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The relationships between land use and amphibian assemblages in a traditional agricultural area, the Sun Moon Lake, of Taiwan

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Data S1. Land use variables

The land use data was accessed from the National Land Surveying and Mapping Center (NLSC) that finished in August, 2005. We updated and corrected the land use data using aerial photographs (1:5000 scale) taken between February, 2007 and October, 2008 (Aerial Survey Office, Forestry Bureau). If it was not possible to discriminate land use types from aerial photographs, "ground truth" was conducted to clarify land use types at those locations. The land use data of 103 land use types from NLSC were recatogroized (National Land Surveying and Mapping Center 2006) into ten categories (1) agricultural land, (2) exposed open area, (3) forest, (4) building, (5) grassland, (6) lake, (7) developing land, (8) pond, (9) river, and (10) roads. We used this data to measure and quantify the area of land use categories within 200 m radius at every site by ArcGIS ver 10.5.1 (Fig. S2). We calculated the proportion of agricultural land, building, developing land, exposed open area, forest, grassland, lake, river, and road within 200m radius for every site (i.e. area of a specific land use variable divided by the total area with 200m radius at each site×100%). Additionally, we counted the number of pond and land use heterogeneity (number of land use types) within 200m radius at each site. We also calculated the distance to nearest forest, grassland, and river (i.e. from a specific sampling site to the closest polygon of land use), the distance would be zero when the point is inside of the polygon. Finally, a total of 14 land use variables were quantified.

Table S1. Comparison of the unified protocol of North American Amphibian Monitoring Program (NAAMP) and the current study.

Protocol Category	**Unified Protocol**	**This study**
Listening duration	5 mins	2 mins
Initial waiting period (before listening duration)	No waiting period	No waiting period
Start and end time	Start survey 30 mins after sunset or later	Start survey 30 mins after sunset or later
Survey completion	Finish by 1 a.m. Route complete in one night	Finish by 1 a.m.
Number of observers per datasheet	One observer per datasheet	At least two observers
Minimum distance between listening stations	0.5 mile minimum distance (though some routes already established with 0.3 mile minimum distance will continue)	500 m apart in road distance
Calling index definitions	1: Individual can be counted; space between calls, 2: Call of individuals can be distinguished; some overlapping of calls, 3: Full chorus, calls are constant, continuous, and overlapping	1: Individual can be counted; space between calls, 2: Call of individuals can be distinguished; some overlapping of calls, 3: Full chorus, calls are constant, continuous, and overlapping
Number of sampling occasions per year	Three survey periods, plus one optional period to target early explosive breeders	One survey per month; a total of 12 survey occasions per year

(This table was modified from Weir and Mossman 2005)

Table S2. The list of anuran species found in the SML region.

			Habitat requirement		
Family	Scientific name	Code	Breeding	Non breeding	Breeding guild
Bufonidae	*Bufo bankorensis#*	BB	Lotic	Terrestrial	Winter
	Duttaphrynus melanostictus	DM	Lentic	Terrestrial	Spring-summer
Dicroglossidae	*Fejervarya limnocharis*	FL	Lentic	Terrestrial	Spring-summer
	Hoplobatrachus rugulosus	HR	Lentic	Terrestrial	Spring-summer
	Limnonectes kuhlii#	LK	Lotic	Terrestrial	Spring-summer
Hylidae	*Hyla chinensis#*	HC	Lentic	Arboreal	Spring-summer
Microhylidae	*Microhyla heymonsi*	MH	Lentic	Terrestrial	Spring-summer
	Microhyla fissipes#	MF	Lentic	Terrestrial	Spring-summer
Ranidae	*Nidirana adenopleura*	NA	Lentic	Terrestrial	Spring–summer
	Sylvirana guentheri	SG	Lentic	Terrestrial	Spring–summer
	Hylarana latouchii	HL	Lentic	Terrestrial	Year round
	Odorrana swinhoana	OS	Lotic	Terrestrial	Spring-summer
	Rana sauteri#	RS	Lotic	Terrestrial	Winter
Rhacophoridae	*Buergeria choui*	BJ	Lotic	Terrestrial	Spring–summer
	Buergeria robusta#	BR	Lotic	Arboreal	Spring–summer
	Kurixalus eiffingeri	KE	Arboreal	Arboreal	Spring–summer
	Kurixalus idiootocus	KI	Lentic	Arboreal	Spring–summer
	Polypedates brauer	PB	Lentic	Arboreal	Spring–summer
	Zhangixalus moltrechti	ZM	Lentic	Arboreal	Year round

species occurred under 7% of total sites

Table S3. Candidate single season site occupancy models for modeling detection probability for each anuran species.

Number	Models
1	p(.)ψ(.)
2	p(jdate)ψ(.)
3	p(jdate + Temp)ψ(.)
4	p(jdate + Temp + Hum)ψ(.)

Abbreviations: jdate, day of the year; Temp, temperature; Hum, relative humidity; p, detection probability; ψ, occupancy rate.

Table S4. Pearson correlation coefficients among land use variables.

	Agri	Build	Dev	D_for	D_grass	D_river	Eoa	For	Grass	Lake	Landdiv	N_pond	River	Road
Agri	1.000													
Build	0.147	1.000												
Dev	0.247*	0.297*	1.000											
D_for	**0.664*****	0.420**	0.186	1.000										
D_grass	-0.241*	-0.293*	0.012	-0.218	1.000									
D_river	-0.116	-0.107	-0.420**	0.052	-0.089	1.000								
Eoa	-0.008	0.116	-0.052	-0.108	-0.147	0.064	1.000							
For	**-0.766*****	-0.526***	-0.454***	**-0.632*****	0.244*	0.125	0.008	1.000						
Grass	-0.033	0.091	0.010	0.019	-0.373*	-0.041	0.091	-0.048	1.000					
Lake	-0.507***	-0.211	-0.292*	-0.340*	0.186	0.346*	-0.141	0.113	-0.100	1.000				
Landdiv	0.301*	0.261*	0.423**	0.044	-0.133	-0.482***	0.211	-0.528***	0.343*	-0.112	1.000			
N_pond	0.389**	0.056	0.089	0.125	-0.146	0.036	0.255*	-0.317*	0.023	-0.239*	0.331*	1.000		
River	0.110	-0.127	0.204	-0.050	0.407**	-0.392**	-0.007	-0.136	-0.062	-0.159	0.376*	0.043	1.000	
Road	0.104	0.468***	0.284*	0.123	-0.387**	-0.151	0.195	-0.377*	0.140	-0.098	0.349*	0.424**	-0.128	1.000

Abbreviations, Agri, proportion of agricultural land within 200 m radius; Build, proportion of building within 200 m radius; Dev, proportion of developing land within 200 m radius; D_for, distance to nearest forest; D_grass, distance to grassland; D_river, distance to river; Eoa, proportion of exposed open area within 200 m radius; For, proportion of forest within 200 m radius; Grass, proportion of grassland within 200 m radius; Lake, proportion of lake within 200 m radius; Landdiv, land use heterogeneity within 200 m radius; N_pond, number of ponds within 200 m radius; River, proportion of river within 200 m radius; Road, proportion of road within 200 m radius at each site.

Bold numbers: r > 0.6

* p <0.05; ** p<0.01; ***p<0.0001

Table S5. Candidate single season site occupancy models used for assessing the associations between individual species' occurrence and land use variables.

Number	Models
1	p(jdate + Temp + Hum)ψ(.)
2	p(jdate + Temp + Hum)ψ(Agri)
3	p(jdate + Temp + Hum)ψ(Build)
4	p(jdate + Temp + Hum)ψ(D_grassland)
5	p(jdate + Temp + Hum)ψ(D_river)
6	p(jdate + Temp + Hum)ψ(Eoa)
7	p(jdate + Temp + Hum)ψ(Grass)
8	p(jdate + Temp + Hum)ψ(N_pond)
9	p(jdate + Temp + Hum)ψ(River)
10	p(jdate + Temp + Hum)ψ(Road)
11	p(jdate + Temp + Hum)ψ(Agri + Build)
12	p(jdate + Temp + Hum)ψ(Agri + D_grassland)
13	p(jdate + Temp + Hum)ψ(Agri + D_river)
14	p(jdate + Temp + Hum)ψ(Agri + Eoa)
15	p(jdate + Temp + Hum)ψ(Agri + Grass)
16	p(jdate + Temp + Hum)ψ(Agri + N_pond)
17	p(jdate + Temp + Hum)ψ(Agri + River)
18	p(jdate + Temp + Hum)ψ(Agri + Road)
19	p(jdate + Temp + Hum)ψ(Build + D_grassland)
20	p(jdate + Temp + Hum)ψ(Build + D_river)
21	p(jdate + Temp + Hum)ψ(Build + Eoa)

22 p(jdate + Temp + Hum)ψ(Build + Grass)
23 p(jdate + Temp + Hum)ψ(Build + N_pond)
24 p(jdate + Temp + Hum)ψ(Build + River)
25 p(jdate + Temp + Hum)ψ(Build +Road)
26 p(jdate + Temp + Hum)ψ(D_grassland + D_river)
27 p(jdate + Temp + Hum)ψ(D_grassland + Eoa)
28 p(jdate + Temp + Hum)ψ(D_grassland + Grass)
29 p(jdate + Temp + Hum)ψ(D_grassland + N_pond)
30 p(jdate + Temp + Hum)ψ(D_grassland + River)
31 p(jdate + Temp + Hum)ψ(D_grassland +Road)
32 p(jdate + Temp + Hum)ψ(D_river+ Eoa)
33 p(jdate + Temp + Hum)ψ(D_river+ Grass)
34 p(jdate + Temp + Hum)ψ(D_river + N_pond)
35 p(jdate + Temp + Hum)ψ(D_river +River)
36 p(jdate + Temp + Hum)ψ(D_river +Road)
37 p(jdate + Temp + Hum)ψ(Eoa + Grass)
38 p(jdate + Temp + Hum)ψ(Eoa + N_pond)
39 p(jdate + Temp + Hum)ψ(Eoa +River)
40 p(jdate + Temp + Hum)ψ(Eoa +Road)
41 p(jdate + Temp + Hum)ψ(Grass + N_pond)
42 p(jdate + Temp + Hum)ψ(Grass + River)
43 p(jdate + Temp + Hum)ψ(Grass +Road)
44 p(jdate + Temp + Hum)ψ(Agri + Build + D_grassland)
45 p(jdate + Temp + Hum)ψ(Agri + D_grassland + D_river)
46 p(jdate + Temp + Hum)ψ(Agri + D_river+ Eoa)

47 p(jdate + Temp + Hum)ψ(Agri + Eoa + Grass)
48 p(jdate + Temp + Hum)ψ(Agri + Grass + N_pond)
49 p(jdate + Temp + Hum)ψ(Agri + N_pond +River)
50 p(jdate + Temp + Hum)ψ(Agri +River +Road)
51 p(jdate + Temp + Hum)ψ(Build + D_grassland + D_river)
52 p(jdate + Temp + Hum)ψ(Build + D_river+ Eoa)
53 p(jdate + Temp + Hum)ψ(Build + Eoa + Grass)
54 p(jdate + Temp + Hum)ψ(Build + Grass + N_pond)
55 p(jdate + Temp + Hum)ψ(Build + N_pond +River)
56 p(jdate + Temp + Hum)ψ(Build +River +Road)
57 p(jdate + Temp + Hum)ψ(D_grassland + D_river+ Eoa)
58 p(jdate + Temp + Hum)ψ(D_grassland + Eoa + Grass)
59 p(jdate + Temp + Hum)ψ(D_grassland + Grass + N_pond)
60 p(jdate + Temp + Hum)ψ(D_grassland + N_pond +River)
61 p(jdate + Temp + Hum)ψ(D_grassland +River +Road)
62 p(jdate + Temp + Hum)ψ(D_river+ Eoa + Grass)
63 p(jdate + Temp + Hum)ψ(D_river + Grass + N_pond)
64 p(jdate + Temp + Hum)ψ(D_river + N_pond +River)
65 p(jdate + Temp + Hum)ψ(D_river +River +Road)
66 p(jdate + Temp + Hum)ψ(Eoa + Grass + N_pond)
67 p(jdate + Temp + Hum)ψ(Eoa + N_pond +River)
68 p(jdate + Temp + Hum)ψ(Eoa +River +Road)
69 p(jdate + Temp + Hum)ψ(Grass + N_pond +River)
70 p(jdate + Temp + Hum)ψ(Grass +River +Road)
71 p(jdate + Temp + Hum)ψ(N_pond +River +Road)

72 p(jdate + Temp + Hum)ψ(Agri + Build + D_grassland + D_river)
73 p(jdate + Temp + Hum)ψ(Agri + D_grassland + D_river+ Eoa)
74 p(jdate + Temp + Hum)ψ(Agri + D_river+ Eoa + Grass)
75 p(jdate + Temp + Hum)ψ(Agri + Eoa + Grass + N_pond)
76 p(jdate + Temp + Hum)ψ(Agri + Grass + N_pond +River)
77 p(jdate + Temp + Hum)ψ(Agri + N_pond +River +Road)
78 p(jdate + Temp + Hum)ψ(Build + D_grassland + D_river+ Eoa)
79 p(jdate + Temp + Hum)ψ(Build + D_river+ Eoa + Grass)
80 p(jdate + Temp + Hum)ψ(Build + Eoa + Grass + N_pond)
81 p(jdate + Temp + Hum)ψ(Build + Grass + N_pond +River)
82 p(jdate + Temp + Hum)ψ(Build + N_pond +River +Road)
83 p(jdate + Temp + Hum)ψ(D_grassland + D_river+ Eoa + Grass)
84 p(jdate + Temp + Hum)ψ(D_grassland + Eoa + Grass + N_pond)
85 p(jdate + Temp + Hum)ψ(D_grassland + Grass + N_pond +River)
86 p(jdate + Temp + Hum)ψ(D_grassland + N_pond +River +Road)
87 p(jdate + Temp + Hum)ψ(D_river+ Eoa + Grass + N_pond)
88 p(jdate + Temp + Hum)ψ(D_river + Grass + N_pond +River)
89 p(jdate + Temp + Hum)ψ(D_river + N_pond +River +Road)
90 p(jdate + Temp + Hum)ψ(Eoa + Grass + N_pond +River)
91 p(jdate + Temp + Hum)ψ(Eoa + Grass + N_pond +Road)
92 p(jdate + Temp + Hum)ψ(Grass + N_pond +River +Road)
93 p(jdate + Temp + Hum)ψ(Agri + Build + D_grassland + D_river+ Eoa)
94 p(jdate + Temp + Hum)ψ(Agri + D_grassland + D_river+ Eoa + Grass)
95 p(jdate + Temp + Hum)ψ(Agri + D_river+ Eoa + Grass + N_pond)
96 p(jdate + Temp + Hum)ψ(Agri + Eoa + Grass + N_pond +River)

97 p(jdate + Temp + Hum)ψ(Agri + Grass + N_pond +River +Road)
98 p(jdate + Temp + Hum)ψ(Build + D_grassland + D_river+ Eoa + Grass)
99 p(jdate + Temp + Hum)ψ(Build + D_grassland + D_river+ Eoa + Grass + N_pond +River +Road)
100 p(jdate + Temp + Hum)ψ(Build + D_river+ Eoa + Grass + N_pond)
101 p(jdate + Temp + Hum)ψ(Build + Eoa + Grass + N_pond +River)
102 p(jdate + Temp + Hum)ψ(Build + Grass + N_pond +River +Road)
103 p(jdate + Temp + Hum)ψ(D_grassland + D_river+ Eoa + Grass + N_pond)
104 p(jdate + Temp + Hum)ψ(D_grassland + Eoa + Grass + N_pond +River)
105 p(jdate + Temp + Hum)ψ(D_grassland + Grass + N_pond +River +Road)
106 p(jdate + Temp + Hum)ψ(D_river+ Eoa + Grass + N_pond +River)
107 p(jdate + Temp + Hum)ψ(D_river+ Eoa + N_pond +River +Road)
108 p(jdate + Temp + Hum)ψ(Eoa + Grass + N_pond +River +Road)
109 p(jdate + Temp + Hum)ψ(Agri + Build + D_grassland + D_river+ Eoa + Grass)
110 p(jdate + Temp + Hum)ψ(Agri + D_grassland + D_river+ Eoa + Grass + N_pond)
111 p(jdate + Temp + Hum)ψ(Agri + D_river+ Eoa + Grass + N_pond +River)
112 p(jdate + Temp + Hum)ψ(Agri + Eoa + Grass + N_pond +River +Road)
113 p(jdate + Temp + Hum)ψ(Build + D_grassland + D_river+ Eoa + Grass + N_pond)
114 p(jdate + Temp + Hum)ψ(Build + D_river+ Eoa + Grass + N_pond +River)
115 p(jdate + Temp + Hum)ψ(Build + Eoa + Grass + N_pond +River +Road)
116 p(jdate + Temp + Hum)ψ(D_grassland + D_river+ Eoa + Grass + N_pond +River)
117 p(jdate + Temp + Hum)ψ(D_grassland + Eoa + Grass + N_pond +River +Road)
118 p(jdate + Temp + Hum)ψ(D_river+ Eoa + Grass + N_pond +River +Road)
119 p(jdate + Temp + Hum)ψ(Agri + Build + D_grassland + D_river+ Eoa + Grass + N_pond)
120 p(jdate + Temp + Hum)ψ(Agri + D_grassland + D_river+ Eoa + Grass + N_pond +River)
121 p(jdate + Temp + Hum)ψ(Agri + D_river+ Eoa + Grass + N_pond +River +Road)

122	p(jdate + Temp + Hum)ψ(Build + D_grassland + D_river+ Eoa + Grass + N_pond +River)
123	p(jdate + Temp + Hum)ψ(Build + D_river+ Eoa + Grass + N_pond +River +Road)
124	p(jdate + Temp + Hum)ψ(D_grassland + D_river+ Eoa + Grass + N_pond +River +Road)
125	p(jdate + Temp + Hum)ψ(Agri + Build + D_grassland + D_river+ Eoa + Grass + N_pond +River)
126	p(jdate + Temp + Hum)ψ(Agri + Build + D_grassland + D_river+ Eoa + Grass + N_pond +River)
127	p(jdate + Temp + Hum)ψ(Agri + D_grassland + D_river+ Eoa + Grass + N_pond +River +Road)
128	p(jdate + Temp + Hum)ψ(Agri + Build + D_river+ Eoa + Grass + N_pond +River +Road)
129	p(jdate + Temp + Hum)ψ(Agri + Build + D_grassland + Eoa + Grass + N_pond +River +Road)
130	p(jdate + Temp + Hum)ψ(Agri + Build + D_grassland + D_river+ Grass + N_pond +River +Road)
131	p(jdate + Temp + Hum)ψ(Agri + Build + D_grassland + D_river+ Eoa + N_pond +River +Road)
132	p(jdate + Temp + Hum)ψ(Agri + Build + D_grassland + D_river+ Eoa + Grass +River +Road)
133	p(jdate + Temp + Hum)ψ(Agri + Build + D_grassland + D_river+ Eoa + Grass + N_pond +Road)
134	p(jdate + Temp + Hum)ψ(Agri + Build + D_grassland + D_river+ Eoa + Grass + N_pond +River +Road)

Abbreviations: jdate, day of the year; Temp, temperature; Hum, relative humidity; Agri, proportion of agricultural land within 200 m radius; Build, proportion of building within 200 m radius; D_grass, distance to grassland; D_river, distance to river; Eoa, proportion of exposed open area within 200 m radius; Grass, proportion of grassland within 200 m radius; N_pond, number of pond within 200 m radius; River, proportion of river within 200 m radius; Road, proportion of road within 200 m radius at each site; p, detection probability; ψ, occupancy rate.

Table S6. The best support single season site occupancy model for each species based on the minimum AICc value.

Species	Model	k	ψ	AICc	w
Kurixalus idiootocus	p(jdate + Temp + Hum)ψ(.)	5	1.000 (0.001)	2048.98	0.13
Kurixalus eiffingeri	p(jdate + Temp + Hum)ψ(Agri + D_grass)	7	0.980 (0.023)	2008.37	0.08
Zhangixalus moltrechti	p(jdate + Temp)ψ(Build + D_river + Eoa + Grass + N_pond)	9	0.999 (0.011)	1886.01	0.16
Fejervarya limnocharis	p(jdate + Temp)ψ(Agri)	5	0.998 (0.011)	1348.67	0.07
Nidirana adenopleura	p(jdate + Temp + Hum)ψ(Agri + Grass)	7	0.729 (0.084)	1029.97	0.22
Hylarana latouchii	p(jdate + Temp + Hum)ψ(Agri + D_grass + D_river + Eoa)	10	0.997 (1.040)	1737.59	0.30
Microhyla heymonsi	p(jdate + Temp + Hum)ψ(Agri + D_river + Eoa + Grass)	9	0.995 (0.568)	996.21	0.27
Duttaphrynus melanostictus	p(jdate + Temp + Hum)ψ(Agri + Road)	7	1.000 (<0.001)	424.36	0.19
Polypedates brauer	p(jdate + Temp)ψ(Agri)	5	0.376 (0.062)	552.11	0.08
Buergeria choui	p(jdate + Temp + Hum)ψ(D_river + Grass + N_pond + River)	9	0.250 (0.115)	453.04	0.13
Sylvirana guentheri	p(jdate + Temp + Hum)ψ(N_pond)	6	0.553 (0.070)	646.47	0.09
Hoplobatrachus rugulosus	p(jdate + Temp + Hum)ψ(D_grass + D_river + Eoa + Grass)	9	0.037 (0.660)	170.9	0.17
Odorrana swinhoana	p(jdate + Temp + Hum)ψ(Build + N_pond)	7	0.006 (0.037)	171.88	0.10

Abbreviations: jdate, day of the year; Temp, temperature; Hum, relative humidity; Agri, proportion of agricultural land within 200 m radius; Build, proportion of building within 200 m radius; D_grass, distance to grassland; D_river, distance to river; Eoa, proportion of exposed open area within 200 m radius; Grass, proportion of grassland within 200 m radius; N_pond, number of pond within 200 m radius; River, proportion of river within 200 m radius; Road, proportion of road within 200 m radius at each site; k, number of parameters; p, detection probability; ψ, estimates of occupancy probability (±SE); AICc, Akaike information criterion corrected for small sample sizes; w, model weight.

Fig. S1. The ephemeral puddles formed after heavy rainfall in bare ground in the SML region.

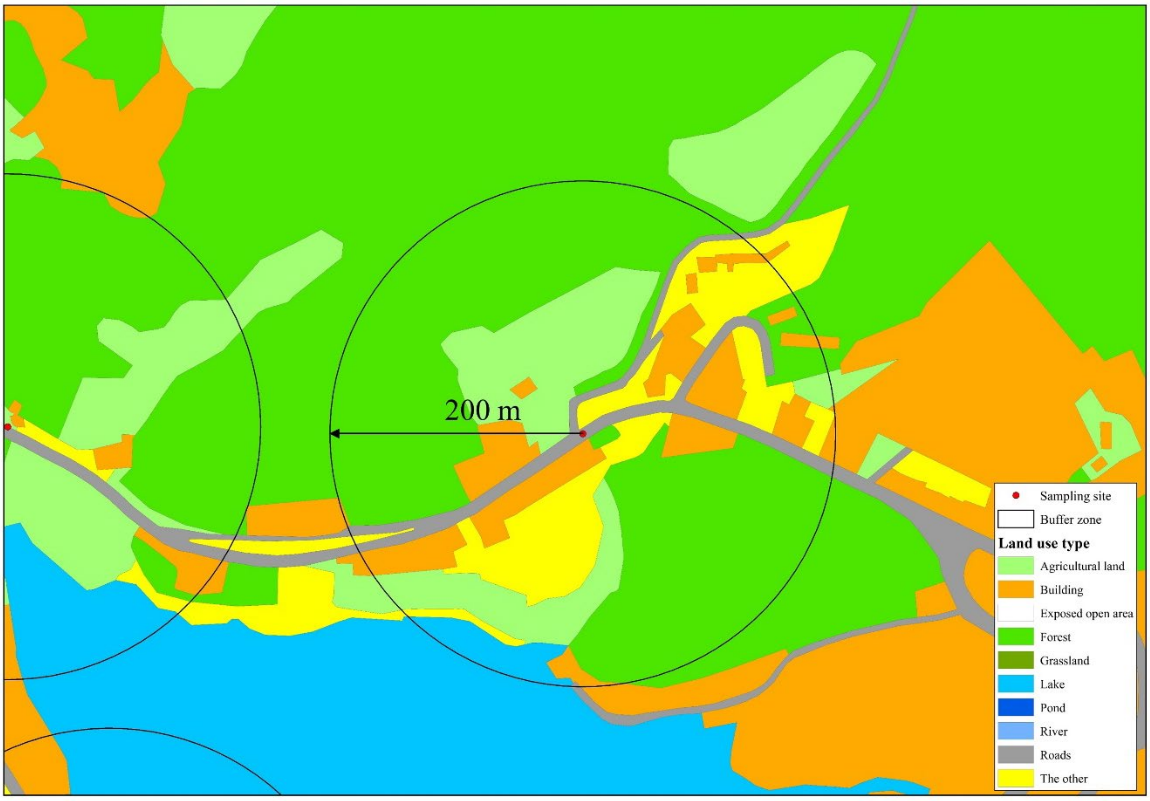

Fig. S2. Land use variables from GIS, a buffer zone within a 200 m radius of survey site.