Assessment Method and Scale of Observation Influence Ecosystem Service Bundles

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Table 1. Area (Km^2) and proportion of each LULC unit across the study site in 2013.

CLC Code	LULC unit	Area (km^2)	%
1.1.1.	Continuous urban fabric	95.05	0.3
2.	Agricultural areas	4254.14	15.4
3.1.1.	Low forest	121.14	0.4
3.2.	Forest plantations	107.70	0.4
3.3.1.	Natural grasslands	16360.39	59.3
3.3.2.	Shrublands	4620.18	16.7
3.4.3.	Sparsely vegetated areas	1048.99	3.8
3.4.5.	Glaciers	61.35	0.2
4.1.2.	Peatbogs and high-Andean wetlands	727.88	2.6
5.1.1.	Water courses	41.82	0.2
5.1.2.	Water bodies	173.73	0.6

Table 2. Land use/cover units resulting from the features of the three-time step data.

CLC code	LULC units	Features	Data Source
1.1.1.	Continuous urban fabric	Cities and settlements	(1) [1]
		Urban area	(2) [2]; (3) [3]
2.	Agricultural areas	Areas modified by human action	(1)
		Crops	(2)
		Andean agriculture	(3)
3.1.1.	Low forest	Inter-Andean xeric montane forest and shrublands Low high-Andean forest High-montane low forest and shrublands	(1)
		Queñoal Inter-Andean xeric forest	(2)
		Inter-Andean xeric forest High-Andean relict forest Meso-Andean relict forest	(3)
3.2.	Forest plantation	Areas modified by human action	(1)
		Afforestation	(2)
		Forest plantation (pinus and eucalyptus species)	(3)
3.3.1.	Natural grassland	High-Andean grassland High-montane grassland	(4) [4]; (3)
		High-Andean grassland Puna grass	(2)
3.3.2.	Shrublands	Inter-Andean xeric montane shrublands Inter-Andean xeric shrublands High-montane shrublands High-Andean shrublands	(1)
		Shrublands	(2); (3)
3.4.3.	Sparsely vegetated areas	Tundra	(4); (2)

		High-Andean areas with rare vegetation	(2); (3)
3.4.5.	Glaciers	Nival	(1)
		Glaciers	(2); (3)
4.1.2.	Peatbogs and high-Andean wetlands	High-Andean wetlands	(1); (2); (3)
5.1.1.	Water courses	Water bodies	(1)
		River	(2); (3)
5.1.2.	Water bodies	Water bodies	(1)
		Lagoons and lakes	(2); (3)

Note. Reprinted from Madrigal-Martinez and Miralles i Garcia (2019) [5]

Table 3. List of land use/cover datasets used in the study.

Time-step	Map	Description	Type	Source
2000	High-Andean ecosystems [1]	Derived from at: 1: 250,000-scale forestry map of Peru [4], 30 Landsat TM images, and bio-climatic indexes (1 Km).	vector	2009, General Secretary of the Andean Community
2009	Flora cover [2]	Scale at 1: 100,000, generated from 69 Landsat 5 (TM) images; with a minimum mapping area of 25 ha and, exceptionally, 5 ha in special cases.	vector	2012, Ministry of Environment of Peru
2013	Flora cover [3]	Scale at 1: 100,000, generated from 43 Landsat 5 (TM) images, RapidEye and Google Earth images for Andean land covers; with a minimum mapping area of 16 ha and, exceptionally, 5 ha in special cases.	vector	2015, Ministry of Environment of Peru

Table 4. Score of each LULC unit associated with regulating and provisioning ES in the moist Puna.

CLC Code	Regulating ES					Provisioning ES	
	Water purification	Regulation of soil erosion	Water flow regulation	Soil quality	Global climate regulation	Crops	Livestock
1.1.1.	0.18	1.21	0.32	0.00	0.00	0.00	0.00
2.	1.50	1.84	2.65	2.26	2.00	2.03	2.61
3.1.1.	3.69	4.33	4.27	4.13	4.32	1.56	1.93
3.2.	2.71	3.63	2.95	2.69	3.89	1.54	2.03
3.3.1.	3.55	4.00	3.76	3.70	3.37	1.49	2.18
3.3.2.	3.45	3.92	3.83	3.80	3.68	1.53	1.73
3.4.3.	0.75	0.50	0.75	0.68	0.61	1.20	1.58
3.4.5.	1.83	1.35	4.56	0.33	1.66	0.00	0.00
4.1.2.	4.54	3.91	4.53	4.29	4.55	2.10	3.49
5.1.1.	3.28	1.29	3.12	1.20	1.72	0.00	0.00
5.1.2.	3.75	1.52	4.54	1.45	2.74	0.00	0.00

CLC code: 1.1.1. Continuous urban fabric; 2. Agricultural areas; 3.1.1. Low forest; 3.2. Forest plantations; 3.3.1. Natural grasslands; 3.3.2. Shrublands; 3.4.3. Sparsely vegetated areas; 3.4.5. Glaciers; 4.1.2. Peatbogs and high-Andean wetlands; 5.1.1. Water courses; 5.1.2. Water bodies.

Note. Reprinted from Madrigal-Martinez and Miralles i Garcia (2019) [6]
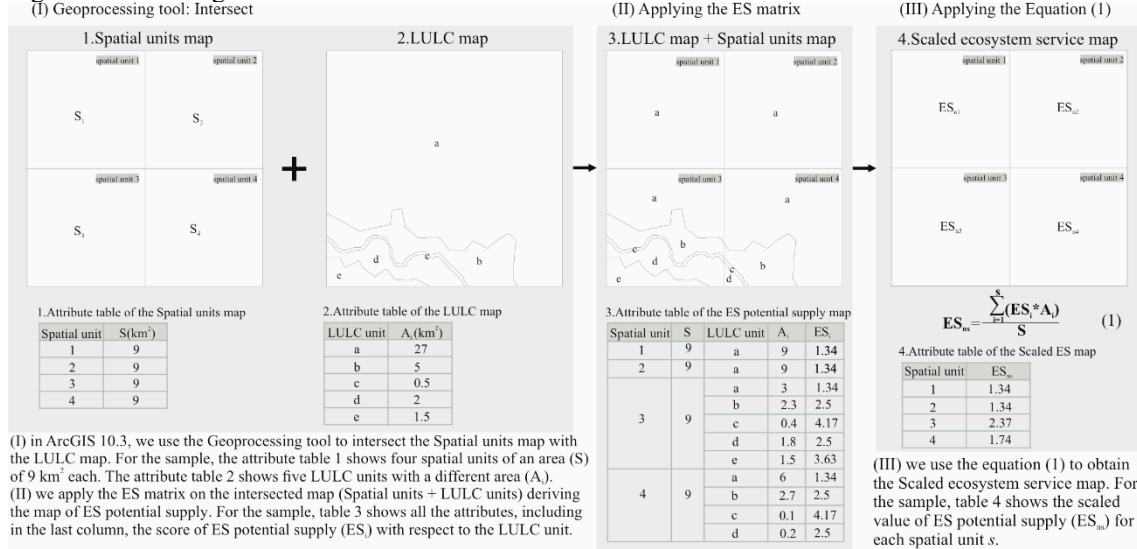
Figure 5. ES scaling method.

Table 6. ES matrix (2009) of the scenario created for the sensitivity analysis.

CLC Code	Regulating ES					Provisioning ES	
	Water purification	Regulation of soil erosion	Water flow regulation	Soil quality	Global climate regulation	Crops	Livestock
1.1.1.	0.18	1.21	0.32	0.00	0.00	0.00	0.00
2.	1.50	2.74	3.55	3.16	2.00	2.93	3.51
3.1.1.	2.79	3.43	3.37	3.23	3.42	0.66	1.03
3.2.	2.71	4.53	3.85	3.59	4.79	1.54	2.03
3.3.1.	2.65	3.10	2.86	2.80	2.47	2.39	3.08
3.3.2.	2.55	3.02	2.93	2.90	2.78	2.43	2.63
3.4.3.	0.75	0.50	0.75	0.68	0.61	1.20	1.58
3.4.5.	0.00	0.00	3.66	0.00	0.76	0.00	0.00
4.1.2.	3.64	3.01	3.43	4.29	3.65	3.00	4.39
5.1.1.	4.18	0.00	4.02	0.00	0.00	0.00	0.00
5.1.2.	4.65	0.00	5	0.00	0.00	0.00	0.00

CLC code: 1.1.1. Continuous urban fabric; 2. Agricultural areas; 3.1.1. Low forest; 3.2. Forest plantations; 3.3.1. Natural grasslands; 3.3.2. Shrublands; 3.4.3. Sparsely vegetated areas; 3.4.5. Glaciers; 4.1.2. Peatbogs and high-Andean wetlands; 5.1.1. Water courses; 5.1.2. Water bodies.

Table 7. ES matrix (2013) of the scenario created for the sensitivity analysis.

CLC Code	Regulating ES					Provisioning ES	
	Water purification	Regulation of soil erosion	Water flow regulation	Soil quality	Global climate regulation	Crops	Livestock
1.1.1.	0.18	1.21	0.32	0.00	0.00	0.00	0.00
2.	1.50	3.14	3.95	3.56	2.00	3.33	3.91

					0.26	0.63
3.1.1.	2.39	3.03	2.97	2.83	3.02	0.26	0.63
3.2.	2.71	4.93	4.25	3.99	5	1.54	2.03
3.3.1.	2.25	2.70	2.46	2.40	2.07	2.79	3.48
3.3.2.	2.15	2.62	2.53	2.50	2.38	2.83	3.03
3.4.3.	0.75	0.50	0.75	0.68	0.61	1.20	1.58
3.4.5.	0.00	0.00	3.26	0.00	0.36	0.00	0.00
4.1.2.	3.24	2.61	3.03	4.29	3.25	3.40	4.79
5.1.1.	4.58	0.00	4.42	0.00	0.00	0.00	0.00
5.1.2.	5	0.00	5	0.00	0.00	0.00	0.00

CLC code: 1.1.1. Continuous urban fabric; 2. Agricultural areas; 3.1.1. Low forest; 3.2. Forest plantations; 3.3.1. Natural grasslands; 3.3.2. Shrublands; 3.4.3. Sparsely vegetated areas; 3.4.5. Glaciers; 4.1.2. Peatbogs and high-Andean wetlands; 5.1.1. Water courses; 5.1.2. Water bodies.

Table 8. Area and percentage of change of bundles generated with ES values at each spatial scale over time.

Scale	Transition id	Year			Area (Km²)	%
		2000	**2009**	**2013**		
Provincial	**1**	**B1**	B1	B1	836	3.03
	2	B1	B1	B2	3431	12.43
	3	B2	B1	B1	4560	16.51
	4	B2	B1	B2	2734	9.90
	5	B2	B2	B2	2814	10.19
	6	B3	B2	B2	4183	15.15
	7	B3	B3	B2	1130	4.09
	8	B3	B3	B3	7924	28.70
Municipal	1	B1	B1	B1	402	1.46
	2	B1	B1	B2	180	0.65
	3	B2	B1	B1	225	0.82
	4	B2	B1	B2	292	1.06
	5	B2	B2	B1	247	0.90
	6	B2	B2	B2	3875	14.03
	7	B2	B2	B3	1185	4.29
	8	B3	B1	B1	61	0.22
	9	B3	B1	B2	40	0.14
	10	B3	B2	B1	12	0.04
	11	B3	B2	B2	1879	6.81
	12	B3	B2	B3	1423	5.15
	13	B3	B3	B2	810	2.93
	14	B3	B3	B3	16979	61.49
Coarse-grid	1	B1	B1	B1	3249	11.96
	2	B1	B1	B2	675	2.48
	3	B1	B1	B3	162	0.60
	4	B1	B2	B1	9	0.03
	5	B1	B2	B2	81	0.30
	6	B1	B2	B3	36	0.13
	7	B2	B1	B1	684	2.52
	8	B2	B1	B2	225	0.83
	9	B2	B1	B3	9	0.03
	10	B2	B2	B1	180	0.66
	11	B2	B2	B2	2403	8.84

	Transition id				Area	%
	12	B2	B2	B3	225	0.83
	13	B2	B3	B2	18	0.07
	14	B2	B3	B3	126	0.46
	15	B3	B1	B1	297	1.09
	16	B3	B1	B2	162	0.60
	17	B3	B1	B3	108	0.40
	18	B3	B2	B1	72	0.26
	19	B3	B2	B2	1179	4.34
	20	B3	B2	B3	414	1.52
	21	B3	B3	B1	45	0.17
	22	B3	B3	B2	450	1.66
	23	B3	B3	B3	16362	60.22
Fine-grid	1	B1	B3	B3	1	0.00
	2	B1	B2	B2	4	0.01
	3	B1	B2	B1	0.3	0.00
	4	B1	B1	B3	4	0.01
	5	B1	B1	B2	30	0.11
	6	B1	B1	B1	1014	3.67
	7	B2	B3	B3	180	0.65
	8	B2	B3	B2	3	0.01
	9	B2	B2	B3	817	2.96
	10	B2	B2	B2	3022	10.95
	11	B2	B2	B1	25	0.09
	12	B2	B1	B2	4	0.01
	13	B2	B1	B1	41	0.15
	14	B3	B3	B3	19985	72.45
	15	B3	B3	B2	476	1.73
	16	B3	B3	B1	24	0.09
	17	B3	B2	B3	435	1.58
	18	B3	B2	B2	1510	5.47
	19	B3	B2	B1	6	0.02
	20	B3	B1	B1	7	0.03

Table 9. Area and percentage of change of bundles generated with ES values of the sensitivity analysis at each spatial scale over time.

Spatial scale	Transition id	2000	2009	2013	Area (km²)	%
Provincial	1	3	2	1	27621.41	100%
Municipal	1	1	2	2	1259.83	5%
	2	1	1	2	30.00	0%
	3	1	1	1	125.59	0%
	4	3	2	2	22982.92	83%
	5	3	2	1	16.92	0%
	6	3	1	2	78.10	0%
	7	3	1	1	3118.98	11%
Coarse-grid	1	1	1	1	1458	5%
	2	1	1	2	36	0%
	3	1	2	1	9	0%
	4	1	2	2	3357	12%
	5	1	3	2	27	0%
	6	2	1	1	54	0%
	7	2	2	1	18	0%
	8	2	2	2	1107	4%
	9	2	3	2	9	0%
	10	3	1	1	270	1%
	11	3	2	1	108	0%
	12	3	2	2	20511	75%
	13	3	2	3	9	0%
	14	3	3	1	9	0%

	15	3	3	2	171	1%
	16	3	3	3	18	0%
Fine-grid	1	1	1	1	1115.75	4%
	2	1	1	2	22.25	0%
	3	1	2	1	2.75	0%
	4	1	2	2	265.5	1%
	5	1	3	1	1.5	0%
	6	1	3	2	2.5	0%
	7	1	3	3	2	0%
	8	2	1	1	57.75	0%
	9	2	1	2	0.5	0%
	10	2	2	1	31.25	0%
	11	2	2	2	3496.75	13%
	12	2	2	3	0.5	0%
	13	2	3	2	10.75	0%
	14	2	3	3	17	0%
	15	3	1	1	129	0%
	16	3	1	2	17.25	0%
	17	3	2	1	51.25	0%
	18	3	2	2	21955.75	80%
	19	3	2	3	6.5	0%
	20	3	3	1	2.75	0%
	21	3	3	2	266.75	1%
	22	3	3	3	129.75	0%

Table 10. Area and percentage of change of bundles resulting from ΔES values at each scale over time.

Scale	Transition id	Time-period		Area (Km²)	%
		2000-2009	2009-2013		
Provincial	**1**	**B1**	B3	7756	28.09
	2	B1	B2	3196	11.58
	3	B2	B2	13229	47.91
	4	B2	B3	3431	12.43
Municipal	1	B1	B1	12	0.04
	2	B1	B2	2083	7.54
	3	B1	B3	1128	4.09
	4	B2	B2	20977	75.97
	5	B2	B3	3412	12.36
Coarse-grid	1	B1	B1	72	0.26
	2	B1	B2	1782	6.56
	3	B1	B3	693	2.55
	4	B2	B1	450	1.66
	5	B2	B2	22689	83.50
	6	B2	B3	1233	4.54
	7	B3	B2	189	0.70
	8	B3	B3	63	0.23
Fine-grid	1	B1	B1	18	0.06
	2	B1	B2	1602	5.81
	3	B1	B3	435	1.58
	4	B2	B1	581	2.11
	5	B2	B2	23882	86.57
	6	B2	B3	883	3.20
	7	B3	B2	180	0.65
	8	B3	B3	6	0.02

Table 11. Area and percentage of change of bundles generated with ΔES values of the sensitivity analysis at each spatial scale during the two periods.

Spatial scale	Transition id	2000-2009	2009-2013	Area (km²)	%
Provincial	1	2	3	7081.31	26%
	2	1	3	20531.11	74%
Municipal	1	1	1	2781.47	10%

	2	1	2	26.24	0%
	3	2	1	525.67	2%
	4	2	2	1041.59	4%
	5	3	2	242.93	1%
	6	3	1	22994.45	83%
Coarse-grid	1	1	1	1998	7%
	2	1	2	45	0%
	3	1	3	18	0%
	4	2	1	3150	12%
	5	2	2	1764	6%
	6	2	3	63	0%
	7	3	1	19314	71%
	8	3	2	765	3%
	9	3	3	54	0%
Fine-grid	1	1	1	1424.25	5%
	2	1	2	75	0%
	3	1	3	157.25	1%
	4	2	1	1535	6%
	5	2	2	2282	8%
	6	2	3	44.75	0%
	7	3	1	20258.5	73%
	8	3	2	1640.5	6%
	9	3	3	168.5	1%

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