Development of optimal ML models for predicting the permanent transverse displacement of CHS steel members

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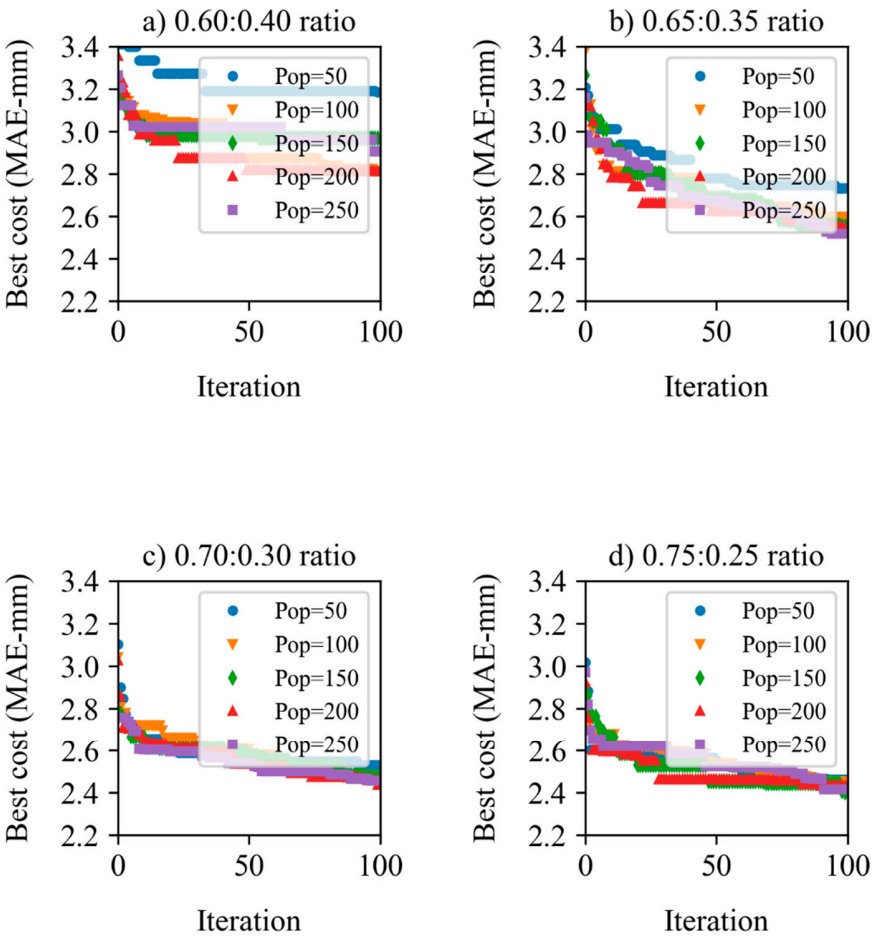


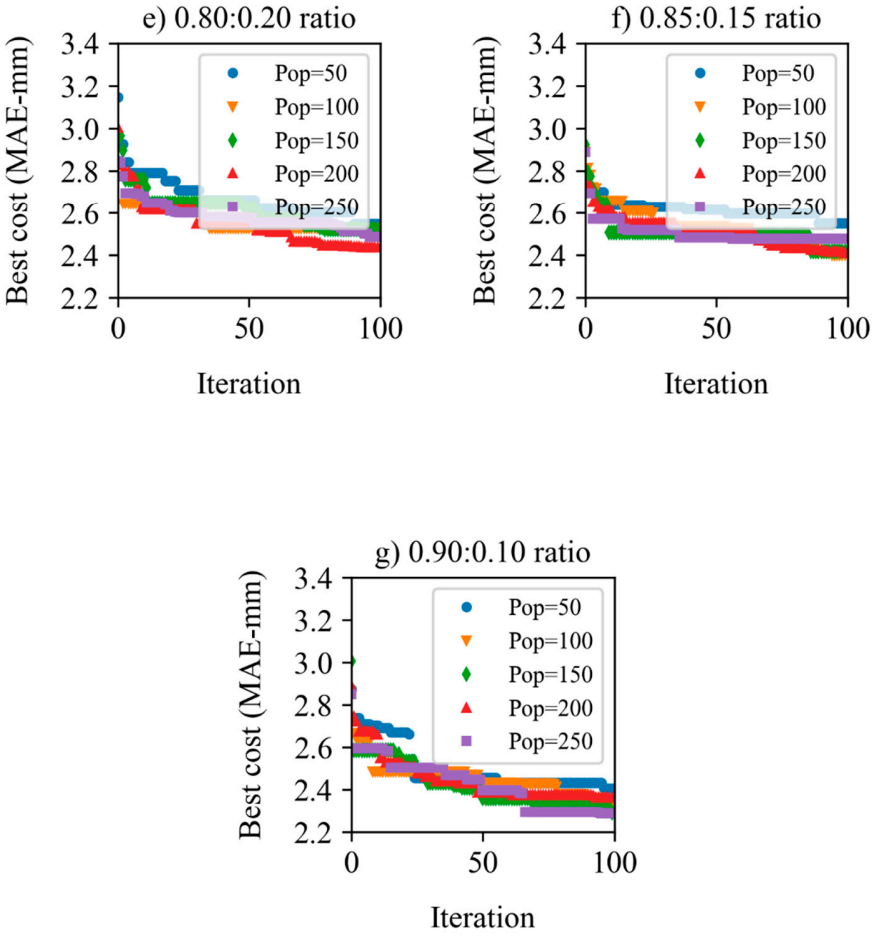
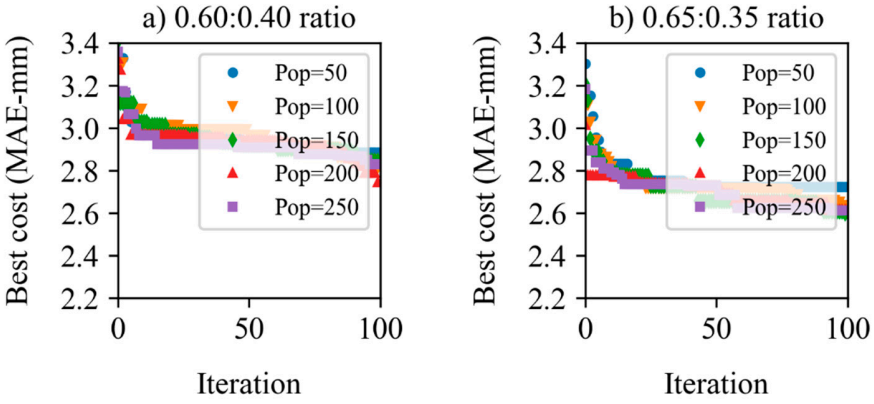


Fig. S-1. PSO-XGB models' optimization process for different population sizes.



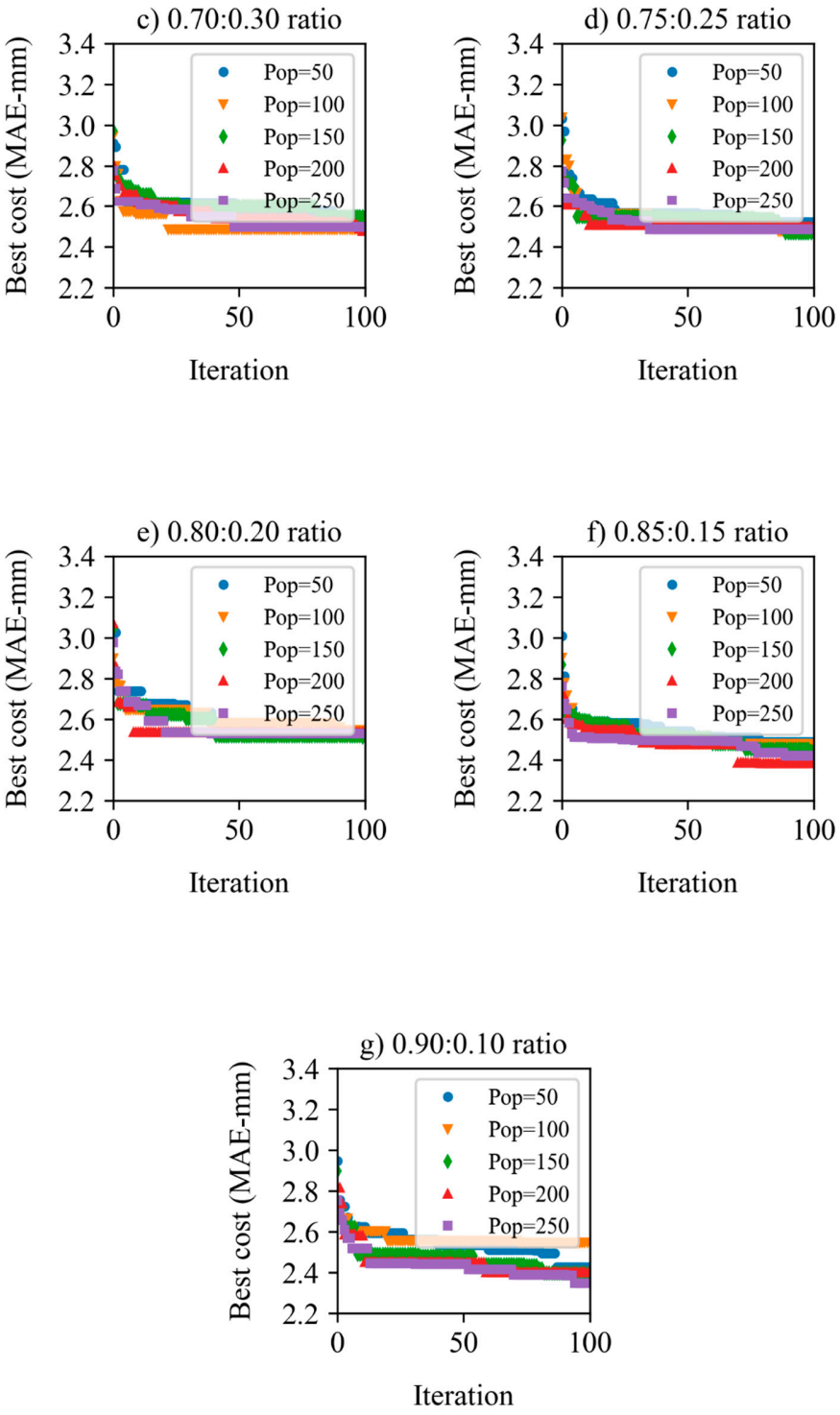
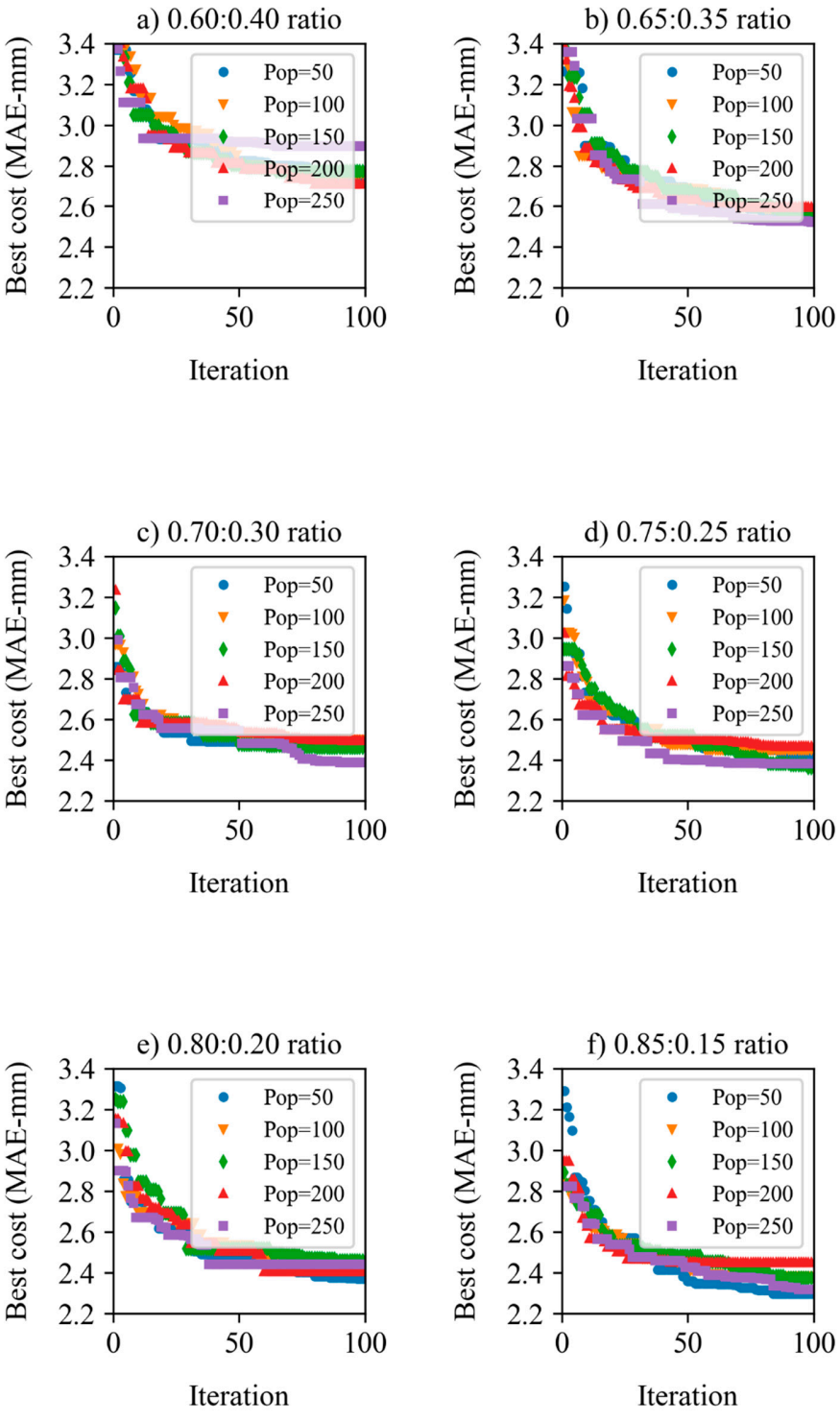


Fig. S-2. GWO-XGB models' optimization process for different population sizes.


a) 0.60:0.40 ratio
b) 0.65:0.35 ratio
c) 0.70:0.30 ratio
d) 0.75:0.25 ratio
e) 0.80:0.20 ratio
f) 0.85:0.15 ratio
Best cost (MAE-mm)
Iteration
Pop=50
Pop=100
Pop=150
Pop=200
Pop=250
3.4
3.2
3.0
2.8
2.6
2.4
2.2
0
50
100

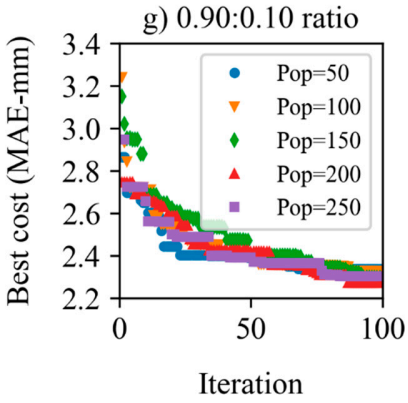
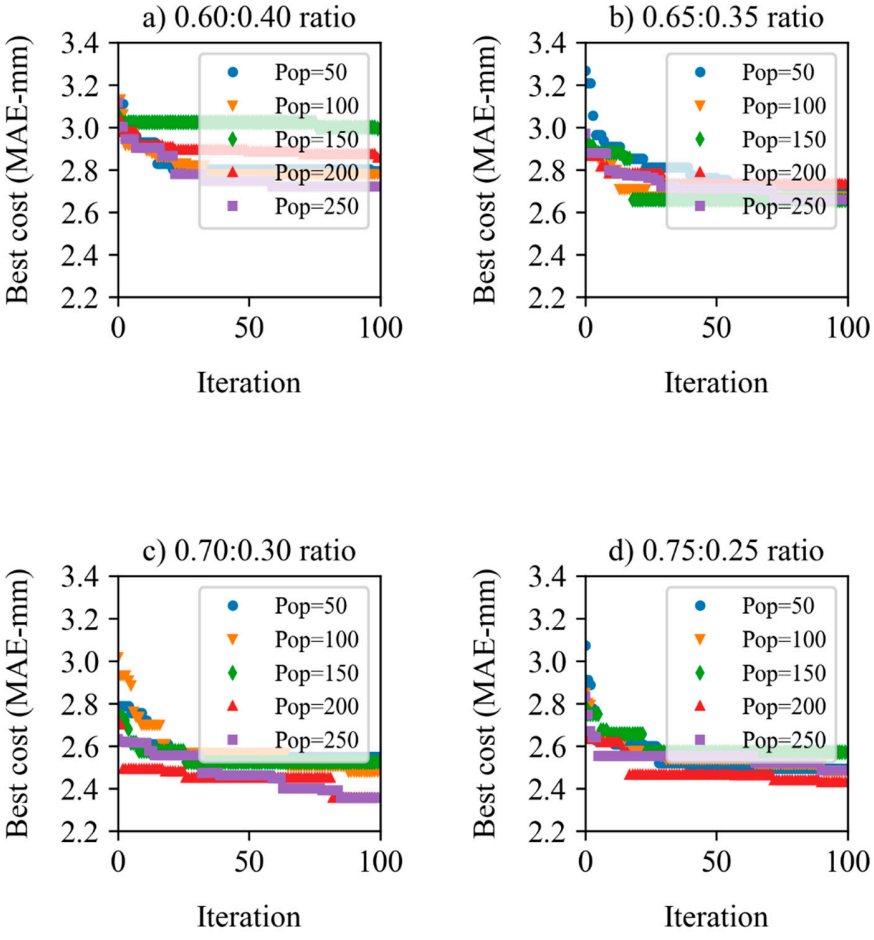


Fig. S-3. MFO-XGB models' optimization process for different population sizes.



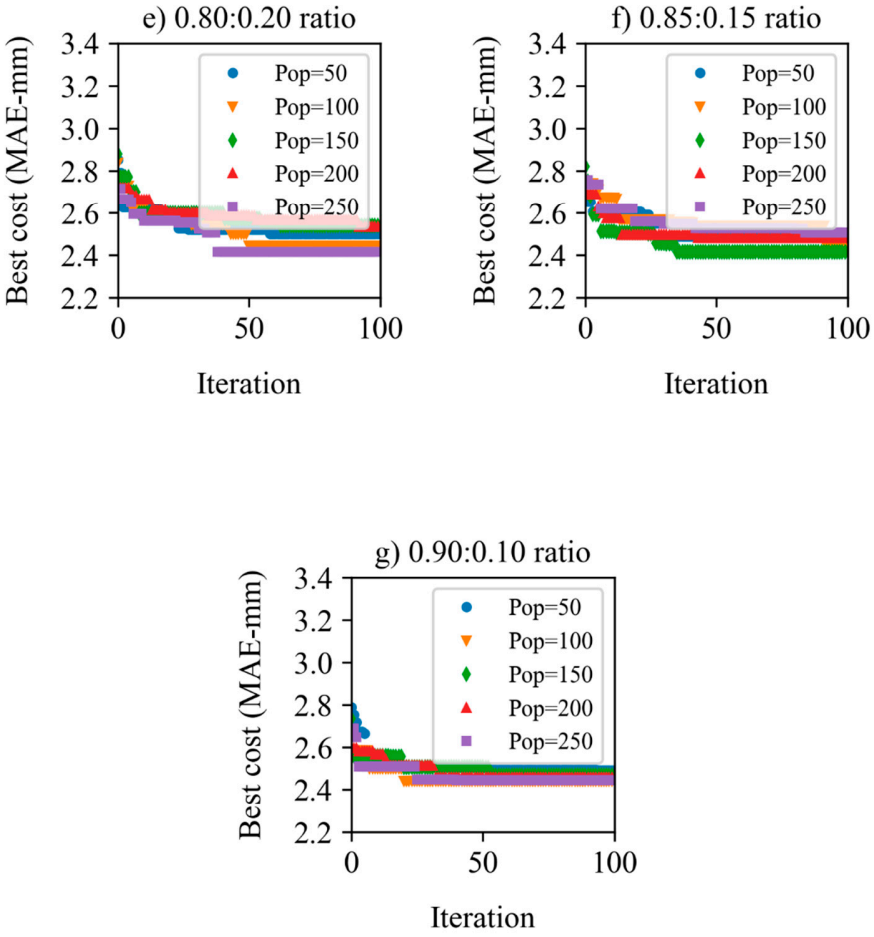
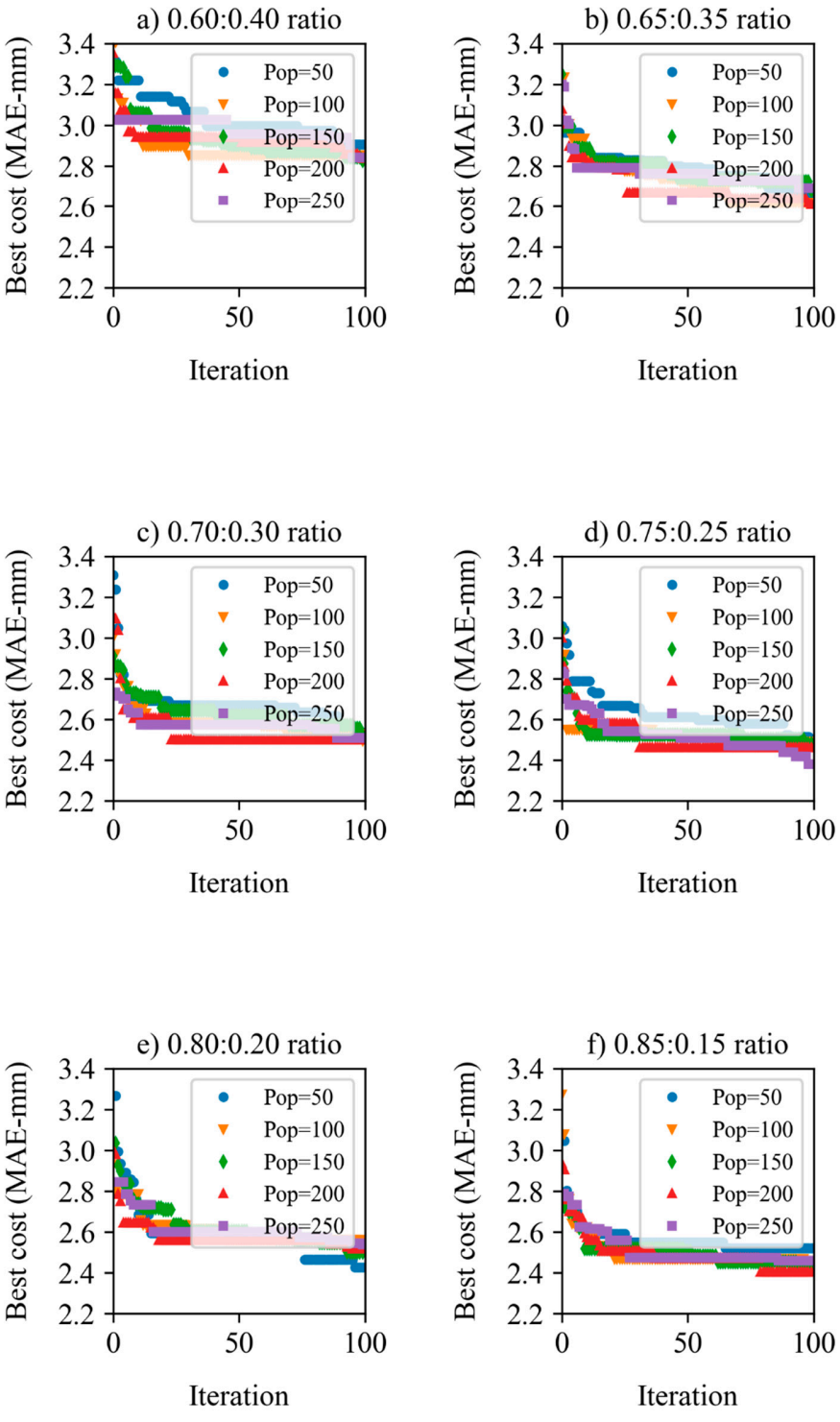


Fig. S-4. JA-XGB models' optimization process for different population sizes.


a) 0.60:0.40 ratio
b) 0.65:0.35 ratio
c) 0.70:0.30 ratio
d) 0.75:0.25 ratio
e) 0.80:0.20 ratio
f) 0.85:0.15 ratio
Best cost (MAE-mm)
Iteration
Pop=50
Pop=100
Pop=150
Pop=200
Pop=250
3.4
3.2
3.0
2.8
2.6
2.4
2.2
0
50
100

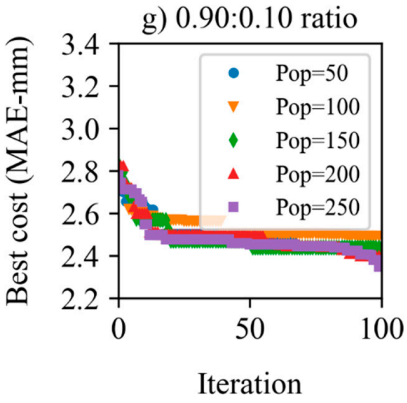


Fig. S-5. MVO-XGB models' optimization process for different population sizes.

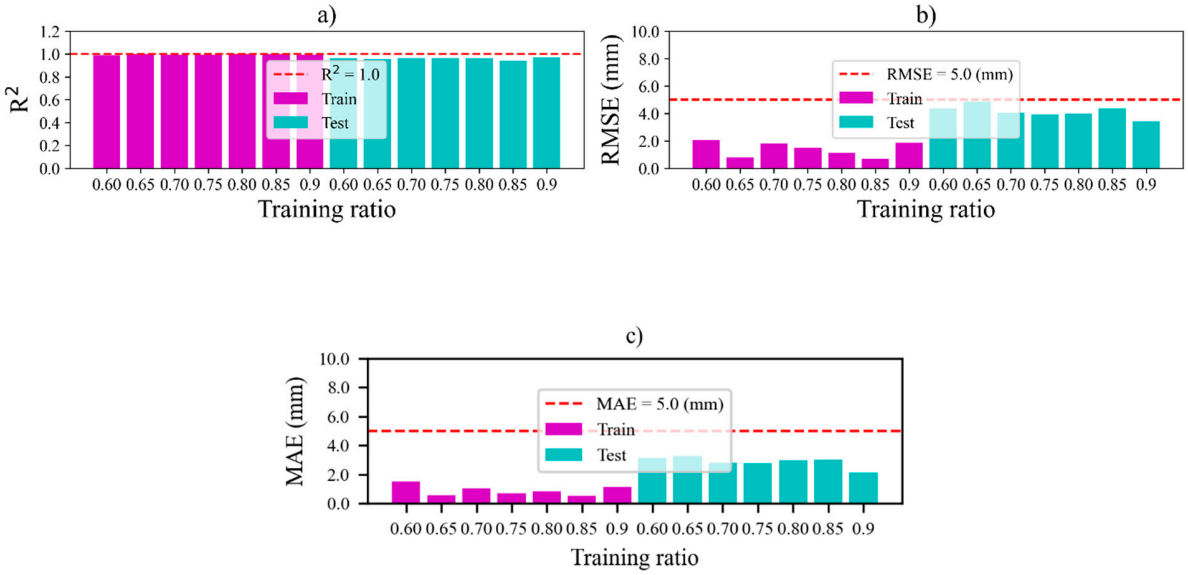


Fig. S-6. Effect of training-test ratios on the PSO-XGB model's performance with population size of 50.

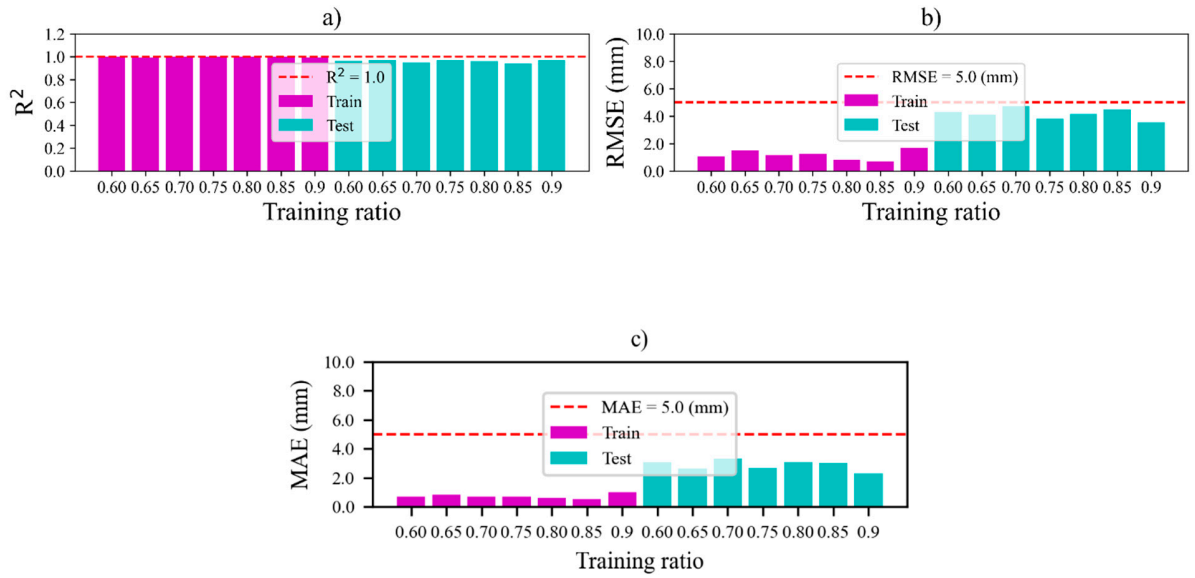


Fig. S-7. Effect of training-test ratios on the PSO-XGB model's performance with population size of 100.

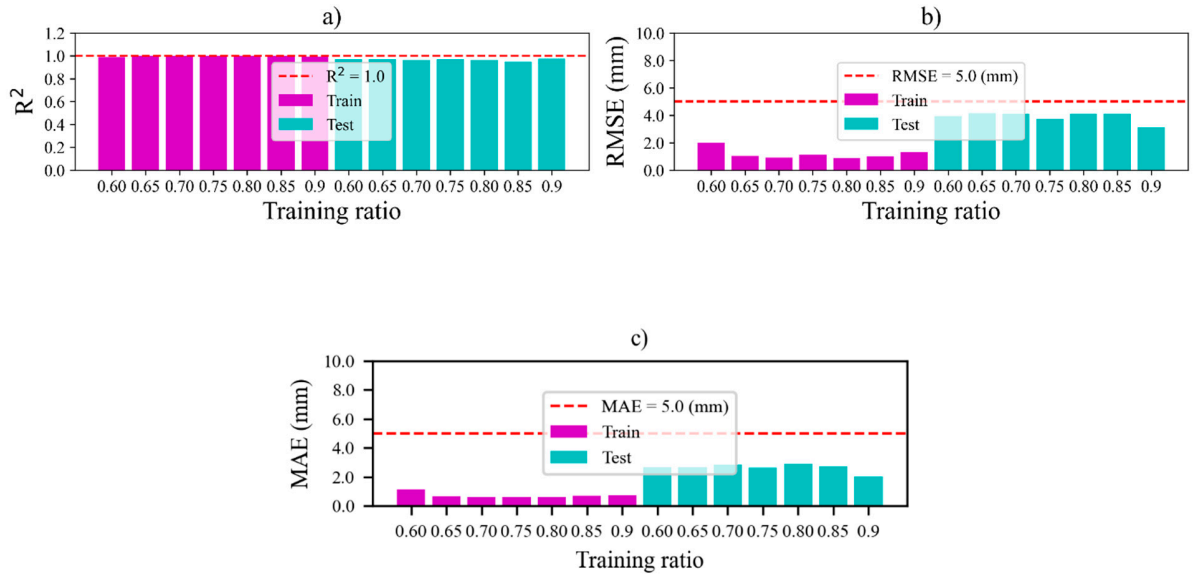


Fig. S-8. Effect of training-test ratios on the PSO-XGB model's performance with population size of 150.

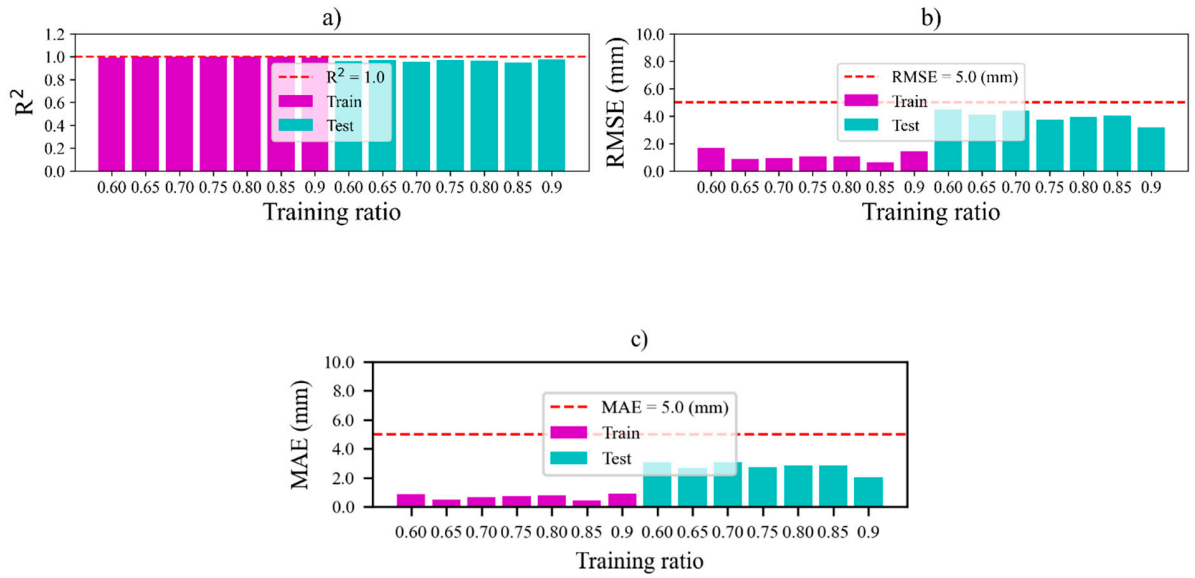


Fig. S-9. Effect of training-test ratios on the PSO-XGB model's performance with population size of 200.

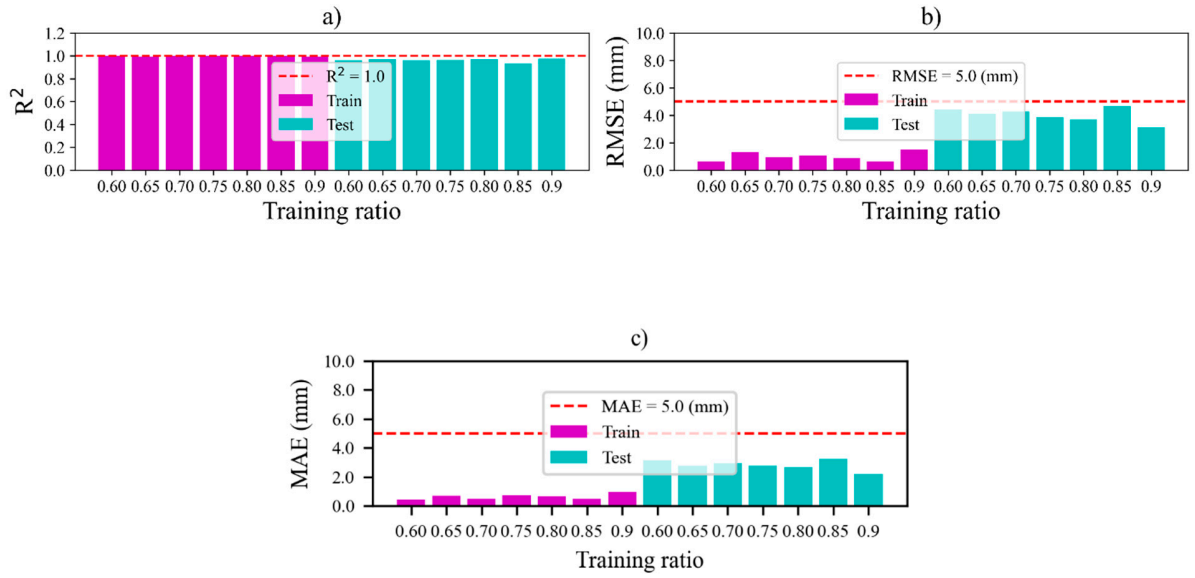


Fig. S-10. Effect of training-test ratios on the PSO-XGB model's performance with population size of 250.

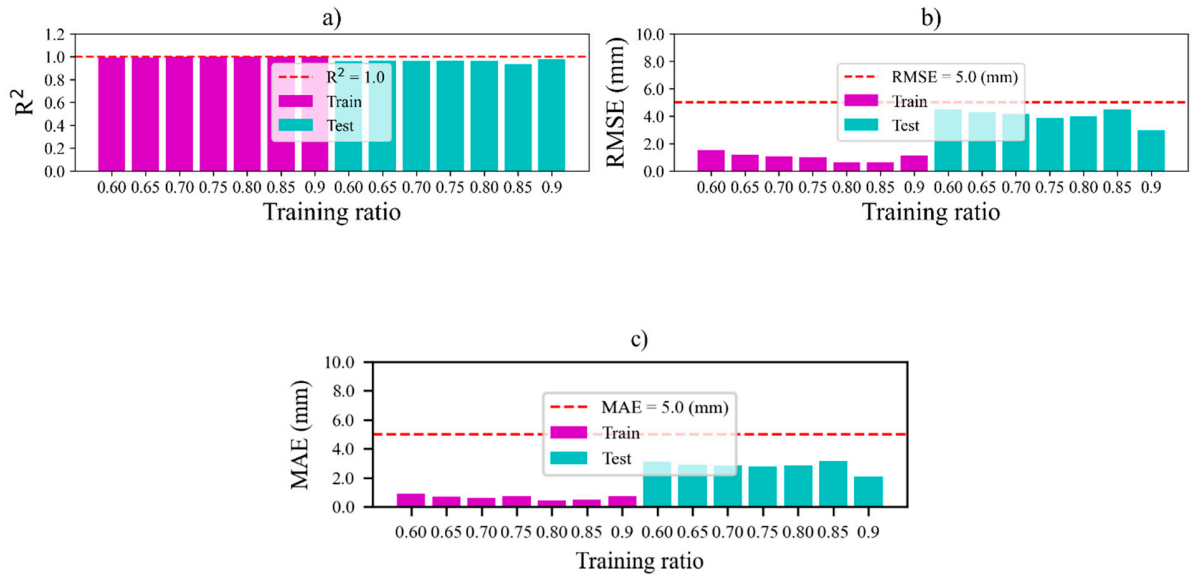


Fig. S-11. Effect of training-test ratios on the GWO-XGB model's performance with population size of 50.

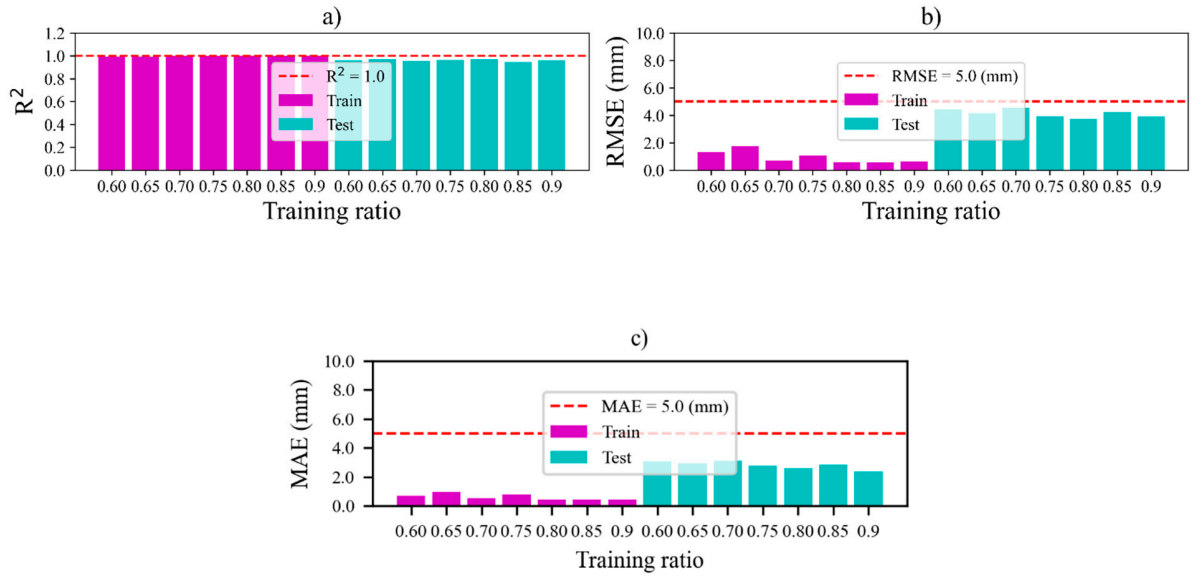


Fig. S-12. Effect of training-test ratios on the GWO-XGB model's performance with population size of 100.

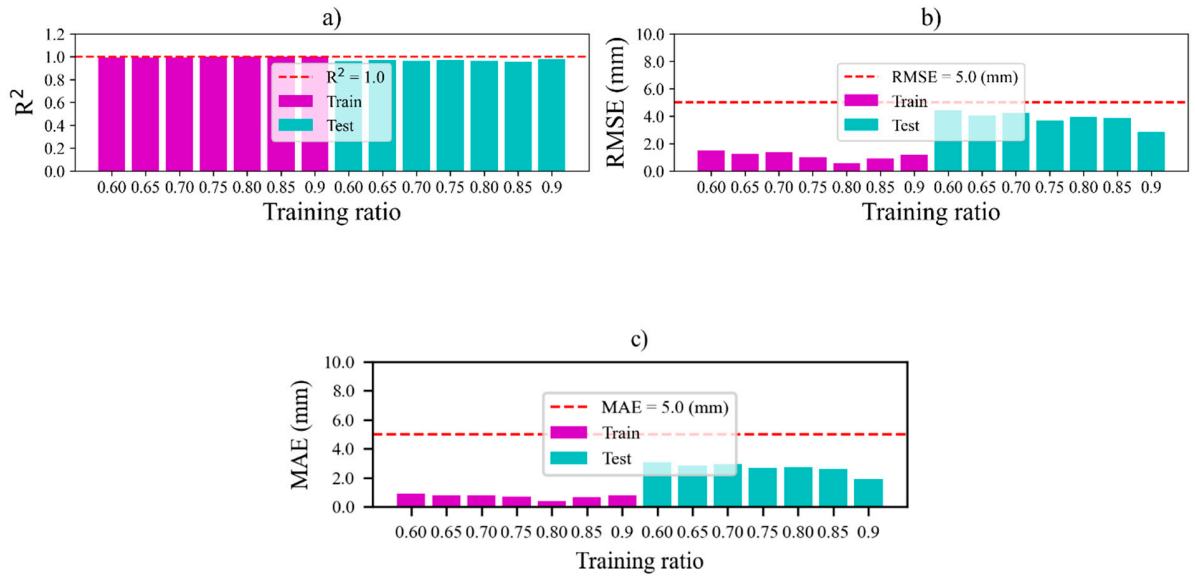


Fig. S-13. Effect of training-test ratios on the GWO-XGB model's performance with population size of 150.

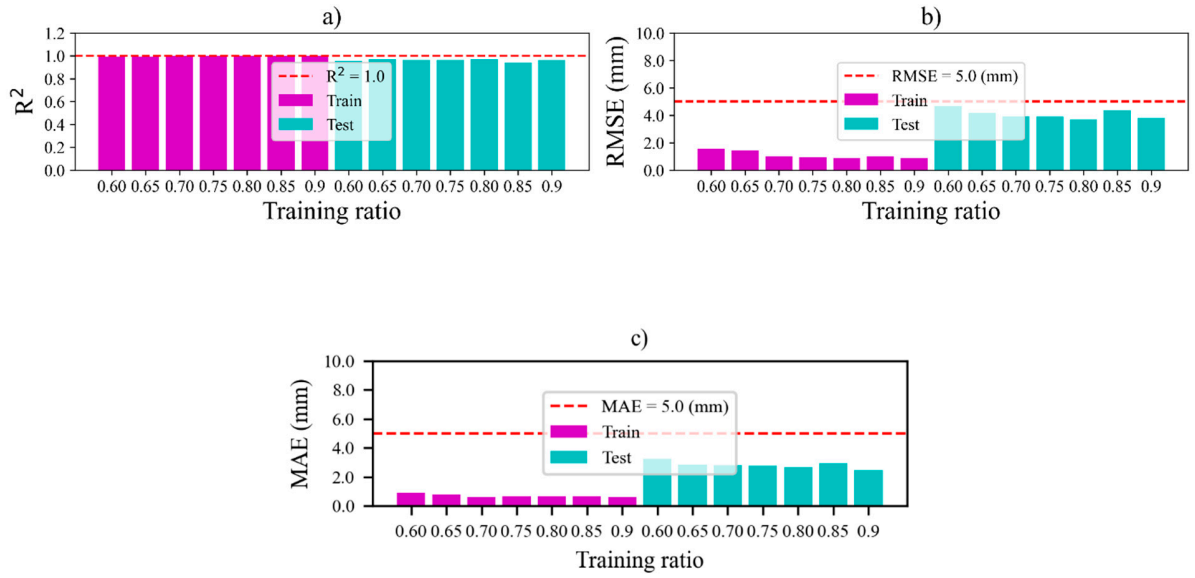


Fig. S-14. Effect of training-test ratios on the GWO-XGB model's performance with population size of 200.

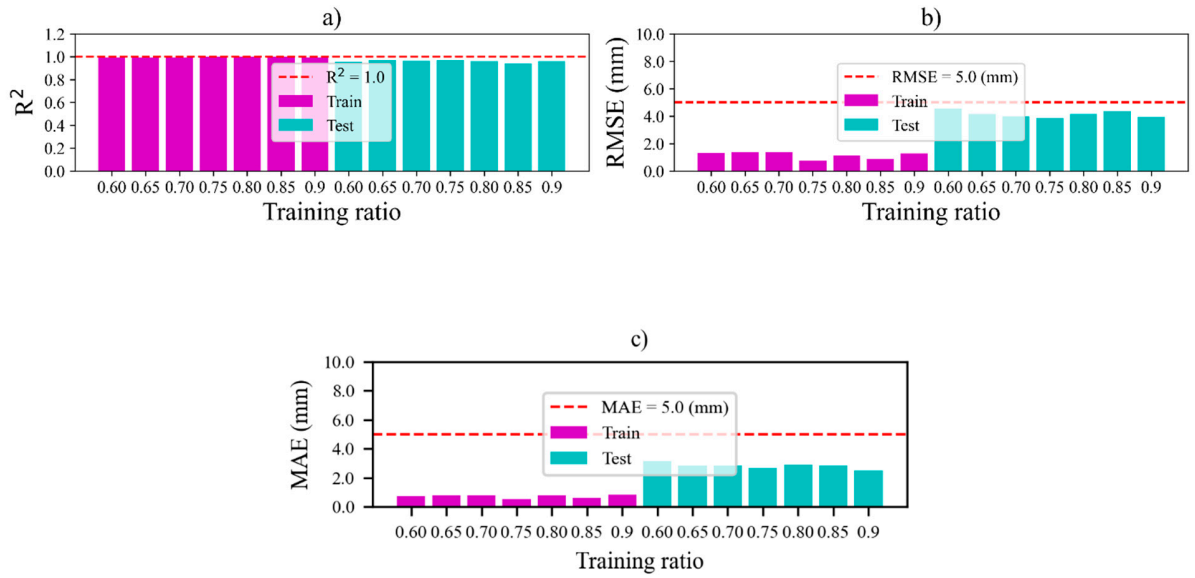


Fig. S-15. Effect of training-test ratios on the GWO-XGB model's performance with population size of 250.

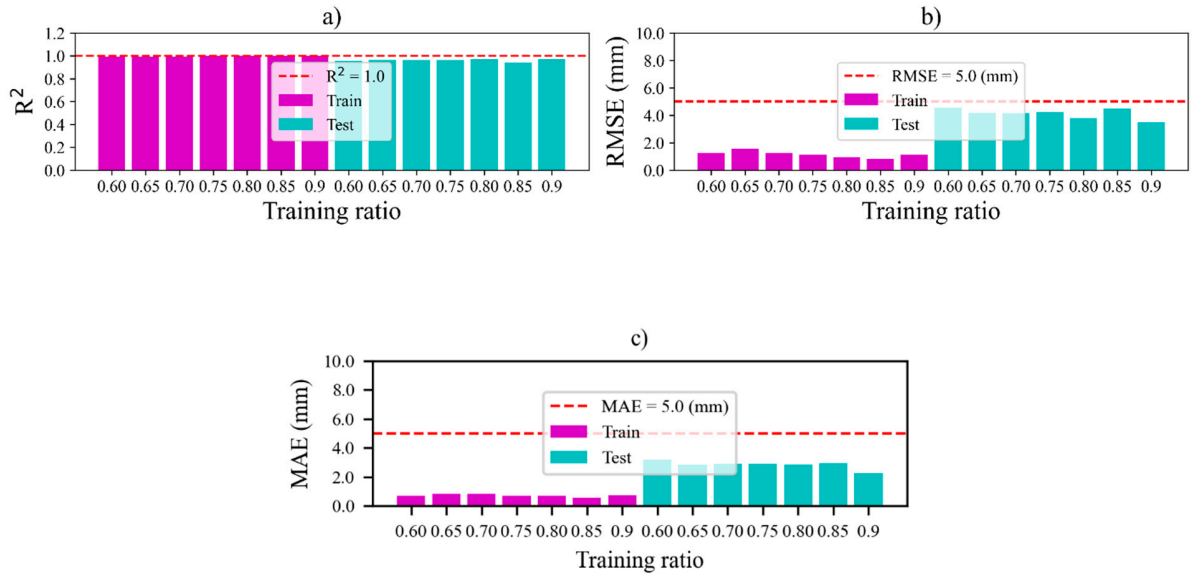


Fig. S-16. Effect of training-test ratios on the MFO-XGB model's performance with population size of 50.

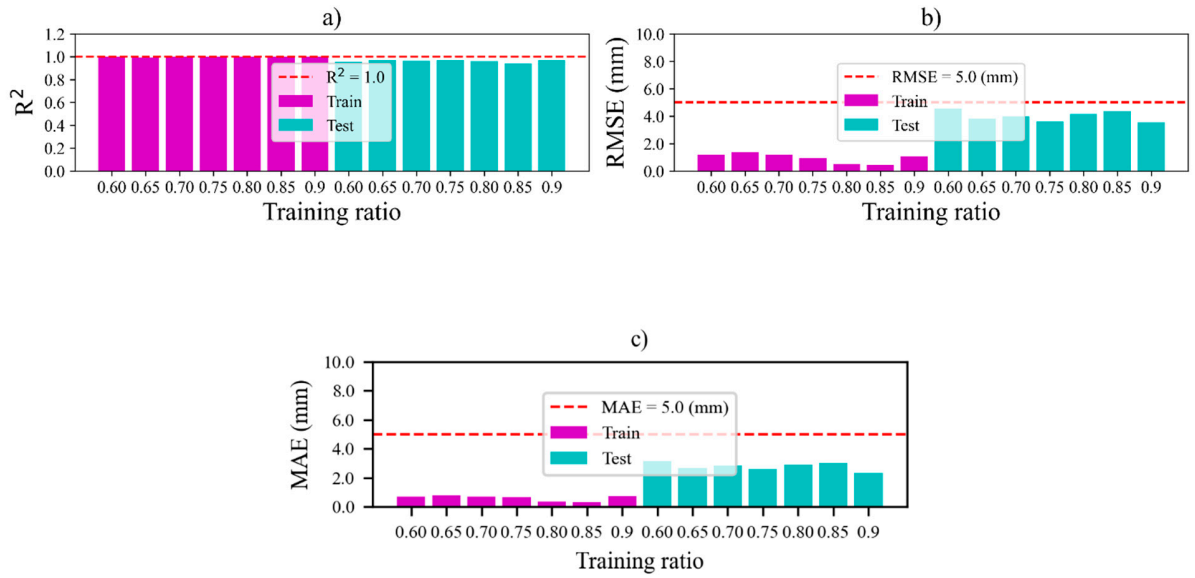


Fig. S-17. Effect of training-test ratios on the MFO-XGB model's performance with population size of 100.

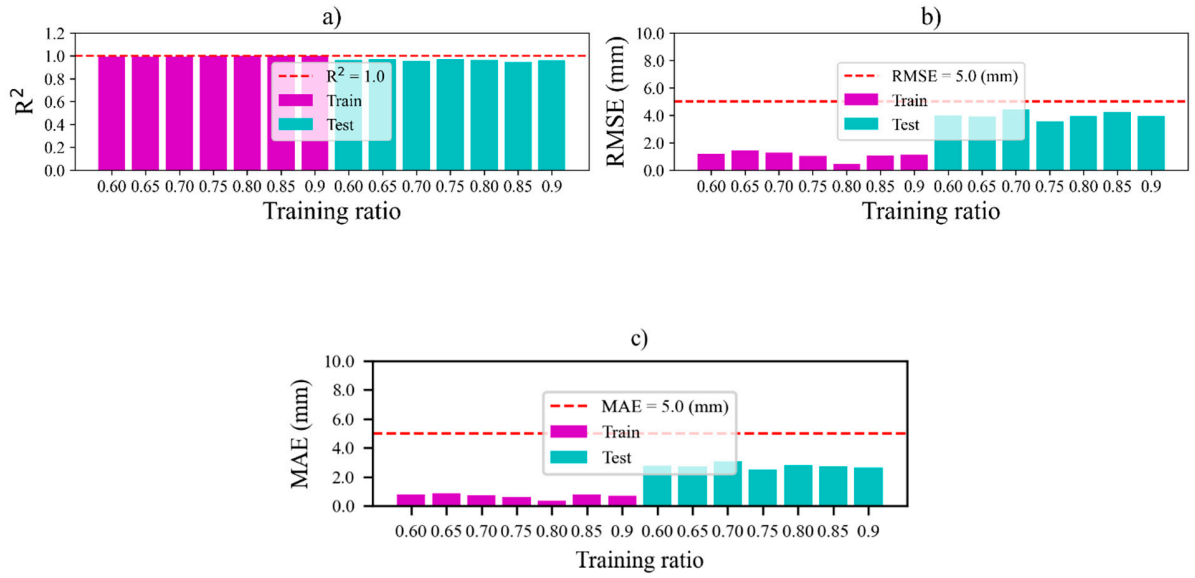


Fig. S-18. Effect of training-test ratios on the MFO-XGB model's performance with population size of 150.

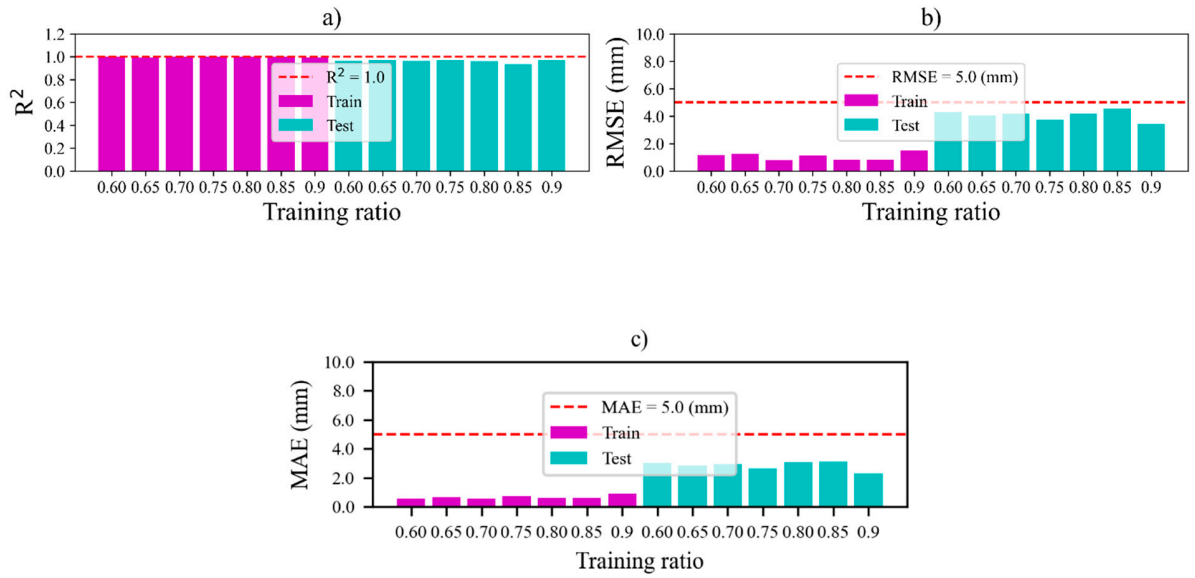


Fig. S-19. Effect of training-test ratios on the MFO-XGB model's performance with population size of 200.

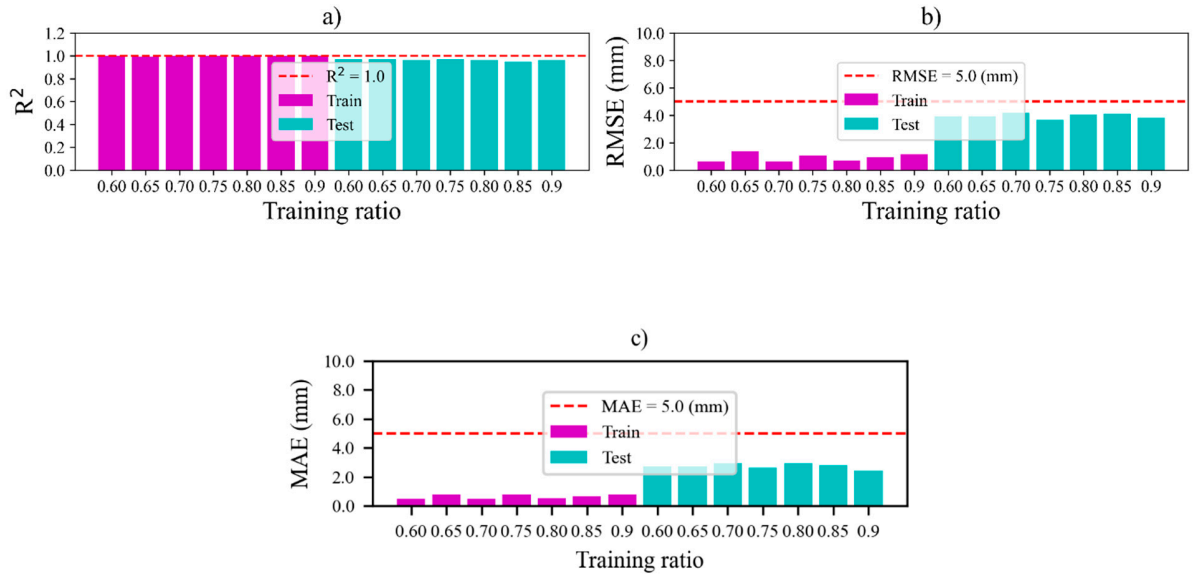


Fig. S-20. Effect of training-test ratios on the MFO-XGB model's performance with population size of 250.

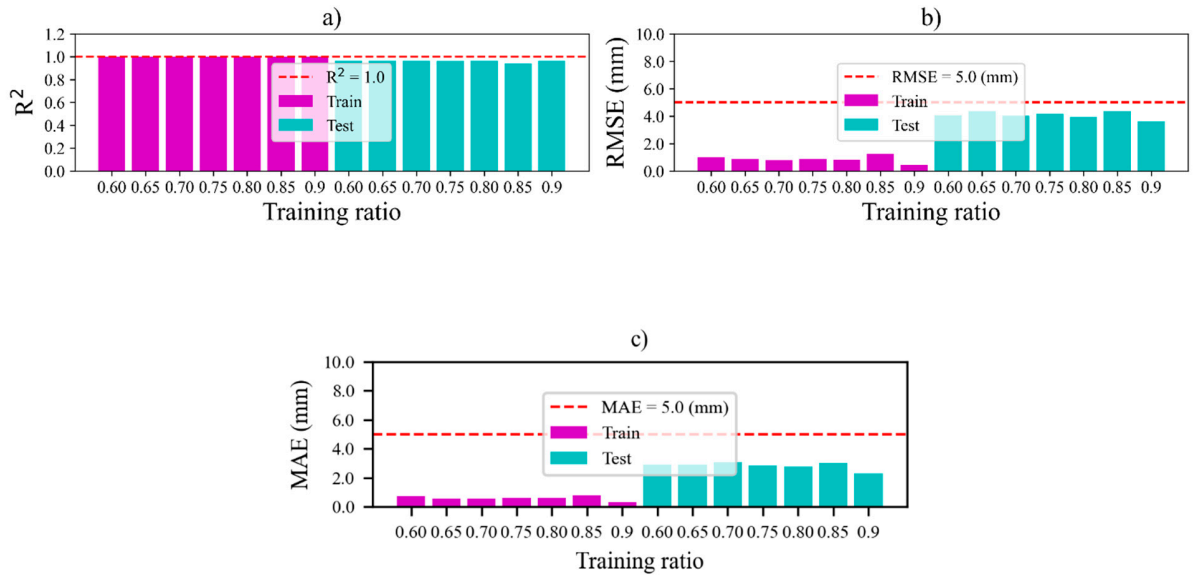


Fig. S-21. Effect of training-test ratios on the JA-XGB model's performance with population size of 50.

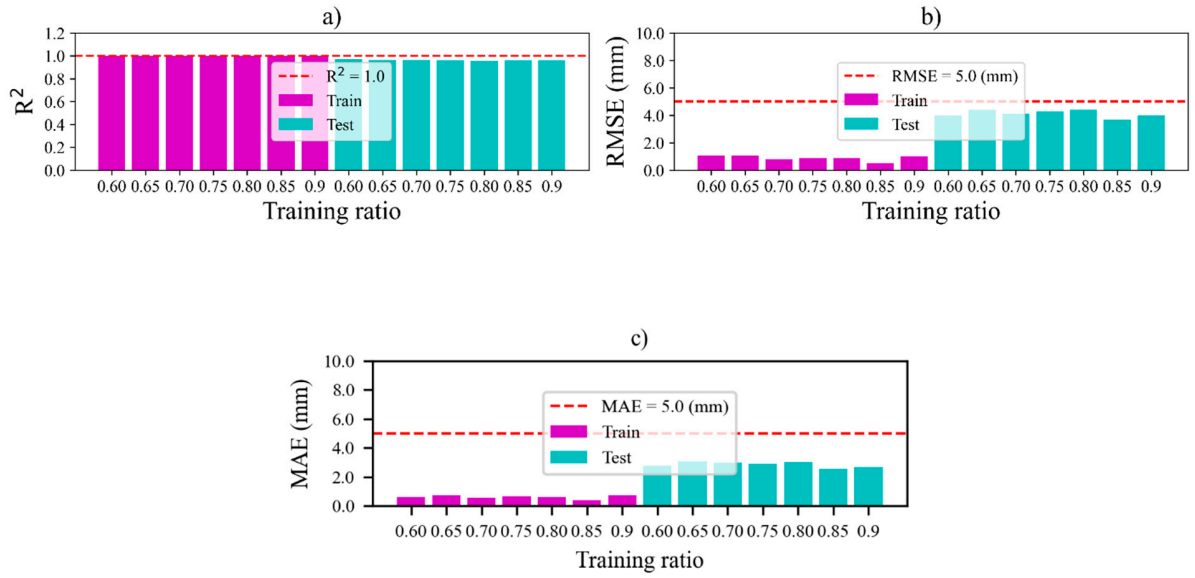


Fig. S-22. Effect of training-test ratios on the JA-XGB model's performance with population size of 100.

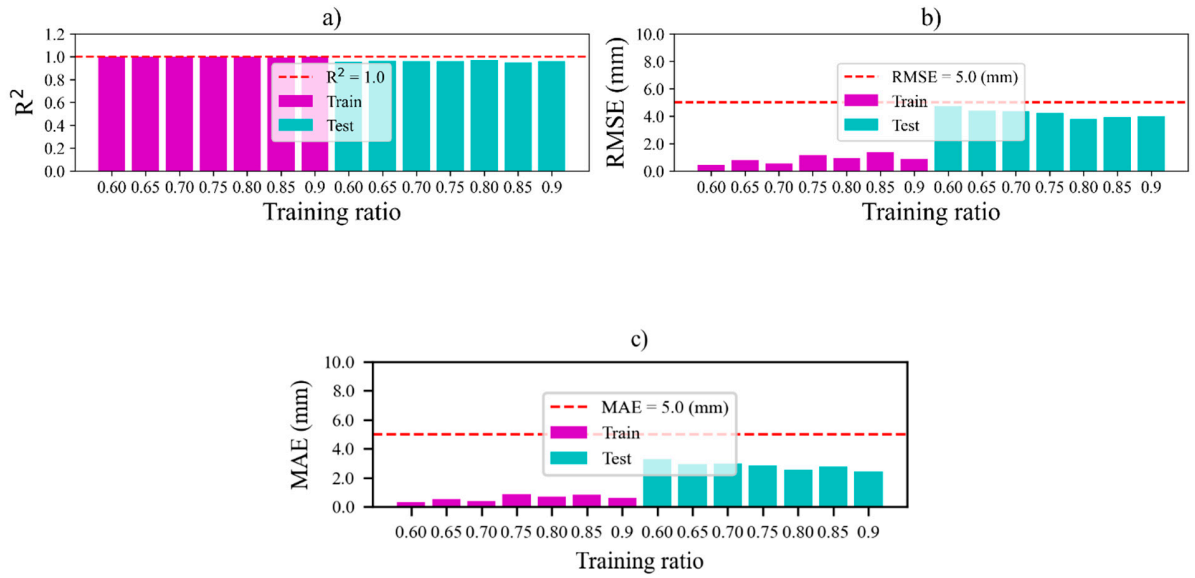


Fig. S-23. Effect of training-test ratios on the JA-XGB model's performance with population size of 150.

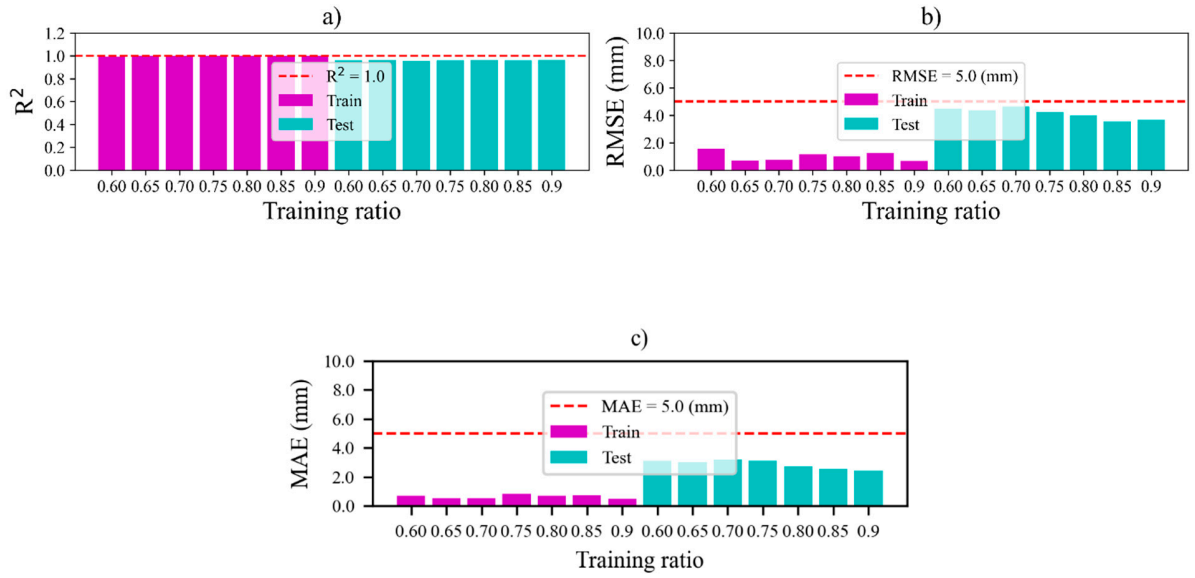


Fig. S-24. Effect of training-test ratios on the JA-XGB model's performance with population size of 200.

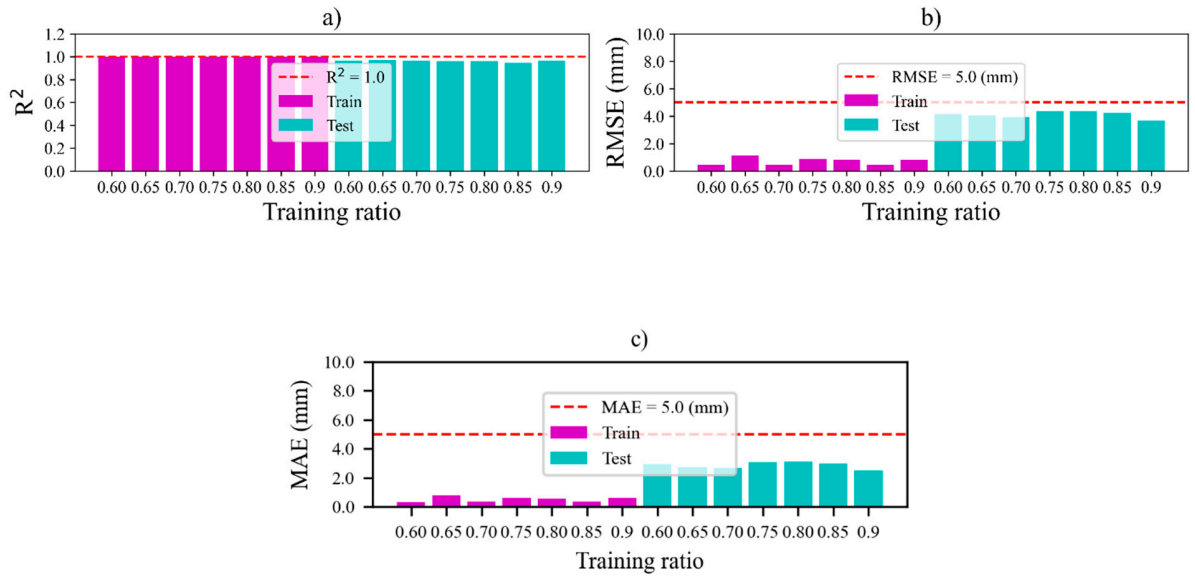


Fig. S-25. Effect of training-test ratios on the JA-XGB model's performance with population size of 250.

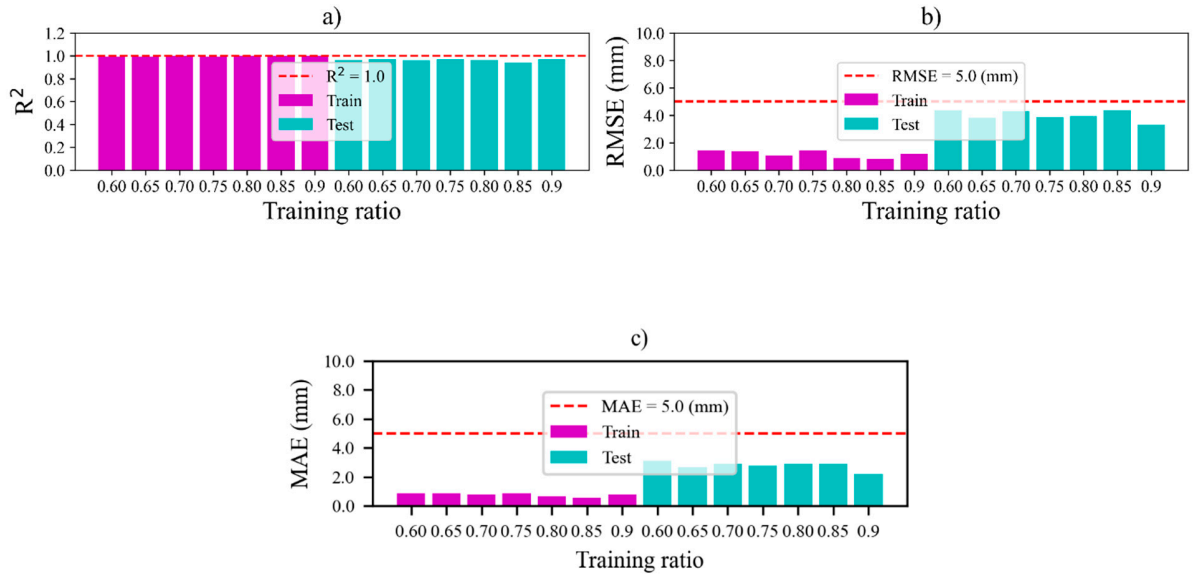


Fig. S-26. Effect of training-test ratios on the MVO-XGB model's performance with population size of 50.

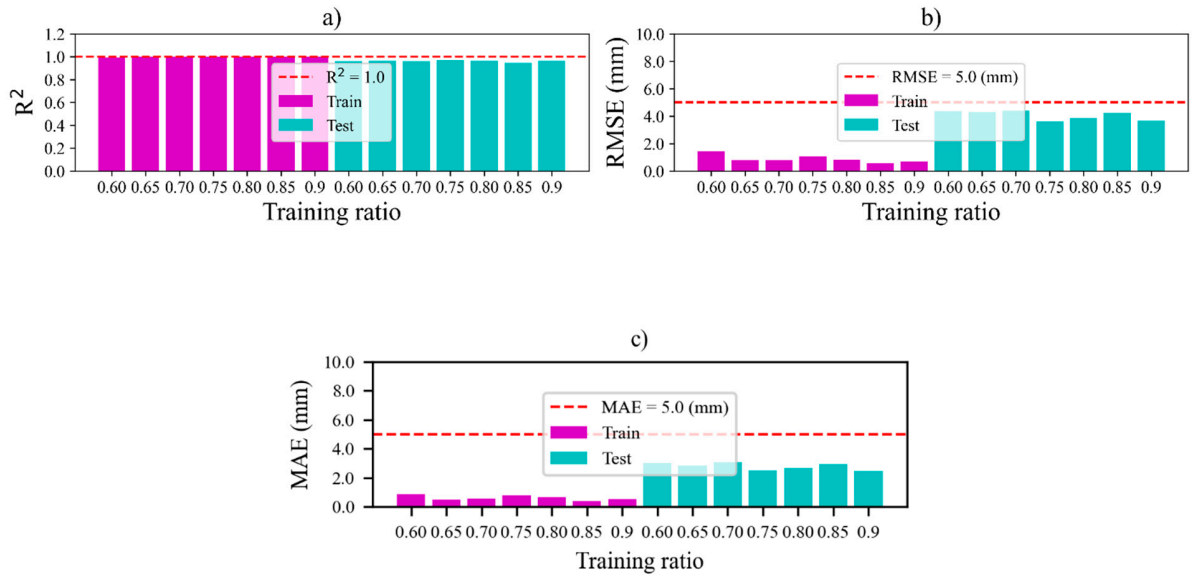


Fig. S-27. Effect of training-test ratios on the MVO-XGB model's performance with population size of 100.

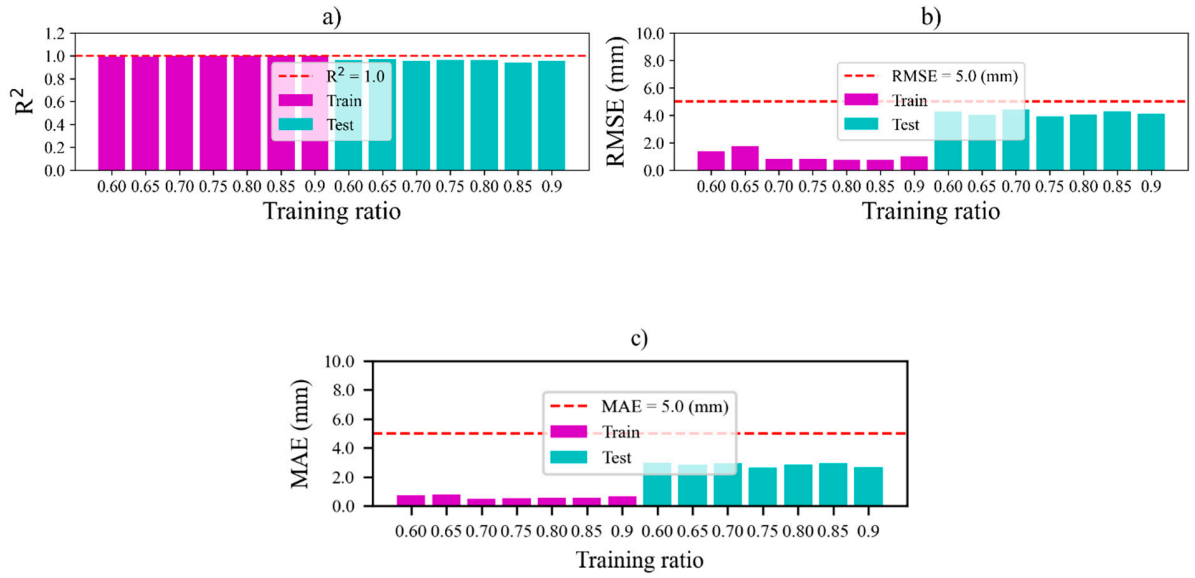


Fig. S-28. Effect of training-test ratios on the MVO-XGB model's performance with population size of 150.

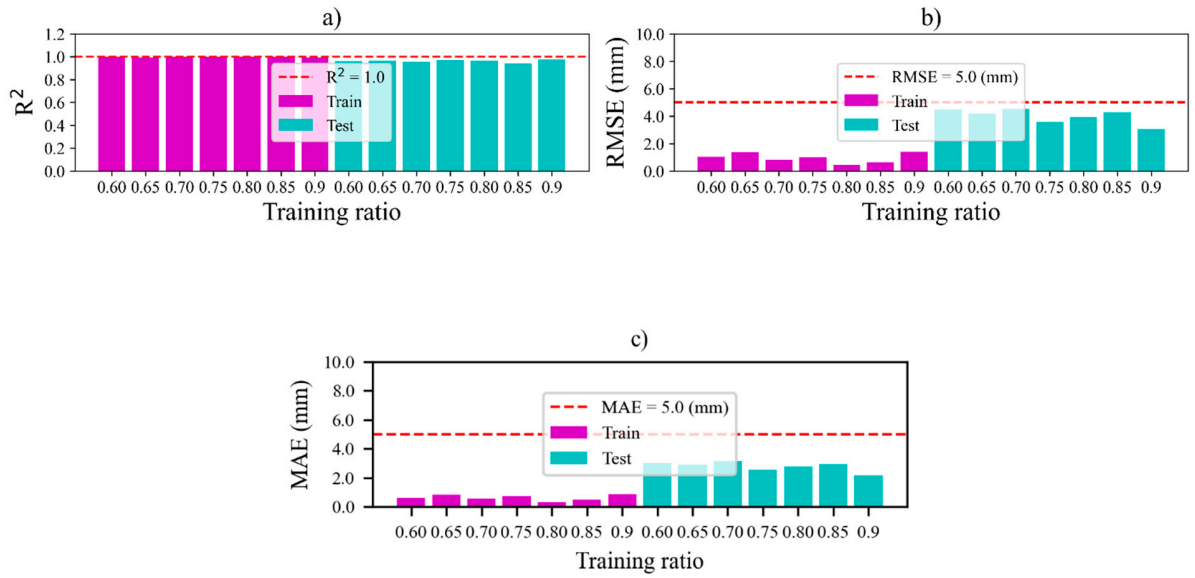


Fig. S-29. Effect of training-test ratios on the MVO-XGB model's performance with population size of 200.

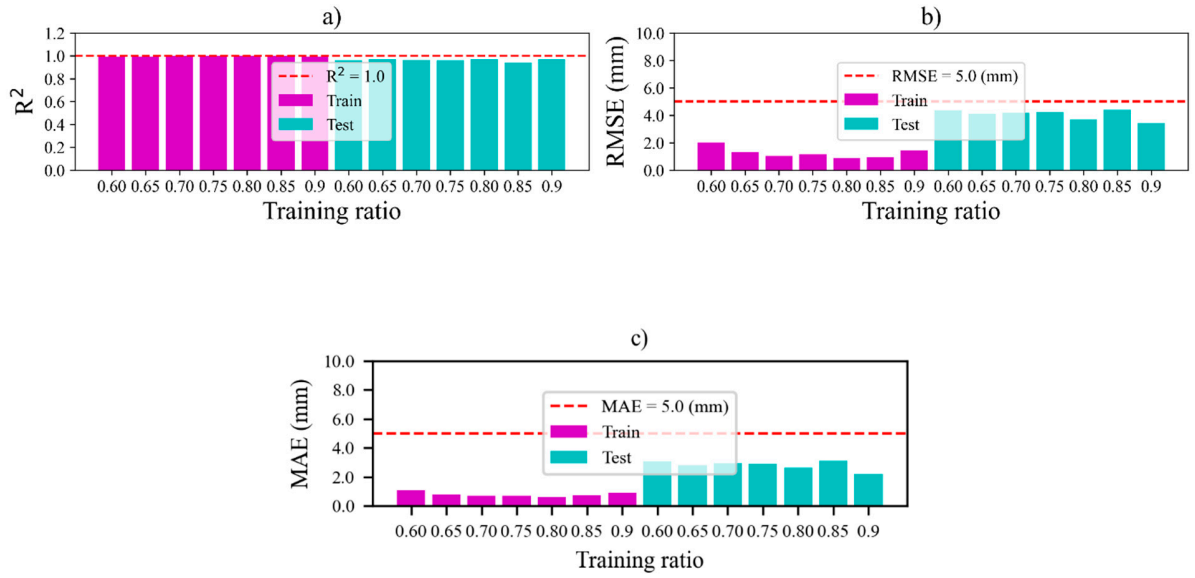


Fig. S-30. Effect of training-test ratios on the MVO-XGB model's performance with population size of 250.

Table S-1 Performance of PSO-XGB models on the test set

Pop. size	Training ratio	R^2	Score	RMSE	Score	MAE	Score	Total
50	0.60	0.961	13	4.365	8	3.143	5	26
	0.65	0.957	7	4.846	1	3.271	2	10
	0.70	0.965	19	4.042	20	2.816	18	57
	0.75	0.966	20	3.923	25	2.778	19	64
	0.80	0.963	16	3.983	22	2.957	12	50
	0.85	0.941	3	4.363	9	3.001	11	23
	0.90	0.969	32	3.398	32	2.134	33	97
100	0.60	0.962	15	4.308	10	3.045	9	34
	0.65	0.968	25	4.096	16	2.624	29	70
	0.70	0.951	6	4.739	2	3.332	1	9
	0.75	0.968	23	3.825	27	2.668	26	76

	0.80	0.96	11	4.14	12	3.07	6	29
	0.85	0.938	2	4.457	5	3.04	10	17
	0.90	0.967	22	3.534	31	2.31	31	84
150	0.60	0.968	27	3.936	23	2.659	27	77
	0.65	0.968	26	4.129	13	2.694	24	63
	0.70	0.964	17	4.098	15	2.831	17	49
	0.75	0.969	30	3.754	28	2.616	30	88
	0.80	0.961	14	4.089	18	2.877	14	46
	0.85	0.947	4	4.105	14	2.721	22	40
	0.90	**0.975**	**34**	**3.097**	**35**	**2.019**	**35**	**104**
200	0.60	0.96	9	4.458	4	3.059	7	20
	0.65	0.969	29	4.082	19	2.656	28	76
	0.70	0.958	8	4.396	7	3.048	8	23
	0.75	0.969	31	3.724	29	2.705	23	83
	0.80	0.964	18	3.931	24	2.846	15	57
	0.85	0.949	5	4.027	21	2.841	16	42
	0.90	0.975	35	3.144	33	2.032	34	102
250	0.60	0.96	10	4.409	6	3.152	4	20
	0.65	0.968	24	4.096	17	2.76	21	62
	0.70	0.961	12	4.277	11	2.915	13	36
	0.75	0.967	21	3.878	26	2.763	20	67
	0.80	0.968	28	3.695	30	2.671	25	83
	0.85	0.932	1	4.66	3	3.254	3	7
	0.90	0.974	33	3.124	34	2.222	32	99

Table S-2 Performance of GWO-XGB models on the test set

Pop. size	**Training ratio**	**R^2**	**Score**	**RMSE**	**Score**	**MAE**	**Score**	**Total**
50	0.60	0.959	10	4.469	5	3.087	5	20
	0.65	0.965	20	4.287	10	2.872	12	42
	0.70	0.963	18	4.131	15	2.841	18	51
	0.75	0.967	25	3.842	28	2.768	22	75
	0.80	0.963	17	3.984	19	2.835	19	55
	0.85	0.937	1	4.483	4	3.156	3	8
	0.90	0.977	34	2.945	34	2.064	34	102
100	0.60	0.96	12	4.435	7	3.062	7	26
	0.65	0.968	28	4.13	16	2.939	9	53
	0.70	0.956	7	4.535	3	3.095	4	14
	0.75	0.966	22	3.926	24	2.764	23	69

	0.80	0.968	29	3.735	31	2.572	30	90
	0.85	0.945	4	4.209	12	2.847	17	33
	0.90	0.961	14	3.883	26	2.383	33	73
150	0.60	0.96	11	4.447	6	3.067	6	23
	0.65	0.969	32	4.045	18	2.859	14	64
	0.70	0.961	15	4.236	11	2.926	10	36
	0.75	0.97	33	3.678	33	2.685	28	94
	0.80	0.964	19	3.949	21	2.732	25	65
	0.85	0.953	5	3.848	27	2.596	29	61
	0.90	**0.981**	**35**	**2.835**	**35**	**1.906**	**35**	**105**
200	0.60	0.955	6	4.657	1	3.229	1	8
	0.65	0.967	27	4.164	13	2.854	16	56
	0.70	0.967	24	3.927	23	2.817	21	68
	0.75	0.966	23	3.902	25	2.76	24	72
	0.80	0.968	31	3.694	32	2.696	26	89
	0.85	0.942	3	4.334	9	2.95	8	20
	0.90	0.963	16	3.789	30	2.474	32	78
250	0.60	0.957	8	4.563	2	3.169	2	12
	0.65	0.968	30	4.139	14	2.831	20	64
	0.70	0.966	21	3.973	20	2.857	15	56
	0.75	0.967	26	3.841	29	2.687	27	82
	0.80	0.96	13	4.129	17	2.884	11	41
	0.85	0.941	2	4.344	8	2.868	13	23
	0.90	0.959	9	3.94	22	2.511	31	62

Table S-3 Performance of MFO-XGB models on the test set

Pop. size	**Training ratio**	**R^2**	**Score**	**RMSE**	**Score**	**MAE**	**Score**	**Total**
50	0.60	0.957	7	4.56	2	3.197	1	10
	0.65	0.967	21	4.169	13	2.856	16	50
	0.70	0.963	18	4.133	15	2.905	13	46
	0.75	0.961	12	4.205	9	2.912	12	33
	0.80	0.967	24	3.761	28	2.855	17	69
	0.85	0.938	2	4.471	4	2.926	10	16
	0.90	0.969	25	3.477	34	2.237	35	94
100	0.60	0.957	6	4.569	1	3.135	2	9
	0.65	0.972	34	3.831	26	2.662	26	86
	0.70	0.966	20	3.977	20	2.868	15	55
	0.75	0.971	31	3.617	31	2.609	30	92

	0.80	0.96	11	4.136	14	2.9	14	39
	0.85	0.941	3	4.362	6	3.031	6	15
	0.90	0.967	23	3.524	33	2.339	33	89
150	0.60	0.967	22	4.002	19	2.779	21	62
	0.65	0.972	33	3.905	25	2.718	23	81
	0.70	0.958	8	4.436	5	3.085	4	17
	0.75	**0.972**	**35**	**3.542**	**32**	**2.485**	**31**	**98**
	0.80	0.964	19	3.947	22	2.798	19	60
	0.85	0.944	4	4.224	8	2.719	22	34
	0.90	0.959	9	3.952	21	2.628	28	58
200	0.60	0.962	17	4.287	7	3.016	7	31
	0.65	0.969	27	4.038	18	2.852	18	63
	0.70	0.962	16	4.188	11	2.928	9	36
	0.75	0.969	28	3.719	29	2.65	27	84
	0.80	0.96	10	4.184	12	3.078	5	27
	0.85	0.936	1	4.532	3	3.111	3	7
	0.90	**0.969**	**29**	**3.433**	**35**	**2.284**	**34**	**98**
250	0.60	0.969	26	3.912	24	2.705	24	74
	0.65	0.971	32	3.93	23	2.702	25	80
	0.70	0.962	14	4.198	10	2.953	8	32
	0.75	0.971	30	3.651	30	2.614	29	89
	0.80	0.962	15	4.05	17	2.917	11	43
	0.85	0.948	5	4.094	16	2.794	20	41
	0.90	0.962	13	3.815	27	2.42	32	72

Table S-4 Performance of JA-XGB models on the test set

Pop. size	**Training ratio**	**R^2**	**Score**	**RMSE**	**Score**	**MAE**	**Score**	**Total**
50	0.60	0.966	31	4.061	20	2.88	19	70
	0.65	0.965	26	4.349	9	2.912	17	52
	0.70	0.965	27	4.029	22	3.044	8	57
	0.75	0.961	18	4.169	17	2.837	21	56
	0.80	0.964	24	3.944	27	2.761	24	75
	0.85	0.94	1	4.364	8	3.038	9	18
	0.90	**0.966**	**29**	**3.593**	**34**	**2.280**	**35**	**98**
100	0.60	0.968	34	3.968	24	2.782	22	80
	0.65	0.963	19	4.387	5	3.051	7	31
	0.70	0.963	20	4.124	19	2.963	14	53
	0.75	0.96	14	4.262	13	2.886	18	45

	0.80	0.958	6	4.395	4	3.013	11	21
	0.85	0.959	7	3.667	31	2.545	31	69
	0.90	0.959	12	4	23	2.678	27	62
150	0.60	0.954	5	4.737	1	3.263	1	7
	0.65	0.964	22	4.378	6	2.95	16	44
	0.70	0.959	11	4.34	11	2.997	12	34
	0.75	0.96	16	4.23	16	2.852	20	52
	0.80	0.967	33	3.758	30	2.561	29	92
	0.85	0.952	3	3.909	29	2.78	23	55
	0.90	0.959	9	3.962	26	2.423	33	68
200	0.60	0.959	13	4.453	3	3.096	4	20
	0.65	0.964	21	4.365	7	3.022	10	38
	0.70	0.954	4	4.638	2	3.172	2	8
	0.75	0.96	15	4.246	14	3.102	3	32
	0.80	0.964	23	3.965	25	2.722	26	74
	0.85	0.961	17	3.517	35	2.547	30	82
	0.90	0.966	30	3.645	33	2.413	34	97
250	0.60	0.965	25	4.144	18	2.955	15	58
	0.65	0.969	35	4.049	21	2.726	25	81
	0.70	0.967	32	3.924	28	2.677	28	88
	0.75	0.959	8	4.338	12	3.066	6	26
	0.80	0.959	10	4.343	10	3.089	5	25
	0.85	0.944	2	4.232	15	2.964	13	30
	0.90	0.965	28	3.648	32	2.514	32	92

Table S-5 Performance of MVO-XGB models on the test set

Pop. size	**Training ratio**	**R^2**	**Score**	**RMSE**	**Score**	**MAE**	**Score**	**Total**
50	0.60	0.962	16	4.361	8	3.112	3	27
	0.65	0.973	34	3.831	28	2.663	27	89
	0.70	0.96	11	4.296	10	2.883	18	39
	0.75	0.968	26	3.835	27	2.773	23	76
	0.80	0.964	19	3.949	23	2.909	16	58
	0.85	0.942	2	4.327	9	2.909	14	25
	0.90	0.971	32	3.301	34	2.206	34	100
100	0.60	0.961	13	4.363	6	3.007	7	26
	0.65	0.965	22	4.285	11	2.867	19	52
	0.70	0.959	9	4.381	5	3.051	5	19
	0.75	0.971	31	3.617	31	2.521	31	93

	0.80	0.966	23	3.842	26	2.666	26	75
	0.85	0.945	5	4.208	16	2.917	13	34
	0.90	0.964	20	3.656	30	2.481	32	82
150	0.60	0.963	18	4.264	14	2.969	8	40
	0.65	0.969	30	4.012	22	2.841	21	73
	0.70	0.958	8	4.407	3	2.931	11	22
	0.75	0.967	25	3.891	25	2.642	29	79
	0.80	0.962	17	4.033	21	2.856	20	58
	0.85	0.943	4	4.274	13	2.948	10	27
	0.90	0.955	6	4.099	20	2.687	25	51
200	0.60	0.96	10	4.452	2	3.01	6	18
	0.65	0.966	24	4.202	17	2.884	17	58
	0.70	0.956	7	4.517	1	3.148	1	9
	0.75	0.971	33	3.583	32	2.569	30	95
	0.80	0.965	21	3.922	24	2.771	24	69
	0.85	0.943	3	4.277	12	2.954	9	24
	0.90	**0.975**	**35**	**3.041**	**35**	**2.152**	**35**	**105**
250	0.60	0.961	14	4.362	7	3.054	4	25
	0.65	0.968	27	4.121	19	2.797	22	68
	0.70	0.962	15	4.202	18	2.923	12	45
	0.75	0.961	12	4.21	15	2.909	15	42
	0.80	0.969	28	3.694	29	2.643	28	85
	0.85	0.939	1	4.396	4	3.114	2	7
	0.90	0.969	29	3.436	33	2.219	33	95