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A Resource Allocation Modelfor Tiger Habitat Protection

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Abstract

Conservation of habitats is critical for survival of endangered tigers. This paper develops a resource allocation model for tiger habitat protection incorporating information about threats to particular tiger subspecies, the quality of remaining habitat areas, the observed effectiveness of habitat protection by country, and the potential costs of protection projects for 74 habitats in Asia. Implementation of the model moves through two stages. The first stage employs user-specified weights to combine numerous subindices into composite indices of species threat, habitat quality, potential project costs and protection effectiveness. The second stage employs additional user-specified weights to combine the composite indices into priority scores and potential project budget shares for all 74 habitat areas.

Exploration of model results suggests that changes in user-specified weights can have very significant consequences for habitat priority scores. Illustrative scenarios indicate that no single priority ordering can be prescribed in such a diverse setting, and actual priorities will depend on the preferences of decision-makers, as revealed in the weights assigned to species threats, habitat quality, cost elements, and effective protection. At the same time, the model can make a useful contribution by identifying priority orderings that are consistent with different sets of preferences. And it can inform policy discussions by allowing for extended exploration of alternative strategies, along with providing feedback to decision makers about the implicit preferences associated with their resource allocation decisions.

Keywords: biodiversity conservation, tiger habitat, resource allocation

1. Introduction

The International Union for Conservation of Nature has classified the tiger as endangered in its Red list of Threatened Species of (http://www.iucnredlist.org/details/15955/0). The wild tiger population of tropical Asia dropped from about 100,000 to 3,500 in the past century. The Bali, Javan and South China subspecies are believed to be extinct in the wild. An estimated 2,380 Bengal tigers survive, along with 340 Indochinese, 500 Malayan and 325 Sumatran tigers. The surviving wild tiger population of tropical Asia inhabits a scattered arc from southwest India to northwest Indonesia, much of it in upland areas. Bengal tigers survive in India, Nepal, Bhutan, Bangladesh and northern Myanmar, while the remaining Indochinese tigers are found in western and southeastern Myanmar, Lao PDR, Vietnam, Cambodia and Thailand. In contrasting geographic concentration, Sumatran tigers are confined to one Indonesian island and Malayan tigers exist only in Peninsular Malaysia and one small area in southern Thailand. Long term survival of the tiger is dependent on conservation of tiger habitats.

The global community has mobilized to conserve the tiger's remaining habitat through the Global Tiger Initiative, which is supported by all countries with known tiger populations, the World Bank, and over 40 civil society organizations. Participating countries and institutions have endorsed the Global Tiger Recovery Program (GTRP), which aims to double the number of wild tigers by 2022 through habitat conservation programs and cooperation across national boundaries to stop poaching and illegal trade in tiger parts.

Operating under tight budget constraints, the GTRP confronts several complicating factors, including the need to conserve specific habitats large enough to accommodate this keystone predator; differential threats to important regional subspecies that must be preserved (Bengal, Indochinese, Malayan and Sumatran tigers); divided national jurisdictions; differences in countries' institutional capabilities, conservation management costs, and willingness to pay for conservation; and, not least, widely-differing and rapidly-changing opportunities for commercial exploitation of remaining habitat areas.

Cost-effective resource allocation under these dynamic conditions involves frequent reassessment of threats and opportunities in many habitat areas scattered across the tiger range countries. Timely analysis requires near-real-time forest monitoring information, which is now available from FORMA (Forest Monitoring for Action), a new database developed by a research consortium that includes the Center for Global Development (http://www.cgdev.org/forma), the World Resources Institute, the University of Maryland, and Resources for the Future, in consultation with World Bank staff, Conservation International, the Nature Conservancy and WWF. Drawing on data from NASA's MODIS system, FORMA provides monthly updates on forest clearing at high spatial resolution for tropical Asian countries with tiger habitat.

From a formal analytical perspective, saving the tiger involves optimal spatial resource allocation with a limited budget, a short time horizon (to prevent extinction), a complex, constantly-changing spatial distribution of potential conservation benefits and costs, and the prospect of rapid, irreversible losses in areas where conservation is weak. Combining the FORMA information with a spatially-disaggregated database of economic, demographic and geographic information, previous papers by the authors have focused on identifying area-specific drivers of habitat destruction (Dasgupta et al., 2012a), and testing the effects of interventions intended to protect habitat (Dasgupta et al., 2012b).

In this paper, we draw on information and insights from the previous papers to develop a model that can inform the allocation of GTRP resources for tiger habitat conservation. Designed for frequent updates as new information becomes available, the model estimates priorities and potential program budget shares for 74 tiger habitat areas in 9 countries: Cambodia, India, Indonesia, Lao PDR, Myanmar, Malaysia, Nepal, Thailand and Vietnam. It incorporates four key factors for resource allocation: differential threats to tiger subspecies, habitat quality, potential project implementation costs, and recent evidence on the effectiveness of countries' protection policies.

2. Method

2.1 Theoretical Framework

To provide a consistent modeling framework, we adopt an approach to optimal allocation that draws on prior theoretical and empirical work by Behrman, Pollak and Taubman (1982), Bolt et al. (2003), Buys et al. (2004), Pandey et al. (2005) and Wheeler (2011). In this model, the welfare impact of conservation project expenditures is a function of their levels and distributions across tiger habitat areas. Resource allocation decisions by the Global Tiger Recovery Program must incorporate and balance three factors: tiger subspecies preservation; representation for all participating countries; and overall welfare maximization. We cannot realistically characterize the program's objective function as linear (infinite elasticity of substitution across habitat areas), because sole allocation to one area is infeasible, whatever the relative scale of its protection problem. Broader geographic coverage is implied by the program's charter. At the same time, the objective function is not purely fixed-coefficient (zero elasticity of substitution across areas), because nothing forces it to maintain cross-country parity in allocation. This is good, since the distribution of habitat protection problems is likely to be far from even across areas.

We adopt an intermediate assumption: that the objective function is characterized by unit-elastic substitution across areas. A unit-elastic (Cobb-Douglas) welfare function permits tailoring of programs to area-specific conditions, while encouraging portfolio diversification through the operation of diminishing returns. Expected welfare gains from expenditures are related to both the scale of habitat protection problems and the cost of successful protection under local conditions.

Formally, we specify the resource allocation problem as follows:

$$\text{Welfare Function: } W = \prod_{ijk} T_{ijk}^{\rho_i} \quad (1)$$

where T_{ijk} = Expected number of surviving tigers of subspecies i in habitat j, country k

ρ_i = Exogenous extinction risk for tigers of subspecies i.

Extinction risk is a function of overall deterioration of the subspecies' habitat in the region (D), the number of surviving tigers in the subspecies (T), and the number of countries (N) that still harbor them:

$$\rho_i = \gamma_0 D_i^{\gamma_1} T_i^{\gamma_2} N_i^{\gamma_3} \tag{2}$$

The expected number of surviving tigers is a function of habitat quality and the effectiveness of habit protection in country k.

$$T_{ijk} = \alpha_0 G_{jk}^{\alpha_1 Q_{jk}^{\alpha_1} P_k^{\alpha_2}} \tag{3}$$

where G_{jk} = Scale of GTRP activity in habitat j, country k

Q_{jk} = Quality of habitat j, country k

P_k = Effectiveness of habitat protection in country k

Habitat quality is a function of habitat size (H) and fragmentation (F):

$$Q_{jk} = \delta_0 H_{jk}^{\delta_1} F_{jk}^{\delta_2} \tag{4}$$

Resource allocation is limited by an overall budget constraint:

$$\bar{B} = \sum_{jk} C_{jk} G_{jk} \tag{5}$$

where B = Available budget

C_{jk} = Unit cost of protection for habitat jk

Unit protection costs reflect a combination of economic incentives for local conservation and the direct cost of habitat protection, which is principally a function of local labor cost.

$$C_{jk} = \beta_0 L_{jk}^{\beta_1} W_k^{\beta_2} \tag{6}$$

where L = Opportunity cost of land in habitat jk

W = Labor cost in country k

Substituting (3) into (1) yields the following welfare function:

$$W = \prod_{ijk} G_{jk}^{\alpha_1 Q_{jk}^{\alpha_1} P_k^{\alpha_2}} \tag{7}$$

Maximization of W subject to the overall budget constraint yields the following ratio of optimal GTRP resource allocations for protection of arbitrarily-chosen habitat areas 1 and 2 with tiger subspecies m and n:

$$\frac{C_1 G_1^*}{C_2 G_2^*} = \frac{\rho_m^{\alpha_1} Q_1^{\alpha_2} P_1^{\alpha_3}}{\rho_n^{\alpha_1} Q_2^{\alpha_2} P_2^{\alpha_3}} \tag{8}$$

Substituting and re-arranging, we obtain:

$$\frac{G_1^*}{G_2^*} = \frac{\hat{\rho}_m^{\alpha_1} \hat{Q}_1^{\alpha_2} P_1^{\alpha_3} \hat{C}_1^{\alpha_4}}{\hat{\rho}_n^{\alpha_1} \hat{Q}_2^{\alpha_2} P_2^{\alpha_3} \hat{C}_2^{\alpha_4}} \tag{9}$$

The program priority score of habitat area 1 is the numerator of (9), where $\hat{\rho}$, $\hat{Q}$ and $\hat{C}$ are calculated from (2), (4) and (6), respectively. Its share of the program budget is

$$s_1 = \frac{S_1}{\sum_{j=1}^{N} S_j} \tag{10}$$

2.2 Quantifying Habitat Protection Factors

To implement the model, we quantify the allocation factors using the database developed in Dasgupta et al. (2012a). For each tiger habitat area, we develop composite measures as follows. Variables are denoted by letters from the previous equations.

(1) Subspecies extinction risk (ρ). Our measure has three components:

a. Species numbers (T): Table 1 provides recent estimates of surviving tiger populations, by subspecies and country. Our measure for each subspecies is its share of the total tiger population.

b. Overall habitat loss (D): For each habitat area, we compute natural forest cover remaining by August, 2011. This combines measures from Hansen, et al. (2006) for 2000, Hansen, et al. (2008) for 2000 – 2005, and FORMA data for January, 2006 to August, 2011. Across all areas, we total original and remaining forest cover by subspecies, and compute the overall percentage of original forest that has been subject to clearing.

c. Species distribution across countries (N): In standard portfolio terms, spreading the remaining tigers across polities should reduce aggregate risk. Our index of "portfolio risk" is the intercountry entropy measure (E) for each subspecies, where

$$E_i = -\sum_{k=1}^{K} s_{ik} \ln s_{ik}$$

ands_k = Country k's share of surviving tigers of subspecies i.

Table 1. Surviving wild tiger population*

Bengal[a]		Indochinese		Malayan		Sumatran	
India	1,706	Thailand	200	Malaysia	500	Indonesia	325
Bangladesh	440	Myanmar	85	(Peninsular)		(Sumatra)	
Nepal	155	Vietnam	20				
Bhutan	75	Cambodia	20				
		Lao PDR	17				
Total	2,376		342		500		325

Note. * Midrange estimates [a] No current estimate for Myanmar

Source: Dasgupta et al. (2012a).

(2) Habitat Quality (Q). This includes two components: Habitat area (H) and the degree of fragmentation (F). For the latter, we use the percentage of habitat area not subject to clearing by August, 2011.

(3) Effectiveness of protection (P): For all tiger habitat areas within a country, we total original and remaining forest area and compute the shares of original forest that were subjected to clearing by 2000 and August, 2011, respectively. The increase in share from 2000 to 2011 is a proxy for the risk of protection failure during the period.

(4) Protection project Cost (C). This includes two components:

a. Habitat land opportunity cost (L): In Dasgupta, et al. (2012a), we specify a model that relates local forest clearing to the profitability of alternative uses for the land. By implication, the best single measure of the opportunity cost of forested land in a locality is the intensity of recent clearing. Accordingly, our proxy for opportunity cost in each habitat is the increase in the percent of its area cleared from 2000 to August, 2011.

b. Labor cost (W): We incorporate relative protection project costs using differential wages, with income per capita as the proxy and an exponential weight (0.6) that reflects the findings of Harrison (2002) on the labor share of income in low- and middle-income countries.

2.3 Model Implementation

We transform all model variables to ranks for ease of use and interpretation, and to ensure robustness against outlier effects. We report the raw variable values in Appendix A. To facilitate the nested procedure that we describe below, our rank-ordering for each variable ensures a positive relationship to the priority scores in (9). Accordingly, higher numerical ranks are assigned to lower values for subspecies numbers (T), subspecies distribution (E), land opportunity cost (L) and labor cost (W). Higher numerical ranks are assigned to higher values for subspecies' overall habitat loss (D), habitat area (H), the percent of habitat remaining (F), and the effectiveness of country protection (P).

Our model incorporates equations (1) – (10) in a two-stage exercise. In the first stage, the user specifies relative weights for the determinants of ρ, Q and C in (2), (4) and (6) above.The model allows the user to specify the parameters for each equation in arbitrary units. After the parameters are specified, the model standardizes to Cobb-Douglas (CD) parameters by dividing each parameter by the sum of parameters for that equation. Then it forms the product of the relevant rank-transformed variables, each weighted by its exponential CD parameter.

At the completion of the first stage, the model has created indices for ρ, Q and C. P (protection effectiveness) has only one component, so that is the second-stage index for this variable. At the beginning of the second stage, the user specifies relative weights for species risk (ρ), habitat quality (Q), protection effectiveness (P) and project cost (C). As before, the model allows the user to specify the weighting parameters in arbitrary units. Then it standardizes to CD parameters and forms the product of the four indices, each weighted by its exponential CD parameter.

The most critical question for our modeling exercise relates to the potential variation in outcomes for different user settings of model parameters. To address this question, Table 2 provides rank correlations for the 8 variables incorporated in the model. The results are almost evenly divided between positive and negative correlations; some are strong but most are relatively weak. Overall, these results indicate that the habitat priorities and implicit budget shares calculated by the model are highly dependent on user-specified weights.

Table 2. Rank correlations for model variables

Obs = 74	Subspecies Numbers	Subspecies Distribution	Subspecies Habitat Threat	Habitat Size	Habitat Percent Remaining	Habitat Land Opp. Cost	Habitat Labor Cost
Subspecies Numbers	1.00						
Subspecies Distribution	0.06	1.00					
Subspecies Habitat Threat	-0.75	-0.43	1.00				
Habitat Size	0.22	-0.18	-0.21	1.00			
Habitat Percent Remaining	0.41	0.20	-0.46	0.16	1.00		
Habitat Land Opp. Cost	-0.57	-0.13	0.62	-0.43	-0.30	1.00	
Habitat Labor Cost	-0.28	-0.35	0.51	0.13	-0.03	0.16	1.00
Country Protection Effectiveness	-0.78	-0.44	0.87	-0.23	-0.43	0.66	0.41

3. Results

To illustrate the possible range of variation, we implement the model for three sets of parameter weights. The first two give extra weight to subspecies threats and project cost elements, while the third assigns equal weight to all variables.

The subspecies threat scenario assigns unit weights to first-stage variables except for subspecies numbers (T) and distributions across countries (N), which are assigned weights of 5. In the second stage, we assign a weight of 3 to subspecies threat and unit weights to the other three indices. The cost scenario assigns a weight of 3 to the cost index in the second stage, leaving all other weights at unit values. The equal-weights scenario assigns unit weights to all variables in both stages.

Table 3 shows that these weighting changes have very significant consequences for the priority rankings of the 74 tiger habitat areas in the model: The rank correlations of Species Threat with Cost and Equal Weights are .41 and .64 respectively, while the correlation between Equal Weights and Cost is .82.

Table 3. Habitat rank correlations

	Species Threat	Cost
Species Threat	1.00	
Cost	0.41	1.00
Equal Weights	0.64	0.82

Table 4 presents results for all 74 habitat areas, sorted by rank in the Species Threat Scenario. Inspection of the top entries indicates that the major beneficiaries of extra weighting for species threat are habitat areas in Indonesian Sumatra, the sole locale of the Sumatran tiger, which rank much higher than in the Cost and Equal

Weighting scenarios. This applies particularly to Bukit Balai Rejang-Selatan and Gunug Leuser, which move to first and second in the priority ordering. Subspecies scores for the critically-threatened Indochinese Tiger are also high, which produces high ranks for several Vietnamese, Laotian and Thai habitat areas (e.g., Northern and Southern Annamites, Phu Miang – Phu Thong, Taman Negara-Belum).

The Cost scenario shifts habitat scores toward areas that have low labor costs, low land opportunity cost indices, or both. As a result, the highest priorities are assigned to some habitat areas in Nepal (Corbett-Sonanadi, Royal Bardia, Royal Chitwan, Royal Suklaphanta), Myanmar (Northern Forest Complex - Namdapha - Royal Manas), and India (Dandeli – Anshi, Royal Chitwan, Kanha û Phen, Western Ghats: Bandipur - Khudrenukh û Bhadra, Simlipal, Kaziranga – Garampani). At the same time, cost advantages in Vietnam and Lao PDR maintain high rankings for several areas with high priorities in the Species Threat scenario (particularly the Northern and Southern Annamites). The Equal Weights scenario favors many of the same protected areas in Nepal, Vietnam, Lao PDR and India.

4. Discussion

The three illustrative cases suggest that the priority rankings of some habitat areas are highly sensitive to variable weighting, while others are not. However, these are only three of many possible scenarios, and the correlations in Table 2 suggest that most habitat areas would change priority ordering substantially for some values of the 8 weighting parameters.

To clarify the aggregative implications of our results, Tables 5(a)-(c) present summaries at the country level for Species Threat, Cost and Equal Weights. The tables reproduce the country-level ranks for Subspecies Numbers, Subspecies Distribution, Subspecies Habitat, Labor Cost and Effective Protection. The ranks for Habitat Size, Habitat Percent and Land Cost are determined from mean values for habitat-level data. The scores for the three criterion variables (Species Threat, Cost, Equal Weights) are means of habitat-level scores.

In Table 5(a) the high Species Threat rankings for Lao PDR, Vietnam and Indonesia are consistent with the previously-noted high rankings for several Tiger Landscapes in Table 4. Similarly, the Cost and Equal Weight summaries in Tables 5(b) and 5(c) confirm the previously-noted advantages of Tiger Landscapes in Nepal, Lao PDR, Vietnam and India.

We conclude that the principal value of our modeling system is educational rather than prescriptive. Undertaking numerous weighting experiments can provide a useful sense of the relationship between decision-makers' preferences and habitat assistance priorities. In the same vein, the model can be used to reveal the preferences of decision-makers who have assigned priorities to different habitats in resource allocation.

5. Summary and Conclusions

In this paper, we have developed and implemented a model that translates detailed information about 74 tiger habitat areas into consistently-derived priority scores and potential project budget shares for those areas. Drawing on the database constructed by Dasgupta, et al. (2012a), the model incorporates information about threats to particular tiger subspecies, the quality of remaining habitat areas, the observed effectiveness of habitat protection by country, and the potential costs of protection projects for different habitats. Implementation of the model moves through two stages. In the first, user-specified weights are employed to combine sub-indices into composite indices of species threat, habitat quality, cost and protection effectiveness. In the second stage, user-specified weights are employed to combine the composite indices into priority scores and potential project budget shares for all 74 habitat areas.

Our investigation of inter-variable correlations suggests that changes in user-specified weights can have very significant consequences for habitat priority scores. In three illustrative scenarios, we investigate the implications of equal weights for all model variables, higher weights for species threats, and higher weights for potential project costs. We find very substantial differences in high-priority habitats across the three scenarios, although habitats in some countries retain high positions in all three.

In summary, we find that great habitat diversity is revealed by the introduction of eight critical variables for priority-setting. No single priority ordering can be prescribed in such a diverse setting, and actual priorities will depend on the preferences of decision-makers, as revealed in the weights assigned to species threats, habitat quality, cost elements, and effective protection. At the same time, we believe that our model can make a useful contribution by identifying priority orderings that are consistent with different sets of preferences. And it can inform policy discussions by allowing for extended exploration of alternative strategies, along with feedback to decision makers about the implicit preferences associated with their resource allocation decisions.

Table 4. Results for three weighting scenarios

		Habitat Ranks			Habitat Scores			Variable Ranks							
Country	Habitat Name (Tiger Landscape)	Species Threat	Cost	Equal Weights	Species Threat	Cost	Equal Weights	Subspecies Numbers	Subspecies Distribution	Subspecies Habitat	Habitat Size	Habitat Percent	Land Cost	Labor Cost	Effective Protection
Indonesia	Bukit BalaiRejang - Selatan	1	39	45	100.00	63.31	70.08	4	3	2	35	71	42	3	2
Indonesia	GunugLeuser	2	54	48	98.44	56.77	68.44	4	3	2	59	61	24	3	2
Vietnam	Northern Annamites	3	14	2	97.78	82.07	97.43	3	1	3	64	67	32	5	7
Vietnam	Southern Annamites	4	15	6	97.15	81.22	95.18	3	1	3	69	50	33	5	7
Laos	Southern Annamites	5	8	4	96.27	85.73	96.49	3	1	3	69	58	36	6	6
Laos	PhuMiang - Phu Thong	6	4	7	95.99	93.71	94.77	3	1	3	54	35	66	6	6
Indonesia	Bukit Barisan Selatan South	7	46	52	94.73	59.74	64.62	4	3	2	19	70	41	3	2
Indonesia	KerinciSeblat	8	61	53	94.50	50.40	64.37	4	3	2	63	56	15	3	2
Thailand	Taman Negara - Belum	9	51	31	94.20	58.28	75.79	2	3	1	67	63	28	2	5
Indonesia	RimboPanti-BatangGadis West	10	43	54	94.17	60.75	64.04	4	3	2	15	72	47	3	2
Vietnam	KonKaKinh	11	17	14	92.88	79.13	90.20	3	1	3	46	46	35	5	7
Nepal	Royal Bardia	12	2	1	92.53	96.63	100.00	1	2	4	48	30	48	8	9
Laos	Nam Et PhouLoey	13	25	33	92.24	75.54	75.12	3	1	3	56	60	23	6	6
Indonesia	Sibologa	14	55	56	91.46	56.69	61.29	4	3	2	14	69	37	3	2
Thailand	KhlongSaeng	15	52	39	91.24	57.41	72.25	2	3	1	40	65	31	2	5
Nepal	Corbett - Sonanadi	16	1	3	90.81	100.00	97.22	1	2	4	44	19	66	8	9
Laos	Nam Ha	17	19	19	90.47	77.00	86.71	3	1	3	33	64	29	6	6
India	Royal Chitwan	18	9	12	90.00	85.12	90.79	1	2	4	36	34	66	4	8
India	Western Ghats: Bandipur - Khudrenukh û Bhadra	19	11	8	89.03	83.40	94.39	1	2	4	58	38	50	4	8
India	Kaziranga - Garampani	20	13	9	88.49	82.62	93.53	1	2	4	51	41	49	4	8
India	Dandeli - Anshi	21	7	10	88.40	86.06	93.38	1	2	4	22	73	63	4	8
Laos	Northern Annamites	22	35	23	88.16	65.65	83.41	3	1	3	64	54	13	6	6
India	Northern Forest Complex - Namdapha - Royal Manas	23	37	11	87.93	64.09	92.64	1	2	4	73	20	20	4	8
Indonesia	Bukit Rimbang Baling	24	67	58	87.88	44.51	57.74	4	3	2	38	53	11	3	2
Indonesia	Bukit Barisan South	25	66	60	87.68	46.23	57.54	4	3	2	28	55	14	3	2
Nepal	Royal Chitwan	26	3	5	86.76	94.94	95.93	1	2	4	36	27	51	8	9
India	Periyar - Megamala	27	16	13	86.45	79.57	90.31	1	2	4	43	40	45	4	8
India	Kanha û Phen	28	10	15	86.07	84.45	89.72	1	2	4	53	21	66	4	8
India	Simlipal	29	12	17	85.25	82.77	88.44	1	2	4	24	44	62	4	8
India	Indravati	30	22	18	84.54	75.98	87.33	1	2	4	66	23	39	4	8
India	Royal Bardia	31	24	20	83.86	75.69	86.29	1	2	4	48	28	40	4	8
Laos	Hin Nam Ho	32	36	27	83.85	64.64	77.37	3	1	3	27	57	16	6	6
Indonesia	Bukit Tigapuluh Landscape	33	69	63	82.78	37.89	52.78	4	3	2	50	36	6	3	2
Vietnam	Bi Dup-Nui Ba	34	38	32	82.53	63.51	75.55	3	1	3	16	59	19	5	7
India	Royal Suklaphanta	35	59	21	82.49	53.89	84.18	1	2	4	11	1	51	4	8
Vietnam	Nam Et PhouLoey	36	41	16	82.21	62.70	89.26	3	1	3	56	17	18	5	7
India	Anamalai-Parambikulam	37	29	22	82.13	70.65	83.63	1	2	4	31	45	30	4	8
Indonesia	Berbak	38	68	66	81.20	38.14	51.28	4	3	2	25	49	7	3	2
India	Corbett - Sonanadi	39	20	24	81.09	76.21	82.04	1	2	4	44	16	51	4	8
Thailand	PhuKhieo	40	50	37	80.19	59.45	72.36	3	1	3	42	39	38	2	5
Myanmar	Northern Forest Complex - Namdapha - Royal Manas	41	6	25	79.71	88.42	79.95	1	2	4	73	68	34	9	4
India	Dandeli North	42	18	26	78.87	77.18	78.70	1	2	4	6	66	65	4	8
Vietnam	Cat Tien	43	47	42	78.87	59.57	70.58	3	1	3	34	18	17	5	7

Cambodia	Cardamom's	44	56	51	78.67	54.97	67.43	3	1	3	60	52	9	7	3
India	Rajaji Minor	45	21	28	77.58	76.11	76.77	1	2	4	10	32	66	4	8
India	Pachmarhi - Satpura - Bori	46	26	29	77.52	72.85	76.68	1	2	4	41	10	51	4	8
India	Radhanagari	47	27	30	77.45	71.55	76.58	1	2	4	30	15	46	4	8
Thailand	PhuMiang - Phu Thong	48	60	49	76.76	51.96	67.77	3	1	3	54	31	22	2	5
Myanmar	Tenasserims	49	45	34	76.57	59.98	74.33	1	2	4	71	51	8	9	4
Thailand	Cardamom's	50	57	44	76.50	54.40	70.32	3	1	3	60	33	25	2	5
Thailand	Tenasserims	51	65	50	75.92	46.85	67.52	3	1	3	71	42	12	2	5
India	Pench	52	28	35	75.91	71.34	74.31	1	2	4	29	11	51	4	8
India	Satkosia-Gorge	53	44	36	74.81	60.64	72.70	1	2	4	26	25	21	4	8
India	Palamau	54	31	38	74.53	70.05	72.30	1	2	4	32	8	51	4	8
Indonesia	Kualar Kampar-Kerumutan	55	70	70	74.43	28.37	45.00	4	3	2	52	29	2	3	2
Nepal	Royal Bardia South	56	23	40	74.00	75.87	71.52	1	2	4	5	22	43	8	9
India	Shendurney	57	42	41	73.63	61.85	70.99	1	2	4	7	62	26	4	8
India	Chandoli	58	33	43	73.18	67.10	70.33	1	2	4	17	14	44	4	8
India	Sunabeda-Udanti	59	32	46	72.67	68.30	69.60	1	2	4	21	9	51	4	8
India	Western Ghats - Sharavathi Valley	60	30	47	72.39	70.47	69.20	1	2	4	2	73	63	4	8
Thailand	KhaoYai	61	53	59	68.90	56.83	57.63	3	1	3	20	7	72	*2*	5
Thailand	Salak-Phra	62	62	62	67.58	47.33	55.98	3	1	3	8	37	27	*2*	5
India	Bandhavgarh - Panpatha	63	40	55	67.06	63.02	61.69	1	2	4	18	4	51	*4*	8
India	Purna	64	34	57	66.36	66.06	60.74	1	2	4	9	5	72	*4*	8
Indonesia	TessoNilo Landscape	65	72	71	65.04	22.09	36.76	4	3	2	23	26	1	*3*	2
Cambodia	Cambodian Northern Plains	66	63	64	64.64	47.28	52.37	3	1	3	62	6	10	*7*	3
India	Rajaji Major	67	49	61	63.29	59.48	56.57	1	2	4	3	12	51	*4*	8
Thailand	ThapLan - Pang Sida	68	64	69	60.19	46.87	47.05	3	1	3	39	1	51	*2*	5
India	Biligiri Range	69	48	65	59.84	59.56	52.00	1	2	4	1	13	72	*4*	8
India	Mahabaleshwar Landscape - South	70	58	67	57.76	54.28	49.31	1	2	4	4	3	51	*4*	8
Nepal	Royal Suklaphanta	71	5	68	57.34	90.84	48.78	1	2	4	11	24	66	*8*	9
Malaysia	Taman Negara - Belum	72	71	72	56.42	22.48	35.13	2	3	1	67	47	4	*1*	1
Malaysia	Endau Rompin	73	74	73	53.09	20.16	32.06	2	3	1	47	43	3	*1*	1
Malaysia	Krau	74	73	74	50.23	20.77	29.51	2	3	1	13	48	5	*1*	1

Table 5. Summary results for countries

(a) Species Threat

Country	Rank	Species Threat	Subspecies Numbers	Subspecies Distribution	Subspecies Habitat	Habitat Size	Habitat Percent	Land Cost	Labor Cost	Effective Protection
Laos	1	91.16	3	1	3	7	8	6	6	6
Vietnam	2	88.57	3	1	3	6	5	5	5	7
Indonesia	3	87.69	4	3	2	3	7	3	3	2
Nepal	4	80.29	1	2	4	2	1	9	8	9
Myanmar	5	78.14	1	2	4	9	9	4	9	4
India	6	77.88	1	2	4	1	2	8	4	8
Thailand	7	76.83	2	3	1	5	4	7	2	5
Cambodia	8	71.66	3	1	3	8	3	2	7	3
Malaysia	9	53.24	2	3	1	4	6	1	1	1

(b) Cost

Country	Rank	Species Threat	Subspecies Numbers	Subspecies Distribution	Subspecies Habitat	Habitat Size	Habitat Percent	Land Cost	Labor Cost	Effective Protection
Laos	1	91.66	1	2	4	2	1	9	8	9
Vietnam	2	77.04	3	1	3	7	8	6	6	6
Indonesia	3	74.2	1	2	4	9	9	4	9	4
Nepal	4	71.39	1	2	4	1	2	8	4	8
Myanmar	5	71.37	3	1	3	6	5	5	5	7
India	6	53.26	2	3	1	5	4	7	2	5
Thailand	7	51.12	3	1	3	8	3	2	7	3
Cambodia	8	47.07	4	3	2	3	7	3	3	2
Malaysia	9	21.14	2	3	1	4	6	1	1	1

(c) Equal Weights

Country	Rank	Species Threat	Subspecies Numbers	Subspecies Distribution	Subspecies Habitat	Habitat Size	Habitat Percent	Land Cost	Labor Cost	Effective Protection
Laos	1	86.37	3	1	3	6	5	5	5	7
Vietnam	2	85.65	3	1	3	7	8	6	6	6
Indonesia	3	82.69	1	2	4	2	1	9	8	9
Nepal	4	77.42	1	2	4	1	2	8	4	8
Myanmar	5	77.14	1	2	4	9	9	4	9	4
India	6	65.19	2	3	1	5	4	7	2	5
Thailand	7	59.9	3	1	3	8	3	2	7	3
Cambodia	8	57.83	4	3	2	3	7	3	3	2
Malaysia	9	32.24	2	3	1	4	6	1	1	1

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Appendix A

Values for Ranked Variables

Country	Habitat Name (Tiger Landscape)	Subspecies Numbers	Subspecies Distribution	Subspecies Habitat	Habitat Size	Habitat Percent	Land Cost	Labor Cost	Effective Protection
Cambodia	Cambodian Northern Plains	0.10	1.14	11.32	26835	5.88	2.625	102.67	2.71
Cambodia	Cardamom's	0.10	1.14	11.32	26345	97.29	2.711	102.67	2.71
India	Anamalai-Parambikulam	0.67	0.84	18.48	3071	92.66	0.550	136.26	0.26
India	Bandhavgarh - Panpatha	0.67	0.84	18.48	2020	4.99	0.010	136.26	0.26
India	Biligiri Range	0.67	0.84	18.48	278	22.66	0.010	136.26	0.26
India	Chandoli	0.67	0.84	18.48	1682	26.63	0.190	136.26	0.26
India	Corbett - Sonanadi	0.67	0.84	18.48	5996	34.04	0.010	136.26	0.26
India	Dandeli - Anshi	0.67	0.84	18.48	2316	99.99	0.010	136.26	0.26
India	Dandeli North	0.67	0.84	18.48	517	99.49	0.010	136.26	0.26
India	Indravati	0.67	0.84	18.48	44238	48.75	0.301	136.26	0.26
India	Kanha û Phen	0.67	0.84	18.48	10598	45.01	0.010	136.26	0.26
India	Kaziranga - Garampani	0.67	0.84	18.48	7514	85.09	0.074	136.26	0.26
India	Mahabaleshwar Landscape - South	0.67	0.84	18.48	344	2.99	0.010	136.26	0.26
India	Northern Forest Complex - Namdapha - Royal Manas	0.67	0.84	18.48	237820	38.44	0.949	136.26	0.26
India	Pachmarhi - Satpura - Bori	0.67	0.84	18.48	4924	16.41	0.010	136.26	0.26
India	Palamau	0.67	0.84	18.48	3209	11.99	0.010	136.26	0.26
India	Pench	0.67	0.84	18.48	2918	16.68	0.010	136.26	0.26
India	Periyar - Megamala	0.67	0.84	18.48	5978	84.10	0.161	136.26	0.26
India	Purna	0.67	0.84	18.48	1002	5.16	0.010	136.26	0.26
India	Radhanagari	0.67	0.84	18.48	2945	32.75	0.151	136.26	0.26
India	Rajaji Major	0.67	0.84	18.48	322	17.24	0.010	136.26	0.26
India	Rajaji Minor	0.67	0.84	18.48	1044	64.99	0.010	136.26	0.26
India	Royal Bardia	0.67	0.84	18.48	6777	61.74	0.257	136.26	0.26
India	Royal Chitwan	0.67	0.84	18.48	4055	65.61	0.010	136.26	0.26
India	Royal Suklaphanta	0.67	0.84	18.48	1144	0.99	0.010	136.26	0.26
India	Satkosia-Gorge	0.67	0.84	18.48	2699	55.44	0.839	136.26	0.26
India	Shendurney	0.67	0.84	18.48	603	99.40	0.604	136.26	0.26
India	Simlipal	0.67	0.84	18.48	2412	89.66	0.010	136.26	0.26
India	Sunabeda-Udanti	0.67	0.84	18.48	2287	14.09	0.010	136.26	0.26
India	Western Ghats - Sharavathi Valley	0.67	0.84	18.48	321	99.99	0.010	136.26	0.26
India	Western Ghats: Bandipur - Khudrenukh û Bhadra	0.67	0.84	18.48	18973	75.16	0.073	136.26	0.26
Indonesia	Berbak	0.09	0.00	9.32	2543	94.28	4.034	158.81	4.91
Indonesia	Bukit BalaiRejang - Selatan	0.09	0.00	9.32	3884	99.78	0.221	158.81	4.91
Indonesia	Bukit Barisan Selatan South	0.09	0.00	9.32	2107	99.77	0.228	158.81	4.91
Indonesia	Bukit Barisan South	0.09	0.00	9.32	2890	97.76	2.236	158.81	4.91
Indonesia	Bukit Rimbang Baling	0.09	0.00	9.32	4395	97.38	2.623	158.81	4.91
Indonesia	Bukit Tigapuluh Landscape	0.09	0.00	9.32	7106	67.22	4.475	158.81	4.91
Indonesia	GunugLeuser	0.09	0.00	9.32	22319	99.29	0.709	158.81	4.91
Indonesia	KerinciSeblat	0.09	0.00	9.32	28162	97.86	2.142	158.81	4.91

Indonesia	Kualar Kampar-Kerumutan	0.09	0.00	9.32	9835	62.35	19.775	158.81	4.91
Indonesia	RimboPanti-BatangGadis West	0.09	0.00	9.32	1486	99.89	0.109	158.81	4.91
Indonesia	Sibologa	0.09	0.00	9.32	1292	99.67	0.334	158.81	4.91
Indonesia	TessoNilo Landscape	0.09	0.00	9.32	2332	56.49	43.514	158.81	4.91
Laos	Hin Nam Ho	0.10	1.14	11.32	2727	98.30	1.701	111.88	1.59
Laos	Nam Et PhouLoey	0.10	1.14	11.32	17866	99.25	0.750	111.88	1.59
Laos	Nam Ha	0.10	1.14	11.32	3217	99.43	0.568	111.88	1.59
Laos	Northern Annamites	0.10	1.14	11.32	28826	97.47	2.525	111.88	1.59
Laos	PhuMiang - Phu Thong	0.10	1.14	11.32	16273	65.99	0.010	111.88	1.59
Laos	Southern Annamites	0.10	1.14	11.32	61252	98.92	0.339	111.88	1.59
Malaysia	Endau Rompin	0.14	0.00	6.14	6505	86.55	13.451	325.28	6.72
Malaysia	Krau	0.14	0.00	6.14	1248	94.25	5.754	325.28	6.72
Malaysia	Taman Negara - Belum	0.14	0.00	6.14	49181	94.16	5.835	325.28	6.72
Myanmar	Northern Forest Complex - Namdapha - Royal Manas	0.67	0.84	18.48	237820	99.60	0.402	74.08	2.07
Myanmar	Tenasserims	0.67	0.84	18.48	162726	96.65	3.351	74.08	2.07
Nepal	Corbett - Sonanadi	0.67	0.84	18.48	5996	36.99	0.010	74.84	0.07
Nepal	Royal Bardia	0.67	0.84	18.48	6777	63.70	0.078	74.84	0.07
Nepal	Royal Bardia South	0.67	0.84	18.48	499	45.99	0.208	74.84	0.07
Nepal	Royal Chitwan	0.67	0.84	18.48	4055	61.72	0.010	74.84	0.07
Nepal	Royal Suklaphanta	0.67	0.84	18.48	1144	49.99	0.010	74.84	0.07
Thailand	Cardamom's	0.10	1.14	11.32	26345	65.26	0.638	245.08	1.94
Thailand	KhaoYai	0.10	1.14	11.32	2253	9.16	0.010	245.08	1.94
Thailand	KhlongSaeng	0.14	0.00	6.14	4816	99.46	0.536	245.08	1.94
Thailand	PhuKhieo	0.10	1.14	11.32	5760	76.25	0.327	245.08	1.94
Thailand	PhuMiang - Phu Thong	0.10	1.14	11.32	16273	64.57	0.763	245.08	1.94
Thailand	Salak-Phra	0.10	1.14	11.32	647	74.85	0.579	245.08	1.94
Thailand	Taman Negara - Belum	0.14	0.00	6.14	49181	99.42	0.577	245.08	1.94
Thailand	Tenasserims	0.10	1.14	11.32	162726	85.95	2.600	245.08	1.94
Thailand	ThapLan - Pang Sida	0.10	1.14	11.32	4445	0.99	0.010	245.08	1.94
Vietnam	Bi Dup-Nui Ba	0.10	1.14	11.32	1660	98.97	1.030	129.77	0.72
Vietnam	Cat Tien	0.10	1.14	11.32	3359	35.50	1.505	129.77	0.72
Vietnam	KonKaKinh	0.10	1.14	11.32	6389	93.75	0.349	129.77	0.72
Vietnam	Nam Et PhouLoey	0.10	1.14	11.32	17866	35.05	1.077	129.77	0.72
Vietnam	Northern Annamites	0.10	1.14	11.32	28826	99.49	0.508	129.77	0.72
Vietnam	Southern Annamites	0.10	1.14	11.32	61252	95.18	0.493	129.77	0.72