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SUPPLEMENTARY INFORMATION

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Weighing the benefits of expanding protected areas versus managing existing ones

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Supplementary Information. Sensitivity analysis methods and results.

Supplementary methods

We conducted a sensitivity analysis to explore changes in the budget allocations to different ratios of management costs to acquisition costs, recovery rates (g) and a full range of possible combinations of rates of loss (α,δ) (e.g., maximum annual deforestation rates of 2.5% and maximum annual weed invasion rates of 7% [1, 2]). We used a generic region with species richness S* = 1000 and assumed a time frame of 10 years (see Supplementary Figure 1 for initial states). For each possible combination of α and δ, in increments of 1% up to a maximum of 100%, we calculated the budget allocation and plotted it for time steps 1, 5, and 10. We found that results ceased to change beyond 10% and have therefore presented results only up to this maximum value. We tested two recovery rates: slow (g=0.1), and fast (g=0.5) [3]. We tested 4 management to acquisition cost ratios (r): 0.5, 1, 3, 10 [4]. We ran the sensitivity analysis for both of our benefit functions (weeds and hunting). Thus, the sensitivity analysis includes all plausible combinations of rates, costs and relative benefits of action leading to robust conclusions across conservation contexts.

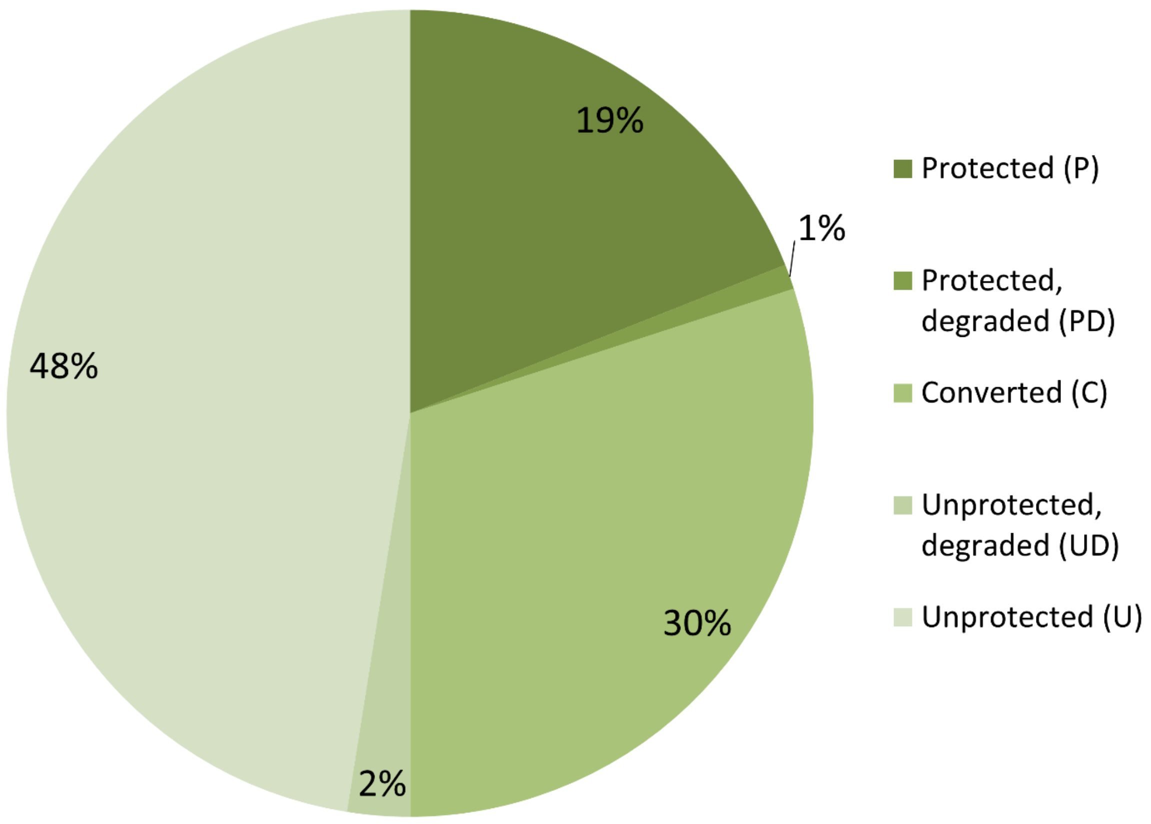
The sensitivity analysis demonstrates that our results are robust across the full range of realistic conversion and degradation rates.

For degradation by habitat transformers, at most cost ratios (r=0.5 - 3), management is the first action (Supplementary Figure 2). The funding allocation switches to protection after about five time steps and ultimately is split across the two actions (Supplementary Figure 2). As the cost ratio increases the first action switches to protection for very high rates of land conversion (δ>7%) (three times the highest observed rates of 2.5%; [2]).

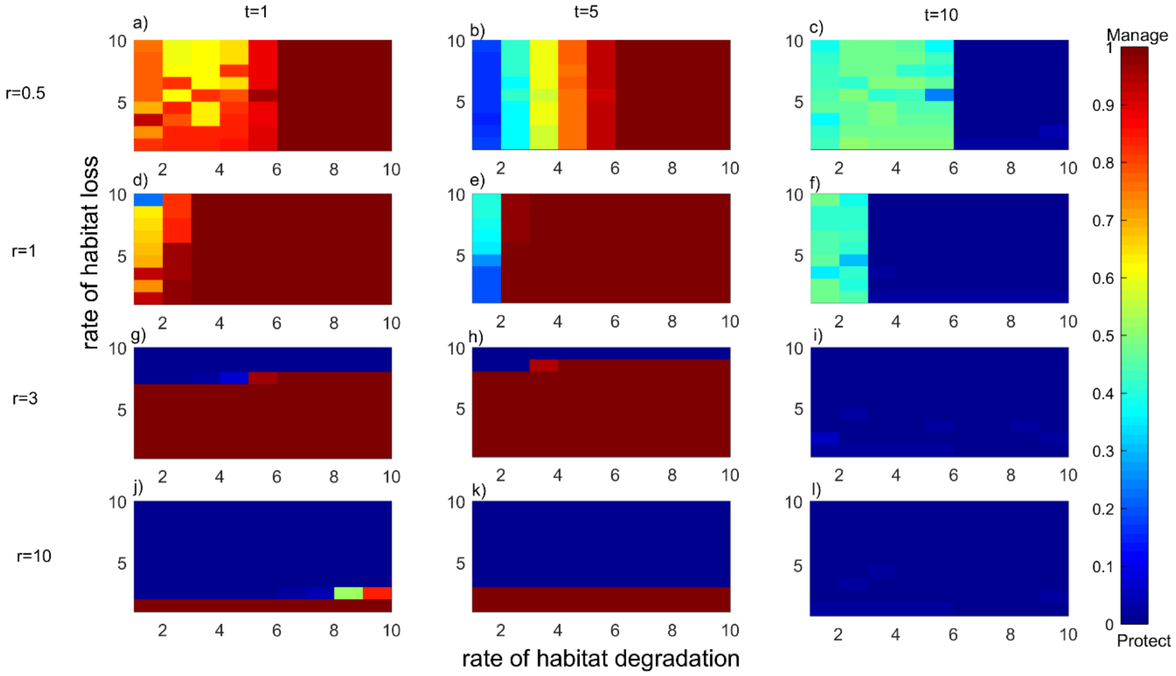
For slower rates of recovery (g=0.1), the pattern of results is similar; the key difference is that the first action switches to protection for cost rations > 3 and for very high rates of land conversion (δ>7%) (Supplementary Figure 3). This is because the relative benefit of management is reduced due to the lower recovery rates.

For degradation by selective pressures we find that the start action is variable: areas with rates of conversion in the observed range of loss (δ<5%) require management first and for extremely high rates of conversion protection is the first action (Supplementary Figure 4). For higher cost ratios (r>=3) the first action is protection for the vast majority of rate combinations with the only exception being for the very lowest rates of conversion (δ=1%) (noting that the majority of observed rates of clearing are <1% annual; [2]). Just as we observe in habitat transformers, for slower rates of recovery (g=0.1), the first action shifts to protection for a larger proportion of the rate combinations reflecting the reduced benefit of management as a result of lower recovery rates (Supplementary Figure 5).

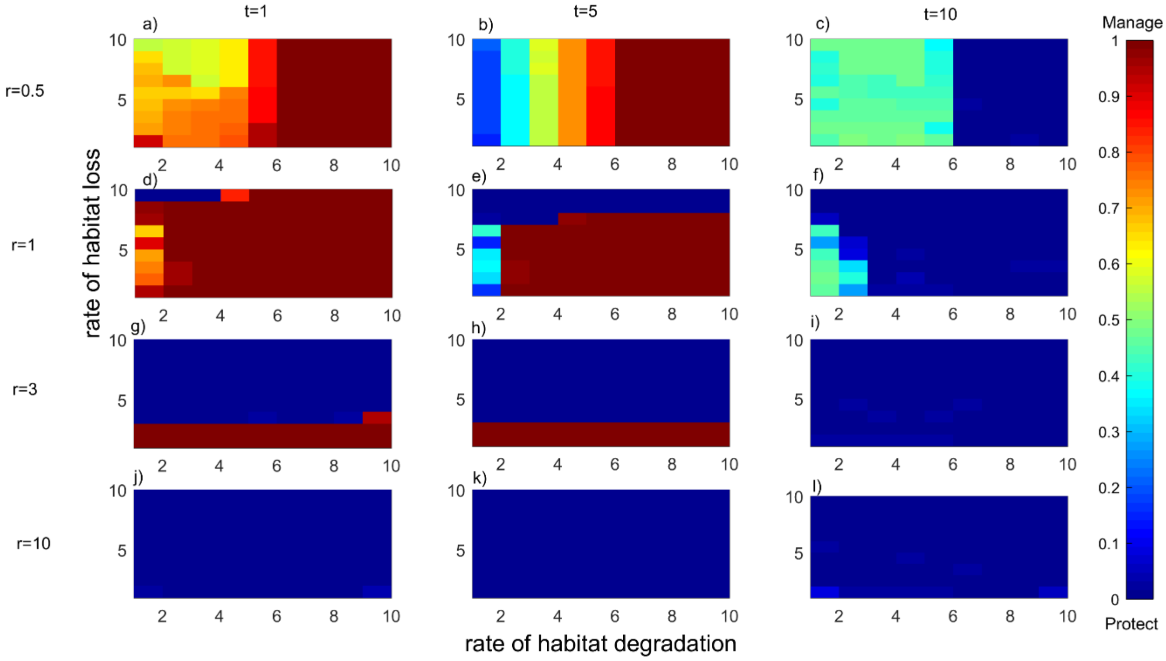
Supplementary Figure 1. Initial state allocations for the generic region used in the sensitivity analysis.



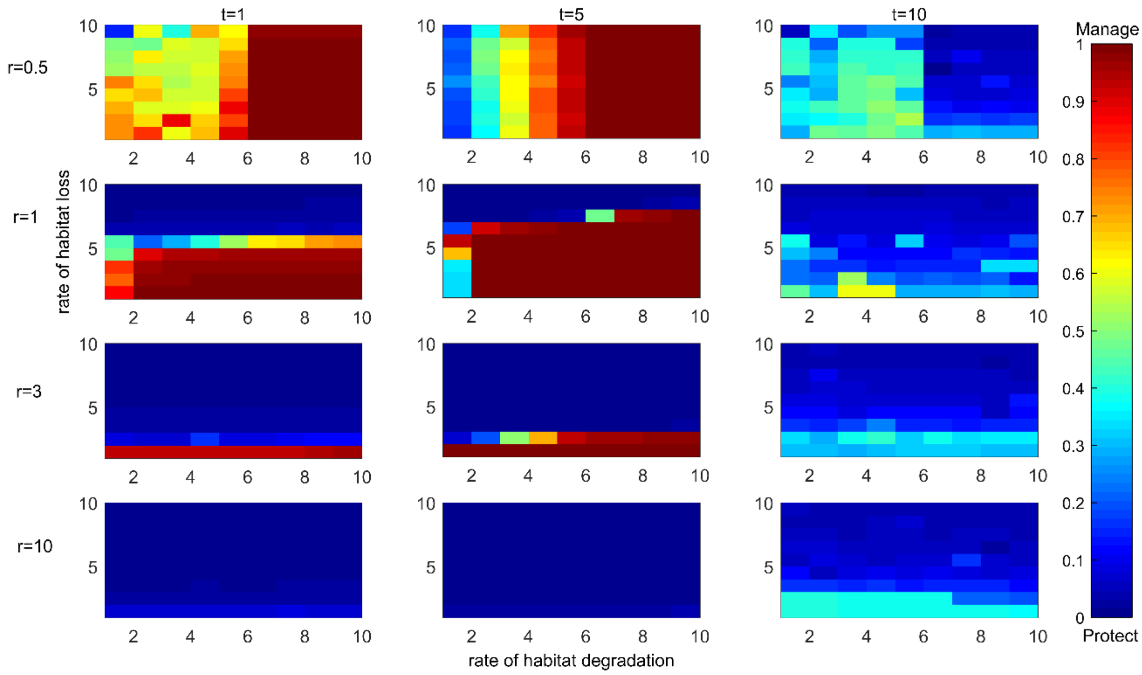
Supplementary Figure 2. Sensitivity analysis for the weed management benefit function. Budget allocations for g=0.5 for four cost ratios (r). Cost ratios(0.5,1,3,10) are shown by row, time steps (1,5,10) are shown by column. Budget allocations for 100% protection are in dark blue and for 100% management are in dark red. A) r=0.5, t=1. B) r=0.5, t=5. C) r=0.5, t=10. D) r=1, t=1. E) r=1, t=5. F) r=1, t=10. G) r=3, t=1. H) r=3, t=5. I) r=3, t=10. J) r=10, t=1. K) r=10 t=5. L) r=10, t=10.



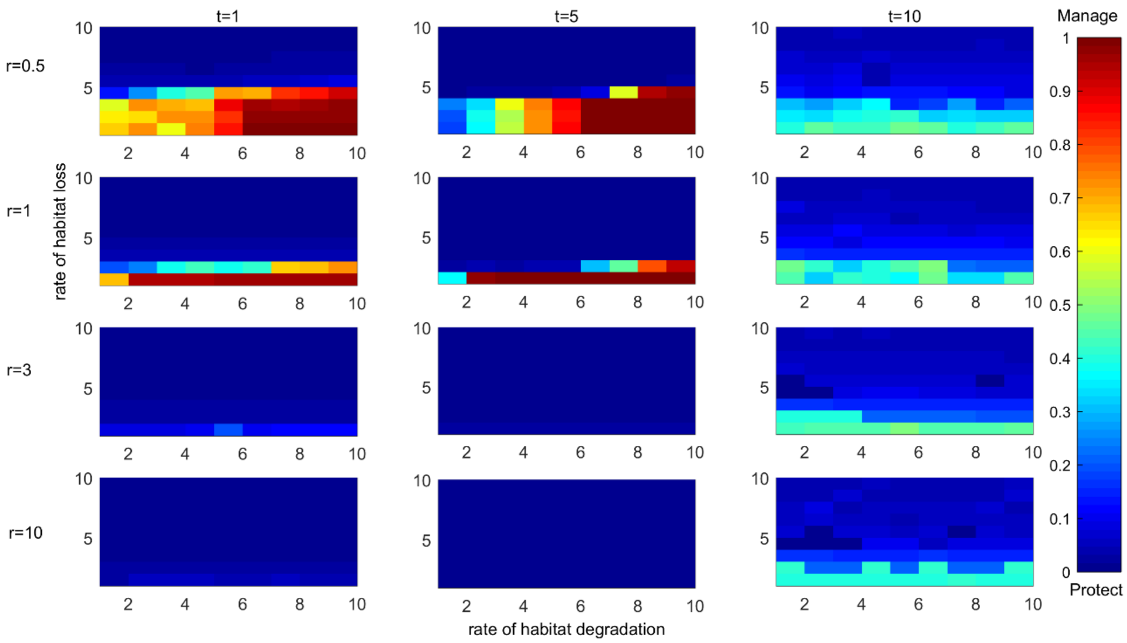
Supplementary Figure 3. Sensitivity analysis for the weed management benefit function. Budget allocations for g=0.1 for four cost ratios (r). Cost ratios (0.5,1,3,10) are shown by row, time steps (1,5,10) are shown by column. Budget allocations for 100% protection are in dark blue and for 100% management are in dark red. A) r=0.5, t=1. B) r=0.5, t=5. C) r=0.5, t=10. D) r=1, t=1. E) r=1, t=5. F) r=1, t=10. G) r=3, t=1. H) r=3, t=5. I) r=3, t=10. J) r=10, t=1. K) r=10 t=5. L) r=10, t=10.



Supplementary Figure 4. Sensitivity analysis for the hunting management benefit function. Budget allocations for g=0.5 for four cost ratios (r). Cost ratios (0.5,1,3,10) are shown by row, time steps (1,5,10) are shown by column. Budget allocations for 100% protection are in dark blue and for 100% management are in dark red. A) r=0.5, t=1. B) r=0.5, t=5. C) r=0.5, t=10. D) r=1, t=1. E) r=1, t=5. F) r=1, t=10. G) r=3, t=1. H) r=3, t=5. I) r=3, t=10. J) r=10, t=1. K) r=10 t=5. L) r=10, t=10.



Supplementary Figure 5. Sensitivity analysis for the hunting management benefit function. Budget allocations for g=0.1 for four cost ratios (r). Cost ratios (0.5,1,3,10) are shown by row, time steps (1,5,10) are shown by column. Budget allocations for 100% protection are in dark blue and for 100% management are in dark red. A) r=0.5, t=1. B) r=0.5, t=5. C) r=0.5, t=10. D) r=1, t=1. E) r=1, t=5. F) r=1, t=10. G) r=3, t=1. H) r=3, t=5. I) r=3, t=10. J) r=10, t=1. K) r=10 t=5. L) r=10, t=10.



Supplementary Table 1. Hotspot Parameter Values. These are reproduced from Bode et al. [5] and Rodrigues et al. [6].

Region	Mammals Richness	Vascular Plants Richness	Habitat loss rate	Land cost (US$/km2)	Total Land (km2)	Available land, %	Reserved land, %	Hunting rank value ([6])	Invasive rank value ([6])	Degradation rate, hunting	Degradation rate, invasive
Atlantic Forest	72	8000	0.019	68,733	1,233,900	6.3	1.8	0.09	0.03	0.018	0.00068
California Floristic Province	18	2124	0.044	865,760	293,800	14.8	10.2	0.09	1.8	0.018	0.04050
Cape Floristic Region	4	6210	0.039	208,660	78,555	7.1	12.9	0.01	0.01	0.002	0.00023
Caribbean Islands	41	6550	0.094	567,170	229,550	2.9	7.1	0.01	0.09	0.002	0.00203
Caucasus	18	1600	0.027	78,508	532,660	20.3	6.7	0.03	0.01	0.006	0.00023
Cerrado	14	4400	0.020	11,414	2,032,000	20.2	1.4	0.09	0.03	0.018	0.00068
Chilean Forests	15	1957	0.061	68,870	397,140	18.8	11.2	0.03	0.03	0.006	0.00068
Coastal Forests E. Africa	11	1750	0.040	2,422	291,250	6.1	3.9	0.03	0.01	0.006	0.00023
E. Afromontane	39	2356	0.034	2,326	1,017,800	4.7	5.8	0.01	0	0.002	0.00000
E. Melanesian Islands	104	3000	0.019	23,846	99,384	30.0	0.0	0.01	0.01	0.002	0.00023
Guinean Forests of W. Africa	67	1800	0.058	16,367	620,310	12.0	3.0	0.01	0	0.002	0.00000
Himalaya	12	3160	0.018	45,888	741,710	14.5	10.5	3.2	0.01	0.64	0.00023
Horn of Africa	20	2750	0.031	8,231	1,659,400	1.9	3.1	0.01	0	0.002	0.00000
Indo-Burma	73	7000	0.017	59,783	2,373,100	0.0	5.6	3.2	0.01	0.64	0.00023
Irano-Anatolian	10	2500	0.030	41,404	899,770	12.1	2.9	0.01	0.01	0.002	0.00023
Japan	46	1950	0.058	3,873,300	373,490	14.1	5.9	0.01	0.01	0.002	0.00023
Madagascar and Indian Ocean Islands	144	11600	0.034	30,444	600,460	7.6	2.4	0.03	0.01	0.006	0.00023

Madrean Pine-Oak Woodlands	6	3975	0.055	326,610	461,270	18.1	1.9	0.03	3.2	0.006	0.07200
Maputaland-Pondoland-Albany	4	1900	0.058	89,969	274,140	17.1	7.4	0.01	0.01	0.002	0.00023
Mediterranean Basin	25	11700	0.047	1,707,200	2,085,300	3.3	1.4	0.01	0.09	0.002	0.00203
Mesoamerica	66	2941	0.053	216,490	1,130,000	14.3	5.7	0.01	1.8	0.002	0.04050
Mountains of Central Asia	6	1500	0.034	17,940	863,360	13.2	6.8	3.2	0	0.64	0.00000
Mountains of Southwest China	5	3500	0.039	81,933	262,450	6.4	1.6	3.2	0	0.64	0.00000
New Caledonia	6	2432	0.035	614,960	18,972	24.4	2.6	0	0.09	0	0.00203
New Zealand	3	1865	0.100	862,010	270,200	0.0	22.1	0	0.09	0	0.00203
Philippines	102	6091	0.032	264,380	297,180	0.9	6.1	0.09	0.01	0.018	0.00023
Polynesia-Micronesia	12	3074	0.070	2,047,600	47,239	16.8	4.4	0.01	0.01	0.002	0.00023
Southwest Australia	12	2948	0.031	178,680	356,720	19.3	10.7	0.01	3.2	0.002	0.07200
Succulent Karoo	2	2439	0.009	70,384	102,690	27.2	1.8	0.01	0.01	0.002	0.00023
Sundaland	172	15000	0.021	89,771	1,501,100	1.5	5.2	3.2	0.03	0.64	0.00068
Tropical Andes	75	15000	0.047	19,045	1,542,600	17.1	7.9	0.09	0.09	0.018	0.00203
Tumbes-Chocó-Magdalena	11	2750	0.019	32,375	274,600	17.1	6.9	0.03	3.2	0.006	0.07200
Wallacea	127	1500	0.018	83,126	338,490	9.2	5.8	3.2	0.03	0.64	0.00068
Western Ghats/Sri Lanka	18	3049	0.092	131,980	189,610	11.8	11.2	0.03	0.01	0.006	0.00023

References

1. Grice AC. The impacts of invasive plant species on the biodiversity of Australian rangelands. The Rangeland Journal. 2006;28(1):27-35. doi: http://dx.doi.org/10.1071/RJ06014.
2. World Bank. 3.4 World Development Indicators: Deforestation and biodiversity In: Bank W, editor. http://wdi.worldbank.org/table/3.42015.
3. Possingham HP, Bode M, Klein CJ. Optimal Conservation Outcomes Require Both Restoration and Protection. PLoS Biol. 2015;13(1):e1002052. doi: 10.1371/journal.pbio.1002052.
4. Armsworth PR. Inclusion of costs in conservation planning depends on limited datasets and hopeful assumptions. Ann N Y Acad Sci. 2014;1322:61-76. Epub 2014/06/13. doi: 10.1111/nyas.12455. PubMed PMID: 24919962.
5. Bode M, Wilson KA, Brooks TM, Turner WR, Mittermeier RA, McBride MF, et al. Cost-effective global conservation spending is robust to taxonomic group. Proc Natl Acad Sci USA. 2008;105(17):6498-501. doi: 10.1073/pnas.0710705105|ISSN 0027-8424. PubMed PMID: WOS:000255534100051.
6. Rodrigues ASL, Brooks TM, Butchart SHM, Chanson J, Cox N, Hoffmann M, et al. Spatially Explicit Trends in the Global Conservation Status of Vertebrates. PLoS ONE. 2014;9(11):e113934. doi: 10.1371/journal.pone.0113934.