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Identifying important plant areas for useful plant species in Colombia

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ABSTRACT

While area-based approaches continue to dominate biodiversity conservation, there is growing recognition of the importance of the human dimensions of biodiversity. We applied the Important Plant Areas (IPA) approach in Colombia to identify key sites for the conservation of plant species with reported human uses. Drawing on the Checklist of Useful Plants of Colombia, we collated 1,045,889 clean occurrence records for 5400 native species from global data repositories and digitized herbaria. Through analysis based on regionalized grid cells, we identified 980 sites meeting IPA thresholds. These are primarily located in forest habitats, with only 19.8 % within existing national natural parks or internationally designated conservation areas. Grid cells were transformed to polygons based on overlapping ecosystems and administrative boundaries to form more meaningful site boundaries. A subsequent two-stage ranking procedure based on conservation value and richness found 46 sites to be of high priority, with 10 selected as top priorities for further investigation and conservation action. These 10 sites support significant populations of 33 threatened useful plant species and represent six of the 13 bioregions of Colombia in just 0.27 % of its land area. To progress from potential to confirmed IPAs, targeted fieldwork is required alongside stakeholder engagement and consultation, crucially involving local resource users. As a megadiverse country ranked second in the world for its botanical richness, effective IPA management would not only contribute to Colombian targets for sustainable development and conservation but would also support global targets to recover biodiversity for both planet and people.

1. Introduction

The Kunming-Montreal Global Biodiversity Framework (GBF) aims for at least 30 % of the world's area to be effectively conserved by 2030. In line with the framework's vision of "living in harmony with nature", this sits alongside targets for sustainable use and benefit-sharing and highlights the need for conservation areas to recognise and respect the rights of indigenous peoples and local communities (CBD, 2022). Amongst the many existing approaches to area-based conservation is the Important Plant Area (IPA) program. Established by Plantlife, it aims to identify and protect a network of best sites for plant conservation in the world (Anderson et al., 2002; Darbyshire et al., 2017).

IPAs are identified according to globally consistent criteria based on the presence of threatened species, botanical richness and threatened habitats. The program was first established for application in Europe, but recognition of gaps in the tropics led to the launch of the Tropical IPA (TIPAs) sub-program (Anderson et al., 2016). Aside from its taxonomic focus on plants and fungi, IPAs can be distinguished from other global conservation prioritisation approaches by the inclusion of socially, economically, and culturally valuable species as potential triggers for site identification (Darbyshire et al., 2017). This recognises the importance of plants in providing ecosystems services and enables the identification of conservation areas with co-benefits for species of both global conservation concern and local community importance. Such an approach could help tackle criticisms of large-scale priority mapping which often ignore local context and different knowledge systems (Wyborn and Evans, 2021; Tamburini et al., 2023). This is particularly pertinent considering the recognition that strict protected area management and marginalization not only poses societal and ethical issues, but is also counterproductive for conservation aims (Dudley et al., 2008).

Like the International Union for Conservation of Nature's (IUCN) Key Biodiversity Area (KBA) standard, IPA designation does not automatically confer national legal protection. Instead, IPA guidelines suggest that they can be used as a conservation tool at a range of scales and actively encourage bottom-up approaches to support national and

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regional strategic planning, or drive community-led sustainable management. As such, it is well-placed to address the needs for plant conservation in line with the goals, targets, and vision of the new GBF.

Colombia is one of the most biodiverse countries on earth, ranked second in the world for the number of plants it contains (Ulloa Ulloa et al., 2017). Combined with its rich cultural diversity, this has resulted in many plants with reported human uses, or useful plant species (Albuquerque et al., 2013; Paniagua-Zambrana and Bussmann, 2020; Diazgranados et al., 2022). Conserving the country's natural resources therefore has vital repercussions both within and beyond its borders. IPAs can help guide the selection of conservation areas for useful plants, however, an IPA network is yet to be described in the country and there are few examples of reserves designated for useful plants (Kor et al., 2021).

The Colombian Peace Agreement of 2016 has provided an opportunity to strengthen conservation action following decades of internal conflict. However, it has simultaneously increased pressures on natural resources, with a steep rise in deforestation rates (Bridge Colombia, 2017; World Resources Institute, 2021). A methodology for IPA identification in Colombia has been prepared but is yet to be applied at the national level (Diazgranados and Castellanos-Castro, 2018). It draws on the global IPA criteria, with some adjustments to account for the country's rich diversity and the challenges of accessing sufficient reliable species distribution data. The methodology addresses the first of the following four steps which are involved in the process of IPA creation: (1) identification based on available data and defined criteria; (2) confirmation by field sampling; (3) design of geographical boundaries; and (4) validation and publication.

In this study, we aim to identify potential IPAs for useful plants in Colombia by applying the national methodology, whose rationale and criteria are extensions of the global IPA concept. This represents the first national-level application of the IPA program in Colombia—one of the most biodiverse countries on earth—and provides a rare example of a systematic conservation approach for useful plants (Margules and Pressey, 2000; UN-WCMC, 2014). We consider the areas presented here as "potential" IPAs as the methods applied focus only on the first of the four steps involved in the IPA creation process.

2. Methodology

The global and Colombian methodologies for IPA identification are based on three criteria: (A) threatened species; (B) exceptional botanical richness; and (C) threatened habitats; each with associated sub-criteria and thresholds. In this study, we applied criteria A and B, as our focus is on useful plant species as biodiversity surrogates. The sub-criteria applied were chosen based on the availability of data and are presented in Table 1.

2.1. Species data

We based our analyses on all the native species listed in the Checklist of Useful Plants of Colombia (CUPC), with no weighting for number of uses. The CUPC was produced as part of the Useful Plants and Fungi of Colombia Project (UPFC) and is the most comprehensive data source on reported plant uses in the country, with 7472 species attributed with uses across ten categories based on the Level 1 uses of Cook (1995) (Diazgranados et al., 2022) (Table A1, Appendix A). We downloaded existing occurrence data from the Global Biodiversity Information Facility (GBIF, 2022), Botanical Information and Ecology Network (BIEN, 2022), and the virtual herbarium of the Jardín Botánico de Bogotá (JBB Herbarium, 2022). Data were taxonomically reconciled against the World Checklist of Vascular Plants v.5.0 (WCVP, 2021), combined, and cleaned including removal of duplicates (Fig. 1, stages 1 and 2).

The list of useful plant species that met criterion A was compiled based on species known to be globally threatened, nationally threatened, or not assessed but potentially restricted range (Fig. 1, stage 3a).

Table 1
IPA sub-criteria A and B and thresholds as defined in Diazgranados and Castellanos-Castro (2018). Criteria applied in this assessment in relation to useful plants of Colombia are indicated and relevant thresholds from the global criteria are presented for comparison.

Sub-criteria (Colombian methodology)	Applied	Colombian thresholds	Relevant global thresholds
(A) Threatened species			
A1. Globally threatened species	Yes	A1 & A2: Sites supporting ≥1 % of the global, ≥5 % of the regional, or ≥ 10 % of the national population	Site known, thought, or inferred to contain ≥1 % of the global population AND/OR ≥5 % "best sites" for that species nationally, whichever is most appropriate *NB. sub-criteria A3 and A6 are not in the global methodology*
A2. Regionally threatened species	No		
A3. Nationally threatened species	Yes	A3, A4, A5 & A6: Sites supporting ≥10 % of reported records OR if very few records, 5 sites with greatest number of specimens OR 6 to 10 UAs may be considered if there are only 1 or 2 specimens per UA Quantification proposed based on % of georeferenced herbarium collections and data repositories (GBIF/ BIEN/ SIB).	
A4. Highly restricted endemic (HRE) species that are potentially threatened	Yes		
A5. Range restricted endemic (RRE) species that are potentially threatened	Yes		
A6: significant populations of taxa of special interest (axiophytes)	No		
(B) Exceptional botanical richness			
B1: Highest estimated plant diversity of the relevant ecosystem type	Yes	B1: Site with the highest estimated diversity for each ecosystem	For each habitat or vegetation type: up to 10 % of the national resource can be selected within the whole national IPA network OR the 5 "best sites" nationally
B2: Areas which together support 10 % of an ecosystem's diversity	Yes	B2: Sites that contain at least 10 % of the total estimated species richness of each ecosystem, complementary to B1	*NB. instead of sub-criterion B2, the global methodology includes exceptional number of: B(ii) species of high conservation importance and B(iii) socially, economically or culturally valuable species. Thresholds: Site known to contain ≥ 3 % of the selected national list of socially, economically or culturally valuable species OR the 15 richest sites nationally, whichever is most appropriate*

Threat status was based on the IUCN Red List (IUCN, 2021) and the preliminary Red List of Plants of Colombia (received from the IUCN Colombian Plant Specialist Group in June 2021). Species listed as critically endangered (CR), endangered (EN) or vulnerable (VU) were included. Additionally, as useful species are the focus of this study, species listed as IUCN extinct in the wild (EW) were also included. For endemic species with no extinction risk assessment, extent of occurrence (EOO) was estimated based on the area of a minimum convex polygon drawn around their occurrence records. Highly Restricted Endemic (HRE; range < 100 km^2) or Restricted Range Endemic (RRE; range 100–5000 km^2) species which have not been assessed fall under IPA criterion A in Colombian and global methodologies (Table 1)

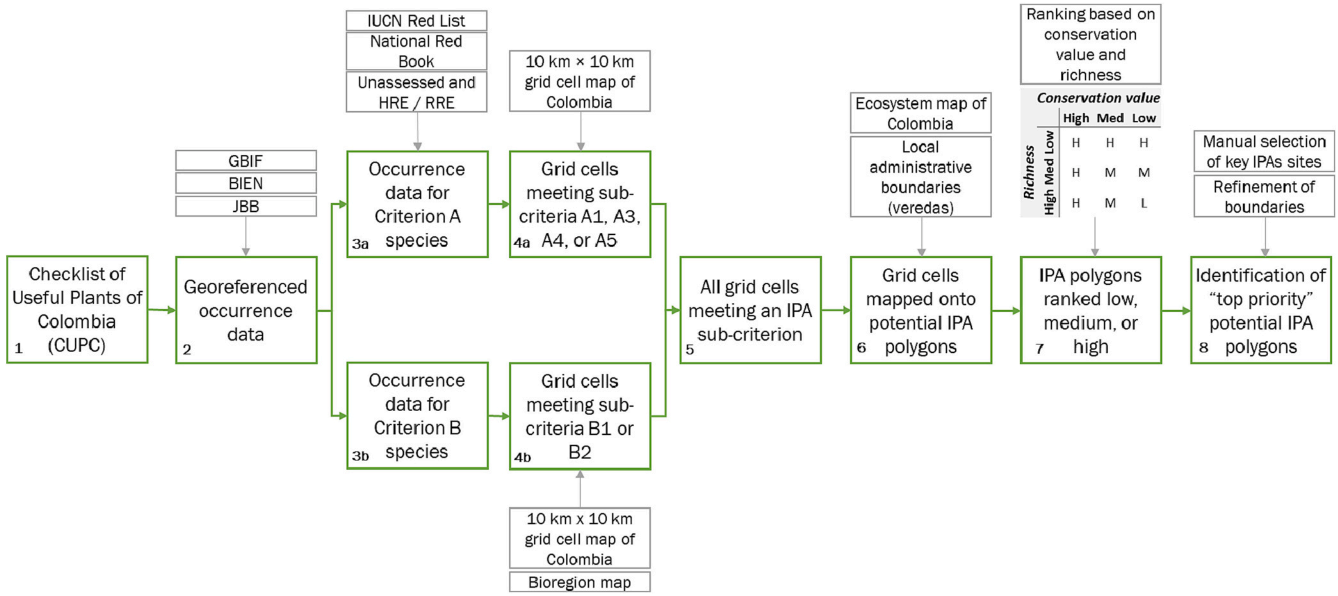

Fig. 1. Summary of workflow used to identify IPAs for useful plants in Colombia. Green boxes show steps taken in the IPA identification process, grey show data inputs at each stage. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

(Darbyshire et al., 2017; Diazgranados and Castellanos-Castro, 2018) (hereafter collectively referred to as *criterion A species*). For criterion B, occurrences of all native CUPC species were used in analyses (Fig. 1, stage 3b).

2.2. Units of analysis and potential IPA polygons

Representativeness is a key concept in Systematic Conservation Planning (Margules and Sarkar, 2007), on which the Colombian IPA methodology is rooted. Therefore, to identify potential IPA sites, we defined our units of analysis (UA) using a mixed approach, splitting the 13 bioregions of Colombia (Bystriakova et al., 2021) into 11,959 square cells of 10 km × 10 km (Fig. A1. Appendix A). This combination of the grid cell and a priori regionalisation was taken to benefit from the advantages of each approach. Grid cells avoid the issue of bias towards larger areas where UA vary in size, while regionalisation allows for representation of each bioregion type.

The number of records of each criterion A species occurring in each grid cell was calculated to form a matrix of UA × features (Margules and Sarkar, 2007). Cells were assessed against IPA thresholds to determine if they met any of the sub-criteria applied (Table 1). As population size for most of the priority CUPC are unknown at both the global and national level, quantification for criterion A was based on the proportion of georeferenced occurrence records in accordance with the Colombian IPA methodology (Diazgranados and Castellanos-Castro, 2018). Therefore, grids with no occurrence records did not feature in the analysis (Fig. 2).

For criterion B, the UA supporting the highest estimated diversity of useful plant species within each bioregion was highlighted (B1). Estimated richness was calculated using Chao 1, chosen as it is suitable for presence-only data and estimations for single sites (in this case grid cells) rather than requiring incidence data and a collection of sites (Gotelli and Colwell, 2011). Where the number of observed species reported as occurring in the qualifying grid did not contain 10 % of the bioregion's observed total species, sub-criterion B2 was also applied. This was undertaken by choosing the site with the next highest observed species richness and calculating if the combined number of unique species in the two grid cells met the 10 % threshold for the bioregion. In all cases, no further cells were required to meet the threshold.

Following the identification of grid cells meeting IPA sub-criteria, more ecologically and politically relevant potential site boundaries were defined (Blasi et al., 2011). This was based on splitting the 30 synthesised ecosystems of Colombia in the *Mapa de Ecosistemas Continentales Marinos y Costeros de Colombia* (MADS et al., 2017) at the borders of Colombia's *veredas* (DANE, 2020). A *vereda* is a subdivisional administrative part of a municipality in Colombia, usually located in rural areas and including between 50 and 1200 inhabitants. The intersection between the 32,305 veredas (DANE, 2020) and the 30 synthesised ecosystems of Colombia resulted in 264,270 polygons. Polygons overlapping with qualifying IPA grid squares were filtered and mapped (Fig. 1, stage 6).

2.3. IPA ranking

A two-step process was used to prioritise the potential IPAs identified across Colombia. In the first step, qualifying grid cells were ranked depending on (a) conservation concern and (b) richness. For conservation concern, grids were ranked based on the number of criterion A species observed, classified as low, medium, or high according to the Natural Breaks (Jenks) function. For richness, grids triggering sub-criterion B1 were ranked as high, B2 cells with the second highest number of species were ranked as medium, and any remaining criterion B trigger grids as low. Overall rank was determined by combining the ranks from each criterion, taking a similar approach to Blasi et al. (2011); cells ranked high for either or both criteria were classified as "high" rank overall; cells with medium values for either or both were classified as "medium", and cells with low values for both criteria were defined as "low" (see matrix in stage 7 of Fig. 1).

In the second step, all grid cells found to be of high rank were further investigated to select "top priority" IPAs for useful plants. This was based on a combination of naturalness and importance of habitat determined through satellite images; whether the area was already under conservation designation; and investigation into occurrence records to ensure they were representative of the area's importance rather than data collection efforts (e.g., in and around urban areas with plant research units). Data on the current system of protected areas and other effective area-based conservation measures (OECMs) in Colombia were downloaded from Protected Planet to support this selection and identify gaps in in-situ conservation (UNEP-WCMC and IUCN, 2023).

Data retrieval, management, and analysis were performed in R

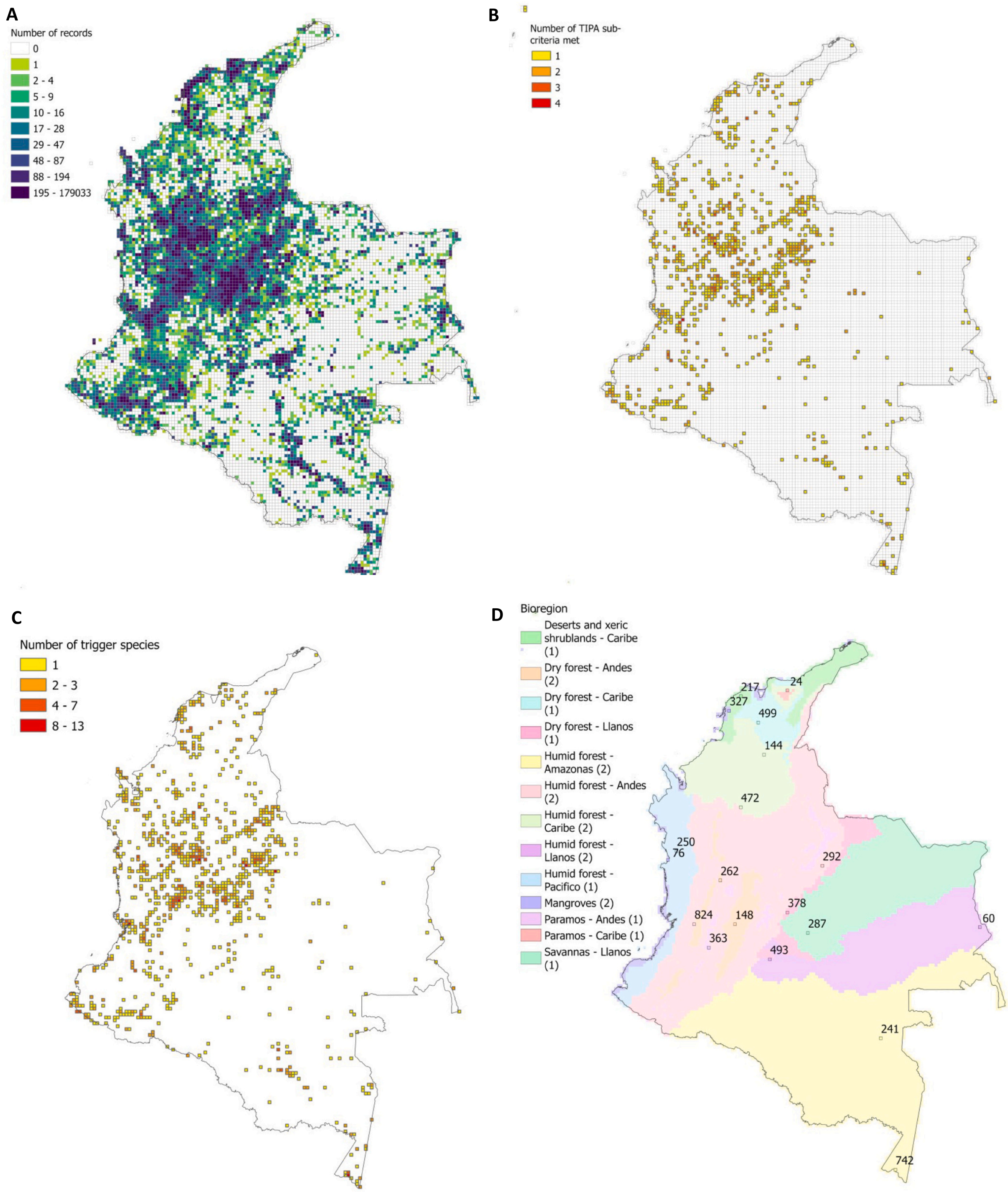

Fig. 2. Process of identification of IPAs in Colombia. A) distribution of occurrences of native useful plants across the units of analysis (UAs), colour distribution displayed using quantile method, B) UAs which met any of the sub-criteria tested, with a potential maximum of five (Table 1), C) UAs which met criterion A for threatened species (colour indicates number of criterion A species recorded in each grid), and D) UAs which met criterion B for exceptional botanical richness displayed according to bioregion, with numbers indicating the number of native useful plant species observed.

version 4.2.0 (R Core Team, 2022) using the *tidyverse* meta-package (Wickham et al., 2019) and the packages *CoordinateCleaner* (Zizka et al., 2019), *rgbif* (Chamberlain et al., 2021), *BIEN* (Maitner Brian et al., 2017), *sf* (Pebesma, 2018), *conR* (Dauby, 2020), and *vegan* (Oksanen et al., 2022). Mapping was undertaken in ArcGIS Pro 3.0.3 (Esri Inc., 2022).

3. Results

Data gathering and processing resulted in 1,045,889 occurrence records in Colombia for 5400 useful plant species, representing 92 % of native species listed on the CUPC (Fig. 2A). All occurrence records were used to assess grid cells against criterion B, while for criterion A, only records for the selected 631 criterion A species were included (i.e., threatened species), with no records available for 24 of these (Table A2, Appendix A).

A total of 980 grid cells were found to meet at least one IPA subcriterion (Fig. 2B). Of these, 975 fell under criterion A, with a maximum of 13 species of conservation concern reported to occur at the threshold level in any single grid cell (Figs. 2C). In seven bioregions, 10 % of the total observed species richness was accounted for in the grid cell estimated to have the highest richness (B1), negating the need to apply sub-criterion B2. In the remaining six bioregions, only one additional grid cell was required to meet the 10 % threshold, with a total of 19 cells therefore qualifying as potential IPAs under criterion B.

Based on the current system of protected areas and OECMs (UNEP-WCMC and IUCN, 2023), 651 qualifying IPA grid cells intersected with existing designations (66.4 %). When we included only designations within the six management categories of Colombia's system of national natural parks and internationally binding designations (Ramsar Sites, World Heritage sites for natural features, UNESCO-MAB Biosphere Reserves, and Specially Protected Areas under the Cartagena Convention), this decreased to 194 grid cells (19.8 %) (Fig. A3. Appendix A).

Overlaying all potential IPA cells with habitat polygons resulted in an area of 38,168,908 ha (36.7 % of Colombia's total land area), spanning all the 32 departments and the capital district of Colombia. While most potential IPA grid cells occurred in the Department of Antioquia (164), the majority of the polygon areas fell within the Amazonas (7,641,891 ha), due to the relatively large size of the polygons defined in the latter department.

The grid cells triggering IPA criteria most commonly occurred in the humid forest, Andes bioregion, followed by the humid forests of the Pacífico, Caribe, and Amazonas. The least represented bioregion was the Páramos, Caribe, reflective of it being the smallest of the bioregions (Bystriakova et al., 2021). Forest ecosystems were the most represented ecosystem type in the potential IPA polygon areas (23,760,714 ha).

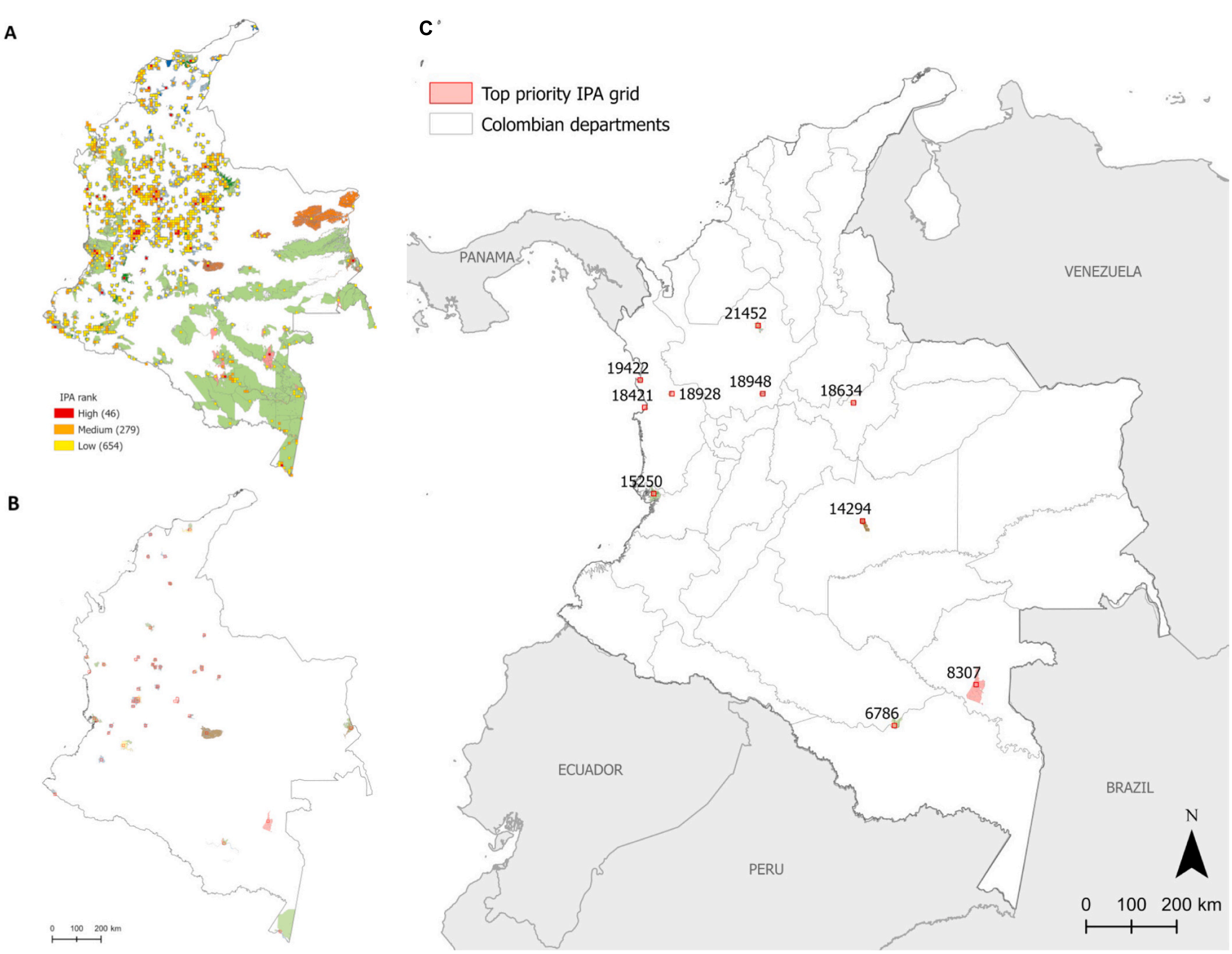

Fig. 3. A) Grids which met IPA criteria, joined with overlapping polygons of ecosystems × veredas; B) IPAs polygons of high rank; and C) Top priority IPAs for useful plants in Colombia (numbers correspond to grid IDs, see Table 2 and Appendix B for details on each site).

3.1. Prioritised IPAs

Through a ranking process, 46 potential IPA grids were found to be high, 280 medium, and 655 low priority (Fig. 3A). Polygon definition of the highly ranked cells resulted in an area covering 2,074,997 ha (2 % of Colombia's land area), with most area falling in the forest bioregion and Department of Amazonas.

Further investigation of the high priority IPA polygons led to the choice of 10 "top priority" sites. We refined their boundary areas, based on the location of occurrence records for the species for which they qualified as potential IPAs (Fig. 3C). The proposed top priority IPAs are summarised in Table 2, with further detail and breakdown of each site in Appendix B. In total, these cover an area of 280,595 ha, with a mean IPA size of 28,060 ha. The sites span 13 municipalities in eight departments, with the most represented department being the Chocó, where three of the ten sites are located. Of these, only one overlaps with an existing site in the Colombian system of National Natural Parks (COL15250). Six of the other sites overlap with related designations such as indigenous reserves (COL6786, COL8307), regional and local parks (COL15250), watershed and integrated management districts (COL18948, COL18421), and a KBA (COL21452) (Table 2).

4. Discussion

Through the application of globally recognised criteria for IPAs and national thresholds designed for Colombia, we present proposed IPAs for useful plant species in the country. These are important first steps in developing solutions for the protection and the long-term sustainable use of plants in one of the most biodiverse countries in the world (UN-WCMC, 2014). In this section, we discuss the work required to move from potential to confirmed IPAs and the characteristics and priorities of the potential IPAs identified.

4.1. From identification to conservation

Our analyses were based on existing occurrence records from multiple data repositories. As with other analyses of this type, data limitations were experienced, with biases in the geographic distribution of records and scant or missing records for some species (Bystriakova et al., 2021). These challenges have affected conservation planning globally, including for IPA networks, with under-sampling of plants acknowledged as a key limitation in the Colombian IPA methodology (Blasi et al., 2011; Diazgranados and Castellanos-Castro, 2018; Hamidah et al., 2020). Additionally, assessments of extinction risk for plants are not representative, with only 45 % of Colombian useful plants having global or national level assessments (Nic Lughadha et al., 2020; Kor et al., 2022). To overcome these gaps, we calculated the EOO of species known to be endemic to Colombia, providing preliminary conservation assessments based on a criteria included in the IUCN approach (Darbyshire et al., 2017). However, these assessments are only as good as the available data. Ongoing efforts to extend the Colombian Red List for plants are therefore hugely encouraging, with the Red List for the endemic trees of Colombia recently completed (Lopez-Gallego and Morales-Morales, 2023). However, more field data and research are still required to improve our understanding of species distribution and support conservation prioritisation.

The areas identified are considered "potential" IPAs, representing the first stage in effective conservation by guiding the selection of areas for local, regional, or national protection. To move from potential to confirmed IPAs, targeted fieldwork is required alongside stakeholder engagement and consultation (e.g., local users, community groups, national, regional, and local government, NGOs) (Margules and Pressey, 2000; Holland et al., 2012). Partnerships with communities are crucial in this process and would help to improve understanding of local plant use, willingness to engage in the IPA process, and context-specific conservation and management measures. This is particularly important as the uses highlighted in the CUPC are based on global data, rather than uses specific to the location of occurrence. Focusing on plants which are used by local people is a means to better engage communities in conservation and sustainable management, with the combination of both scientific and local knowledge shown to generate the most comprehensive understanding (Kor et al., *in press*). Stakeholder engagement must also involve relevant local and regional authorities, and seek to collaborate with other national conservation efforts, such as the Colombian KBA programme.

Once confirmed, effective management of IPAs for useful plants could become an important means to provide social, environmental, and economic co-benefits by protecting species of both conservation concern and community importance. This goes some way to dealing with issues associated with area-based conservation prioritisation and targets, which have been criticised for their top-down nature, ignoring local context and different knowledge systems (Wyborn and Evans, 2021; Tamburini et al., 2023).

Table 2
Details on the ten top priority potential IPAs for useful plants identified in Colombia (further details and maps in Appendix B).

ID	IPA criteria[a]	Municipality	Department	Bioregion[b]	Overlapping designations[c]	Area (ha)
COL6786	A1, A3	Solano	Caquetá	Humid Forest, Amazonas	None	33,368
COL8307	B1	Pacoa	Vaupés	Humid Forest, Amazonas	None	136,621
COL14294	B1	San Martín	Meta	Savanas, Llanos	None	26,253
COL15250	A1, A3	Buenaventura	Valle del Cauca	Humid Forest, Pacífico	*La Sierpe Regional National Park*; Coastal Environmental Unit of the Málaga-Buenaventura Complex	43,217
COL18634	A1, A3	Sotaquirá and Paipa; Gámbita	Boyacá; Santander	Humid Forest, Andes	None	7979
COL18948	A1, A3	San Luis	Antioquia	Humid Forest, Andes	None	7298
COL18928	A1, A3, A4	Medio Atrato	Chocó	Humid Forest, Pacífico	None	5334
COL18421	A1, B1	Nuquí	Chocó	Mangroves	Integrated Management District of the Golf of Tribuga Cabo Corrientes	2028
COL19422	A1, A3	Bahía Solano	Chocó	Humid Forest, Pacífico	None	5645
COL21452	A1, A3, B2	Anorí	Antioquia	Humid forest, Caribe	*Key Biodiversity Area Reserva Regional Bajo Cauca Nechí*	12,852

[a] Based on Colombian methodology (Table 1).
[b] Based on Bystriakova et al., 2021.
[c] Based on the Colombian system of protected areas and OECMs, with national and international level designations in italics (UNEP-WCMC and IUCN, 2023).

4.2. Potential IPAs in Colombia

Of the 980 potential IPAs identified, the majority were triggered by Colombian IPA sub-criterion A1 for the presence of globally threatened species, followed by A3 for the presence of nationally threatened species. This is in line with the recognised importance of extinction risk assessments in conservation prioritisation (Nic Lughadha et al., 2020) and the results of other Tropical IPA (TIPAs) projects, with 97.7 % of the 172 designated sites on the TIPAs Explorer qualifying under criterion A (RGB Kew, 2016). Such findings reflect the nature of IPA guidelines; as criterion B thresholds are linked to species richness per ecosystem, the number of sites which can be triggered is limited by the number of ecosystem types, whereas criterion A can be triggered by any site which meets the threshold for a potentially very long list of threatened species (Table 1) (Diazgranados and Castellanos-Castro, 2018). As our focus was on useful plant species as biodiversity surrogates, we did not apply criterion C, which is based on threatened habitats and does not contain sub-criteria relevant to useful plants. This could be an important future focus for IPA identification in Colombia, which could utilise the existing Colombian Red List of ecosystems (Etter et al., 2017).

The bioregions with the highest number of potential IPA grids were the humid forests of the Andes and Pacífico. This reflects the areas' high species richness, with both bioregions known to support some of the highest number of useful plants in Colombia and overlapping with global biodiversity hotspots (Myers et al., 2000; Bystriakova et al., 2021). However, results are also likely to reflect biases in data availability. Bystriakova et al. (2021) found that dry bioregions have the highest proportion of under-sampled areas for plants in Colombia, recommending that future research focuses on such areas, including the llanos (Orinoquia) regions.

Regarding current conservation, only 19.8 % of the potential IPA grid cells overlap with either Colombia's existing system of national protected areas or areas under international designations (UNEP-WCMC and IUCN, 2023). This represents a gap in in-situ conservation for socio-economically important species in Colombia. Just one national park in the country is designated specifically for its plants with medicinal uses—the *Santuario de Flora Plantas Medicinales Orito Ingi-Ande*, which was first proposed by the Kofanes community in southwestern Colombia (WWF-Colombia, 2008).

The potential IPAs for useful plants we highlighted in this study could inform the designation of further such biocultural areas in Colombia. In addition, since the inclusion of socially, economically, and culturally important species in IPA guidelines, this study is the first known example of its application at the national level (Darbyshire et al., 2017). Other relevant examples include work in the Himalaya region and in China to identify conservation areas for medicinal plants (Hamilton et al., 2007; Chi et al., 2017).

Our delineation of IPA polygons was based on combining ecosystems and veredas. This gave both socio-political and ecological meaning to our site boundaries and enables the identification of local authorities and communities who would be most relevant in supporting site recognition and management. However, polygon delineation resulted in a large area of land being highlighted (36.7 % of Colombia's land area) and the IPA polygons were of variable size (Fig. 3A). For example, extremely large IPAs were identified in the Department of Amazonas, which was more homogenously categorized as forest habitat and where sparse population density gives rise to large vereda and municipality borders. Therefore, while only 9 % of the triggered grid cells were in the Amazonas, the potential IPA polygons in the department accounted for 20 % of the total area initially identified. This is reflective of criticisms of the "land hungry" nature of IPA and KBA criteria, especially in mega-diverse countries (Darbyshire et al., 2017). In line with IPA guidelines, which suggest selecting the most important sites from those that meet the criteria, we therefore undertook a two-step ranking procedure.

4.3. 4.2. Top priority IPAs for useful plants

Ranking approaches have been commonly used to inform the identification of IPAs (Hamidah, 2020; Hamidah et al., 2020). As with Blasi et al. (2011), we based the first step of our ranking on values of conservation and richness. The sites categorized as being of high value were then subject to review by the authors of this study to select 10 top priority potential IPAs. This was based on investigating satellite images, existing designations, and other relevant data to determine the reliability of occurrence records, identify sites with greater in-situ conservation gaps, and refine polygon boundaries.

Three of the 10 sites occur in the Department of Chocó. This area is dominated by neotropical rainforest and mangroves and is recognised as a global hotspot of both biological and human diversity (Myers et al., 2000; Medina-Rivas et al., 2016). However, while a large proportion of the Colombian Chocó is collectively titled to Amerindian and Afro-American groups, protected areas and OECMs are poorly represented (Fig. A3. Appendix A) (Cámara-Leret et al., 2016). Work on confirming these potential IPAs for useful plants could therefore provide a means to facilitate wider stakeholder consultation beyond the scientific community and engage local communities in long term protection and sustainable management, while acknowledging the importance of wild species for livelihoods in one of the most bioculturally diverse regions on earth (Darbyshire et al., 2017).

The remaining top priority sites identified are distributed across the country. They support significant populations of 33 threatened useful plant species and represent six of the 13 bioregions of Colombia in just 0.27 % of its land area. Currently, just one of these sites overlaps with an existing National Natural Park (La Sierpe Regional National Park) and another is located within a KBA (Reserva Regional Bajo Cauca Nechí), representing significant in situ conservation gaps for the most important sites for useful plant conservation in Colombia. While all the potential IPA areas identified in this study warrant attention, we suggest that these 10 sites are prioritised for further investigation and conservation action.

5. Conclusions

IPA identification supports Global Biodiversity Framework targets for 30 % of land to be under effective conservation management by 2030, of which Colombia is a signatory (CBD, 2022). Meanwhile, our focus on useful plants helps to address growing recognition of the importance of biodiversity to humans, and the need to involve human dimensions of conservation for effective and equitable outcomes (Díaz et al., 2015). This is also in line with Colombia's National Strategy on Plant Conservation objectives on sustainable use and useful plant protection (Castellanos-Castro et al., 2017). In addition, it contributes to calls to integrate biodiversity conservation and bioeconomic growth in the country's post-conflict development (Baptiste et al., 2017).

While this first step in IPA identification has been largely based on scientific data, sustainable wild plant use is most successful when conservation and management is driven by local resource users. Knowledge of harvesting rates, practices, and species biology is also crucial in developing site management plans (Kor et al., 2021). We therefore encourage the sites identified to be further investigated for conservation action involving a range of stakeholders including local users, regional authorities, national governments, species experts, and conservation and development organizations. This crucially requires further field data, with this research joining others in highlighting many geographic gaps and biases in plant occurrence records across Colombia (Bystriakova et al., 2021; Kor et al., 2022).

As a global biodiversity hotspot and centre of endemism, the protection of Colombia's habitats and wildlife are crucial for both national and international wellbeing. But this cannot be achieved without the involvement of people. Strict protected area management and marginalization of communities has been increasingly shown to not just pose societal and ethical issues, but to also be counteractive for conservation aims (Dudley et al., 2008). We therefore encourage more conservation prioritisation efforts to consider the human dimensions of biodiversity. Through the inclusion of socio-economically valuable plant species, IPA guidelines provide a consistent framework for this, yet this study is to our knowledge the first national-level assessment focusing on useful species. Our approach is readily transferable and can help to support the wider application of area-based conservation approaches “for the benefit of [both] planet and people” (CBD, 2022).

CRediT authorship contribution statement

Laura Kor: Conceptualization, Methodology, Data gathering and curation, Formal analysis, Visualisation, Writing- original draft. **Mauricio Diazgranados**: Conceptualization, Methodology, Supervision, Writing- review & editing, Funding acquisition.

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

The dataset supporting this article is openly available on the Figshare data repository (DOI: https://doi.org/10.6084/m9.figshare.23290103) and code used for analysis will be shared on the lead author’s GitHub repository.

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Appendices. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.biocon.2023.110187.

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