Invasive Plant Science and Management

www.cambridge.org/inp

A global census of weed risk assessment standards

William Pfadenhauer[1], Benjamin Kesler[2], Justin Salva[3], Luca Pillidge[3], Taesung Smith[4], Charles Chimera[5] and Bethany Bradley[6]

[1]PhD Candidate, Organismic and Evolutionary Biology, University of Massachusetts Amherst, Amherst, MA, USA; [2]Undergraduate Student, Biology, University of Massachusetts Amherst, Amherst, MA, USA; [3]University of Massachusetts Amherst, Amherst, MA, USA; [4]Research Intern, Economics, Information Technology, and Business, University of Massachusetts Amherst, Amherst, MA, USA; [5]Weed Risk Assessment Specialist, Hawai'i Invasive Species Council, Honolulu, HI, USA and [6]Professor of Biogeography and Spatial Ecology, Environmental Conservation, University of Massachusetts Amherst, Amherst, MA, USA

Research Article

Cite this article: Pfadenhauer W, Kesler B, Salva J, Pillidge L, Smith T, Chimera C, and Bradley B (2025). A global census of weed risk assessment standards. Invasive Plant Sci. Manag **18**(e28): 1–11. doi: 10.1017/inp.2025.10030

Received: 16 February 2025
Revised: 31 August 2025
Accepted: 15 September 2025

Associate Editor:
Jacob N. Barney, Virginia Tech.

Keywords:
Invasive plants; invasive species policy; pest risk analysis; plant biosecurity; preventative management

Corresponding author:
William G. Pfadenhauer;
Email: wpfadenhauer@umass.edu

Abstract

Weed Risk Assessments (WRAs) aim to distinguish potentially invasive plants from non-invasive plants using traits such as the likelihood that the species will be introduced, establish, spread, and/or have negative impacts and (sometimes) whether it can be managed effectively. International standards for the criteria used to assess risk have been proposed to improve the sharing and transferability of WRA results. However, it is unclear whether existing WRAs follow these standards. Here, we compiled a global database of national-level and subnational-level (state/province) WRAs and evaluated their assessment criteria relative to an amended list of proposed minimum standards. We searched for WRAs in 240 countries and retrieved 20 unique assessments associated with 81 countries. The most comprehensive WRA was the "Guidelines for the Generic Ecological Impact Assessment of Alien Species" created by Norway, which satisfied 23 of 24 standards. The International Plant Protection Convention (IPPC) Pest Risk Analysis Framework and the European and Mediterranean Plant Protection Organization (EPPO) Express Pest Risk Analysis were also comprehensive, fulfilling 21 of 24 standards. All national-level WRAs included a description of the focal species' taxonomy, a description of risk assessment area, an assessment of the likelihood of spread of the focal species, and an assessment of the likelihood of impact of the focal species. Conversely, it was rare for WRAs to include a history of spread of the focal species or an evaluation of the possible effects of climate change. States/provinces showed a similar pattern (i.e., rarely discussed climate change), but also frequently lacked assessment of impact on ecosystem services and metrics of uncertainty. Many WRAs are shared between countries, but few are shared between states/provinces. Adopting similar WRA standards would allow policymakers and governing bodies to more effectively share information and results from completed WRAs, improving consistency of regulated plants across jurisdictional borders.

Introduction

Invasive species regulations are inconsistent across national (Early et al. 2016) and state/provincial borders (Beaury et al. 2021a; Lakoba et al. 2020), making it more likely that potentially harmful plants will be introduced to new locations. One way to improve regulatory consistency would be to standardize pre-border and post-border WRAs. Pre-border WRAs aim to identify high-risk invasive plants that are not yet present to prevent their intentional introduction and planting (often at the national level), while post-border WRAs aim to identify high-risk plants that may or may not be present to prevent their further introduction and spread (often at the state/provincial level). Increasing the consistency of WRA criteria across political boundaries could improve the consistency of regulations and also facilitate the sharing of risk assessment information across borders. Minimum standards for invasive species risk assessments have been proposed (Roy et al. 2018), but it is unclear whether existing WRA protocols meet these standards such that results could be easily shared to improve regulatory consistency.

WRAs are formalized lists of criteria that researchers or land managers can use to evaluate the invasion risk of a target plant. "Invasion risk" refers to the likelihood of a target non-native species spreading and causing negative impacts in a new location. A wide variety of variables can be used to predict a species' invasion risk. Each WRA combines a set of these predictive variables to estimate invasion risk for incoming non-native species before their introduction. WRAs were first introduced in the 1990s and were used primarily in Australia and New Zealand to inform regulations that prohibited the introduction of high-risk, potentially invasive plants (Pheloung et al. 1999; Scott and Panetta 1993; Williams 1996). Since then, WRAs have become a common tool worldwide for evaluating the likelihood that a plant will become invasive (e.g., Chong et al. 2011; Koop et al. 2012;

© The Author(s), 2025. Published by Cambridge University Press on behalf of Weed Science Society of America. This is an Open Access article, distributed under the terms of the Creative Commons Attribution licence (https://creativecommons.org/licenses/by/4.0/), which permits unrestricted re-use, distribution and reproduction, provided the original article is properly cited.

Management Implications

Preventing the introduction of invasive species is well known to be the most effective form of management. For invasive plants, which are predominantly introduced through horticulture, prevention is largely achieved by regulating and restricting the sale of species that are known to be (or have the potential to become) invasive. Unfortunately, invasive plant regulations in many locations (except for some European nations) are inconsistent across national and state/provincial borders, leading to an ineffective patchwork of laws that do little to slow the introduction of invasive plants. Sharing completed weed risk assessments (WRAs), which are used to evaluate invasion risk, could increase capacity and improve regulatory consistency across borders if risk assessment criteria are similar in different regions. Here we compiled global WRA protocols used to inform regulations at the national scale and state/provincial scale. For each, we evaluated the scoring criteria relative to a proposed set of minimum standards. It was common for multiple countries to use the same WRA protocol, but rare for states or provinces. All national and state/provincial WRAs evaluated the likelihood of species spread and almost all WRAs evaluated the likelihood of negative impacts. This information about target species could be readily shared across borders to decrease redundancy and improve consistency in invasive plant regulations. In contrast, national and state/provincial WRAs rarely included any consideration of climate change, which misses an opportunity to proactively regulate emerging invasive plants.

MacLeod 2010; Pheloung et al. 1999; Roy et al. 2018), and general guidelines about information to include in WRAs have been presented (FAO 2019b; Roy et al. 2018). While WRAs vary in their ability to correctly differentiate invasive from non-invasive species, they demonstrate high cost-effectiveness (Keller et al. 2007), because they enable the management of non-native species before invasion.

During the WRA process, assessors (who are often researchers or management specialists at governmental, academic, or nonprofit institutions) gather data pertaining to the predictive variables (criteria) using published literature, gray literature (e.g., agriculture, horticulture, or forestry publications), or personal experiences, and subsequently aggregate the results to determine the overall invasive potential of a target plant in the focal area. Criteria within a WRA may be qualitative (e.g., the Comité de Sanidad Vegetal del Cono Sur (COSAVE) WRA requires the assessor to describe the "effects on ecological systems or processes") or quantitative (e.g., the WRA for Brazil requires the assessor to determine the amount of economic damage that could be caused by a species), and they typically focus on plant traits and environmental tolerances that influence establishment and spread as well as observed ecological and/or socioeconomic impacts (Bartz and Kowarik 2019; Roy et al. 2018; Vilà et al. 2019). WRAs can be used to evaluate species that are likely to be introduced into a region both intentionally (e.g., as ornamental plants; Reichard and White 2001) or accidentally (e.g., as seed contaminants; Lehan et al. 2013). Ultimately, information from WRAs may be weighed by policymakers against potential benefits (e.g., agricultural or ornamental value; Roberts et al. 2011) to determine whether a species should be regulated (Simberloff 2005).

WRAs are especially useful because they are implemented before the introduction of non-native plants into the focal area (Kumschick and Richardson 2013). The most cost-effective way to reduce the impacts of invasive species is to prevent their introduction, rather than attempting to control or remediate the negative effects of the species postinvasion (Leung et al. 2002). Recent analyses of expenses incurred by species invasion emphasize the efficacy of investment and intervention preinvasion (Ahmed et al. 2022; Cuthbert et al. 2022). WRAs are one proven method for maximizing preinvasion investments, as they allow managers to triage non-native species and (ideally) lead to regulations of high-risk species while allowing for the introduction (and subsequent economic benefits) of low-risk species.

Several studies have compared existing risk assessment protocols, often finding large differences in the types of approaches (Essl et al. 2011) and the criteria within each (Bartz and Kowarik 2019; Roy et al. 2018; Vilà et al. 2019). Inconsistent criteria can lead to different evaluations of risk for the same species across different protocols (i.e., asking different questions yields different answers; González-Moreno et al. 2019), which could further reduce consistency in regulated species lists (Bradley et al. 2022). However, previous comparisons have not differentiated between regulatory risk assessments and those developed primarily for academic purposes (e.g., Bartz and Kowarik 2019; Essl et al. 2011; Roy et al. 2018; Vilà et al. 2019), and several new regulatory WRAs have been adopted in recent years. Therefore, a new census of regulatory pre-border WRAs is necessary to determine the extent of inconsistencies worldwide for national and subnational (state/provincial) geographies.

Here, we compiled all available pre-border national-level and pre/post-border state/provincial-level WRAs that have been adopted for invasive plant regulation. We adapted the proposed minimum standards for risk assessments developed by Roy et al. (2018) to create an amended list of 24 standards, which we used to evaluate consistency across protocols, identifying criteria that are commonly (and less commonly) included. This analysis provides a comprehensive snapshot of existing pre-border regulatory frameworks, highlighting opportunities to enhance consistency and strengthen the prevention of invasive plant introductions across nations, states, and provinces.

Materials and Methods

Compiling National-Level WRAs

We searched for pre-border WRAs that applied to any of the countries included in the International Organization for Standardization (ISO) 3166 classification scheme (https://www.iso.org/home.html). Using Google and Google Scholar, we searched the name of each country and the keywords "weed risk assessment," "wra," "pest risk analysis," "pra," "invasive policy," "phytosanitary measures," and "invasive plant law." When searching, we combined these keywords one by one with the name of each country (e.g., "Armenia weed risk assessment"), and we examined the first two pages of results on Google Scholar and the equivalent number of results (20) on Google. We performed these searches between June 2022 and June 2025. We only collected WRAs that had been officially adopted (or otherwise implemented) through regulations/legislation or by a government official or agency of the respective country. When there were multiple WRAs that met these guidelines for a country, we included the one that had been cited most often at the time of data collection. We excluded WRAs that were published in academic literature but were not officially adopted for regulation in a specific country. For completeness, we also checked all WRAs listed in prior reviews by Bartz and Kowarik (2019), Canavan et al. (2025),

https://doi.org/10.1017/inp.2025.10030 Published online by Cambridge University Press

Essl et al. (2011), Roy et al. (2018), and Vilà et al. (2019) and retained the ones that aligned with our objectives. For countries that yielded no results using these methods, we sent email requests to the phytosanitary contacts listed on the International Plant Protection Convention (IPPC) website (https://www.ippc.int/en/countries/all/contactpoints/) requesting a copy of their national-level WRA (if one existed). We sent follow-up emails to contacts that had not responded within 2 months of our initial request. This approach is likely to have missed some national WRAs that were not available in English.

Compiling State/Province-Level WRAs

To better understand whether pre-border WRAs at the subnational level follow international guidelines, we also searched for state/province-level WRAs in countries that had developed an independent national-scale WRA (i.e., those not implementing an international protocol). These countries were: Australia, Belgium, Brazil, Canada, Germany, Ireland, Latvia, Mexico, New Zealand, Norway, South Africa, South Korea, United Kingdom, United States, and Zambia. (Canada created its own WRA, but later adopted the WRA developed by the United States, which we learned through personal communication. This is why we searched for province-level WRAs in Canada, even though they do not appear to have their own national-scale WRA.) Kesler (2021) previously evaluated the content of state-level WRAs in the United States using similar methods, so we did not repeat searches for the United States and instead incorporated the results from Kesler (2021) directly. Where methods differed, we used notes provided by Kesler's Appendix S1 to rescore WRAs using our methods. Kesler (2021) provided web links to WRA sources, some of which had subsequently become defunct. For links that were still live, we downloaded the relevant WRAs. For defunct links, we re-searched for updated versions of WRAs and downloaded them when available.

Between April 2024 and August 2025, we used Google and Google Scholar to search for the name of each state/province/territory and the keywords "weed risk assessment," "wra," "pest risk analysis," "pra," "invasive policy," "phytosanitary measures," and "invasive plant law." When searching, we combined these keywords one by one with the name of each state and country (e.g., "Victoria Australia weed risk assessment"), and we examined the first two pages of results on Google Scholar and the equivalent number of results (20) on Google. State/province-level WRAs were rare, and our search process was time-intensive; therefore we started with each country's most populous state or province. If we could not find a WRA for a country's most populous state or province, we did not continue searching the remaining states or provinces. It is possible that these methods may have overlooked WRAs in countries where less-populous states have been quicker to adopt WRAs than more populated states (as was the case in Australia), or in instances where less-populous states are of particular importance for conservation (e.g., the Galapagos Islands in Ecuador).

Scoring WRAs

To assess the scope and content of each WRA, we applied a list of "minimum standards" adapted from Roy et al. (2018; Table 1), which are intended to improve the consistency and quality of invasive species risk assessments. The first three minimum standards contain multiple parts (e.g., Standard 2 asks whether the risk assessment considers the likelihood that the target species will be introduced, establish, spread, and/or have impact). Because these component parts are sometimes considered separately in WRAs (e.g., multiple WRAs include information about the history of negative impacts but not the history of spread), we considered the component parts individually, resulting in a final list of 24 standards (Table 1). For our assessment, we rephrased each of the minimum standards in the form of yes/no questions to reduce ambiguity (Table 1). If the standard was partially, but not fully met, we answered no (e.g., for Standard 4 about vectors of secondary spread, some WRAs included criteria about long-distance dispersal by animals but did not include long-distance dispersal associated with human activity; these criteria were scored as not fulfilling the minimum standards for vectors of secondary spread, as they do not account for both intentional and unintentional vectors). For each national and subnational WRA, we evaluated whether each of the 24 minimum standards were satisfied and summed the results. A minimum of three coauthors independently reviewed each WRA to ensure that we consistently applied the 24 standards to each WRA. We reconciled scoring differences between coauthors by collectively reviewing the WRA and discussing the standards until a consensus was reached. We created maps to visualize how many minimum standards were met by global WRAs. We also identified standards that were less often met and visualized the countries and states/provinces that met those standards. For each WRA, we also recorded the total number of questions/criteria used, the year of initial publication, and whether each WRA was primarily derived from an earlier, preexisting WRA.

To further understand the global landscape of risk assessments, we assigned each WRA to a category based on the structure of its decision-making process. We used the same categories previously described by Hulme (2012) and the Council for Agricultural Science and Technology (2024). Quantitative WRAs are those that apply statistical models to trait or distribution data for plant species to determine the risk of invasion of each. Qualitative WRAs are those that combine expert opinions about the invasion risk of plant species to determine invasion risk (qualitative WRAs may lack a consistent or well-defined system for arriving at final determination). Finally, semiquantitative WRAs combine aspects of qualitative and quantitative WRAs. For a given species, semiquantitative WRAs generate scores for multiple invasion risk factors, often using expert opinions. These scores are subsequently summed (or otherwise combined using a predetermined method) to arrive at a final invasiveness ranking or management outcome.

Results and Discussion

Geography of WRAs

We found 20 unique national-level WRAs used by a total of 81 countries (Table 2). Twelve WRAs were used by a single country; eight were used by multiple countries. We were unable to find WRAs for 159 countries, only 4 of which (Bahrain, Cabo Verde, Colombia, Nigeria) confirmed via email that they do not have a WRA. It is concerning that we were only able to locate WRAs for 81 of 240 countries (34%). Most invasive plants are introduced intentionally as ornamental plants (Beaury et al. 2021b; Reichard and White 2001), making WRAs and subsequent regulations highly effective for proactively preventing invasions when they are used to consistently screen new species before import. WRAs and border control policies are cost-effective (Keller et al. 2007), particularly when considering the high economic costs of invasive plants (Diagne et al. 2021). Moreover, proactive exclusion of

https://doi.org/10.1017/inp.2025.10030 Published online by Cambridge University Press

Table 1. Minimum standards for invasive species risk assessments proposed by Roy et al. (2018; left column) and corresponding standards used to evaluate global weed risk assessments (WRAs) used in the present analysis (right column).

Minimum standards from Roy et al. (2018) (verbatim)	Altered and rephrased standards used to score WRAs in the present analysis
1. Description (taxonomy, invasion history, distribution range [native and introduced], geographic scope, socioeconomic benefits)	1A. Does the WRA require a specific focal taxa to be identified for assessment? 1B. Does the WRA ask whether the focal taxa is invasive in a location outside the WRA area? Or, does the WRA ask for the previous locations invaded by the focal taxa? 1C. Does the WRA require the assessor to describe or list the area(s) where the focal taxa is native? 1D. Does the WRA require the assessor to describe or list the area(s) where the focal taxa is introduced? Or, does the WRA ask whether an introduced range exists for the focal taxa? 1E. Does the WRA require the assessor to define the WRA area? Or, is the WRA explicit about only being used for a specific area? 1F. Does the WRA require the assessor to list or describe any socioeconomic benefits of the focal taxa?
2. Likelihood of introduction, establishment, spread and magnitude of impact	2A. Does the WRA attempt to determine the likelihood that the focal taxa will be introduced to the WRA area? (This may include questions about human-mediated dispersal or primary introduction pathways.) 2B. Does the WRA attempt to determine the likelihood that the focal taxa will establish (once introduced) in the WRA area? (This may include questions about climate matching, habitat suitability, or the presence of a needed host organism.) 2C. Does the WRA attempt to determine the likelihood that the focal taxa will spread (once established) in the WRA area? (This may include questions about methods of reproduction or natural dispersal syndromes.) 2D. Does the WRA attempt to determine the likelihood that the focal taxa will cause negative impacts (once established) in the WRA area? (This may include questions about potentially harmful traits, like allelopathy, or impacts caused by the focal taxa in other locations.)
3. Description of the current and potential distribution, spread and magnitude of impact	3A. Does the WRA require the assessor to describe or list all area(s) within the global distribution of the focal taxa? Or, does the WRA require the assessor to describe or list all area(s) within the WRA area that are likely to be suitable for the focal taxa? 3B. Does the WRA require the assessor to explicitly consider or describe the history of spread of the focal taxa? (This is different from 1B "invasion history," because a species can spread without causing negative impacts and vice versa.) 3C. Does the WRA require the assessor to explicitly consider or describe the magnitude of existing negative impacts of the focal taxa? (This is different from 1B "invasion history," because the severity of impacts can vary widely across invasive species. This can either include magnitude of direct effects or magnitude of control costs.)
4. Inclusion of multiple pathways and vectors of introduction and spread both intentional and unintentional	4. Does the WRA require the assessor to consider possible vectors of introduction/spread into/within the WRA area, including those that are both intentional and unintentional?
5. Assessment of environmental impacts with respect to biodiversity (and ecosystem) patterns and processes	5. Does the WRA require the assessor to explicitly consider the environmental impacts of the species? (This can be either within the WRA area or in other locations, but should require the assessor to name, list, quantify, or otherwise delineate the individual components of environmental impacts as they pertain to biodiversity or ecosystem functioning.)
6. Assessment of adverse impacts with respect to ecosystem services	6. Does the WRA require the assessor to explicitly consider the impacts of the species on ecosystem services? (This can be either within the WRA or in other locations, but should require the assessor to name, list, quantify, or otherwise delineate the individual components of effects of ecosystem services. These impacts should only be negative. Positive effects on ecosystem services are encompassed by 1F.)
7. Assessment of adverse socioeconomic impacts	7. Does the WRA require the assessor to explicitly consider the social, economic, or cultural impacts of the species? (These impacts should be negative. Positive effects are encompassed by 1F.)
8. Status (threatened or protected) of species or habitat under threat	8. Does the WRA require the assessor to explicitly consider the status (threatened, endangered, protected, rare, endemic, etc.) of the species or habitat under threat? (This does not include any potential positive impacts of the species to threatened species.)
9. Possible effects of climate change in the foreseeable future	9. Does the WRA require the assessor to consider future climate change scenarios (or resulting effects of future climate change scenarios) when estimating climate suitability or establishment risk? (WRAs cannot fulfill this standard by suggesting reassessment in the future when/if the climate changes. The purpose of this standard is to encourage assessors to incorporate future impacts into *current* risk assessments.)
10. Data limitations	10. Does the WRA have a defined procedure for dealing with unanswered questions (i.e., questions for which data are limited or unavailable)?
11. Information sources	11. Does the WRA require the assessor to list references or information sources?
12. Summary of the different components of the risk assessment in a consistent and interpretable form and an overall summary	12. Does the WRA provide a standardized way of summarizing all components of risk? And does the WRA have a standardized way of translating the summarized risk value into appropriate management actions?
13. Uncertainty (confidence)	13. Does the WRA have a way for the assessor to describe or quantify the confidence or uncertainty associated with the *answered* questions? (Unanswered questions are assumed to be completely uncertain and are addressed in Standard 10.)
14. Quality assurance	14. Does the WRA have a way to ensure that different assessors will produce consistent and accurate results? And, does the WRA have a way to ensure that the standards are applied consistently across species?

invasive plants prevents substantial negative impacts on native species and ecosystems (Roy et al. 2024). While we only searched for WRAs in English, the spatial pattern of border control measures (or lack thereof) is consistent with a previous analysis of other proactive invasive species policies based on U.N. Convention on Biological Diversity implementation documents (Early et al. 2016). Nevertheless, we acknowledge that it is possible that our methods excluded some WRAs written in languages other than English.

Encouragingly, our analysis identifies opportunities for sharing WRA policies across neighboring countries—at least one country on every continent except Antarctica uses a WRA (Figure 1). Seven

https://doi.org/10.1017/inp.2025.10030 Published online by Cambridge University Press

Table 2. National-scale weed risk assessments (WRAs) and their corresponding scores (number of "minimum standards" met out of 24; see Table 1)[a]. State-scale scores can be found in Appendix S1.

Name	Abbreviation	Countries	Score	Type	Reference
Australian Weed Risk Assessment System	AUS	Australia	15	Semiquantitative	Pheloung et al. (1999)
Harmonia +	BEL	Belgium, The Netherlands	18	Semiquantitative	D'hondt et al. (2015)
Guide for Developing Pest Risk Analysis	BRA	Brazil	14	Qualitative	Brazil Ministry of Agriculture and Livestock (2021)
CABI Pest Risk Analysis Tool	CABI	Zimbabwe, Eswatini	18	Qualitative	CABI (2021)
Guidelines for Pest Risk Analysis of Imported Plants and Plant Products	CARIB	Anguilla, Antigua and Barbuda, The Bahamas, Barbados, Belize, Bermuda, British Virgin Islands, The Cayman Islands, Dominica, Grenada, Guyana, Haiti, Jamaica, Montserrat, Saint Kitts and Nevis, Saint Lucia, Saint Vincent and the Grenadines, Suriname, Trinidad and Tobago, The Turks and Caicos Islands	15	Semiquantitative	Goldsmith (2016)
Southern Cone Plant Health Committee Guidelines of Procedures for Risk Assessment of Plants as Pests (Weeds)	COSAVE	Argentina, Bolivia, Chile, Paraguay, Peru, Uruguay	18	Qualitative	Inter-American Institute for Cooperation on Agriculture (2018)
European and Mediterranean Plant Protection Organization Express Pest Risk Analysis	EPPO	Austria, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Greece, Hungary, Italy, Latvia, Lithuania, Luxembourg, Malta, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden	21	Qualitative	EPPO (2012)
Methodology of Nature Conservation Invasiveness Assessment for Alien Species	GER	Germany	20	Semiquantitative	Nehring et al. (2013)
International Plant Protection Convention Pest Risk Analysis Framework	IPPC	Bangladesh, Japan, Solomon Islands, Pakistan, Philippines	21	Qualitative	FAO (2019a)
Risk Analysis and Prioritisation for Invasive and Non-native Species in Ireland and Northern Ireland	IRE	Ireland	19	Semiquantitative	Kelly et al. (2013)
Assessing Ecological Risk of Invasive Alien Plants in South Korea	KOR	South Korea	10	Semiquantitative	Kil et al. (2004)
Guidelines for Species Inclusion on the List of Invasive Species in Latvia	LAT	Latvia	19	Semiquantitative	Ozols et al. (2021)
Rapid Assessment of Invasiveness Method for Exotic Species in Mexico	MEX	Mexico	16	Semiquantitative	CONABIO (2015)
Guidelines for the Generic Ecological Impact Assessment of Alien Species	NOR	Norway	23	Semiquantitative	Sandvik et al. (2017)
New Zealand Weed Risk Assessment Model	NZ	New Zealand	16	Semiquantitative	Williams (1996)
Hawai'i Pacific Islands Weed Risk Assessment	PAC IS	American Samoa, Cook Islands, Kiribati, Marshall Islands, Micronesia, Niue, Samoa, Tonga, Tuvalu, Vanuatu	15	Semiquantitative	Daehler and Carino (2000)
A Framework to Support Alien Species Regulation: The Risk Analysis for Alien Taxa	RAAT	South Africa	20	Semiquantitative	Kumschick et al. (2020)
The UK Risk Assessment Scheme for All Non-native Species	UK	United Kingdom	20	Semiquantitative	Baker et al. (2008)
U.S. Department of Agriculture Animal and Plant Health Inspection Service Plant Protection and Quarantine Weed Risk Assessment	USA	United States, Canada	20	Semiquantitative	Koop et al. (2012)
Pest Risk Assessment: A Zambian Perspective	ZAM	Zambia	13	Semiquantitative	Msiska (2013)

[a]More details about each WRA and its score can be found in Supplementary Appendix S2. PDFs of each WRA can be found on GitHub at the following link: https://github.com/wpfadenhauer/Global-WRAs/tree/main/WRA_Documents.

WRAs applied to countries in Europe; three WRAs applied to countries in Africa; three WRAs applied to countries in North America (including the Caribbean); two WRAs applied to countries in each of Asia, South America, and Oceania; and one WRA applied to Australia. The most-represented continents were South America (9/14 countries used a WRA; 64%), Europe (28/51; 55%), Oceania (14/26; 54%), and North America/Caribbean (20/41; 49%). In contrast, much smaller percentages of the countries in Asia (6/53; 11%) and Africa (4/60; 7%) used WRAs. The lack of WRAs in Asia and Africa is consistent with existing biases in invasive plant ecology, which illustrate that most studies focus on a subset of species that are harmful in wealthier nations (Laginhas et al. 2022; Pyšek et al. 2008). Pyšek et al. (2008) suggested that the lack of data on invasive species in many locations is a result of an overall lack of funding invested in research by these countries. Lack of WRAs may also be related to political will and maturity of an

https://doi.org/10.1017/inp.2025.10030 Published online by Cambridge University Press

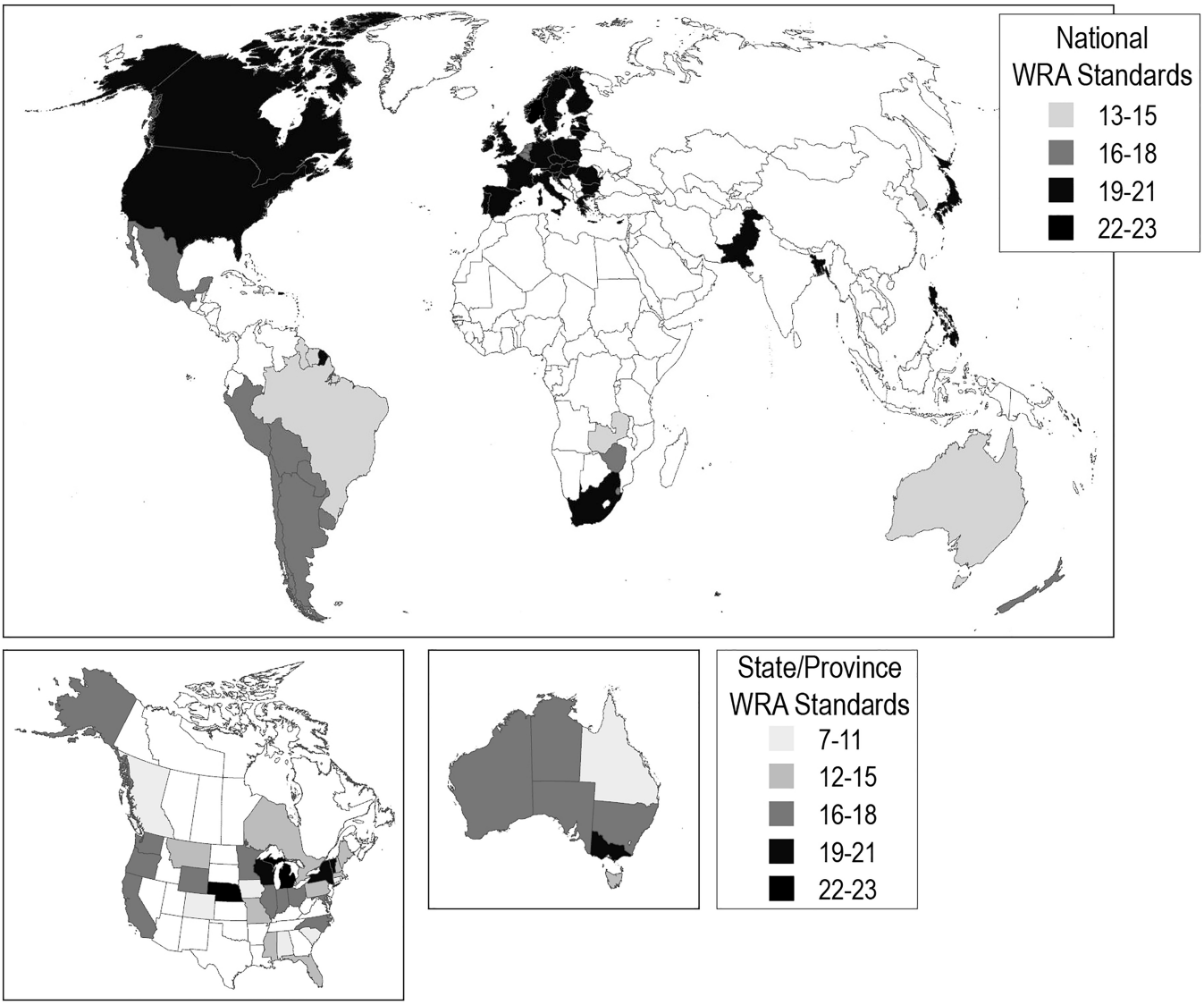


Figure 1. Weed risk assessment (WRA) standards met by nations and states. The global map (top panel) displays the number of minimum standards (out of 24) met by 20 unique WRAs used by 81 countries. The global map uses a Robinson projection and is at a scale of 1:200,000,000. The continental maps (bottom panels) display WRAs used by 38 states or provinces (37 total WRAs). The continental maps use Albers equal area conic projections and are at a scale of 1:150,000,000. We were unable to find WRAs for countries and states/provinces shown in white.

import assessment process. For example, invasion scientists in both India (Sreekanth et al. 2022) and China (Wang et al. 2024) have developed WRAs but they have not yet been implemented as regulations.

Similar patterns of lack of scientific capacity and/or lack of political will may also exist within countries. In the United States, state invasive plant councils often lack the necessary funding to conduct risk assessments for all potentially harmful species. Thus, increasing the consistency of existing WRAs across national and state/provincial borders could enable sharing of completed risk assessments, which would stretch limited resources further by reducing duplicate effort while also potentially increasing consistency in regulated species lists (Bradley et al. 2022). Similarly, several states that have yet to implement a WRA or regulate invasive plants could adopt protocols from neighbors.

Countries located in tropical regions were particularly unlikely to have national WRAs. Notably, WRAs were lacking across tropical regions of Central America, Central Africa, and Southeast Asia. A recent analysis of plant invasion risk suggested that the tropics are particularly susceptible to invasions and that the low number of previously reported invasions in the tropics was more likely due to fewer introductions rather than lack of susceptibility (Pfadenhauer and Bradley 2024). This analysis also noted that WRAs are likely to be most useful in areas such as these, with high ratios of invasive to established plant species. The lack of WRA protocols coupled with elevated risk to tropical regions highlights a major gap in proactive invasive plant policy and management at a global scale. However, a past analysis of the Australian WRA applied to multiple regions suggests that the same criteria effectively identify invasive plants in both temperate and tropical regions (Gordon et al. 2008). This finding suggests that using one of the existing national WRAs would lead to effective invasive plant identification for any country.

We found state/provincial-level WRAs for Australia, Canada, the United States (previously collected by Kesler [2021]), and Ecuador. For Belgium, Brazil, Germany, Ireland, New Zealand,

https://doi.org/10.1017/inp.2025.10030 Published online by Cambridge University Press

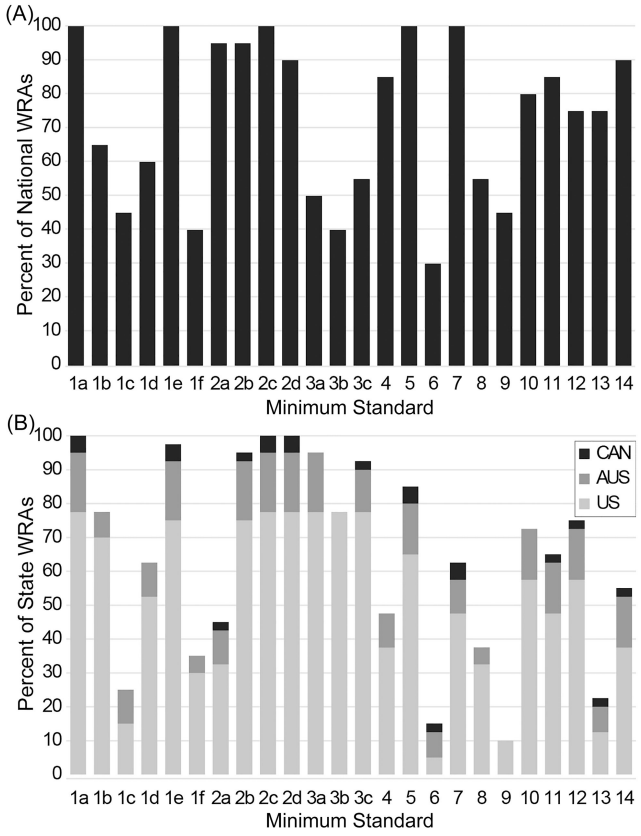


Figure 2. Percentage weed risk assessments (WRAs) that fulfilled each minimum standard. (A) Fulfillment of minimum standards by national WRAs (out of 20 total) and (B) fulfillment of minimum standards by state WRAs (out of 37 total; CAN = 2, AUS = 7, ECU = 1, US = 27). See Table 2 for descriptions of each minimum standard.

Norway, South Africa, South Korea, United Kingdom, and Zambia, we were unable to find WRAs for their most populous state/province, and therefore did not search for the remaining states and provinces. We found unique WRAs for 7 of the 9 states/territories in Australia, 2 of the 13 provinces/territories in Canada, and 1 of the 24 provinces in Ecuador. For comparison, Kesler (2021) found unique WRAs for 31 states within the United States, with 2 additional states using a WRA that was created by a different state (we were unable to locate the WRAs for some of these states; our results include WRAs for 28 U.S. states). Although it was common for countries to use the same WRAs across borders, it was less common for states/provinces to use the same WRAs. For states/provinces that do not yet have WRAs, using an existing protocol from a neighboring state rather than creating a new one could be more efficient and enable more direct sharing of completed risk assessments. Even though state WRAs are often unique, sharing of completed risk assessments would still benefit others because risk assessment criteria often overlap (Bradley et al. 2022).

Meeting Minimum Standards

The average number of standards met by each national-level WRA was 17.6 ± 3.2 (SD) out of 24 total standards. For the state/provincial-level WRAs in Canada, Australia, the United States, and Ecuador, the average was 14.4 ± 3.7 (SD). There were several standards that were commonly met by both national-level and state/provincial-level WRAs that could be shared across jurisdictions to reduce replication of effort (Figure 2). Almost all assessments included criteria related to the likelihood that the species will establish, spread, and have negative impacts within the region (Standards 2B–2D; Figure 2). Broadly, this information aligns with the general guidelines for WRAs recommended by the IPPC (FAO 2019b). This type of information could readily inform risk assessment for neighboring regions and beyond, given the many similarities between climate and ecoregions globally. Similarly, most WRAs included information about negative environmental (Standard 5) and socioeconomic impacts (Standard 7; Figure 2). Roy et al. (2018) noted that many of the risk assessments they evaluated did not include socioeconomic impacts, while our analysis found that most did. One possible explanation for this pattern may be that regulatory WRAs (i.e., the ones we sampled) are more likely to include a wider range of possible impacts that reflect a country's widely varied interests. Moreover, the IPPC (FAO 2019b), which provides general guidelines for national WRAs, emphasizes socioeconomic impacts but not ecological impacts. In contrast, risk assessments developed primarily for academic purposes (which were included in the Roy et al. [2018] analysis) may primarily reflect a researcher's area of expertise (e.g., ecology), without evaluating possible consequences in other disciplines. Nevertheless, given that our analysis focused only on regulatory WRAs, it is encouraging that both ecological and socioeconomic impacts are usually included. Finally, most WRAs included a list of data sources (Standard 11). This suggests that a considerable amount of similar information and number of associated sources is being compiled about invasive plant distributions and impacts across jurisdictions. We reiterate calls for global, open-source repositories of invasive species information (Barney et al. 2015; Culina et al. 2018; Fusco et al. 2023) to reduce the likelihood of redundant efforts to compile that same information (e.g., documentation of ecological impacts, introduction pathways, or potential habitat).

Conversely, there were several minimum standards that were frequently missing from WRAs. Fewer than 50% of both national and state/provincial-level WRAs included information about the native range (Standard 1C) or socioeconomic benefits (Standard 1F)—both of these standards are part of the "basic species description." Native range is not relevant as a risk factor by itself, but instead can inform assessments of likelihood of introduction and establishment (Standards 2A and 2B). Socioeconomic benefits are also not a risk factor (Carneiro et al. 2024), but could be useful for contextualizing the motivation for introducing the species. Additionally, fewer than 50% of WRAs included information about potential impacts on ecosystem services (Standard 6) or the effects of climate change on invasion risk (Standard 9). These latter two were also sparse in the Roy et al. (2018) analysis, and were surprisingly absent in some of the most recently adopted regulatory WRAs in our analysis (COSAVE, Guide for Developing Pest Risk Analysis (BRA), A Framework to Support Alien Species Regulation: The Risk Analysis for Alien Taxa (RAAT), and Centre for Agriculture and Biosciences International Pest Risk Analysis Tool (CABI)). One plausible explanation for these omissions is that both impacts on ecosystem services and interactions with climate change are challenging to estimate without existing scientific data and are therefore unlikely to be observed based on expert knowledge alone.

The persistent lack of explicit consideration of climate change (Standard 9; Figure 3) is particularly concerning, because climate change is likely to change the sets of species that pose high risk within countries or states (Bradley et al. 2023; Colberg et al. 2024) and is a top concern for invasive species management (Beaury et al. 2020). The Global South in particular appears ill-prepared to assess interactions between invasive plants and climate change. Models of

https://doi.org/10.1017/inp.2025.10030 Published online by Cambridge University Press

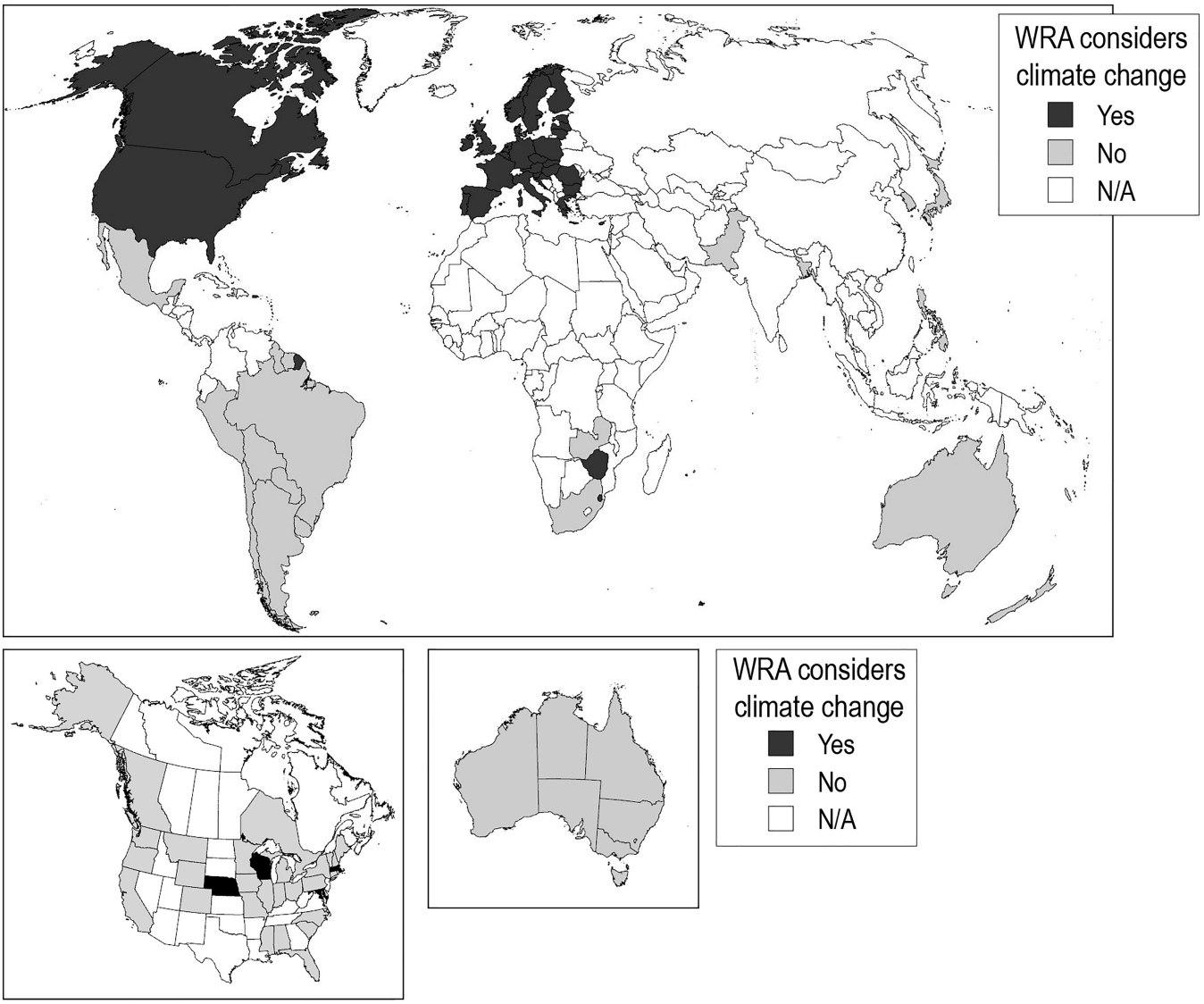


Figure 3. Climate change consideration (Standard 9) remains rare in national-level and state/provincial-level weed risk assessments (WRAs). The global map (top panel) uses a Robinson projection and is at a scale of 1:200,000,000. The continental maps (bottom panels) display WRAs used by 38 states or provinces (37 total WRAs). The continental maps use Albers equal area conic projections and are at a scale of 1:150,000,000. We were unable to find WRAs for countries and states/provinces shown in white.

climate change impacts on invasive species range shifts are becoming increasingly common at both global and regional scales, such that assessors in the future could more easily find information about potential for establishment (e.g., Allen and Bradley 2016; Bezeng et al. 2017; Gallagher et al. 2013) and abundance/impact (e.g., Evans et al. 2024; O'Neill et al. 2021). In the absence of future distribution or abundance projections, assessors could consider whether the species currently poses a risk to ecosystems warmer than their target region and extrapolate risk. Explicitly including climate change in WRAs, even if data are currently lacking, ensures that assessors are thinking about the changing likelihood of establishment and impact due to warming. Failing to include climate change misses an opportunity to proactively prevent future invasions (Bradley et al. 2023).

Limitations

Although Roy et al.'s (2018) minimum standards include a comprehensive set of criteria for WRA, all of these criteria are not necessarily strong predictors of invasion risk. Past studies of risk assessment efficacy have found high levels of accuracy with fewer criteria or questions (Caley and Kuhnert 2006; Conser et al. 2015; Gordon et al. 2008; Koop et al. 2012). Criteria with high predictive power include whether a species has established and/or become invasive elsewhere (Caley and Kuhnert 2006; Conser et al. 2015; Koop et al. 2012), whether the species has negative ecological impacts (Conser et al. 2015; Koop et al. 2012), whether the species has an invasive congener (Buonaiuto et al. 2023; Conser et al. 2015), and whether the species has broad climatic tolerance (Higgins and Richardson 2014; Pfadenhauer et al. 2023). Including additional criteria (as is typical in the WRAs we assessed) makes it likely that more information will be available to potentially inform assessments in other jurisdictions. However, additional criteria may also make the WRA process time-prohibitive for some countries or states. For example, Verbrugge et al. (2010) estimated that some comprehensive risk assessments could take up to a week of time to complete for a single species. Given that an estimated 14,000 plants have been introduced and established outside their

https://doi.org/10.1017/inp.2025.10030 Published online by Cambridge University Press

native ranges (van Kleunen et al. 2015), it might be a more realistic approach to start with a shorter risk assessment process such as horizon scanning (Kendig et al. 2022) and then only complete full WRAs for higher priority species that result from the initial screening process.

As implemented here, the minimum standards are also biased toward environmental impacts. Three separate standards focus on various components of environmental effects (Standard 5: biodiversity; Standard 6: ecosystem services; and Standard 8: threatened species and habitats), while only one standard focuses on socioeconomic impacts (Standard 7). To reduce bias toward environmental impacts, future reviews of WRAs may opt to split Standard 7 into three separate standards, with one for social, economic, and cultural impacts, respectively. Similarly, future assessors may choose to include separate questions about these three categories of impact in their WRAs.

Conclusions

Our analysis reveals a high degree of consistency across both national and state/provincial-level WRA criteria. Broad adoption of the same protocols (e.g., EPPO, IPPC, Hawai'i Pacific Islands Weed Risk Assessment (PAC IS), Guidelines for Pest Risk Analysis of Imported Plants and Plant Products (CARIB), and COSAVE) across national borders supports the sharing of completed risk assessments, reducing duplication of effort in a field with limited resources (Beaury et al. 2020). Using the same or similar protocols and sharing results would be an important advance toward unified defenses against potential invasive plants. An approach of sharing completed assessments is also critical at state/provincial levels, where regulated species are highly inconsistent across borders (Beaury et al. 2021a; Lakoba et al. 2020), leading to patchy defenses against potential invasive plants.

Unfortunately, most nations and states do not appear to have WRAs or a regulatory process for preventing the introduction of invasive plants. While it is probable that some WRAs in non-English languages were not captured, our study, combined with previous analyses of proactive invasive species policies (Early et al. 2016), nevertheless suggests that many gaps remain in phytosanitary practices globally. Countries without WRAs would benefit from adopting one of the established protocols outlined here, optimally from a neighbor, to increase regional consistency in approach. It is well known that preventing introductions is the most environmentally effective and cost-efficient approach to managing invasive species, underscoring the need for broader implementation of these critical tools. Policymakers should prioritize adopting comprehensive WRAs that account for climate change, uncertainty, and ecosystem service impacts to enhance regulatory consistency and effectiveness.

Supplementary material. To view supplementary material for this article, please visit https://doi.org/10.1017/inp.2025.10030

Acknowledgments. We thank the members of the Spatial Ecology Lab at UMass for their ideas, feedback, and inspiration throughout this project. We also thank Mathew Cocking for helping to form new connections and collaborations among the coauthors.

Funding statement. This work was funded by a U.S. Geological Survey Northeast Climate Adaptation Science Center grants G19AC00091 and G21AC10648.

Competing interests. The authors declare no conflicts of interest.

References

Ahmed DA, Hudgins EJ, Cuthbert RN, Kourantidou M, Diagne C, Haubrock PJ, Leung B, Liu C, Leroy B, Petrovskii S, Beidas A, Courchamp F (2022) Managing biological invasions: the cost of inaction. Biol Invasions 24:1927–1946

Allen JM, Bradley BA (2016) Out of the weeds? Reduced plant invasion risk with climate change in the continental United States. Biol Conserv 203:306–312

Baker RHA, Black R, Copp GH, Haysom KA, Hulme PE, Thomas MB, Brown A, Brown M, Cannon RJC, Ellis J, Ellis M, Ferris R, Glaves P, Gozlan RE, Holt J, et al. (2008) The UK risk assessment scheme for all non-native species. Pages 46–57 *in* Rabitsch D, Essl F, Klingenstein F, eds. Biological Invasions – from Ecology to Conservation. Berlin: NEOBIOTA

Barney JN, Tekiela DR, Barrios-Garcia MN, Dimarco RD, Hufbauer RA, Leipzig-Scott P, Nuñez MA, Pauchard A, Pyšek P, Vítková M, Maxwell BD (2015) Global Invader Impact Network (GIIN): toward standardized evaluation of the ecological impacts of invasive plants. Ecol Evol 5:2878–2889

Bartz R, Kowarik I (2019) Assessing the environmental impacts of invasive alien plants: a review of assessment approaches. NeoBiota 43:69–99

Beaury EM, Fusco EJ, Allen JM, Bradley BA (2021a) Plant regulatory lists in the United States are reactive and inconsistent. J Appl Ecol 58:1957–1966

Beaury EM, Fusco EJ, Jackson MR, Laginhas BB, Morelli TL, Allen JM, Pasquarella VJ, Bradley BA (2020) Incorporating climate change into invasive species management: insights from managers. Biol Invasions 22:233–252

Beaury EM, Patrick M, Bradley BA (2021b) Invaders for sale: the ongoing spread of invasive species by the plant trade industry. Front Ecol Environ 19:550–556

Bezeng BS, Morales-Castilla I, van der Bank M, Yessoufou K, Daru BH, Davies TJ (2017) Climate change may reduce the spread of non-native species. Ecosphere 8:e01694

Bradley BA, Beaury EM, Fusco EJ, Lopez BE (2023) Invasive species policy must embrace a changing climate. BioScience 73:124–133

Bradley BA, Beaury EM, Fusco EJ, Munro L, Brown-Lima C, Coville W, Kesler B, Olmstead N, Parker J (2022) Breaking down barriers to consistent, climate-smart regulation of invasive plants: a case study of US Northeast states. Ecosphere 13:e4014

Brazil Ministry of Agriculture and Livestock (2021) Guide for Developing Pest Risk Analysis. Brasília: Comité Regional de Sanidad Vegetal del Cono Sur. Pp. 1–18

Buonaiuto DM, Evans AE, Fertakos ME, Pfadenhauer WG, Salva J, Bradley BA (2023) Phylogenetic relationships of invasive plants are useful criteria for weed risk assessments. Conserv Lett 16:e12979

Caley P, Kuhnert PM (2006) Application and evaluation of classification trees for screening unwanted plants. Austral Ecol 31:647–655

Canavan S, Canavan K, Kumschick S, Gordon DR, Wilson JR, Lieurance D (2025) Invasive species risk assessment in practice: insights from a survey of practitioners. NeoBiota 99:341–362

Carneiro L, Hulme PE, Cuthbert RN, Kourantidou M, Bang A, Haubrock PJ, Bradshaw CJA, Balzani P, Bacher S, Latombe G, Bodey TW, Probert AF, Quilodrán CS, Courchamp F (2024) Benefits do not balance costs of biological invasions. BioScience 74:340–344

[CABI] Centre for Agriculture and Bioscience International (2021) Pest Risk Analysis Tool. Wallingford, Oxon, UK: CAB International

Chong KY, Corlett RT, Yeo DCJ, Tan HTW (2011) Towards a global database of weed risk assessments: a test of transferability for the tropics. Biol Invasions 13:1571–1577

Colberg EM, Bradley BA, Morelli TL, Brown-Lima CJ (2024) Climate-smart invasive species management for 21st century global change challenges. Global Change Biol 30:e17531

CONABIO (2015) Método de Evaluación Rápida de Invasividad (MERI) para especies exóticas en México. Mexico City, Mexico: CONABIO. Pp. 1–12

Conser C, Seebacher L, Fujino DW, Reichard S, DiTomaso JM (2015) The development of a plant risk evaluation (PRE) tool for assessing the invasive potential of ornamental plants. PLoS ONE 10:e0121053

[CAST] Council for Agricultural Science and Technology (2024) Preventing the Next Plant Invasion: Opportunities and Challenges. Issue Paper 73. Ames, IA: CAST. Pp. 1–20

Culina A, Baglioni M, Crowther TW, Visser ME, Woutersen-Windhouwer S, Manghi P (2018) Navigating the unfolding open data landscape in ecology and evolution. Nat Ecol Evol 2:420–426

Cuthbert RN, Diagne C, Hudgins EJ, Turbelin A, Ahmed DA, Albert C, Bodey TW, Briski E, Essl F, Haubrock PJ, Gozlan RE, Kirichenko N, Kourantidou M, Kramer AM, Courchamp F (2022) Biological invasion costs reveal insufficient proactive management worldwide. Sci Total Environ 819:153404

Daehler CC, Carino DA (2000) Predicting invasive plants: prospects for a general screening system based on current regional models. Biol Invasions 2:93–102

D'hondt B, Vanderhoeven S, Roelandt S, Mayer F, Versteirt V, Adriaens T, Ducheyne E, San Martin G, Gregoire J-C, Stiers I, Quoilin S, Cigar J, Heughebaert A, Branquart E (2015) Harmonia+ and Pandora+: risk screening tools for potentially invasive plants, animals and their pathogens. Biol Invasions 17:1869–1883

Diagne C, Leroy B, Vaissière A-C, Gozlan RE, Roiz D, Jarić I, Salles J-M, Bradshaw CJA, Courchamp F (2021) High and rising economic costs of biological invasions worldwide. Nature 592:571–576

Early R, Bradley BA, Dukes JS, Lawler JJ, Olden JD, Blumenthal DM, Gonzalez P, Grosholz ED, Ibañez I, Miller LP, Sorte CJB, Tatem AJ (2016) Global threats from invasive alien species in the twenty-first century and national response capacities. Nat Commun 7:12485

Essl F, Nehring S, Klingenstein F, Milasowszky N, Nowack C, Rabitsch W (2011) Review of risk assessment systems of IAS in Europe and introducing the German–Austrian Black List Information System (GABLIS). J Nat Conserv 19:339–350

[EPPO] European and Mediterranean Plant Protection Organization (2012) Decision-support scheme for an Express Pest Risk Analysis. EPPO Bull 42:457–462

Evans AE, Jarnevich CS, Beaury EM, Engelstad PS, Teich NB, LaRoe JM, Bradley BA (2024) Shifting hotspots: climate change projected to drive contractions and expansions of invasive plant abundance habitats. Divers Distrib 30:41–54

[FAO] Food and Agriculture Organization of the United Nations (2019a) ISPM 2: Framework for Pest Risk Analysis. Rome: International Plant Protection Convention. Pp. 1–20

[FAO] Food and Agriculture Organization of the United Nations (2019b) ISPM 11: Pest Risk Analysis for Quarantine Pests. Rome: International Plant Protection Convention. Pp. 1–36

Fusco EJ, Beaury EM, Bradley BA, Cox M, Jarnevich CS, Mahood AL, Nagy RC, Nietupski T, Halofsky JE (2023) The invasive plant data landscape: a synthesis of spatial data and applications for research and management in the United States. Landsc Ecol 38:3825–3843

Gallagher RV, Hughes L, Leishman MR (2013) Species loss and gain in communities under future climate change: consequences for functional diversity. Ecography 36:531–540

Goldsmith J (2016) Guidelines for Pest Risk Analysis of Imported Plants and Plant Products. Paramaribo, Suriname: Caribbean Agricultural Health & Food Safety Agency. Pp. 1–33

González-Moreno P, Lazzaro L, Vilà M, Preda C, Adriaens T, Bacher S, Brundu G, Copp GH, Essl F, Garcia-Berthou E, Katsanevakis S, Moen TL, Lucy F, Nentwig W, Roy HE, et al. (2019) Consistency of impact assessment protocols for non-native species. NeoBiota 44:1–25

Gordon DR, Onderdonk DA, Fox AM, Stocker RK (2008) Consistent accuracy of the Australian weed risk assessment system across varied geographies. Divers Distrib 14:234–242

Higgins SI, Richardson DM (2014) Invasive plants have broader physiological niches. Proc Natl Acad Sci USA 111:10610–10614

Hulme PE (2012) Weed risk assessment: a way forward or a waste of time? J Appl Ecol 49:10–19

Inter-American Institute for Cooperation on Agriculture (2018) Guidelines of Procedures for Risk Assessment of Plants as Pests (Weeds). Montevideo, Uruguay: Comité Regional de Sanidad Vegetal del Cono Sur. Pp. 1–42

Keller RP, Lodge DM, Finnoff DC (2007) Risk assessment for invasive species produces net bioeconomic benefits. Proc Natl Acad Sci USA 104:203–207

Kelly J, O'Flynn C, Maguire C (2013) Risk Analysis and Prioritisation: For Invasive and Non-native Species in Ireland and Northern Ireland. Lisburn, Ireland: Invasive Species Ireland. Pp. 1–59

Kendig AE, Canavan S, Anderson PJ, Flory SL, Gettys LA, Gordon DR, Iannone BV, Kunzer JM, Petri T, Pfingsten IA, Lieurance D (2022) Scanning the horizon for invasive plant threats using a data-driven approach. NeoBiota 74:129–245

Kesler B (2021) Consistency among States in Evaluating the Risk of Nonnative Plants. Bachelor's thesis. University of Massachusetts Amherst, Amherst. 24 p. https://hdl.handle.net/20.500.14394/54638

Kil J-H, Shim K-C, Lee H-J (2004) Assessing ecological risk of invasive alien plants in South Korea. Weed Technol 18:1490–1492

Kleunen M van, Dawson W, Essl F, Pergl J, Winter M, Weber E, Kreft H, Weigelt P, Kartesz J, Nishino M, Antonova LA, Barcelona JF, Cabezas FJ, Cárdenas D, Cárdenas-Toro J, et al. (2015) Global exchange and accumulation of non-native plants. Nature 525:100–103

Koop AL, Fowler L, Newton LP, Caton BP (2012) Development and validation of a weed screening tool for the United States. Biol Invasions 14:273–294

Kumschick S, Richardson DM (2013) Species-based risk assessments for biological invasions: advances and challenges. Divers Distrib 19:1095–1105

Kumschick S, Wilson JRU, Foxcroft LC (2020) A framework to support alien species regulation: the Risk Analysis for Alien Taxa (RAAT). NeoBiota 62:213–239

Laginhas BB, Fertakos ME, Bradley BA (2022) We don't know what we're missing: evidence of a vastly undersampled invasive plant pool. Ecol Appl 33: e2776

Lakoba VT, Brooks RK, Haak DC, Barney JN (2020) An analysis of US state regulated weed lists: a discordance between biology and policy. BioScience 70:804–813

Lehan NE, Murphy JR, Thorburn LP, Bradley BA (2013) Accidental introductions are an important source of invasive plants in the continental United States. Am J Bot 100:1287–1293

Leung B, Lodge DM, Finnoff D, Shogren JF, Lewis MA, Lamberti G (2002) An ounce of prevention or a pound of cure: bioeconomic risk analysis of invasive species. Proc R Soc Lond B Biol Sci 269:2407–2413

MacLeod A (2010) The EPPO pest risk analysis scheme: comments on using risk scales. EPPO Bull 40:131–138

Msiska KK (2013) Pest risk assessment: a Zambian perspective. J Biol 3:105–112

Nehring S, Essl F, Rabitsch W (2013) Methodik der naturschutzfachlichen Invasivitätsbewertung für gebietsfremde Arten. BfN-Skripten 340:1–46

O'Neill MW, Bradley BA, Allen JM (2021) Hotspots of invasive plant abundance are geographically distinct from hotspots of establishment. Biol Invasions 23:1249–1261

Ozols J, Bojÿre A, Evarts-Bunders P, Evartes-Bundere G, Jakubÿne I, Balalaikins M, Valainis U, Birzaks J, Paidere J, Dukule-Jakušenoka K, Garkÿje A, Rutkovska S, Dzenis J, Priede A, Melnbÿrde M (2021) Guidelines for Species Inclusion on the List of Invasive Species in Latvia. Daugavpils, Latvia: LatViaNature

Pfadenhauer WG, Bradley BA (2024) Quantifying vulnerability to plant invasion across global ecosystems. Ecol Appl 34:e30310

Pfadenhauer WG, Nelson MF, Laginhas BB, Bradley BA (2023) Remember your roots: biogeographic properties of plants' native habitats can inform invasive plant risk assessments. Divers Distrib 29:4–18

Pheloung PC, Williams PA, Halloy SR (1999) A weed risk assessment model for use as a biosecurity tool evaluating plant introductions. J Environ Manag 57:239–251

Pyšek P, Richardson DM, Pergl J, Jarošík V, Sixtová Z, Weber E (2008) Geographical and taxonomic biases in invasion ecology. Trends Ecol Evol 23:237–244

Reichard SH, White P (2001) Horticulture as a pathway of invasive plant introductions in the United States. BioScience 51:103

Roberts W, Harrod O, Mitterdorfer B, Pheloung P (2011) Regulating invasive plants and use of weed risk assessments. Curr Opin Environ Sustain 3:60–65

Roy HE, Pauchard A, Stoett P, Renard Truong T (2024) IPBES Invasive Alien Species Assessment: Full Report. Zenodo. https://zenodo.org/records/10676915

Roy HE, Rabitsch W, Scalera R, Stewart A, Gallardo B, Genovesi P, Essl F, Adriaens T, Bacher S, Booy O, Branquart E, Brunel S, Copp GH, Dean H, D'hondt B, et al. (2018) Developing a framework of minimum standards for the risk assessment of alien species. J Appl Ecol 55:526–538

Sandvik H, Gederaas L, Hilmo O (2017) Guidelines for the Generic Ecological Impact Assessment of Alien Species. Trondheim: Norwegian Biodiversity Information Centre. P 106

Scott JK, Panetta FD (1993) Predicting the Australian Weed Status of Southern African Plants. J Biogeogr 20:87–93

https://doi.org/10.1017/inp.2025.10030 Published online by Cambridge University Press

Simberloff D (2005) The politics of assessing risk for biological invasions: the USA as a case study. Trends Ecol Evol 20:216–222

Sreekanth D, Pawar D, Chethan CR, Singh PK, Sondhia S, Chander S, Singh MC (2022) Indian quarantine weeds invasiveness assessment using bio-security tool: Weed Risk Assessment. Indian J Weed Sci 54:110–115

Verbrugge LNH, Leuven RSEW, van der Velde G (2010) Evaluation of International Risk Assessment Protocols for Exotic Species. Nijmegen, Netherlands: Institute for Water and Wetland Research. Pp. 59

Vilà M, Gallardo B, Preda C, García-Berthou E, Essl F, Kenis M, Roy HE, González-Moreno P (2019) A review of impact assessment protocols of non-native plants. Biol Invasions 21:709–723

Wang F, Huang J, Zhang N, Li Y, He S, Wen J, Yin L, Liang Y (2024) Exploring plant characteristics for constructing a pre-border weed risk assessment for China. Biol Invasions 26:909–933

Williams PA (1996) A Weed Risk Assessment Model for Screening Plant Imports into New Zealand. LC9596/080. Nelson, NZ: Landcare Research. Pp. 1–46

https://doi.org/10.1017/inp.2025.10030 Published online by Cambridge University Press