	0.8810	11
	gWDRVI_Ne_NR	0.9098	0.7324	0.8368	16	**1.0518**	**0.8075**	**0.8950**	**2**

	Clgreen_Ne_Viña	0.8036	0.5997	0.8438	11	1.1989	0.9815	0.8946	9
	Clgreen_Ne_NR	0.8840	0.7098	0.8348	14	**1.0774**	**0.8280**	**0.8946**	**3**
Non-parametric methods	SVM_Empirical	1.1422	1.0108	0.8309	29	1.1861	0.8826	0.7786	15
	NN_Empirical	1.5080	1.2174	0.8212	32	1.2516	1.0680	0.8821	13
	RF_Empirical	1.2933	1.0348	0.7560	35	1.4771	1.2319	0.8389	23

Table S6. Statistical summary for **corn** at Mead and Bushland sites using **physical approaches**. Top five methods are in bold

Methods		**Mead**				**Bushland**			
Group	**Name**	**RMSE**	**MAE**	**R^2**	**Rank**	**RMSE**	**MAE**	**R^2**	**Rank**
Parametric methods	NDVI_CA_Liu	1.5133	1.2023	0.8164	18	1.9223	1.3259	0.8971	22
	SR_ES1_Liang	1.8172	1.4928	0.7194	29	2.1166	1.4908	0.8454	33
	SR_ES2_Liang	1.8253	1.4884	0.7194	31	2.1560	1.5190	0.8454	35
	EVI_ES1_Liang	3.6843	2.7502	0.0039	44	2.8580	2.3915	0.9039	40
	EVI_ES2_Liang	3.9340	2.9228	0.0029	45	2.8600	2.4145	0.8991	42
	EVI2_CA_Liu	1.2728	0.9955	0.8031	14	1.6902	1.1796	0.9173	11
	RDVI_CA_ Haboudane	1.5136	1.2104	0.7334	23	1.9851	1.4314	0.8802	28
	RDVI_ES1_Liang	1.7493	1.3859	0.7875	24	2.1238	1.5738	0.9011	31
	RDVI_ES2_Liang	1.8798	1.4956	0.7746	32	2.2147	1.6494	0.8918	36
	OSAVI_CA_Liu	1.3495	1.0682	0.8047	16	1.7914	1.2284	0.9122	16
	OSAVI_ES1_Liang	1.4795	1.1799	0.7919	19	1.9788	1.4187	0.8957	24
	OSAVI_ES2_Liang	1.5614	1.2459	0.7933	22	2.0174	1.4468	0.8966	27
	MSAVI_CA_ Haboudane	2.9361	2.3093	0.6664	43	2.6131	1.8350	0.8415	44
	MTVI1_ES1_Liang	1.9590	1.5337	0.8130	28	2.0251	1.4244	0.9254	23
	MTVI1_ES2_Liang	2.1555	1.6924	0.8034	37	2.1720	1.5587	0.9242	30
	MTVI2_CA_ Haboudane	1.8778	1.5041	0.6333	38	2.1868	1.5636	0.8676	37
	MTVI2_CA_Liu	1.2020	0.9306	0.7828	11	1.8335	1.3120	0.8642	26
	MTVI2_ES1_Liang	1.7330	1.4150	0.7469	26	1.9904	1.4010	0.8933	25
	MTVI2_ES2_Liang	1.8383	1.4969	0.7502	33	2.0433	1.4387	0.8943	29
	SPVI_ES1_Liang	1.3062	1.0558	0.7983	15	**0.9156**	**0.7956**	**0.9142**	**1**
	SPVI_ES2_Liang	1.1596	0.9156	0.7941	8	**0.9378**	**0.7522**	**0.9139**	**2**
Non-parametric methods	SVM_Physical	2.0050	1.2527	0.5944	34	1.5405	1.3507	0.8455	20
	NN_Physical	1.3615	1.1063	0.6774	20	1.7458	1.2135	0.9200	14
	RF_Physical	1.4447	1.1124	0.7670	21	1.6951	1.1674	0.9325	9
RTM-LUT inversion		1.1181	0.9683	0.7938	9	1.5205	1.0273	0.9215	6

Table S7. Statistical summary for **soybean** at Mead and Bushland sites using **physical approaches**. Top five methods are in bold.

Methods		Mead				Bushland			
Group	**Name**	**RMSE**	**MAE**	**R^2**	**Rank**	**RMSE**	**MAE**	**R^2**	**Rank**
Parametric methods	NDVI_CA_Liu	0.7722	0.6178	0.8721	6	1.8243	1.4058	0.7776	39
	SR_ES1_Liang	0.9736	0.7986	0.7866	25	1.9096	1.4794	0.8659	32
	SR_ES2_Liang	0.9753	0.7813	0.7866	24	1.9458	1.5098	0.8659	36
	EVI_ES1_Liang	2.9598	2.2400	0.7879	41	2.6240	1.8874	0.4359	43
	EVI_ES2_Liang	3.0921	2.2634	0.7814	43	2.6500	1.9025	0.3568	45
	EVI2_CA_Liu	**0.6371**	**0.5097**	**0.8680**	**1**	1.1213	0.8923	0.8733	8
	RDVI_CA_ Haboudane	0.7032	0.5487	0.8313	8	1.3744	1.1037	0.8239	21
	RDVI_ES1_Liang	0.8256	0.6295	0.8659	10	1.6750	1.3856	0.8391	29
	RDVI_ES2_Liang	0.9271	0.7103	0.8591	12	1.7770	1.4751	0.8343	33
	OSAVI_CA_Liu	**0.6496**	**0.5255**	**0.8549**	**3**	1.3620	1.0613	0.8818	14
	OSAVI_ES1_Liang	**0.6900**	**0.5355**	**0.8663**	**2**	1.5484	1.2369	0.8710	19
	OSAVI_ES2_Liang	**0.7409**	**0.5733**	**0.8671**	**5**	1.6122	1.2874	0.8714	22
	MSAVI_CA_ Haboudane	2.9553	2.2211	0.4193	44	2.5130	1.8763	0.8029	42
	MTVI1_ES1_Liang	1.0249	0.7925	0.8468	20	1.6731	1.3274	0.8612	25
	MTVI1_ES2_Liang	1.1843	0.8989	0.8466	28	1.8452	1.4851	0.8587	35
	MTVI2_CA_ Haboudane	0.9111	0.6954	0.8071	17	1.8137	1.4409	0.8186	37
	MTVI2_CA_Liu	**0.6905**	**0.5382**	**0.8527**	**4**	1.3141	1.0662	0.8501	16
	MTVI2_ES1_Liang	0.8612	0.7180	0.8410	13	1.6670	1.2964	0.8316	27
	MTVI2_ES2_Liang	0.9437	0.7812	0.8425	19	1.7493	1.3602	0.8320	31
	SPVI_ES1_Liang	2.0943	1.9552	0.8626	33	1.1294	0.9355	0.8596	12
	SPVI_ES2_Liang	1.8537	1.7010	0.8618	31	0.9546	0.7351	0.8587	7
Non-parametric methods	SVM_Physical	1.1532	0.8925	0.7777	30	1.4709	1.2138	0.7277	24
	NN_Physical	0.9331	0.7757	0.7398	22	1.3895	1.0522	0.7936	19
	RF_Physical	0.9901	0.7501	0.7979	21	1.6937	1.2616	0.7448	30
RTM-LUT inversion		1.1181	0.8020	0.6314	15	0.7833	1.3491	1.0206	18

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