Supporting Information. Olivia M. Smith, Christina M. Kennedy, Jeb P. Owen, Tobin D. Northfield, Christopher E. Latimer, William E. Snyder. 2019. Highly diversified crop–livestock farming systems reshape wild bird communities. *Ecological Applications.*

Appendix S1

Table S1. List of variables used in models, hypothesized impact of variable on farm birds, and hypothesized mechanisms.

Variable	Hypothesized impact	Mechanism(s)
Bird Conservation Region (BCR)	Each region represents unique community structures Greater impact on foraging guilds common to grassland or intensified arable landscapes (Coastal California)	- Regions delineated by unique biomes (Sauer et al. 2003) - Grassland/intensified arable landscapes (Coastal California) may attract granivores and omnivores through food resources (Kennedy et al. 2010, Gove et al. 2013, Dross et al. 2018) - Smaller impact on insectivorous species which may be more abundant in the forests of the Pacific Northwest Rainforest Region (Kennedy and Marra 2010, Otieno et al. 2011)
Natural habitat in the landscape (% Natural Land)	Increase native density and richness; decrease invasive density	- Native species may be more common in landscapes with more native habitat (Batáry, Matthiesen, & Tscharntke, 2010; Otieno, Gichuki, Farwig, & Kiboi, 2011; Wilson et al., 2017), though the greater richness of native compared to non-native species may reduce total impact due to diverse habitat

		requirements of communities across farms (Rodewald, 2015) - Invasive species should be more common in less-natural landscapes (Rodewald, 2015) - Granivorous/omnivorous species may be most numerous on farms embedded in the least natural landscapes, while insectivores may increase or not respond to increasing natural habitat in the landscape (Kennedy et al. 2010, Gove et al. 2013, Dross et al. 2018)
Crop–livestock integration (CLS)	Increase density and richness of all guilds	- CLS will have more diverse habitat types/higher heterogeneity (landscape complementation) (Benton et al. 2003, Tscharntke et al. 2012); high heterogeneity may reduce patch sizes and increase foraging (see below) (Somers and Morris 2002, Boesing et al. 2017) - CLS will have greater addition of pasture/hay for grassland birds - CLS will have greater food provisioning (grain, insects on feces and bodies) (Evans et al. 2006, Carlson et al. 2015, Hald et al. 2016) - CLS will have more nesting structures (Hiron et al. 2013, Šálek et al. 2017)
Livestock presence at point (Livestock at point)	Increase density and richness of granivorous, insectivorous, and structure nesting birds that can benefit from local physical presence of livestock	- Presence at point will have greater food provisioning (grain, insects on feces and bodies) (Evans et al. 2006, Carlson et al. 2015, Hald et al. 2016) - Presence at point will have more nesting structures

		(Hiron et al. 2013, Šálek et al. 2017)
Natural habitat in landscape × Crop–livestock system	Greatest benefits of livestock integration in least natural landscapes	- The greatest benefits of farm diversification are often proposed to be seen in more simplified landscapes (e.g., 1-20% non-crop habitat) where the provision of local resources are not redundant with the resources in the surrounding landscape (Batáry et al. 2010, Geiger et al. 2010, Tscharntke et al. 2012, Tuck et al. 2014). - Refugia, nesting habitat, and food resources are of highest benefit in simplified landscapes where resources are not redundant (Tscharntke et al. 2012)
On-farm crop field size, patch richness, structures/ha, and percentage land in row crops, woody crops, and pasture/hay	These variables change when livestock are integrated and directly increase wild bird density and richness Farming system will have greater predictive power than individual components	- Smaller field sizes often associated with lower pesticide and herbicide input (and thus more food) (Yan and Roy 2016); often associated with higher field heterogeneity (Fahrig et al. 2015). Birds should have higher foraging rates due to higher edge:interior ratio (Somers and Morris 2002, Boesing et al. 2017). - Patch richness increases bird abundance and richness through landscape complementation (Benton et al. 2003, Tscharntke et al. 2012) - Increased structures/ha promote nesting by structure nesting species (Hiron et al. 2013, Šálek et al. 2017) - Frequent disturbance in row crops may attract ground foragers by increasing access to soil biota and reducing

		weeds; conversely, may reduce other guilds through structural simplification (Kennedy et al. 2017) - Woody crops may promote arboreal birds and provide cavities for nesting (Petit and Petit 2003, Haslem and Bennett 2008, Boesing et al. 2017) - Pasture/hay may promote grassland species (Petit and Petit 2003, Haslem and Bennett 2008) -Farming system will have a greater impact than individual factors by combining benefits of each to impact a diverse range of species. The individual impacts of each farm variable may influence several species, while the sum of the parts could influence more species to have a greater total effect.
Farm size	Increasing farm size decreases densities and richness of all bird guilds	- Larger farms have larger patch sizes (fields, pastures, etc.) (see hypotheses above, Fig. 4, and Fig. S2, S4, and S9 below) - Larger farms may have more row crop (see hypotheses above, Fig. 4, and Fig. S2, S4, and S9 below) and otherwise more simplified habitats, with greater intensification and mechanization to meet profit needs to cover machinery, land, and input costs (Frei et al. 2018) (Fig. S9 below) - Smaller farms may have greater crop diversification (Frei et al. 2018), particularly if they switch from contracts with large wholesalers

		including only a few crops with high production requirements to providing weekly produce for Community Supported Agriculture (CSA) members or farmers markets that desire diverse weekly produce options - Smaller farms may have higher habitat heterogeneity and bolster birds through landscape complementation (Tscharntke et al. 2012, Boesing et al. 2017)
Non-native species density	Decrease native species densities and richness, particularly native cavity nesters	- Cavity exclusion (Weitzel 1988, Lindell et al. 2018) - Priority effects whereby resident non-natives can reach cavities before migratory native species (Radunzel et al. 1997) - Behavioral interference (Crozier et al. 2006, Val et al. 2018) - Numerical dominance

Table S2. Models included in paper, response variables, predictor variables, corresponding Figure(s), and corresponding tables.

Model	**Response**	**Predictor variables**	**Figure(s)**	**Table(s)**
NMDS Primary comparison of interest: Community composition by farming system	Community composition	4 groups: Coastal California CS, Coastal California CLS, Pacific Northwest Rainforest CS, Pacific Northwest Rainforest CLS	Fig. 2	N/A
SEM 1 Primary comparisons of interest: impact of farming system and impact of non-	Native density Native richness Non-native density	Direct effects: Bird Conservation Region, landscape (% natural habitat within 1500 m), farming system (crop system versus crop–livestock system), farm	Fig. 3a	Table S3

native species on native species		size, and non-native species impacts on native species		
SEM 2 Primary comparisons of interest: impact of livestock presence and impact of non-native species on native species	Native density Native richness Non-native density	Direct effects: Bird Conservation Region, landscape (% natural habitat within 1500 m), livestock presence at point, farm size, and non-native species impacts on native species	Fig. 3b	Table S4
SEM 3 (8 model sets) Primary comparison of interest: mechanism of impact of farming system	Native density Native richness Non-native density	Direct effects: Bird Conservation Region, landscape (% natural habitat within 1500 m), a series of farm management variables, farm size, and non-native species impacts on native species Indirect effects: Farming system indirectly mediates farm management variables which directly impact wild birds	Fig. 4 and Fig. S11	Table S5
SEM 4 Primary comparison of interest: ecosystem service and disservice potential by farming system	Native insectivore density Native omnivore density Native granivore density Non-native density	Direct effects: Bird Conservation Region, landscape (% natural habitat within 1500 m), farming system (crop system versus crop–livestock system), farm size, and non-native species impacts on native species diet guilds	Fig. 5a	Table S6
SEM 5 Primary comparison of interest: ecosystem service and disservice potential by farming system	Native insectivore density Native omnivore density Native granivore density Non-native density	Direct effects: Bird Conservation Region, landscape (% natural habitat within 1500 m), livestock presence at point, farm size, and non-native species impacts on native species diet guilds	Fig. 5b	Table S7
SEM 6	Native cavity nester density	Direct effects: Bird Conservation Region,	Fig. S12a	Table S8

Primary comparison of interest: non-native cavity nester impacts on native cavity nesters	Non-native cavity nester density	landscape (% natural habitat within 1500 m), farming system (crop system versus crop–livestock system), farm size, and non-native species impacts on native species		
SEM 7 Primary comparison of interest: non-native cavity nester impacts on native cavity nesters	Native cavity nester density Non-native cavity nester density	Direct effects: Bird Conservation Region, landscape (% natural habitat within 1500 m), livestock presence at point, farm size, and non-native species impacts on native species	Fig. S12b	Table S9
SEM 8 Primary comparisons of interest: impact of farming system, landscape context, and non-native species on species of concern	Species of concern density Non-native density	Direct effects: Bird Conservation Region, landscape (% natural habitat within 1500 m), farming system (crop system versus crop–livestock system), farm size, and non-native species impacts on species of concern	Fig. S13a	Table S10
SEM 9 Primary comparison of interest: impact of livestock presence, landscape context, and non-native species on species of concern	Species of concern density Non-native density	Direct effects: Bird Conservation Region, landscape (% natural habitat within 1500 m), livestock presence at point, farm size, and non-native species impacts on species of concern	Fig. S13b	Table S11

Table S3. Estimates from structural equation model depicted in Fig. 3a modeling non-native density, native density, and native richness as a function of farm size, % natural habitat in the landscape, on farm livestock, and Bird Conservation Region. Crop system and Coastal California are the reference groups for livestock and Bird Conservation Region, respectively. Global model *Fisher's C* = 1.21, *P* = 0.55. Non-native bird density model marginal pseudo R_2 = 0.25 and conditional pseudo R_2 = 0.59. Native bird density marginal pseudo R_2 = 0.25 and conditional pseudo R_2 = 0.56. Native bird richness marginal pseudo R_2 = 0.39 and conditional pseudo R_2 = 0.50.

Response	**Predictor**	**Estimate**	**Standard Error**	***P* value**
Non-native density	Farm size	-1.1173	0.1841	<0.0001***
Non-native density	% Natural land	-0.8636	0.1571	<0.0001***
Non-native density	Livestock	1.288	0.3101	<0.0001***
Native density	BCR	0.0425	0.1003	0.6715
Native density	Farm size	-0.2748	0.0504	<0.0001***
Native density	% Natural land	0.2105	0.0731	0.004**
Native density	Livestock	0.1682	0.0909	0.0644
Native density	Non-native density	0.0101	0.004	0.0109*
Native density	% Natural land*Livestock	-0.2182	0.0906	0.016*
Native richness	BCR	-0.1454	0.0599	0.0152*
Native richness	Farm size	-0.2878	0.0346	<0.0001***
Native richness	% Natural land	0.2095	0.0428	<0.0001***
Native richness	Livestock	0.2565	0.0543	<0.0001***
Native richness	Non-native density	-0.0005	0.0026	0.8443
Native richness	Native density	0.0153	0.0013	<0.0001***
Native richness	% Natural land*Livestock	-0.1343	0.0533	0.0118*

Table S4. Estimates from structural equation model depicted in Fig. 3b modeling non-native density, native density, and native richness as a function of farm size, % natural habitat in the landscape, livestock presence in a point, and Bird Conservation Region. Livestock absence from a point and Coastal California are the reference groups for livestock and Bird Conservation Region, respectively. Global model *Fisher's C* = 0.60, *P* = 0.74. Non-native bird density model marginal pseudo R_2 = 0.24 and conditional pseudo R_2 = 0.57. Native bird density marginal pseudo R_2 = 0.24 and conditional pseudo R_2 = 0.56. Native bird richness marginal pseudo R_2 = 0.369 and conditional pseudo R_2 = 0.50.

Response	**Predictor**	**Estimate**	**Standard Error**	*P* value
Non-native density	Farm size	-1.0487	0.1759	<0.0001***
Non-native density	% Natural land	-0.6496	0.1396	<0.0001***
Non-native density	Livestock at point	1.259	0.2473	<0.0001***
Native density	BCR	0.0395	0.1006	0.6948
Native density	Farm size	-0.2934	0.0495	<0.0001***

Native density	% Natural land	0.1691	0.055	0.0021**
Native density	Livestock at point	0.1606	0.0802	0.0452*
Native density	Non-native density	0.010	0.004	0.0123*
Native density	% Natural land*Livestock at point	-0.1928	0.0711	0.0067**
Native richness	BCR	-0.1313	0.0623	0.035*
Native richness	Farm size	-0.3247	0.0356	<0.0001***
Native richness	% Natural land	0.2029	0.0336	<0.0001***
Native richness	Livestock at point	0.0461	0.0522	0.3768
Native richness	Non-native density	0.0009	0.0027	0.7411
Native richness	Native density	0.0152	0.0014	<0.0001***
Native richness	% Natural land*Livestock at point	-0.1058	0.0439	0.0159*

Table S5. CIC comparison of models substituting farm management variables correlated with livestock integration. We evaluated a model combining the top two models (CLS only and structures/ha) which had a ΔCIC of 14.4, so we did not further evaluate ways to improve indirect effects models.

Model	CIC	ΔCIC	Fisher's C	D-sep *P* value	Significant missing links[a]
CLS only	51.2	0	1.21	0.55	
Structures/ha	131.4	80.2	79.4	<0.0001	Non-native density ~ Livestock Native richness ~ Livestock Structures/ha ~ Farm size
% Woody crops	187.6	136.4	135.6	<0.0001	Non-native density ~ Livestock Native richness ~ Livestock % Woody crops ~ Farm size % Woody crops ~ % natural in landscape % Woody crops ~ BCR
% Pasture/hay	292.7	241.5	240.7	<0.0001	Non-native density ~ Livestock Native density ~ Livestock Native richness ~ Livestock % Pasture/hay ~ % natural in landscape % Pasture/hay ~ BCR
Patch richness	360.8	309.6	308.8	<0.0001	Non-native density ~ Livestock Native richness ~ Livestock Patch richness ~ Farm size Patch richness ~ % natural in landscape Patch richness~ BCR
% Row crops	423.7	372.5	371.6	<0.0001	Non-native density ~ Livestock

					Native richness ~ Livestock % Row crop ~ Farm size % Row crop ~ % natural in landscape % Row crop ~ BCR
Field size	1474.0	1422.8	1422.0	< 0.0001	Non-native density ~ Livestock Native richness ~ Livestock Field size ~ Farm size Field size ~ % natural in landscape Field size ~ BCR

[a] $P < 0.05$

Table S6. Estimates from structural equation model depicted in Fig. 5a modeling non-native density diet guild density as a function of farm size, % natural habitat in the landscape, on farm livestock, and Bird Conservation Region. Crop system and Coastal California are the reference groups for livestock and Bird Conservation Region, respectively. Global *Fisher's C* = 15.2, *P* = 0.23. Non-native bird density marginal pseudo R^2 = 0.25 and conditional pseudo R^2 = 0.59. Native granivore density marginal pseudo R^2 = 0.19 and conditional pseudo R^2 = 0.51. Native insectivore density marginal pseudo R^2 = 0.15 and conditional pseudo R^2 = 0.46. Native omnivore density marginal pseudo R^2 = 0.13 and conditional pseudo R^2 = 0.41.

Response	**Predictor**	**Estimate**	**Standard Error**	**P value**
Non-native density	Farm size	-1.1173	0.1841	<0.0001***
Non-native density	% Natural land	-0.8636	0.1571	<0.0001***
Non-native density	Livestock	1.288	0.3101	<0.0001***
Omnivore density	Farm size	-0.2756	0.0697	0.0001***
Omnivore density	% Natural land	0.2751	0.0655	<0.0001***
Omnivore density	Livestock	-0.0458	0.1338	0.7324
Omnivore density	Non-native density	0.0085	0.0064	0.1815
Granivore density	BCR	-0.8111	0.2005	0.0001***
Granivore density	Farm size	-0.7923	0.1086	<0.0001***
Granivore density	% Natural land	-0.1062	0.096	0.2688
Granivore density	Livestock	0.0655	0.1824	0.7193
Granivore density	Non-native density	0.0266	0.0073	0.0003***
Insectivore density	Farm size	-0.2597	0.0584	<0.0001***
Insectivore density	% Natural land	0.085	0.0567	0.1338
Insectivore density	Livestock	0.2594	0.1145	0.0234*
Insectivore density	Non-native density	0.0031	0.0054	0.5647

Table S7. Estimates from structural equation model depicted in Fig. 5b modeling non-native density diet guild density as a function of farm size, % natural habitat in the landscape, livestock presence in a point, and Bird Conservation Region. Livestock absence from a point and Coastal California are the reference groups for livestock and Bird Conservation Region, respectively. Global *Fisher's C* = 14.6, *P* = 0.26. Non-native bird density marginal pseudo R_2 = 0.24 and conditional pseudo R_2 = 0.57. Native granivore density marginal pseudo R_2 = 0.19 and conditional pseudo R_2 = 0.51. Native insectivore density marginal pseudo R_2 = 0.14 and conditional pseudo R_2 = 0.45. Native omnivore density marginal pseudo R_2 = 0.13 and conditional pseudo R_2 = 0.42.

Response	**Predictor**	**Estimate**	**Standard Error**	**P value**
Non-native density	Farm size	-1.0487	0.1759	<0.0001***
Non-native density	% Natural land	-0.6496	0.1396	<0.0001***
Non-native density	Livestock at point	1.259	0.2473	<0.0001***
Omnivore density	Farm size	-0.2651	0.0694	0.0001***
Omnivore density	% Natural land	0.2533	0.0618	<0.0001***
Omnivore density	Livestock at point	0.1255	0.1174	0.2853
Omnivore density	Non-native density	0.0069	0.0065	0.284
Granivore density	BCR	-0.7897	0.2	0.0001***
Granivore density	Farm size	-0.7854	0.1084	<0.0001***
Granivore density	% Natural land	-0.116	0.0938	0.2163
Granivore density	Livestock at point	0.1022	0.1539	0.5066
Granivore density	Non-native density	0.026	0.0073	0.0004***
Insectivore density	Farm size	-0.2804	0.0583	<0.0001***
Insectivore density	% Natural land	0.1394	0.0532	0.0088**
Insectivore density	Livestock at point	0.0545	0.1018	0.5929
Insectivore density	Non-native density	0.0042	0.0055	0.4441

Table S8. Estimates from structural equation model depicted in Fig. S12a modeling native and non-native cavity nester densities as a function of farm size, % natural habitat in the landscape, on farm livestock, and Bird Conservation Region (BCR). Crop system and Coastal California are the reference groups for livestock and Bird Conservation Region, respectively. Global *Fisher's C* = 0.56, *P* = 0.76. Non-native cavity nester density marginal pseudo R_2 = 0.22 and conditional pseudo R_2 = 0.56, and native cavity nester density marginal pseudo R_2 = 0.22 and conditional pseudo R_2 = 0.45.

Response	**Predictor**	**Estimate**	**Standard Error**	**P value**
Non-native cavity nester density	Farm size	-1.03	0.19	<0.0001***
Non-native cavity nester density	% Natural land	-0.75	0.16	<0.0001***

Non-native cavity nester density	Livestock	1.31	0.32	<0.0001***
Native cavity nester density	Farm size	-0.32	0.12	0.008 **
Native cavity nester density	% Natural land	0.38	0.098	0.0001***
Native cavity nester density	Livestock	1.08	0.19	<0.0001***
Native cavity nester density	Non-native density	0.013	0.008	0.099
Native cavity nester density	BCR	-0.24	0.21	0.26

Table S9. Estimates from structural equation model depicted in Fig. S12b modeling native and non-native cavity nester densities as a function of farm size, % natural habitat in the landscape, livestock presence within a point, and Bird Conservation Region. No livestock and Coastal California are the reference groups for livestock and Bird Conservation Region, respectively. Global *Fisher's C* = 0.004, *P* = 0.99. Non-native cavity nester density marginal pseudo R_2 = 0.21 and conditional pseudo R_2 = 0.54, and native cavity nester density marginal pseudo R_2 = 0.17 and conditional pseudo R_2 = 0.46.

Response	**Predictor**	**Estimate**	**Standard Error**	**P value**
Non-native cavity nester density	Farm size	-0.97	0.18	<0.0001***
Non-native cavity nester density	% Natural land	-0.54	0.14	0.0002***
Non-native cavity nester density	Livestock at point	1.29	0.26	<0.0001***
Native cavity nester density	Farm size	-0.46	0.13	0.0003***
Native cavity nester density	% Natural land	0.51	0.10	<0.0001***
Native cavity nester density	Livestock at point	-0.003	0.16	0.99
Native cavity nester density	Non-native density	0.018	0.008	0.027*
Native cavity nester density	BCR	-0.098	0.23	0.66

Table S10. Estimates from structural equation model depicted in Fig. S13a modeling species of concern and non-native densities as a function of farm size, % natural habitat in the landscape, livestock on farm, and Bird Conservation Region. Crop system and Coastal California are the reference groups for livestock and Bird Conservation Region, respectively. Global *Fisher's C* = 1.21, *P* = 0.55. Non-native density marginal pseudo R^2 = 0.25 and conditional pseudo R^2 = 0.59, and species of concern density marginal pseudo R^2 = 0.08 and conditional pseudo R^2 = 0.35.

Response	**Predictor**	**Estimate**	**Standard Error**	**P value**
Non-native density	Farm size	-1.12	0.18	< 0.0001***
Non-native density	% Natural land	-0.86	0.16	<0.0001***
Non-native density	Livestock	1.29	0.31	<0.0001***
Species of concern density	Farm size	-0.042	0.090	0.64
Species of concern density	% Natural land	0.41	0.13	0.002**
Species of concern density	Livestock	0.48	0.16	0.003**
Species of concern density	Non-native density	-0.005	0.009	0.59
Species of concern density	BCR	-0.15	0.18	0.39
Species of concern density	% Natural*Livestock	-0.37	0.16	0.023*

Table S11. Estimates from structural equation model depicted in Fig. S13b modeling species of concern and non-native densities as a function of farm size, % natural habitat in the landscape, livestock presence within a point, and Bird Conservation Region. No livestock and Coastal California are the reference groups for livestock and Bird Conservation Region, respectively. Global *Fisher's C* = 0.44, *P* = 0.80. Non-native density marginal pseudo R^2 = 0.25 and conditional pseudo R^2 = 0.57, and species of concern density marginal pseudo R^2 = 0.05 and conditional pseudo R^2 = 0.34.

Response	**Predictor**	**Estimate**	**Standard Error**	**P value**
Non-native density	Farm size	-1.07	0.18	< 0.0001***
Non-native density	% Natural land	-0.68	0.14	<0.0001***
Non-native density	Livestock at point	1.26	0.25	<0.0001***
Species of concern density	Farm size	-0.11	0.09	0.23
Species of concern density	% Natural land	0.36	0.10	0.0003***
Species of concern density	Livestock at point	0.17	0.15	0.26
Species of concern density	Non-native density	-0.004	0.009	0.71
Species of concern density	BCR	-0.15	0.18	0.41
Species of concern density	% Natural*Livestock at point	-0.29	0.13	0.031*

SI REFERENCES

Batáry, P., T. Matthiesen, and T. Tscharntke. 2010. Landscape-moderated importance of hedges in conserving farmland bird diversity of organic vs. conventional croplands and grasslands. Biological Conservation 143:2020–2027.

Benton, T. G., J. A. Vickery, and J. D. Wilson. 2003. Farmland biodiversity: Is habitat heterogeneity the key? Trends in Ecology and Evolution 18:182–188.

Boesing, A. L., E. Nichols, and J. P. Metzger. 2017. Effects of landscape structure on avian-mediated insect pest control services: a review. Landscape Ecology 32:931–944.

Carlson, J. C., D. R. Hyatt, J. W. Ellis, D. R. Pipkin, A. M. Mangan, M. Russell, D. S. Bolte, R. M. Engeman, T. J. Deliberto, and G. M. Linz. 2015. Mechanisms of antimicrobial resistant Salmonella enterica transmission associated with starling – livestock interactions. Veterinary Microbiology 179:60–68.

Crozier, A. M. L., M. E. Seamans, R. J. Gutiérrez, J. Peter, and R. B. Horn. 2006. Does the presence of barred owls suppress the calling behavior of spotted owls? The Conder 108:760–769.

Dross, C., K. Princé, F. Jiguet, and M. Tichit. 2018. Contrasting bird communities along production gradients of crops and livestock in French farmlands. Agriculture, Ecosystems and Environment 253:55–61.

Evans, D. M., S. M. Redpath, S. A. Evans, D. A. Elston, C. J. Gardner, P. Dennis, and R. J. Pakeman. 2006. Low intensity, mixed livestock grazing improves the breeding abundance of a common insectivorous passerine. Biology Letters:636–638.

Fahrig, L., J. Girard, D. Duro, J. Pasher, A. Smith, S. Javorek, D. King, K. F. Lindsay, S. Mitchell, and L. Tischendorf. 2015. Farmlands with smaller crop fields have higher within-field biodiversity. Agriculture, Ecosystems and Environment 200:219–234.

Frei, B., D. Renard, M. G. E. Mitchell, V. Seufert, R. C. Jeanine, and M. R. Elena. 2018. Bright spots in agricultural landscapes: Identifying areas exceeding expectations for multifunctionality and biodiversity. Journal of Applied Ecology 55:2731–2743.

Geiger, F., G. R. De Snoo, F. Berendse, I. Guerrero, M. B. Morales, J. O. Juan, S. Eggers, T. Pärt, R. Bommarco, J. Bengtsson, L. W. Clement, W. W. Weisser, A. Olszewski, P. Ceryngier, V. Hawro, P. Inchausti, C. Fischer, and A. Flohre. 2010. Landscape composition influences farm management effects on farmland birds in winter: A pan-European approach. Agriculture, Ecosystems and Environment 139:571–577.

Gove, A. D., K. Hylander, S. Nemomissa, A. Shimelis, W. Enkossa, A. D. Gove, and E. T. Al. 2013. Structurally complex farms support high avian functional diversity in tropical montane Ethiopia. Journal of Tropical Ecology 29:87–97.

Hald, B., M. N. Skov, E. M. Nielsen, C. Rahbek, J. J. Madsen, M. Wainø, M. Chriél, S. Nordentoft, D. L. Baggesen, and M. Madsen. 2016. Campylobacter jejuni and Campylobacter coli in wild birds on Danish livestock farms. Acta Veterinaria Scandinavica 58:1–10.

Haslem, A., and A. F. Bennett. 2008. Countryside elements and the conservation of birds in agricultural environments. Agriculture, Ecosystems & Environment 125:191–203.

Hiron, M., Å. Berg, S. Eggers, J. Josefsson, and T. Pärt. 2013. Bird diversity relates to agri-environment schemes at local and landscape level in intensive farmland. Agriculture, Ecosystems and Environment 176:9–16.

Kennedy, C. M., and P. P. Marra. 2010. Matrix mediates avian movements in tropical forested landscapes: Inference from experimental translocations. Biological Conservation 143:2136–2145.

Kennedy, C. M., P. P. Marra, W. F. Fagan, and M. C. Neel. 2010. Landscape matrix and species traits mediate responses of Neotropical resident birds to forest fragmentation in Jamaica. Ecological Monographs 80:651–669.

Kennedy, C. M., E. F. Zipkin, and P. P. Marra. 2017. Differential matrix use by Neotropical birds based on species traits and landscape condition: Ecological Applications 27:619–631.

Lindell, C., R. A. Eaton, P. H. Howard, S. M. Roels, and M. E. Shave. 2018. Enhancing agricultural landscapes to increase crop pest reduction by vertebrates. Agriculture, Ecosystems and Environment 257:1–11.

Otieno, N. E., N. Gichuki, N. Farwig, and S. Kiboi. 2011. The role of farm structure on bird assemblages around a Kenyan tropical rainforest. African Journal of Ecology 49:410–417.

Petit, L. J., and D. R. Petit. 2003. Evaluating the importance of human-modified lands for neotropical bird conservation. Conservation Biology 17:687–694.

Radunzel, L. A., D. M. Muschitz, V. M. Bauldry, and P. Arcese. 1997. A long-term study of the breeding success of eastern bluebirds by year and cavity type. Journal of Field Ornithology 68:7–18.

Šálek, M., M. Bažant, and M. Zmihorski. 2017. Active farmsteads are year-round strongholds for farmland birds. Journal of Applied Ecology 55:1908–1918.

Sauer, J., J. Fallon, and R. Johnson. 2003. Use of North American Breeding Bird Survey Data to Estimate Population Change for Bird Conservation Regions. The Journal of Wildlife Management 67:372–389.

Somers, C. M., and R. D. Morris. 2002. Birds and wine grapes: Foraging activity causes small-scale damage patterns in single vineyards. Journal of Applied Ecology 39:511–523.

Tscharntke, T., J. M. Tylianakis, T. A. Rand, R. K. Didham, L. Fahrig, P. Batáry, J. Bengtsson, Y. Clough, T. O. Crist, C. F. Dormann, R. M. Ewers, J. Fründ, R. D. Holt, A. Holzschuh, A. M. Klein, D. Kleijn, C. Kremen, D. A. Landis, W. Laurance, D. Lindenmayer, C. Scherber, N. Sodhi, I. Steffan-Dewenter, C. Thies, W. H. van der Putten, and C. Westphal. 2012. Landscape moderation of biodiversity patterns and processes - eight hypotheses.

Tuck, S. L., C. Winqvist, F. Mota, J. Ahnström, L. A. Turnbull, and J. Bengtsson. 2014. Land-use intensity and the effects of organic farming on biodiversity: A hierarchical meta-analysis. Journal of Applied Ecology 51:746–755.

Val, J., D. J. Eldridge, S. K. Travers, and I. Oliver. 2018. Livestock grazing reinforces the competitive exclusion of bodied birds by large aggressive birds. Journal of Applied Ecology 55:1919–1929.

Weitzel, N. H. 1988. Nest-site competition between the european starling and native breeding birds in Northwestern Nevada. The Condor 90:515–517.

Yan, L., and D. P. Roy. 2016. Remote sensing of environment conterminous United States crop field size quantification from multi-temporal Landsat data. Remote Sensing and Environment 172:67–86.

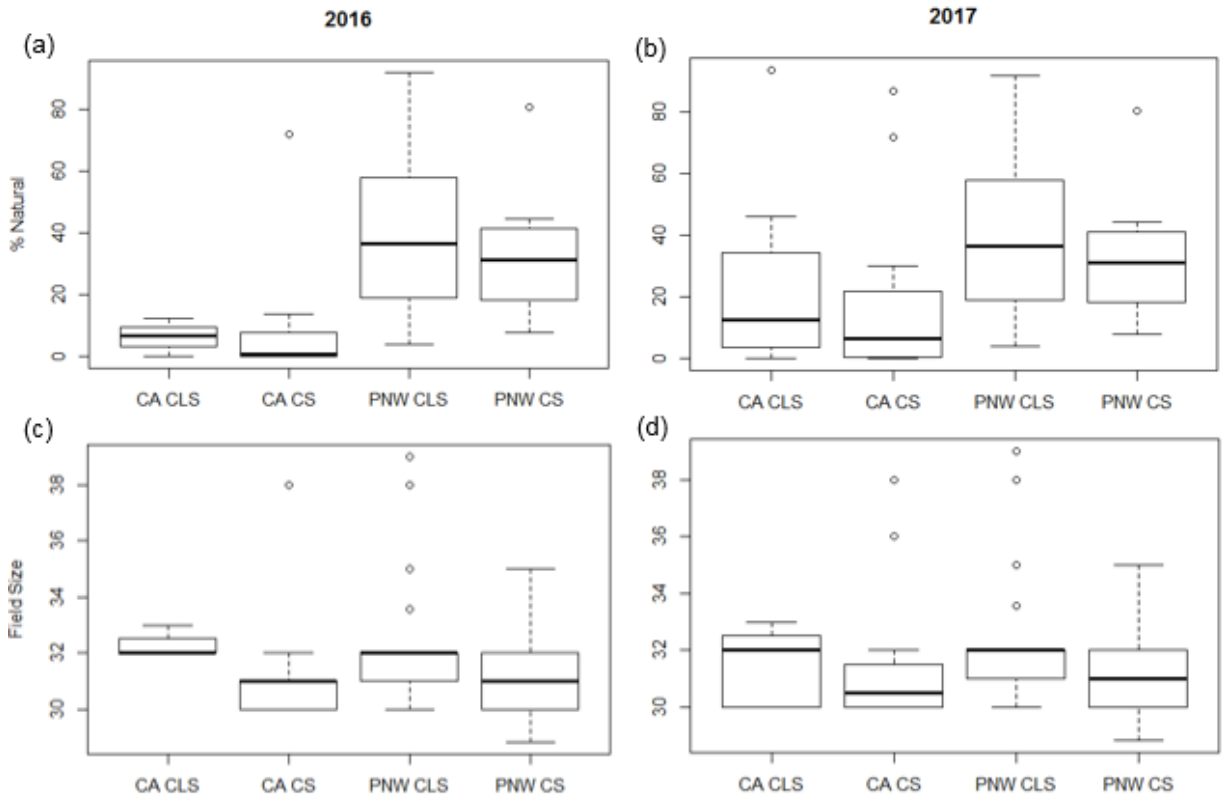

Fig. S1. Boxplots showing range of (a-b) natural habitat calculated form the National Land Cover Database and (c-d) average crop field size in the landscape calculated from the IIASA-IFPRI global field size map (Yan and Roy 2016) in a 1500 m radius from farm center by farming system (CS = crop system, CLS = crop–livestock system) and Bird Conservation Bird Conservation Region (CA = Coastal California, PNW = Pacific Northwest Rainforest) for farms surveyed in 2016 (top) and 2017 (bottom).

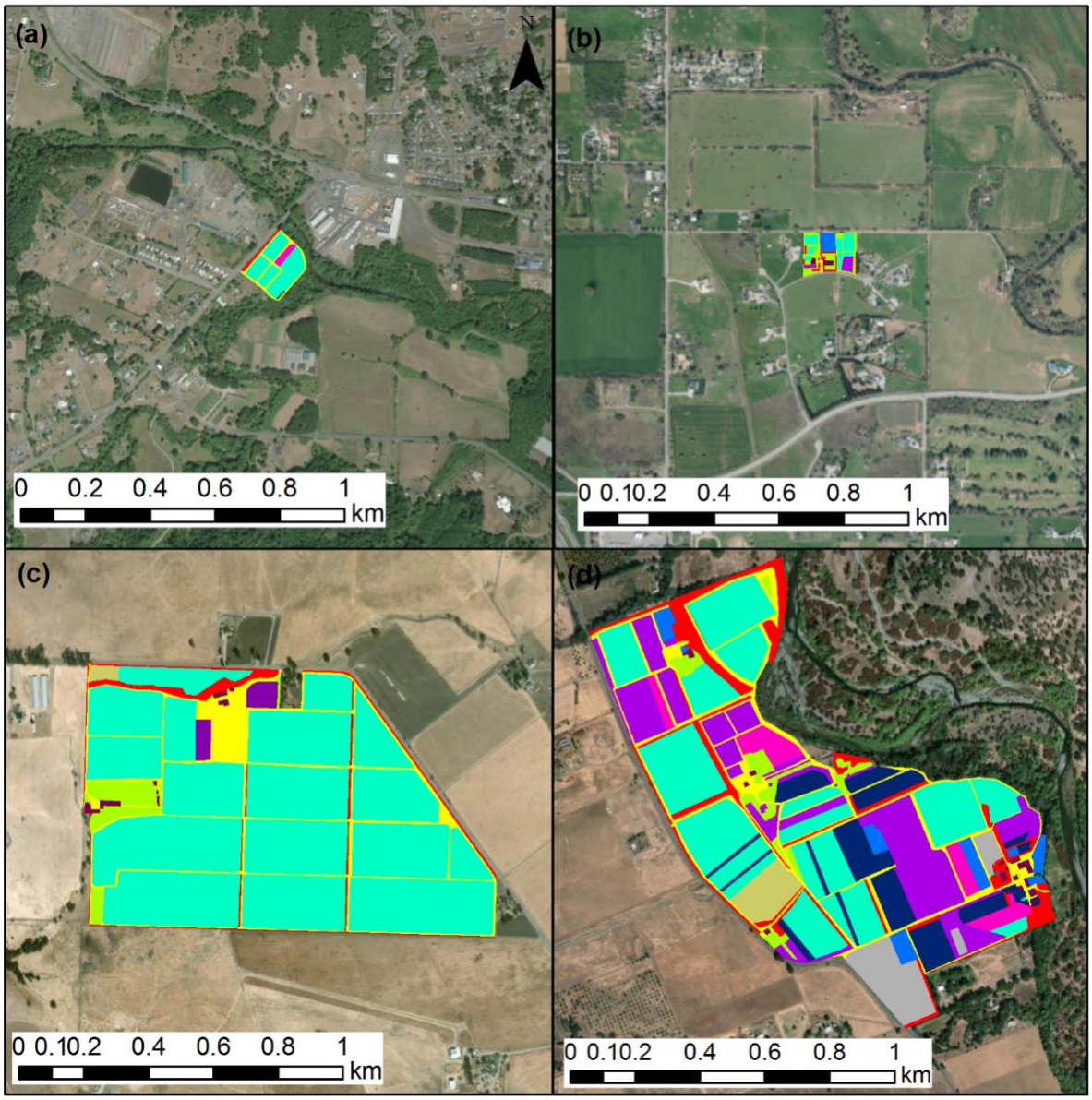

Fig. S2. Maps comparing habitat diversity and size of an (a) small, crop system, (b) small, crop–livestock system, (c) large, crop system, and (d) large, crop–livestock system. Color coding and scale are consistent throughout panels for comparison. Color coding: red hedge or woody ditch, purple woody crop, yellow road, lime green mowed grass, brown structure, blue livestock, gray orchard with livestock, olive pasture/hay, pink cover crop, dark navy flowers.

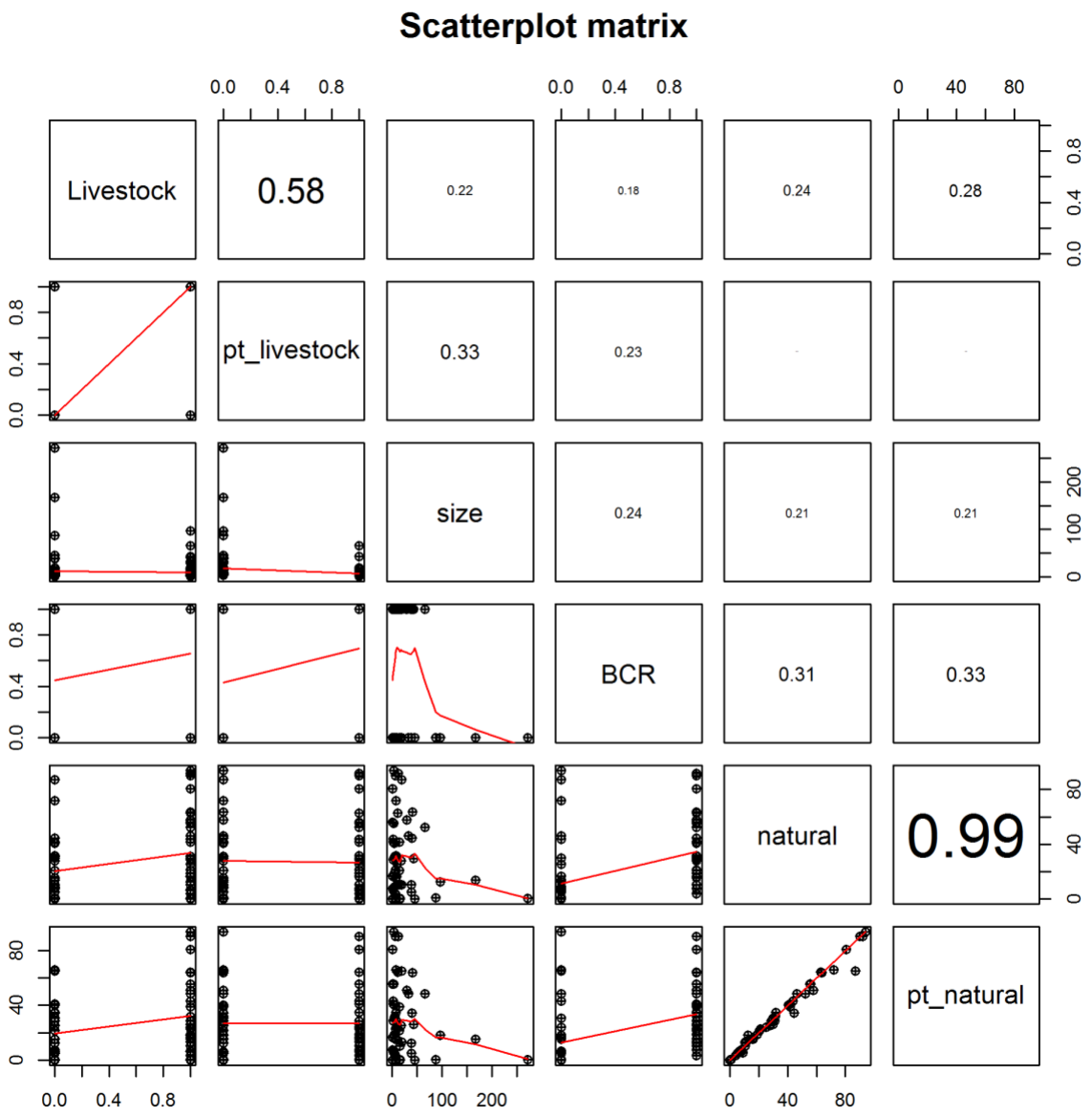

Fig. S3. Pairwise scatterplot showing Pearson's R_2 correlations between variables in structural equation models including livestock presence/absence on farm, farm in a survey point, farm size (ha), Bird Conservation Bird Conservation Region, % natural/semi-natural habitat in the landscape (1500 m) from the farm center, and % natural habitat in the landscape from each point center.

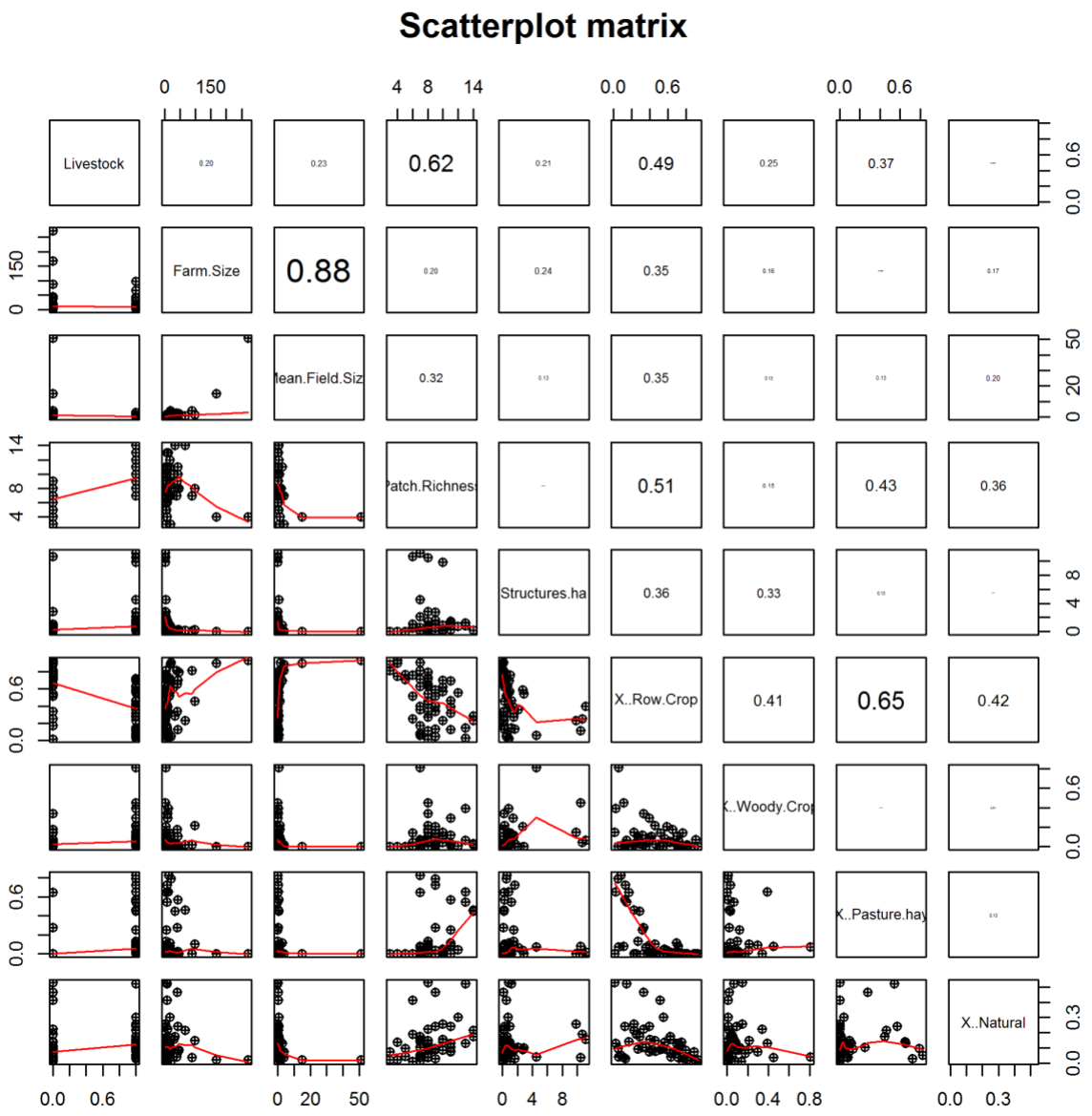

Fig. S4. Pairwise scatterplot showing Pearson's R_2 correlations between on farm variables livestock presence/absence on farm, farm size, farm mean crop field size, farm patch richness, structures/ha on farm, farm % row crop, farm % woody crop, farm % pasture/hay, and on-farm % natural/semi-natural habitat.

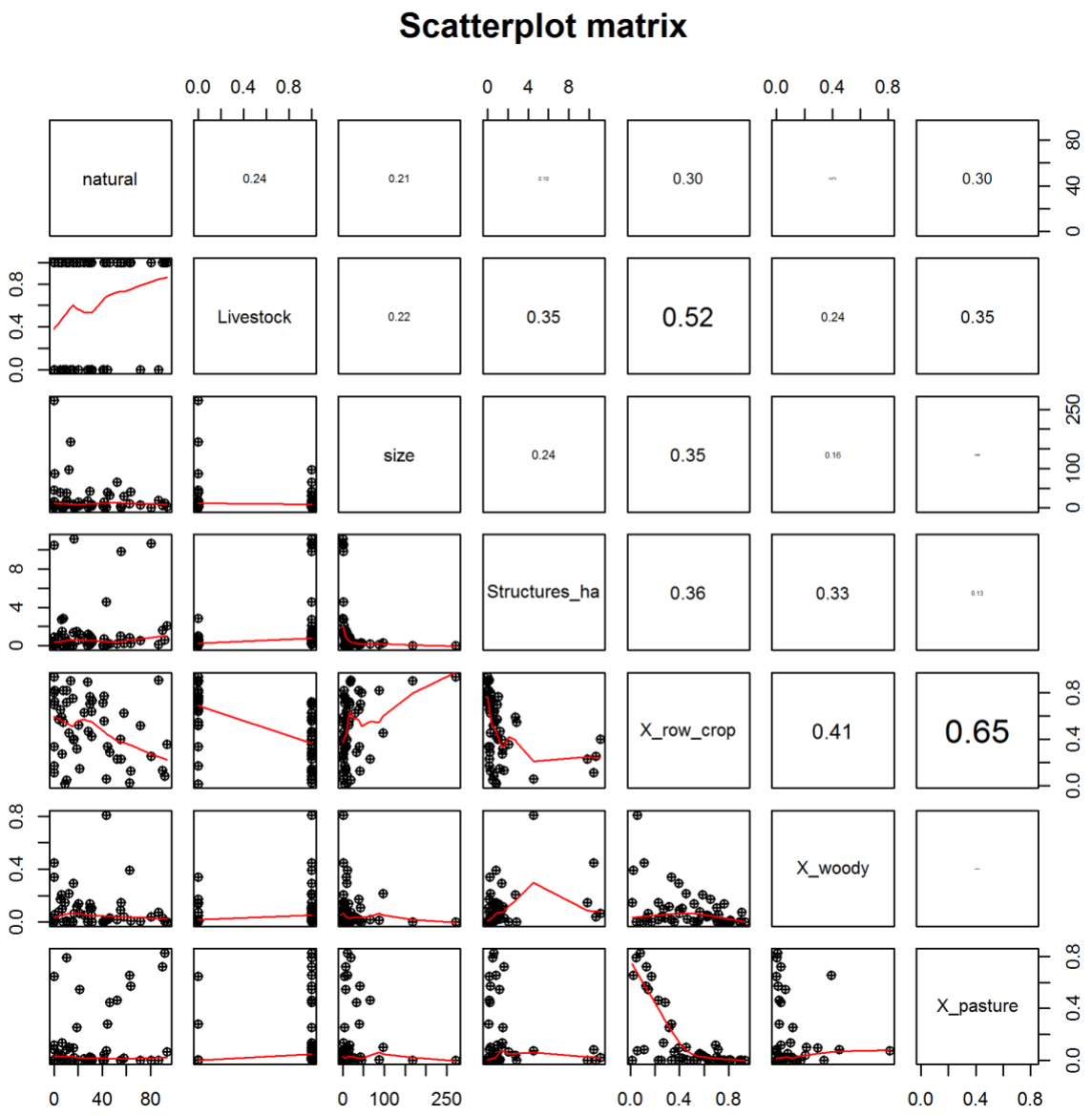

Fig. S5. Pairwise scatterplot showing Pearson's R_2 correlations between on variables used in SEM to test mechanistic hypotheses described in Table S4: % natural in the landscape (1500 m), farm livestock presence/absence, farm size, structures/ha, % row crop on farm, % woody crop on farm, and % pasture/hay on farm.

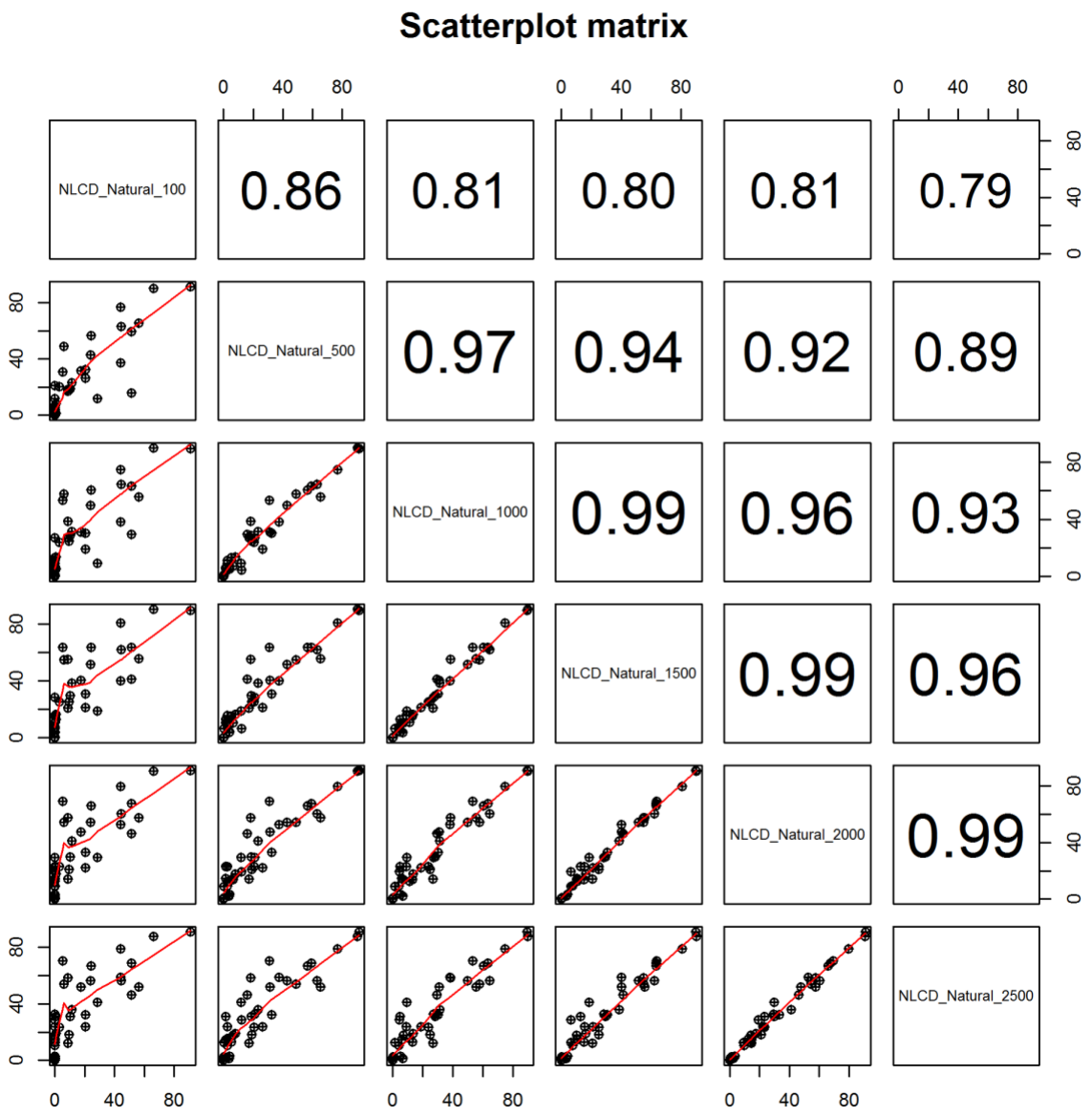

Fig. S6. Pairwise scatterplot showing Pearson's R_2 correlations between percentage natural habitat in the landscape from 100 m to 2500 m.

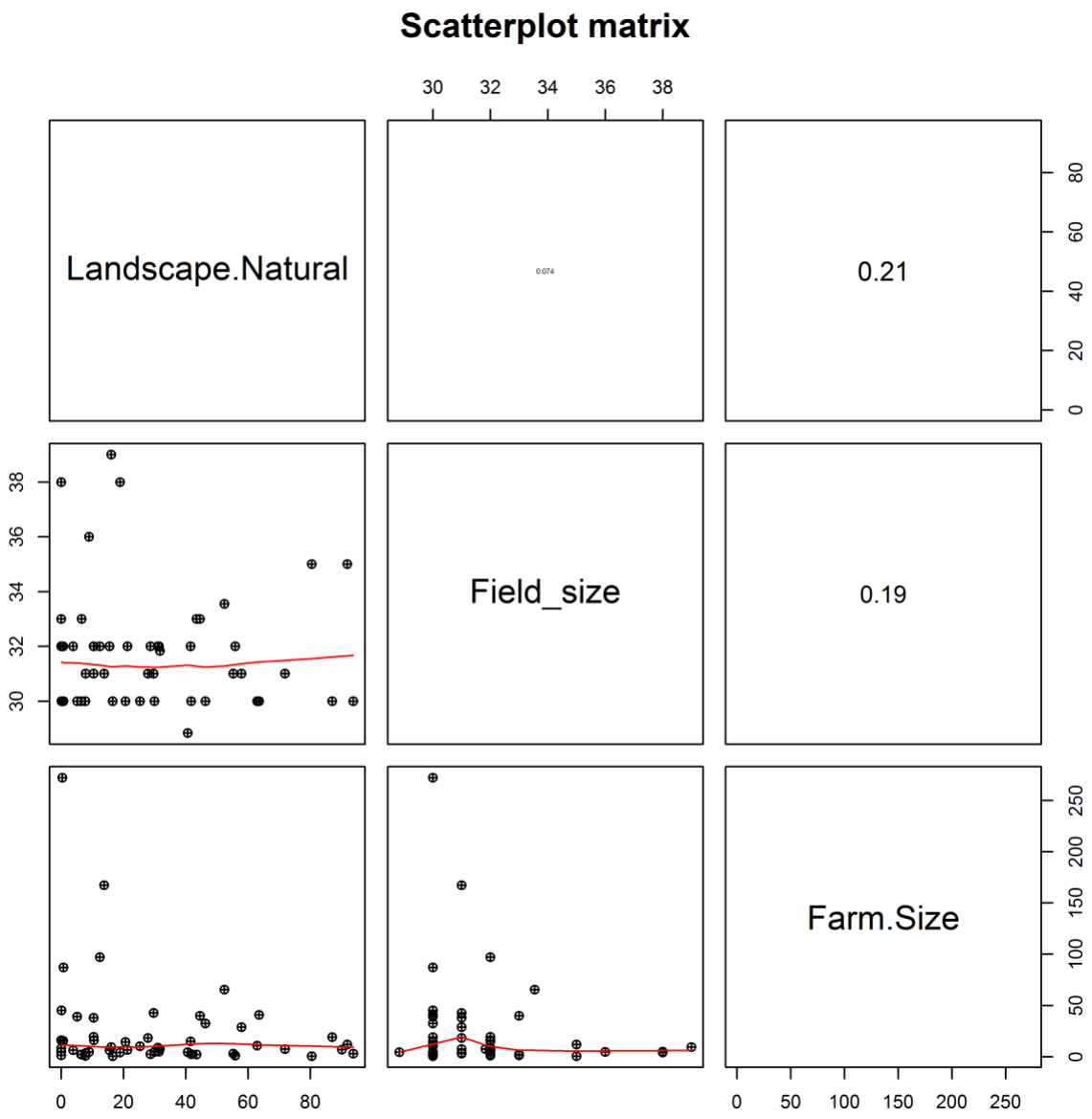

Fig. S7. Pairwise scatterplot showing Pearson's R_2 correlations between percentage natural habitat in the landscape, average field size in the landscape, and size of the farm surveyed.

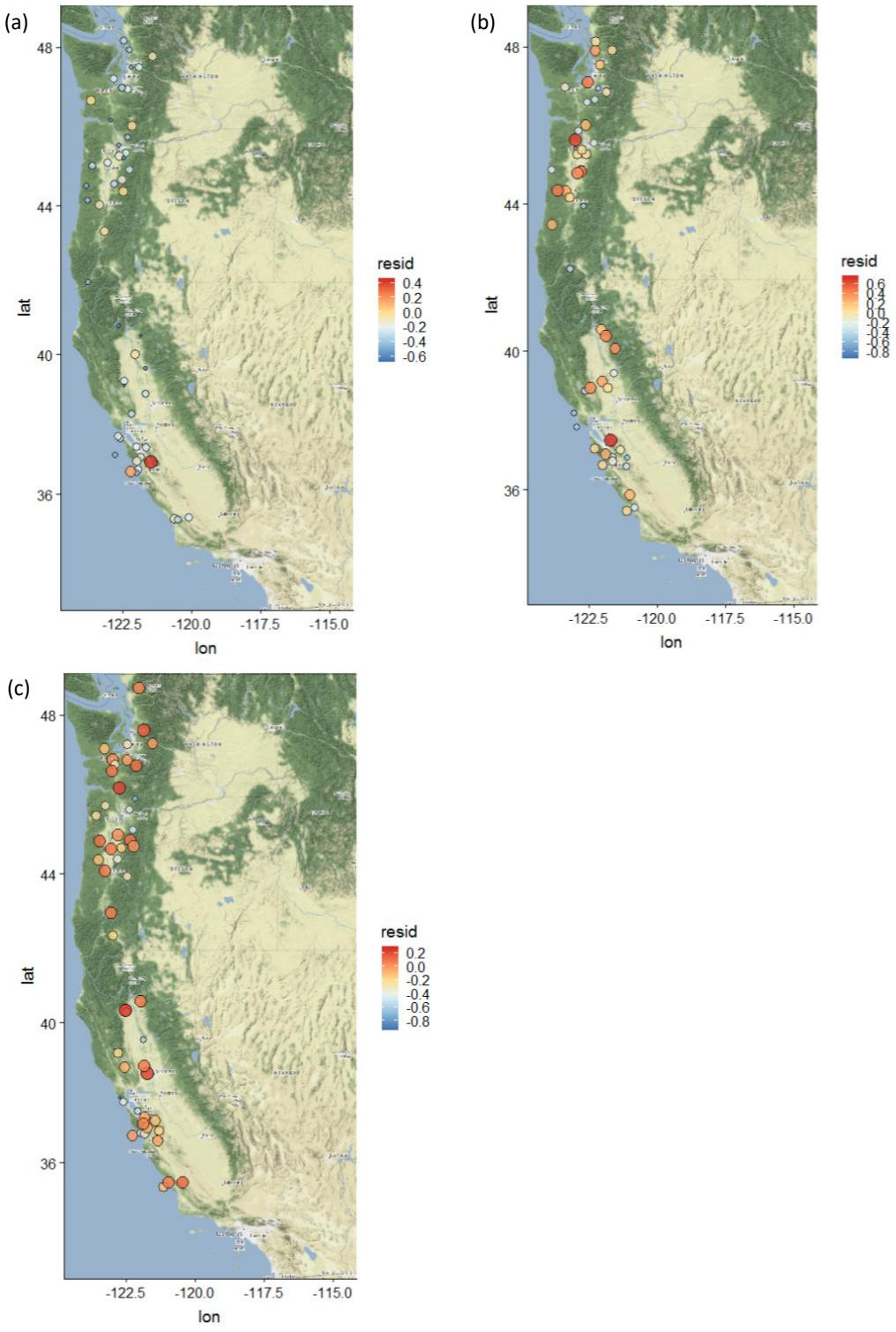

Fig. S8. Spatial residuals for (a) non-native bird density, (b) native bird density, and (c) native bird richness.

Fig. S9. Photos showing example of (a) a small farm and (b) a large farm.

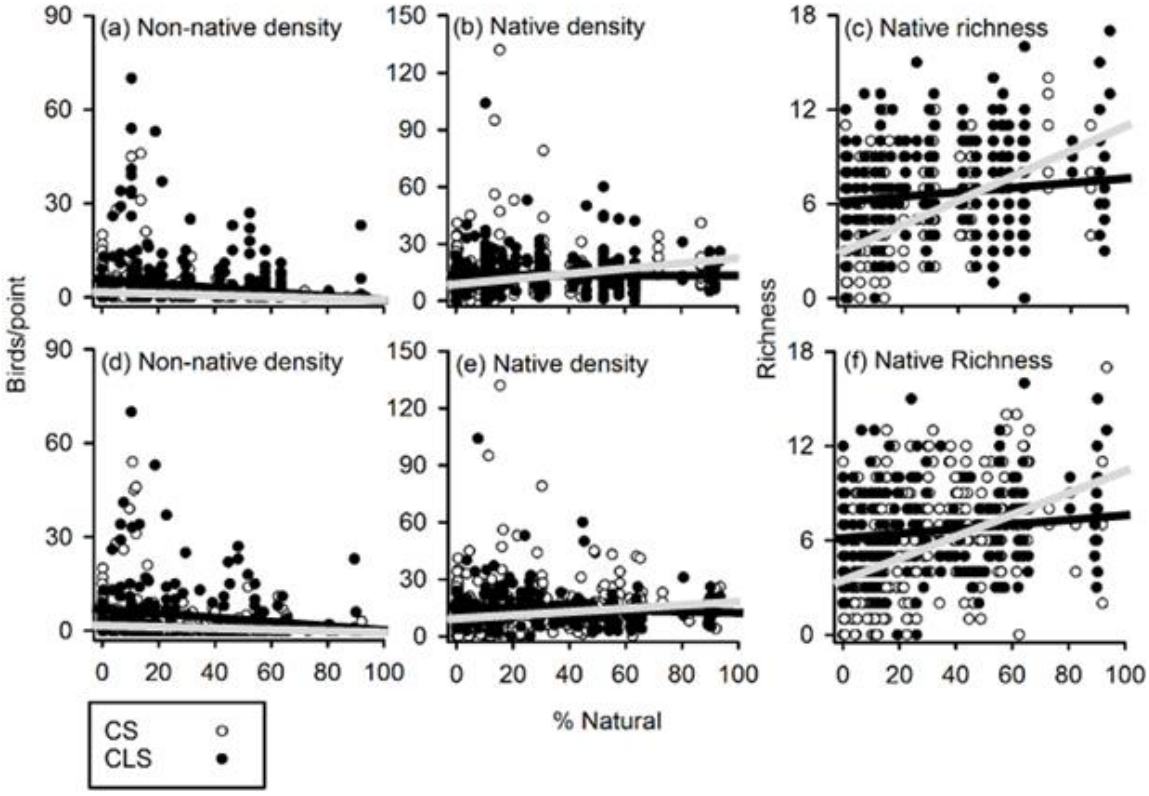

Fig. S10. Interactions between farming system (crop system (CS) and crop–livestock system (CLS) and % natural habitat in the landscape for (a) non-native species density, (b) native species density, and (c) native species richness. Interactions between livestock presence at survey point and % natural habitat in the landscape for (a) non-native species density, (b) native species density, and (c) native species richness.

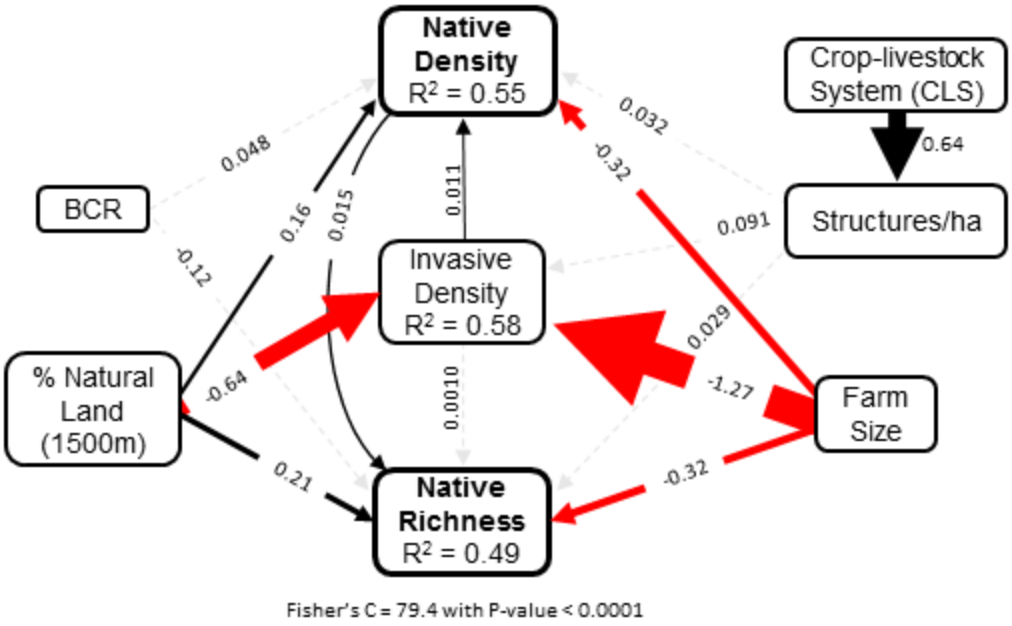

Fig. S11. Example of structural equation model presented in Table S5 with an indirect effect of livestock integration on wild bird communities.

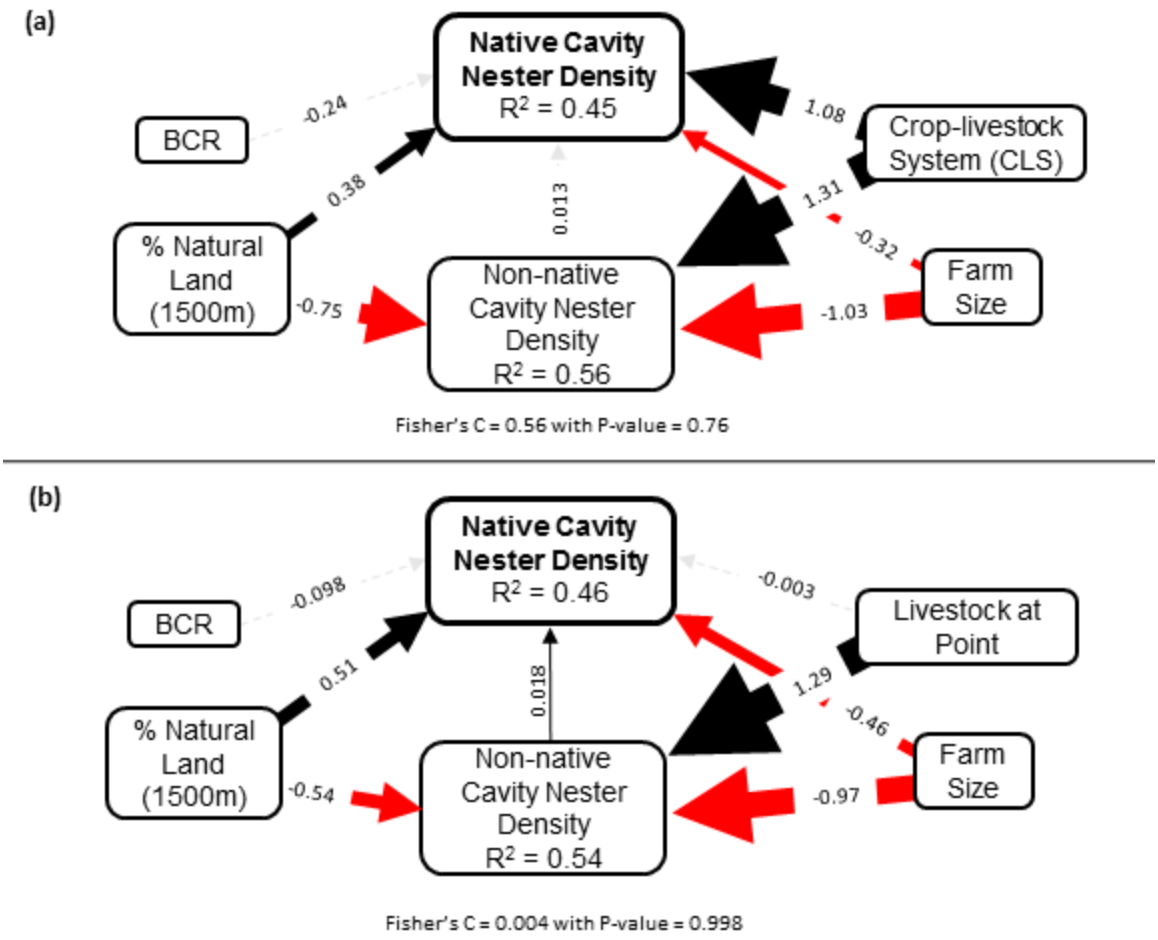

Fig. S12. Structural equation model showing links between (a) Bird Conservation Region (BCR), % natural land cover, crop–livestock system (CLS), farm size, non-native cavity nester density and native cavity nester density, and (b) % natural land cover buffered around a point, livestock presence at point, farm size, non-native cavity nester density and native cavity nester density. Black solid lines indicate positive relationships, red solid arrows indicate negative relationships, solid circles indicate interactions, and dashed gray lines indicate non-significant relationships. Lines are scaled to coefficients.

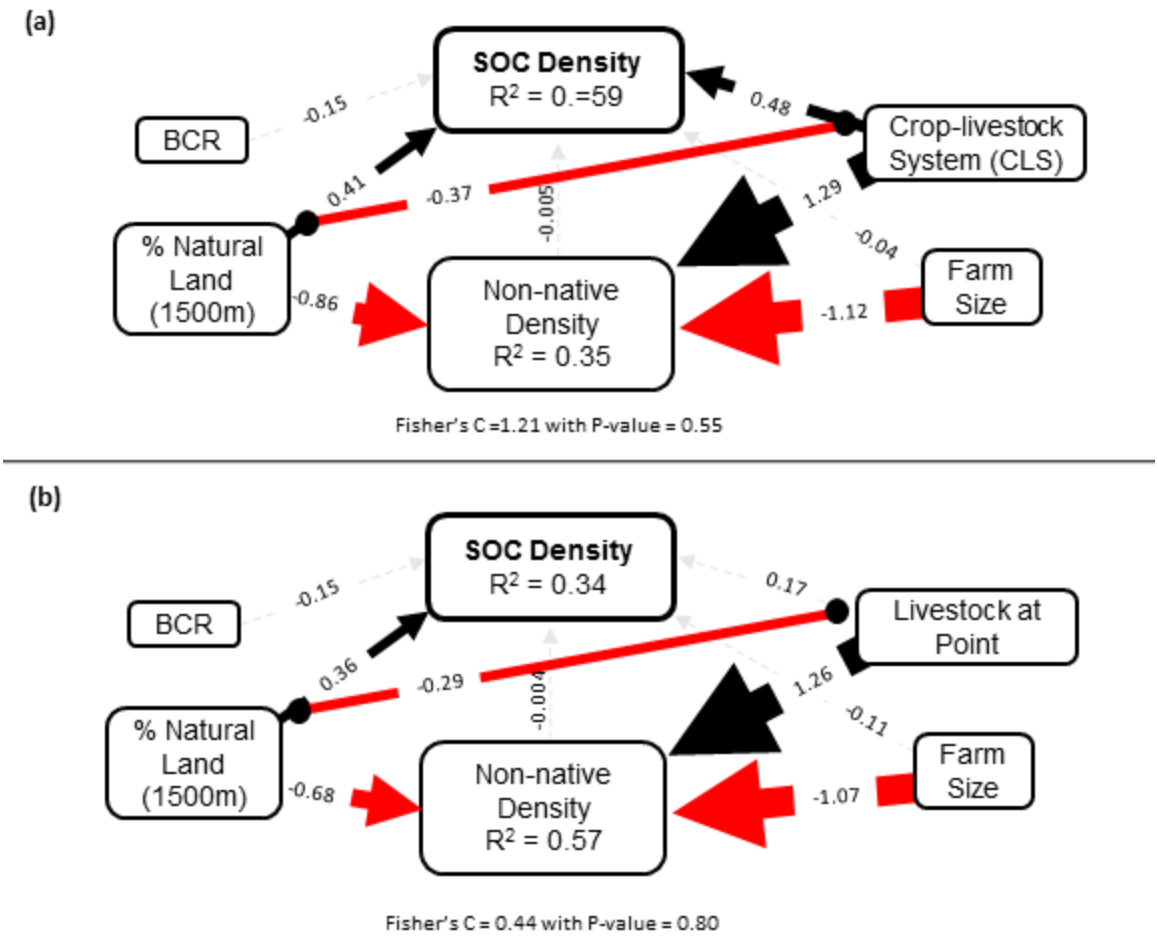

Fig. S13. Structural equation model showing links between (a) Bird Conservation Region (BCR), % natural land cover, crop–livestock system (CLS), farm size, species of concern (SOC) density and non-native density, and (b) % natural land cover buffered around a point, livestock presence at point, farm size, species of concern (SOC) density and non-native density. Black solid lines indicate positive relationships, red solid arrows indicate negative relationships, solid circles indicate interactions, and dashed gray lines indicate non-significant relationships. Lines are scaled to coefficients.