A Geospatial Approach for the Assessment and Management Prioritization of Philippine Terrestrial Key Biodiversity Areas: Towards Meeting Global Sustainability Targets

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Abstract

Biodiversity plays a major role in sustaining life on Earth, with innumerable benefits to society. However, biodiversity loss and extinction due to external threats have been increasing globally. Key biodiversity areas (KBAs), although without an established legal basis, are important sites that contribute to the persistence of biodiversity. The use of geospatial technology has been proven to be a reliable, cost-effective, and targeted approach for biodiversity conservation and ecological management. In this study, data integration and spatial analysis were used in developing an easily interpretable and adaptable quantitative assessment and prioritization of KBAs. The identification of priority KBAs was based on threatened species, human-made structures, forest fragmentation, and forest loss. The integrated rankings revealed that Sibutu and Tumindao, Ragay Gulf, and Simunul and Manuk Manka Islands were the three highest priority KBAs based on the integrated factor scores, with all having almost zero overlap with protected areas (PAs). Among the top twenty KBAs, twelve sites had less than 2% overlap with PAs. Priority KBAs were identified in this study, either by means of the integrated rankings or by analyzing the relationships of the factor values. Implementing a management system in these identified priority KBAs, either as PAs or other effective conservation measures (OECMs) will lead to improving the condition in these sites. Moreover, these additional areas for conservation can contribute towards SDG 15 and in meeting the Philippines' commitment to the "30 by 30" target under the Kunming-Montreal Global Biodiversity Framework.

1. Introduction

1.1 Background

Biological diversity or biodiversity is the variety of living species and ecosystems on Earth, across all domains and scales (Secretariat of the CBD, 2005; Sodhi and Ehrlich, 2010). Various studies have explored the benefits of biodiversity on sustaining life on the planet, such as providing ecosystems services to humans in terms of food, medicine, protection, energy, economy, recreation, and culture, among others (Mittermeier et al., 2004; Larsen et al., 2012). Aside from being fundamental to human well-being, biodiversity ensures a balanced and healthy planet, supporting all systems of life on Earth (CBD, 2022). In 2000, the World Conservation Monitoring Centre of the United Nations Environment Program recognized 17 megadiverse countries. Megadiverse countries are those that have a high number of species, with a significant percentage of endemic species. These countries comprise only 10% of the Earth's surface area but house more than 70% of the world's biological diversity (Mittermeier et al., 1999).

However, despite efforts from various groups and some localized success, the world's biodiversity and habitat has still been declining. In a study by Butchart et al. (2010), it was concluded that biodiversity has been declining from 1970 to 2010 as evidenced by the negative trend in eight out of ten indicators. The primary threat to biodiversity is posed by anthropogenic activities leading to habitat conversion and habitat loss (CEPF, 2001). To date, there are 36 countries known as biodiversity hotspots, which are the most biologically rich but also severely threatened areas in the world. The establishment of priority sites for conservation is a method that may be applied to safeguard the existence of species in identified areas (Brooks et al., 2006). During the historic September 2015 UN Summit, world leaders agreed on adopting the 17 Sustainable Development Goals (SDGs) geared towards the well-being and resilience of people and the planet through economic growth, inclusivity, and environmental protection (UN, 2015). Part of this agenda was the SDG 15 (Life on Land), which aims at protecting and restoring the terrestrial ecosystems and halting biodiversity loss. Among the four goals and 23 targets to be achieved by 2030 under the Kunming-Montreal Global Biodiversity Framework (GBF) are to have at least 30% of effectively managed and conserved areas, to restore at least 30% of degraded ecosystems, and to stop human induced extinction of known threatened species (CBD, 2022).

Although extinction is a natural process, anthropogenic threats to biodiversity hasten the rate of species extinction (Isbell et al., 2017). Pimm et al. (1995) showed estimates of future extinction rates ranging from a thousand to several thousand based on their own projections and from various literature. Currently, more than 42,100 of the world's species are threatened according to the IUCN Red List. Various actions were taken over the years, which are aimed at mitigating biodiversity loss to avoid extinction. The types of threats, both natural and anthropogenic, and how they impact biodiversity vary depending on the specific ecosystem. Therefore, the conservation strategy and the identification of specific areas of application should also be carefully planned to ensure its effectiveness. Being able to identify specific areas of ecological importance experiencing threats, such as biodiversity hotspots, ensures a targeted and effective approach to conservation.

The importance of spatial data in planning for biodiversity conservation and management has been emphasized in various studies (Ferrier and Drielsma, 2010; Portocarrero-Aya et al., 2014; Holness et al., 2022). Knowing where to focus action through systematic conservation and spatial conservation prioritization can be an efficient and cost-effective approach to ensure the persistence of biodiversity in light of the interrelated factors affecting it (Kukkala and Moilanen, 2017; Sinclair, et al., 2018). It is crucial to consider external but relevant factors, such as human population, in the overall conservation management strategy to be able to work towards a realistic and sustainable goal (Silva and Topf, 2020; Perschke, 2024). An integrated approach, such as an ecosystem-based management approach, that considers connectivity, dependence, and analyzes the landscape as a whole is imperative for effective management (Saunders et al., 1991; Grimmel et al., 2019). Geospatial technologies and landscape metrics were utilized for various topics related to the ecology and biodiversity. Specifically, the combination of geographic information systems (GIS), remote sensing (RS), and landscape metrics have proven useful in biodiversity conservation and ecological management studies all over the globe (Murthy et al., 2003; Kabba and Li, 2011; Chapungu et al., 2014; Bera et al., 2020). Integration of data from different sources and the use of geoprocessing tools facilitate the extraction of additional insight toward problem-solving and decision-making.

PAs are "portions of land and water set aside by reason of their unique physical and biological significance, managed to enhance biological diversity and protected against destructive human exploitation" (E-NIPAS Act, 2018). Key biodiversity areas (KBAs), meanwhile, are "sites contributing significantly to the global persistence of biodiversity" (IUCN, 2016). KBAs can be used as a decision support tool to aid countries in conservation planning and sustainability management. The engagement of stakeholders in the development of the KBA methodology was initiated during the World Conservation Congress of 2004. In 2016, after a series of consultative workshops and site identifications in various parts of the world, the IUCN released the global standards for the identification of KBAs. In the Philippines, a nationwide consultative process over several years led to the identification of conservation priority areas (Ong et al., 2002). This partly served as reference for the identification of Philippine KBAs, which started from the terrestrial and freshwater KBAs completed in 2006, to the marine KBAs completed in 2009, and eventually the integrated KBAs (Ambal et al., 2012).

1.2 Objectives and Scope

This study focused on the assessment of Philippine terrestrial KBAs using a number of data sources described in the methodology. It aimed at quantifying and comparing the status of each KBA in terms of protection, presence of terrestrial threatened species, existence of anthropogenic threats, and forest integrity. The integrity of forest habitat in this study used measures of forest loss and forest fragmentation, while the threat indicators were the presence of artificial or human-made structures. The known range of threatened species per KBA area was used to represent species richness. Since there are already previously identified KBAs for the country, the goal is to quantitatively assess and rank the already defined KBA sites. This ultimately led to determining which specific KBAs can be recommended for management prioritization.

Aside from quantification, it is also important to perform a spatial analysis of both the individual and combined factors previously described. In this study, the geographic distribution of each data layer with respect to the KBAs was mapped. Moreover, each KBA was ranked based on the combined input layers and their spatial relationships were analyzed. Looking at the overall picture through spatial analysis enables us to detect patterns that may not be evident in the individual data. Analyzing the condition of biologically important areas provides sound scientific basis for planning towards systematic conservation management.

2. Methodology

2.1 Study Area

The Philippines is an archipelagic country in Southeast Asia, located at 121° 52' 03" E and 13° 33' 41" N, with a land area amounting to approximately 300,000 km^2 or 0.2% of the Earth's land surface. Within the various islands of the country exists more than 1,130 terrestrial faunal species and more than 10,000 floral species, of which about half are endemic (Ong et al., 2002). This amount of biodiversity within a small area also makes the Philippines one of the 17 megadiverse countries. However, the country in its entirety is also one of the 36 biodiversity hotspots, having high endemism but with only a small percentage of its original vegetation remaining (Mittermeier et al., 2004). At least 167 native terrestrial mammal species in the country were recorded as of 2004, with more than 60% endemic to the Philippines, one of the highest endemism levels in any of the hotspots (Mittermeier, 2004).

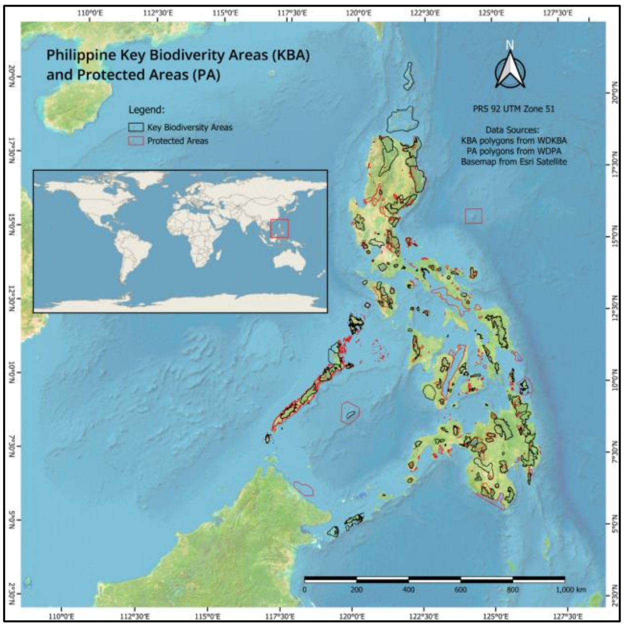

Figure 1. Map of the Philippines showing the KBAs and PAs.

2.2 Data

The data used in this study are all downloadable from the internet to ensure accessibility through the various websites. The datasets described below and some relevant information are summarized in Table 1. The Philippine KBAs available in the World Database of Key Biodiversity Areas (WDKBA) were used (https://wdkba.keybiodiversityareas.org/). The July 2024 version of the protected area shapefiles were downloaded from the World Database of Protected Areas (WDPA) through the Protected Planet website (https://www.protectedplanet.net/). Although both the KBA and PA datasets (Figure 1) are being updated, these specific versions were used for the purpose of this study. The entire process may be replicated in future assessments with the availability of updated information.

The presence of species was represented by the known range of species downloaded from the IUCN Global List of Threatened Species (https://www.iucnredlist.org/). These range maps do not indicate the actual presence of species but the known range of the threatened species. Administrative boundary shapefiles, from the country level to the barangay level, were downloaded from the

Humanitarian Data Exchange (HDX) managed by the Centre for Humanitarian Data under the United Nations Office for the Coordination of Human Affairs (OCHA) (https://data.humdata.org/organization/ocha-philippines).

Anthropogenic activities, such as land conversion and deforestation leading to habitat fragmentation and loss, were identified as the primary threat to biodiversity (Haddad et al., 2015). This threat was analyzed in this study using change in forest cover, degree of forest fragmentation, and evidence of human activity. The presence of artificial structures, such as houses, buildings, roads, and railways, was used as evidence of human activity. OpenStreetMap (OSM) data for the country containing these features was downloaded from Geofabrik GmbH's free download server (https://download.geofabrik.de/asia/philippines.html). Only the major roads (motorways, trunk, primary, secondary, and tertiary), highway links, and residential roads were extracted for the road data and subways were excluded from the railways data. All entries in the OSM building data were used in the processing.

Land cover mapping for the country is produced every five years by the National Mapping and Resource Information Authority (NAMRIA), the mandated national agency for mapping outputs. The 2020 land cover map (LCM) was downloaded from the Geoportal Philippines as separate shapefiles per region (https://www.geoportal.gov.ph/). These were merged in QGIS and then used as forest cover input in FragScape to determine forest fragmentation within each of the 129 KBAs. The Global Forest Change data from 2000 to 2020 was downloaded from the Global Forest Watch (GFW) as a series of raster tiles with a spatial resolution of 30 meters near the equator (https://data.globalforestwatch.org/). The dataset '*year of gross forest cover loss event (lossyear)*', which is part of the version 1.11 dataset, was used to quantify deforestation. This is an updated version of the global analysis based on Hansen et al. (2013). The raster dataset is encoded with values from 0 to 23, representing no loss as 0 and forest loss from 2001 to 2023 as 1 to 23.

Dataset	Format	Source
Key Biodiversity Areas	polygon	WDKBA
Range of Threatened Species	polygon	IUCN Red List
Buildings	polygon	OSM Geofrabrik
Roads, and Railways	line	OSM Geofrabrik
2020 Land Cover	polygon	NAMRIA
2000-2020 Global Forest Change (Tree Loss)	raster	Global Forest Watch
Protected Areas	polygon	WDPA
Administrative Boundaries	polygon	OCHA

Table 1. List of data used in the analysis.

2.3 Methods

The following subsections describe the methodology used in deriving the results, from preparing the data to integration analysis. GIS data preparation and processing were implemented using QGIS 3.36.3, a free and open-source software licensed under the GNU GPLv2+. The flowchart in Figure 2 summarizes the data processing steps starting from pre-processing of each input data layer until the determination of the computed quantities for each KBA. After the pre-processing steps applied to each data layer, the KBAs were ranked according to the predetermined ranking rule for each data layer. The steps involved in the individual ranking, data integration, overall ranking, and final prioritization are illustrated in Figure 3.

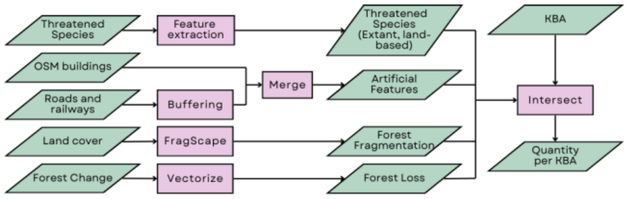

Figure 2. Flowchart used for the first phase of data processing to prepare each data layer.

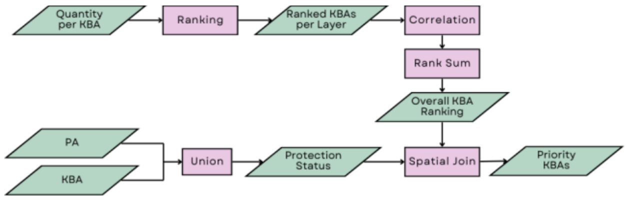

Figure 3. Flowchart used for the second phase of data processing, which involves data integration and ranking.

2.3.1 Processing: Since the datasets used were from various sources, with different data types, geometry, scales, and coverage, it was crucial to pre-process the data prior to integration and analysis. This involved reprojection, raster-to-vector conversions, clipping to the study area or the terrestrial areas of interest, and feature selection or filtering. All shapefiles were reprojected to the Philippine Reference System of 1992 Universal Transverse Mercator Zone 51N. The use of the vector shapefile format was selected for all the datasets for more realistic feature representations, better geographic accuracy, and more flexibility in geoprocessing and attribute editing.

A total of 129 KBAs and 247 PAs were used in in the processing, after excluding redundant, superseded, and non-terrestrial areas. The union geoprocessing tool was used to capture the overlaps and non-overlaps between the KBA and PA polygons. Attribute table computations were then performed to determine the area and percent of overlap for each KBA. Aggregation was used to merge all the entries corresponding to each KBA. The results of the overlap analysis did not factor into the ranking, but was used as an additional filter to identify which KBAs are not protected.

The polygon data for all the downloaded IUCN species, which includes amphibians, mammals, reptiles, plants, and those in the freshwater groups, were merged into a single shapefile. This shapefile was then intersected with the KBA shapefile to reduce the data size for further processing. Species classified as terrestrial and freshwater were retained, with the assumption that these are the groups that will likely be affected by deforestation or forest fragmentation. Marine species were not included in the analysis. Birds were not included in this analysis since these were not readily downloadable from the IUCN website. Extant (resident) species falling under the vulnerable (VU), endangered (EN), and critically-endangered (CR) were extracted. Extant species are those that are known or thought to be very likely to currently exist in the area. Since KBAs are supposed to be reassessed every 8 to 12 years with updated information (IUCN, 2022), only the species data from 2010 onwards were included in the analysis. After extracting the threatened extant species within the land areas of the KBA polygons, the latest available records that remained were only until 2018. The shapefile with the remaining records was then aggregated by KBA Name, resulting to the number of threatened terrestrial species count per KBA.

The quantification of artificial features was performed using the building polygons and merged railways/roads lines. The linear OSM features were converted to polygons by buffering using varying widths, depending on the road feature classification. According to highway design standards in the country, 2-lane highways with a lane width of 3.35 meters is recommended for drivers' ease of operation and safety (DPWH, 2014). Based on this guideline and upon random inspection of the OSM road data overlaid with a satellite basemap, a buffer of 5 meters per side was applied for motorway and motorway link double-line features to generate a total buffer width of about 20 meters. For the trunk, trunk_link, primary, primary_link, secondary, and secondary_link OSM road features, a total buffer width of 13.4 meters was used. A total buffer width of 6.7 meters was used for the tertiary, tertiary_link, and residential road classes. Finally, a 1-meter total buffer width was applied for the railways line features. The OSM building, railway, and road polygons were merged into a single shapefile and the area for each record was computed. This merged shapefile was intersected with the KBA shapefile, and then aggregated to determine the artificial features within each KBA. To normalize the quantification of artificial features across all the KBAs, the total area of the OSM features per KBA was divided by the terrestrial area of the KBA.

Forest fragmentation describes the process in which large, contiguous areas of natural forests are gradually divided into smaller disjoint forest patches intermixed with other land cover types (Saunders et al., 1991; Mengist et al., 2022). This impact of changes in human land use results to habitat modification and separation of species populations, thus affecting biodiversity (Andronache et al., 2019). Moreover, the presence of transportation infrastructure such as roads and railroads are a leading cause of fragmentation due to noise pollution and the area is removes from the natural landscape, and this can be expressed in terms of effective mesh size (Jaeger et al., 2006). Forest fragmentation and other landscape metrics were computed using a QGIS plugin called FragScape, a tool that implements effective mesh size computation (Chailloux et al., 2020). Given that the Philippine KBAs used in this study vary drastically in terms of area, from as small as 1.6 km^2 to as big as 8,097.5 km^2, effective mesh size (MSIZ) is applicable due to its mathematical simplicity, and low sensitivity to varying patch size and varying levels of urban development (Jaeger, 2000). MSIZ, denoted by Equation 1, represents the unit size when the entire region is subdivided into a specified number of units. This parameter is based on the probability that two randomly-selected points within a region will be connected. The probability that two individuals of the same species will encounter each other in the fragmented landscape, is the same as the probability of encounter in a region divided by the mesh with the computed size. A lower MSIZ indicates a more fragmented landscape.

$$MSIZ = \frac{A_t}{S} = \frac{1}{A_t}\sum_{i=1}^{n} A_i^2 \quad (1)$$

where A_t = total area in the region
S = number of areas
A_i = area of each patch

The merged 2020 LCM polygon shapefile from NAMRIA was used as the input land cover data for computing forest fragmentation using MSIZ. Prior to input in FragScape, the shapefile was first clipped to the terrestrial area of the KBA polygons using the level 0 administrative boundary shapefile from OCHA. The clipped KBA polygons were also used as the reporting layer in the fragmentation computation to exclude the marine portion of the KBAs from the computation of MSIZ. The land cover classes '*Closed Forest*', '*Inland Water*', '*Mangrove Forest*', '*Marshland/Swamp*', and '*Open Forest*' were used as natural environment input in FragScape. The merged and buffered road plus railways OSM data described previously was used as additional fragmentation layer in the processing. Cross-boundary computation was not performed, since the goal is to assess fragmentation strictly within the KBA boundaries. The fragmentation results for the case without additional fragmentation data and with additional fragmentation data were compared.

The forest cover change according to 'lossyear' was converted to vector polygons. The area of forest loss for each attribute table record was computed and records with no forest loss were removed. The data was then aggregated by KBA Name, and the loss values were summed, resulting to the total forest change per KBA from 2010 to 2022. The percentage of total forest loss per terrestrial area of the KBA was also computed. Since our objective for this study was to determine the total forest loss per KBA, the historical trend of loss was not included in the analysis.

2.3.2 Ranking: The Pearson's correlation coefficient of the results per layer was investigated to check possible relationships between the factors used. The rules for prioritization used in this study was according to the greatest number of distinct threatened species, greatest area of artificial features per KBA area, highest forest fragmentation (lowest MSIZ), and highest cumulative forest loss percentage. The KBAs for each data layer were ranked according to the set rule to show which of the KBAs should be prioritized for each layer. The same rank number was given to records with equivalent numerical values. An integrated analysis was performed by joining the attributes of the four data layers into a single shapefile. The overall ranking of the KBAs was determined by summing the KBA rankings from each of the layers and an integrated map was produced.

Integration and spatial analysis were applied using the individual layers to eventually determine an overall assessment of the Philippine KBAs. To retain the relative order among KBAs per data layer, a ranking system was used for the individual layers and the overall prioritization was based on these individual rankings. This approach ensured that the contribution of each data layer to the integrated ranking will be standardized. The assumption is that each factor had an equal contribution to the final result.

3. Results and Discussion

A total of four maps showing the distribution of these factors in the Philippine KBA network were generated (Figure 4). To simplify the visualization, the mode of symbology classification used for the individual maps was Natural Breaks (Jenks). Darker colors for the threatened species, artificial features, forest fragmentation by MSIZ, and percent forest loss indicate a higher level of threat.

The FragScape results revealed that the overall forest fragmentation, measured in terms of global MSIZ and with no additional fragmentation layer used, was 417.01 km^2. As a further experiment, the road-railway polygon shapefile was used in another iteration to determine how the result will be affected. The use of this additional fragmentation layer resulted to a global MSIZ of 371.48 km^2 or an 11% decrease, indicating increased fragmentation. Moreover, the paired t-test using the entire dataset of MSIZ values per KBA resulted to a two-tailed P value of 0.006 indicating a statistically significant difference between the two datasets. This showed that not all of the linear features were captured in the LCM as built-up, given the resolution limitation. The inclusion of the OSM linear data as additional fragmentation layer made a significant difference in the results, leading to a possibly more realistic representation of the landscape fragmentation pattern.

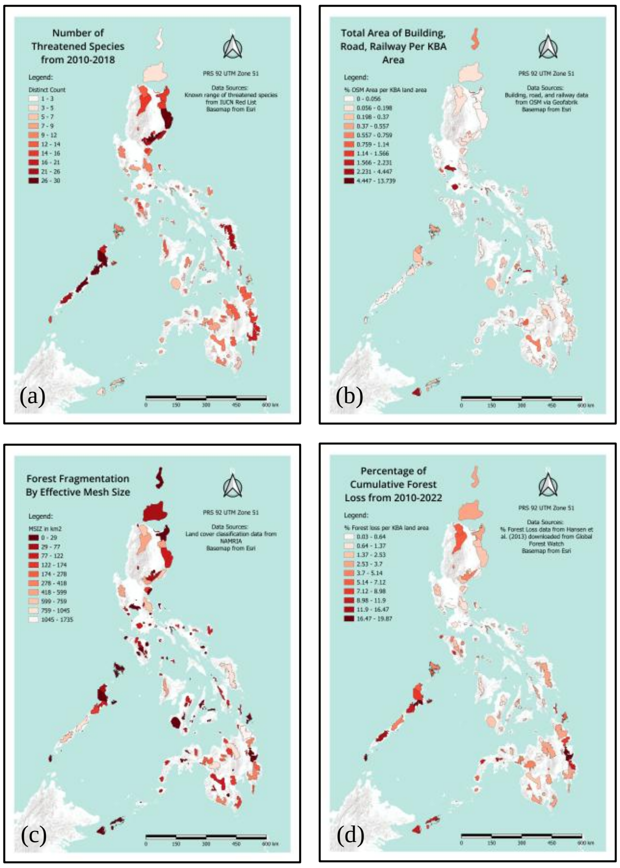

Figure 4. Spatial distributions of (a) Unique species count per KBA based on known range of threatened species; (b) Percentage of building, road, and railway areas per KBA land area; (c) Forest fragmentation per KBA with additional fragmentation data; (d) Percentage of forest loss in KBA per KBA land area.

The correlation analysis on the data layer rankings revealed that the number of threatened species ranking had a moderate negative correlation with the fragmentation ranking at -0.47809. This indicates that the less fragmented sites tend to contain a higher number of species that need to be conserved. The ranking according to area covered by OSM features per KBA land area yielded a moderate positive correlation of 0.42884 with the fragmentation ranking. This correlation result is to be expected since the presence of artificial structures such as roads and buildings are one of the factors that contribute to natural landscape fragmentation. Moreover, the road features were used as fragmentation input in FragScape. Upon inspecting the OSM layer, however, it was noted that the number of artificial features captured in the shapefile was still an underestimation of the actual current status based on recent satellite basemaps.

The contributions of the computed data layer values to the KBA rankings may be visualized using the stacked bar graph in Figure 5. The KBAs that were recommended to be prioritized based on the factors included in this study were the ones with the largest sum of scores from each data layer, therefore, the highest ranking. It is evident in this graph that the individual factor scores do not necessarily exhibit the same pattern as the overall KBA rank. This seemingly random pattern is stronger in the lower 80% of the rankings.

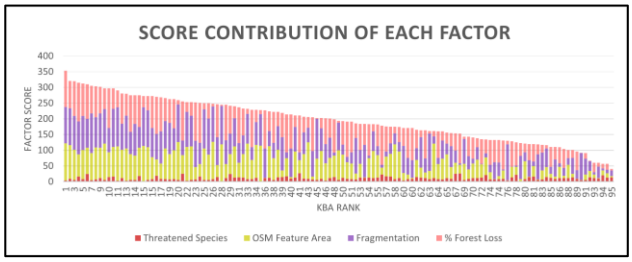

Figure 5. Ranking of the KBAs based on the sum of factor scores, with the highest rank (rank 1) given to the KBA with the greatest sum of factor scores.

Two KBAs mostly covering marine areas, Apo Reef Marine Natural Park and Tubbataha Reef National Marine Park were eventually excluded from the integrated rankings due to the absence of forest cover and forest loss data for these sites. The map of final KBA rankings for the remaining 127 sites are shown in Figure 6.

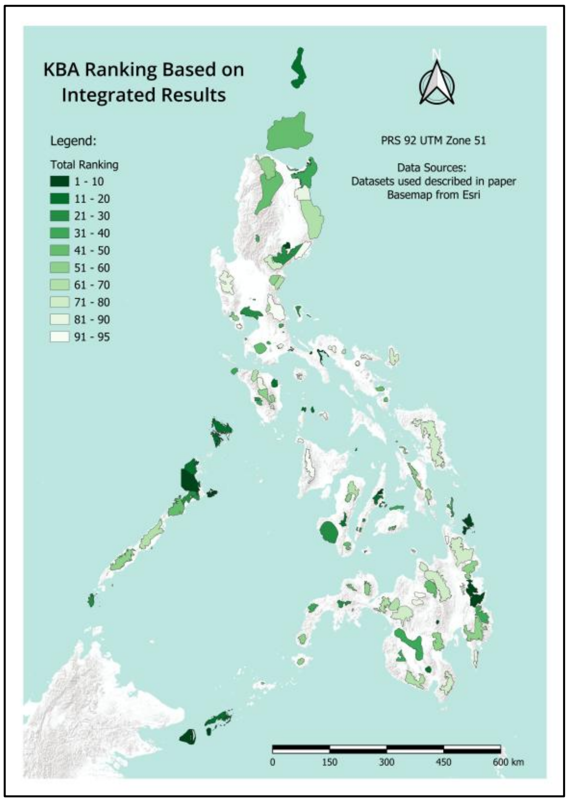

Figure 6. Final KBA ranking based on the integration of individual ranks of the four data layers.

The 127 KBAs used in the analysis had a total land area of 70,622.10 km^2, with only 29,585.70 km^2 overlapping with PAs. Among these KBAs, 48 had less than 5% overlap with protected areas. Of the 27 KBAs ranked at the top 20 based on overall ranking, 12 had less than 2% overlap with PAs (Table 2). These top 20 KBAs had a total land area of 8,136.84 km^2, with 3,726.76 km^2 not covered by PAs. The unprotected top-ranked KBAs were considered as priority KBAs.

Rank	KBA Name	Distinct Species Count	% Artificial Area	Forest Fragmentation (MSIZ)	% Forest Loss	% PA Overlap
1	Sibutu and Tumindao Islands	4	2.99997	0.13199	10.02744	0
2	Ragay Gulf	9	0.93800	0.06349	4.11283	0.39173
3	Simunul and Manuk Manka Islands	6	0.55734	0.62466	8.62534	0
4	Dumaran - Araceli	16	0.21770	0.74809	15.92217	99.41306
5	Mount Sinaka	8	0.49946	0.32937	6.37921	0
6	Malampaya Sound Protected Landscape and Seascape	27	0.32162	5.34083	8.10605	99.99993
7	Mount Capayas	5	0.34277	0.0002	4.14794	0
8	Siargao Island	7	0.69928	1.96456	5.47705	100
9	Pagbilao and Tayabas Bay	11	0.61583	0.27389	3.98955	19.78398
10	Lalaguna Marsh	6	2.23138	0.23711	2.62236	0
10	Bislig (South Diwata Range)	15	0.28226	22.2147	19.59186	1.62363
10	Cave no 6 Disiluad and associated hydrobasin	16	0.51461	0.01069	2.53140	7.45097
11	Romblon Island	3	1.07326	0.00047	2.01113	0
12	Busuanga Island	11	0.46458	9.53069	5.13804	99.78825
13	Batanes Islands Protected Landscape and Seascape	3	0.70983	0.94503	3.00185	100
14	Tawi-tawi Island	6	0.29655	26.2865	10.15007	0
14	Balogo watershed	6	0.26950	1.25047	4.31445	24.86108
14	El Nido	20	0.42143	40.2908	5.90080	99.99893
15	South and North Gigante Island	2	1.38379	0.00103	1.22588	0
15	Central Cebu (including Tabunan)	6	0.75405	0.09762	1.64481	89.04253
15	Culion Island	8	0.19756	3.94997	5.94913	99.45106
16	Lake Manguao	21	0.10062	13.65983	11.13162	99.99996
17	Calauit Island	9	0.09480	1.01729	7.94383	99.11162
18	Mount Matutum	8	0.64789	7.10981	3.23213	67.87420
19	Ban-ban	7	0.29305	1.39413	3.43405	0.98699
19	Lake Naujan	8	0.47308	27.08954	4.75949	54.00518
20	Mactan, Kalawisan and Cansaga Bays	6	13.73938	0.01468	0.54951	0

Table 2. Top 20 KBAs based on overall rank, with information on individual factor values. KBAs with zero to very low percent overlap with PAs are highlighted.

Although there was no consistent pattern in terms of the factor contribution to the overall ranking, some KBA analysis may be performed based on the individual computed factor values and their relationship with one another. The distinct species count based on the IUCN Red List for the top KBAs shown in Table 2 varied from 2 threatened species in South and North Gigante Island to as many as 27 in Malampaya Sound Protected Landscape and Seascape. The percentage of artificial area within these KBAs were generally low at less than 3%, except for Mactan, Kalawisan and Cansaga Bays KBA with 14% combined area percentage of OSM building, roads, and railways. The forest fragmentation in terms of MSIZ also varied greatly at a standard deviation of 10%, with MSIZ values from 0.0002 to 40.2908. The 12-year percent forest loss within these KBAs had a mean value of 6%, ranging from as little as 0.55% to an alarming loss of 19.59% in Bislig (South Diwata Range). Ironically, the KBA with lowest forest loss at 0.55% was Mactan, Kalawisan and Cansaga Bays, which also had the largest artificial area at 14%. This indicates that the particular KBA was already highly urbanized several years ago, thus the low forest loss. On the other hand, Bislig (South Diwata Range), which had a very high forest loss, had low forest fragmentation at 22.2147, indicating relatively intact forest areas. This high rate of forest loss implies deforestation threats in the Bislig KBA that warrants attention to prevent further degradation and to protect the recorded 15 distinct threatened species in that area.

4. Conclusions and Recommendations

GIS is a geospatial technology whose strength lies in the ability to perform analysis using various data layers towards decision-making and planning. Through this technology, patterns not obvious in the individual data become evident after integrating the various spatial datasets. In this study, geospatial tools such as RS, GIS, and landscape metrics were used to assess and identify priority KBAs. The prioritization of KBAs was based on the greatest number of distinct threatened species, largest percentage of human-made structures, highest forest fragmentation, and highest percentage of cumulative forest loss. The protection status of the ranked KBAs were used as an additional layer to determine gaps in the management of critical areas.

The overall rankings revealed that Sibutu and Tumindao, Ragay Gulf, and Simunul and Manuk Manka Islands were the three highest-ranking KBAs based on the integrated factor scores. These top 3 KBAs have zero to only 0.4% PA overlap, indicating low protection level. Among the top 20 KBAs, nine sites have no overlap with PAs and three more sites have less than 2% PA overlap. The top 63 KBAs ranked 1 to 48, which have a combined land area of 28,156.20 km^2, only have a PA overlap of 10,108.30 km^2. There is a total area of 41,036.40 km^2 of unprotected Philippine KBAs, which accounts to 58% of the total KBA land area. Given that these areas have no formal management regime, implementing targeted conservation action in these sites, especially for the identified high-ranking KBAs, can lead to improvement in habitat condition and biodiversity status. Overlaying other effective conservation measures (OECM) or other management regimes, such as ancestral domains, will enable us to further identify which particular KBAs absolutely do not have any existing conservation measure in place.

The approach used was simple and easily interpretable to non-technical readers, and shows specific sites where urgent action is needed. Flexibility and adaptability are important characteristics that were incorporated in this research. The exclusion or inclusion of factors in the ranking may be modified based on available information and specific criteria. If it has been decided that the factors used should have varying weights then a weighted ranking may also be performed. The prioritization rules, whether according to increasing or decreasing order, may also be modified depending on the decision criteria. For instance, instead of prioritizing KBAs with the highest fragmentation and greatest forest loss, a reverse prioritization may be done if the decision is based on protecting the more intact sites. This method may also be adapted to marine KBAs using appropriate factors.

This research may be used in future national-level gap analysis studies to determine specific locations requiring conservation management, given the available spatial information on species, habitat, and threat. Flexible and accountable monitoring systems are crucial to the success of implementing Target 3 of the Kunming-Montreal Global GBF (WWF and IUCN WPA, 2023). Furthermore, KBAs identified as high priority and unprotected may be used as candidate areas for the expansion of the network of Philippine PAs, OECMs, and ADs. Focusing action or management strategies on these KBAs can contribute to SDG 15 and to the Philippine's commitment in meeting the Target 3 of the Kunming-Montreal GBF.

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