Biogeographia – The Journal of Integrative Biogeography 2023, 38 (2): a031
https://doi.org/10.21426/B638262151

Two Open Access datasets from the digitization of 50,493 herbarium sheets from Pondicherry and Baroda collections with a focus on the Western Ghats

JULIEN ANDRIEU[1,*], AYYAPPAN NARAYANAN[1], BALACHANDRAN NATESAN[1], BALASUBRAMANIAN DHANDAPANI[1], RIYA ENGINEER[2], PRADEEP CHANDRASEGARANE[1], KRISHNA RAJPUT[2], RAMESHKUMAR KOTHANDAPANI[1], SRILATHA RAMAKRISHNAN[1], PADAMNABHI S. NAGAR[2]

[1] French Institute of Pondicherry CNRS MEAE, 11 Saint Louis Street, 605001 Pondicherry, India
[2] BARO Herbarium, Department of Botany, Faculty of Science, The Maharaja Sayajirao University of Baroda, 32 Aurobindo Ghosh road, 390002 Vadodara, India

** email corresponding author: julien.andrieu@ifpindia.org*

Keywords: GBIF, Herbarium, India, Open biodiversity data, plants, Western Ghats.

SUMMARY

Human activities have led to a substantial loss of biodiversity, with terrestrial ecosystems experiencing over a 20% average reduction. Conservation priorities are crucial, but data on species, threats, and protection are limited, especially in tropical countries like India. Open biodiversity data, facilitated by platforms like the Global Biodiversity Information Facility (GBIF), are a powerful tool for addressing these challenges. This paper describes two datasets (for a total of more than 50,000 plant occurrences), primarily from the Western Ghats, a UNESCO World Heritage site and biodiversity hotspot. The two datasets could play a pivotal role in supporting conservation policies, since they provide valuable insights into the unique biodiversity of the Western Ghats.

INTRODUCTION

As a result of human activities, terrestrial ecosystems are estimated to have lost more than 20% of their biodiversity (Hill et al., 2018; Pörtner et al., 2021). According to Pimm et al. (2014), global extinction rates are estimated to be 100 to 1000 times greater than the background rate of extinction. 20% of plants are threatened (Brummit et al., 2015) because of habitat loss, mainly due to agricultural expansion (NicLughadha et al., 2020). However, plants play a less significant role than animals in determining conservation priorities (Corlett, 2016).

Anthropogenic impacts are of growing scientific, political, and societal concern (Diaz et

al., 2019). Therefore, setting priorities for conservation has been the focus of research at the global level (Mittermeier et al., 1998; Myers et al., 2000; NicLughadha et al., 2020), as well as at regional and local scales (Darbyshire et al., 2017; Sanchez et al., 2021). Tools dedicated to aiding decision-making focus on taxonomy, such as the IUCN Red List (IUCN, 2022), or on space, such as the Important Plant Area (IPA) (Darbyshire et al., 2017). However, data on plants (e.g., species occurrence and threats) show important geographical and taxonomical gaps (Sanchez et al., 2021). The same holds true for plant threats and conservation (Darbyshire et al., 2017). Plant conservation is under-resourced when compared to animal conservation (Havens et al., 2014). Information on rare and threatened plants and habitats is limited, difficult to access, and often outdated. For example, only around 5% of all plant species have been assessed applying IUCN criteria (Bachman et al., 2019). Important Plant Areas have not been defined yet for several countries, including India (Darbyshire et al., 2017).

Open biodiversity data are a powerful tool for science applied to conservation (Farley et al, 2018). Science relies on open biodiversity data, in particular on 'presence-only' datasets (Mandeville et al., 2021). Global efforts to collect, digitize, publish, and aggregate distribution data, in particular through the Global Biodiversity Information Facility (GBIF), enabled access to large quantities of occurrence records (Meyer et al., 2015). Production and use of open biodiversity data increases reproducibility (Alston and Rick, 2021); enables various analysis of a dataset (Chawinga and Zinn, 2019); helps researchers in receiving citations of datasets (Costello et al. 2013; Brown, 2021). It also reduces the duplication of research effort (Troudet et al., 2017).

Biodiversity open data availability should be enhanced in several tropical countries, including India (listed as one of the 17 mega biodiversity countries). India has 4 biodiversity hotspots (Meyer et al., 2015), including the Western Ghats (listed as one of the UNESCO World Heritage sites).

The Western Ghats Mountains are an ecological unicum, consisting of different types of tropical forests and grasslands harboring a large biological diversity and a relevant amount of endemic species (Champion and Seth, 1968; Subramanyam and Nayar, 1974; Pascal, 1988; Reddy et al., 2021). The Western Ghats are highly valuable for biodiversity conservation, climate change mitigation, and long-term environmental sustenance, and they are one of the eight biological hotspots in the world inscribed as a UNESCO World Heritage site. The forests of the Western Ghats are under the influence of human threats, such as deforestation from agricultural expansion and urbanization, and indirect threats, such as climate change. Recent studies have revealed that the Western Ghats lost 35% of forest cover between 1920 and 2013 (Reddy et al., 2016).

The Western Ghats have been the object of biodiversity investigation for decades by both the French Institute of Pondicherry and The Maharaja Sayajirao University of Baroda. These activities resulted in the collection of a relevant amount of data. This paper presents two datasets, for a total of 50,493 occurrence records of plants, the very large majority located in the Western Ghats, published through the Global Biodiversity Information Facilities (Edwards et al., 2000). The data were mobilized at the end of an 18-month project targeting Information from natural history collections (NHCs), which are important in the context of Open Data mobilization (Graham et al., 2004).

MATERIALS AND METHODS

Data collection

This database contains the specimens of vascular flora recorded in two herbaria, gathered, curated and published separately. They share very strong similarities in data collection and archives and have been digitized with the same protocol. Parts of this paper will reveal common method. Other

will separately present the 2 datasets as long as they are published separately on the GBIF.

The Herbarium of The Maharaja Sayajirao University of Baroda, Department of Botany, Faculty of Science "BARO" as indexed in INDEX HERBARORIUM, is the only recognized largest herbarium of Gujarat currently holding over 36,000 specimens, representing 2,539 species, 1,144 genera and 199 families (33,000 herbarium specimens at BARO Herbarium of which around 3,598 are exclusively of The Dangs and that of Waghai Botanical Garden collection). It has exclusive collection of 43 specimens of endangered and threatened species, which includes 10 near threatened, 5 critically endangered, 19 vulnerable, and 9 endangered species. BARO is one of the major collections of the plants from Kachchh district, which is characterized by a high level of endemism. The herbarium started as a repository of plants for researchers and students at the erstwhile Baroda College in the late 1880s. The herbarium was formally structured with the inception of the Department of Botany in 1957. The herbarium was enriched by taxonomic research into the flora of different areas of Gujarat which have resulted in more than 25 Ph.D. theses. The specimens represent the diversity found in four of the biogeographical regions of India which are found in Gujarat.

The Herbarium of the Institut Français de Pondichéry (HIFP) collection encompasses 27,094 herbarium specimens representing 4,659 species, 1,418 genera and 268 families, which were collected since the establishment of the Institute in 1955, 11, St Louis Street, Pondicherry, India. Though HIFP have collections from all habitats and regions of India including Andaman Islands, the majority of collections were from south and central Western Ghats i) to develop vegetation maps for peninsular India, and explicitly for the Western Ghats, subsequently ii) to develop field guides for species identification (both by vegetative and e-keys), iii) to identify the vegetation dynamics and forest cover change and iv) to decipher the distribution pattern of endemic species and rationalize the conservation areas in the Western Ghats.

Sampling description

The two herbaria are collections of botanical observations associated with sample collection and conservation. It has not been built with a precise sampling method but results instead of various methods put together.

Archives

Specimen processing followed a standard procedure described in Bridson and Forman (2000) concerning collection mounting and conservation. Specimens are pressed and dried at the laboratories of Pondicherry and Baroda. Dried specimens are mounted on acid-free paper. They are labelled to provide information on taxonomy, distribution, collection date, legitimavit and determinavit and various other observations. Finally, a unique identifier is provided for each specimen, which is then integrated into the herbarium collection.

Data capture

The digitization of data is conducted in two parts. The first part involves developing the master data sheet in MS Excel format. Trained team members review the specimens from the collection and verify the coincidence with the assigned taxonomic information. Subsequently, colleagues hired for the funded project manually capture and digitize the information from the labels using an Excel sheet. The information is input into different columns of a record, including Species Name, Genus, Family, Scientific authority, Date of collection, Place of collection, State of Collection, Collector, Vernacular Name, Remarks by the collector, and Identity confirmation expert as the basic columns. Additional columns are based on information available in the field notebooks.

During the second part of digitization, the specimen is scanned using an overhead scanner at 300 dpi resolution. Standard scanning protocols are followed, and a color checker card as well as a scale are included during the

scanning process. The data in the image file is then cross-checked with the data entered in the master data sheet.

Data curation

This Excel file has been curated, information has been cross-checked, and gaps in data were identified. To check taxonomy and accuracy, we compared scientific names with The Plant of the World online (https://powo.science.kew.org/) and used the GBIF's Taxon Match Tool (https://www.gbif.org/tools/species-lookup). Given that the taxonomy of many groups has changed in recent decades, making it sometimes tricky to track, we also revised the taxonomy to avoid any uncertainty about the identity of the species. Finally, the curated data were uploaded to the GBIF platform to make them publicly available.

Table 1. Variables recorded for each occurrence, with explanation of the type of data and reference system.

variable	type of data
occurenceId	unique identifier
basisOfRecord	text
eventDate	date
eventRemarks	text
catalogNumber	unique identifier
recordNumber	unique identifier
kingdom	text
scientificName	text
occurrenceRemarks	text
verbatimLocality	text
decimalLatitude	numerical, WGS84 reference system
decimalLongitude	numerical, WGS84 reference system
geodeticDatum	text
coordinateUncertaintyInMeters	numerical
georeferenceProtocol	text
georeferenceVerificationStatus	text
countryCode	unique identifier for country, according to XX
country	text
collectionCode	unique identifier
georeferencedDate	Date
institutionCode	unique identifier
institutionID	unique identifier
type	Text
preparations	Text
license	Text
recordedBy	Text

The specimens that were collected prior to 2005 generally have localities only, and precise geographical coordinates were not collected at the time of specimen collection. Most of the collections have been part of restricted floristic works by different researchers, and in most cases, the locations are precise to the village/locality. Geographical coordinates for these specimens are estimated using the Geolocate online tool, which also produces an evaluation of uncertainty in meters. For most collections after 2005, GPS

coordinates have been collected during specimen collection. Approximately 70% of the specimens belonging to the Dangs region have precise GPS coordinates.

Various tools have been used to track and correct typographic mistakes (Excel, OpenRefine, Specify 6). The fields have been formatted according to The Darwin Core standards. The dataset has been submitted to the GBIF's data-validator tool.

RESULTS

Datasets

In these two separate but consistent datasets (.csv files, comma delimited), each row represents the single record of a plant species in one geographical point. Moreover, 26 additional variables are reported for each record (Table 1).

Dataset 1 - BARO

Dataset name 1: BARO Herbarium, The M.S University of Baroda

Format name: csv.

Character encoding: UTF_8.

Distribution: Accessible through the GBIF at https://www.gbif.org/dataset/0a5eec5f-ea21-4c00-b55a-9e5a5d336c3c and identified by DOI: https://doi.org/10.15468/hdwj5g.

Date of publication: 27 April 2023.

Date of last review: 27 April 2023.

Update policy: none.

Language: English.

Resource citation: Nagar P, Raole V, Shah D, Andrieu J, Engineer R, Rajput K (2023). BARO Herbarium, The M.S University of Baroda. Version 1.5. BARO Herbarium, The Maharaja Sayajirao University of Baroda. Occurrence dataset https://doi.org/10.15468/hdwj5g.

Database managers: Nagar P.

Temporal coverage: 1892-02-02 - 2018-12-28

Record basis: Preserved specimen.

Sampling methods: The data set was created collating different botanical observations.

Funding grants: BIFA grant Japanese Ministry of Environment.

Geographic coverage: Western Ghats, India

Dataset 2 - HIFP

Dataset name 2: Herbarium of the French Institute of Pondicherry

Format name: csv.

Character encoding: UTF_8.

Distribution: Accessible through the GBIF at https://www.gbif.org/dataset/89fa407a-f4f3-4f9c-90a2-3d37388a90ab and identified by DOI: https://doi.org/10.15468/un3c1t

Date of publication: 8 May 2023.

Date of last review: 8 May 2023.

Update policy: none.

Language: English.

Resource citation: Chandrasegarane P, Andrieu J (2023). Herbarium of the French Institute of Pondicherry. Version 1.6. French Institute of Pondicherry. Occurrence dataset https://doi.org/10.15468/un3c1t.

Database managers: Srilatha R. (HIFP).

Temporal coverage: 1847-01-01 - 2022-05-17.

Record basis: Preserved specimen.

Sampling methods: The data set was created collating different botanical observations.

Funding grants: BIFA grant Japanese Ministry of Environment.

Geographic coverage: Western Ghats, India

Summary statistics

By publishing 50,493 occurrences, we added to the knowledge about the world's flora 48,692 occurrences shared between 4,941 species.

Within such dataset, 1,741 species, 86 genera and 5 families are being published for the first time on GBIF.

The Herbarium of the French Institute of Pondicherry published 25,023 occurrences (25,014 Plantae, 9 Fungi) covering 267 families (Figure 1).

The BARO Herbarium published 25,473 occurrences of Plantae, covering 199 families (Figure 1).

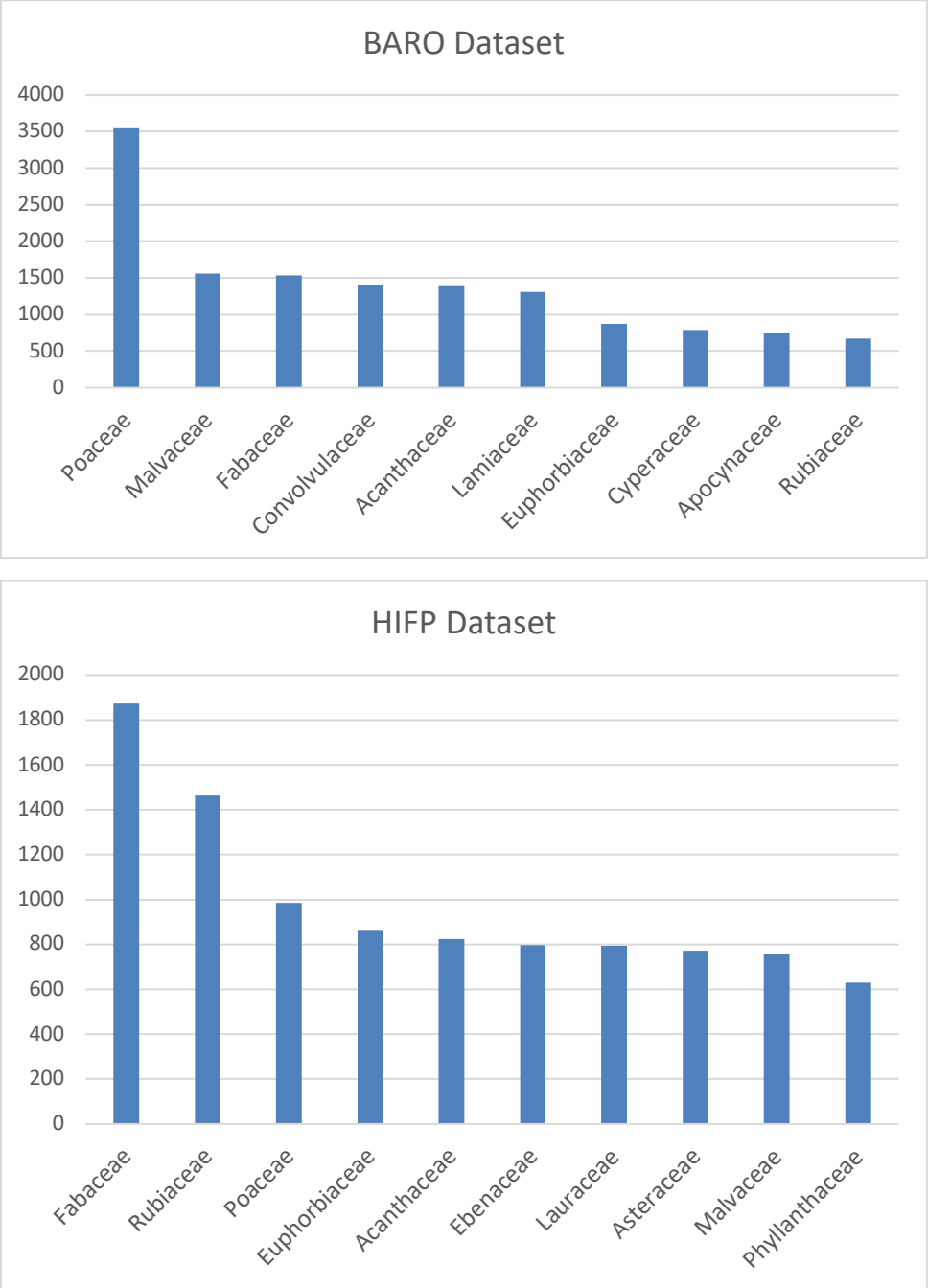

Figure 1. The 10 families with the highest number of occurrences in the two herbaria. Families are listed on the X axis in order of abundance of occurrences; the Y axis reports the number of occurrences.

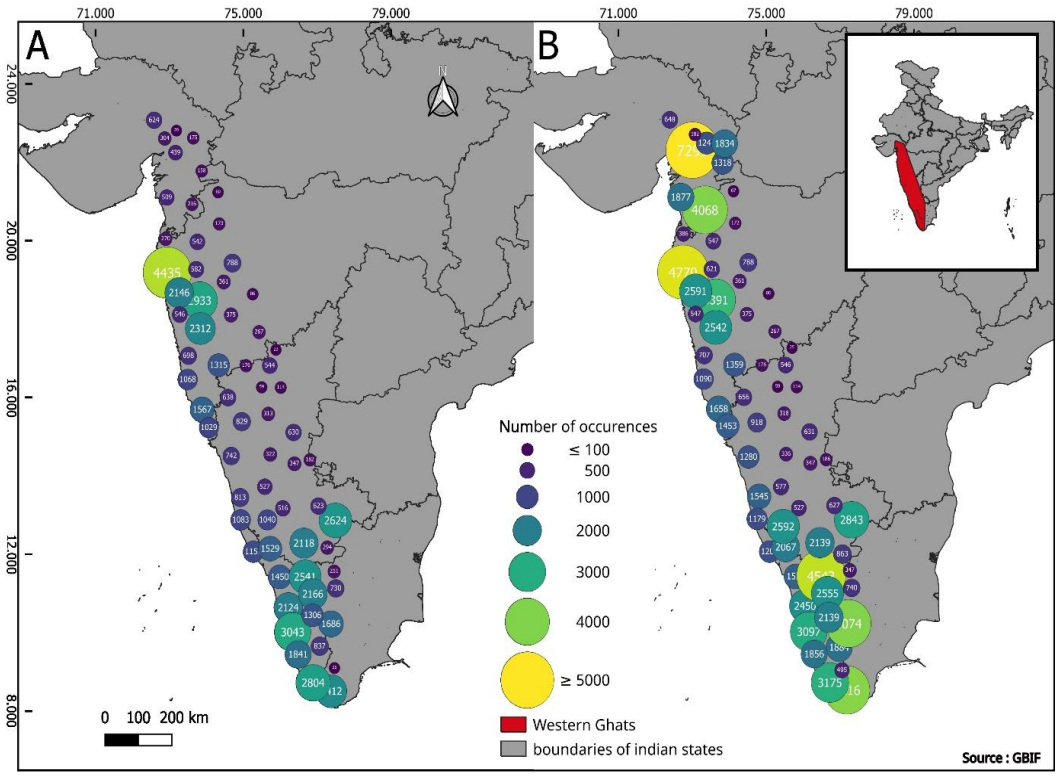

Figure 2. Map of South India with (A) previously available data for Western Ghats, and (B) after the addition of BARO and HIFP datasets. Geographic coordinates of the maps are in WGS84 reference system.

Table 2. Comparison between previous and currently published data on plants of the Western Ghats on GBIF.

	Before the publication of these two datasets	BARO herbarium	HIFP	New
Occurrences	64,467	20,324	13,674	33,998
Species	5,778	1,784	2,334	1,768
Genera	1,846	786	1,018	181
Family	362	154	205	4

Table 3. Contribution of BARO and HIFP datasets to knowledge on IUCN RedList species.

	Before the publication	New data on Western Ghats from the 2 datasets here presented
Extinct in the wild (EW)	6	2
Critically endangered (CR)	47	95
Endangered (EN)	375	440
Vulnerable (VU)	866	936
Near threatened (NT)	436	525
Least concern (LC)	16,577	5,714
TOT (Adequate data)	18,307	7,712
Not evaluated (NE) or data deficient (DD)	46,160	26,026

Focus on the Western Ghats

A total of 96.5% samples are in India out of which 66.8% are in the Western Ghats Biodiversity Hotspot. When focusing on this scale one can better realize the added value. Previous data available on GBIF (Kingdom: Plantae, geographical filter of the Western Ghats, with a few filters on quality data) are compared to the new dataset in Table 2 and mapped in figure 2.

The number of species with an occurrence on GBIF within the Western Ghats has increased of 30.6% by the publication of this datasets. This publication added the first occurrence of the following four families within the Western Ghats: Calycanthaceae, Davalliaceae, Parnassiaceae, and Resedaceae, 181 genera, and 1,768 new species.

Table 3 reports the number of species inscribed on the IUCN red list for a focus on plant conservation.

DISCUSSION

BARO herbarium

The publication of the complete herbaria collections of Baroda (MSU) online also has significantly expanded the pool of open biodiversity data related to plants in India and, in particular, the same Biodiversity Hotspots. This data might, in the future, play a crucial role in monitoring biodiversity by providing information on species richness and regional species composition.

Despite meticulous data capture and extensive curation efforts, the 53,493 entries in this collection exhibit minor biases and uncertainties. One notable challenge is the precision of the geographical coordinates from ancient observations. However, adhering to GBIF standards, uncertainties in meters have been disclosed. This allows users to filter occurrences, opting for a geostatistical approach when only highly accurate coordinates are suitable. Addressing uncertainties related to taxonomy and changes over time, the availability of scanned herbarium sheets empowers trained botanists to conduct further verifications.

HIFP

The online publication of the complete herbaria collections of the French Institute of Pondicherry significantly increased the volume of open biodiversity data on plants, mostly of one of the Biodiversity Hotspots. This data will help in monitoring biodiversity in terms of species richness and regional species composition.

Even after cautious data capture and long data curation, these occurrences contain bias and uncertainties. The major issue concerns the precision of the geographical coordinates of ancient observations. However, the uncertainty in meters has been indicated following GBIF standards, enabling users to filter part of these occurrences if only very accurate coordinates are eligible for a geostatistical approach.

Regarding uncertainty on taxonomy and changes over time regarding taxonomy, the availability of the scanned herbarium sheets offers the possibility for trained botanists to conduct further verifications.

ACKNOWLEDGMENTS

The data is mobilized at the end of an 18 months' project funded by the Japanese Ministry of Japan through the Biodiversity Information Fund for Asia (BIFA) targeting Information from natural history collections (NHCs).

REFERENCES

Alston, J.M., & Rick, J.A. (2021). A beginner's guide to conducting reproducible research. Bulletin of the Ecological Society of America, 102(2), 1-14. DOI: 10.1002/bes2.1801

Bachman, S.P., Field, R., Reader, T., Raimondo, D., Donaldson, J., Schatz, G.E., & Lughadha, E.N. (2019). Progress, challenges and opportunities for Red Listing. Biological Conservation, 234, 45-55. DOI: 10.1016/j.biocon.2019.03.002

Brown, R.F. (2021). The importance of data citation. BioScience, 71(3), 211. DOI: 10.1093/biosci/biab012

Bridson, D., & Forman, L. (Eds.). (2000). Herbarium Handbook. 3rd Edition. Kew Publishing, London., 346 pp.

Brummitt, N.A., Bachman, S.P., Griffiths-Lee, J., Lutz, M., Moat, J.F., Farjon, A., Donaldson, J.S., Hilton-Taylor, C., Meagher, T.R., Albuquerque, S., Aletrari, E., Andrews, A.K., Atchison, G., Baloch, E., Barlozzini, B., Brunazzi, A., Carretero, J., Celesti, M., Chadburn, H., … & Lughadha, E.M.N. (2015). Green plants in the red: a baseline global assessment for the IUCN sampled Red List Index for plants. PLoS ONE, 10(8), e0135152. DOI: 10.1371/journal.pone.0135152

Champion, H.G., & Seth, S.K. 1968 A revised survey of the forest types of India. Delhi: Govt. of India Press, 404 pp.

Chawinga, W.D., & Zinn, S. (2019). Global perspectives of research data sharing: a systematic literature review. Library & Information Science Research, 41(2), 109-122. DOI: 10.1016/j.lisr.2019.04.004

Costello, M.J., Michener, W.K., Gahegan, M., Zhang, Z.-Q., & Bourne, P.E. (2013). Biodiversity data should be published, cited, and peer reviewed. Trends in Ecology & Evolution, 28(8), 454-461. DOI: 10.1016/j.tree.2013.05.002

Corlett, R.T. (2016). Plant diversity in a changing world: Status, trends, and conservation needs. Plant Diversity, 38(1), 10-16. DOI: 10.1016/j.pld.2016.01.001

Darbyshire, I., Anderson, S., Asatryan, A., Byfield, A., Cheek, M., Clubbe, C., Ghrabi, Z., Harris, T., Heatubun, C.D., Kalema, J., Magassouba, S., McCarthy, B., Milliken, W., de Montmollin, B., Lughadha, E.N., Onana, J.-M., Saïdou, D., Sârbu, A., Shrestha, K., & Radford, E.A. (2017). Important Plant Areas: revised selection criteria for a global approach to plant conservation. Biodiversity and Conservation, 26(8), 1767-1800. DOI: 10.1007/s10531-017-1336-6

Díaz, S., Settele, J., Brondízio, E.S., Ngo, H.T., Agard, J., Arneth, A., Balvanera, P., Brauman, K.A., Butchart, S.H., Chan, K.M. and Garibaldi, L.A., … & Zayas, C.N. (2019). Pervasive human-driven decline of life on Earth points to the need for transformative change. Science, 366(6471), eaax3100. DOI: 10.1126/science.aax3100

Farley, S.S., Dawson, A., Goring, S.J., & Williams, J. W. (2018). Situating ecology as a big-data science: current advances, challenges, and solutions. BioScience, 68(8), 563-576. DOI: 10.1093/biosci/biy068

Havens, K., Kramer, A.T., Guerrant, E.O., & Herendeen, E.P.S. (2014). Getting plant conservation right (or not): the case of the United States. International Journal of Plant Sciences, 175(1), 3-10. DOI: 10.1086/674103

Hill, S.L.L., Gonzalez, R., Sanchez-Ortiz, K., Caton, E., Espinoza, F., Newbold, T., Tylianakis, J., Scharlemann, J.P.W., Palma, A.D., & Purvis, A. (2018). Worldwide impacts of past and projected future land-use change on local species richness and the Biodiversity Intactness Index. bioRxiv. DOI: 10.1101/311787

IUCN (2022). The IUCN Red List of Threatened Species. Version 2022-2. https://www.iucnredlist.org

Kumar, K., Patwardhan, S., Kulkarni, A., Kamala, K., Kundeti, K., & Jones, R. (2011). Simulated projections for summer monsoon climate over India by a high-resolution regional climate model (PRECIS). Current Science, 101, 312-326.

Mandeville, C.P., Koch, W., Nilsen, E.B., & Finstad, A.G. (2021). Open data practices among users of primary biodiversity data. BioScience, 71(11), 1128-1147. DOI: 10.1093/biosci/biab072

Meyer, C., Kreft, H., Guralnick, R., & Jetz, W. (2015). Global priorities for an effective information basis of biodiversity distributions. Nature Communications, 6(1), 8221. DOI: 10.1038/ncomms9221

Mittermeier, R.A., Myers, N., Thomsen, J.B., da Fonseca, G.A.B., & Olivieri, S. (1998). Biodiversity hotspots and major tropical wilderness areas: approaches to setting conservation priorities. Conservation Biology, 12(3), 516-520. DOI: 10.1046/j.1523-1739.1998.012003516.x

Myers, N., Mittermeier, R.A., Mittermeier, C.G., da Fonseca, G.A.B., & Kent, J. (2000). Biodiversity hotspots for conservation priorities. Nature, 403(6772), 6772. DOI: 10.1038/35002501

NicLughadha, E., Bachman, S., Leão, T., Forest, F., Halley, J., Moat, J., Acedo, C., Bacon, K., Brewer, R., Gâteblé, G., Gonçalves, S., Govaerts, R., Hollingsworth, P., Krisai-Greilhuber, I., De Lirio, E., Moore, P., Negrão, R., Onana, J., Rajaovelona, L., & Walker, B. (2020). Extinction risk and threats to plants and fungi. Plants People Planet, 2, 389-408. DOI: 10.1002/ppp3.10146

Pascal, J.P. (1988). Wet evergreen forests of the Western Ghats of India (Ecology, structure, floristic composition and succession. Institut Francais de Pondichery: Travaux de la Section Scientifique et Technique, Tome XXIII.

Pimm, S.L., Jenkins, C.N., Abell, R., Brooks, T.M., Gittleman, J.L., Joppa, L.N., Raven, P.H., Roberts, C.M., & Sexton, J.O. (2014). The biodiversity of species and their rates of extinction, distribution, and protection. Science, 344(6187), 1246752. DOI: 10.1126/science.1246752

Pörtner, H.O., Scholes, R.J., Agard, J., Archer, E., Arneth, A., Bai, X., Barnes, D., Burrows, M., Chan, L., Cheung, W.L., Diamond, S., Donatti, C., Duarte, C., Eisenhauer, N., Foden, W., Gasalla, M. A., Handa, C., Hickler, T., Hoegh-Guldberg, O., Ichii, K., Jacob, U., Insarov, G., Kiessling, W., Leadley, P., Leemans, R., Levin, L., Lim, M., Maharaj, S., Managi, S., Marquet, P. A., McElwee, P., Midgley, G., Oberdorff, T., Obura, D., Osman, E., Pandit, R., Pascual, U., Pires, A. P. F., Popp, A., Reyes-García, V., Sankaran, M., Settele, J., Shin, Y. J., Sintayehu, D. W., Smith, P., Steiner, N., Strassburg, B., Sukumar, R., Trisos, C., Val, A.L., Wu, J., Aldrian, E., Parmesan, C., Pichs-Madruga, R., Roberts, D.C., Rogers, A.D., Díaz, S., Fischer, M., Hashimoto, S., Lavorel, S., Wu, N., & Ngo, H.T. (2021). Scientific outcome of the IPBES-IPCC co-sponsored workshop on biodiversity and climate change; IPBES secretariat, Bonn, Germany, 10.5281/zenodo.4659158

Ramachandra, T.V., & Setturu, B. (2019). Geoinformatics based valuation of forest landscape dynamics in Central Western Ghats, India. Journal of Remote Sensing & GIS, 7(1), 1000227. DOI: 10.4172/2469-4134.1000227

Reddy, C.S., Joseph A., Abraham G.A., & Sabu M.M. (2021). Patterns of animal and plant discoveries, distribution and endemism in India-implications on the effectiveness of the protected area network. Environmental Monitoring and Assessment, 193, 62. DOI: 10.1007/s10661-020-08820-2

Reddy, C.S., Jha C.S., & Oadhwal V.K. (2016). Assessment and monitoring of long-term forest cover changes (1920-2013) in Western Ghats biodiversity hotspot. Journal of Earth System Science, 125(1), 103-114. DOI: 10.1007/s12040-015-0645-y

Sanchez, M., Clubbe, C., Woodfield-Pascoe, N., Bárrios, S., Abbott, J., Heller, T., Harrigan, N., Grant, K., Titley-O'Neal, C., & Hamilton, M. (2021). Tropical Important Plant Areas, plant species richness and conservation in the British Virgin Islands. Nature Conservation, 45, 11-39. DOI: 10.3897/natureconservation.45.73544

Subramanyam, K., & Nayar, M.P. (1974). Vegetation and Phytogeography of the Western Ghats. In : M.S. Mani (ed.), Ecology and Biogeography in India, pp. 178-196. Dr. W. Junk b.v. Publishers, The Hague.

Troudet, J., Grandcolas, P., Blin, A., Vignes-Lebbe, R., & Legendre, F. (2017). Taxonomic bias in biodiversity data and societal preferences. Scientific Reports, 7(1), 9132. DOI: 10.1038/s41598-017-09084-6

Submitted:27 September 2023

First decision: 30 October 2023

Accepted: 25 November 2023

Edited by Diego Fontaneto