

Figure S1. Statistical indicators of inputs and output used in the study

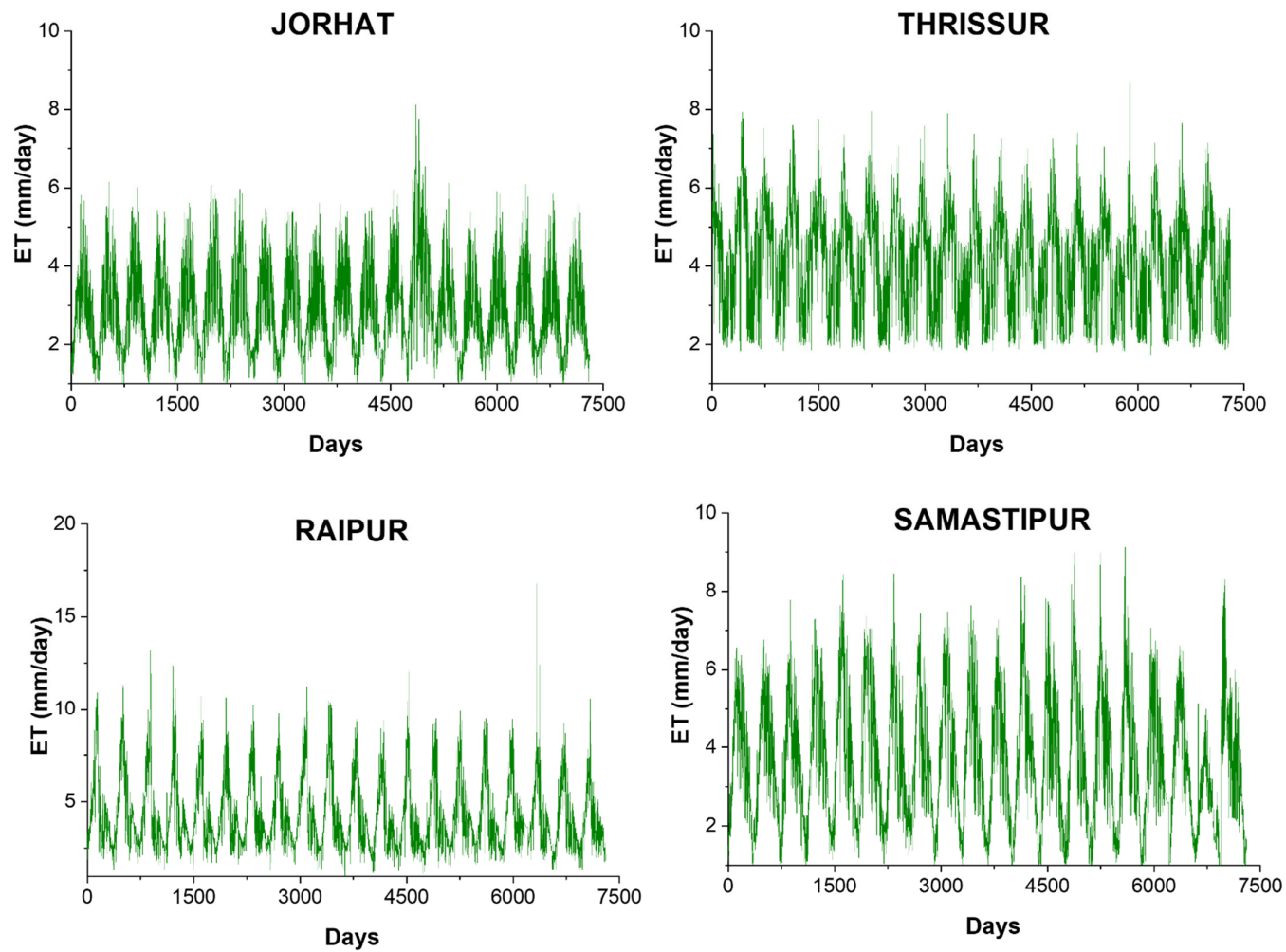


Figure S2. Time series graphs of ET_0 (mm/day) at humid (Jorhat, Thrissur) and sub-humid (Raipur, Samastipur) stations

Table S1. Performance indicators of empirical models at humid stations

Jorhat						Mohanpur				Palampur					Thrissur			
S. No.	MODE L	d	MBE (mm/da y)	RMSE (mm/da y)	R ²	d	MBE (mm/da y)	RMSE (mm/da y)	R ²	MODE L	d	MBE (mm/da y)	RMSE (mm/da y)	R ²	d	MBE (mm/da y)	RMSE (mm/da y)	R ²
1	ALB	0.68	1.115	1.325	0.51	0.60	1.869	2.115	0.39	ALB	0.83	1.179	1.510	0.65	0.78	1.441	1.831	0.71
		5			3	5			9		8			6	2			3
2	MAH	0.62	1.437	1.630	0.42	0.50	2.402	2.635	0.36	MAH	0.84	1.143	1.507	0.67	0.77	1.624	1.916	0.71
		9			5	6			4		2			2	3			3
3	PEN	0.60	1.172	1.412	0.36	0.58	1.708	2.075	0.27	PEN	0.81	1.087	1.370	0.65	0.81	1.147	1.330	0.69
		0			8	4			8		1			5	3			8
4	JH	0.78	1.207	1.375	0.91	0.68	1.962	2.124	0.96	JH	0.93	0.649	0.814	0.87	0.74	1.507	1.674	0.83
		5			0	7			1		9			7	8			6
5	MAK	0.91	0.465	0.574	0.84	0.94	0.442	0.518	0.88	MAK	0.88	0.682	0.896	0.85	0.82	0.878	1.031	0.83
		5			7	4			9		2			7	0			8
6	MGB	0.43	2.890	3.222	0.48	0.47	3.037	3.275	0.57	MGB	0.74	1.328	1.856	0.55	0.38	2.888	3.168	0.02
		5			0	5			5		5			1	3			0
7	PT	0.93	0.557	0.626	0.92	0.90	0.780	0.830	0.97	PT	0.93	0.608	0.725	0.78	0.87	0.665	0.785	0.64
		0			5	9			8		7			1	9			6
8	TUR	0.94	0.352	0.467	0.87	0.93	0.467	0.572	0.90	TUR	0.97	0.319	0.451	0.90	0.95	0.318	0.502	0.85
		7			2	9			8		5			8	2			6
9	HS	0.70	1.048	1.237	0.48	0.77	1.040	1.205	0.67	HS	0.93	0.524	0.707	0.78	0.71	0.859	1.058	0.38
		3			2	1			1		5			2	0			2
10	HS1	0.64	1.353	1.543	0.51	0.70	1.373	1.507	0.71	HS1	0.90	0.657	0.892	0.75	0.63	1.112	1.305	0.34
		1			8	8			5		5			6	0			1
11	HS2	0.66	1.236	1.435	0.48	0.72	1.284	1.446	0.67	HS2	0.92	0.585	0.801	0.78	0.68	0.997	1.184	0.38
		1			4	4			4		3			2	7			3
12	THO	0.64	1.274	1.510	0.47	0.72	1.133	1.376	0.57	THO	0.85	0.795	0.995	0.55	0.46	1.090	1.344	0.12
		9			1	6			6		6			5	2			1
13	COP	0.65	1.789	1.961	0.78	0.59	2.406	2.553	0.82	COP	0.74	1.824	1.990	0.84	0.69	1.840	2.003	0.85
		1			8	7			1		3			5	3			8
14	VA1	0.74	1.036	1.133	0.82	0.80	1.011	1.092	0.90	VA1	0.56	1.946	2.225	0.44	0.59	1.705	1.937	0.47
		6			7	0			7		4			8	5			0
15	VA2	0.91	0.534	0.642	0.84	0.86	0.843	0.951	0.87	VA2	0.96	0.370	0.501	0.88	0.94	0.496	0.589	0.84
		2			6	9			4		7			4	4			2

Table S2. Performance indicators of empirical models at sub-humid stations

S. No.	MODEL	Faizabad				Jabalpur				Raipur			
		d	MBE	RMSE	R ²	d	MBE	RMSE	R ²	d	MBE	RMSE	R ²
1	ALB	0.724	2.609	3.890	0.744	0.649	2.599	4.217	0.801	0.650	2.780	4.369	0.781
2	MAH	0.726	2.603	4.377	0.873	0.711	2.116	3.616	0.847	0.692	2.427	4.088	0.862
3	PEN	0.849	1.551	2.036	0.619	0.817	1.569	2.118	0.716	0.816	1.682	2.188	0.688
4	JH	0.904	1.133	1.375	0.779	0.883	1.183	1.370	0.874	0.864	1.329	1.516	0.828
5	MAK	0.699	1.286	1.935	0.713	0.785	0.920	1.334	0.756	0.738	1.062	1.544	0.698
6	MGB	0.740	2.150	2.528	0.597	0.691	2.148	2.530	0.598	0.667	2.342	2.670	0.575
7	PT	0.818	0.898	1.519	0.642	0.895	0.613	0.944	0.755	0.863	0.707	1.098	0.711
8	TUR	0.887	0.774	1.236	0.757	0.951	0.529	0.728	0.831	0.924	0.629	0.900	0.773
9	HS	0.865	1.097	1.393	0.684	0.887	0.991	1.149	0.794	0.900	0.887	1.063	0.774
10	HS1	0.852	1.255	1.499	0.703	0.854	1.202	1.344	0.816	0.869	1.081	1.242	0.802
11	HS2	0.856	1.255	1.510	0.686	0.855	1.216	1.383	0.796	0.876	1.067	1.246	0.777
12	THO	0.826	1.118	1.482	0.616	0.864	0.850	1.125	0.622	0.829	0.949	1.239	0.623
13	COP	0.819	1.644	1.849	0.702	0.735	1.961	2.175	0.708	0.752	1.865	2.103	0.662
14	VA1	0.510	2.670	3.311	0.262	0.512	2.254	2.737	0.224	0.505	2.374	2.891	0.212
15	VA2	0.868	0.860	1.304	0.708	0.925	0.693	0.853	0.801	0.908	0.756	0.965	0.752
S. No.	MODEL	Ranchi				Ranichauri				Samastipur			
		d	MBE	RMSE	R ²	d	MBE	RMSE	R ²	d	MBE	RMSE	R ²
1	ALB	0.781	1.217	1.621	0.545	0.794	1.070	1.349	0.532	0.724	2.609	3.890	0.744
2	MAH	0.768	1.337	1.634	0.554	0.752	1.143	1.436	0.535	0.726	2.603	4.377	0.873
3	PEN	0.773	1.146	1.385	0.480	0.672	1.357	1.603	0.526	0.849	1.551	2.036	0.619
4	JH	0.819	1.273	1.489	0.912	0.955	0.492	0.611	0.934	0.904	1.133	1.375	0.779
5	MAK	0.899	0.563	0.742	0.825	0.964	0.339	0.437	0.942	0.699	1.286	1.935	0.713
6	MGB	0.601	2.198	2.542	0.584	0.766	1.102	1.529	0.609	0.740	2.150	2.528	0.597
7	PT	0.949	0.517	0.615	0.893	0.951	0.475	0.583	0.879	0.818	0.898	1.519	0.642
8	TUR	0.956	0.385	0.502	0.863	0.986	0.230	0.299	0.950	0.887	0.774	1.236	0.757
9	HS	0.830	0.983	1.164	0.745	0.949	0.397	0.540	0.832	0.865	1.097	1.393	0.684
10	HS1	0.778	1.244	1.408	0.762	0.912	0.559	0.744	0.815	0.852	1.255	1.499	0.703

11	HS2	0.784	1.224	1.410	0.747	0.936	0.458	0.628	0.832	0.856	1.255	1.510	0.686
12	THO	0.855	0.715	0.955	0.587	0.856	0.724	0.875	0.599	0.826	1.118	1.482	0.616
13	COP	0.635	2.232	2.405	0.758	0.654	2.178	2.307	0.920	0.819	1.644	1.849	0.702
14	VA1	0.668	1.467	1.634	0.700	0.648	1.408	1.600	0.619	0.510	2.670	3.311	0.262
15	VA2	0.928	0.606	0.707	0.866	0.987	0.222	0.278	0.951	0.868	0.860	1.304	0.708

Table S3. Performance indicators of conventional ML models at Jorhat

RANK	MODEL	GPI	d	MBE	RMSE	R ²	MODEL	GPI	d	MBE	RMSE	R ²	MODEL	GPI	d	MBE	RMSE	R ²
1	RF17	1.416	0.987	0.106	0.240	0.952	XGB17	1.636	0.993	0.086	0.177	0.974	LGB18	1.589	0.992	0.082	0.192	0.970
2	RF18	1.379	0.985	0.109	0.252	0.947	XGB18	1.610	0.992	0.088	0.186	0.971	LGB17	1.588	0.992	0.085	0.190	0.970
3	RF8	1.320	0.985	0.139	0.253	0.946	XGB8	1.411	0.988	0.136	0.228	0.956	LGB8	1.379	0.988	0.132	0.232	0.954
4	RF9	1.319	0.985	0.140	0.254	0.946	XGB9	1.056	0.976	0.176	0.322	0.910	LGB12	1.106	0.979	0.160	0.301	0.922
5	RF12	1.081	0.977	0.169	0.315	0.914	XGB12	1.039	0.976	0.181	0.325	0.909	LGB9	1.101	0.979	0.161	0.302	0.921
6	RF7	0.943	0.973	0.201	0.340	0.900	XGB7	0.901	0.972	0.209	0.350	0.894	LGB7	0.923	0.974	0.196	0.334	0.904
7	RF5	0.890	0.972	0.212	0.350	0.894	XGB5	0.882	0.971	0.215	0.353	0.892	LGB5	0.903	0.974	0.202	0.336	0.902
8	RF16	0.803	0.969	0.247	0.356	0.892	XGB16	0.851	0.972	0.245	0.345	0.897	LGB16	0.861	0.974	0.232	0.331	0.906
9	RF15	0.677	0.965	0.271	0.380	0.876	XGB15	0.681	0.966	0.274	0.378	0.876	LGB15	0.681	0.968	0.263	0.363	0.886
10	RF14	0.224	0.946	0.333	0.470	0.809	XGB14	0.133	0.943	0.345	0.486	0.797	LGB14	0.203	0.950	0.321	0.453	0.822
11	RF4	0.042	0.938	0.361	0.502	0.783	XGB4	0.000	0.937	0.365	0.508	0.778	LGB4	0.050	0.944	0.344	0.477	0.803
12	RF13	-0.587	0.901	0.445	0.599	0.689	XGB13	-0.630	0.902	0.447	0.604	0.685	LGB13	-0.625	0.909	0.426	0.577	0.712
13	RF10	-0.619	0.901	0.442	0.612	0.678	XGB10	-0.739	0.897	0.452	0.628	0.663	LGB10	-0.736	0.905	0.429	0.600	0.689
14	RF2	-1.151	0.870	0.516	0.687	0.597	XGB2	-1.178	0.872	0.513	0.687	0.599	LGB2	-1.168	0.881	0.488	0.654	0.631
15	RF11	-1.507	0.839	0.546	0.729	0.541	XGB11	-1.562	0.843	0.547	0.736	0.537	LGB11	-1.669	0.846	0.535	0.712	0.562
16	RF6	-1.694	0.830	0.570	0.759	0.508	XGB6	-1.786	0.828	0.568	0.766	0.501	LGB6	-1.762	0.842	0.543	0.726	0.544
17	RF3	-1.950	0.806	0.593	0.785	0.469	XGB3	-1.941	0.814	0.586	0.779	0.480	LGB3	-2.017	0.819	0.564	0.749	0.513
18	RF1	-2.584	0.767	0.673	0.876	0.371	XGB1	-2.364	0.783	0.636	0.827	0.418	LGB1	-2.407	0.795	0.610	0.792	0.457

Table S4. Performance indicators of conventional ML models at Mohanpur

RANK	MODEL	GPI	d	MBE	RMSE	R ²	MODEL	GPI	d	MBE	RMSE	R ²	MODEL	GPI	d	MBE	RMSE	R ²
1	RF17	1.541	0.998	0.075	0.117	0.991	XGB17	1.741	0.998	0.064	0.096	0.994	LGB17	1.710	0.998	0.064	0.097	0.994
2	RF18	1.522	0.997	0.076	0.123	0.990	XGB18	1.703	0.998	0.069	0.106	0.992	LGB18	1.676	0.998	0.065	0.107	0.992
3	RF9	1.426	0.997	0.097	0.142	0.986	XGB8	1.553	0.997	0.098	0.137	0.987	LGB8	1.535	0.997	0.093	0.133	0.988
4	RF8	1.424	0.997	0.098	0.142	0.986	XGB9	1.238	0.992	0.132	0.211	0.970	LGB9	1.237	0.993	0.126	0.199	0.973
5	RF12	1.166	0.993	0.128	0.206	0.971	XGB12	1.211	0.992	0.136	0.216	0.968	LGB12	1.214	0.993	0.128	0.204	0.972
6	RF7	1.128	0.992	0.138	0.211	0.970	XGB7	1.177	0.992	0.144	0.221	0.967	LGB7	1.185	0.993	0.136	0.206	0.971
7	RF5	1.034	0.991	0.152	0.230	0.964	XGB5	1.094	0.990	0.156	0.235	0.963	LGB5	1.089	0.991	0.149	0.224	0.966
8	RF16	0.851	0.988	0.187	0.260	0.954	XGB16	0.923	0.988	0.189	0.260	0.954	LGB16	0.899	0.989	0.181	0.252	0.957
9	RF15	0.819	0.988	0.192	0.265	0.952	XGB15	0.877	0.987	0.195	0.268	0.951	LGB15	0.860	0.988	0.187	0.257	0.955
10	RF14	0.385	0.979	0.248	0.343	0.920	XGB14	0.385	0.978	0.252	0.350	0.917	LGB14	0.372	0.980	0.242	0.335	0.924
11	RF4	0.244	0.976	0.265	0.367	0.909	XGB4	0.263	0.976	0.266	0.369	0.908	LGB4	0.259	0.978	0.255	0.352	0.916
12	RF11	-1.176	0.938	0.407	0.568	0.782	XGB11	-1.392	0.935	0.417	0.584	0.770	LGB11	-1.354	0.941	0.396	0.554	0.792
13	RF10	-1.221	0.937	0.421	0.572	0.779	XGB10	-1.411	0.935	0.428	0.585	0.771	LGB10	-1.392	0.941	0.409	0.556	0.791
14	RF13	-1.362	0.933	0.436	0.586	0.767	XGB13	-1.548	0.931	0.442	0.597	0.760	LGB13	-1.511	0.937	0.421	0.567	0.782
15	RF6	-1.598	0.926	0.455	0.618	0.744	XGB6	-1.695	0.927	0.452	0.615	0.746	LGB6	-1.661	0.933	0.431	0.584	0.769
16	RF3	-1.746	0.921	0.472	0.633	0.730	XGB3	-1.790	0.924	0.464	0.623	0.739	LGB3	-1.771	0.930	0.441	0.594	0.761
17	RF2	-1.979	0.914	0.500	0.658	0.710	XGB2	-2.070	0.917	0.493	0.652	0.716	LGB2	-2.058	0.923	0.471	0.621	0.739
18	RF1	-2.459	0.899	0.544	0.712	0.665	XGB1	-2.259	0.910	0.508	0.668	0.700	LGB1	-2.290	0.916	0.489	0.642	0.721

Table S5. Performance indicators of conventional ML models at Palampur

RANK	MODEL	GPI	d	MBE	RMSE	R ²	MODEL	GPI	d	MBE	RMSE	R ²	MODEL	GPI	d	MBE	RMSE	R ²
1	RF18	1.659	0.997	0.099	0.146	0.990	XGB18	1.793	0.998	0.095	0.132	0.992	LGB18	1.775	0.998	0.082	0.115	0.994
2	RF17	1.598	0.997	0.112	0.159	0.988	XGB17	1.784	0.998	0.096	0.134	0.991	LGB17	1.750	0.998	0.087	0.120	0.993
3	RF7	0.999	0.990	0.196	0.290	0.960	XGB7	1.010	0.989	0.203	0.298	0.957	LGB7	0.972	0.990	0.194	0.284	0.961
4	RF16	0.857	0.988	0.231	0.308	0.954	XGB16	0.865	0.988	0.237	0.315	0.952	LGB16	0.860	0.989	0.222	0.296	0.958
5	RF8	0.630	0.984	0.255	0.353	0.940	XGB8	0.599	0.983	0.261	0.365	0.936	LGB8	0.586	0.985	0.249	0.346	0.942
6	RF9	0.623	0.984	0.255	0.354	0.940	XGB12	0.357	0.980	0.290	0.404	0.922	LGB12	0.359	0.982	0.274	0.383	0.929
7	RF12	0.384	0.980	0.284	0.396	0.925	XGB9	0.344	0.979	0.290	0.406	0.921	LGB9	0.352	0.981	0.276	0.383	0.929
8	RF14	0.307	0.979	0.297	0.407	0.920	XGB14	0.281	0.979	0.304	0.413	0.918	LGB14	0.282	0.981	0.288	0.392	0.926
9	RF10	0.237	0.978	0.300	0.420	0.915	XGB10	0.163	0.976	0.309	0.434	0.909	LGB10	0.181	0.979	0.293	0.410	0.919
10	RF5	0.051	0.974	0.325	0.449	0.903	XGB5	0.086	0.975	0.321	0.444	0.905	LGB5	0.049	0.977	0.310	0.428	0.912
11	RF15	0.049	0.975	0.333	0.445	0.905	XGB15	-0.018	0.973	0.339	0.457	0.900	LGB15	-0.019	0.976	0.325	0.435	0.909
12	RF13	-0.112	0.972	0.356	0.468	0.895	XGB13	-0.175	0.971	0.362	0.476	0.891	LGB13	-0.163	0.974	0.345	0.453	0.901
13	RF11	-0.644	0.960	0.404	0.548	0.856	XGB2	-0.755	0.960	0.422	0.555	0.852	LGB2	-0.737	0.963	0.403	0.530	0.865
14	RF2	-0.804	0.958	0.431	0.568	0.846	XGB11	-0.799	0.958	0.411	0.566	0.847	LGB11	-0.747	0.962	0.393	0.535	0.862
15	RF4	-0.856	0.956	0.431	0.577	0.841	XGB4	-0.808	0.958	0.421	0.564	0.847	LGB4	-0.783	0.962	0.403	0.537	0.861
16	RF6	-1.200	0.948	0.455	0.624	0.814	XGB6	-1.186	0.950	0.445	0.615	0.819	LGB6	-1.136	0.954	0.426	0.584	0.836
17	RF3	-1.436	0.943	0.491	0.650	0.798	XGB3	-1.333	0.947	0.473	0.627	0.812	LGB3	-1.355	0.951	0.458	0.605	0.824
18	RF1	-2.341	0.921	0.576	0.754	0.730	XGB1	-2.207	0.927	0.549	0.723	0.750	LGB1	-2.225	0.931	0.535	0.698	0.766

Table S6. Performance indicators of conventional ML models at Thrissur

RANK	MODEL	GPI	d	MBE	RMSE	R ²	MODEL	GPI	d	MBE	RMSE	R ²	MODEL	GPI	d	MBE	RMSE	R ²
1	RF17	1.298	0.997	0.077	0.128	0.990	XGB17	1.493	0.998	0.068	0.102	0.993	LGB18	1.478	0.998	0.065	0.100	0.994
2	RF18	1.264	0.997	0.083	0.140	0.988	XGB18	1.482	0.998	0.071	0.106	0.993	LGB17	1.474	0.998	0.065	0.101	0.993
3	RF8	1.088	0.993	0.117	0.200	0.974	XGB8	1.223	0.994	0.116	0.193	0.976	LGB16	1.220	0.995	0.121	0.173	0.981
4	RF9	1.087	0.993	0.117	0.200	0.974	XGB16	1.222	0.995	0.129	0.183	0.979	LGB8	1.199	0.994	0.112	0.189	0.977
5	RF16	1.085	0.994	0.130	0.191	0.977	XGB15	1.072	0.992	0.157	0.226	0.967	LGB15	1.061	0.992	0.151	0.217	0.970
6	RF15	0.969	0.992	0.156	0.225	0.967	XGB7	0.584	0.978	0.217	0.362	0.916	LGB7	0.578	0.980	0.208	0.347	0.923
7	RF7	0.555	0.979	0.213	0.349	0.922	XGB14	0.463	0.975	0.244	0.385	0.905	LGB14	0.479	0.978	0.232	0.363	0.915
8	RF14	0.441	0.977	0.241	0.373	0.911	XGB12	0.164	0.965	0.286	0.450	0.871	LGB12	0.157	0.968	0.276	0.430	0.881
9	RF12	0.162	0.967	0.281	0.439	0.876	XGB9	0.123	0.964	0.295	0.456	0.867	LGB9	0.129	0.967	0.281	0.435	0.879
10	RF4	-0.032	0.960	0.321	0.478	0.854	XGB4	-0.001	0.960	0.316	0.479	0.853	LGB4	0.038	0.964	0.298	0.450	0.870
11	RF11	-0.211	0.955	0.375	0.501	0.839	XGB11	-0.235	0.954	0.381	0.510	0.833	LGB11	-0.205	0.959	0.360	0.483	0.850
12	RF13	-0.225	0.954	0.376	0.505	0.837	XGB5	-0.242	0.951	0.348	0.525	0.824	LGB13	-0.229	0.958	0.361	0.488	0.847
13	RF5	-0.243	0.951	0.349	0.522	0.826	XGB13	-0.251	0.954	0.382	0.514	0.831	LGB5	-0.236	0.955	0.333	0.501	0.839
14	RF3	-0.427	0.947	0.411	0.544	0.811	XGB3	-0.413	0.948	0.409	0.543	0.812	LGB3	-0.396	0.953	0.389	0.515	0.830
15	RF10	-0.902	0.925	0.474	0.631	0.745	XGB10	-0.962	0.925	0.476	0.637	0.742	LGB10	-0.951	0.931	0.455	0.608	0.763
16	RF2	-1.136	0.915	0.507	0.672	0.712	XGB2	-1.114	0.918	0.498	0.660	0.723	LGB2	-1.121	0.924	0.479	0.633	0.744
17	RF6	-2.069	0.864	0.613	0.822	0.576	XGB6	-2.101	0.870	0.602	0.807	0.591	LGB6	-2.153	0.876	0.579	0.779	0.613
18	RF1	-2.702	0.829	0.690	0.919	0.487	XGB1	-2.507	0.846	0.643	0.855	0.539	LGB1	-2.522	0.855	0.614	0.821	0.569

Table S7. Performance indicators of conventional ML models at Faizabad

RANK	MODEL	GPI	d	MBE	RMSE	R ²	MODEL	GPI	d	MBE	RMSE	R ²	MODEL	GPI	d	MBE	RMSE	R ²
1	RF17	1.816	0.997	0.150	0.233	0.990	XGB17	2.087	0.998	0.134	0.203	0.992	LGB17	2.115	0.998	0.120	0.191	0.993
2	RF18	1.806	0.997	0.148	0.242	0.989	XGB18	2.067	0.998	0.141	0.210	0.991	LGB18	2.097	0.998	0.122	0.201	0.992
3	RF9	1.437	0.993	0.243	0.380	0.972	XGB16	1.643	0.994	0.267	0.357	0.975	LGB16	1.665	0.994	0.250	0.342	0.977
4	RF8	1.428	0.992	0.245	0.384	0.971	XGB8	1.594	0.992	0.253	0.392	0.970	LGB8	1.603	0.993	0.242	0.377	0.972
5	RF16	1.392	0.993	0.273	0.383	0.971	XGB15	1.300	0.989	0.341	0.474	0.956	LGB15	1.316	0.989	0.325	0.454	0.959
6	RF15	1.104	0.988	0.342	0.479	0.955	XGB13	1.105	0.986	0.398	0.526	0.946	LGB13	1.114	0.987	0.380	0.507	0.949
7	RF13	0.949	0.986	0.388	0.520	0.947	XGB11	0.951	0.982	0.404	0.585	0.933	LGB11	0.968	0.984	0.387	0.560	0.938
8	RF11	0.818	0.983	0.396	0.572	0.936	XGB3	0.686	0.978	0.474	0.649	0.917	LGB3	0.716	0.980	0.452	0.618	0.925
9	RF3	0.521	0.978	0.474	0.648	0.917	XGB7	-0.631	0.946	0.641	0.986	0.810	LGB7	-0.603	0.951	0.617	0.941	0.826
10	RF7	-0.593	0.951	0.621	0.944	0.825	XGB9	-0.806	0.943	0.688	1.016	0.798	LGB9	-0.822	0.947	0.664	0.978	0.812
11	RF12	-0.916	0.943	0.685	1.012	0.799	XGB12	-0.835	0.942	0.687	1.025	0.795	LGB12	-0.859	0.946	0.664	0.989	0.808
12	RF10	-0.921	0.944	0.701	1.007	0.801	XGB5	-0.887	0.941	0.703	1.030	0.792	LGB5	-0.925	0.944	0.679	0.999	0.804
13	RF5	-0.990	0.941	0.704	1.024	0.794	XGB10	-0.917	0.941	0.715	1.036	0.791	LGB10	-0.960	0.944	0.693	1.004	0.802
14	RF14	-1.076	0.939	0.723	1.038	0.788	XGB14	-1.048	0.937	0.734	1.062	0.780	LGB14	-1.088	0.941	0.712	1.026	0.793
15	RF4	-1.471	0.929	0.799	1.116	0.757	XGB6	-1.436	0.928	0.799	1.140	0.749	LGB4	-1.406	0.933	0.771	1.079	0.771
16	RF6	-1.556	0.927	0.808	1.138	0.749	XGB4	-1.443	0.928	0.805	1.138	0.749	LGB6	-1.507	0.931	0.780	1.103	0.762
17	RF2	-1.568	0.926	0.819	1.131	0.749	XGB2	-1.516	0.925	0.817	1.145	0.744	LGB2	-1.541	0.930	0.788	1.104	0.760
18	RF1	-2.181	0.910	0.915	1.253	0.697	XGB1	-1.913	0.915	0.881	1.221	0.712	LGB1	-1.885	0.921	0.845	1.161	0.736

Table S8. Performance indicators of conventional ML models at Jabalpur

RANK	MODEL	GPI	d	MBE	RMSE	R ²	MODEL	GPI	d	MBE	RMSE	R ²	MODEL	GPI	d	MBE	RMSE	R ²
1	RF17	1.705	0.998	0.105	0.163	0.991	XGB18	1.981	0.998	0.097	0.143	0.993	LGB18	2.004	0.999	0.085	0.128	0.995
2	RF18	1.693	0.998	0.104	0.169	0.991	XGB17	1.979	0.998	0.098	0.143	0.993	LGB17	1.981	0.999	0.089	0.134	0.994
3	RF16	1.289	0.995	0.179	0.251	0.979	XGB16	1.511	0.995	0.178	0.241	0.981	LGB16	1.517	0.996	0.167	0.226	0.983
4	RF8	1.254	0.994	0.169	0.269	0.977	XGB8	1.392	0.994	0.177	0.276	0.975	LGB8	1.389	0.994	0.166	0.262	0.978
5	RF9	1.254	0.994	0.168	0.269	0.976	XGB15	1.023	0.991	0.240	0.337	0.963	LGB15	1.035	0.992	0.226	0.317	0.967
6	RF15	0.893	0.991	0.235	0.330	0.964	XGB13	0.157	0.981	0.353	0.473	0.927	LGB13	0.127	0.982	0.338	0.454	0.933
7	RF11	0.056	0.980	0.319	0.484	0.924	XGB11	0.101	0.979	0.328	0.495	0.920	LGB11	0.092	0.981	0.312	0.471	0.928
8	RF13	0.054	0.981	0.351	0.470	0.928	XGB7	-0.052	0.977	0.339	0.519	0.912	LGB12	-0.065	0.979	0.328	0.492	0.921
9	RF7	-0.055	0.978	0.330	0.501	0.918	XGB12	-0.092	0.976	0.347	0.524	0.911	LGB7	-0.081	0.979	0.327	0.496	0.920
10	RF12	-0.057	0.978	0.334	0.499	0.919	XGB9	-0.109	0.976	0.348	0.526	0.910	LGB9	-0.117	0.978	0.334	0.499	0.919
11	RF5	-0.272	0.976	0.365	0.529	0.909	XGB5	-0.226	0.975	0.366	0.539	0.905	LGB5	-0.251	0.977	0.351	0.515	0.914
12	RF14	-0.426	0.974	0.386	0.550	0.901	XGB14	-0.437	0.972	0.395	0.566	0.896	LGB3	-0.466	0.975	0.395	0.535	0.907
13	RF3	-0.539	0.973	0.415	0.561	0.898	XGB3	-0.453	0.973	0.415	0.562	0.897	LGB14	-0.472	0.975	0.379	0.542	0.904
14	RF4	-0.720	0.970	0.427	0.588	0.887	XGB4	-0.677	0.969	0.426	0.595	0.885	LGB4	-0.686	0.972	0.408	0.565	0.896
15	RF10	-0.935	0.965	0.424	0.626	0.873	XGB10	-1.044	0.963	0.438	0.649	0.863	LGB10	-1.054	0.966	0.418	0.618	0.876
16	RF6	-1.302	0.960	0.462	0.673	0.853	XGB6	-1.369	0.958	0.468	0.688	0.846	LGB6	-1.325	0.962	0.444	0.648	0.863
17	RF2	-1.602	0.956	0.516	0.702	0.840	XGB2	-1.667	0.954	0.521	0.715	0.834	LGB2	-1.635	0.959	0.494	0.674	0.852
18	RF1	-2.292	0.944	0.588	0.783	0.802	XGB1	-2.018	0.949	0.556	0.752	0.816	LGB1	-1.996	0.954	0.529	0.711	0.835

Table S9. Performance indicators of conventional ML models at Raipur

RANK	MODEL	GPI	d	MBE	RMSE	R ²	MODEL	GPI	d	MBE	RMSE	R ²	MODEL	GPI	d	MBE	RMSE	R ²
1	RF17	1.853	0.997	0.109	0.187	0.990	XGB18	2.156	0.998	0.105	0.164	0.992	LGB18	2.150	0.998	0.093	0.161	0.992
2	RF18	1.827	0.997	0.113	0.195	0.989	XGB17	2.154	0.998	0.105	0.165	0.992	LGB17	2.140	0.998	0.097	0.161	0.992
3	RF16	1.512	0.995	0.175	0.260	0.980	XGB16	1.764	0.995	0.175	0.251	0.982	LGB16	1.772	0.996	0.163	0.237	0.984
4	RF9	1.366	0.993	0.182	0.302	0.973	XGB8	1.554	0.993	0.190	0.306	0.973	LGB8	1.533	0.993	0.182	0.295	0.974
5	RF8	1.362	0.993	0.182	0.303	0.973	XGB15	1.268	0.991	0.243	0.355	0.963	LGB15	1.283	0.992	0.230	0.334	0.967
6	RF15	1.096	0.991	0.237	0.348	0.965	XGB13	0.488	0.982	0.356	0.485	0.931	LGB13	0.469	0.983	0.342	0.466	0.936
7	RF13	0.344	0.982	0.351	0.479	0.933	XGB11	0.375	0.980	0.346	0.513	0.923	LGB11	0.369	0.981	0.333	0.490	0.930
8	RF11	0.257	0.980	0.341	0.503	0.926	XGB3	-0.108	0.974	0.417	0.579	0.902	LGB3	-0.068	0.977	0.396	0.548	0.912
9	RF3	-0.218	0.975	0.417	0.571	0.904	XGB7	-0.419	0.968	0.399	0.646	0.879	LGB7	-0.434	0.970	0.383	0.617	0.889
10	RF7	-0.381	0.970	0.384	0.616	0.889	XGB12	-0.423	0.968	0.409	0.643	0.880	LGB12	-0.444	0.970	0.392	0.616	0.889
11	RF12	-0.418	0.970	0.398	0.618	0.888	XGB9	-0.573	0.966	0.421	0.664	0.872	LGB9	-0.506	0.969	0.401	0.623	0.886
12	RF14	-0.640	0.967	0.430	0.647	0.878	XGB14	-0.640	0.965	0.440	0.668	0.870	LGB5	-0.645	0.968	0.417	0.640	0.880
13	RF5	-0.658	0.967	0.430	0.650	0.876	XGB5	-0.700	0.964	0.437	0.681	0.866	LGB14	-0.693	0.967	0.425	0.645	0.878
14	RF4	-1.006	0.962	0.485	0.692	0.860	XGB4	-0.989	0.960	0.485	0.711	0.853	LGB4	-0.962	0.964	0.463	0.674	0.867
15	RF10	-1.152	0.959	0.486	0.717	0.850	XGB10	-1.207	0.956	0.496	0.742	0.840	LGB10	-1.164	0.960	0.473	0.702	0.856
16	RF6	-1.479	0.954	0.527	0.756	0.833	XGB6	-1.385	0.954	0.525	0.759	0.832	LGB6	-1.395	0.957	0.502	0.726	0.846
17	RF2	-1.518	0.954	0.543	0.758	0.832	XGB2	-1.471	0.953	0.542	0.766	0.829	LGB2	-1.553	0.955	0.524	0.742	0.839
18	RF1	-2.147	0.943	0.611	0.835	0.798	XGB1	-1.844	0.946	0.582	0.808	0.810	LGB1	-1.850	0.951	0.560	0.772	0.826

Table S10. Performance indicators of conventional ML models at Ranchi

RANK	MODEL	GPI	d	MBE	RMSE	R ²	MODEL	GPI	d	MBE	RMSE	R ²	MODEL	GPI	d	MBE	RMSE	R ²
1	RF17	1.764	0.996	0.107	0.164	0.984	XGB17	2.003	0.998	0.087	0.124	0.991	LGB17	1.991	0.998	0.081	0.123	0.991
2	RF18	1.737	0.995	0.109	0.172	0.983	XGB18	1.987	0.997	0.088	0.130	0.990	LGB18	1.965	0.997	0.082	0.132	0.990
3	RF8	1.489	0.992	0.149	0.223	0.970	XGB8	1.557	0.992	0.152	0.225	0.970	LGB8	1.564	0.993	0.144	0.213	0.973
4	RF9	1.484	0.992	0.149	0.225	0.970	XGB16	1.264	0.988	0.203	0.276	0.955	LGB16	1.260	0.989	0.192	0.264	0.959
5	RF16	1.142	0.987	0.208	0.284	0.952	XGB15	1.020	0.984	0.237	0.319	0.940	LGB15	1.004	0.986	0.226	0.306	0.944
6	RF15	0.950	0.984	0.236	0.318	0.940	XGB12	0.715	0.977	0.251	0.381	0.914	LGB12	0.733	0.980	0.237	0.360	0.923
7	RF12	0.700	0.978	0.246	0.372	0.918	XGB9	0.660	0.976	0.255	0.391	0.910	LGB9	0.680	0.979	0.243	0.368	0.920
8	RF7	0.608	0.977	0.260	0.386	0.912	XGB7	0.621	0.976	0.264	0.395	0.908	LGB7	0.606	0.978	0.252	0.379	0.915
9	RF5	0.534	0.975	0.271	0.396	0.907	XGB5	0.584	0.975	0.272	0.399	0.906	LGB5	0.569	0.977	0.261	0.382	0.913
10	RF14	0.105	0.967	0.333	0.456	0.877	XGB14	0.118	0.966	0.337	0.463	0.874	LGB14	0.085	0.968	0.324	0.445	0.883
11	RF4	-0.011	0.964	0.348	0.472	0.868	XGB4	0.052	0.965	0.346	0.471	0.869	LGB4	0.062	0.968	0.329	0.447	0.882
12	RF11	-0.892	0.941	0.429	0.591	0.793	XGB11	-0.963	0.939	0.437	0.605	0.784	LGB11	-0.956	0.944	0.416	0.575	0.804
13	RF13	-0.991	0.939	0.448	0.600	0.787	XGB13	-1.056	0.937	0.457	0.612	0.779	LGB13	-1.011	0.943	0.431	0.578	0.802
14	RF3	-1.272	0.931	0.478	0.633	0.763	XGB3	-1.276	0.931	0.478	0.637	0.761	LGB3	-1.272	0.937	0.456	0.605	0.783
15	RF10	-1.552	0.923	0.494	0.671	0.736	XGB6	-1.664	0.920	0.506	0.685	0.726	LGB6	-1.628	0.927	0.478	0.646	0.753
16	RF6	-1.612	0.921	0.503	0.676	0.731	XGB10	-1.686	0.919	0.506	0.690	0.723	LGB10	-1.653	0.927	0.478	0.652	0.750
17	RF2	-1.948	0.912	0.541	0.711	0.703	XGB1	-1.938	0.912	0.540	0.708	0.706	LGB1	-1.993	0.918	0.518	0.679	0.727
18	RF1	-2.236	0.904	0.572	0.744	0.679	XGB2	-1.997	0.911	0.544	0.717	0.700	LGB2	-2.006	0.918	0.519	0.683	0.725

Table S11. Performance indicators of conventional ML models at Ranichauri

RANK	MODEL	GPI	d	MBE	RMSE	R ²	MODEL	GPI	d	MBE	RMSE	R ²	MODEL	GPI	d	MBE	RMSE	R ²
1	RF18	1.446	0.997	0.084	0.127	0.989	XGB17	1.674	0.998	0.072	0.102	0.993	LGB17	1.669	0.999	0.066	0.094	0.994
2	RF17	1.411	0.997	0.091	0.133	0.988	XGB18	1.634	0.998	0.077	0.110	0.992	LGB18	1.652	0.998	0.067	0.098	0.994
3	RF7	1.099	0.994	0.135	0.191	0.976	XGB7	1.176	0.994	0.137	0.193	0.975	LGB7	1.167	0.994	0.129	0.183	0.978
4	RF9	0.837	0.991	0.173	0.233	0.964	XGB9	0.887	0.990	0.176	0.237	0.963	LGB8	0.863	0.991	0.168	0.227	0.966
5	RF8	0.832	0.991	0.174	0.234	0.964	XGB8	0.887	0.990	0.174	0.237	0.962	LGB9	0.862	0.991	0.169	0.227	0.966
6	RF12	0.825	0.991	0.175	0.235	0.963	XGB12	0.853	0.990	0.181	0.241	0.961	LGB12	0.846	0.991	0.171	0.229	0.965
7	RF5	0.700	0.989	0.192	0.254	0.957	XGB5	0.760	0.989	0.192	0.255	0.957	LGB5	0.740	0.990	0.183	0.244	0.960
8	RF16	0.480	0.985	0.211	0.291	0.944	XGB16	0.475	0.985	0.216	0.298	0.941	LGB16	0.480	0.986	0.204	0.283	0.947
9	RF14	0.263	0.982	0.235	0.323	0.931	XGB14	0.214	0.981	0.243	0.333	0.926	LGB14	0.211	0.983	0.231	0.317	0.933
10	RF15	0.056	0.978	0.262	0.350	0.919	XGB15	0.030	0.978	0.264	0.355	0.916	LGB15	0.016	0.980	0.253	0.339	0.924
11	RF10	-0.081	0.975	0.263	0.374	0.907	XGB10	-0.191	0.974	0.270	0.388	0.900	LGB10	-0.182	0.976	0.258	0.368	0.910
12	RF4	-0.186	0.974	0.288	0.382	0.903	XGB4	-0.213	0.974	0.290	0.384	0.902	LGB4	-0.216	0.976	0.277	0.365	0.911
13	RF11	-0.475	0.968	0.307	0.421	0.882	XGB11	-0.662	0.966	0.318	0.440	0.872	LGB11	-0.646	0.969	0.302	0.417	0.884
14	RF13	-0.773	0.963	0.344	0.453	0.863	XGB13	-0.922	0.961	0.352	0.464	0.858	LGB13	-0.890	0.965	0.333	0.439	0.872
15	RF6	-0.897	0.960	0.347	0.471	0.852	XGB6	-1.010	0.959	0.349	0.476	0.850	LGB6	-1.008	0.963	0.333	0.453	0.863
16	RF2	-1.228	0.953	0.388	0.504	0.831	XGB2	-1.366	0.953	0.389	0.509	0.829	LGB2	-1.341	0.957	0.371	0.482	0.845
17	RF3	-1.756	0.941	0.431	0.560	0.792	XGB3	-1.900	0.941	0.430	0.559	0.793	LGB3	-1.890	0.947	0.410	0.533	0.811
18	RF1	-2.554	0.923	0.496	0.641	0.732	XGB1	-2.326	0.932	0.465	0.596	0.765	LGB1	-2.331	0.938	0.446	0.569	0.785

Table S12. Performance indicators of conventional ML models at Samastipur

RANK	MODEL	GPI	d	MBE	RMSE	R ²	MODEL	GPI	d	MBE	RMSE	R ²	MODEL	GPI	d	MBE	RMSE	R ²
1	RF17	1.470	0.997	0.115	0.179	0.987	XGB17	1.670	0.998	0.098	0.142	0.992	LGB17	1.653	0.998	0.088	0.129	0.993
2	RF18	1.382	0.995	0.122	0.216	0.982	XGB18	1.620	0.997	0.108	0.160	0.990	LGB18	1.627	0.998	0.091	0.139	0.992
3	RF9	1.144	0.992	0.187	0.275	0.970	XGB8	1.207	0.992	0.194	0.281	0.968	LGB8	1.190	0.993	0.183	0.263	0.972
4	RF8	1.142	0.992	0.188	0.275	0.970	XGB16	0.974	0.988	0.237	0.343	0.953	LGB16	0.959	0.989	0.223	0.323	0.958
5	RF16	0.928	0.988	0.231	0.332	0.956	XGB7	0.824	0.985	0.264	0.379	0.942	LGB7	0.797	0.986	0.251	0.362	0.948
6	RF7	0.784	0.986	0.256	0.371	0.945	XGB12	0.682	0.982	0.288	0.413	0.932	LGB15	0.663	0.984	0.282	0.388	0.940
7	RF15	0.647	0.983	0.289	0.400	0.936	XGB15	0.668	0.982	0.297	0.413	0.932	LGB12	0.641	0.983	0.275	0.398	0.937
8	RF12	0.559	0.981	0.291	0.428	0.927	XGB9	0.665	0.982	0.295	0.415	0.931	LGB9	0.638	0.983	0.277	0.398	0.937
9	RF5	0.482	0.980	0.317	0.440	0.922	XGB5	0.537	0.979	0.318	0.443	0.922	LGB5	0.517	0.981	0.302	0.422	0.929
10	RF14	0.128	0.971	0.378	0.517	0.893	XGB14	0.105	0.970	0.391	0.533	0.887	LGB14	0.088	0.973	0.373	0.508	0.897
11	RF4	-0.290	0.961	0.449	0.600	0.856	XGB4	-0.285	0.960	0.455	0.606	0.854	LGB4	-0.257	0.965	0.429	0.569	0.870
12	RF13	-0.394	0.957	0.454	0.624	0.844	XGB13	-0.509	0.953	0.473	0.653	0.830	LGB13	-0.492	0.958	0.447	0.618	0.847
13	RF10	-0.608	0.950	0.469	0.669	0.821	XGB10	-0.690	0.947	0.482	0.690	0.811	LGB10	-0.671	0.952	0.457	0.653	0.829
14	RF11	-0.737	0.946	0.490	0.691	0.809	XGB11	-0.859	0.942	0.506	0.718	0.795	LGB11	-0.815	0.949	0.479	0.674	0.818
15	RF3	-1.150	0.934	0.557	0.759	0.770	XGB3	-1.241	0.932	0.567	0.777	0.761	LGB3	-1.203	0.939	0.537	0.733	0.785
16	RF2	-1.362	0.928	0.593	0.792	0.750	XGB2	-1.433	0.926	0.596	0.804	0.744	LGB2	-1.397	0.933	0.566	0.760	0.769
17	RF6	-1.596	0.918	0.597	0.837	0.721	XGB6	-1.603	0.919	0.595	0.838	0.723	LGB6	-1.591	0.926	0.567	0.795	0.747
18	RF1	-2.530	0.886	0.737	0.973	0.631	XGB1	-2.330	0.895	0.704	0.931	0.657	LGB1	-2.347	0.903	0.676	0.889	0.684

Table S13. Best hyper parameters in RF models at humid stations

	Jorhat			Mohanpur			Palampur			Thrissur		
	n_estimat ors	min_samples_ leaf	max_de pth	n_estimat ors	min_samples_ leaf	max_de pth	n_estimat ors	min_samples_ leaf	max_de pth	n_estimat ors	min_samples_ leaf	max_de pth
RF1	110	1	6	240	1	6	230	5	6	70	5	6
RF2	330	5	8	100	1	8	380	5	8	440	5	8
RF3	250	1	6	250	3	6	430	5	8	50	5	8
RF4	180	5	8	270	1	8	430	5	10	350	5	6
RF5	270	5	8	160	5	12	70	5	10	140	5	6
RF6	170	3	6	180	5	8	400	5	8	480	5	8
RF7	230	5	12	320	3	None	420	3	16	330	5	10
RF8	280	1	16	430	1	14	430	5	12	480	1	14
RF9	270	5	16	350	3	18	150	5	14	440	5	10
RF10	130	5	8	170	1	8	150	5	10	380	5	8
RF11	400	1	8	250	1	8	380	5	10	240	3	10
RF12	130	5	18	90	3	None	160	5	16	270	5	12
RF13	330	5	10	470	1	8	370	5	10	110	3	10
RF14	390	3	10	260	3	10	470	3	12	450	5	10
RF15	410	1	10	490	1	10	330	5	14	470	1	12
RF16	280	1	18	420	1	12	280	1	16	470	1	None
RF17	380	1	18	330	1	None	470	1	None	320	1	16
RF18	160	1	18	350	1	18	350	1	18	410	1	18

Table S14. Best hyper parameters in XGB models at humid stations

	Jorhat			Mohanpur			Palampur			Thrissur		
	n_estimators	learning_rate	max_depth	n_estimators	learning_rate	max_depth	n_estimators	learning_rate	max_depth	n_estimators	learning_rate	max_depth
XGB1	150	0.05	2	220	0.1	2	100	0.05	4	50	0.3	2
XGB2	190	0.15	2	180	0.05	4	110	0.05	4	120	0.05	4
XGB3	110	0.05	4	140	0.05	4	110	0.05	4	190	0.05	4
XGB4	80	0.1	4	150	0.1	4	60	0.15	4	110	0.05	4
XGB5	140	0.05	4	60	0.1	6	230	0.05	4	120	0.05	4
XGB6	50	0.1	4	170	0.05	4	230	0.05	4	320	0.05	4
XGB7	160	0.05	4	120	0.05	6	190	0.05	6	420	0.15	2
XGB8	490	0.05	4	460	0.1	4	170	0.1	4	180	0.1	4
XGB9	480	0.1	2	190	0.1	4	110	0.05	6	120	0.05	6
XGB10	60	0.1	4	250	0.05	4	240	0.05	4	180	0.05	4
XGB11	150	0.05	4	300	0.05	4	100	0.05	6	130	0.05	6
XGB12	140	0.1	4	60	0.1	8	110	0.1	4	430	0.05	4
XGB13	190	0.05	4	470	0.05	2	260	0.05	4	60	0.1	6
XGB14	210	0.05	4	140	0.1	6	460	0.05	4	160	0.05	4
XGB15	350	0.05	4	280	0.1	4	110	0.05	6	460	0.05	4
XGB16	480	0.05	4	430	0.1	4	490	0.05	4	490	0.1	4
XGB17	490	0.15	4	490	0.15	4	490	0.3	2	490	0.1	4
XGB18	490	0.1	4	490	0.15	4	490	0.1	4	490	0.3	2

Table S15. Best hyper parameters in LGB models at humid stations

	Jorhat			Mohanpur			Palampur			Thrissur		
	n_estimators	learning_rate	max_depth	n_estimators	learning_rate	max_depth	n_estimators	learning_rate	max_depth	n_estimators	learning_rate	max_depth
LGB1	140	0.05	2	90	0.05	4	80	0.05	4	180	0.1	2
LGB2	130	0.05	4	90	0.05	6	110	0.05	4	110	0.05	4
LGB3	50	0.1	4	290	0.1	2	80	0.05	14	210	0.05	4
LGB4	80	0.1	4	260	0.05	4	120	0.05	6	100	0.05	4
LGB5	100	0.1	4	140	0.05	6	100	0.05	8	90	0.05	4
LGB6	90	0.05	4	130	0.05	4	120	0.1	4	30	0.15	18
LGB7	200	0.05	4	170	0.05	14	160	0.05	10	460	0.1	2
LGB8	220	0.05	16	300	0.05	12	110	0.05	10	490	0.05	4
LGB9	480	0.1	2	360	0.05	4	130	0.05	6	90	0.05	6
LGB10	60	0.1	4	80	0.1	6	100	0.05	6	90	0.05	18
LGB11	140	0.05	4	180	0.05	4	50	0.1	14	110	0.05	8
LGB12	380	0.1	2	160	0.05	10	370	0.05	4	290	0.05	4
LGB13	150	0.05	4	370	0.1	2	300	0.05	4	110	0.05	10
LGB14	130	0.1	4	220	0.1	4	170	0.05	8	150	0.05	4
LGB15	440	0.05	4	490	0.05	4	110	0.05	10	140	0.05	8
LGB16	240	0.05	14	390	0.05	8	490	0.05	4	490	0.3	2
LGB17	490	0.1	4	490	0.1	8	490	0.1	4	490	0.1	4
LGB18	490	0.1	4	490	0.05	14	490	0.1	4	490	0.3	2

Table S16. Best hyper parameters in RF models at sub-humid stations

	Faizabad			Jabalpur			Raipur			Ranchi			Ranichauri			Samastipur		
	n_estimators	min_samples_leaf	max_depth	n_estimators	min_samples_leaf	max_depth	n_estimators	min_samples_leaf	max_depth	n_estimators	min_samples_leaf	max_depth	n_estimators	min_samples_leaf	max_depth	n_estimators	min_samples_leaf	max_depth
RF1	480	1	6	460	5	6	30	5	6	70	5	6	310	1	6	30	3	6
RF2	70	5	8	390	5	8	150	5	8	80	5	6	420	5	8	330	1	8
RF3	460	1	8	280	5	8	330	3	8	320	5	8	170	5	8	480	5	8
RF4	490	5	10	140	5	10	210	1	8	410	5	8	320	5	10	240	3	8
RF5	110	1	8	200	3	8	240	1	8	160	5	8	460	5	8	400	1	8
RF6	330	3	8	260	5	8	250	5	8	430	5	8	280	5	8	80	1	8
RF7	230	3	12	190	5	18	290	1	10	190	5	18	290	1	14	450	1	10
RF8	370	3	14	440	1	14	120	1	14	390	1	14	240	1	10	410	1	12
RF9	310	3	12	180	5	12	300	5	12	290	5	16	330	3	12	410	1	12
RF10	280	1	10	350	5	10	150	5	8	290	5	8	210	5	10	340	1	10
RF11	400	5	16	270	5	18	300	3	10	180	3	10	230	3	10	230	1	10
RF12	380	5	18	170	5	12	420	1	10	150	5	12	260	5	16	150	1	10
RF13	310	1	10	210	5	12	350	3	12	240	3	8	480	5	10	330	3	10
RF14	290	5	14	300	5	14	210	1	10	480	5	10	270	3	12	200	3	12
RF15	190	1	12	330	1	12	440	1	12	310	1	12	340	3	10	300	3	14
RF16	300	1	18	440	1	16	480	1	18	470	1	18	280	1	18	480	1	None
RF17	320	1	None	320	1	None	450	1	18	280	1	18	480	1	None	400	1	None
RF18	470	1	18	440	1	18	440	1	16	240	1	16	430	1	None	260	1	None

Table S17. Best hyper parameters in XGB models at sub-humid stations

	Faizabad			Jabalpur			Raipur			Ranchi			Ranichauri			Samastipur		
	n_estim ators	learning _rate	max_d epth	n_estim ators	learning _rate	max_d epth	n_estim ators	learning _rate	max_d epth	n_estim ators	learning _rate	max_d epth	n_estim ators	learning _rate	max_d epth	n_estim ators	learning _rate	max_d epth
XG B1	140	0.05	4	100	0.05	4	120	0.05	2	140	0.1	2	50	0.1	4	50	0.1	4
XG B2	140	0.05	4	50	0.1	4	50	0.1	4	430	0.05	2	40	0.15	4	60	0.1	6
XG B3	130	0.1	4	170	0.1	4	80	0.1	4	420	0.05	2	140	0.05	4	140	0.05	4
XG B4	60	0.1	6	210	0.05	4	450	0.05	2	160	0.05	4	250	0.05	4	330	0.05	4
XG B5	220	0.05	4	210	0.05	4	120	0.05	4	120	0.05	4	120	0.05	6	160	0.1	4
XG B6	210	0.05	4	100	0.1	4	110	0.05	4	50	0.1	4	200	0.05	4	90	0.15	4
XG B7	140	0.05	6	310	0.05	4	120	0.05	6	220	0.05	4	480	0.05	4	170	0.05	6
XG B8	270	0.1	4	490	0.05	4	320	0.05	6	340	0.05	6	160	0.05	6	490	0.05	4
XG B9	200	0.1	4	150	0.1	4	100	0.05	6	250	0.05	4	210	0.05	6	340	0.05	4
XG B10	130	0.05	6	120	0.05	6	110	0.05	4	170	0.05	4	100	0.05	6	220	0.05	4
XG B11	320	0.05	4	150	0.1	4	260	0.05	4	60	0.15	4	120	0.05	6	130	0.05	6
XG B12	70	0.15	6	160	0.1	4	50	0.1	6	220	0.05	4	130	0.05	6	140	0.05	6
XG B13	490	0.05	4	130	0.05	6	330	0.05	4	80	0.1	4	190	0.05	4	280	0.05	4
XG B14	140	0.05	6	370	0.05	4	100	0.05	6	50	0.15	6	350	0.05	4	120	0.05	6
XG B15	350	0.1	4	470	0.05	4	370	0.1	4	460	0.05	4	130	0.05	6	470	0.05	4
XG B16	490	0.15	4	490	0.1	4	490	0.1	4	490	0.3	2	480	0.05	4	400	0.05	6
XG B17	490	0.1	4	490	0.1	4	490	0.15	4	490	0.15	4	490	0.3	2	490	0.1	4
XG B18	490	0.1	4	490	0.1	4	490	0.15	4	490	0.15	4	490	0.1	4	490	0.1	4

Table S18. Best hyper parameters in LGB models at sub-humid stations

	Faizabad			Jabalpur			Raipur			Ranchi			Ranichauri			Samastipur		
	n_estimators	learning_rate	max_depth	n_estimators	learning_rate	max_depth	n_estimators	learning_rate	max_depth	n_estimators	learning_rate	max_depth	n_estimators	learning_rate	max_depth	n_estimators	learning_rate	max_depth
LGB 1	200	0.05	4	100	0.05	4	40	0.1	4	50	0.1	4	80	0.05	4	60	0.1	4
LGB 2	80	0.05	14	110	0.05	4	120	0.05	4	130	0.05	4	110	0.05	4	160	0.05	6
LGB 3	160	0.05	4	50	0.1	6	280	0.05	4	300	0.1	2	110	0.05	6	180	0.05	4
LGB 4	130	0.05	16	100	0.05	6	80	0.05	6	290	0.05	4	100	0.05	8	120	0.05	10
LGB 5	290	0.05	4	170	0.05	4	460	0.05	2	210	0.05	4	120	0.05	6	110	0.05	None
LGB 6	270	0.05	4	90	0.05	6	30	0.15	4	130	0.05	4	110	0.05	None	100	0.05	16
LGB 7	100	0.05	8	140	0.05	6	30	0.15	6	150	0.05	6	490	0.05	4	220	0.05	16
LGB 8	160	0.05	8	490	0.05	4	490	0.1	4	190	0.05	16	150	0.05	None	410	0.05	4
LGB 9	360	0.1	4	260	0.05	4	100	0.05	6	140	0.05	6	180	0.05	16	200	0.05	8
LGB 10	100	0.05	12	90	0.05	6	110	0.05	4	180	0.05	4	120	0.05	6	110	0.05	8
LGB 11	290	0.05	6	170	0.05	6	140	0.05	10	260	0.05	4	130	0.05	6	120	0.05	12
LGB 12	80	0.1	6	120	0.05	6	300	0.15	2	120	0.05	6	210	0.05	6	200	0.05	10
LGB 13	170	0.05	12	390	0.05	4	130	0.05	8	280	0.05	4	190	0.05	4	110	0.05	8
LGB 14	130	0.05	12	60	0.1	6	100	0.05	14	370	0.05	4	180	0.1	4	180	0.05	12
LGB 15	490	0.05	6	280	0.05	8	490	0.15	4	210	0.05	10	170	0.05	8	250	0.05	8
LGB 16	490	0.1	4	490	0.1	4	490	0.15	4	450	0.15	4	250	0.05	10	410	0.05	14
LGB 17	490	0.1	12	490	0.15	4	490	0.15	4	490	0.1	None	490	0.3	2	490	0.1	4
LGB 18	490	0.1	16	490	0.1	4	490	0.15	4	490	0.3	4	490	0.15	4	490	0.1	4

Table S19. Performance indicators of hybrid ML models at Jorhat

RANK	MODEL	GPI	d	MBE	RMSE	R ²	MODEL	GPI	d	MBE	RMSE	R ²	MODEL	GPI	d	MBE	RMSE	R ²
1	GWORF17	1.527	0.987	0.105	0.240	0.952	GWOXGB17	1.648	0.995	0.069	0.144	0.983	GWOLGB18	1.639	0.994	0.072	0.168	0.977
2	GWORF18	1.481	0.985	0.108	0.252	0.947	GWOXGB18	1.640	0.995	0.067	0.148	0.982	GWOLGB17	1.619	0.993	0.075	0.174	0.975
3	GWORF8	1.414	0.985	0.139	0.253	0.946	GWOXGB8	1.370	0.990	0.127	0.207	0.963	GWOLGB8	1.350	0.988	0.131	0.231	0.955
4	GWORF9	1.371	0.984	0.142	0.263	0.941	GWOXGB9	1.036	0.980	0.157	0.298	0.923	GWOLGB12	1.098	0.980	0.156	0.294	0.925
5	GWORF12	1.204	0.979	0.158	0.300	0.922	GWOXGB12	1.023	0.979	0.158	0.301	0.921	GWOLGB9	1.089	0.980	0.157	0.297	0.924
6	GWORF7	1.027	0.975	0.192	0.329	0.906	GWOXGB7	0.867	0.975	0.193	0.327	0.907	GWOLGB7	0.915	0.975	0.193	0.326	0.908
7	GWORF5	0.994	0.974	0.199	0.333	0.903	GWOXGB5	0.842	0.975	0.198	0.331	0.905	GWOLGB5	0.891	0.975	0.199	0.330	0.906
8	GWORF16	0.812	0.970	0.246	0.354	0.893	GWOXGB16	0.829	0.976	0.230	0.318	0.913	GWOLGB16	0.827	0.974	0.232	0.330	0.906
9	GWORF15	0.666	0.965	0.270	0.377	0.878	GWOXGB15	0.627	0.970	0.262	0.357	0.890	GWOLGB15	0.642	0.968	0.264	0.362	0.887
10	GWORF14	0.224	0.950	0.320	0.452	0.822	GWOXGB14	0.175	0.952	0.317	0.443	0.830	GWOLGB14	0.182	0.951	0.320	0.448	0.826
11	GWORF4	0.078	0.944	0.342	0.472	0.806	GWOXGB4	0.005	0.945	0.340	0.471	0.808	GWOLGB4	0.040	0.945	0.341	0.469	0.809
12	GWORF13	-0.716	0.906	0.431	0.581	0.708	GWOXGB13	-0.591	0.915	0.418	0.559	0.730	GWOLGB13	-0.632	0.910	0.423	0.568	0.722
13	GWORF10	-0.721	0.907	0.423	0.587	0.701	GWOXGB10	-0.726	0.908	0.422	0.585	0.703	GWOLGB10	-0.718	0.908	0.423	0.587	0.702
14	GWORF2	-1.196	0.884	0.481	0.644	0.641	GWOXGB2	-1.129	0.887	0.478	0.635	0.650	GWOLGB2	-1.148	0.884	0.478	0.640	0.645
15	GWORF11	-1.773	0.845	0.534	0.705	0.570	GWOXGB11	-1.573	0.856	0.525	0.687	0.591	GWOLGB11	-1.679	0.847	0.531	0.701	0.576
16	GWORF6	-1.835	0.843	0.540	0.712	0.559	GWOXGB6	-1.751	0.844	0.536	0.710	0.562	GWOLGB6	-1.742	0.844	0.536	0.708	0.564
17	GWORF3	-2.081	0.822	0.558	0.735	0.533	GWOXGB3	-1.941	0.827	0.553	0.728	0.541	GWOLGB3	-2.013	0.821	0.558	0.736	0.531
18	GWORF1	-2.473	0.801	0.599	0.776	0.478	GWOXGB1	-2.349	0.800	0.598	0.772	0.483	GWOLGB1	-2.361	0.800	0.598	0.772	0.482

Table S20. Performance indicators of hybrid ML models at Mohanpur

RANK	MODEL	GPI	d	MBE	RMSE	R ²	MODEL	GPI	d	MBE	RMSE	R ²	MODEL	GPI	d	MBE	RMSE	R ²
1	GWORF17	1.687	0.998	0.074	0.116	0.991	GWOXGB17	1.738	0.999	0.051	0.076	0.996	GWOLGB17	1.734	0.999	0.052	0.083	0.995
2	GWORF18	1.666	0.997	0.075	0.122	0.990	GWOXGB18	1.720	0.999	0.053	0.081	0.996	GWOLGB18	1.692	0.998	0.055	0.096	0.994
3	GWORF8	1.553	0.997	0.097	0.141	0.987	GWOXGB8	1.509	0.997	0.090	0.127	0.989	GWOLGB8	1.512	0.997	0.091	0.130	0.989
4	GWORF9	1.543	0.996	0.098	0.143	0.986	GWOXGB9	1.189	0.993	0.125	0.199	0.973	GWOLGB9	1.209	0.993	0.125	0.197	0.974
5	GWORF12	1.245	0.993	0.128	0.206	0.971	GWOXGB12	1.140	0.992	0.129	0.210	0.970	GWOLGB12	1.183	0.993	0.127	0.203	0.972
6	GWORF7	1.211	0.992	0.137	0.208	0.971	GWOXGB7	1.131	0.993	0.136	0.207	0.971	GWOLGB7	1.153	0.993	0.136	0.205	0.971
7	GWORF5	1.119	0.991	0.149	0.224	0.966	GWOXGB5	1.031	0.991	0.150	0.225	0.965	GWOLGB5	1.056	0.991	0.149	0.222	0.966
8	GWORF16	0.885	0.988	0.185	0.258	0.955	GWOXGB16	0.881	0.989	0.180	0.245	0.959	GWOLGB16	0.868	0.989	0.180	0.250	0.957
9	GWORF15	0.841	0.988	0.192	0.264	0.953	GWOXGB15	0.853	0.989	0.185	0.250	0.958	GWOLGB15	0.866	0.989	0.184	0.249	0.958
10	GWORF14	0.362	0.980	0.243	0.337	0.923	GWOXGB14	0.318	0.980	0.244	0.336	0.923	GWOLGB14	0.345	0.980	0.243	0.333	0.925
11	GWORF4	0.240	0.977	0.257	0.353	0.915	GWOXGB4	0.241	0.978	0.254	0.347	0.918	GWOLGB4	0.258	0.979	0.253	0.345	0.919
12	GWORF11	-1.397	0.941	0.396	0.549	0.795	GWOXGB10	-1.324	0.943	0.402	0.543	0.800	GWOLGB11	-1.351	0.942	0.396	0.546	0.797
13	GWORF10	-1.424	0.941	0.406	0.551	0.794	GWOXGB11	-1.349	0.942	0.395	0.548	0.796	GWOLGB10	-1.374	0.942	0.403	0.549	0.796
14	GWORF13	-1.569	0.937	0.420	0.564	0.784	GWOXGB13	-1.444	0.940	0.413	0.554	0.792	GWOLGB13	-1.463	0.940	0.414	0.555	0.791
15	GWORF6	-1.680	0.934	0.426	0.576	0.775	GWOXGB6	-1.618	0.935	0.426	0.573	0.777	GWOLGB6	-1.630	0.935	0.427	0.573	0.777
16	GWORF3	-1.859	0.930	0.442	0.592	0.762	GWOXGB3	-1.735	0.932	0.436	0.584	0.769	GWOLGB3	-1.726	0.932	0.435	0.582	0.770
17	GWORF2	-2.111	0.924	0.468	0.615	0.743	GWOXGB2	-2.016	0.925	0.465	0.611	0.747	GWOLGB2	-2.066	0.923	0.467	0.614	0.744
18	GWORF1	-2.313	0.918	0.483	0.633	0.728	GWOXGB1	-2.262	0.918	0.484	0.633	0.728	GWOLGB1	-2.266	0.917	0.483	0.632	0.729

Table S21. Performance indicators of hybrid ML models at Palampur

RANK	MODEL	GPI	d	MBE	RMSE	R ²	MODEL	GPI	d	MBE	RMSE	R ²	MODEL	GPI	d	MBE	RMSE	R ²
1	GWORF18	1.743	0.997	0.098	0.145	0.990	GWOXGB18	1.809	0.999	0.072	0.099	0.995	GWOLGB18	1.801	0.999	0.072	0.099	0.995
2	GWORF17	1.678	0.997	0.111	0.157	0.988	GWOXGB17	1.793	0.999	0.076	0.102	0.995	GWOLGB17	1.782	0.999	0.076	0.104	0.995
3	GWORF7	1.010	0.990	0.194	0.286	0.961	GWOXGB7	0.957	0.990	0.192	0.283	0.962	GWOLGB7	0.943	0.990	0.193	0.283	0.961
4	GWORF16	0.830	0.988	0.231	0.308	0.954	GWOXGB16	0.852	0.989	0.221	0.293	0.959	GWOLGB16	0.845	0.989	0.221	0.292	0.959
5	GWORF8	0.617	0.985	0.249	0.345	0.943	GWOXGB8	0.539	0.985	0.252	0.350	0.941	GWOLGB8	0.567	0.985	0.248	0.343	0.943
6	GWORF9	0.608	0.985	0.250	0.347	0.942	GWOXGB12	0.349	0.982	0.274	0.380	0.930	GWOLGB12	0.358	0.982	0.272	0.377	0.932
7	GWORF12	0.359	0.981	0.276	0.385	0.929	GWOXGB9	0.321	0.981	0.276	0.385	0.929	GWOLGB9	0.336	0.982	0.274	0.380	0.930
8	GWORF14	0.255	0.980	0.291	0.399	0.924	GWOXGB14	0.275	0.981	0.287	0.390	0.927	GWOLGB14	0.270	0.981	0.286	0.389	0.927
9	GWORF10	0.198	0.979	0.292	0.409	0.920	GWOXGB10	0.200	0.979	0.289	0.404	0.921	GWOLGB10	0.180	0.979	0.290	0.405	0.921
10	GWORF5	0.059	0.977	0.308	0.427	0.912	GWOXGB5	0.031	0.977	0.311	0.427	0.912	GWOLGB5	0.039	0.977	0.308	0.424	0.913
11	GWORF15	-0.029	0.976	0.326	0.436	0.909	GWOXGB15	-0.049	0.975	0.325	0.436	0.908	GWOLGB15	-0.045	0.976	0.325	0.433	0.909
12	GWORF13	-0.174	0.973	0.345	0.454	0.901	GWOXGB13	-0.145	0.974	0.341	0.448	0.903	GWOLGB13	-0.161	0.974	0.342	0.449	0.903
13	GWORF2	-0.740	0.964	0.400	0.525	0.867	GWOXGB2	-0.675	0.964	0.396	0.519	0.870	GWOLGB2	-0.686	0.964	0.396	0.518	0.871
14	GWORF11	-0.763	0.963	0.393	0.531	0.864	GWOXGB11	-0.788	0.961	0.396	0.537	0.862	GWOLGB11	-0.758	0.962	0.392	0.531	0.864
15	GWORF4	-0.816	0.962	0.403	0.536	0.862	GWOXGB4	-0.793	0.962	0.405	0.535	0.862	GWOLGB4	-0.796	0.962	0.402	0.534	0.863
16	GWORF6	-1.190	0.954	0.427	0.582	0.837	GWOXGB6	-1.135	0.954	0.424	0.581	0.838	GWOLGB6	-1.116	0.955	0.422	0.576	0.840
17	GWORF3	-1.387	0.951	0.455	0.601	0.826	GWOXGB3	-1.351	0.950	0.457	0.601	0.826	GWOLGB3	-1.360	0.950	0.456	0.599	0.827
18	GWORF1	-2.257	0.933	0.530	0.689	0.771	GWOXGB1	-2.191	0.932	0.530	0.691	0.770	GWOLGB1	-2.199	0.932	0.532	0.688	0.772

Table S22. Performance indicators of hybrid ML models at Thrissur

RANK	MODEL	GPI	d	MBE	RMSE	R ²	MODEL	GPI	d	MBE	RMSE	R ²	MODEL	GPI	d	MBE	RMSE	R ²
1	GWORF17	1.404	0.997	0.076	0.127	0.990	GWOXGB18	1.513	0.999	0.053	0.073	0.997	GWOLGB18	1.514	0.999	0.054	0.074	0.996
2	GWORF18	1.369	0.997	0.082	0.138	0.988	GWOXGB17	1.488	0.999	0.056	0.084	0.996	GWOLGB17	1.490	0.999	0.056	0.085	0.995
3	GWORF16	1.163	0.994	0.129	0.189	0.977	GWOXGB16	1.205	0.995	0.119	0.167	0.982	GWOLGB16	1.217	0.996	0.119	0.164	0.983
4	GWORF8	1.162	0.994	0.116	0.199	0.975	GWOXGB8	1.179	0.994	0.112	0.184	0.978	GWOLGB8	1.193	0.995	0.110	0.182	0.979
5	GWORF9	1.142	0.993	0.122	0.202	0.974	GWOXGB15	1.038	0.993	0.150	0.214	0.971	GWOLGB15	1.036	0.992	0.150	0.216	0.970
6	GWORF15	1.027	0.992	0.154	0.223	0.968	GWOXGB7	0.578	0.981	0.207	0.338	0.926	GWOLGB7	0.581	0.981	0.207	0.338	0.927
7	GWORF7	0.567	0.980	0.207	0.341	0.925	GWOXGB14	0.473	0.978	0.231	0.357	0.918	GWOLGB14	0.481	0.979	0.230	0.355	0.919
8	GWORF14	0.456	0.978	0.231	0.360	0.917	GWOXGB12	0.134	0.968	0.277	0.429	0.882	GWOLGB12	0.150	0.969	0.275	0.424	0.884
9	GWORF12	0.123	0.968	0.275	0.428	0.882	GWOXGB9	0.104	0.967	0.281	0.434	0.879	GWOLGB9	0.117	0.967	0.280	0.430	0.881
10	GWORF4	0.030	0.966	0.293	0.442	0.874	GWOXGB4	0.057	0.966	0.290	0.442	0.875	GWOLGB4	0.059	0.966	0.292	0.440	0.876
11	GWORF5	-0.245	0.957	0.329	0.491	0.845	GWOXGB5	-0.210	0.956	0.326	0.491	0.845	GWOLGB5	-0.220	0.956	0.329	0.491	0.845
12	GWORF13	-0.306	0.957	0.365	0.490	0.846	GWOXGB11	-0.236	0.958	0.361	0.483	0.850	GWOLGB11	-0.220	0.959	0.358	0.479	0.852
13	GWORF11	-0.313	0.957	0.367	0.490	0.845	GWOXGB13	-0.270	0.957	0.364	0.490	0.846	GWOLGB13	-0.248	0.958	0.360	0.485	0.849
14	GWORF3	-0.460	0.952	0.389	0.514	0.830	GWOXGB3	-0.388	0.953	0.386	0.509	0.834	GWOLGB3	-0.398	0.953	0.387	0.509	0.833
15	GWORF10	-1.043	0.930	0.457	0.607	0.763	GWOXGB10	-0.945	0.932	0.453	0.601	0.768	GWOLGB10	-0.964	0.931	0.454	0.602	0.767
16	GWORF2	-1.205	0.924	0.478	0.631	0.745	GWOXGB2	-1.115	0.925	0.477	0.625	0.749	GWOLGB2	-1.130	0.925	0.477	0.626	0.748
17	GWORF6	-2.277	0.875	0.580	0.776	0.614	GWOXGB6	-2.117	0.878	0.574	0.769	0.622	GWOLGB6	-2.172	0.876	0.577	0.773	0.617
18	GWORF1	-2.596	0.857	0.607	0.812	0.577	GWOXGB1	-2.487	0.857	0.608	0.811	0.578	GWOLGB1	-2.486	0.858	0.605	0.809	0.580

Table S23. Performance indicators of hybrid ML models at Faizabad

RANK	MODEL	GPI	d	MBE	RMSE	R ²	MODEL	GPI	d	MBE	RMSE	R ²	MODEL	GPI	d	MBE	RMSE	R ²
1	GWORF17	1.956	0.997	0.150	0.234	0.990	GWOXGB17	2.123	0.999	0.100	0.157	0.995	GWOLGB17	2.121	0.999	0.098	0.165	0.995
2	GWORF18	1.946	0.997	0.146	0.243	0.989	GWOXGB18	2.120	0.999	0.101	0.157	0.995	GWOLGB18	2.102	0.998	0.102	0.174	0.994
3	GWORF8	1.522	0.992	0.244	0.383	0.971	GWOXGB16	1.650	0.995	0.241	0.325	0.979	GWOLGB16	1.667	0.995	0.236	0.323	0.980
4	GWORF9	1.517	0.992	0.246	0.384	0.971	GWOXGB8	1.564	0.993	0.239	0.370	0.973	GWOLGB8	1.559	0.993	0.240	0.374	0.973
5	GWORF16	1.484	0.993	0.273	0.382	0.972	GWOXGB15	1.288	0.990	0.323	0.445	0.961	GWOLGB15	1.280	0.990	0.323	0.450	0.960
6	GWORF15	1.161	0.988	0.341	0.476	0.955	GWOXGB13	1.099	0.987	0.376	0.495	0.952	GWOLGB13	1.077	0.987	0.378	0.505	0.950
7	GWORF13	1.007	0.986	0.384	0.512	0.948	GWOXGB11	0.939	0.984	0.385	0.554	0.940	GWOLGB11	0.928	0.984	0.386	0.559	0.939
8	GWORF11	0.859	0.983	0.390	0.564	0.937	GWOXGB3	0.691	0.980	0.450	0.613	0.926	GWOLGB3	0.700	0.980	0.447	0.612	0.926
9	GWORF3	0.606	0.980	0.455	0.619	0.925	GWOXGB7	-0.618	0.951	0.612	0.939	0.826	GWOLGB7	-0.591	0.952	0.613	0.930	0.829
10	GWORF7	-0.725	0.952	0.614	0.933	0.829	GWOXGB9	-0.834	0.947	0.665	0.976	0.812	GWOLGB12	-0.851	0.946	0.663	0.981	0.811
11	GWORF12	-1.037	0.945	0.670	0.990	0.807	GWOXGB12	-0.881	0.946	0.665	0.990	0.808	GWOLGB5	-0.870	0.946	0.673	0.981	0.811
12	GWORF10	-1.070	0.945	0.686	0.991	0.807	GWOXGB5	-0.889	0.946	0.677	0.985	0.809	GWOLGB9	-0.871	0.946	0.668	0.985	0.809
13	GWORF5	-1.077	0.944	0.682	0.993	0.806	GWOXGB10	-0.936	0.945	0.688	0.993	0.806	GWOLGB10	-0.911	0.945	0.686	0.986	0.808
14	GWORF14	-1.223	0.941	0.710	1.018	0.796	GWOXGB14	-1.103	0.940	0.711	1.025	0.793	GWOLGB14	-1.088	0.941	0.708	1.022	0.794
15	GWORF4	-1.599	0.933	0.774	1.080	0.770	GWOXGB4	-1.405	0.933	0.769	1.077	0.772	GWOLGB4	-1.408	0.933	0.770	1.076	0.772
16	GWORF2	-1.604	0.933	0.777	1.078	0.771	GWOXGB6	-1.461	0.932	0.776	1.088	0.767	GWOLGB6	-1.472	0.932	0.775	1.091	0.766
17	GWORF6	-1.683	0.931	0.780	1.098	0.763	GWOXGB2	-1.470	0.931	0.780	1.085	0.768	GWOLGB2	-1.491	0.930	0.781	1.086	0.767
18	GWORF1	-2.039	0.922	0.845	1.148	0.740	GWOXGB1	-1.877	0.921	0.847	1.154	0.738	GWOLGB1	-1.879	0.921	0.847	1.154	0.738

Table S24. Performance indicators of hybrid ML models at Jabalpur

RANK	MODEL	GPI	d	MBE	RMSE	R ²	MODEL	GPI	d	MBE	RMSE	R ²	MODEL	GPI	d	MBE	RMSE	R ²
1	GWORF17	1.920	0.998	0.104	0.163	0.991	GWOXGB18	2.058	0.999	0.071	0.105	0.996	GWOLGB18	2.055	0.999	0.071	0.104	0.997
2	GWORF18	1.909	0.998	0.103	0.168	0.991	GWOXGB17	2.052	0.999	0.073	0.105	0.996	GWOLGB17	2.052	0.999	0.072	0.104	0.997
3	GWORF16	1.434	0.995	0.178	0.249	0.980	GWOXGB16	1.542	0.996	0.158	0.214	0.985	GWOLGB16	1.545	0.996	0.157	0.211	0.985
4	GWORF8	1.392	0.994	0.167	0.266	0.977	GWOXGB8	1.370	0.995	0.165	0.257	0.978	GWOLGB8	1.361	0.994	0.164	0.258	0.978
5	GWORF9	1.336	0.994	0.173	0.276	0.975	GWOXGB15	1.017	0.992	0.224	0.313	0.968	GWOLGB15	0.989	0.992	0.225	0.317	0.967
6	GWORF15	0.966	0.991	0.233	0.327	0.965	GWOXGB13	0.118	0.983	0.335	0.448	0.935	GWOLGB13	0.107	0.983	0.336	0.448	0.935
7	GWORF13	0.044	0.982	0.339	0.455	0.932	GWOXGB11	0.061	0.981	0.314	0.467	0.929	GWOLGB11	0.054	0.981	0.310	0.468	0.929
8	GWORF11	0.003	0.981	0.312	0.473	0.927	GWOXGB12	-0.103	0.979	0.327	0.490	0.922	GWOLGB12	-0.091	0.979	0.325	0.486	0.923
9	GWORF12	-0.156	0.979	0.328	0.492	0.921	GWOXGB7	-0.105	0.979	0.325	0.492	0.921	GWOLGB7	-0.094	0.979	0.323	0.488	0.922
10	GWORF7	-0.182	0.979	0.327	0.497	0.919	GWOXGB9	-0.159	0.979	0.334	0.497	0.919	GWOLGB9	-0.148	0.979	0.333	0.494	0.921
11	GWORF5	-0.345	0.977	0.352	0.513	0.914	GWOXGB5	-0.267	0.977	0.349	0.510	0.915	GWOLGB5	-0.266	0.978	0.349	0.507	0.916
12	GWORF3	-0.580	0.975	0.395	0.534	0.907	GWOXGB3	-0.487	0.976	0.394	0.530	0.908	GWOLGB14	-0.504	0.975	0.379	0.535	0.907
13	GWORF14	-0.590	0.974	0.379	0.541	0.905	GWOXGB14	-0.514	0.975	0.379	0.540	0.905	GWOLGB3	-0.507	0.975	0.394	0.531	0.908
14	GWORF4	-0.833	0.972	0.409	0.566	0.896	GWOXGB4	-0.701	0.972	0.405	0.560	0.898	GWOLGB4	-0.710	0.972	0.405	0.558	0.899
15	GWORF10	-1.104	0.968	0.411	0.604	0.881	GWOXGB10	-1.049	0.967	0.411	0.610	0.879	GWOLGB10	-1.012	0.968	0.410	0.601	0.882
16	GWORF6	-1.405	0.964	0.438	0.636	0.868	GWOXGB6	-1.319	0.963	0.441	0.638	0.867	GWOLGB6	-1.301	0.964	0.438	0.633	0.869
17	GWORF2	-1.731	0.960	0.487	0.662	0.857	GWOXGB2	-1.573	0.961	0.485	0.659	0.859	GWOLGB2	-1.585	0.961	0.486	0.658	0.859
18	GWORF1	-2.077	0.956	0.520	0.695	0.842	GWOXGB1	-1.942	0.955	0.520	0.697	0.842	GWOLGB1	-1.945	0.956	0.520	0.694	0.843

Table S25. Performance indicators of hybrid ML models at Raipur

RANK	MODEL	GPI	d	MBE	RMSE	R ²	MODEL	GPI	d	MBE	RMSE	R ²	MODEL	GPI	d	MBE	RMSE	R ²
1	GWORF17	2.032	0.997	0.108	0.186	0.990	GWOXGB17	2.184	0.999	0.077	0.125	0.995	GWOLGB17	2.174	0.999	0.082	0.136	0.995
2	GWORF18	2.001	0.997	0.111	0.193	0.989	GWOXGB18	2.171	0.999	0.077	0.130	0.995	GWOLGB18	2.162	0.999	0.084	0.138	0.994
3	GWORF16	1.646	0.995	0.173	0.257	0.981	GWOXGB16	1.765	0.996	0.153	0.219	0.986	GWOLGB16	1.771	0.996	0.156	0.223	0.985
4	GWORF8	1.464	0.993	0.181	0.301	0.974	GWOXGB8	1.481	0.994	0.177	0.290	0.975	GWOLGB8	1.510	0.994	0.178	0.286	0.976
5	GWORF9	1.415	0.993	0.187	0.310	0.972	GWOXGB15	1.216	0.992	0.228	0.333	0.967	GWOLGB15	1.216	0.992	0.230	0.335	0.967
6	GWORF15	1.154	0.991	0.236	0.347	0.965	GWOXGB13	0.448	0.984	0.338	0.458	0.939	GWOLGB13	0.427	0.984	0.340	0.462	0.937
7	GWORF13	0.337	0.983	0.343	0.470	0.935	GWOXGB11	0.290	0.981	0.336	0.490	0.930	GWOLGB11	0.313	0.982	0.332	0.488	0.930
8	GWORF11	0.214	0.981	0.337	0.496	0.928	GWOXGB3	-0.140	0.976	0.399	0.547	0.912	GWOLGB3	-0.120	0.977	0.396	0.545	0.913
9	GWORF3	-0.222	0.976	0.399	0.549	0.912	GWOXGB7	-0.396	0.972	0.377	0.601	0.894	GWOLGB7	-0.415	0.971	0.379	0.602	0.894
10	GWORF7	-0.520	0.971	0.380	0.606	0.892	GWOXGB12	-0.454	0.971	0.388	0.607	0.892	GWOLGB12	-0.443	0.971	0.392	0.603	0.893
11	GWORF12	-0.528	0.971	0.390	0.604	0.893	GWOXGB9	-0.520	0.970	0.397	0.615	0.889	GWOLGB9	-0.522	0.970	0.399	0.613	0.890
12	GWORF5	-0.712	0.969	0.412	0.624	0.886	GWOXGB5	-0.592	0.969	0.412	0.621	0.887	GWOLGB5	-0.597	0.969	0.412	0.622	0.887
13	GWORF14	-0.811	0.968	0.422	0.636	0.881	GWOXGB14	-0.707	0.968	0.422	0.636	0.881	GWOLGB14	-0.707	0.968	0.424	0.635	0.882
14	GWORF4	-1.072	0.965	0.459	0.662	0.871	GWOXGB4	-0.928	0.965	0.459	0.659	0.873	GWOLGB4	-0.944	0.965	0.457	0.660	0.872
15	GWORF10	-1.251	0.962	0.470	0.685	0.862	GWOXGB10	-1.119	0.962	0.468	0.686	0.862	GWOLGB10	-1.097	0.962	0.467	0.681	0.864
16	GWORF6	-1.531	0.958	0.499	0.715	0.850	GWOXGB6	-1.392	0.958	0.502	0.715	0.850	GWOLGB6	-1.413	0.958	0.503	0.715	0.850
17	GWORF2	-1.647	0.957	0.517	0.725	0.846	GWOXGB2	-1.491	0.957	0.517	0.724	0.846	GWOLGB2	-1.490	0.957	0.516	0.723	0.847
18	GWORF1	-1.968	0.953	0.552	0.757	0.832	GWOXGB1	-1.816	0.952	0.556	0.758	0.832	GWOLGB1	-1.826	0.952	0.553	0.757	0.832

Table S26. Performance indicators of hybrid ML models at Ranchi

RANK	MODEL	GPI	d	MBE	RMSE	R ²	MODEL	GPI	d	MBE	RMSE	R ²	MODEL	GPI	d	MBE	RMSE	R ²
1	GWORF17	1.916	0.996	0.107	0.167	0.984	GWOXGB18	2.025	0.999	0.062	0.092	0.995	GWOLGB17	2.014	0.998	0.065	0.105	0.994
2	GWORF18	1.898	0.996	0.108	0.171	0.983	GWOXGB17	2.021	0.999	0.064	0.092	0.995	GWOLGB18	1.995	0.998	0.071	0.107	0.993
3	GWORF8	1.601	0.992	0.149	0.224	0.970	GWOXGB8	1.493	0.993	0.142	0.211	0.974	GWOLGB8	1.505	0.993	0.143	0.213	0.973
4	GWORF9	1.563	0.992	0.152	0.231	0.968	GWOXGB16	1.259	0.990	0.184	0.250	0.963	GWOLGB16	1.248	0.990	0.187	0.255	0.961
5	GWORF16	1.204	0.988	0.207	0.283	0.953	GWOXGB15	0.958	0.986	0.224	0.302	0.946	GWOLGB15	0.954	0.986	0.226	0.305	0.945
6	GWORF15	0.995	0.985	0.233	0.315	0.941	GWOXGB12	0.683	0.980	0.236	0.357	0.924	GWOLGB12	0.696	0.980	0.235	0.356	0.925
7	GWORF12	0.742	0.980	0.240	0.362	0.922	GWOXGB9	0.635	0.979	0.242	0.364	0.922	GWOLGB9	0.645	0.979	0.241	0.364	0.922
8	GWORF7	0.616	0.978	0.254	0.379	0.915	GWOXGB7	0.557	0.978	0.253	0.375	0.917	GWOLGB7	0.571	0.978	0.251	0.374	0.917
9	GWORF5	0.591	0.977	0.260	0.380	0.914	GWOXGB5	0.552	0.978	0.256	0.374	0.917	GWOLGB5	0.563	0.978	0.257	0.373	0.918
10	GWORF4	0.030	0.968	0.330	0.447	0.881	GWOXGB4	0.029	0.968	0.327	0.443	0.884	GWOLGB14	0.056	0.969	0.322	0.441	0.885
11	GWORF14	0.026	0.968	0.327	0.450	0.880	GWOXGB14	0.020	0.968	0.325	0.446	0.882	GWOLGB4	0.032	0.969	0.327	0.443	0.884
12	GWORF11	-1.062	0.944	0.417	0.575	0.804	GWOXGB11	-0.933	0.946	0.412	0.565	0.811	GWOLGB11	-0.927	0.946	0.409	0.563	0.812
13	GWORF13	-1.132	0.943	0.433	0.578	0.802	GWOXGB13	-1.003	0.945	0.429	0.569	0.807	GWOLGB13	-1.001	0.945	0.426	0.569	0.808
14	GWORF3	-1.343	0.938	0.453	0.599	0.787	GWOXGB3	-1.216	0.939	0.450	0.592	0.792	GWOLGB3	-1.223	0.940	0.449	0.591	0.792
15	GWORF6	-1.741	0.928	0.475	0.642	0.756	GWOXGB6	-1.569	0.929	0.470	0.633	0.762	GWOLGB6	-1.574	0.930	0.468	0.632	0.763
16	GWORF10	-1.754	0.928	0.474	0.645	0.754	GWOXGB10	-1.597	0.929	0.471	0.639	0.758	GWOLGB10	-1.607	0.930	0.470	0.638	0.759
17	GWORF1	-2.067	0.920	0.510	0.668	0.735	GWOXGB1	-1.940	0.920	0.511	0.668	0.735	GWOLGB1	-1.965	0.920	0.510	0.667	0.735
18	GWORF2	-2.083	0.920	0.510	0.672	0.733	GWOXGB2	-1.975	0.920	0.514	0.674	0.731	GWOLGB2	-1.982	0.920	0.512	0.672	0.733

Table S27. Performance indicators of hybrid ML models at Ranichauri

RANK	MODEL	GPI	d	MBE	RMSE	R ²	MODEL	GPI	d	MBE	RMSE	R ²	MODEL	GPI	d	MBE	RMSE	R ²
1	GWORF18	1.632	0.997	0.084	0.127	0.989	GWOXGB17	1.711	0.999	0.056	0.083	0.995	GWOLGB17	1.707	0.999	0.056	0.082	0.996
2	GWORF17	1.592	0.997	0.090	0.133	0.988	GWOXGB18	1.700	0.999	0.058	0.085	0.995	GWOLGB18	1.699	0.999	0.057	0.083	0.995
3	GWORF7	1.216	0.994	0.135	0.190	0.976	GWOXGB7	1.150	0.994	0.129	0.182	0.978	GWOLGB7	1.144	0.994	0.129	0.182	0.978
4	GWORF9	0.922	0.991	0.170	0.229	0.965	GWOXGB8	0.844	0.991	0.167	0.227	0.966	GWOLGB8	0.840	0.991	0.167	0.226	0.966
5	GWORF12	0.920	0.991	0.170	0.229	0.965	GWOXGB9	0.830	0.991	0.169	0.228	0.965	GWOLGB9	0.836	0.991	0.168	0.226	0.966
6	GWORF8	0.913	0.991	0.171	0.230	0.965	GWOXGB12	0.823	0.991	0.170	0.229	0.965	GWOLGB12	0.830	0.991	0.169	0.227	0.966
7	GWORF5	0.800	0.990	0.184	0.244	0.960	GWOXGB5	0.717	0.990	0.183	0.244	0.961	GWOLGB5	0.719	0.990	0.182	0.242	0.961
8	GWORF16	0.464	0.985	0.210	0.290	0.944	GWOXGB16	0.470	0.987	0.204	0.279	0.948	GWOLGB16	0.455	0.986	0.203	0.282	0.947
9	GWORF14	0.230	0.982	0.232	0.318	0.933	GWOXGB14	0.195	0.983	0.231	0.314	0.934	GWOLGB14	0.193	0.983	0.231	0.314	0.934
10	GWORF15	0.014	0.980	0.255	0.340	0.923	GWOXGB15	-0.006	0.980	0.252	0.337	0.924	GWOLGB15	-0.013	0.980	0.253	0.338	0.924
11	GWORF10	-0.163	0.976	0.257	0.365	0.911	GWOXGB10	-0.198	0.976	0.258	0.364	0.912	GWOLGB10	-0.170	0.977	0.255	0.361	0.913
12	GWORF4	-0.214	0.976	0.276	0.364	0.912	GWOXGB4	-0.216	0.977	0.274	0.360	0.913	GWOLGB4	-0.231	0.977	0.275	0.362	0.913
13	GWORF11	-0.660	0.969	0.301	0.414	0.886	GWOXGB11	-0.668	0.969	0.302	0.414	0.886	GWOLGB11	-0.646	0.969	0.300	0.412	0.887
14	GWORF13	-0.951	0.965	0.333	0.439	0.872	GWOXGB13	-0.869	0.966	0.329	0.431	0.876	GWOLGB13	-0.868	0.966	0.329	0.431	0.876
15	GWORF6	-1.033	0.963	0.332	0.449	0.866	GWOXGB6	-1.015	0.963	0.332	0.448	0.866	GWOLGB6	-1.014	0.963	0.331	0.449	0.866
16	GWORF2	-1.353	0.958	0.366	0.475	0.850	GWOXGB2	-1.328	0.958	0.366	0.475	0.850	GWOLGB2	-1.315	0.958	0.366	0.474	0.850
17	GWORF3	-1.960	0.947	0.407	0.528	0.814	GWOXGB3	-1.851	0.948	0.404	0.522	0.818	GWOLGB3	-1.873	0.948	0.406	0.526	0.816
18	GWORF1	-2.368	0.939	0.439	0.559	0.792	GWOXGB1	-2.289	0.939	0.437	0.558	0.793	GWOLGB1	-2.293	0.939	0.440	0.558	0.793

Table S28. Performance indicators of hybrid ML models at Samastipur

RANK	MODEL	GPI	d	MBE	RMSE	R ²	MODEL	GPI	d	MBE	RMSE	R ²	MODEL	GPI	d	MBE	RMSE	R ²
1	GWORF17	1.603	0.997	0.113	0.175	0.988	GWOXGB17	1.714	0.999	0.074	0.104	0.996	GWOLGB17	1.694	0.999	0.074	0.104	0.996
2	GWORF18	1.516	0.996	0.119	0.207	0.983	GWOXGB18	1.683	0.999	0.080	0.115	0.995	GWOLGB18	1.659	0.999	0.080	0.117	0.995
3	GWORF8	1.223	0.992	0.186	0.273	0.970	GWOXGB8	1.178	0.993	0.183	0.264	0.972	GWOLGB8	1.178	0.993	0.181	0.258	0.973
4	GWORF9	1.221	0.992	0.186	0.273	0.970	GWOXGB16	0.944	0.989	0.221	0.326	0.958	GWOLGB16	0.956	0.990	0.218	0.318	0.960
5	GWORF16	0.968	0.989	0.230	0.332	0.956	GWOXGB7	0.796	0.987	0.249	0.359	0.948	GWOLGB7	0.774	0.987	0.250	0.360	0.948
6	GWORF7	0.810	0.986	0.255	0.368	0.946	GWOXGB9	0.624	0.983	0.277	0.397	0.937	GWOLGB15	0.646	0.985	0.280	0.385	0.940
7	GWORF15	0.654	0.984	0.287	0.396	0.937	GWOXGB12	0.623	0.983	0.275	0.399	0.936	GWOLGB12	0.622	0.984	0.273	0.396	0.937
8	GWORF12	0.578	0.982	0.285	0.419	0.930	GWOXGB15	0.605	0.983	0.287	0.398	0.937	GWOLGB9	0.611	0.983	0.276	0.398	0.937
9	GWORF5	0.524	0.981	0.305	0.424	0.928	GWOXGB5	0.501	0.981	0.303	0.421	0.929	GWOLGB5	0.497	0.981	0.301	0.419	0.929
10	GWORF14	0.063	0.972	0.375	0.511	0.895	GWOXGB14	0.050	0.972	0.377	0.510	0.896	GWOLGB14	0.067	0.973	0.371	0.506	0.898
11	GWORF4	-0.281	0.964	0.427	0.569	0.870	GWOXGB4	-0.258	0.965	0.426	0.565	0.872	GWOLGB4	-0.262	0.965	0.424	0.564	0.872
12	GWORF13	-0.507	0.959	0.445	0.612	0.850	GWOXGB13	-0.502	0.959	0.444	0.615	0.849	GWOLGB13	-0.501	0.959	0.444	0.612	0.850
13	GWORF10	-0.716	0.952	0.455	0.651	0.830	GWOXGB10	-0.641	0.954	0.449	0.641	0.835	GWOLGB10	-0.654	0.954	0.450	0.642	0.835
14	GWORF11	-0.914	0.948	0.484	0.679	0.815	GWOXGB11	-0.861	0.948	0.482	0.675	0.817	GWOLGB11	-0.821	0.949	0.475	0.667	0.821
15	GWORF3	-1.216	0.940	0.531	0.720	0.792	GWOXGB3	-1.191	0.940	0.534	0.722	0.791	GWOLGB3	-1.189	0.940	0.533	0.722	0.791
16	GWORF2	-1.460	0.934	0.563	0.754	0.772	GWOXGB2	-1.419	0.934	0.566	0.756	0.771	GWOLGB2	-1.395	0.934	0.562	0.752	0.773
17	GWORF6	-1.671	0.926	0.565	0.790	0.750	GWOXGB6	-1.560	0.928	0.561	0.782	0.755	GWOLGB6	-1.577	0.927	0.562	0.784	0.754
18	GWORF1	-2.397	0.905	0.665	0.875	0.693	GWOXGB1	-2.286	0.905	0.663	0.871	0.696	GWOLGB1	-2.306	0.905	0.666	0.874	0.694