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Supplementary Materials: Habitat Suitability Estimation Using a Two-Stage Ensemble Approach

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Table S1. Sensitivity comparison.

Target Species	GLM	GBM	CTA	SNN	FDA	MARS	RF	SRE	MAXENT	DNN (Stage 1)	EMED	TSEM (Stage 2)
Anas platyrhynchos	0.937	0.911	0.886	0.853	0.897	0.881	0.881	0.478	0.807	0.740	0.880	**0.978**
Anas zonorhyncha	0.887	0.903	0.862	0.875	0.889	0.877	0.889	0.544	0.818	0.714	0.936	**0.969**
Ardea cinerea	0.882	0.912	0.876	0.861	0.889	0.888	0.886	0.561	0.844	0.744	0.899	**0.978**
Cyanopica cyanus	0.855	0.917	0.843	0.926	0.870	0.936	0.858	0.522	0.779	0.743	0.943	**0.971**
Hyla japonica	0.819	0.774	0.799	0.816	0.770	0.787	0.821	0.607	0.616	0.730	0.904	**0.932**
Hynobius leechii	0.836	0.853	0.820	0.770	0.834	0.779	0.881	0.537	0.691	0.752	0.914	**0.956**
Hypsipetes amaurotis	0.894	0.889	0.888	0.878	0.920	0.879	0.912	0.582	0.715	0.755	0.912	**0.942**
Passer montanus	0.867	0.874	0.874	0.852	0.874	0.866	0.903	0.589	0.810	0.733	0.897	**0.967**
Rana dybowskii	0.745	0.837	0.791	0.859	0.817	0.866	0.876	0.565	0.826	0.794	0.841	**0.974**
Rana huanrenensis	0.792	0.906	0.871	0.867	0.862	0.860	0.912	0.692	0.847	0.842	0.922	**0.983**
Streptopelia orientalis	0.895	0.898	0.886	0.871	0.895	0.833	0.921	0.558	0.843	0.778	0.905	**0.978**
Avg.	0.855	0.879	0.854	0.857	0.865	0.859	0.885	0.567	0.781	0.757	0.905	**0.966**

The highest values are in bold. DNN: deep neural network.

Table S2. Specificity comparison.

Target Species	GLM	GBM	CTA	SNN	FDA	MARS	RF	SRE	MAXENT	DNN (Stage 1)	EMED	TSEM (Stage 2)
Anas platyrhynchos	0.778	0.913	0.903	0.907	0.893	0.896	0.964	0.970	0.913	**0.981**	0.980	0.941
Anas zonorhyncha	0.857	0.863	0.864	0.878	0.870	0.855	0.933	0.869	0.605	**0.957**	0.903	0.910
Ardea cinerea	0.888	0.882	0.854	0.903	0.883	0.888	0.949	0.86	0.600	**0.962**	0.933	0.910
Cyanopica cyanus	0.766	0.856	0.875	0.816	0.844	0.768	**0.951**	0.876	0.886	0.893	0.854	0.906
Hyla japonica	0.827	0.915	0.849	0.837	0.893	0.868	0.937	0.848	0.925	**0.954**	0.882	0.851
Hynobius leechii	0.875	0.939	0.911	0.939	0.933	0.918	0.961	0.953	0.915	**0.972**	0.914	0.927
Hypsipetes amaurotis	0.843	0.909	0.858	0.844	0.852	0.866	0.927	0.850	0.897	**0.949**	0.912	0.946
Passer montanus	0.844	0.899	0.862	0.848	0.876	0.858	0.940	0.893	0.879	**0.951**	0.908	0.927
Rana dybowskii	0.898	0.943	0.912	0.908	0.933	0.862	0.946	0.935	0.891	0.960	**0.978**	0.927
Rana huanrenensis	0.738	0.963	0.954	0.927	0.960	0.935	0.977	0.992	0.638	**0.990**	0.865	0.966
Streptopelia orientalis	0.851	0.883	0.877	0.874	0.876	0.872	0.927	0.898	0.831	**0.961**	0.896	0.911
Avg.	0.833	0.906	0.884	0.880	0.892	0.871	0.947	0.904	0.816	**0.957**	0.911	0.920

The highest values are in bold.

Table S3. AUC comparison.

Target Species	GLM	GBM	CTA	SNN	FDA	MARS	RF	SRE	MAXENT	DNN (Stage 1)	EMED	TSEM (Stage 2)
Anas platyrhynchos	0.874	0.971	0.915	0.937	0.958	0.953	0.974	0.724	0.896	0.804	0.982	**0.992**
Anas zonorhyncha	0.933	0.949	0.905	0.931	0.937	0.925	0.967	0.706	0.824	0.856	0.973	**0.984**
Ardea cinerea	0.939	0.955	0.902	0.931	0.947	0.943	0.97	0.710	0.870	0.899	0.973	**0.986**
Cyanopica cyanus	0.849	0.941	0.862	0.908	0.922	0.905	0.965	0.699	0.881	0.769	0.967	**0.985**
Hyla japonica	0.895	0.919	0.882	0.898	0.907	0.898	0.946	0.727	0.787	0.854	0.962	**0.967**
Hynobius leechii	0.897	0.946	0.903	0.912	0.936	0.921	0.963	0.745	0.818	0.933	0.975	**0.980**
Hypsipetes amaurotis	0.934	0.951	0.900	0.922	0.941	0.931	0.966	0.716	0.854	0.945	0.968	**0.980**
Passer montanus	0.926	0.950	0.918	0.907	0.939	0.925	0.974	0.740	0.913	0.964	0.973	**0.981**
Rana dybowskii	0.826	0.941	0.887	0.907	0.923	0.915	0.960	0.750	0.877	0.815	0.967	**0.985**
Rana huanrenensis	0.765	0.972	0.922	0.948	0.960	0.956	0.976	0.842	0.871	0.957	0.984	**0.988**
Streptopelia orientalis	0.932	0.951	0.914	0.921	0.946	0.925	0.974	0.728	0.889	0.948	0.973	**0.981**
Avg.	0.888	0.950	0.901	0.920	0.938	0.927	0.967	0.735	0.862	0.886	0.972	**0.983**

The highest values are in bold.

Table S4. Kappa statistic comparison.

Target Species	GLM	GBM	CTA	SNN	FDA	MARS	RF	SRE	MAXENT	DNN (Stage 1)	EMED	TSEM (Stage 2)
Anas platyrhynchos	0.622	0.814	0.758	0.742	0.781	0.756	0.859	0.520	0.717	0.810	0.905	**0.915**
Anas zonorhyncha	0.705	0.746	0.690	0.734	0.727	0.696	0.820	0.431	0.632	0.740	0.861	**0.879**
Ardea cinerea	0.762	0.780	0.712	0.762	0.771	0.763	0.841	0.438	0.667	0.771	0.863	**0.878**
Cyanopica cyanus	0.548	0.718	0.683	0.652	0.672	0.616	0.817	0.413	0.650	0.708	0.846	**0.869**
Hyla japonica	0.651	0.704	0.646	0.654	0.672	0.654	0.773	0.469	0.571	0.657	0.810	**0.824**
Hynobius leechii	0.712	0.801	0.737	0.726	0.776	0.710	0.851	0.523	0.626	0.747	0.870	**0.890**
Hypsipetes amaurotis	0.723	0.795	0.729	0.709	0.747	0.732	0.835	0.446	0.632	0.784	0.857	**0.914**
Passer montanus	0.709	0.773	0.733	0.698	0.748	0.718	0.847	0.498	0.696	0.732	0.862	**0.901**
Rana dybowskii	0.618	0.785	0.678	0.724	0.749	0.674	0.821	0.536	0.688	0.704	0.852	**0.860**
Rana huanrenensis	0.495	0.879	0.834	0.808	0.842	0.799	0.905	0.742	0.762	0.842	0.928	**0.934**
Streptopelia orientalis	0.740	0.780	0.759	0.743	0.77	0.707	0.848	0.473	0.670	0.791	0.827	**0.889**
Avg.	0.662	0.780	0.724	0.723	0.750	0.711	0.838	0.499	0.665	0.753	0.862	**0.887**

The highest values are in bold.

Table S5. TSS comparison.

Target Species	GLM	GBM	CTA	SNN	FDA	MARS	RF	SRE	MAXENT	DNN (Stage 1)	EMED	TSEM (Stage 2)
Anas platyrhynchos	0.716	0.825	0.789	0.760	0.791	0.777	0.845	0.447	0.721	0.821	0.860	**0.919**
Anas zonorhyncha	0.745	0.766	0.726	0.753	0.760	0.732	0.821	0.413	0.619	0.748	0.839	**0.879**
Ardea cinerea	0.769	0.793	0.730	0.764	0.773	0.776	0.836	0.420	0.661	0.772	0.832	**0.888**
Cyanopica cyanus	0.622	0.772	0.718	0.742	0.716	0.706	0.809	0.397	0.666	0.709	0.797	**0.877**
Hyla japonica	0.646	0.689	0.648	0.654	0.664	0.653	0.758	0.455	0.543	0.661	**0.786**	0.783
Hynobius leechii	0.711	0.792	0.731	0.710	0.766	0.698	0.842	0.489	0.607	0.749	0.828	**0.883**
Hypsipetes amaurotis	0.736	0.798	0.746	0.724	0.772	0.745	0.839	0.431	0.613	0.791	0.824	**0.888**
Passer montanus	0.711	0.774	0.736	0.701	0.750	0.723	0.843	0.481	0.688	0.738	0.805	**0.894**
Rana dybowskii	0.644	0.780	0.702	0.768	0.750	0.728	0.822	0.500	0.719	0.720	0.819	**0.901**
Rana huanrenensis	0.530	0.869	0.825	0.796	0.822	0.795	0.888	0.684	0.730	0.845	0.787	**0.949**
Streptopelia orientalis	0.747	0.782	0.763	0.745	0.773	0.704	0.848	0.456	0.675	0.793	0.801	**0.889**
Avg.	0.689	0.785	0.738	0.738	0.758	0.731	0.832	0.470	0.658	0.759	0.816	**0.886**

The highest values are in bold.

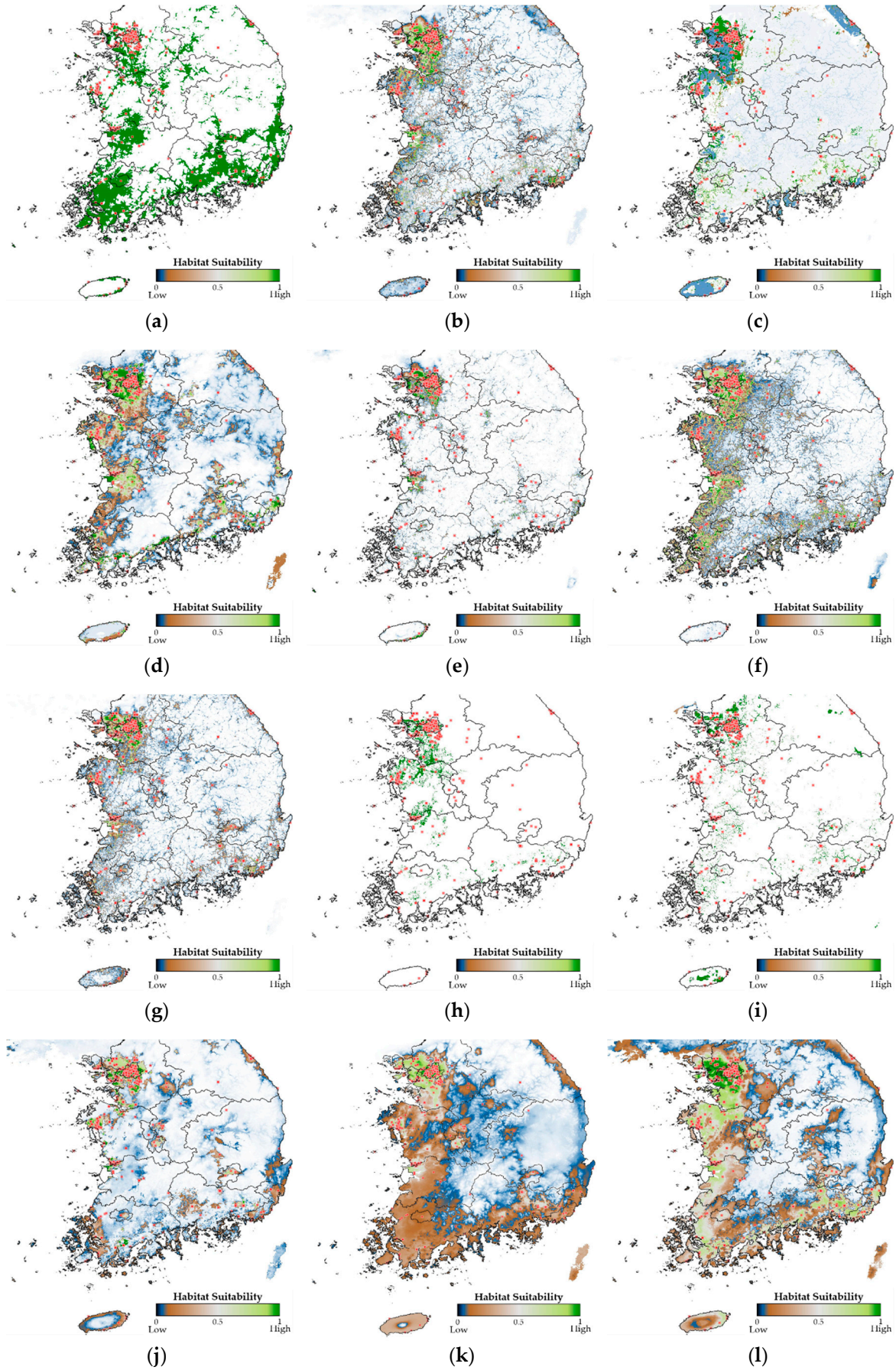

Figure S1. Habitat suitability visualization of *Anas platyrhynchos*–(a) GLM; (b) GBM; (c) CTA; (d) SNN; (e) FDA; (f) MARS; (g) RF; (h) SRE; (i) MAXENT; (j) DNN; (k) EMED; (l) TSEM.

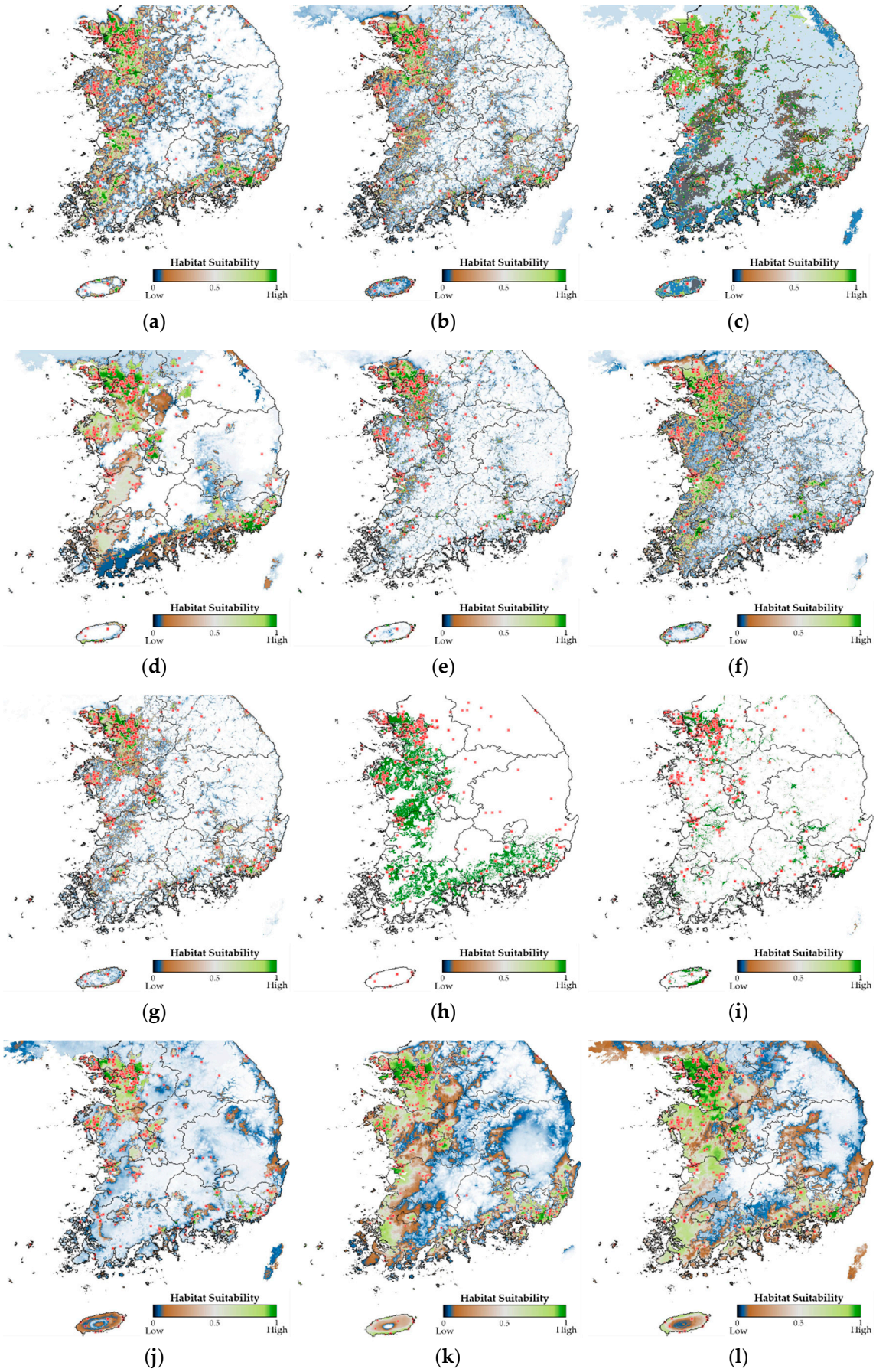

Figure S2. Habitat suitability visualization of *Anas zonorhyncha*–(a) GLM; (b) GBM; (c) CTA; (d) SNN; (e) FDA; (f) MARS; (g) RF; (h) SRE; (i) MAXENT; (j) DNN; (k) EMED; (l) TSEM.

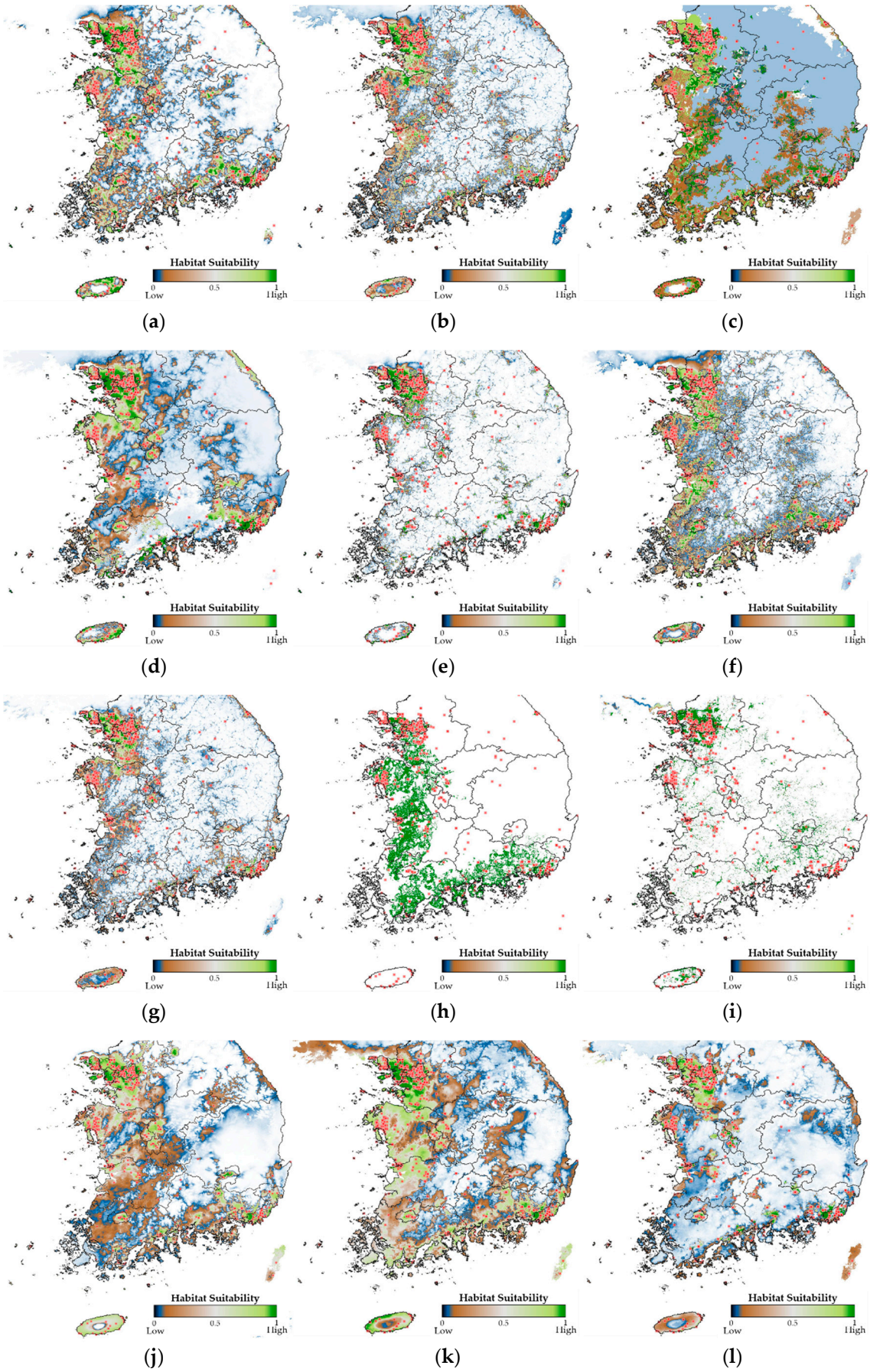

Figure S3. Habitat suitability visualization of *Ardea cinerea*–(a) GLM; (b) GBM; (c) CTA; (d) SNN; (e) FDA; (f) MARS; (g) RF; (h) SRE; (i) MAXENT; (j) DNN; (k) EMED; (l) TSEM.

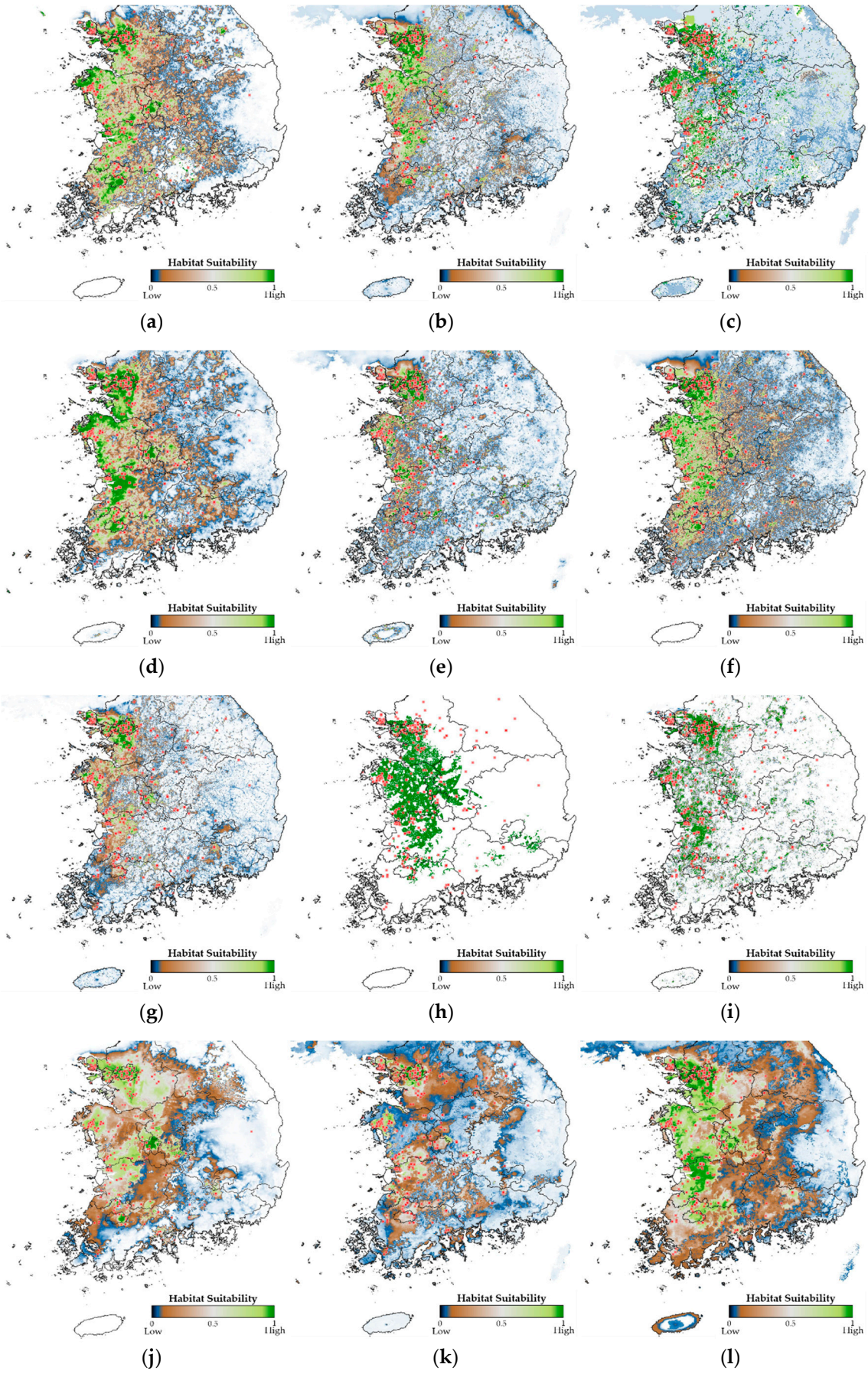

Figure S4. Habitat suitability visualization of *Cyanopica cyanus*–(a) GLM; (b) GBM; (c) CTA; (d) SNN; (e) FDA; (f) MARS; (g) RF; (h) SRE; (i) MAXENT; (j) DNN; (k) EMED; (l) TSEM.

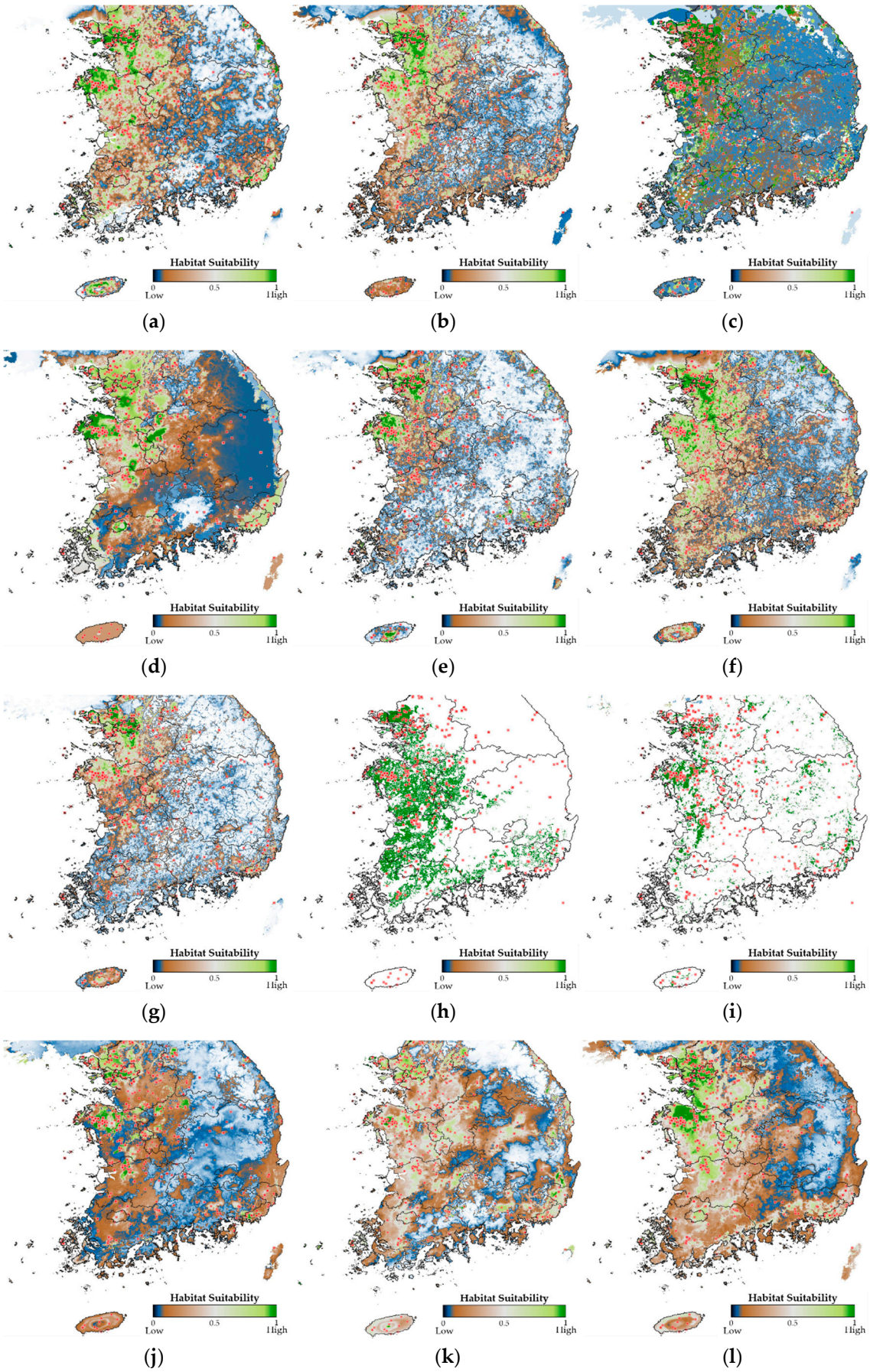

Figure S5. Habitat suitability visualization of *Hyla japonica*–(a) GLM; (b) GBM; (c) CTA; (d) SNN; (e) FDA; (f) MARS; (g) RF; (h) SRE; (i) MAXENT; (j) DNN; (k) EMED; (l) TSEM.

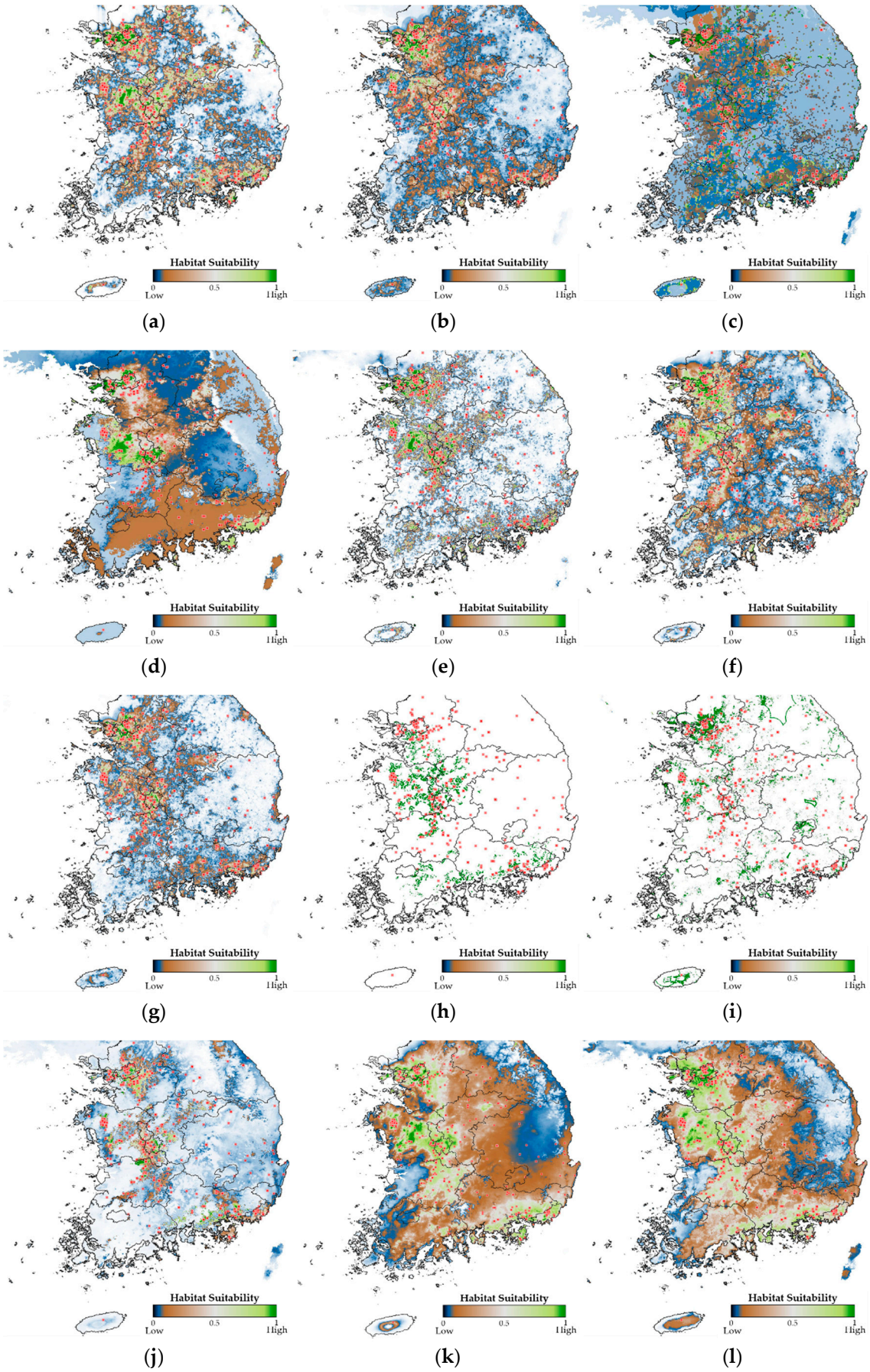

Figure S6. Habitat suitability visualization of *Hynobius leechii*–(a) GLM; (b) GBM; (c) CTA; (d) SNN; (e) FDA; (f) MARS; (g) RF; (h) SRE; (i) MAXENT; (j) DNN; (k) EMED; (l) TSEM.

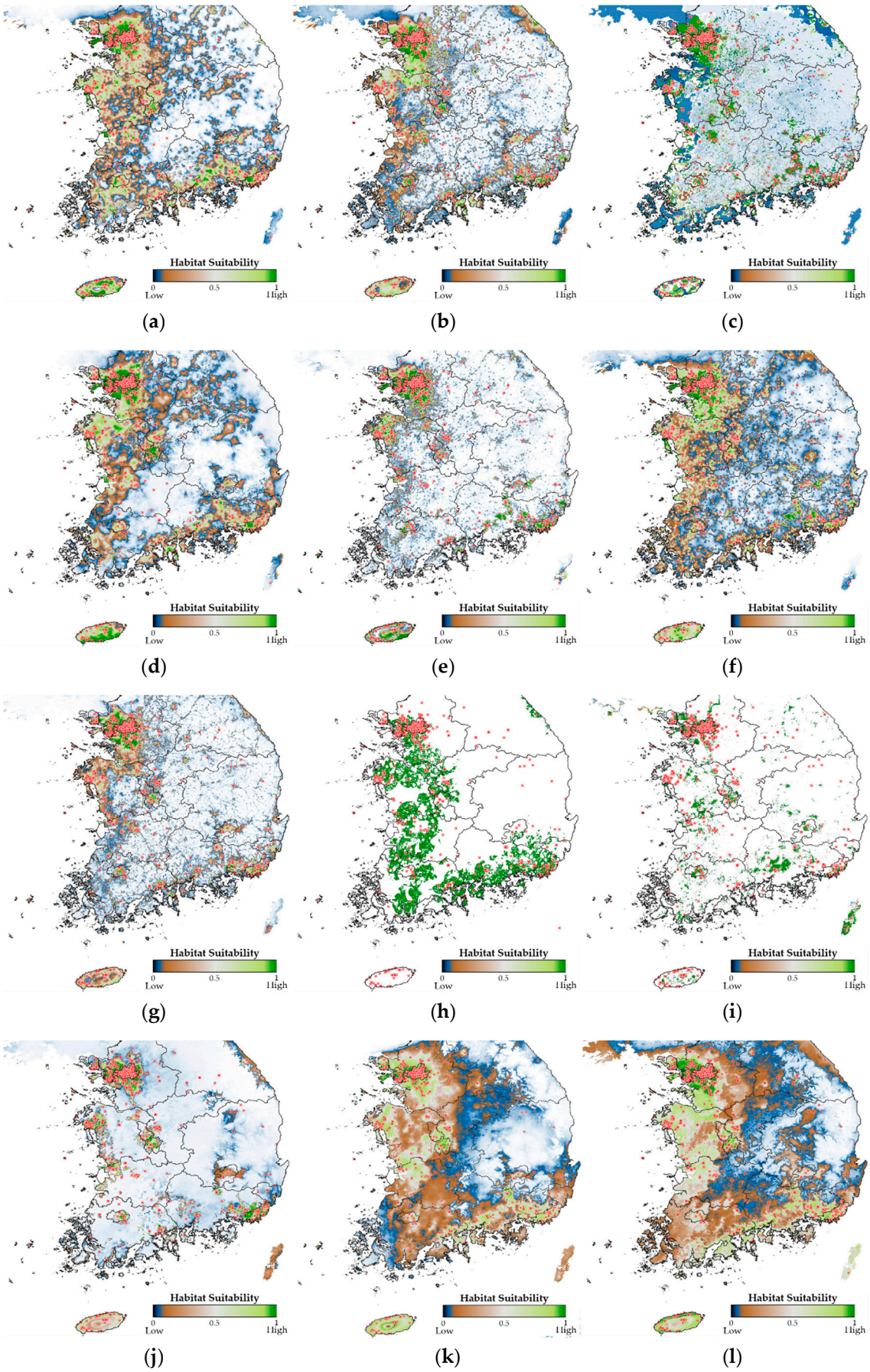

Figure S7. Habitat suitability visualization of *Hypsipetes amaurotis*–(a) GLM; (b) GBM; (c) CTA; (d) SNN; (e) FDA; (f) MARS; (g) RF; (h) SRE; (i) MAXENT; (j) DNN; (k) EMED; (l) TSEM.

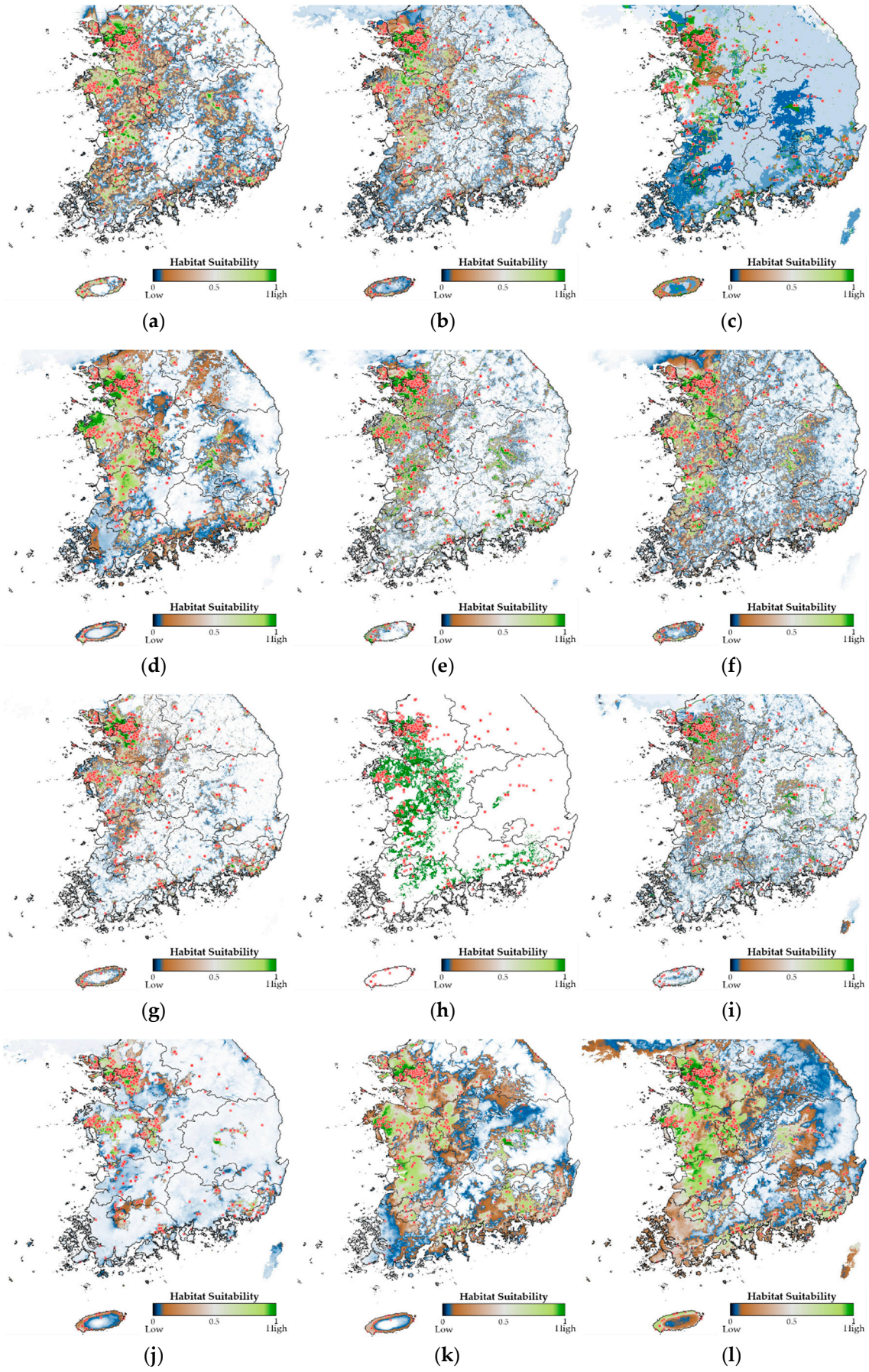

Figure S8. Habitat suitability visualization of *Passer montanus*–(a) GLM; (b) GBM; (c) CTA; (d) SNN; (e) FDA; (f) MARS; (g) RF; (h) SRE; (i) MAXENT; (j) DNN; (k) EMED; (l) TSEM.

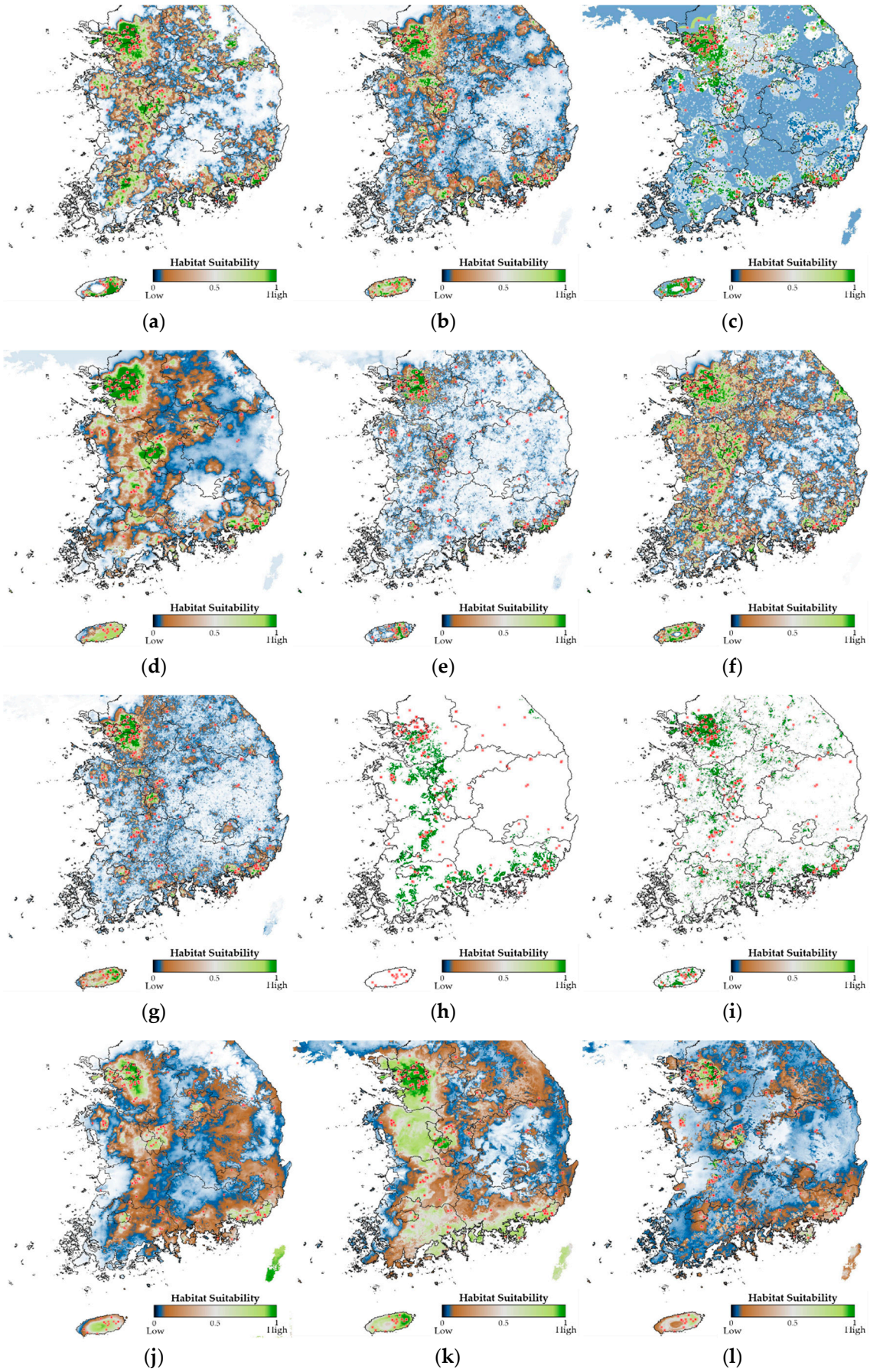

Figure S9. Habitat suitability visualization of *Rana dybowskii*–(a) GLM; (b) GBM; (c) CTA; (d) SNN; (e) FDA; (f) MARS; (g) RF; (h) SRE; (i) MAXENT; (j) DNN; (k) EMED; (l) TSEM.

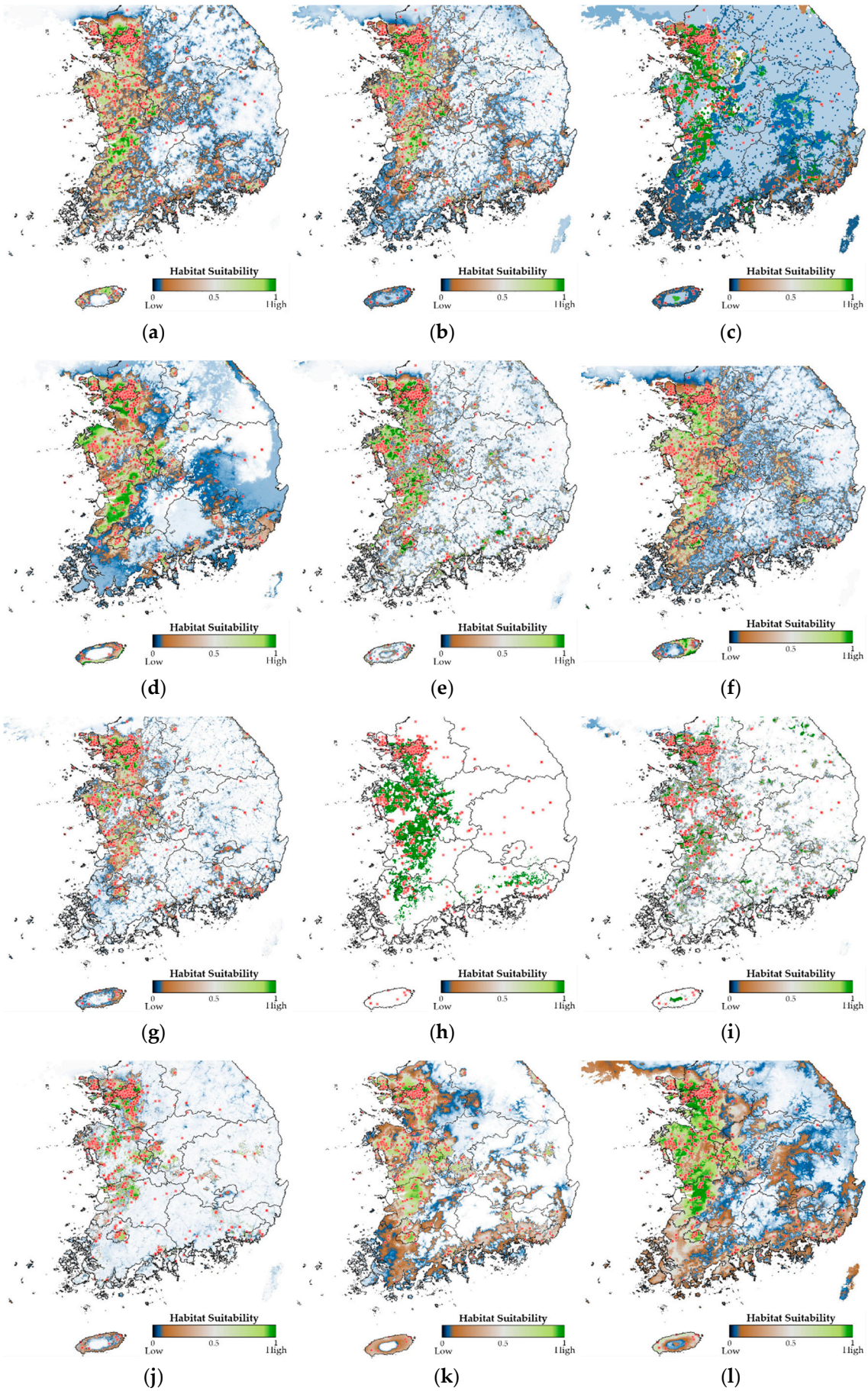

Figure S10. Habitat suitability visualization of *Streptopelia orientalis*–(a) GLM; (b) GBM; (c) CTA; (d) SNN; (e) FDA; (f) MARS; (g) RF; (h) SRE; (i) MAXENT; (j) DNN; (k) EMED; (l) TSEM.