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Integral evaluation of Important Bird and Biodiversity Areas (IBAs) of the Tropical Andes

Tesis

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Resumen

Las Áreas de Importantes para la Conservación de las Aves y la Biodiversidad (AICAs) son sitios identificados por BirdLife International, los cuales son considerados como clave para la conservación de las aves y, más recientemente, para la biodiversidad en general. A pesar de ser importantes sitios de conservación, su protección y monitoreo ha quedado relegada en los últimos años. En este estudio evaluamos los impactos antropogénicos dentro de las AICAS de los Andes Tropicales, actualizamos la información de las especies que podrían cumplir los requisitos de las AICAS, la presencia de especies de anfibios, aves, mamíferos y reptiles que pueden cumplir esos requisitos, y evaluamos la conectividad estructural en las AICAS de los países de Bolivia, Colombia, Ecuador, Perú y Venezuela. Se encontró un bajo número de AICAS que tienen especies que cumplen el criterio A1 para especies amenazadas de aves, anfibios, mamíferos y reptiles, diferencias significativas al comparar las distintas actividades antropogénicas dentro de las AICAS, se identificaron posibles áreas prioritarias de conservación y se encontró una baja conectividad en el lado occidental de los Andes. Las AICAS son herramientas exitosas para la conservación, pero se recomiendan posibles mejoras para incrementar su éxito.

Palabras clave: Áreas Importantes para la Conservación de las Aves y la Biodiversidad, Andes Tropicales, especies amenazadas.

Abstract

Important Bird and Biodiversity Areas (IBAs) are sites defined as key for the conservation of birds and, more recently, for general biodiversity, identified by BirdLife International. Despite being important conservation sites, their protection and monitoring have been relegated in the last few years. In this study, we evaluated anthropogenic impacts inside IBAs of the Tropical Andes, updated their trigger species information, presence of possible trigger species of amphibians, birds, mammals, and reptiles, and evaluated structural connectivity in the countries of Bolivia, Colombia, Ecuador, Perú, and Venezuela. We found a low number of IBAs with trigger species of birds, amphibians, mammals, and reptiles for the A1 criterion and significant differences between anthropogenic activities within the IBAs. We also identified potential priority conservation sites based on threatened species, anthropogenic activities, and low connectivity between IBAs. While IBAs are successful conservation tools, we recommend possible improvements to increase their success.

Key words: Important Bird and Biodiversity Areas, Tropical Andes, threatened biodiversity.

TABLA DE CONTENIDO

Introduction

In-situ conservation focuses on preserving and managing natural habitats to safeguard their biodiversity (United Nations, 1992). *In-situ* conservation strategies employ a wide range of approaches, including establishing protected areas, habitat restoration, and community-based conservation initiatives (Berkes 2007). While protected areas are the most common *in-situ* conservation strategy that provides a protection network for biodiversity, some areas are not protected and must be identified for their importance in conservation (Berkes 2007). For this, some tools have been created to identify important sites for biodiversity conservation and recognize them for their importance, like Important Bird and Biodiversity Areas, which are tools for systematic conservation planning.

Important Bird and Biodiversity Areas (IBAs) are sites identified by BirdLife International defined as key for the conservation of birds and, more recently, for general biodiversity (BirdLife International 2005, Yépez et al. 2010). They are usually identified nationally by independent entities acting through BirdLife International using standardized international criteria that address how vulnerable or irreplaceable each proposed site is (BirdLife International 2005, Yépez et al. 2010, BirdLife International 2022). The species that comply with these criteria are known as trigger species, and scientists and other actors can use them to propose the IBA to be accepted by BirdLife International (BirdLife International 2005). The main aim of the IBA Programme is to ensure the long-term conservation of all identified sites, which add up to 13000 IBAs worldwide, covering more than 200 countries, distributed in different regions known for high levels of biodiversity (BirdLife International 2022). From those, 1287 IBAs are in South America strategically located in crucial habitats for bird migration, breeding, and feeding activities (BirdLife International 2022). While most IBAs are not inside a protected area or hold a management program to ensure their conservation, they surround many biodiversity hotspots, highlighting their importance (Myers et al., 2000).

The original focus of IBAs was birds, as they are considered a charismatic umbrella group and are one of the best-known taxa (García-Moreno et al. 2007; Kukkala et al. 2016). Nevertheless, some studies have suggested that birds are not always the best surrogates for conservation strategies, such as IBAs in their early stages, suggesting that bird information should be integrated with information from other groups to increase conservation efforts (Wugt Larsen et al. 2012). Amphibians, reptiles, and mammals are among the taxa suggested to increase this knowledge, which is a good indicator for habitat fragmentation and other threats (Hager 1998).

Despite their possible protection, IBAs are inside a matrix of anthropogenic activities and are usually affected by different land uses and extractive activities (Steven et al., 2015). Among these are agriculture, urbanization, and extractive activities such as sand and oil extraction, mining, and logging (Sims 2014, Steven et al. 2015, Santiago-Ramos & Feria-Toribio 2021). For IBAs to succeed, there must be a periodic evaluation and monitoring of these impacts and their biodiversity so that people in charge may develop new conservation policies or restructure existing ones (Donald et al. 2019). Nevertheless, continuous monitoring is very resource-consuming, and finding updated biodiversity data for these sites is almost impossible due to the little availability of this type of data (Dixon & Sherman 1991, Watson et al. 2014, Kukkala et al. 2016). Available biodiversity data of good quality is a must when creating regional, national, or international conservation policies, as they provide the necessary information about the current population and diversity trends.

While IBAs have been established since the 1990s, few studies have evaluated how well they cover other taxa besides birds and how they face anthropogenic activities' pressure (Brooks et al. 2006, BirdLife 2022). This analysis evaluated the anthropogenic impact of IBAs in the Tropical Andean countries of Venezuela, Colombia, Ecuador, Perú, and Bolivia. We explored the potential for these areas to protect other threatened taxonomic groups beyond birds, such as amphibians, mammals, and reptiles. Also, we present an updated analysis of threatened tetrapod biodiversity, their compliance with the IBAs criteria for threatened species, anthropogenic threats' effect on each IBA, and separated by countries, and evaluate if IBAs are mainly identified inside protected areas. Finally, we also evaluated structural connectivity between IBAs.

Materials & Methods

IBAs were created to protect naturally occurring populations across bird species ranges based on global standard criteria. There are four criteria as follows: (A1) sites with a significant presence of globally threatened species, (A2) sites with a significant population of at least two range-restricted species, (A3) sites with significant breeding assemblages of biome-restricted species, and (A4) globally significant concentrations of species (BirdLife International 2005). Given that globally threatened species' red list status changes with time, we chose the A1 criterion to be the focus of our analysis, which asks for trigger species to comply with at least 95 % of their distribution inside the IBAs' area. We obtained the IBAs information and shapefiles from the World Bird DataBase provided by BirdLife International.

We analyzed the following data from continental Venezuela, Colombia, Ecuador, Perú, and Bolivia: (1) Threatened tetrapod species diversity inside IBAs, (2) Updating the Red List status of trigger species of A1 criterion, (3) Number of IBAs that hold at least one species of threatened amphibians, birds, mammals, and reptiles that comply with the A1 criterion, (4) IBAs inside and outside of protected areas, (5) Amount of land lost by threats inside each IBA, and (6) Structural connectivity between IBAs.

Threatened biodiversity analysis.

We obtained the distribution polygons for birds, amphibians, mammals, and reptiles that are categorized as Critically Endangered (CR), Endangered (EN) and Vulnerable (VU), from the International Union for the Conservation of Nature IUCN Red List of Threatened Species (IUCN 2023). These polygons were converted into rasters by using the “Polygon to raster” tool in ArcGIS Pro 2.4.0. With these rasters, we overlapped the different species to calculate the accumulation of species per IBA by using the tool “Cell statistics”, so we obtained the total number of species per IBA. We also calculated an index, dividing the total number of species by the total area of each IBA.

Compliance analysis.

We compiled information about the trigger species of all the IBAs created following A1 criterion and reviewed each species current red list status. We performed the Wilcoxon signed-rank test with continuity correction to compare the number of trigger species, by IBA, that are still considered as threatened by the IUCN and those that are not evaluated as threatened.

With the distribution polygons of the threatened species obtained from the IUCN, we developed a script to evaluate how many species of birds, amphibians, mammals, and reptiles may comply with the A1 criterion of 95% distribution of the species inside each IBA. We performed this analysis in R Studio (v4.2.2, R Core Team, 2022) using the packages: sp, raster, rgdal, ggplot2, rgeos, lattice, latticeExtra, automap, dplyr, mapview, knitr, kableExtra, sf, Rmisc, RColorBrewer, rasterVis, plotly, and DT (Pebesma & Bivand 2005, Hiemstra 2008, Sarkar 2008, Bivand et al. 2013, Xie 2014, Xie 2015, Wickham 2016, Pebesma 2018, Sievert 2020, Zhu 2021, Appelhans et al. 2022, Hope 2022, Neuwirth 2022, Sarkar & Andrews 2022, Bivand & Rundel 2023, Bivand et al. 2023, Hijmans 2023, Pebesma & Bivand 2023, Perpiñán & Hijsman 2023, Wickham et al. 2023, Xie 2023, Xie et al. 2023).

Anthropogenic impact & structural connectivity analysis.

For land use information, we downloaded the rasters from Potapov et al. (2022) and Hansen et al. (2013), and reclassified their uses into agriculture, deforestation, urbanization, and none. We considered deforestation only of the last 20 years as it is the period since IBAs were created. For oil extraction, roads, mining, and protected areas we obtained the information available from Global Forest Watch (2023) and national repositories, but mining information was inaccessible for the countries of Bolivia, Perú, and Venezuela. We created buffers for roads and oil extraction wells to represent the direct impact of both activities, following the recommendations of Ortega-Andrade et al. (2021). We only analyzed protected areas managed by the central government.

We transformed all rasters into polygons by using the “Raster to Polygon” and used the tool “Erase” to calculate the area, in square kilometers, affected by anthropogenic activities of each IBA. We overlapped IBAs polygons with protected areas polygons and calculated the area inside them with the tool “Clip”. We created a “threat index” by standardizing the presence of human activities with the tool “Zonal Statistics”. We used the species index calculated for the biodiversity analysis, and the threat index to create a prioritization map and identify the most diverse and threatened IBAs.

For statistical analyses, we performed the Wilcoxon signed-rank test with continuity correction to compare (1) the area of IBAS inside protected areas vs. their whole areas, and (3) the original areas and the areas affected by mining in Ecuador and Colombia. We performed the Kruskall-Wallis rank-sum test with a posthoc pairwise comparison using Wilcoxon rank-sum tests adjusted by the Bonferroni method, to see if there were significant differences between the amount of area affected by the different anthropogenic activities of deforestation, urbanization, agriculture, oil extraction, and roads; and the Kruskal-Wallis test with a posthoc test using Dunn’s test with a Bonferroni correction for multiple comparisons to see if the countries may influence those differences, if present, and to see possible differences of the activities in IBAs inside and outside protected areas. All the statistical tests were also performed in R Studio by using the package dplyr (Wickham et al. 2023).

We adapted Esri's tutorial for corridor development (Esri's Learn Team, 2023), where we used "Distance Accumulation" to calculate the impact created by roads, and "Rescale by Function" to transform those distances and "Reclassify" to give different weights to anthropogenic impacts following the information provided by Ortega-Andrade et al. (2021). All anthropogenic impacts, oil extraction, roads, agriculture, and reforestation, were classified in a scale from one to ten, being one the least affected and ten the most. Then, we performed a cost analysis with the tool "Weighted Sum" with "Optimal Region Connections" to finally obtain the cost after considering all anthropogenic activities and overlapping that cost layer with the IBAs polygon.

Results

Threatened biodiversity analysis.

After evaluating the number of threatened tetrapod species that overlap their distribution ranges with the IBAs, we found that "Mindo y Estribaciones Occidentales" IBA, in Ecuador, holds the higher number of threatened species (n=97, 49 amphibians, 20 birds, 12 mammals, and 16 reptiles), while "Parque Nacional Sajama" IBA, in Bolivia, holds the lower number of threatened species (n=7, one amphibian, three birds, and three mammals; Figure 1). This pattern holds after obtaining the index of threatened species, where "Mindo y Estribaciones Occidentales" still is the IBA with the higher number of species, and those IBAs surrounding it, "Río Toachi-Chiriboga", "Maquipucuna-Río Guayllabamba", and "Mashpi-Pachijal" also have a higher index (Figure 2). The northern part of the Andes, in Colombia, also represents a high index, for example in the IBA of "Parque Nacional Perijá" and "Selva de Florencia" (Figure 2).

Compliance analysis.

We analyzed 441 IBAs distributed in the tropical Andes, of which 91% (n=400) of the IBAs do not comply with the requirement for criterion A1 (95% of the distribution of a threatened species inside its territory) for amphibians, birds, mammals, and reptiles. The 41 IBAs that complied with the A1 criterion were mainly in Venezuela (n=14), followed by Ecuador (n=13), Colombia, (n=9), Bolivia (n=3), and Peru (n=3). We found that 8 % (n=37) of IBAs protect at least one amphibian species each, 0.6% (n=2) hold one reptile species, 0.2% (n=1) protect one bird species and one amphibian species, and 0.2% (n=1) protect one mammal species (Table 1).

From those 441 IBAs, 409 were created by complying with the A1 criterion for threatened species. We found that 64% (n=260) of the IBAs lost at least one trigger species due to the change of threatened status in the Red List, 21% (n=86) lost all their original trigger species, and 15% (n=63) of the IBAs did not change their trigger species' red list status. Of those 86 IBAs that lost all their original trigger species, 30% (n=26) were created only by complying with the A1 criterion, therefore they may lose their IBA designation. We found significant differences between the initial number of trigger species for this criterion with the current red list status of those species ($V= 59685$, $p<2.2e-16$) after performing the Wilcoxon signed rank test.

Anthropogenic impact & structural connectivity analysis.

For anthropogenic impacts, we analyzed the same 441 IBAs that we analyzed for threatened biodiversity. We found significant differences between the original area vs. the area affected by anthropogenic activities (Kruskal-Wallis X2=148.09, df=4, p<2.2e-16), and it was also confirmed after performing the pairwise Wilcoxon rank-sum test. The IBAs cover 859965.20 km2, of which 91.96% (790789.56 km2) has been affected by anthropogenic activities, being agriculture the biggest threat (30.55%) and urbanization the smallest (0.49%, Table 2, Figure 3). We found significant differences (Kruskal-Wallis X^2=272.17, df=24, p<2.2e-16) after testing the interaction between the anthropogenic activities and the countries, being Venezuela the most affected country and Colombia the least affected. When analyzing the impact of mining in Ecuador and Colombia, we found significant differences for area lost (V= 14028, p<2.2e-16), and between countries (W=442, p=0.003) being Ecuador the most impacted (Table 2, Figure 4).

After overlapping IBAs with protected areas, we found that 54.65% (n=241) are completely outside of a protected area while 45.35% (n=200) of the IBAs are completely, or partly, inside a protected area. We found significant differences by comparing the amount of land inside protected areas and their whole sizes (V=82820, p<2.2e-16), after performing the Wilcoxon signed rank test. We also found significant differences when comparing the impacts on IBAS inside protected areas vs. those outside protected areas (Kruskal-Wallis X^2=156.82, df=9, p<2.2e-16). After analyzing the prioritization map (Figure 5) we found that many of the most vulnerable areas are not inside protected areas, but the bigger ones, like “Parque Nacional Cayambe-Coca”, in Ecuador, or “Parque Nacional Henry Pittier” in Venezuela, are protected by protected areas.

After performing the cost analysis for structural connectivity, we found that we can find higher connectivity in areas close to cities and that roads are one of the anthropogenic activities that modify the landscape the most (Figure 6). Also, there is higher connectivity cost in the western side of the Andes, specially where ports may be located, in comparison with the eastern side of the Andes.

Discussion

We found that most IBAs do not comply with the requirements of the A1 criterion; this may be due to the extensive distribution most threatened species have. IBAs consider the IUCN Red List of Threatened Species, a globally scaled evaluation of parameters such as distributional range and population size, among others (IUCN 2023). However, applying a globally scaled list to apply conservation on a national level can have a problematic potential. Therefore, the IUCN encourages it to follow the international guidelines but to evaluate the species nationally and create a national red list (Rodrigues et al. 2006, Brito et al. 2010, Hayward 2011). This problematic potential may explain why it is almost impossible for the IBAs to comply with the 95% distribution requirement. If IBAs were created by following national red lists, the species distribution range might vary between countries, thus facilitating the compliance of the A1 criterion for all taxa.

Amphibians were the only taxa where IBAs held more than one species, but it also relates to the smaller distribution this taxon has and higher endemism rates. According to Brito et al. (2010) and Gärdenfors et al. (2001), the total number of threatened species tends to increase when evaluating an area nationally instead of globally, and their conservation status is higher when considering a smaller area of distribution. While this may not change much for smaller vertebrates, such as amphibians and reptiles, with small distribution ranges, using the national red lists instead of global ones may dramatically change conservation strategies for mammals and birds. An example is the Andean bear (*Tremarctos ornatus*), categorized as vulnerable on the global red list but endangered on the Ecuadorian one (IUCN 2023, Tirira 2011). If we only applied the A1 criteria based on the global Red List status and their global distribution, it would not be considered a trigger species. However, it is highly threatened in Ecuador. This reflects the need to use more than the global red list status for conservation. This change may also encourage scientists to create these national evaluations of their biodiversity, thus increasing available information about them.

According to Zamin et al. (2010), national red list evaluations may help increase the knowledge gap regarding the no evaluated species, which are as important as those with more information. Also, focusing efforts at a regional level may be a cost-efficient mechanism to assess many species in a specific area, for example, the efforts carried out with the Red List of South Asian Primates, the Southern African Plant Red Data List, the Red Book of Ecuadorian Mammals, or the Red Book of Colombian Reptiles (Golding 2002, Molur et al. 2003, Zamin et al. 2010, Tirira 2011, Morales-Betancourt et al. 2015). However, there are few studies about threatened species, which may become a shortcoming while trying to use the red list categorization as part of systematic conservation planning, such as IBAs (Gjerde et al. 2018). Also, the threat status of a species may be updated after changes in its taxonomy and population status, which makes them a possible liability when trying to apply those Red List statuses as a value for site selection at a finer scale (Gjerde et al. 2018). Such liability was proven with our result of the loss of trigger species due to changes in their threatened status which in some cases resulted in the loss of the IBA designation. While IBAs have been proven as a successful conservation tool, they are the first step of many for them to become a holistic method for systematic conservation planning. For this, IBAs, or decision makers using it as a tool, should consider not only threatened ecosystems and taxa, but also technical, economic, and social aspects (Karimi et al. 2017, Gjerde et al. 2018).

The loss of trigger species, and in the worst case, the loss of the IBA designation, reflects the necessity of periodically updating the IBAs inventory as conservation or taxonomic status may constantly change for some taxa (Donald et al. 2019). This evaluation may be carried out using citizen science and other monitoring techniques, such as following the BirdLife IBA monitoring framework to follow trends that have been successful in the past (Mwangi et al. 2010, Buchanan et al. 2013, Ndan'ang'a et al. 2016). Another way of carrying out this updating may be to include them in the monitoring plans of protected areas where some IBAs are located. Some studies have proven that protected areas paired with important sites for biodiversity slow the extinction rate and reduce the monitoring costs (Butchart et al. 2012, Donald et al. 2019). While being inside a protected area may not stop anthropogenic impacts from affecting biodiversity, we have shown that it may diminish their impacts, which is another reason for trying to merge both conservation strategies. Nevertheless, it is crucial to consider that many protected areas in the tropical Andes were created with people and urban land within their borders, which may also affect their conservation (Elmqvist et al. 2013).

There is a growing demand for cropland and extractive activities in South America as their population continues growing, and extraction activities are one of their main economic activities (Ramirez-Villegas et al. 2012, Elmqvist et al. 2013, Tilman et al. 2017). At the same time, urban development in South America was already high and developed mainly by the 2000s (Elmqvist et al. 2013). This may explain why agriculture was the most impactful activity urbanization was so low in our analyses. According to Laurance et al. (2014), the pressures for food production may increase in the following decades, mainly in the tropics; therefore, expanding agricultural lands may also increase. Agricultural processes in the tropics are dominated by relatively inefficient technologies, which result in more extensive areas being modified (Laurance et al. 2014). In the last decades of the 1900s, the agricultural frontier heavily expanded and was projected to grow even more significantly, deriving from deforestation and colonization (Perz et al. 2005). While we analyzed the anthropogenic threats individually, in practice, all the threats have additive impacts. Oil extraction, for example, also generates road openings, deforestation, colonization, and agriculture, while mining may also increase water pollution and could become a health hazard, besides the threats mentioned (O'Rourke & Connoly 2003, Lessmann et al. 2016, Barraza et al. 2018, Capparelli et al. 2020). An example of this can be seen in north-eastern Ecuador, where the presence of the oil industry has derived from the presence of roads, colonizers, and an increase in the wild meat trade (Suárez et al. 2009).

Lack of connectivity is also caused by anthropogenic threats like agriculture, urbanization, deforestation, extractive activities, and road development, which causes habitat fragmentation (Haddad et al. 2015). According to Donald et al. (2019) and BirdLife International (2005), one of the primary purposes of IBAs is to become a network for different species. However, for it to work, it must be possible for species to travel between them. As mentioned before, the connectivity cost was higher near ports and cities, but we could observe the road matrix of the Tropical Andean countries. While roads did not cause the most significant impact on land lost inside IBAs, the presence of roads is the determining factor to increase habitat fragmentation as it completely disrupts the landscape (Keller & Largiadèr 2003, Cushman et al. 2010, Haddad et al. 2015). This reflects how high habitat fragmentation is in the Tropical Andes, increasing the isolation of the different populations (Haddad et al. 2015). This isolation may also cause heavy genetical pressure as their capability to mix up with other populations is diminished (Keyghobadi 2007, Haddad et al. 2015). The lack of connectivity is also related to the loss of habitat resources that can be used by the species, which leads to a decrease in population sizes (Herrera et al. 2017).

As mentioned above, activities may derive different levels of impact that should be addressed nationally with different policies that ensure the maintenance of habitat connectivity and functionality. This could be carried out by constantly monitoring and identifying important sites facing heavier impacts than others, as observed in our prioritization map. The use of protected areas as a management unit to protect IBAs that have been recognized as priority sites is a very good alternative, as we have seen in our results, so we recommend analyzing the possibility of creating more protected areas in sites that have been identifying as vulnerable, including a more holistic approach, or the possibility of creating corridors to increase connectivity.

While we analyzed only protected areas managed by the central government, other protected areas, such as private protected areas, could cover gaps in our analyses. For that, the following steps include incorporating them in the analysis to understand how important those independently managed areas in conserving nature are. Also, it is relevant for future studies to cover the limitations of available information for different species and anthropogenic activities, as some of them are not available to the public.

Conclusion

IBAs have become important sites for biodiversity conservation and the predecessors of Key Biodiversity Areas, which were proposed by the IUCN and supported by BirdLife International to cover more taxa and their possible threats. Nevertheless, using global distributions as the default criterion for threatened species may only cover some species' needs that may face different threats in different countries. Also, evaluating different aspects of the areas of interest is essential, as the economic and social situations may require a different approach than just a species-based one. While animals do not follow political borders, this should be considered when proposing conservation strategies, as governments are some of the principal actors in conservation. Decision-makers should consider using tools such as IBAs as their basis for systematical conservation planning. However, they should move along with the process and end up with recognized conservation units with a management and monitoring plan that may provide periodic results.

Also, those areas outside protected areas are more threatened than IBAs inside protected areas. This may reflect the need for IBAs (or KBAs in the future) to be recognized as conservation units by the governments where they are established to be appropriately protected. Nevertheless, it is essential to mention that privately protected and non-central government-protected areas are abundant in the Tropical Andean countries so that they may diminish the impact of anthropogenic activities in priority sites. Finally, the lack of connectivity needs to be solved by creating corridors, habitat restoration, and a decrease in land modification so the species protected by the IBAs can use this vast network of 441 IBAs in the Tropical Andes. Also, this reflects an overfocus on protecting specific sites but not enough interest in keeping those sites connected between them and a high need for habitat restoration.

IBAs are a successful and valuable conservation tool, but their monitoring and protection have been left aside. Therefore, it is crucial to keep up with these studies so their success increases, and decision-maker can use them as the first step to achieving a systematic conservation strategy.

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TABLES

Table 1.- Important Bird and Biodiversity Areas that hold at least 95% of the distribution range of at least one threatened species, categorized by the IUCN (2023).

Country	IBA name	Threatened amphibians	Threatened birds	Threatened mammals	Threatened Reptiles	Total of threatened species
Bolivia	Noel Kempff Mercado	0	0	0	1	**1**
Bolivia	Yungas Superiores de Apolobamba	6	0	0	0	**6**
Bolivia	Yungas Superiores de Carrasco	2	0	0	0	**2**
Colombia	Cañón del Río Guatiquía	1	0	0	0	**1**
Colombia	Cuchilla de San Lorenzo	0	0	1	0	**1**

Colombia	Farallones de Cali Natural National Park	1	0	0	0	**1**
Colombia	La Planada Natural Reserve	1	0	0	0	**1**
Colombia	Parque Nacional Natural Chingaza and surroundings	2	0	0	0	**2**
Colombia	Parque Nacional Natural Tatamá	1	0	0	0	**1**
Colombia	Selva de Florencia	3	0	0	0	**3**
Colombia	Serranía de las Minas	1	0	0	0	**1**
Colombia	Serranía de los Paraguas	8	0	0	0	**8**

Ecuador	Bosque Protector Alto Nangaritza	1	0	0	0	**1**
Ecuador	Cordillera de Kutukú	1	0	0	0	1
Ecuador	Cordillera del Cóndor	3	0	0	0	3
Ecuador	Corredor Ecológico Llanganates-Sangay	1	0	0	0	1
Ecuador	La Bonita-Santa Bárbara	1	0	0	0	1
Ecuador	Mache Chindul Ecological Reserve and surrouding areas (Reserva Ecológica Mache-Chindul IBA)	1	0	0	0	1

Ecuador	Mindo and western foothills of Volcan Pichincha	2	0	0	0	2
Ecuador	Parque Nacional Cayambe-Coca	1	0	0	0	1
Ecuador	Parque Nacional Llanganates	1	0	0	0	1
Ecuador	Parque Nacional Podocarpus	2	0	0	0	2
Ecuador	Parque Nacional Sangay	3	0	0	0	3
Ecuador	Parque Nacional Sumaco-Napo Galeras	2	0	0	0	2
Ecuador	Río Conambo-Bobonaza	1	0	0	0	1

Perú	Carpish	2	0	0	0	2
Perú	Lago de Junín	0	1	0	0	1
Perú	Reserva Comunal El Sira	1	1	0	0	2
Venezuela	Dinira National Park and surrounding areas (Refugio de Fauna Silvestre y Reserva de Pesca Parque Nacional Dinira IBA)	1	0	0	0	1
Venezuela	Henri Pittier National Park (Parque Nacional Henri Pittier IBA)	4	0	0	0	4

Venezuela	Monumento Natural Tepui Yavi	1	0	0	0	1
Venezuela	Parque Nacional Canaima	6	0	0	0	6
Venezuela	Parque Nacional Duida-Marahuaca	1	0	0	0	1
Venezuela	Parque Nacional Guaramacal	2	0	0	0	2
Venezuela	Parque Nacional Páramos Batallón y La Negra and surrounding areas	3	0	0	0	3
Venezuela	Parque Nacional Serranía La Neblina	2	0	0	0	2
Venezuela	Parque Nacional Sierra La Culata	2	0	0	0	2

Venezuela	Parque Nacional Sierra Nevada	2	0	0	0	2
Venezuela	Parque Nacional Yapacana	1	0	0	0	1
Venezuela	Reserva Forestal Sipapo	1	0	0	0	1
Venezuela	Zona Protectora Macizo Montañoso del Turimiquire	0	0	0	1	1
Venezuela	Zona Protectora Macizo Montañoso del Turimiquire	2	0	0	0	2

Table 2.- Percentages (%) of area lost by deforestation, agriculture, urbanization, oil extraction and mining inside the IBAs. The values marked with an asterisk (*) represent the higher values for each threat.

Country	Area affected by						
	Oil extraction	**Agriculture**	**Roads**	**Deforestation**	**Urbanization**	**Mining**	**Total of area lost**
Venezuela	13.76	8.67	3.62	1.98	0.04	-	28.08
Bolivia	13.64	9.12	2.98	0.77	0.07	-	26.59
Ecuador	5.83	2.50	0.76	0.29	0.15	11.74	21.26
Peru	7.67	7.34	3.89	0.65	0.08	-	19.63
Colombia	3.24	2.92	1.30	0.52	0.17	8.36	16.49

FIGURES

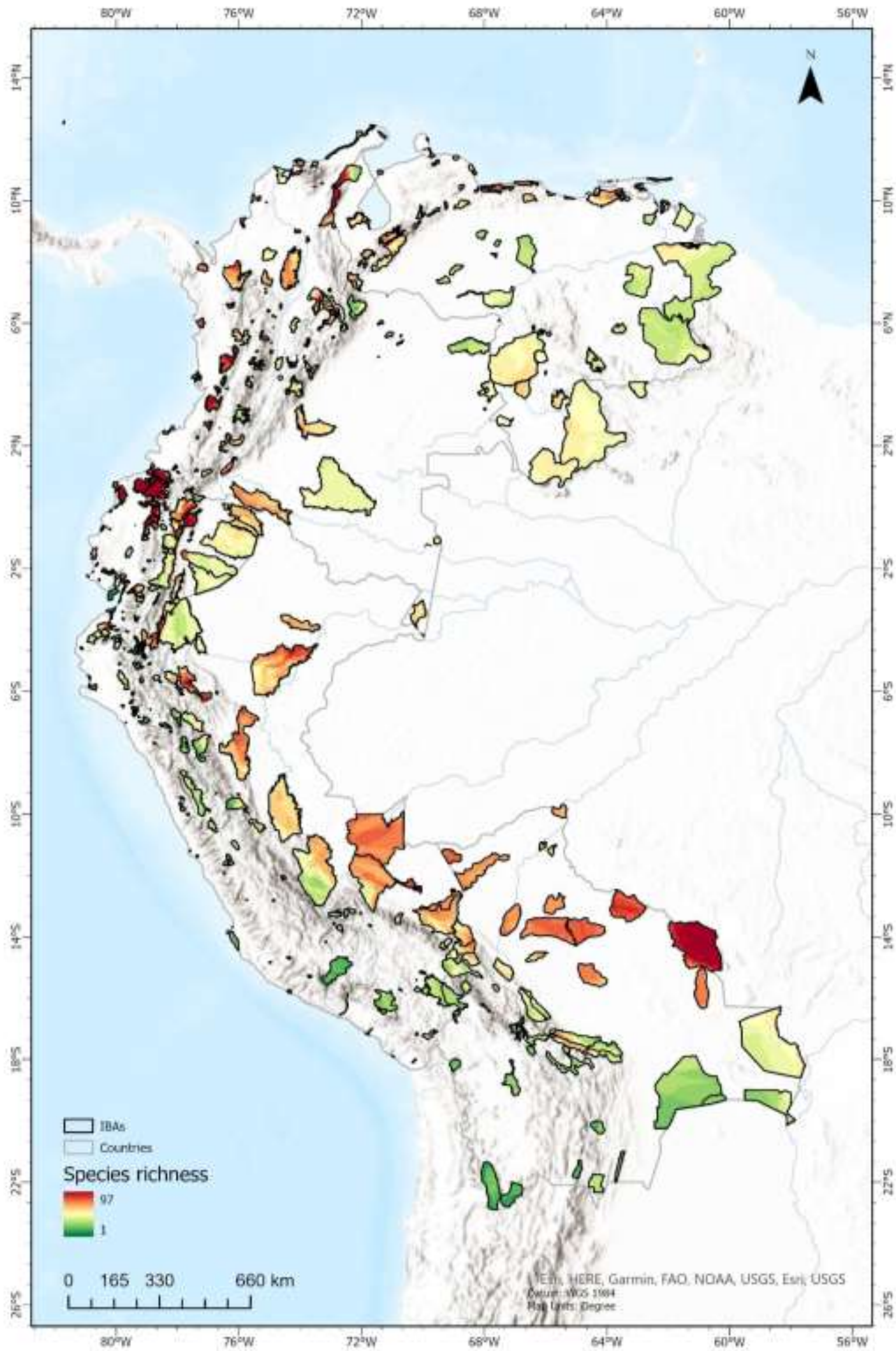

Figure 1.- Total number of amphibians, birds, mammals and reptiles for each Important Bird and Biodiversity Area. Higher numbers are represented by red, while lower numbers are represented by green.

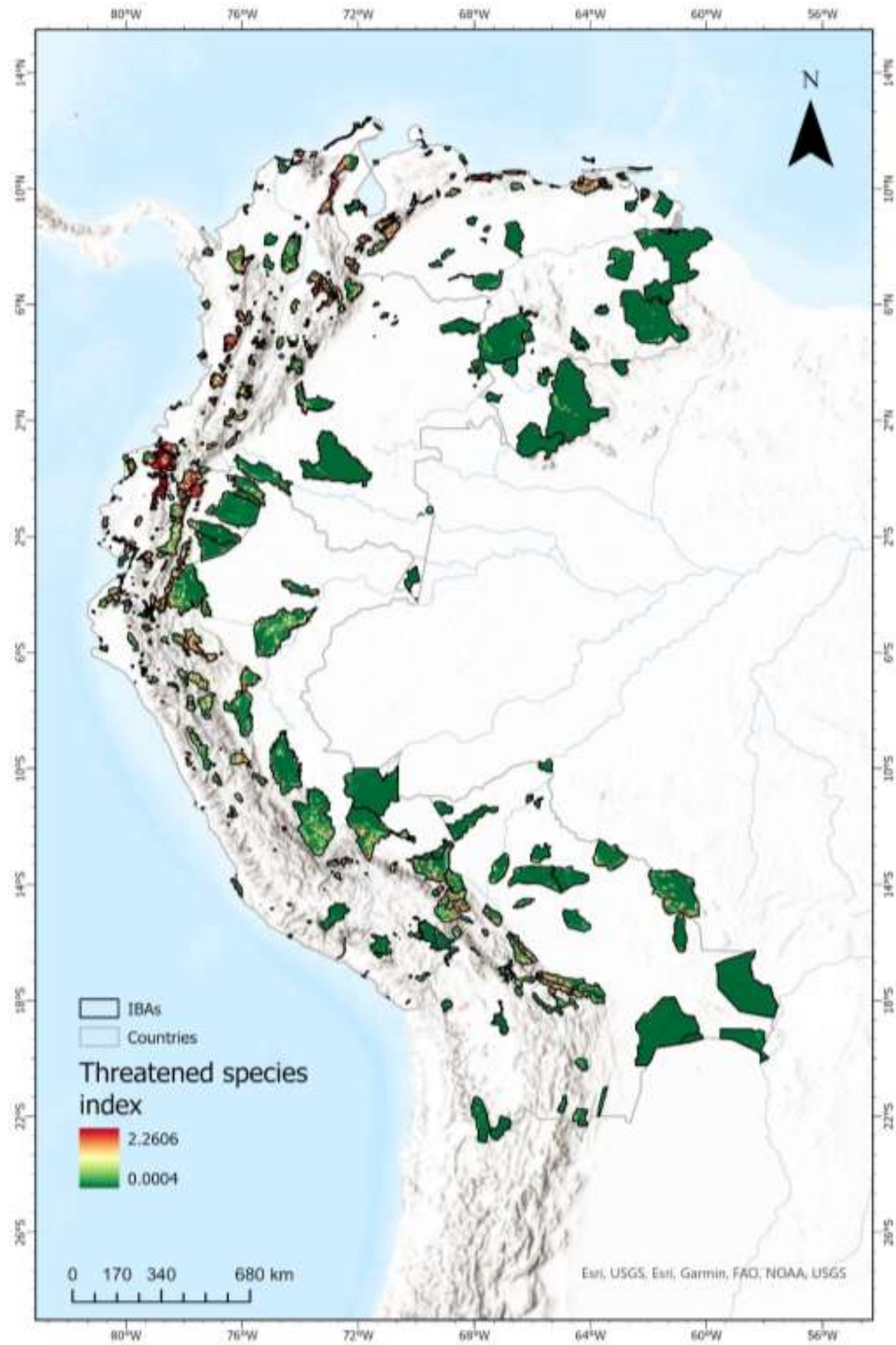

Figure 2.- Threatened index of amphibians, birds, mammals and reptiles for each Important Bird and Biodiversity Area. Higher numbers are represented by red, while lower numbers are represented by green.

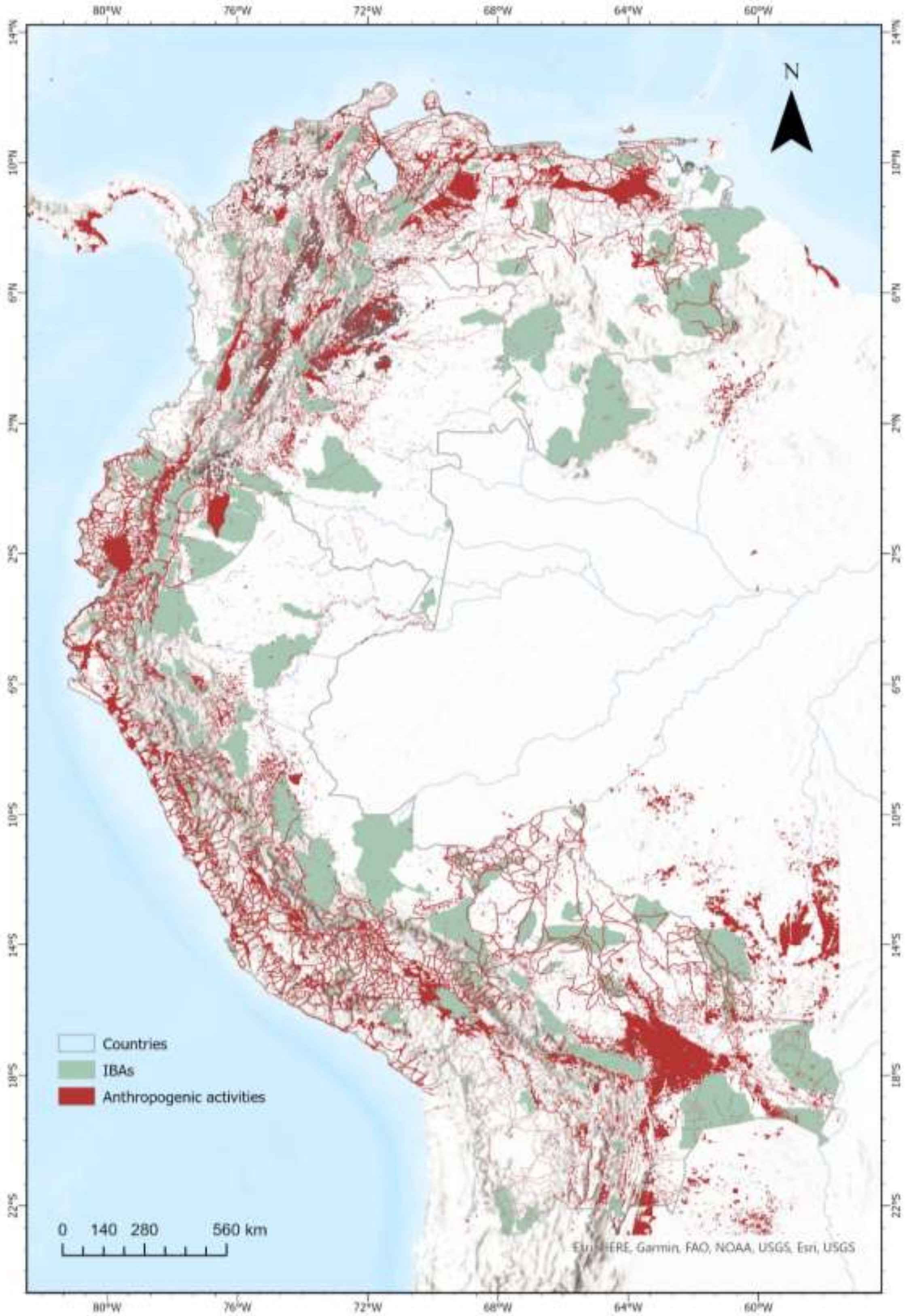

Figure 3.- Anthropogenic activities overlapped with Important Bird and Biodiversity Areas. Anthropogenic activities are represented in red, and IBAs are represented in green.

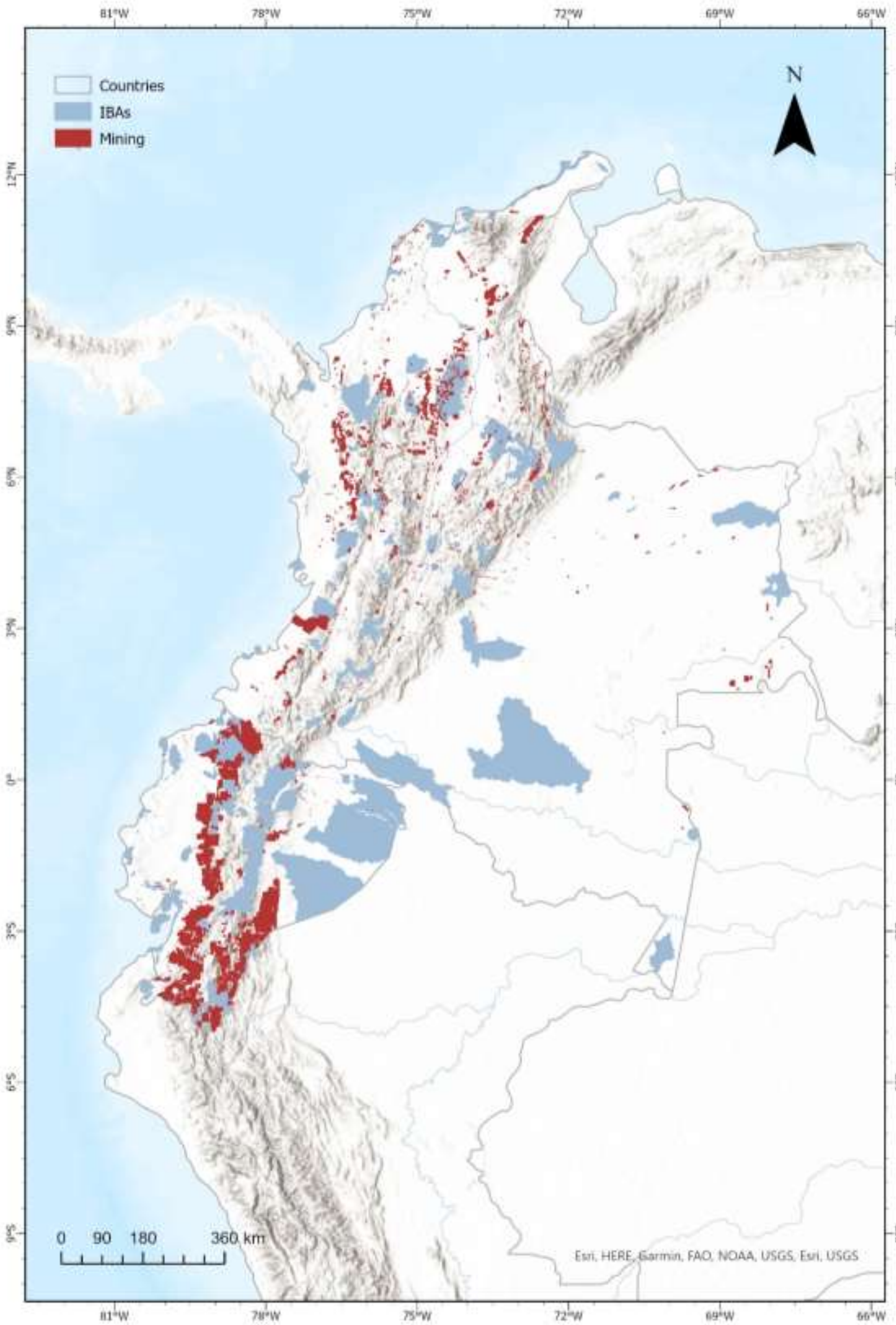

Figure 4.- Mining overlapped with Important Bird and Biodiversity Areas of Ecuador and Colombia. Anthropogenic activities are represented in red, and IBAs are represented in blue.

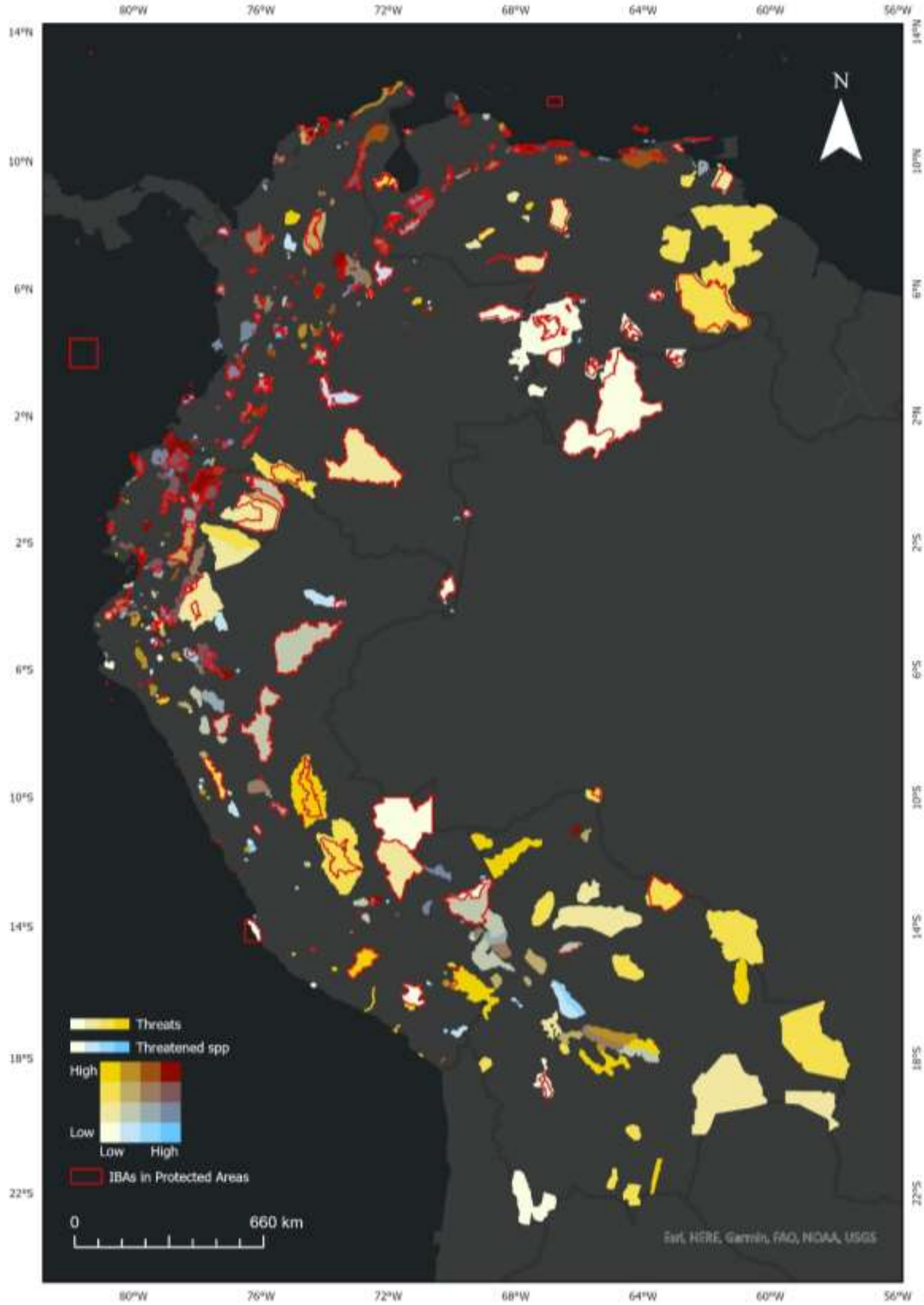

Figure 5.- Priority conservation sites based on anthropogenic activities index and threatened species index. As the color goes darker, the level of priority increases.

Figure 6.- Connectivity cost matrix, red represents a high connectivity cost and green represents low connectivity cost.