Received: 28 July 2022 | Revised: 5 December 2022 | Accepted: 21 December 2022

DOI: 10.1002/ppp3.10355

RESEARCH ARTICLE

Plants People Planet PPP Open Access

Plant conservation assessment at scale: Rapid triage of extinction risks

Taylor AuBuchon-Elder[1] | Patrick Minx[1] | Bess Bookout[1,2] | Elizabeth A. Kellogg[1]

[1]Donald Danforth Plant Science Center, St. Louis, Missouri, USA

[2]Division of Biology, Kansas State University, Manhattan, Kansas, USA

Correspondence
Taylor AuBuchon-Elder, Donald Danforth Plant Science Center, 975 North Warson Road, St. Louis, MO, USA.
Email: tayaubuchon@gmail.com

Present address
Bess Bookout, Division of Biology, Kansas State University, Manhattan, Kansas, USA.

Funding information
NSF, Grant/Award Number: 1822330

Societal Impact Statement

The current rate of global biodiversity loss creates a pressing need to increase efficiency and throughput of extinction risk assessments in plants. We must assess as many plant species as possible, working with imperfect knowledge, to address the habitat loss and extinction threats of the Anthropocene. Using the biodiversity database, Botanical Information and Ecology Network (BIEN), and the Andropogoneae grass tribe as a case study, we demonstrate that large-scale, preliminary conservation assessments can play a fundamental role in accelerating plant conservation pipelines and setting priorities for more in-depth investigations.

Summary

- The International Union for the Conservation of Nature (IUCN) Red List criteria are widely used to determine extinction risks of plant and animal life. Here, we used The Red List's criterion B, Geographic Range Size, to provide preliminary conservation assessments of the members of a large tribe of grasses, the Andropogoneae, with ∼1100 species, including maize, sorghum, and sugarcane and their wild relatives.
- We used georeferenced occurrence data from the Botanical Information and Ecology Network (BIEN) and automated individual species assessments using ConR to demonstrate efficacy and accuracy in using time-saving tools for conservation research. We validated our results with those from the IUCN-recommended assessment tool, GeoCAT.
- We discovered a remarkably large gap in digitized information, with slightly more than 50% of the Andropogoneae lacking sufficient information for assessment. ConR and GeoCAT largely agree on which taxa are of least concern (>90%) or possibly threatened (<10%), highlighting that automating assessments with ConR is a viable strategy for preliminary conservation assessments of large plant groups. Results for crop wild relatives are similar to those for the entire dataset.
- Increasing digitization and collection needs to be a high priority. Available rapid assessment tools can then be used to identify species that warrant more comprehensive investigation.

KEYWORDS
Andropogoneae, Botanical Information and Ecology Network (BIEN), ConR, International Union for the Conservation of Nature (IUCN), preliminary conservation assessment

1 | INTRODUCTION

Anthropogenic change has led to steep drops in biodiversity in every biome on the planet (Hautier et al., 2015), contributing to what some suggest is the world's sixth mass extinction (Cowie et al., 2022; Kling et al., 2018). The essential role of biodiversity in ecosystem function and ecosystem services is well established (Díaz et al., 2006), and plants are integral players in these services (Pelletier et al., 2018). However, knowledge of the extinction risk of plant species is patchy, leaving us in the dark about rates of ecosystem decline or biodiversity loss (Panter et al., 2020; Rivers et al., 2011), and hindering our ability to mitigate and prioritize risks to wild plant species. Declining diversity among crop wild relatives is also cause for concern (Khoury et al., 2022) because of their importance to agricultural research and food security (Castañeda-Álvarez et al., 2016; Khoury et al., 2020). The Global Strategy for Plant Conservation (GSPC) of the 2011–2020 United Nations Convention on Biological Diversity (CBD) called for assessment of the conservation status of all known plant species, but this ambitious goal remains unattained.

The International Union for Conservation of Nature (IUCN) Red List criteria (Figure 1) provide the authoritative framework for assessing conservation status and contributing to the GSPC objectives (Sharrock, 2020). Criterion B (species geographic range) is the most common method used for plants, as initial preliminary assessments can be done using only georeferenced locality data at a single time point. The major subcriteria are B1, Extent of Occurrence (EOO), and B2, Area of Occupancy (AOO), where EOO is the area encompassed by the minimum convex or alpha hull that includes all reported locations and AOO determines the number of grid cells of a specified size within the EOO occupied by the species (Dauby et al., 2017).

These values permit an important initial step in preliminary determination of a taxon's conservation status. Additional subcriteria will ultimately need to be met before the final conservation category (Data Deficient [DD], Least Concern [LC], Near Threatened [NT], Vulnerable [VU], Endangered [EN], Critically Endangered [CR], Extinct in the Wild [EW], or Extinct [EX]) can be determined (IUCN, 2012). Final assessments require detailed investigation of factors on the ground and how they change over time.

While Red List methods are the gold standard for conservation assessment, they can require extensive expertise, time, funding, and geographic accessibility, and for logistical reasons are not always feasible (Le Breton et al., 2019; Rivers et al., 2011). Biases in number of assessments, geographic preferences, and organism types also exacerbate the gaps in conservation data (Walker et al., 2020). Among plants, woody perennials and species with known human use are overrepresented in Red List assessments while Lamiaceae, Orchidaceae, Poaceae, and Asteraceae are notably underrepresented (Nic Lughadha et al., 2020). Only 10.5% of the ∼383,670 species of vascular plants have been globally assessed by the IUCN Red List (Holz et al., 2022; Nic Lughadha et al., 2016, 2020), well short of the GSPC 2020 targets.

Documenting and assessing plant species at a speed that matches the urgency of the extinction crisis requires high throughput methods, even if they are imperfect. Such preliminary conservation assessments can then be shared with on-the-ground experts and stakeholders with the critical local knowledge, resources, and community

Criterion A: Population size reduction		
Criterion B: Geographic range size		
B1	*Extent of occurrence (EOO)*	*“area contained within the shortest continuous imaginary boundary that can be drawn to encompass all the known, inferred or projected sites of present occurrence of a taxon, excluding cases of vagrancy ”*
B2	*Area of occupancy (AOO)*	*“the area within its extent of occurrence’ that is occupied by a taxon, excluding cases of vagrancy”*
(a)	*Number of locations or fragmented populations*	
(b)	*"Continuing decline observed, estimated, inferred, or projected in any of (i) EOO; (ii) AOO; (iii) area, extent and/or quality of habitat; (iv) number of locations or subpopulations; (v) number of mature individuals"*	
(c)	*"Extreme fluctuations in any of: (i) EOO; (ii) AOO; (iii) number of locations or subpopulations; (iv) number of mature individuals"*	
Criterion C: Small population size and decline		
Criterion D: Very small or restricted population		
Criterion E: Quantitative analysis		

FIGURE 1 International Union for the Conservation of Nature (IUCN) criteria for assessing risk of extinction, redrawn and directly quoted from IUCN (2012). Criteria with green shading evaluated in this paper. Note that criteria A, C, B2b, and c all require repeated observations over time whereas B1, B2, and B2a can be estimated from single records.

connections to (a) confirm or deny the preliminary conservation status conclusion, (b) provide expert detail on current threats and population outlooks beyond those available in online databases, and (c) set ecological and/or evolutionary priorities for species and habitat conservation.

Here, we assess extinction risk for a large clade of plants, the grass tribe Andropogoneae (Poaceae: Panicoideae), using automated tools for download and analysis of species occurrences, and have validated the approach with less automated methods. The tribe includes ~1100 species of grasses that are prevalent in many of the world's most endangered ecosystems (Estep et al., 2014; Lehmann et al., 2019; Scholtz & Twidwell, 2022). They are the ecologically dominant species in the North American tallgrass prairie, African savannas, and south Asian tropical grasslands (Figure 2). Andropogoneae are often used for forage, aid in erosion mitigation, and may provide bigger carbon sinks than forests (Dass et al., 2018). In addition, the tribe includes some of the world's most aggressive weeds, including *Sorghum halepense*, *Imperata cylindrica*, and *Heteropogon contortus*.

Andropogoneae also includes some of the world's most valuable crop species (*Zea mays*, *Sorghum bicolor*, and *Saccharum officinarum*) and their wild relatives (*Tripsacum* and *Miscanthus*). Research on the tribe thus improves cereal crop efficiency and agricultural sustainability due to their highly adaptive C_4 photosynthesis and drought tolerance (Hattersley & Watson, 1992). In contrast to the well-known crops, the tribe also includes many species about which we know little beyond their original descriptions.

Only 100 species of Andropogoneae have been assessed in the IUCN Red List (Dataset S1), including 26 crop wild relatives plus *Z. mays* itself. We have performed preliminary conservation assessments for the remaining 1100 species, based on the Red List Criteria EOO and AOO. We used one automated tool, ConR, and compared it with the more widely used web tool, GeoCAT, for validation (Bachman et al., 2011). For georeferenced locality data, we started with the Botanical Information and Ecology Network (BIEN) (Enquist et al., 2016) and added extensive taxonomic curation to account for synonymy and other data artifacts such as misspelling of names. We

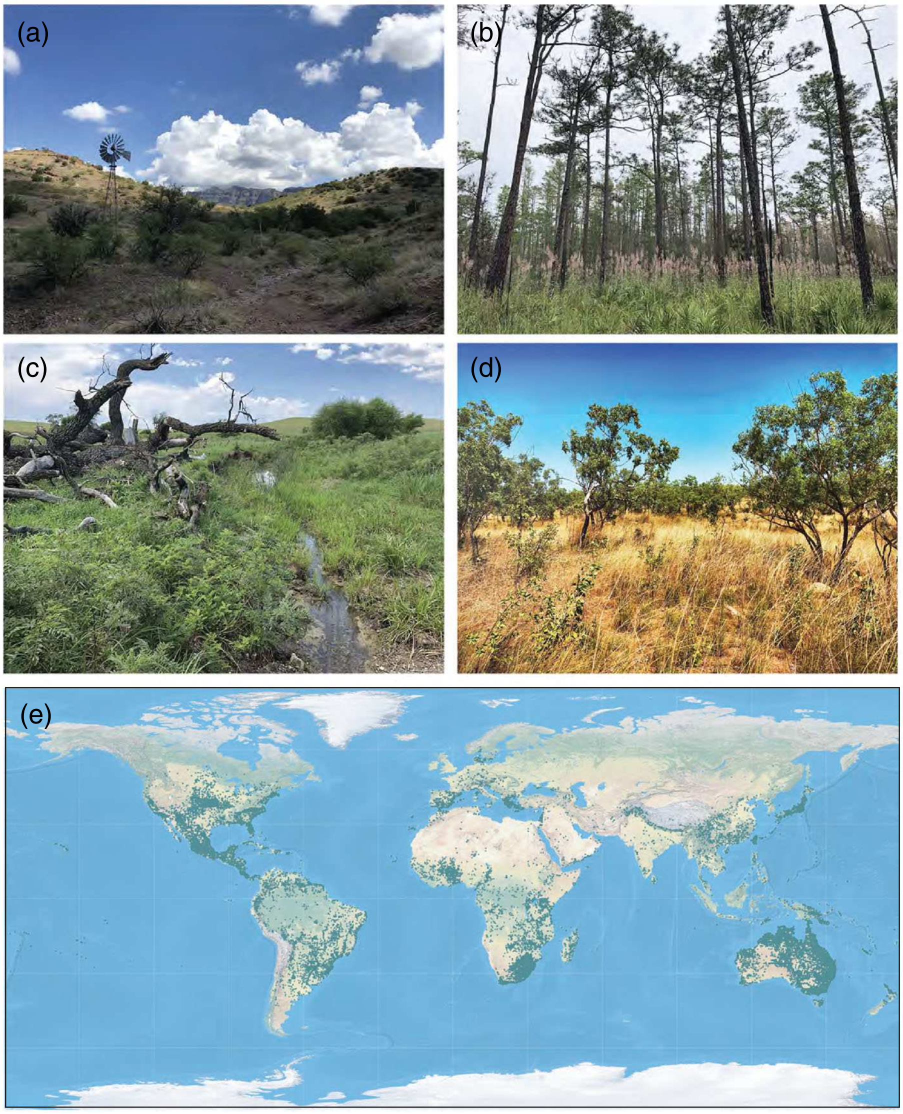

FIGURE 2 Ecosystems where Andropogoneae naturally occur. Clockwise from top left: (a) upper riparian sloped grassland in southern Arizona, USA; (b) mesic longleaf pine flatwoods in central Florida, USA; (c) bottomland tallgrass prairie in Flint Hills, Kansas, USA; and (d) dry tropical savanna in Northern Territory, Australia. (e) Estimated range map of Andropogoneae (excluding *Zea mays*, *Sorghum bicolor*, and *Sorghum halepense*) using available locality data (colored in green). Mapped with QGIS-LTR Version 3.22.4. Graticules from Natural Earth. Photos taken by TAE

demonstrate that just under half of the species in the tribe can be assessed under criterion B, with the remainder having few or no records in online databases.

Of those that could be assessed, a large majority (91%) appear not to be globally threatened, permitting future studies to prioritize the 46–50 species that may be at risk. Most of the potentially threatened species are severely undercollected and/or digitized, with fewer than 10 unique georeferenced occurrences. This alone may be reason enough to focus first on those species. We also checked the phylogeny to see whether potentially threatened species were overrepresented in particular taxa or clades but found instead that they were distributed across the tribe.

2 | MATERIAL AND METHODS

Our workflow involved (1) assembling a comprehensive list of species names, (2) taxonomic reconciliation, (3) retrieval and organization of occurrence data, and (4) preliminary conservation assessment of each species (Figure 3). Taxonomic and occurrence data were provided by BIEN (Enquist et al., 2016), accessed and manipulated with the R package BIEN R (Maitner, 2020).

2.1 | Databases and comprehensive lists of species names

A list of all Poaceae species in the BIEN database was downloaded using the query [BIEN_full_taxonomy_family] and then filtered to retain only species in genera assigned to Andropogoneae by

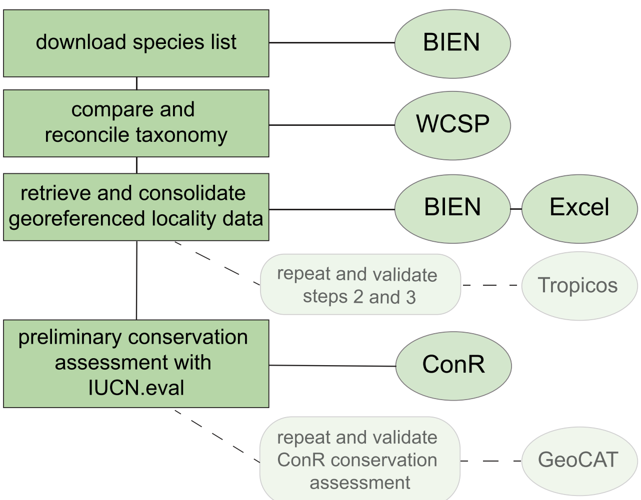

FIGURE 3 Steps in workflow for conservation assessment of Andropogoneae. Primary workflow in boxes on left side of figure. Tools used in ovals on the right for Botanical Information and Ecology Network (BIEN), World Checklist of Selected Plant Families (WCSP), Microsoft Excel, Tropicos, ConR R package, and GeoCAT. Validation steps used for this paper in rounded rectangles and ovals, with lighter fill

GrassBase (Clayton et al., 2006) and the more recent World Checklist of Selected Plant Families (December 2021) (http://wcsp.science.kew.org/) (hereafter, "WCSP"). We note that WCSP recently merged with Plants of the World Online (POWO, 2020) as of October 2022.

Our query retrieved all recorded species names, whether or not they were currently accepted. Many are placed in synonymy by GrassBase, WCSP or BIEN itself via the Taxonomic Names Resolution Service (TNRS) (Boyle et al., 2013; https://tnrs.biendata.org/), although the most recent release of the TNRS (Boyle et al., 2021) appeared after the taxonomic work described here was complete. The list also included names that were misspelled, attributed to the wrong taxonomic authority, or given the wrong Latin ending. We wished to capture records associated with as many species names as possible to avoid missing localities digitized under outdated synonyms or erroneous names, which are often attached to only a few records and thus may appear, incorrectly, as threatened. After retrieving all species names in all Andropogoneae genera, we had two species lists: (a) the authoritative WCSP list (1157 names) and (b) the BIEN list (1556 names). Lists were compared side by side in a single .csv file.

2.2 | Taxonomic reconciliation

We compared the two lists using the Excel code (=IFERROR (VLOOKUP(A2,$D$2:$D$1556,1,0),("not in BIEN"))) or "not in WCSP"), where A and D are the columns WCSP and BIEN, respectively, and 1556 is the number of rows (names). Exact matches were placed into an "Exact match" list. Species names appearing only in the BIEN list were manually checked against WCSP. If the species was accepted in WCSP, we added it into a "consolidated working list" (the "Exact match list" + new additions). If the species was a synonym, it was recorded along with the preferred name. If the preferred accepted name was still valid but not already in the "consolidated working list," it was added. We also verified the taxonomic authority of each name. Duplicates produced by minor misspellings or discrepancies in gender determinations were manually corrected, using WCSP as the authority. Species names that appeared only in BIEN, did not have synonyms, and appeared as "Unplaced" in the WCSP database were removed.

The "Cleaned Species List" then included (1) exact matches between the two lists, (2) accepted names only in the WCSP list, (3) accepted names only in the BIEN list plus their WCSP list synonyms, and (4) unplaced names. This produced a final working dataset with 1130 unique names, a number slightly lower than the number of 1224 species estimated by Welker et al. (2020).

2.3 | Retrieval of occurrence data

We downloaded specimen-based occurrence data for all genera in the Cleaned Species List with [BIEN_occurrence_genus], retrieving information for political boundaries and collection information [political.boundaries=TRUE, collection.info=TRUE]. This returned a dataframe containing all available occurrence records for each genus and species: scrubbed genus and species, country, state, county, locality, latitude, longitude, date collected, datasource, dataset, data owner, data source ID, catalog number, identified by, and date identified. Names without occurrences were automatically skipped by the program. Occurrences for BIEN-only synonyms were consolidated with those of their accepted name.

To validate our query of BIEN, we repeated the same process but with the Tropicos database (https://tropicos.org) as it is specimen-based and does not require the level of data cleaning needed for GBIF records. We reconciled names between Tropicos and WCSP and then retrieved all available coordinates from Tropicos for each species. While nearly all results were redundant, we gained usable localities for nine species that lacked coordinates in BIEN.

Andropogoneae already in IUCN's Red List assessment data were kept in our analyses (Dataset S2). *Z. mays* and *S. bicolor* were omitted because they are cultivated worldwide; *S. halepense* was omitted because it is an aggressive weed with a global distribution. The final number of species for assessment was 1127.

2.4 | Conservation assessments of accepted species

Extinction risk was assessed with the R-based tool ConR (Dauby et al., 2017) and validated with the web-based and IUCN-approved tool GeoCAT (Bachman et al., 2011). Both tools automate risk assessment and generation of maps. Comma-separated files (.csv) with species name, latitude, and longitude were extracted from the main dataframes and as specified by each program. ConR uses batch uploads and automatically generates spreadsheets of the results (Dauby et al., 2017). Within ConR, we used the modules [EOO.computing] and [IUCN.eval]. For comparison, we also used GeoCAT with grid cells of 2 km by 2 km, as recommended (IUCN, 2012). GeoCAT lacks a batch upload option and requires manual recording of outputs.

Both analytical tools produced (a) EOO km^2 and AOO km^2, (b) EOO- and AOO-based risk ratings, and (c) number of unique occurrences. ConR also automatically estimated number of locations, where "location" is "a geographically or ecologically distinct area in which a single threat can rapidly affect all individuals of the taxon present" (IUCN, 2012). The number of locations did not affect the overall analysis. ConR uses only unique occurrences and skips exact duplicates, whereas GeoCAT includes the duplicates, but these do not change the convex hulls so EOO and AOO values are unaffected. EOO values for ConR and GeoCAT were compared in bivariate plots to identify outliers, which were manually checked; all represented typographical errors that were corrected.

ConR could not compute EOO for 62 species with ranges spanning the 180th meridian, although GeoCAT could. We manually inspected the GeoCAT maps and found that 15 species included vagrants that could be manually removed and the analysis rerun. ConR analyzed seven of them, whereas the remaining species still had ranges that were too broad.

2.5 | Phylogenetic clustering

We explored whether potentially threatened species were concentrated in particular clades using the plastome phylogeny and subtribal classification of Andropogoneae provided by Welker et al. (2020) (Figure 4). To normalize the number of threatened species by size of the subtribe, we used species numbers provided by Welker et al. (2020).

3 | RESULTS

3.1 | Fewer than half of Andropogoneae species had enough georeferenced data for preliminary assessment

The reconciled species list included 1130 unique species of Andropogoneae (Dataset S2), retrieved 59,186 individual occurrences (as of 2021); eliminating two crops (*Z. mays* and *S. bicolor*) and one aggressive weed (*S. halepense*) gave a dataset of 1127 species. The preliminary conservation status of 573 (51%) of them could not be rapidly assessed with ConR.

Of the 573, 337 had no accessible georeferenced occurrence data. Of the 337, 18 had already been assessed in the IUCN Red List, so we inferred their localities were protected or did not have digitized specimen data. The other 319 lacked digitized coordinates. An additional 181 species had only one to two occurrences per species, which prevented preliminary assessments because EOO estimates require at least three occurrences. The remaining 55 species could be assessed by GeoCAT but not ConR because ConR does not provide results for species with ranges that cross the 180th meridian (Dataset S2).

Lack of data could reflect low collection numbers, lack of digitization, or locality data without georeferencing, among other causes. The five countries with the most data-deficient species were India, Myanmar, China, Thailand, and Vietnam, each with more than 50 species without digitized georeferenced locality data (∼223 species, 78, 62, 78, and 51, respectively) (Figure 5).

3.2 | Nine percent of rapidly assessed Andropogoneae are potentially threatened

Five hundred fifty-four species (49% of the tribe) could be assessed by both GeoCAT and ConR, which produced EOO and AOO values that were nearly identical (EOO, $r^2 = 1$; AOO, $r^2 = 0.998$). Most of the species (504/554 or 91%) were assessed by both tools as LC or NT. GeoCAT listed 487 of these as LC and 17 as NT, whereas ConR does not distinguish LC from NT. Of the 55 species with coordinates that cross the 180th meridian, GeoCAT assessed all as being LC and confirmed 10 species previously assessed for the IUCN Red List as LC.

The remaining 9% (50/554) of the assessed species were assessed as CR, EN, or VU by one or both tools. Of these, 46 appeared threatened (2 CR, 26 EN, and 18 VU) according to ConR or 50 (7 CR,

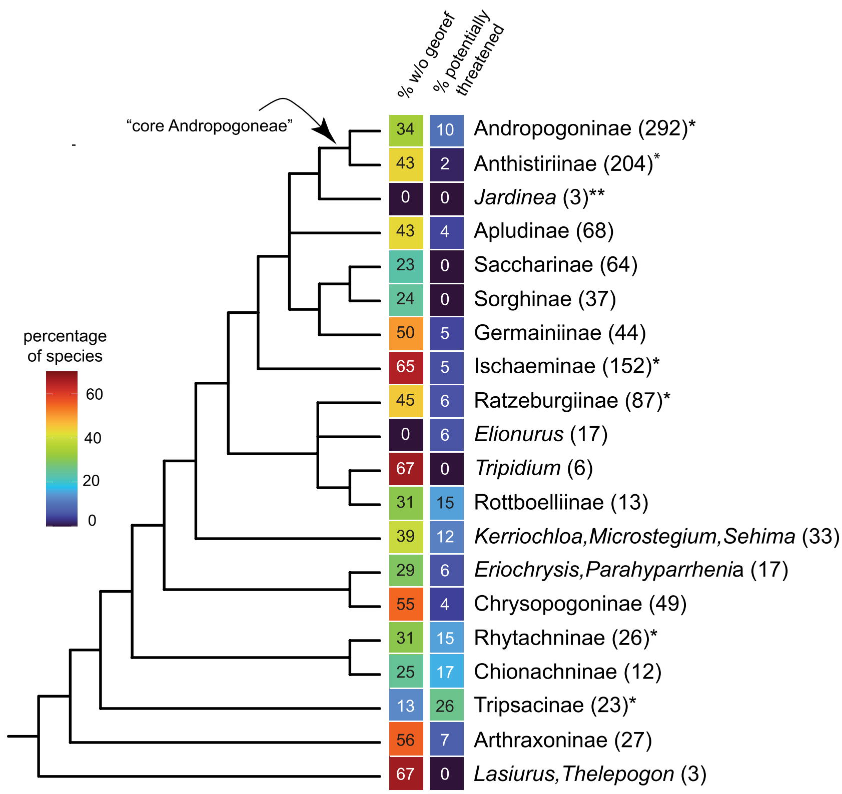

FIGURE 4 Phylogeny of subtribes of Andropogoneae, following Welker et al. (2020). Percentage of species with insufficient locality data for assessment (left gradient) and percentage potentially or actually threatened (right gradient). Numbers in parentheses = total number of species in the subtribe or clade, according to Welker et al. (2020). *Subtribe contains threatened species that have been fully assessed for the International Union for the Conservation of Nature (IUCN). ***Jardinea* species are placed in *Phacelurus* in the World Checklist of Selected Plant Families (WCSP) species list, but the two genera are unrelated.

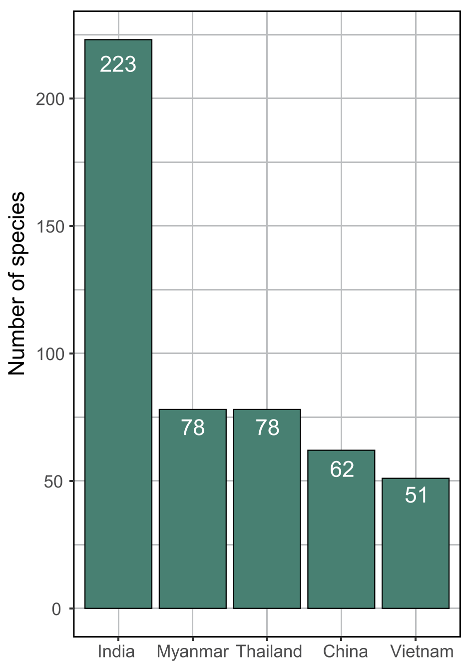

FIGURE 5 Countries with the largest numbers of species lacking digitized locality data. Number of species based on reported native ranges based on political boundaries (Plants of the World Online [POWO], accessed December 2021).

28 EN, and 13 VU) according to GeoCAT. ConR did not indicate that *Microstegium japonicum* and *Rottboellia parodiana* were threatened, although GeoCAT did, despite having similar EOO values. Subcategories of potentially threatened status (CR, EN, and VU) varied more between the two tools. Twenty-six percent of the 50 potentially threatened species differed in their EOO letter grade (Table 1).

3.3 | Phylogenetic clustering

Each subtribe contained a few (generally 1–8) species that were potentially threatened, although the largest subtribe, Andropogoninae, had 30 (Figure 4). The WCSP species list (Dataset S2) does not provide subtribal assignments, and Welker et al. (2020) provide only species numbers, not lists, for their subtribes, estimates of species numbers are approximate. In addition, a few genera listed by WCSP are polyphyletic in the phylogeny. This polyphyly affects the genera *Phacelurus*, one species of which is segregated as the genus *Jardinea*, and *Rottboellia*, some species of which are segregated as *Mnesithea* by Welker et al. and thus placed in subtribe Ratzeburgiinae rather than Rottboelliinae. Groups affected by these discrepancies are noted with an asterisk in Figure 4. Percent of species threatened ranged from 0% to 26.1% of each subtribe. The highest percentage is in Tripsacinae, a slightly misleading number since this subtribe also includes the largest percentage of species formally assessed by IUCN. The next highest percentages are Rhytachninae and Chionachninae, with 15.4% and 16.7% potentially threatened, respectively.

The apparently low percentage of threatened species reflects the general paucity of locality data (Figure 5). In general, the percentage of species lacking digitized data is appreciably higher than the percentage that is potentially threatened. For example, while only eight

TABLE 1 Andropogoneae species identified in this analysis as possibly threatened by either GeoCAT, ConR, or both

Species	GeoCAT AOO rating	GeoCAT EOO rating	ConR AOO rating	ConR EOO rating	POWO range
Anadelphia liebigiana	EN	EN	EN	EN	Benin, Ivory Coast, Togo
Andropogon aequatoriensis	EN	EN	VU	VU	Columbia, Ecuador
Andropogon auriculatus	EN	VU	EN	VU	Cameroon, Chad, Gabon, Gambia, Guinea, Guinea-Bissau, Ivory Coast, Nigeria, Senegal, Sierra Leone
Andropogon bourgaei	EN	VU	EN	VU	Belize, Mexico Gulf, Mexico Southeast, Mexico Southwest
Andropogon brasiliensis	EN	EN	EN	EN	Brazil
Andropogon crassus	EN	VU	EN	VU	Venezuela
Andropogon crossotos	EN	LC	EN	EN	Yemen
Andropogon imerinensis	EN	EN	VU	VU	Madagascar
Andropogon lima	EN	EN	EN	EN	Cameroon, Ethiopia, Kenya, Malawi, Rwanda, Sudan, Tanzania, Uganda
Andropogon pteropholis	EN	EN	VU	VU	Burkina, Ghana, Togo
Arthraxon antsirabensis	EN	EN	EN	EN	Madagascar
Arthraxon junnarensis	EN	VU	EN	VU	China, India, Oman
Bothriochloa bunyensis	EN	EN	VU	VU	Australia
Bothriochloa campii	EN	EN	EN	EN	Ecuador
Chrysopogon nodulibarbis	EN	EN	EN	EN	India, Myanmar, Sri Lanka, Thailand, West Himalaya
Chrysopogon rigidus	EN	VU	EN	VU	Australia
Clausospicula extensa	EN	EN	VU	VU	Australia
Coix gasteenii	EN	CR	EN	EN	Australia
Cymbopogon bhutanicus	EN	EN	EN	EN	East Himalaya
Dimeria ballardii	EN	EN	EN	EN	Sri Lanka
Elionurus euchaetus	EN	EN	EN	EN	Burkina, Ivory Coast
Eremochloa eriopoda	EN	CR	EN	EN	Cambodia, Laos, Sulawesi, Thailand, Vietnam
Eulalia mollis	EN	EN	EN	EN	East Himalaya, Nepal, Tibet, West Himalaya
Hackelochloa porifera	EN	VU	EN	VU	China, East Himalaya, Myanmar, Vietnam
Homozeugos eylesii	EN	EN	EN	EN	Malawi, Tanzania, Zambia, Zaïre
Homozeugos huillense	EN	VU	EN	VU	Angola
Hyparrhenia violascens	EN	EN	EN	EN	Burkina, Cameroon, Chad, Nigeria
Imperata cheesemanii	EN	CR	EN	CR	Kermadec Is.
Imperata flavida	EN	EN	EN	EN	China
Ischaemum commutatum	EN	EN	EN	EN	India, Sri Lanka
Ischaemum nativitatis	EN	CR	EN	EN	Christmas Island
Ischaemum setaceum	EN	VU	VU	VU	Taiwan
Loxodera caespitosa	EN	EN	EN	EN	Tanzania, Zambia, Zimbabwe
Microstegium falconeri	EN	VU	EN	VU	East Himalaya, West Himalaya
Microstegium fauriei	EN	EN	VU	VU	Taiwan
Microstegium japonicum	EN	VU	LC or NT	LC or NT	China, Japan, Korea, Taiwan
Microstegium somae	EN	LC	EN	EN	China, Japan, Taiwan

TABLE 1 (Continued)

Species	GeoCAT AOO rating	GeoCAT EOO rating	ConR AOO rating	ConR EOO rating	POWO range
Mnesithea annua	EN	VU	VU	VU	Australia
Parahyparrhenia laegaardii	EN	CR	EN	CR	Thailand
Polytoca javanica	EN	EN	EN	EN	Jawa, Lesser Sunda Islands
Polytoca massiei	CR	EN	EN	LC or NT	China, Laos, Thailand, Vietnam
Rhytachne furtiva	EN	VU	VU	VU	Burkina, Ghana
Rhytachne megastachya	EN	EN	EN	EN	Ghana, Guinea, Liberia, Sierra Leone
Rottboellia coelorachis	CR	CR	EN	LC or NT	New Caledonia, Vanuatu
Rottboellia parodiana	LC	EN	EN	LC or NT	Argentina Northeast, Paraguay
Schizachyrium cubense	EN	EN	EN	EN	Cuba
Schizachyrium djalonicum	EN	VU	EN	VU	Guinea, Sierra Leone
Schizachyrium lomaense	EN	EN	EN	EN	Ivory Coast, Liberia, Sierra Leone
Schizachyrium reedii	EN	EN	EN	EN	Cuba
Spodiopogon yuexiensis	EN	CR	EN	EN	China

Note: Forty-six species appeared threatened in ConR versus 50 in GeoCat. Potentially threatened species are not concentrated in one region. Abbreviations: AOO, Area of Occupancy; CR, Critically Endangered; EN, Endangered; EOO, Extent of Occurrence; LC, Least Concern; NT, Near Threatened; POWO, Plants of the World Online; VU, Vulnerable.

of the 152 species of subtribe Ischaeminae (5.3%) are potentially threatened, 99 (65.1%) lack enough locality data for even the very basic assessments that we have undertaken here.

3.4 | Comparison to species with full assessments

Of the 100 Andropogoneae species already assessed for the Red List (Dataset S1), 57 were also included in our analyses, which assigned the same extent of risk to 45 of them. ConR estimated a greater risk than the Red List for four species and a lower risk for six. This was expected, as Red List assessments include information on population decline and location threats, neither of which is offered by rapid analyses. We could assess two species designated as DD in the Red List, suggesting that updated assessments for them are likely warranted. We could not assess 42 of the Red List species because they lack digitized locality data; of those, 18 are designated as threatened. The Red List also assessed *Z. mays*, whereas we excluded it.

Combining the IUCN data with our other assessments, we suggest ~11% of assessed Andropogoneae may be threatened.

3.5 | Crop wild relatives

We addressed the conservation status of wild relatives of the major crops in Andropogoneae (maize, sorghum, and sugarcane). Excluding *Z. mays*, *S. halepense*, and *S. bicolor*, we filtered the species list for the 96 species in the genera *Zea*, *Tripsacum*, *Sorghum*, *Saccharum*, *Miscanthus*, *Hemisorghum*, and *Cleistachne*, which are the groups most likely to include crop wild relatives (Dataset S3). The results mirrored those of the full dataset: 26% of the species lacked sufficient records for assessment, 11.5% spanned the 180th meridian, and 62.5% could be assessed. Most of the latter group had EOO ratings of LC/NT; 10 species were estimated as either VU or EN under AOO, justifying further exploration.

The IUCN Red List has already assessed 27 species within the Andropogoneae crop wild relative genera. Of those, *Zea diploperennis*, *Tripsacum zopilotense*, *Tripsacum maizar*, *Tripsacum intermedium*, and *Tripsacum peruvianum* are EN, *Zea luxurians* is VU, and *Zea perennis* is CE (Aragón Cuevas, Contreras, et al., 2019; Aragón Cuevas, Menjívar, et al., 2019; Giraldo-Cañas et al., 2020; González Ledesma & Contreras, 2020a, 2020b; González Ledesma et al., 2020; Sanchez et al., 2019). All seven were Red Listed using criterion B, except *Z. perennis*, which was assessed with criterion A (population size reduction). Our analyses for the six species ConR could assess resulted in EOO ratings of LC/NT. None of the species newly assessed here were estimated to be threatened.

4 | DISCUSSION

We show here that existing tools can provide rapid conservation assessments for a large set of species (1127), dividing them quickly into those that are (a) data deficient, (b) likely not globally threatened, and (c) in need of immediate attention. In Andropogoneae, over half the species lacked sufficient locality data in online databases, with five countries accounting for much of the missing data (Figure 5). These regions are clearly targets for enhanced collecting and digitization efforts and collaborative botanical surveys. This percentage is similar to that reported by Zizka et al., 2021 for Orchidaceae, in which only 47% of the known species could be assessed. Insufficient geographic knowledge is also a pervasive problem among crop wild relatives (Castañeda-Álvarez et al., 2016; Khoury et al., 2020).

Of the species assessed, over 90% are likely not under imminent threat globally, although follow-up regional analyses and assessments may be warranted. Meanwhile, the most pressing need for further work is among the 50 species classified as potentially threatened by at least one assessment tool (Figure 6). We suggest that the next step after rapid triage be Red List assessments and/or conservation prioritization.

Criterion B is only the first step toward a full Red List assessment, and assessments relying primarily on this criterion present clear limitations. Plant collection is often biased by taxon and locality (Nic Lughadha et al., 2020; Walker et al., 2020). As seen in Figure 2e, sparse records at high latitudes of both hemispheres likely reflect climate preferences of most species whereas the lack of records in, for example, India, almost certainly reflects lack of collecting or digitization. Nonetheless, criterion B is often the necessary first step for assessments of plants (Pérez-Sarabia et al., 2020; Schmidt et al., 2017).

Assessment under Criterion B lends itself to automation (Zizka et al., 2021). We have found here that ConR produces EOO and AOO values that are virtually identical to those of GeoCAT, the tool that is recommended by the IUCN for use in Red List entries, and it assigns most of the same taxa to the combined category LC/NT. The batch processing and automated output of ConR can assess hundreds of species at once and thus is useful for rapidly setting priorities. Although not attempted in the current study, it can also integrate data on protected areas (where available) and overlay them on EOO maps for further assessment of potential threats. ConR does fail when species distributions cross the 180th meridian, but this only affected a small percentage of species in our study. In the near future, we expect that ConR will be surpassed by newer, even more sophisticated tools using automation and deep learning such as IUC-NN (Zizka et al., 2021).

Phylogenetic diversity can also be used for setting conservation priorities (Davies, 2019; Forest et al., 2007; Li et al., 2018). Placing potentially threatened species on a phylogeny is becoming easier, with phylogenies that are increasingly available for many plant clades. More elaborate analyses (e.g., Evolutionarily Distinct and Globally Endangered [EDGE]; Isaac et al., 2007) could then be done, although these go beyond the rapid triage that we are attempting here.

Reconciliation of names and synonyms was the most time-consuming step of the process used here. More robust tools for automated retrieval of currently accepted taxonomy will directly benefit rapid conservation assessment. Taxonomic irregularities are inevitable in any large clade and need to be addressed, particularly for apparently rare species that may be masquerading under misapplied (or simply misspelled) names. The TNRS (Boyle et al., 2013) is a big step forward toward automation, although the most recent update was released after we had largely completed the taxonomic component of this project. BIEN R itself clears up some taxonomic errors but still requires additional checks for taxa that have multiple names in common use. We note that preliminary conservation assessment relies on good taxonomy but can proceed even while species limits are being reconsidered.

We acknowledge there are various data sources that can contribute to a project such as this one. Some resources in BIEN are similar to those in the Global Biodiversity Information Facility (GBIF), but BIEN provides additional data cleaning, with species occurrence data validated for spatial errors (Maitner et al., 2018); it also retrieves more occurrence records per species than GBIF (Panter et al., 2020).

Among the crop wild relatives, the Red List listed six as threatened, while ConR suggested LC/NT. These seemingly contradictory results further support the argument that these preliminary assessments should serve as a first pass for either continuing to more

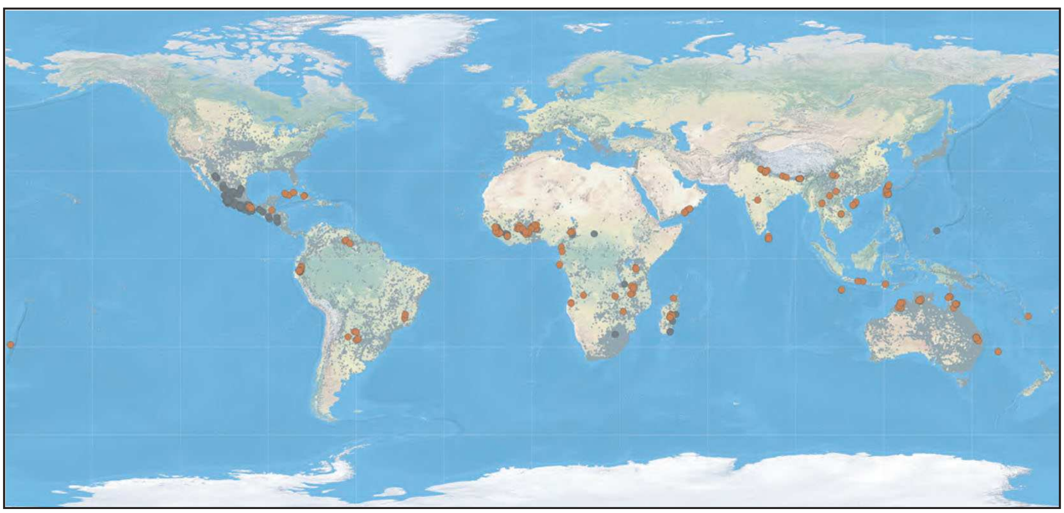

FIGURE 6 Global location of potentially threatened species of Andropogoneae (orange) and International Union for the Conservation of Nature (IUCN) Red List-assessed taxa (dark gray) layered on estimated range of Andropogoneae (light gray). Mapped with QGIS-LTR Version 3.22.4. Graticules from Natural Earth

thorough Red List assessments or conservation prioritizing; while a taxon may be widespread, a closer regional analysis may identify specific threats like major changes in land use or competition with invasive species.

Obvious next steps for our priority species would be in-depth approaches like gap analysis (Carver et al., 2021; Sowa et al., 2007), connectivity analysis (Fajardo et al., 2014), or ecological modeling (Rodríguez et al., 2007), to name just a few. We hope to provide a basis for identifying and pursuing such studies, as our methods could be applied to many other groups.

Our work highlights three focal areas for conservation efforts: (1) massively increased digitization and high-quality georeferencing of existing herbarium collections, particularly in species-rich regions; (2) authoritative lists of species names and synonyms; and (3) rapid automated tools for assessment of risk. Large-scale and preliminary conservation assessments deserve cautious evaluation but are increasingly necessary to accelerate the process of predicting extinction risks of plants.

ACKNOWLEDGEMENTS

We thank the Missouri Botanical Garden's Burgund Bassuner, Roy Gereau, Patricia Barbera Sanchez, and Iván Jiménez for their initial guidance on IUCN Red Listing and Maria Vorontsova at Royal Botanic Gardens Kew for access to GrassBase taxonomy data. This work was supported by NSF Grant 1822330 to EAK. Specimen data from hundreds of herbaria made this study possible.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

AUTHOR CONTRIBUTIONS

Taylor AuBuchon-Elder and Elizabeth A. Kellogg designed the research and wrote the manuscript. Taylor AuBuchon-Elder, Patrick Minx, and Bess Bookout collected the data. Taylor AuBuchon-Elder, Patrick Minx, and Elizabeth A. Kellogg analyzed and interpreted the data. Taylor AuBuchon-Elder and Elizabeth A. Kellogg created figures and maps.

DATA AVAILABILITY STATEMENT

Raw locality data, species lists, ConR maps for potentially threatened species, the BIEN herbaria list, and R code are available on Github (https://github.com/ekellogg-lab/Androp_conservation).

ORCID

Taylor AuBuchon-Elder https://orcid.org/0000-0002-0051-8403
Elizabeth A. Kellogg https://orcid.org/0000-0003-1671-7447

REFERENCES

Aragón Cuevas, F., Contreras, A., de la Cruz Larios, L., González Ledesma, M., Ruíz Corral, J. A., Menjívar, J., & Sánchez, J. J. (2019). Zea diploperennis. The IUCN Red List of Threatened Species 2019, e. T77726057A77726102. https://doi.org/10.2305/IUCN.UK.2019-2.RLTS.T77726057A77726102.en

Aragón Cuevas, F., Menjívar, J., Ruíz Corral, J. A., González Ledesma, M., Contreras, A., Azurdia, C., de la Cruz Larios, L., & Sánchez, J. J. (2019). Zea luxurians. The IUCN Red List of Threatened Species 2019, e. T77726182A77726358. https://doi.org/10.2305/IUCN.UK.2019-2.RLTS.T77726182A77726358.en

Bachman, S., Moat, J., Hill, A., de la Torre, J., & Scott, B. (2011). Supporting Red List threat assessments with GeoCAT: geospatial conservation assessment tool. *ZooKeys*, *150*, 117–126. https://doi.org/10.3897/zookeys.150.2109

Boyle, B., Hopkins, N., Lu, Z., Raygoza Garay, J. A., Mozzherin, D., Rees, T., Matasci, N., Narro, M. L., Piel, W. H., McKay, S. J., Lowry, S., Freeland, C., Peet, R. K., & Enquist, B. J. (2013). The taxonomic name resolution service: an online tool for automated standardization of plant names. *BMC Bioinformatics*, *14*, 16. https://doi.org/10.1186/1471-2105-14-16

Boyle, B. L., Matasci, N., Mozzherin, D., Rees, T., Barbosa, G. C., Kumar Sajja, R., & Enquist, B. J. (2021). Taxonomic name resolution service, version 5.0. In Botanical Information and Ecology Network. https://tnrs.biendata.org/ (accessed December, 2021).

Carver, D., Sosa, C. C., Khoury, C. K., Achicanoy, H. A., Diaz, M. V., Sotelo, S., Castañeda-Álvarez, N. P., & Ramirez-Villegas, J. (2021). GapAnalysis: an R package to calculate conservation indicators using spatial information. *Ecography*, *44*, 1000–1009. https://doi.org/10.1111/ecog.05430

Castañeda-Álvarez, N. P., Khoury, C. K., Achicanoy, H. A., Bernau, V., Dempewolf, H., Eastwood, R. J., Guarino, L., Harker, R. H., Jarvis, A., Maxted, N., Müller, J. V., Ramirez-Villegas, J., Sosa, C. C., Struik, P. C., Vincent, H., & Toll, J. (2016). Global conservation priorities for crop wild relatives. *Nature Plants*, *2*, 16022. https://doi.org/10.1038/nplants.2016.22

Clayton, W.D, Vorontsova, M.S., Harman, K.T., & Williamson, H. (2006 onwards). GrassBase—The Online World Grass Flora. http://www.kew.org/data/grasses-db.html (accessed December 14, 2021).

Cowie, R. H., Bouchet, P., & Fontaine, B. (2022). The Sixth Mass Extinction: Fact, fiction or speculation? *Biological Reviews of the Cambridge Philosophical Society*, *97*, 640–663. https://doi.org/10.1111/brv.12816

Dass, P., Houlton, B. Z., Wang, Y., & Warlind, D. (2018). Grasslands may be more reliable carbon sinks than forests in California. *Environmental Research Letters*, *13*, 074027. https://doi.org/10.1088/1748-9326/aacb39

Dauby, G., Stévart, T., Droissart, V., Cosiaux, A., Deblauwe, V., Simo-Droissart, M., Sosef, M. S. M., Lowry, P. P. 2nd, Schatz, G. E., Gereau, R. E., & Couvreur, T. L. P. (2017). ConR: An R package to assist large-scale multispecies preliminary conservation assessments using distribution data. *Ecology and Evolution*, *7*, 11292–11303. https://doi.org/10.1002/ece3.3704

Davies, T. J. (2019). The macroecology and macroevolution of plant species at risk. *The New Phytologist*, *222*, 708–713. https://doi.org/10.1111/nph.15612

Díaz, S., Fargione, J., Chapin, F. S. III, & Tilman, D. (2006). Biodiversity loss threatens human well-being. *PLoS Biology*, *4*, e277. https://doi.org/10.1371/journal.pbio.0040277

Enquist, B. J., Condit, R., Peet, R. K., Schildhauer, M., & Thiers, B. M. (2016). Cyberinfrastructure for an integrated botanical information network to investigate the ecological impacts of global climate change on plant biodiversity. PeerJ Preprints.

Estep, M. C., McKain, M. R., Vela Diaz, D., Zhong, J., Hodge, J. G., Hodkinson, T. R., Layton, D. J., Malcomber, S. T., Pasquet, R., & Kellogg, E. A. (2014). Allopolyploidy, diversification, and the Miocene grassland expansion. *Proceedings of the National Academy of Sciences of the United States of America*, *111*, 15149–15154. https://doi.org/10.1073/pnas.1404177111

Fajardo, J., Lessmann, J., Bonaccorso, E., Devenish, C., & Muñoz, J. (2014). Combined use of systematic conservation planning, species distribution modelling, and connectivity analysis reveals severe conservation gaps in a megadiverse country (Peru). *PLoS ONE*, *9*, e114367. https://doi.org/10.1371/journal.pone.0114367

Forest, F., Grenyer, R., Rouget, M., Davies, T. J., Cowling, R. M., Faith, D. P., Balmford, A., Manning, J. C., Procheş, S., van der Bank, M., Reeves, G., Hedderson, T. A. J., & Savolainen, V. (2007). Preserving the evolutionary potential of floras in biodiversity hotspots. *Nature*, *445*, 757–760. https://doi.org/10.1038/nature05587

Giraldo-Cañas, D., & Gonzales Arce, P. (2020). Tripsacum peruvianum. *The IUCN Red List of Threatened Species 2020*. e. T117764621A117765769. https://doi.org/10.2305/IUCN.UK.2020-2.RLTS.T117764621A117765769.en

González Ledesma, M., & Contreras, A. (2020a). Tripsacum intermedium (amended version of 2019 assessment). The IUCN Red List of Threatened Species 2020, e.T101338903A173972090. https://doi.org/10.2305/IUCN.UK.2020-2.RLTS.T101338903A173972090.en

González Ledesma, M., & Contreras, A. (2020b). Tripsacum zopilotense (amended version of 2019 assessment). The IUCN Red List of Threatened Species 2020, e.T101340317A173974344. https://doi.org/10.2305/IUCN.UK.2020-3.RLTS.T101340317A173974344.en

González Ledesma, M., Contreras, A., Aragón Cuevas, F., & de la Cruz Larios, L. (2020). Tripsacum maizar (amended version of 2019 assessment). The IUCN Red List of Threatened Species 2020, e. T101338328A173973720. https://doi.org/10.2305/IUCN.UK.2020-2.RLTS.T101338328A173973720.en

Hattersley, P. W., & Watson, L. (1992). Diversification of photosynthesis. In G. P. Chapman (Ed.). *Grass evolution and domestication* (pp. 38–116). Cambridge University Press.

Hautier, Y., Tilman, D., Isbell, F., Seabloom, E. W., Borer, E. T., & Reich, P. B. (2015). Plant ecology. Anthropogenic environmental changes affect ecosystem stability via biodiversity. *Science*, *348*, 336–340. https://doi.org/10.1126/science.aaa1788

Holz, H., Segar, J., Valdez, J., & Staude, I. R. (2022). Assessing extinction risk across the geographic ranges of plant species in Europe. *Plants, People, Planet*, *4*, 303–311. https://doi.org/10.1002/ppp3.10251

International Union for the Conservation of Nature. (2012). *IUCN Red List categories and criteria, version 3.1* (2nd ed.). IUCN.

Isaac, N. J. B., Turvey, S. T., Collen, B., Waterman, C., & Baillie, J. E. M. (2007). Mammals on the EDGE: Conservation priorities based on threat and phylogeny. *PLoS ONE*, *2*, e296. https://doi.org/10.1371/journal.pone.0000296

Khoury, C. K., Brush, S., Costich, D. E., Curry, H. A., de Haan, S., Engels, J. M. M., Guarino, L., Hoban, S., Mercer, K. L., Miller, A. J., Nabhan, G. P., Perales, H. R., Richards, C., Riggins, C., & Thormann, I. (2022). Crop genetic erosion: understanding and responding to loss of crop diversity. *The New Phytologist*, *233*, 84–118. https://doi.org/10.1111/nph.17733

Khoury, C. K., Carver, D., Greene, S. L., Williams, K. A., Achicanoy, H. A., Schori, M., León, B., Wiersema, J. H., & Frances, A. (2020). Crop wild relatives of the United States require urgent conservation action. *Proceedings of the National Academy of Sciences of the United States of America*, *117*, 33351–33357. https://doi.org/10.1073/pnas.2007029117

Kling, M. M., Mishler, B. D., Thornhill, A. H., Baldwin, B. G., & Ackerly, D. D. (2018). Facets of phylodiversity: Evolutionary diversification, divergence and survival as conservation targets. *Philosophical Transactions of the Royal Society of London. Series B, Biological Sciences*, *374*, 20170397. https://doi.org/10.1098/rstb.2017.0397

Le Breton, T. D., Zimmer, H. C., Gallagher, R. V., Cox, M., Allen, S., & Auld, T. D. (2019). Using IUCN criteria to perform rapid assessments of at-risk taxa. *Biodiversity and Conservation*, *28*, 863–883. https://doi.org/10.1007/s10531-019-01697-9

Lehmann, C. E. R., Griffith, D. M., Simpson, K. J., Michael Anderson, T., Archibald, S., Beerling, D. J., Bond, W. J., Denton, E., Edwards, E. J., Forrestel, E. J., Fox, D. L., Georges, D., Hoffmann, W. A., Kluyver, T., Mucina, L., Pau, S., Ratnam, J., Salamin, N., Santini, B., … Osborne, C. P. (2019). Functional diversification enabled grassy biomes to fill global climate space. *bioRxiv*, 583625. https://doi.org/10.1101/583625

Li, J., Gale, S. W., Kumar, P., Zhang, J., & Fischer, G. A. (2018). Prioritizing the orchids of a biodiversity hotspot for conservation based on phylogenetic history and extinction risk. *Botanical Journal of the Linnean Society*, *186*(4), 473–497. https://doi.org/10.1093/botlinnean/box084#supplementary-data

Maitner, B. (2020). Tools for accessing the Botanical Information and Ecology Network database [R package BIEN version 1.2.4].

Maitner, B. S., Boyle, B., Casler, N., Condit, R., Donoghue, J. II, Durán, S. M., Guaderrama, D., Hinchliff, C. E., Jørgensen, P. M., Kraft, N. J. B., McGill, B., Merow, C., Morueta-Holme, N., Peet, R. K., Sandel, B., Schildhauer, M., Smith, S. A., Svenning, J. C., Thiers, B., … Enquist, B. J. (2018). The BIEN R package: A tool to access the Botanical Information and Ecology Network (BIEN) database. *Methods in Ecology and Evolution*, *9*, 373–379. https://doi.org/10.1111/2041-210X.12861

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

Nic Lughadha, E., Govaerts, R., Belyaeva, I., Black, N., Lindon, H., Allkin, R., Magill, R. E., & Nicolson, N. (2016). Counting counts: Revised estimates of numbers of accepted species of flowering plants, seed plants, vascular plants and land plants with a review of other recent estimates. *Phytotaxa*, *272*, 82–88. https://doi.org/10.11646/phytotaxa.272.1.5

Panter, C. T., Clegg, R. L., Moat, J., Bachman, S. P., Klitgård, B. B., & White, R. L. (2020). To clean or not to clean: Cleaning open-source data improves extinction risk assessments for threatened plant species. *Conservation Science and Practice*, *2*, e311. https://doi.org/10.1111/csp2.311

Pelletier, T. A., Carstens, B. C., Tank, D. C., Sullivan, J., & Espíndola, A. (2018). Predicting plant conservation priorities on a global scale. *Proceedings of the National Academy of Sciences of the United States of America*, *115*, 13027–13032. https://doi.org/10.1073/pnas.1804098115

Pérez-Sarabia, J. E., de Stefano, R. D., Cetzal-Ix, W., Alvarado-Segura, A. A., & Basu, S. K. (2020). Conservation assessment using the IUCN criterion B: A case study on palms of the Mexican portion of the Yucatán Peninsula Biotic Province. *Kew bulletin / Royal Botanic Gardens*, *75*, 40. https://doi.org/10.1007/s12225-020-09896-2

Rivers, M. C., Taylor, L., Brummitt, N. A., Meagher, T. R., Roberts, D. L., & Nic Lughadha, E. (2011). How many herbarium specimens are needed to detect threatened species? *Biological Conservation*, *144*, 2541–2547. https://doi.org/10.1016/j.biocon.2011.07.014

Rodríguez, J. P., Brotons, L., Bustamante, J., & Seoane, J. (2007). The application of predictive modelling of species distribution to biodiversity conservation. *Diversity and Distributions*, *13*, 243–251. https://doi.org/10.1111/j.1472-4642.2007.00356.x

Plants of the World Online (POWO). (2020). Royal Botanic Gardens, Kew. http://www.plantsoftheworldonline.org/

Sánchez, J. J., Ruíz Corral, J. A., de la Cruz Larios, L., & Contreras, A. (2019). Zea perennis. *The IUCN Red List of Threatened Species 2019*. e. T77727073A77727085. https://doi.org/10.2305/IUCN.UK.2019-2.RLTS.T77727073A77727085.en

Schmidt, M., Zizka, A., Traoré, S., Ataholo, M., & Thiombiano, A. (2017). Diversity, distribution and preliminary conservation status of the flora of Burkina Faso. *Phytotaxa*, *304*, 1–215. https://doi.org/10.11646/phytotaxa.304.1.1

Scholtz, R., & Twidwell, D. (2022). The last continuous grasslands on Earth: Identification and conservation importance. *Conservation Science and Practice*, *4*, e626. https://doi.org/10.1111/csp2.626

Sharrock, S. (2020). Plant Conservation Report 2020: A review of progress towards the Global Strategy for Plant Conservation 2011-2020.

Sowa, S. P., Annis, G., Morey, M. E., & Diamond, D. D. (2007). A gap analysis and comprehensive conservation strategy for riverine ecosystems of Missouri. *Ecological Monographs*, *77*, 301–334. https://doi.org/10.1890/06-1253.1

Tropicos Missouri Botanical Garden. Tropicos v3.3.2. https://tropicos.org

Walker, B. E., Leão, T. C. C., Bachman, S. P., Bolam, F. C., & Nic Lughadha, E. (2020). Caution needed when predicting species threat status for conservation prioritization on a global scale. *Frontiers in Plant Science*, *11*, 520. https://doi.org/10.3389/fpls.2020.00520

Welker, C. A. D., McKain, M. R., Estep, M. C., Pasquet, R. S., Chipabika, G., Pallangyo, B., & Kellogg, E. A. (2020). Phylogenomics enables biogeographic analysis and a new subtribal classification of Andropogoneae (Poaceae—Panicoideae). *Journal of Systematics and Evolution*, *58*, 1003–1030. https://doi.org/10.1111/jse.12691

World Checklist of Selected Plant Families (WCSP). (2021). World Checklist of Selected Plant Families. http://wcsp.science.kew.org/

Zizka, A., Silvestro, D., Vitt, P., & Knight, T. M. (2021). Automated conservation assessment of the orchid family with deep learning. *Conservation Biology: the Journal of the Society for Conservation Biology*, *35*, 897–908. https://doi.org/10.1111/cobi.13616

SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

How to cite this article: AuBuchon-Elder, T., Minx, P., Bookout, B., & Kellogg, E. A. (2023). Plant conservation assessment at scale: Rapid triage of extinction risks. *Plants, People, Planet*, *5*(3), 386–397. https://doi.org/10.1002/ppp3.10355