HIGH CONSERVATION VALUE AREAS AS A STRATEGIC APPROACH FOR PROTECTED AREA MANAGEMENT IN THE PHILIPPINES

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ABSTRACT: Establishing protected area networks is a key strategy to reduce biodiversity loss and contributes to global conservation efforts. In the Philippines, where 240 protected areas have been designated and set aside for the conservation of biological diversity, approaches are needed to effectively conserve and manage these areas. Identifying High Conservation Value Areas (HCVA) is a practical approach to guide protected area managers for prioritising conservation action and monitoring conservation success. We applied the approach in seven sites (c. 555,000 ha) representing three major biogeographic regions of the Philippines National Integrated Protected Areas System. Using maximum entropy (MaxEnt) algorithm, we modeled species distributions from environmental predictors (e.g., topographic, bioclimatic, land cover, forest structure, and soil image layers) derived from remotely sensed data, and point occurrence data of species (comprised of birds, trees, mammals, amphibians, and reptiles) observed during field surveys in the selected protected areas. Species distributions from a total of 109 trigger species were modeled, and final species that fit the criteria were stacked to generate species richness maps for identifying HCVAs. Forest habitat change was delineated using official 2003 and 2010 national land cover maps that were generated from Landsat imagery. Results showed park boundaries that were inconsistent with areas of high species congruence. Forest habitat loss (c. 30,100 ha) was observed in all seven protected areas, mainly along forest edges and encroaching within park boundaries. Spatial analysis highlighted conservation hotspots where forest habitat loss threatened highly species-rich areas. The HCVA approach provided spatially explicit inputs for reformulating protected area management zones, setting measureable conservation targets, designing monitoring protocols, and establishing patrolling routes.

1. INTRODUCTION

The Philippines is one of 17 mega-diverse countries in the world in terms of biological diversity with more than 52,177 known species, half of which are endemic to the country (Ong et al., 2002; Mittermeier et al., 2005). It harbors more endemic species on a per area basis compared to Brazil and Madagascar, such that the Philippines is regarded as the “Galapagos Island multiplied tenfold” (Heaney & Regalado, 1998). However, the Philippine archipelago is also recognised as one of 34 global biodiversity hotspots (Myers et al., 2000), highlighting it as being one of the highest global priorities for biodiversity conservation. Habitat loss is considered as the primary threat to Philippine biodiversity (Mallari et al., 2001; De Alban, 2005; Conservation International – Philippines et al., 2006).

In 1992, the National Integrated Protected Areas System Act (RA 7586) was enacted as the primary policy for the management of biodiversity in the Philippines. This law provided the enabling mechanism for the identification of protected areas, which were set aside for their remarkable biological attributes, and the management of these areas against unsustainable resource uses. As of 2013, a total of 240 protected areas have been established under the system, covering 5.45M ha (14.2%) of the country’s total land area (Biodiversity Management Bureau et al., 2014).

The Department of Environment and Natural Resources (DENR) is the designated national government agency responsible for implementing the national protected areas system. In collaboration with the United States Agency for International Development, the DENR designed a five-year technical assistance programme, the Biodiversity and Watersheds Improved for Stronger Economy and Ecosystem Resilience (B+WISER), intended to support

DENR and local management authorities by developing integrated approaches and tools to implement science-based planning and decision-making in selected protected areas. These include seven sites under the National Integrated Protected Areas System across three major biogeographic regions (Figure 1), specifically: (A) Greater Luzon: (1) Northern Sierra Madre Natural Park, (2) Kaliwa Watershed Forest Reserve, (3) Upper Marikina River Basin Protected Landscape; (B) Negros-Panay: (4) North Negros Natural Park and (5) Mt Kanlaon Natural Park; and, (C) Greater Mindanao: (6) Mt Kitanglad Range Natural Park and (7) Mt Apo Natural Park.

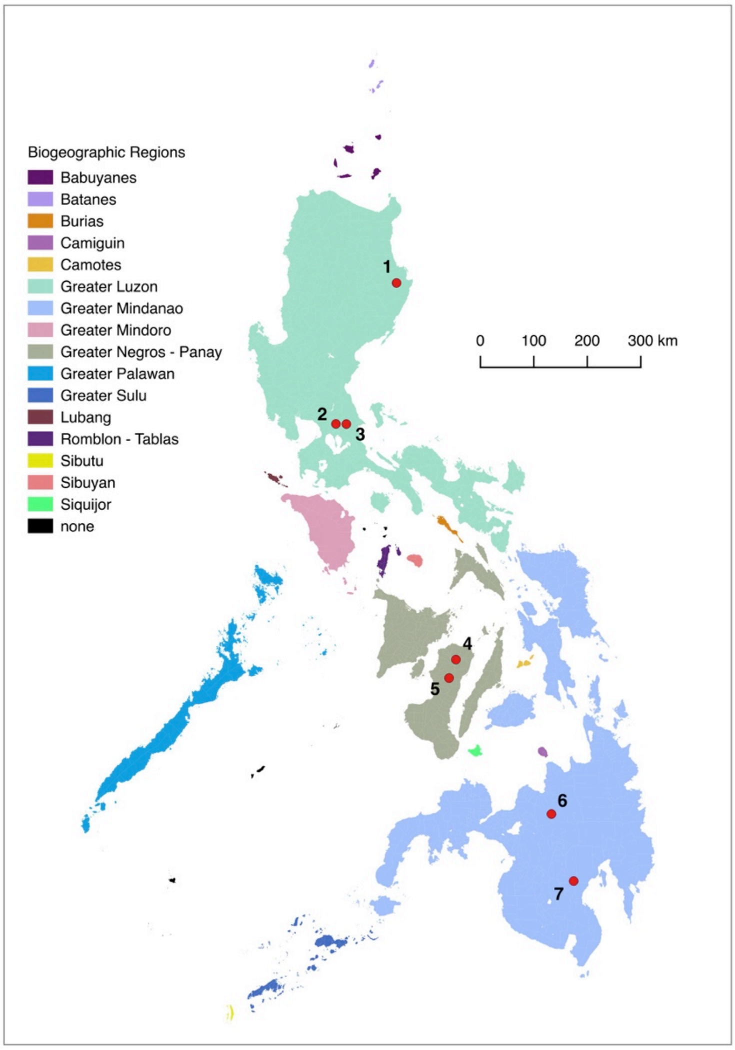

Figure 1. Location of Philippine biogeographic regions and the selected seven protected areas (study sites).

Based on a review of protected area management plans conducted by B+WISER, the key findings highlighted that most management plans suffered from insufficient baseline data, such as on species and habitat conditions and requirements, estimates of species populations, and spatially explicit information on land cover changes and distributions of key species—all of which provide the bases for formulating measureable conservation objectives and targets, and appropriate management interventions to ensure the conservation of biodiversity (Mercado, 2014). In effect, existing protected area management plans lacked clear objectives and measurable indicators for monitoring the effectiveness of site-level conservation actions and for determining whether conservation outcomes have been ultimately achieved.

To address these critical gaps, several science-based assessments, which employed spatial approaches and tools, were conducted through B+WISER in the identified protected areas to provide baseline information for enhancing existing management plans. In this study, we demonstrated a combination of approaches using geospatial technologies, particularly species distribution modeling and forest cover change detection, aimed at identifying spatially explicit areas of high biodiversity value, or High Conservation Value Areas (HCVA), and prioritising these areas for site-level conservation action in support of effectively managing these protected areas.

2. DEFINITIONS

Management zones. Protected areas are divided into two major management zones, specifically strict protection zone and multiple use zone (Department of Environment and Natural Resources, 2008). *Strict protection zones* comprise natural areas with high biodiversity value, closed to all human activities except for scientific or religious purposes. These zones may include habitats of threatened species, or degraded areas identified for restoration and subsequent protection. *Multiple use zones* comprise areas where the following activities may be allowed: settlement; traditional or sustainable land use including agriculture, agro-forestry, and other livelihood activities that may be allowed consistent with the management plan; recreational tourism; educational or environmental awareness; and interests of national significance including establishing facilities such as for renewable energy, telecommunication, or power generation. *Buffer zones* may be established outside the adjacent boundaries of protected areas for the purpose of minimizing threats to the protected area. These buffer zones may be delineated as additional layers of protection to provide extension of habitats and wildlife corridors; as areas for community livelihood activities to deflect anthropogenic pressures from the protected area; and as a social fence against encroachment of communities residing near the protected area.

High Conservation Value Areas. HCVAs are natural areas of outstanding and critical importance due to their environmental, socio-economic, biodiversity, or landscape values. It provides a framework for identifying areas that are valuable for biodiversity and/or local communities, which would support the design and implementation of appropriate management options in order to maintain or enhance their key ecological and socio-economic values (Brown et al., 2013). The approach introduced in this study can be replicated for identifying two of the six global HCV categories, specifically: HCVA 1 (Species Diversity) defined as concentrations of biodiversity including endemic species, rare, or threatened species that are significant at global, regional, or national levels; and, HCVA 2 (Landscape-level Ecosystems and Mosaics) defined as large landscape-level ecosystems and ecosystem mosaics that are significant at global, regional or national levels, and that contain viable populations of the great majority of the naturally occurring species in natural patterns of distribution and abundance (Brown et al., 2013).

3. METHODS

3.1 Species Distribution Modeling

We performed the Maximum Entropy (MaxEnt) modeling technique on presence-only field data to create the predictive species distribution models for birds, mammals, herps, and trees. We collected field data in each protected area through biodiversity surveys conducted in 2014 using a combination of field survey techniques employed for each taxa. A minimum of 14 transects (2 km long) were established in each site using random stratified sampling, which covered altitudinal gradients and specific habitat types (primary, secondary forest, montane, riverine, and cultivated). The point locations of species observed on transects during the field surveys were recorded using global navigation satellite system receivers.

We examined the probability of occurrence in presence-only data using the MaxEnt models as a function of 26 environmental predictor variables, specifically: forest aboveground biomass (Distribution of Forest Above Ground Biomass; Saatchi et al., 2011; ftp://www-radar.jpl.nasa.gov/projects/carbon/datasets); temperature and precipitation (World Climate Database; Hijmans et al., 2005; http://www.worldclim.org); elevation (Shuttle Radar Topography Mission Digital Elevation Database v.4.1 of the CGIAR Consortium for Spatial Information; Jarvis et al., 2015; http://www.cgiar-csi.org/data); aspect and slope derived from the SRTM v.4.1; forest canopy height (Global Forest Canopy Height; Simard et al., 2011; http://lidarradar.jpl.nasa.gov); land cover (Global Land Cover Characterization Database v.2.0 available from the United States Geological Survey; https://lta.cr.usgs.gov/GLCC); and, soil (Harmonised World Soil Database; International Institute for Applied Systems Analysis; Nachtergaele et al., 2008; https://www.iiasa.ac.at). All layers were resampled to 1 km^2 spatial resolution.

The linear feature of MaxEnt was used because it is recommended for small samples (Phillips & Dudík, 2008). We executed the species distribution modeling twice to evaluate the responses of environmental predictors with a maximum of five cross-validated replicates for each run. Species with less than five training samples were excluded from the modeling (Hernandez et al., 2006). To avoid bias of clustered points on a cell, we filtered initial records of species occurrence to ensure that there was only one record per 1 km^2 pixel for each species (Hernandez et al., 2006). We used all environmental predictors to generate models for each species during the first run. The significance of each predictor was subsequently evaluated from each species model using a jackknife procedure (Pearson et al., 2007), and predictors with zero contribution to each model were excluded in the second run.

To evaluate the performance of the models in discriminating presence and absence predictions, we calculated the value of area under the curve (AUC) of receiver operating characteristic (ROC) from the average of five replicates. AUC values >0.5 indicate a better-than-random model prediction. For each species, 25% of samples were randomly set aside for performing these tests. Species presence samples were used in combination with MaxEnt's random background samples selected from environmental data of the entire study area (Phillips et al., 2006). We converted the continuous logistic output for species prediction into presence-absence maps using a lowest predicted value threshold to ensure zero omission error (Pearson et al., 2007). Using the minimum training presence rule, we calculated the threshold values for each species, and subsequently created binary maps of habitat suitability (0 – unsuitable; 1 – suitable) using these threshold values. The binary maps in each biogeographic region were stacked to produce species richness maps for each taxa and a final map combining all taxa.

3.2 Forest Change Detection

We utilised 2003 and 2010 official land cover data produced by the National Mapping and Resource Information Authority (NAMRIA) for analysing historical forest cover change. The land cover data at both time points were generated through visual interpretation and manual editing of 30-m resolution Landsat data adopting a multi-level, hierarchical land cover classification system (see Annex 1). We aggregated the detailed land cover categories into either forest or non-forest according to this classification system. Changes in forest cover were mapped into four categories using spatial analysis: forest to non-forest (forest loss); non-forest to forest (forest gain); forest remaining as forest (no change in forest); and, non-forest remaining as non-forest (no change in non-forest).

We developed an Activity Data Toolbox using ArcGIS v.10.2 ModelBuilder to calculate land area figures of changes in forest cover (or activity data) within protected area boundaries (Philippine Biodiversity Conservation Priority-setting Programme) and the park management zones (from available protected area management plans). The attribute tables of the 2003 and 2010 land cover data were organised based on the classification system prior to executing the Activity Data Toolbox, ensuring four columns were added to show the classification level. Forest cover changes are identified using the intersect function of ArcGIS v.10.2 using land cover data at each time point as inputs, and clipped using boundaries of spatial units (i.e., protected area, management zone). Area calculations for all spatial units were computed (in hectares) and tabulated.

Our analysis recognises that the 2003 land cover data produced by NAMRIA was not ground-truthed to validate the maps, and that NAMRIA has yet to publish the documentation and accuracy assessments of both their 2003 and 2010 land cover data. We utilised the final electronic copies of these land cover datasets provided by DENR as is, although these limitations would need to be kept in mind when interpreting the results of this analysis. Some discrepancies were observed in the computed land area figures, specifically between protected area boundary and management zone data, since the thematic layers originated from various data sources. It may be argued that change from non-forest to forest within a span of seven years (2003 to 2010) may not yet be categorised as forest gain since in reality this period may not be sufficient time for forests to reach maturity. This forest change may be more appropriately treated as an incremental change in vegetation biomass.

3.3 Identification of High Conservation Value Areas

The HCVAs were delineated using the species richness map generated from the stacked species distribution models of various taxa. Pixels showing high species congruence were considered as HCVAs, specifically for their biodiversity value, falling within categories HCVA 1 or HCVA 2. These HCVAs were identified as priority sites for conservation within protected areas and were used for developing management recommendations to guide land use planning in protected areas (Stewart et al., 2008; Brown et al., 2013). Using spatial analysis, overlaps between areas of forest change and suitable habitats of trigger species were identified as priority HCVAs where specific management measures and conservation actions in each protected area should be focused. Gaps in conservation designation and protection were assessed by overlaying protected area boundaries and identified HCVAs.

4. RESULTS AND DISCUSSION

4.1 Species Distribution Modeling

All trigger species (endemic and threatened species) recorded during the field surveys in each protected area were used for the initial modeling. Species with less than five samples were identified as a result of removing duplicate records after the first modeling, and were subsequently excluded from the second modeling. To generate the final species models for each biogeographic region, a total of 55 species were used in Luzon, 19 in Negros-Panay, and

12 in Mindanao (Table 1). High AUC scores (>0.95) were obtained for all species models indicating that these models accurately distinguished between localities at which the species is present or not.

Table 1. Number of species records in each biogeographic region for species distribution modeling using MaxEnt.

Biogeographic region		**Luzon**	**Negros-Panay**	**Mindanao**
	Protected area	Northern Sierra Madre, Kaliwa Watershed, Upper Marikina	North Negros and Mt Kanlaon	Mt Kitanglad and Mt Apo
Taxa	Birds	32 (32/5)	11 (11/2)	8 (8/4)
	Herps	6 (6/5)	3 (3/1)	
	Mammals	3 (3/0)	2 (2/0)	3 (3/0)
	Trees	14 (7/15)	3 (3/3)	1 (1/1)

Note: values in parenthesis denote the following notation: (endemic species/threatened species)

4.2 Forest Change Detection

Summary of Forest Cover Change within Protected Areas

The results of the historical forest cover change analysis showed that deforestation occurred in all protected areas, of which the largest extent and highest rates of annual forest cover loss were observed in Mt Apo and Northern Sierra Madre (Table 2). Forest gain or regrowth was also observed across all protected areas, albeit to a lesser extent compared to forest loss, of which the largest extent and the highest annual rates of forest cover gain were calculated in Northern Sierra Madre and Mt Kitanglad. A net negative change in forest cover was observed in all protected areas, except Mt Kitanglad, despite forest cover gain observed in all sites. The highest net negative and net positive forest changes were calculated in Mt Apo (9,910 ha; 1,420 ha/yr) and Mt Kitanglad (3,770 ha; 540 ha/yr), respectively. Across the seven protected areas, a net negative forest change of 16,912 ha was calculated within the seven-year period at an annual net negative rate of change of 2,422 ha/yr.

Table 2. Summary of forest cover and change statistics from 2003 to 2010 in each protected area.

Site	**Total land area (ha)**	**Forest loss (ha)**	**Forest gain (ha)**	**No change in forest cover (ha)**	**Net forest change (ha)**	**Annual rate of net change (ha/yr)**
Northern Sierra Madre	299,380	10,260	5,720	270,510	-4,540	-650
Kaliwa Watershed	27,620	2,250	1,030	11,440	-1,210	-170
Upper Marikina	26,130	790	330	5,780	-460	-70
North Negros	67,919	4,476	1,070	23,861	-3,407	-487
Mt Kanlaon	23,562	260	1,415	9,387	-1,155	-165
Mt Kitanglad	47,210	1,010	4,790	39,210	3,770	540
Mt Apo	63,190	11,090	1,180	18,230	-9,910	-1,420
Total	555,011	30,136	15,535	378,418	-16,912	-2,422

Forest Cover Change within Management Zones of Protected Areas

Table 3. Forest cover loss and gain within each management zone of protected areas.

Protected area	**Management zone**	**Land area of zone (ha)**	**Forest cover loss within zone (ha)**	**Forest cover gain within zone (ha)**
Northern Sierra Madre	Strict protection	232,360	2,460	1,590
	Multiple use	60,060	5,580	3,930
	Buffer	16,300	1,010	60
Kaliwa Watershed	Strict protection	6,450	520	150
	Multiple use	21,490	1,760	910
Upper Marikina	Strict protection	9,910	810	300
	Multiple use	19,950	30	20
Mt Apo	Strict protection	30,890	8,880	1,070
	Multiple use	25,120	2,380	80
	Buffer	9,110	770	70

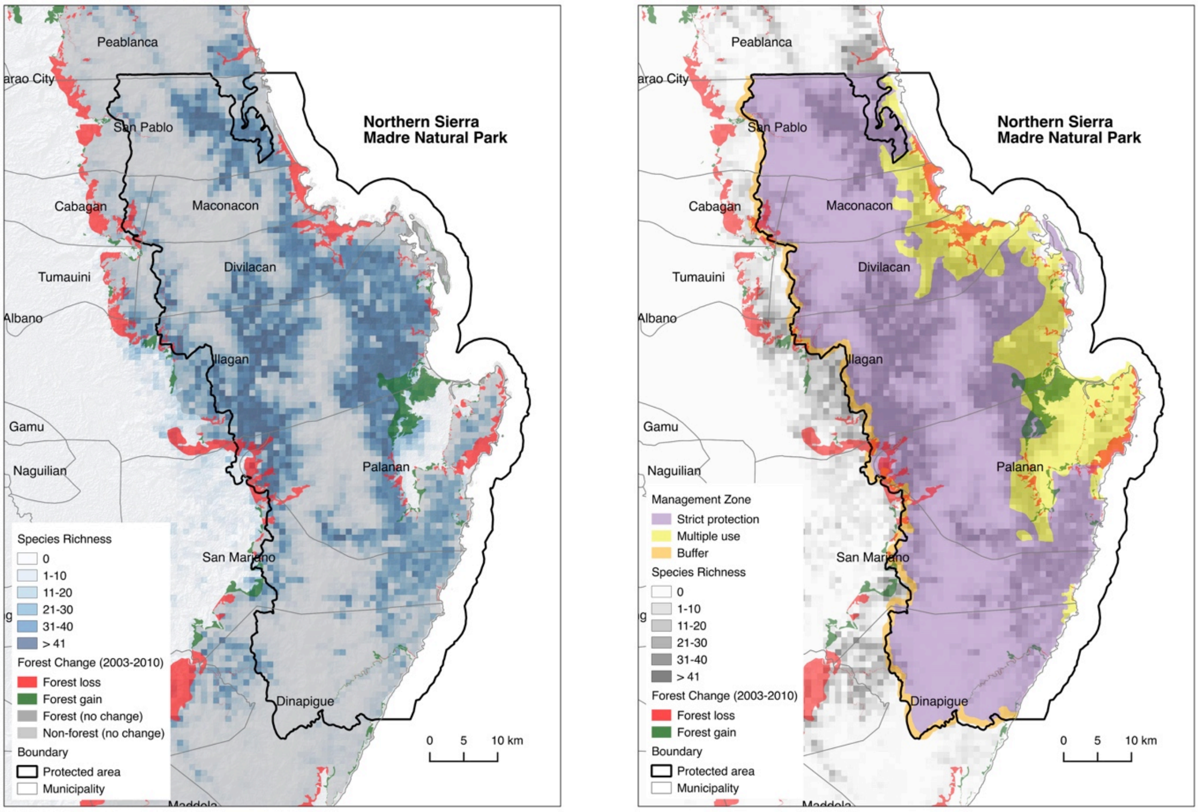

Figure 2. Forest change and HCVAs (left) and gaps in protected area management (right) in Northern Sierra Madre.

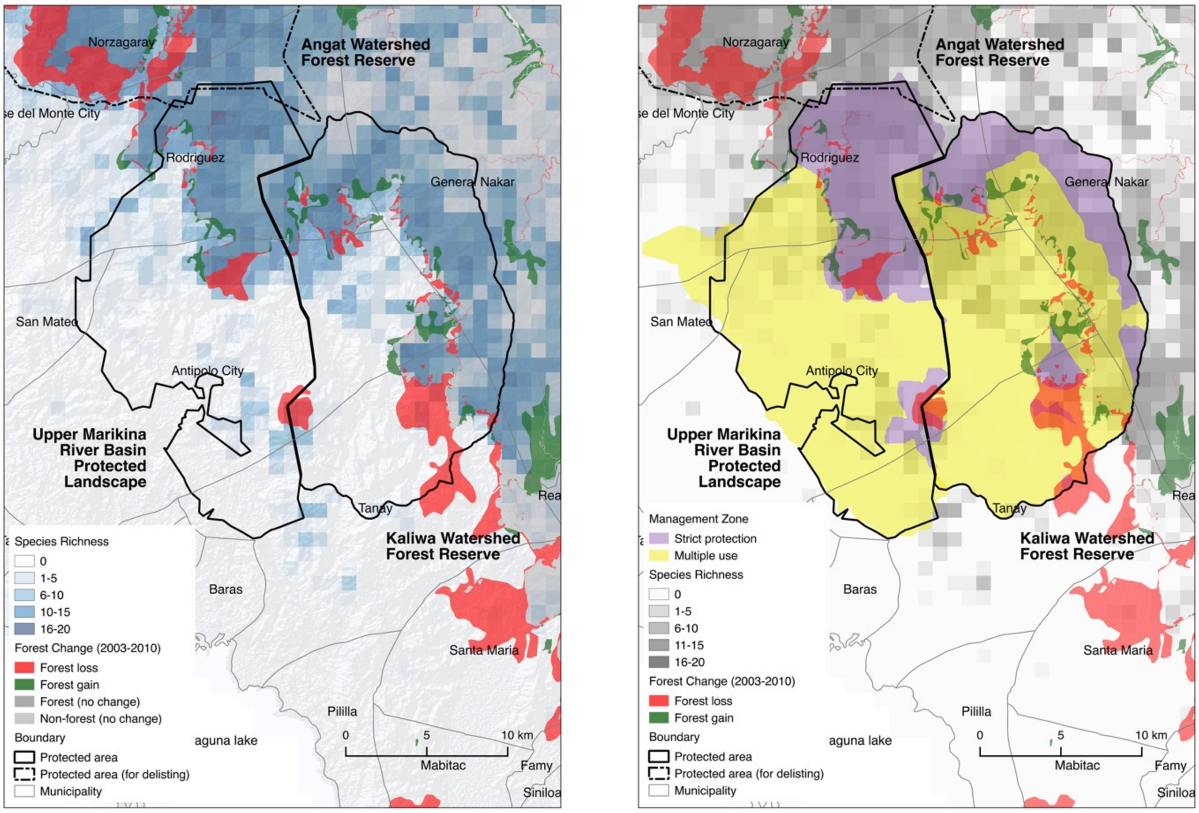

Figure 3. Forest change and HCVAs (left) and gaps in protected area management (right) in Kaliwa Watershed and Upper Marikina.

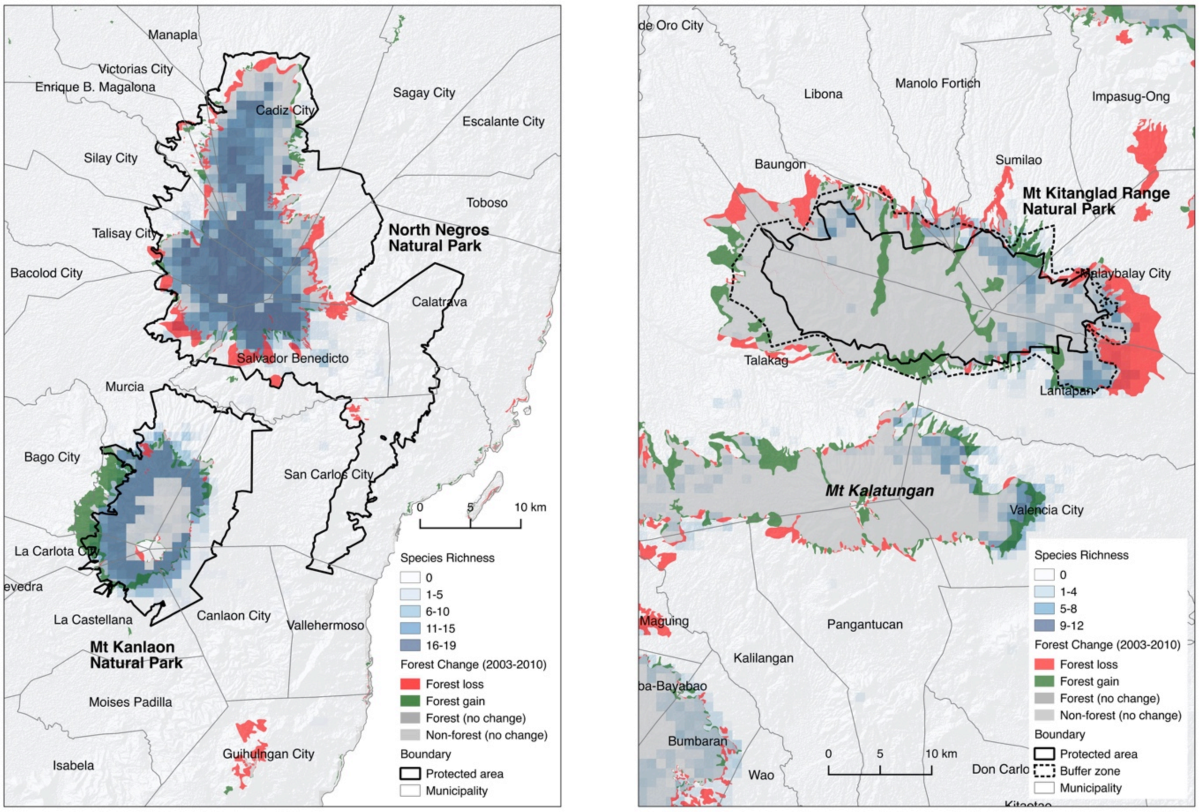

Figure 4. Forest change and HCVAs in North Negros and Mt Kanlaon (left) and Mt Kitanglad (right).

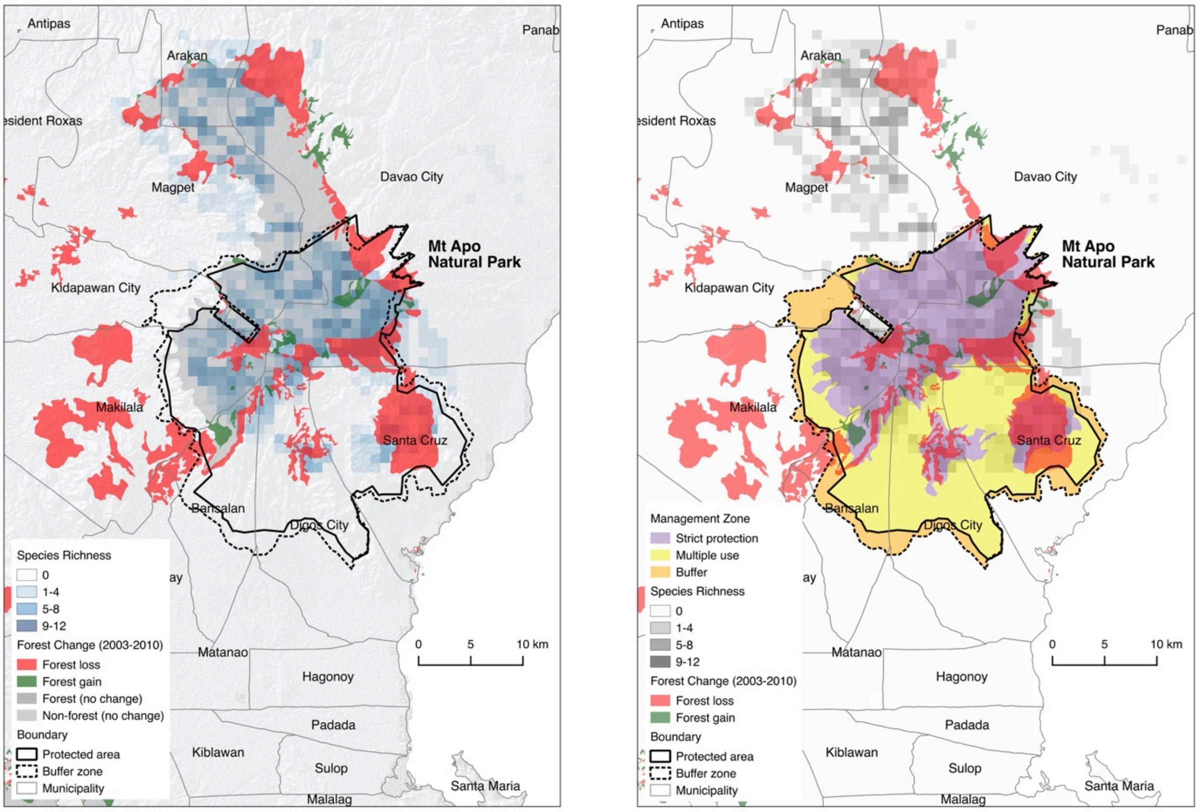

Figure 5. Forest change and HCVAs (left) and gaps in protected area management (right) in Mt Apo.

Data on management zones from protected area management plans were available in four sites, namely: Northern Sierra Madre, Kaliwa Watershed, Upper Marikina, and Mt Apo. Deforestation was observed in all strict protection zones of these protected areas (Table 3), which indicates that the original intent of establishing these zones (e.g., no anthropogenic disturbance in forests) have not been met, and suggests that law enforcement should be strengthened.

4.3 Identifying High Conservation Value Areas

HCVAs, or areas of high species richness, were observed in all protected areas, albeit were not widely distributed within the entire coverage of protected areas (Figures 2,3,4,5). While the HCVAs identified the most critical sites (i.e., areas of high species concentrations) for conserving biodiversity within protected areas, it also revealed gaps in protected area coverage. To address these gaps, protected area management zones can be redesigned such that strict protection zones focus on HCVAs, whilst establishing multiple use zones to cover less suitable habitats of species, particularly in Kaliwa Watershed, Upper Marikina, North Negros and Mt Kanlaon.

Identified HCVAs were threatened by forest habitat loss, mainly observed along forest frontiers or edges such as in Northern Sierra Madre, Kaliwa Watershed, Upper Marikina, and North Negros. Law enforcement efforts can be strengthened in these localities where conservation hotspots are extensive by activating regular patrol routes to mitigate further deforestation and habitat loss. Overlaps of forest loss with high species-rich areas may be identified as priority sites for forest restoration where tree-planting activities can be implemented.

In some cases, HCVAs were found outside protected area boundaries. In Northern Sierra Madre, buffer zones can be expanded on the western and southwestern parts to cover HCVAs and remaining forests, thereby placing these areas under formal protection and management. In Mt Apo, HCVAs and large remaining forests were mapped outside the protected area boundary toward the northern portion, which suggests the need to revisit the extent of the protected area by modifying its boundaries to cover more HCVAs compared to less suitable areas. Similar to the case of Mt Apo, the coverage of Upper Marikina and Kaliwa Watershed may need to be modified to sufficiently cover these HCVAs and large remaining forests. Other formal protection instruments may be established in order to place these areas under protection.

Our analysis also revealed evidence of positive outcomes in managing these protected areas, particularly in the case of Mt Kanlaon and Mt Kitanglad (Figure 4). Forest gain was observed outside the boundary of Mt Kanlaon toward the western part, thereby increasing suitable forest habitats that can allow species populations to thrive. In Mt Kitanglad, deforestation was effectively kept from encroaching inside the protected area whilst increases in forest habitats were observed.

5. CONCLUSIONS

Our analyses demonstrated spatially explicit approaches and tools for identifying High Conservation Value Areas that can guide site managers and decision makers in effectively managing landscape- and site-scale protected areas. The results of our analyses provide important inputs for many aspects of biodiversity conservation, particularly for analysing gaps in protected area management; for formulating spatial conservation plans; defining conservation targets and monitoring conservation outcomes; and for designing site-level management interventions such as environmental law enforcement actions and forest restoration efforts. To complement our work, we recommend further studies on determining the drivers of deforestation/forestation to understand the underlying causes or activities leading to forest loss or forest gain in each site; and assessing species-habitat associations to understand key conservation requirements of species and habitats to inform site-level interventions.

Earth observation is regarded as an important tool for assessing and monitoring the status and trends of biodiversity globally (O'Connor et al., 2015). In this study, we demonstrated the role of remote sensing data in acquiring observations of the earth's surface to measure essential biodiversity variables in aid of addressing the Aichi Biodiversity Targets defined by the Convention on Biological Diversity, particularly on measuring biodiversity values, monitoring habitat loss and fragmentation, and assessing the status of protected areas.

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ANNEXES

Annex 1. Multi-level, hierarchical land cover classification system.

20 Classes (Complete)	14 Classes (Condensed)	6 classes (IPCC)	2 classes (FNF)
Closed forest, broadleaved	Closed forest	Forestland	Forest
Closed forest, coniferous			
Closed forest, mixed			
Open forest, broadleaved	Open forest		
Open forest, coniferous			
Open forest, mixed			
Forest plantation, broadleaved			
Forest plantation, coniferous			
Mangrove forest	Mangrove forest		
Other land, built-up area	Built-up	Settlements	Non-Forest
Other land, cultivated, annual crop	Annual crop	Cropland	
Other land, cultivated, perennial crop	Perennial crop		
Other land, fishpond	Fishpond	Wetland	
Inland water	Inland water		
Other land, natural, marshland	Marshland / swamp		
Other land, natural, barren land	Open / barren	Other land	
Other land, natural, grass land	Grassland	Grassland	
Other wooded land, fallow	Fallow		
Other wooded land, shrubs	Shrubs		
Other wooded land, wooded grassland	Wooded grassland		

Annex 2. Species selected for species distribution modeling using MaxEnt. Species in bold italics are threatened species based on 2013 IUCN Red List; asterisks (*) denote Philippines endemic species; superscripts indicate biogeographic region: 1 – Luzon, 2 – Negros-Panay, and 3 – Mindanao.

Taxa (# species)	Selected species
Birds (n=44)	***Aethopyga primigenia***[*3], *Actenoides lindsayi*[*1], ***Buceros hydrocorax***[*1], *Centropus melanops*[*3], ***Centropus unirufus***[*1], *Centropus viridis*[*1], ***Ceyx melanurus***[*1], *Copsychus luzoniensis*[*1], *Coracina coerulescens*[*1], *Cuculus fugax*[*1], *Cyornisa herioti*[*1], *Dendrocopus maculatus*[*2], *Dicaeum hypoleucum*[*1], *Dicrurus balicassius*[*12], *Harpactes ardens*[*1], *Hypocryptadius cinnamomeus*[*3], ***Hypothymis coelestis***[*3], ***Hypothymis helenae***[*3], *Hypsipetes philippinus*[*1], *Irena cyanogastra*[*1], *Ixos philippinus*[*2], *Lalage melanoleuca*[*1], *Loriculus philippensis*[*1], *Mulleripicus funebris*[*1], *Orthotomus castaneiceps*[*12], *Otus megalotis*[*1], *Pachycephala philippinensis*[*1], *Parus elegans*[*12], *Penelopides affinis*[*3], *Penelopides manillae*[*1], ***Penelopides panini***[*2], *Phaenicophaeus cumingi*[*1], *Phapitreron amethystina*[*1], *Phapitreron leucotis nigrorum*[*12], ***Prioniturus waterstradti***[*3], *Prionochilus olivaceus*[*1], *Pycnonotus urostictus*[*12], *Rhipidura cyaniceps*[*12], *Rhipidura nigrocinnamomea*[*3], *Sarcops calvus*[*2], ***Stachyris nigrorum***[*2], ***Sterrhoptilus dennistouni***[*1], *Zosterops nigrorum*[*1], ***Zosterornis striatus***[*1]
Herps (n=9)	*Eutropis multicarinata borealis*[*1], ***Hylarana similis***[*1], ***Kaloula kalingensis***[*1], ***Limnonectes macrocephalus***[*1], ***Platymantis cagayanensis***[*1], *Platymantis corrugatus*[*2], *Platymantis dorsalis*[*2], ***Platymantis hazalae***[*2], ***Sanguirana luzonensis***[*1]
Mammals (n=4)	*Haplonycteris fischeri*[*123], *Ptenochirus jagori*[*123], *Ptenochirus minor*[*3], *Rattus everetti*[*1]
Trees (n=15)	***Cinnamomum mercadoi***[*3], ***Dillenia philippinensis***[*1], ***Diospyros philippensis***[*1], ***Dipterocarpus grandiflorus***[1], ***Ficus variegata***[1], ***Macaranga bicolor***[1], ***Mangifera altissima***[1], ***Parashorea malaanonan***[1], ***Pterocarpus indicus***[1], ***Shorea astylosa***[*1], ***Shorea contorta***[*12], ***Shorea negrosensis***[*12], ***Shorea palosapis***[1], ***Shorea polysperma***[*12], ***Swietenia macrophylla***[1]