

Supplementary for: Habitat integrity in protected areas threatened by LULC changes and fragmentation: A case study in Tehran province, Iran

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Table S1. Ground truth and LULC classes

Lar national park							
Year		2019					
Land use	Built-up	Water body	Cropland and garden	High-density pasture	Low-density pasture	Total	
Built-up	35	0	0	6	4	45	
Water body	0	25	0	0	0	25	
Cropland and garden	0	0	22	3	5	30	
High-density pasture	2	0	4	54	8	68	
Low-density pasture	0	0	3	9	120	132	
Total	37	25	29	72	137	300	
Jajrud PA							
Land use	Built-up	Water body	Cropland and garden	High-density pasture	Low-density pasture	Planted forests	Total
Built-up	92	0	4	3	6	0	105
Water body	2	24	0	0	0	0	26
Cropland and garden	0	0	12	1	3	2	18
High-density pasture	0	0	0	36	6	0	42
Low-density pasture	0	0	3	2	68	0	73
Planted forests	0	0	4	1	0	31	36
Total	94	24	23	43	83	33	300
Tangeh Vashi natural monument							
Land use	Built-up	Bare land	High-density pasture		Low-density pasture	Total	
Built-up	69	6	0		0	75	
Bare land	3	118	2		12	135	
High-density pasture	0	0	28		4	32	
Low-density pasture	0	5	47		6	58	
Total	72	129	77		22	300	

Table S2. Confusion matrix

Lar national park												
Year	2019											
Land use	Built-up	Water body	Cropland and garden	High-density pasture	Low-density pasture	Total	Commiss ion (%)	Omission (%)	User's Acc.	Producer's Acc.	Overall accuracy	
Built-up	11.66	0	0	2	1.33	14.99	0.03	0.83	0.87 ± 0.05	0.92 ± 0.17	0.92± 0.04	
Water body	0	8.33	0	0	0	8.33	0.04	0.16	0.70 ± 0.30	0.50 ± 0.37		
Cropland and garden	0	0	7.33	1	1.66	9.99	0.02	0.01	0.80 ± 0.26	0.25 ± 0.13		
High-density pasture	0.66	0	1.33	18	2.66	22.65	0.4	0.02	0.93 ± 0.08	0.67 ± 0.12		
Low-density pasture	0	0	1	3	40	44	0.07	0.44	0.90 ± 0.20	0.81 ± 0.24		
Jajrud PA												
Land use	Built-up	Water areas	Cropland and garden	High-density pasture	Low-density pasture	Planted forests	Total	Commiss ion (%)	Omission (%)	User's Acc.	Producer's Acc.	Overall accuracy
Built-up	30.66	0	1.33	1	2	0	34.98	0.32	0.87	0.88 ± 0.04	0.98 ± 0.02	0.97± 0.02
Water areas	0.66	8	0	0	0	0	8.66	0.56	0.04	0.84 ± 0.12	0.78 ± 0.13	
Cropland and garden	0	0	4	0.33	1	0.66	5.98	1.3	0.1	0.79 ± 0.19	0.67 ± 0.18	
High-density pasture	0	0	0	12	2	0	14	0.02	0.16	0.90 ± 0.20	0.79 ± 0.22	
Low-density pasture	0	0	1	0.66	22.66	0	24.32	0.9	1.1	0.94 ± 0.08	0.81 ± 0.24	
Planted forests	0	0	1.33	0.33	0	10.32	11.98	0.3	0.1	0.80 ± 0.21	0.93 ± 0.15	
Tangeh Vashi natural monument												
Land use	Built-up	Bare land	High-density pasture		Low-density pasture	Total	Commiss ion (%)	Omission (%)	User's Acc.	Producer's Acc.	Overall accuracy	
Built-up	23	2	0		0	25	0.3	0.1	0.81 ± 0.20	0.75 ± 0.18	0.98± 0.01	
Bare land	1	93.33	0.66		4	98.99	0.02	0.18	0.78 ± 0.18	0.98 ± 0.02		
High-density pasture	0	0	9.33		1.33	10.66	0.07	0.1	0.50 ± 0.33	0.90 ± 0.22		
Low-density pasture	0	1.66	15.66		2	19.32	0.03	0.16	0.80 ± 0.21	0.93 ± 0.75		

Table S3. Impacts of habitat fragmentation in the studied areas (results of round 1 of Delphi method)

Study site	Impacts	n	Mean	SD	V	Rank	Total mean
Lar national park	(1) Decrease of habitat integrity (source and sink)	40	4.38	1.000	2.000	1	3.11
	(2) Change of the patterns and spatial elements' structure (size, shape, number, type, composition, and status of habitat)	40	3.95	1.000	1.060	3	
	(3) Change in the ecosystem function (flow of matter, energy and information, etc.)	40	4.28	1.029	1.000	2	
	(4) Decrease of stability and increase of the edge effect of patches	40	3.66	1.000	2.030	5	
	(5) Change of ecological flows	40	3.72	1.000	1.000	4	
	(6) Decreased of resilience and biological capacity of species	40	3.15	1.029	1.000	10	
	(7) Habitat destruction and decrease of biodiversity and genetic	40	3.36	1.000	1.000	6	
	(8) Increase of inbreeding among species	40	2.46	1.000	1.000	22	
	(9) Extinction of biologically valuable species (fauna and flora)	40	3.15	1.000	2.000	8	
	(10) Change of the species' diet and their migration path	40	2.93	1.000	2.055	13	
	(11) Change of habitat' boundary	40	2.43	1.000	1.000	23	
	(12) Change of ecological process in the area	40	3.27	1.000	1.000	7	
	(13) Increase of isolated habitat	40	2.58	1.029	1.064	21	
	(14) Reduction and loss of vegetation in the area	40	3.05	1.000	1.000	9	
	(15) Increase of climate change	40	3.01	1.000	1.000	11	
	(16) Increased environmental pollution	40	2.98	1.000	1.000	12	
	(17) Decrease of the reservoirs of groundwater aquifers and change in surface water regime	40	2.88	1.000	1.000	14	
	(18) Change of geo-biochemical cycles	40	2.81	1.000	1.000	16	
	(19) Decrease of ecosystem services	40	2.84	1.000	2.030	15	
	(20) Increase of water evaporation level	40	2.76	1.030	1.000	17	
	(21) Increase of soil erosion level (sedimentation and decrease of soil fertility level)	40	2.60	1.000	1.000	20	
	(22) Disturbance of landscape and environmental desirability	40	2.71	1.000	1.000	18	
	(23) Increase of abrupt environmental crises (such as storm, flood earthquake, etc.)	40	2.62	1.000	1.000	19	
Jajroud PA	(1) Decrease of habitat integrity (source and sink)	40	4.38	1.000	1.000	2	3.63
	(2) Change of the patterns and spatial elements' structure (size, shape, number, type, composition, and status of habitat)	40	4.75	1.000	2.000	1	
	(3) Change in the ecosystem function (flow of matter, energy and information, etc.)	40	4.26	1.000	1.060	3	
	(4) Decrease of stability and increase of the edge effect of patches	40	4.16	1.000	1.000	5	
	(5) Change of ecological flows	40	4.20	1.000	1.043	4	
	(6) Decreased of resilience and biological capacity of species	40	3.92	1.000	1.000	7	
	(7) Habitat destruction and decrease of biodiversity and genetic	40	4.03	1.029	1.000	6	
	(8) Change of habitat' boundary	40	2.48	1.000	1.000	22	
	(9) Extinction of biologically valuable species (fauna and flora)	40	3.88	1.000	1.000	8	
	(10) Change of the species' diet and their migration path	40	3.84	1.000	1.000	9	
	(11) Increase of inbreeding among species	40	2.43	1.000	1.000	23	
	(12) Change of ecological process in the area	40	3.80	1.000	1.000	10	
	(13) Increase of isolated habitat	40	2.56	1.000	1.000	21	
	(14) Reduction and loss of vegetation in the area	40	3.77	1.000	2.030	11	
	(15) Increase of climate change	40	3.66	1.000	1.000	13	
	(16) Increased environmental pollution	40	3.72	1.000	1.000	12	
	(17) Decrease of the reservoirs of groundwater aquifers and change in surface water regime	40	3.54	1.000	1.000	15	
	(18) Change of geo-biochemical cycles	40	3.48	1.000	1.000	16	
	(19) Decrease of ecosystem services	40	3.57	1.000	1.000	14	
	(20) Increase of water evaporation level	40	3.21	1.000	1.000	20	
	(21) Increase of soil erosion level (sedimentation and decrease of soil fertility level)	40	3.42	1.000	1.000	17	
	(22) Disturbance of landscape and environmental desirability	40	3.27	1.000	1.000	19	
	(23) Increase of abrupt environmental crises (such as storm, flood earthquake, etc.)	40	3.35	1.000	2.000	18	

	(1) Decrease of habitat integrity (source and sink)	40	3.43	1.029	1.064	6	3.01
Tangeh Vashi natural monument	(2) Change of the patterns and spatial elements' structure (size, shape, number, type, composition, and status of habitat)	40	3.64	1.000	1.000	3	
	(3) Change in the ecosystem function (flow of matter, energy and information, etc.)	40	3.55	1.000	1.000	4	
	(4) Decrease of stability and increase of the edge effect of patches	40	3.80	1.000	1.000	1	
	(5) Change of ecological flows	40	3.72	1.000	1.000	2	
	(6) Decreased of resilience and biological capacity of species	40	3.46	1.000	2.033	5	
	(7) Habitat destruction and decrease of biodiversity and genetic	40	3.38	1.000	1.000	7	
	(8) Change of habitat' boundary	40	2.41	1.000	1.000	23	
	(9) Extinction of biologically valuable species (fauna and flora)	40	3.26	1.000	1.054	8	
	(10) Change of the species' diet and their migration path	40	3.08	1.000	1.000	11	
	(11) Change of ecological process in the area	40	3.10	1.000	1.000	10	
	(12) Increase of isolated habitat	40	2.50	1.000	1.000	21	
	(13) Reduction and loss of vegetation in the area	40	3.15	1.000	1.000	9	
	(14) Increase of climate change	40	2.77	1.000	1.000	15	
	(15) Increase of inbreeding among species	40	2.44	1.000	1.000	22	
	(16) Increased environmental pollution	40	2.85	1.000	1.055	14	
	(17) Decrease of the reservoirs of groundwater aquifers and change in surface water regime	40	2.95	1.000	1.033	12	
	(18) Change of geo-biochemical cycles	40	2.73	1.029	1.000	16	
	(19) Decrease of ecosystem services	40	2.56	1.000	1.000	19	
	(20) Increase of water evaporation level	40	2.58	1.000	2.000	18	
	(21) Increase of soil erosion level (sedimentation and decrease of soil fertility level)	40	2.63	1.000	1.000	17	
	(22) Disturbance of landscape and environmental desirability	40	2.53	1.000	1.000	20	
	(23) Increase of abrupt environmental crises (such as storm, flood earthquake, etc.)	40	2.88	1.000	1.000	13	

Table S4. Impacts of habitat fragmentation in the studied areas (results of round 2 of Delphi method)

Study site	Impacts	n	Mean	SD	V	Rank	Total mean
Lar national park	(1) Decrease of habitat integrity (source and sink)	36	4.46	1.000	2.000	1	3.21
	(2) Change of the patterns and spatial elements' structure (size, shape, number, type, composition, and status of habitat)	36	4.41	1.000	1.060	2	
	(3) Change in the ecosystem function (flow of matter, energy and information, etc.)	36	4.38	1.029	1.000	3	
	(4) Decrease of stability and increase of the edge effect of patches	36	3.73	1.000	2.030	5	
	(5) Change of ecological flows	36	3.78	1.000	1.000	4	
	(6) Decreased of resilience and biological capacity of species	36	3.09	1.029	1.000	10	
	(7) Habitat destruction and decrease of biodiversity and genetic	36	3.28	1.000	1.000	6	
	(8) Extinction of biologically valuable species (fauna and flora)	36	3.15	1.000	2.000	8	
	(9) Change of the species' diet and their migration path	36	2.94	1.000	2.055	13	
	(10) Change of ecological process in the area	36	3.22	1.000	1.000	7	
	(11) Increase of isolated habitat	36	2.48	1.029	1.064	21	
	(12) Reduction and loss of vegetation in the area	36	3.12	1.000	1.000	9	
	(13) Increase of climate change	36	3.06	1.000	1.000	11	
	(14) Increased environmental pollution	36	3.00	1.000	1.000	12	
	(15) Decrease of the reservoirs of groundwater aquifers and change in surface water regime	36	2.90	1.000	1.000	14	
	(16) Change of biogeochemical cycles	36	2.85	1.000	1.000	16	
	(17) Decrease of ecosystem services	36	2.88	1.000	2.030	15	
	(18) Increase of water evaporation level	36	2.76	1.030	1.000	17	
	(19) Increase of soil erosion level (sedimentation and decrease of soil fertility level)	36	2.61	1.000	1.000	20	
	(20) Disturbance of landscape and environmental desirability	36	2.75	1.000	1.000	18	
	(21) Increase of abrupt environmental crises (such as storm, flood earthquake, etc.)	36	2.64	1.000	1.000	19	
Jajroud PA	(1) Decrease of habitat integrity (source and sink)	36	4.48	1.000	1.000	2	3.77
	(2) Change of the patterns and spatial elements' structure (size, shape, number, type, composition, and status of habitat)	36	4.55	1.000	2.000	1	
	(3) Change in the ecosystem function (flow of matter, energy and information, etc.)	36	4.43	1.000	1.060	3	
	(4) Decrease of stability and increase of the edge effect of patches	36	4.24	1.000	1.000	5	
	(5) Change of ecological flows	36	4.38	1.000	1.043	4	
	(6) Decreased of resilience and biological capacity of species	36	3.95	1.000	1.000	7	
	(7) Habitat destruction and decrease of biodiversity and genetic	36	4.05	1.029	1.000	6	
	(8) Extinction of biologically valuable species (fauna and flora)	36	3.91	1.000	1.000	8	
	(9) Change of the species' diet and their migration path	36	3.88	1.000	1.000	9	
	(10) Change of ecological process in the area	36	3.86	1.000	1.000	10	
	(11) Increase of isolated habitat	36	2.43	1.000	1.000	21	
	(12) Reduction and loss of vegetation in the area	36	3.81	1.000	2.030	11	
	(13) Increase of climate change	36	3.68	1.000	1.000	13	
	(14) Increased environmental pollution	36	3.75	1.000	1.000	12	
	(15) Decrease of the reservoirs of groundwater aquifers and change in surface water regime	36	3.58	1.000	1.000	15	
	(16) Change of biogeochemical cycles	36	3.52	1.000	1.000	16	
	(17) Decrease of ecosystem services	36	3.64	1.000	1.000	14	
	(18) Increase of water evaporation level	36	3.08	1.000	1.000	20	
	(19) Increase of soil erosion level (sedimentation and decrease of soil fertility level)	36	3.48	1.000	1.000	17	
	(20) Disturbance of landscape and environmental desirability	36	3.21	1.000	1.000	19	
	(21) Increase of abrupt environmental crises (such as storm, flood earthquake, etc.)	36	3.33	1.000	2.000	18	
Tangeh Vashi natural	(1) Decrease of habitat integrity (source and sink)	36	3.41	1.029	1.064	6	3.06
	(2) Change of the patterns and spatial elements' structure (size, shape, number, type, composition, and status of habitat)	36	3.54	1.000	1.000	3	
	(3) Change in the ecosystem function (flow of matter, energy and information, etc.)	36	3.48	1.000	1.000	4	

(4) Decrease of stability and increase of the edge effect of patches	36	3.66	1.000	1.000	1
(5) Change of ecological flows	36	3.61	1.000	1.000	2
(6) Decreased of resilience and biological capacity of species	36	3.44	1.000	2.033	5
(7) Habitat destruction and decrease of biodiversity and genetic	36	3.38	1.000	1.000	7
(8) Extinction of biologically valuable species (fauna and flora)	36	3.25	1.000	1.054	8
(9) Change of the species' diet and their migration path	36	3.07	1.000	1.000	11
(10) Change of ecological process in the area	36	3.14	1.000	1.000	10
(11) Increase of isolated habitat	36	2.42	1.000	1.000	21
(12) Reduction and loss of vegetation in the area	36	3.16	1.000	1.000	9
(13) Increase of climate change	36	2.81	1.000	1.000	15
(14) Increased environmental pollution	36	2.84	1.000	1.055	14
(15) Decrease of the reservoirs of groundwater aquifers and change in surface water regime	36	2.95	1.000	1.033	12
(16) Change of biogeochemical cycles	36	2.77	1.029	1.000	16
(17) Decrease of ecosystem services	36	2.61	1.000	1.000	19
(18) Increase of water evaporation level	36	2.65	1.000	2.000	18
(19) Increase of soil erosion level (sedimentation and decrease of soil fertility level)	36	2.74	1.000	1.000	17
(20) Disturbance of landscape and environmental desirability	36	2.55	1.000	1.000	20
(21) Increase of abrupt environmental crises (such as storm, flood earthquake, etc.)	36	2.91	1.000	1.000	13

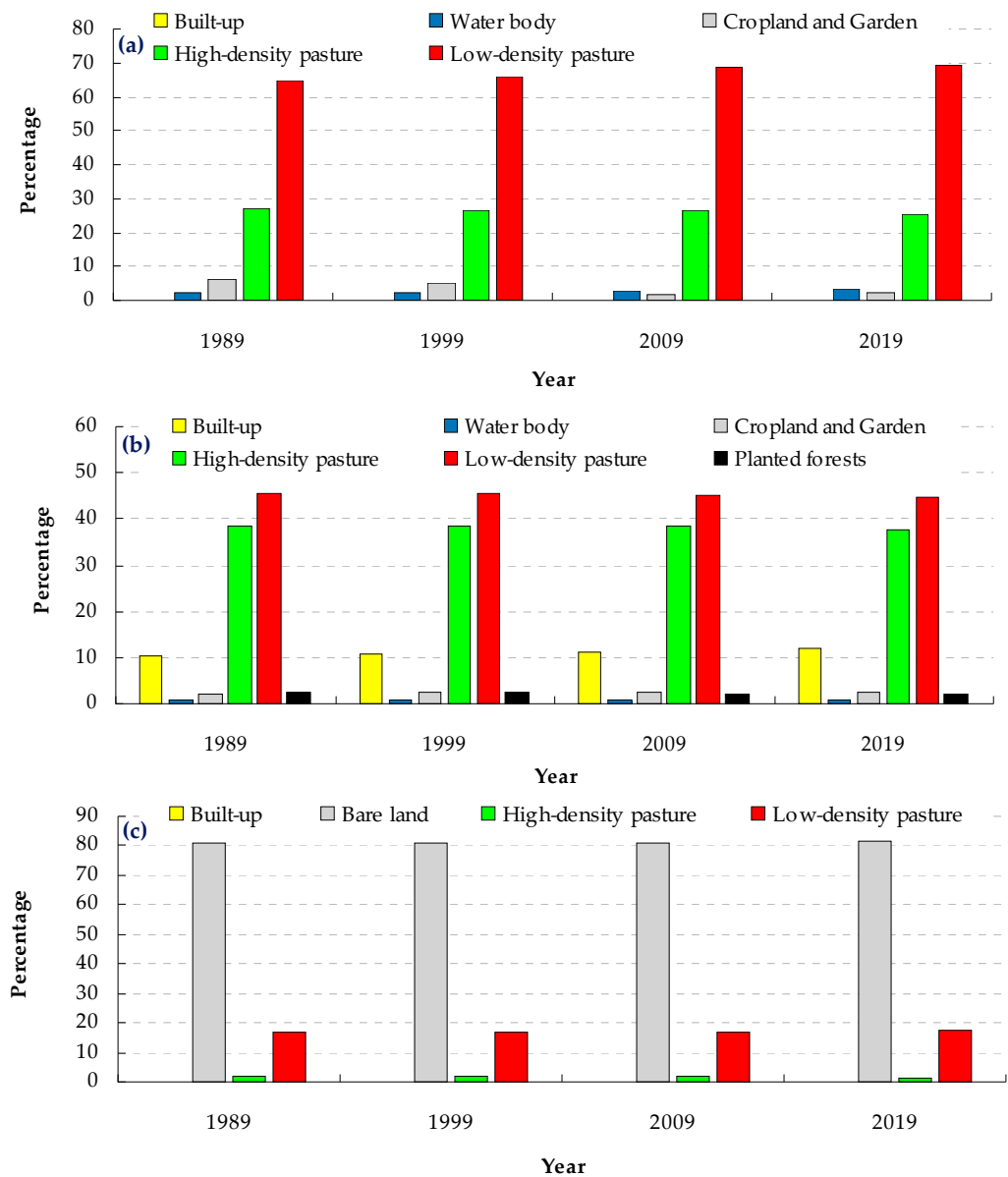


Figure S1. Percentage of LULC changes in the studied areas from 1989 to 2019; a) Lar, b) Jajrud, c) TangehVashi.