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ANALYSIS ARTICLE

Bibliographic analysis of modelling weed distribution and invasion with global perspective

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ABSTRACT

Invasive alien weeds are of great concern because of their capability of spreading fast, their high competitiveness and ability to settle in new areas within short period of time. Thus, they are the second biggest threat to biodiversity after habitat destruction. It is therefore necessary to prevent the introduction, establishment, and spread of these invasive alien weeds (IAWs) into newer areas. Ecological niche modelling (ENMs) and species distribution modelling (SDMs) are two commonly used approaches in theoretical and applied studies in ecology to study the species behavior in future climatic conditions. In this study, we undertook a bibliographic analysis of scholarly articles on the modelling studies on species invasion under current and future climatic scenarios. In addition, results of different studies on modelling and prediction on distribution of IAWs on global as well as India level were also discussed. Study revealed that researchers started getting interest and published more work in the subject between 2015 and 2020. The greater number of related articles were published in the subjects such as ecology, biology, habitat and climate change and published mostly by Wiley, Elsevier and Springer publishers. Further, the shortcomings of species distribution modelling and future prospects were also discussed.

Keywords: Bibliographic analysis, Invasive alien weeds, Modelling, Species distribution modelling

INTRODUCTION

Invasive organism is defined as a non-native organism whose introduction causes, or is likely to cause, economic or environmental harm, or harm to human, animal, or plant health (Reaser *et al.* 2020). The invasive alien species are those that are introduced into places outside their natural range, adversely impacting native biodiversity, ecosystem or human well-being. According to Convention on Biological Diversity (2005), invasive alien species are introduced purposefully or accidentally outside their natural habitat, where they exhibit the ability to establish themselves, invade, out-compete native weeds and take over the new environment within short period of time. Thus, they have the potential to harm the biodiversity, ecosystem and human well-being (Ansong and Pickering 2015; Beaumont *et al.* 2014; Kleunen *et al.* 2015). They put significant social, ecological and economic impacts on the invaded environment (Gharde *et al.* 2018). The nature and severity of the impacts of these weeds on society, environment, health and national heritage are of great concern (McNeely *et al.* 2001). They are also highly tolerant to climatic and edaphic changes and have ability to compete and drive off other species from their habitat. Thus, they are the second biggest threat to biodiversity after habitat destruction. They reduce agricultural yields, and interfere with crop lands, grazing areas, water availability, and contribute to spread of many diseases (Essa *et al.* 2006). Further, their uncontrolled expansion in agriculture ecosystem may cause huge crop yield losses (Chauhan *et al.* 2011; Fahad *et al.* 2015; Parker 2012).

In the era of globalization, it is necessary to prevent the introduction, establishment, and spread of these invasive alien weeds (IAWs) into newer areas (Rao *et al.* 2017). It is usually accepted that prevention before the establishment of the invasive weeds is a much better economic strategy than control or eradication (Seebens *et al.* 2017) after the establishment (Jarnevich *et al.* 2010; Braun *et al.* 2016). Moreover, management of invasive species relies on information about their expected distributional potential and relative abundance under current and future climate scenarios. Therefore, it is important to know the areas which are favorable for occurrence of these species so that planning can be done for appropriate long-term management strategies for the control of these species before its invasion in the new areas. Further, how species will respond to projected future climate change is of fundamental importance for effective management

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and conservation of biodiversity (Hannah *et al.* 2002; Hijmans and Graham 2006). It is reported that some extreme weather events such as droughts and floods may increase due to climate change and can cause huge impacts on the global ecosystem, including rise in sea levels (Lee 2010), change in areas of crop production and spread of species (Kwak *et al.* 2008; Pearson and Dawson 2003). As per estimate reported by Intergovernmental Panel on Climate Change (IPCC), the earth temperature is estimated to increase by about 1.4–5.8°C from 1990 to 2100, whereas precipitation is estimated to increase by up to 1.0% for the mid- and high-latitude regions and 0.3% for the tropical zones (IPCC 2014). It was also confirmed that South Asia will experience a substantial change in its climate during the 21st century. It is established that climate change has already changed many species' behaviors, biodiversity, their distribution and habitat substantially. As the climate is known to be the most significant factor affecting the growth and development (Rosenzweig *et al.* 2001), invasive weeds are heavily influenced by climate change and can extend their range, thereby causing increased damage to ecosystem and agricultural production.

However, the relationship between IAW and climate change is complex (Hellmann *et al.* 2008). Climatic factors are considered as one of the main factors determining the overall distribution of invasive species due to their synergistic effects (Guisan and Thuiller 2005; Bai *et al.* 2013; Gharde *et al.* 2019). However, Sathischandra *et al.* (2014) reported the absence of a linear correlation between the occurrence of weeds and insect pests with climate variables. Hence, with such complexities, there is need for precise prediction on dynamics of IAW under future climate change scenarios in order to manage such weeds (Kariyawasam *et al.* 2019).

To address these questions, we undertook a bibliographic analysis of scholarly articles on the modelling studies on species invasion under current and future climatic scenarios. Specifically, two approaches used for modelling, *viz.* ecological niche modelling and species distribution modelling along with different commonly used algorithms were discussed. Results of different studies on modelling and prediction on distribution of IAWs on global as well as India level were also discussed. Further, this article summarizes shortcomings of species distribution modelling (SDM) and future prospects.

Ecological niche modelling and species distribution modelling

Ecological niche modelling (ENMs) and SDM are two commonly used approaches in theoretical and applied studies in ecology (Peterson *et al.* 2015). Most common applications of these models are finding suitable sites for species (Guisan and Zimmermann 2000), predicting the impacts of future climate change on species' distributions (Pearson and Dawson 2003), assessing the invasive potential of alien species (Jiménez-Valverde *et al.* 2011), and subsequently the conservation planning (Guisan *et al.* 2013).

However, there is considerable difference between these two approaches. SDM refers to the approach for modelling the objects in G-space (the geographical space occupied by the species), on the other hand, ENM refers to approach for modelling the objects in E-space (all the environmental combinations available in the study region) (Soberón *et al.* 2017). ENM requires an overt estimation of the fundamental niche of the species, and are envisioned to model the processes that defined the area of distribution of the species (Peterson and Soberón 2012). Usually SDM can only target the species' distribution, and preferably must restrict model calibration to accessible areas of the study region, account for true absences and integrate dispersal and colonization abilities (Peterson and Soberón 2012). Three main classes of models are recognized in this field: correlative models, the most commonly used models found in the literature, which estimate the ecological requirements of species by relating their known spatial distributions to a set of environmental/climatic variables (Araújo and Guisan 2006; Franklin 2010); mechanistic models which use exhaustive physiological information and first principles of biophysics (Kearney and Porter 2009); and process-oriented models, which estimate species' distributions in terms of processes, including dispersal capability and biotic interactions (Peterson *et al.* 2015).

Use of ecological niche models (ENMs) plays important role in early detection of IAWs and to identify the ecologically sensitive areas for further monitoring and making necessary control measures (Srivastava *et al.* 2019; Yan *et al.* 2020; Marambe and Wijesundara, 2021). Species distribution modelling makes use of point-occurrence data and raster data layers summarizing environmental information (**Figure 1**). These species distribution models thus infer species' environmental requirements, and have been used to anticipate the geographic potential of species (Wisz *et al.* 2008). These models have become the extensively useful tool to determine the relationships between species and their environments and are used to predict extreme impacts of climate change, biogeographic studies, improve species management and answer conservation biology questions.

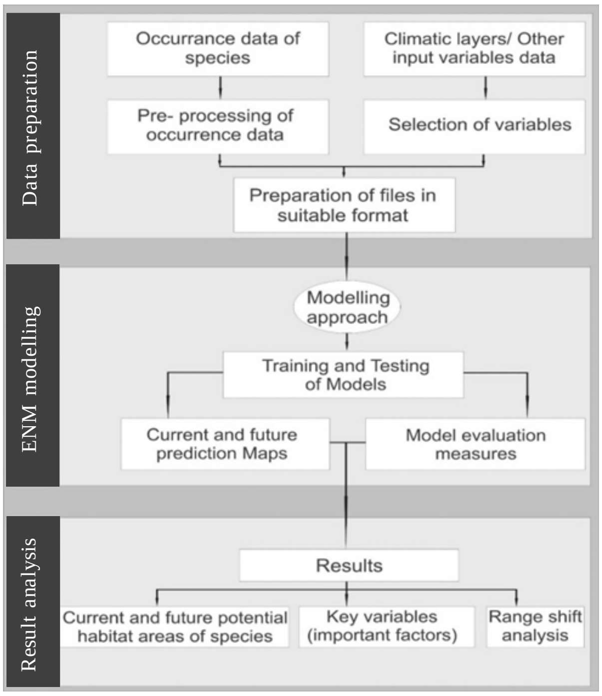

Figure 1. Steps used in species distribution modelling

BIOCLIM, DOMAIN, and Maxent are the frequently used ENMs known for their simplicity and the data accessibility (Elith *et al.* 2011; Katz and Zellmer 2018; Srivastava *et al.* 2019). However, compared to BIOCLIM and DOMAIN, Maxent exhibited much higher predictive performance (Phillips *et al.* 2006; Peterson and Anamza 2015), and it can generate much more robust results especially when applied to small sample sizes (Phillips *et al.* 2006; Elith and Leathwick 2009) when most of the technique fail to produce the adequate results. Thus, Maxent has been successfully applied to model the distributions of invasive species (Srivastava *et al.* 2019).

Additionally, several researchers have used remote sensing data to map the distribution of IAWs using phenology-based approaches (Ishii and Washitani 2013; Bradley *et al.* 2018; Huang and Geiger 2008). Remote detection of IAWs based on their distinct biochemical, physiological and structural traits are important in cases where IAWs and native species have similar phenology (Glenn *et al.* 2005; Mitchell and Glenn 2009; Yang and Everitt 2010). However, success of these approaches depends on the availability of hyperspectral data (Gholizadeh *et al.* 2022).

Species invasion under climate change scenarios

Several studies have been conducted to investigate the potential impact of global climate change on the geographic distribution of IAWs, but the results are somewhat different in each case (Buckley and Csergo 2017; Merow *et al.* 2017). Some studies reported that climate change may favour the expansion of geographic distribution of these species (Priyanka and Joshi 2013; Banerjee *et al.* 2017; Wei *et al.* 2017; Shrestha *et al.* 2018; Thapa *et al.* 2018); whereas, others have reported that climate change may constrain the geographic distribution of some IAW species (**Table 1** and **2**) (Bradley 2009; Taylor and Kumar 2013; Roger *et al.* 2015; Allen and Bradley 2016; Manzoor *et al.* 2018). Hence, prediction on areas of high/low invasion risk or varied invasion impact for the future is full of uncertainties and mainly depends upon the invasive species or biome type (Buckley and Csergo 2017).

Bibliographic analysis of articles on weeds distribution modelling

Bibliographic analysis is defined as the evaluation of published scientific literature including articles, books, book chapter and provide a way to measure the impact of publication among the scientific community. Research in SDMs in predicting the future distribution of IAW has expanded significantly over the past few decades with evolution of different algorithms. Hence, the present bibliographic analysis, study was done using the literatures available in the area of modelling of IAW distribution. For this purpose, published research articles were accessed and analysis was done with the help of LENS.ORG free access database. It is meant for search, analyze and manage patent as well as Scholarly data. Here, scholarly data was used for the purpose, and keywords, *viz*. invasive alien plant species climate change future distribution and modelling were used for selection of the articles out of total 252,116,476 scholarly literature available in the LENS.ORG. Using these keywords, 3244 articles have been filtered out. Results were also shown as the impact of the scholarly articles present in the area searched. These includes active author information; citation of the scholarly works; classification of articles based on their research area as well as institution where the work was conducted and publication trend of the documents over the years. These results are presented through **Figure 2** to **Figure 6**.

Figure 2 revealed that researchers started getting interest and published more work between 2015 and 2020. Many documents were published during these years with maximum observed during 2017 with more than 270 articles. These articles were more related to ecology (1360), biology (1218), geography (813), biodiversity (513), introduced species (406), invasive species (398), habitat (343), Climate change (325), ecosystem (302) and rest with other areas of interest (**Figure 3**). Most of the research were published by Spanish National

Table 1. The global prediction of species invasion under future climate scenario using distribution modelling

Weeds	Region	Contraction/expansion in areas	Reference	Weed type
Ageratina adenophora (Spreng.) R. M. King et H. Rob., *Alternanthera philoxeroides* (Mart.) Griseb., *Ambrosia artemisiifolia* L. *Mikania micrantha* Kunth	China	Expansion	Tu *et al.* 2021	Terrestrial
Parthenium hysterophorus L.	World and Oman	Contraction in areas in 2081–2100 at global level. Expansion during 2021-40 and a decrease during 2081–2100	Amna *et al.* 2022	Terrestrial
Cynodon dactylon, Cyperus rotundus, Echinochloa colona, Echinochloa crus-galli, Eichhornia crassipes, Eleusine indica, Imperata cylindrica, Lantana camara, Panicum maximum, and *Sorghum halepense*	World	Expansion	Wan and Wang 2019	Terrestrial and agro-ecosystem
Parthenium hysterophorus L.	Bangladesh	Expansion	Masum *et al.* 2022	Terrestrial
Ageratina adenophora	China	Expansion of the dispersal zone towards the northeast and coastal areas, and a slight contraction in the Yunnan–Guizhou plateau	Zhang *et al.* 2022	Terrestrial
Ageratina adenophora	Global	Contraction in potential suitable area globally and range expansion in six biodiversity hotspot regions	Changjun *et al.* 2021	Terrestrial
Ambrosia artemisiifolia, Ambrosia trifida, Symphyotrichum pilosum, Ageratina altissima, Hypochaeris radicata, Lactuca serriola, Paspalum dilatatum, Paspalum distichum, Rumex acetosella, Sicyos angulatus, Solanum carolinense, Solidago altissima	South Korea	Expansion	Adhikari *et al.* 2022	Terrestrial
Spartina alterniflora Loisel	China	Expansion	Yuan *et al.* 2021	Terrestrial
Verbesina encelioides (Cav.) Benth. & Hook. Fil ex Gray	South Africa	Expansion	Moshobane *et al.* 2022	Terrestrial
Ageratina adenophora (Sprengel) R. King and H. Robinson	Chitwan–Annapurna Landscape (CHAL) of Nepal	Expansion	Poudel *et al* 2020	Terrestrial
Parthenium Hysterophorus L.	Bhutan	Expansion	Dorji *et al.* 2022	Terrestrial
Apium leptophyllum, Astragalus sinicus, Bromus unioloides, Chenopodium ambrosioides, Coronopus didymus, Gnaphalium calviceps, Lolium multiflorum, Modiola caroliniana, Oenothera laciniata, Paspalum dilatatum, Sida rhombifolia, Silene gallica, Sisymbrium officinale, Sisyrinchium angustifolium, Spergularia rubra, Malva parviflora	South Korea	Expansion	Hong *et al.* 2021	Terrestrial
Urochloa panicoides P. Beauv.	World	Reductions in climate suitability in Brazil, Australia, India, and Africa, and an increase in suitability in Mexico, the United States, European countries, and China	Duque *et al.* 2022	Terrestrial
Amaranthus palmeri	USA	Northward range expansion and significantly increased suitability across large portions of the U.S. Overall	Runquist *et al.* 2019	Terrestrial
Parthenium hysterophorus	Chitwan Annapurna Landscape, Nepal	Expansion in the suitable habitat under RCP 4.5 scenario in 2050 and 2070, however decrease in suitable areas under RCP 8.5 scenario in 2050 and 2070	Maharjan *et al.* 2019	Terrestrial
Alstonia macrophylla Wall., *Annona glabra* L., *Austroeupatorium inulifolium* (H.B.K.) R. M. King & H. Rob, *Clidemia hirta* (L.) D. Don, *Dillenia suffruticosa* (Griff ex Hook.f. & Thomson) Martelli, *Lantana camara* L., *Leucaena leucocephala* (Lam.) de Wit, *Mimosa pigra* L., *Opuntia dillenii* (Ker-Gawl.) Haw, *Panicum maximum* Jacq., *Parthenium hysterophorus* L., *Prosopis juliflora* (Sw.) DC., *Sphagneticola trilobata* (L.) Pruski, *Ulex europaeus* L.	Sri Lanka	Contraction of the very low class and expansion of the moderate class of suitability.	Kariyawasam *et al.* 2019	Terrestrial
Myriophyllum aquaticum, Pistia stratiotes, Azolla filiculoides,, Eichhornia crassipes, Salvinia molesta	South Africa	Contraction in *Myriophyllum aquaticum* and *Pistia stratiotes* suitable areas and expansion in rest three areas	Hoveka *et al.* 2016	Freshwater weeds
Nitellopsis obtusa	United States	Decrease of the species' suitable range	Romero-Alvarez *et al.* 2017	Aquatic weed

Weeds	Region	Contraction/expansion in areas	Reference	Weed type
Alternanthera philoxeroides, Ceratophyllum demersum, Crassula helmsii, Elodea canadensis, Hydrilla verticillata, Ludwigia peruviana, Najas minor, Pistia stratiotes, Potamogeton crispus, Sagittaria platyphylla	World	Significantly higher climatic suitability for temperate coastal rivers and temperate floodplain rivers	Wang *et al.* 2017	Freshwater weeds
Lantana camara L.	World	Climatically suitable areas globally will contract. However, some areas in North Africa, Europe and Australia may become climatically suitable. In South Africa and China, its potential distribution could expand further inland.	Taylor *et al.* 2012	Terrestrial
Butomus umbellatus	North America	Decrease of suitable areas, though two of three global circulation models predict range expansion across gas emission scenarios	Banerjee *et al.* 2020	Terrestrial
Ageratum conyzoides, Praxelis clematidea, Solidago canadensis, Anredera cordifolia, Lantana camara, Conyza sumatrensis, Chenopodium ambrosioides, Parthenium hysterophorus, Avena fatua, Pharbitis purpurea, Aster subulatus	China	Species will expand northward	Guan *et al.* 2020	Terrestrial
Mikania micrantha	South and Southeast Asia, Australia, Oceania and parts of the USA	Predicted to expand toward cold and dry areas of the invasive range	Banerjee *et al.* 2019	Terrestrial
Lonicera japonica	Forests of the Cumberland Plateau and Mountain Region in the southeast of USA	Expansion	Lemke *et al.* 2011	Forest land
Chromolaena odorata	World	Expansion	Kriticos *et al.* 2004	Terrestrial
Amaranthus retroflexus, Amaranthus spinosus, Amaranthus viridis, Bidens pilosa, Conyza bonariensis, Conyza canadensis, Galinsoga parviflora, Physalis angulata	China	Expansion	Wan *et al.* 2017	Terrestrial
Lantana camara L.	Queensland, Australia	Reduction in climatic suitability	Taylor and Kumar 2013	Terrestrial

Table 2. The prediction of a few weed species invasion in India under future climate scenarios

Weeds	Region	Contraction/expansion in areas	Reference	Weed type
Lantana camara	Jharkhand, eastern India	Expansion up to 20–26% by 2050	Tiwari *et al.* 2022	Terrestrial
Parthenium hysterophorus	India	Overall decrease in habitat suitability with some highly vulnerable (Western Himalaya) region to its invasion under future climate	Ahmad *et al.* 2019	Terrestrial
Chromolaena odorata L. (King) & H.E. Robins	India	Higher suitability for species in northeastern states, the central Himalayan provinces and the Western Ghats and Eastern Ghats	Barik and Adhikari 2012	Terrestrial
Ageratina adenophora L., *Ageratum conyzoides* L., *Ageratum houstonianum* Mill., *Amaranthus spinosus* L., *Bidens pilosa* L., *Erigeron karvinskianus* DC., *Lantana camara* L., *Parthenium hysterophorus* L., *Senna occidentalis* (L.) Link., *Senna tora* (L.) Roxb., *Xanthium strumarium* L.	Western Himalaya, India	Most of these invasive plants are expected to expand under future climatic scenarios	Thapa *et al.* 2018	Terrestrial
Cassia tora and Lantana camara	India	Distribution ranges of both species could shift in the northern and north-eastern directions in India	Panda *et al.* 2018	Terrestrial
Chromolaena odorata and *Tridax procumbens*	India	Both are likely to reduce their potential distribution areas in the future climate	Panda and Behera 2019	Terrestrial

Research Council in all major areas and it was followed by Stellenbosch University in case of Ecology, Biology and Introduced Species. PloS one, PloS biology, PloS neglected tropical diseases are some of the leading free access journals who published the work related to modelling IAW invasion. The Wiley, Elsevier, Springer and Wiley-Blackwell are the leading publishers of research results on these areas (**Figure 5** and **6**).

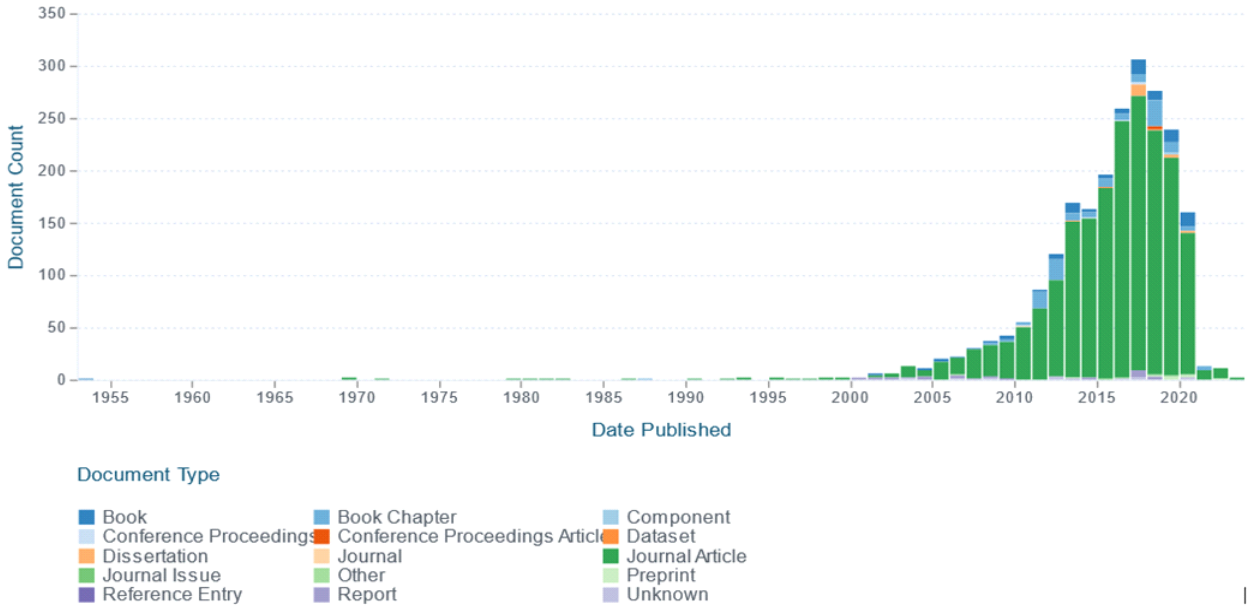

Figure 2. Published literature on modelling weed invasion over the years (from 1955-2022)

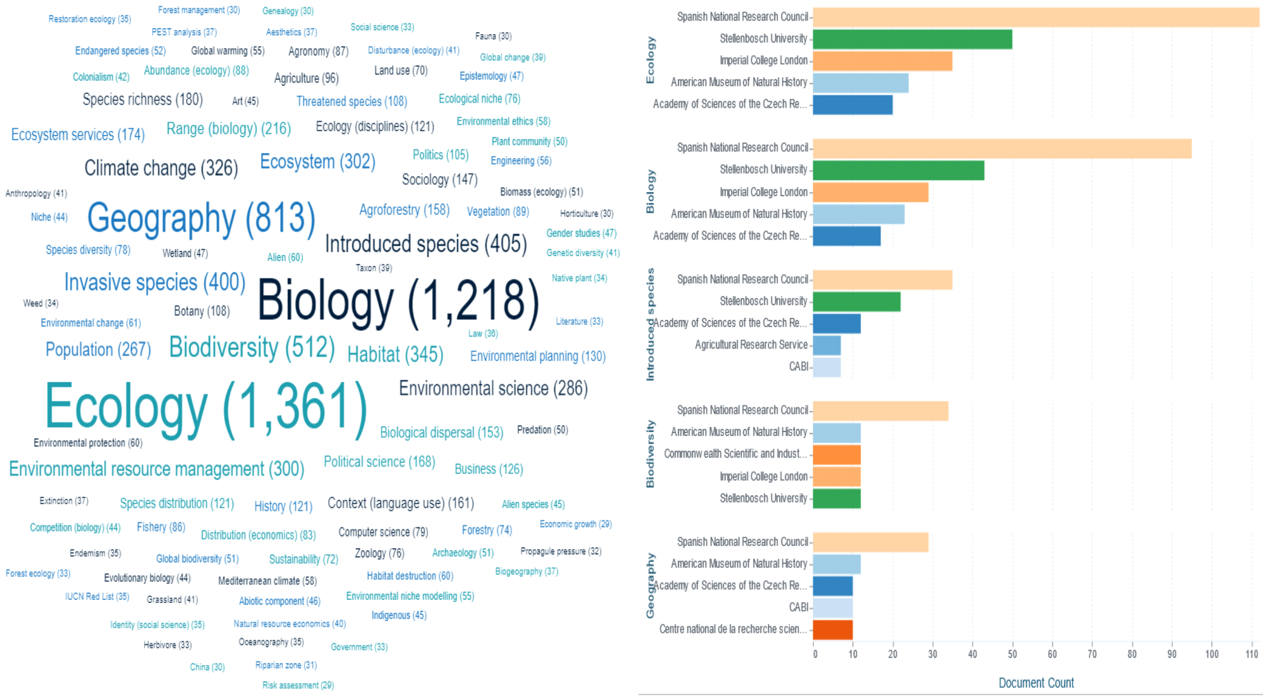

Figure 3. Classification of articles according to the research areas and research institutions

Implications of future climate on invasive alien weeds

The predicted distributional maps, based on the results of many studies, showed that climate change would significantly affect the global distribution of IAWs (Ahmad *et al.* 2019; Guan *et al.* 2020). Many studies have reported a range expansion for invasive species under climate change (Taylor *et al.* 2012, Cunze *et al.* 2013, Buczkowski and Bertelsmeier 2017, Kadioglu and Farooq 2017, Wei *et al.* 2017, Trethowan *et al.* 2011, Bradley BA *et al.* 2012, Bellard 2013, Priyanka and Joshi 2013). The possible reason may be that these species incline to expand their ranges with increasing temperature under climate change scenarios (Ju *et al.* 2015). In particular, the areas adjacent to the current distribution range of the species fall under high risk of invasion (Ahmad *et al.* 2019). However, many researchers reported that climate change may constrain the geographic range of some IAW species (Bradley 2009, Taylor and Kumar 2013, Roger *et al.* 2015, Allen and Bradley 2016, Manzoor *et al.* 2018).

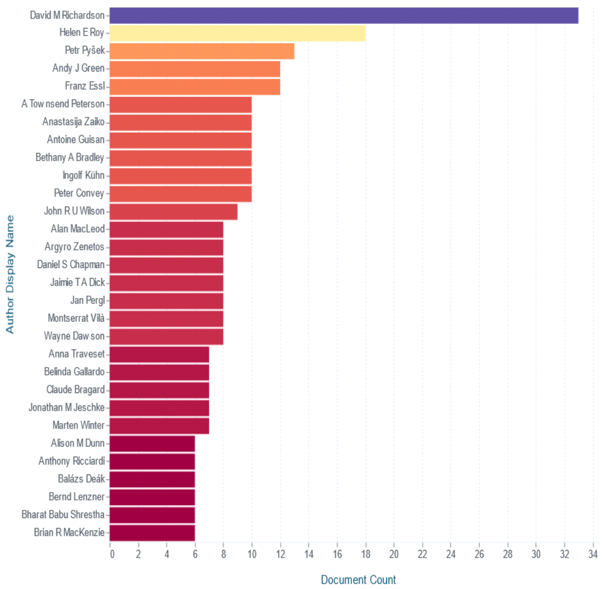

Figure 4. Leading authors who have contributed more to studies on the weed invasion in future climatic conditions

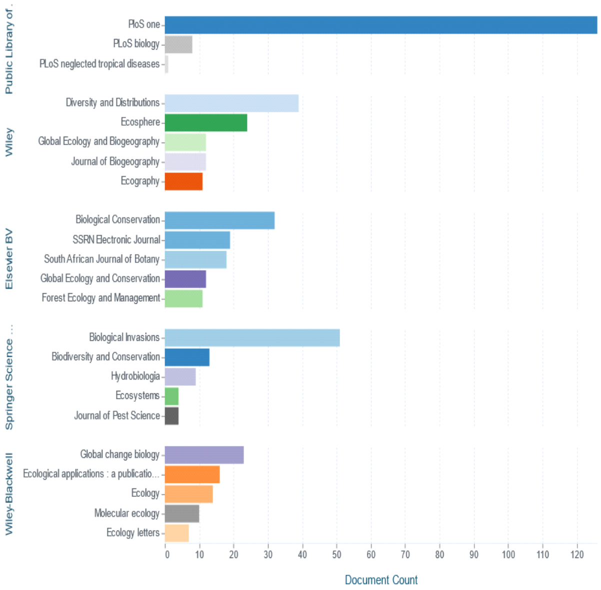

Figure 5. The leading journals which published work on weed invasion under future climatic scenarios

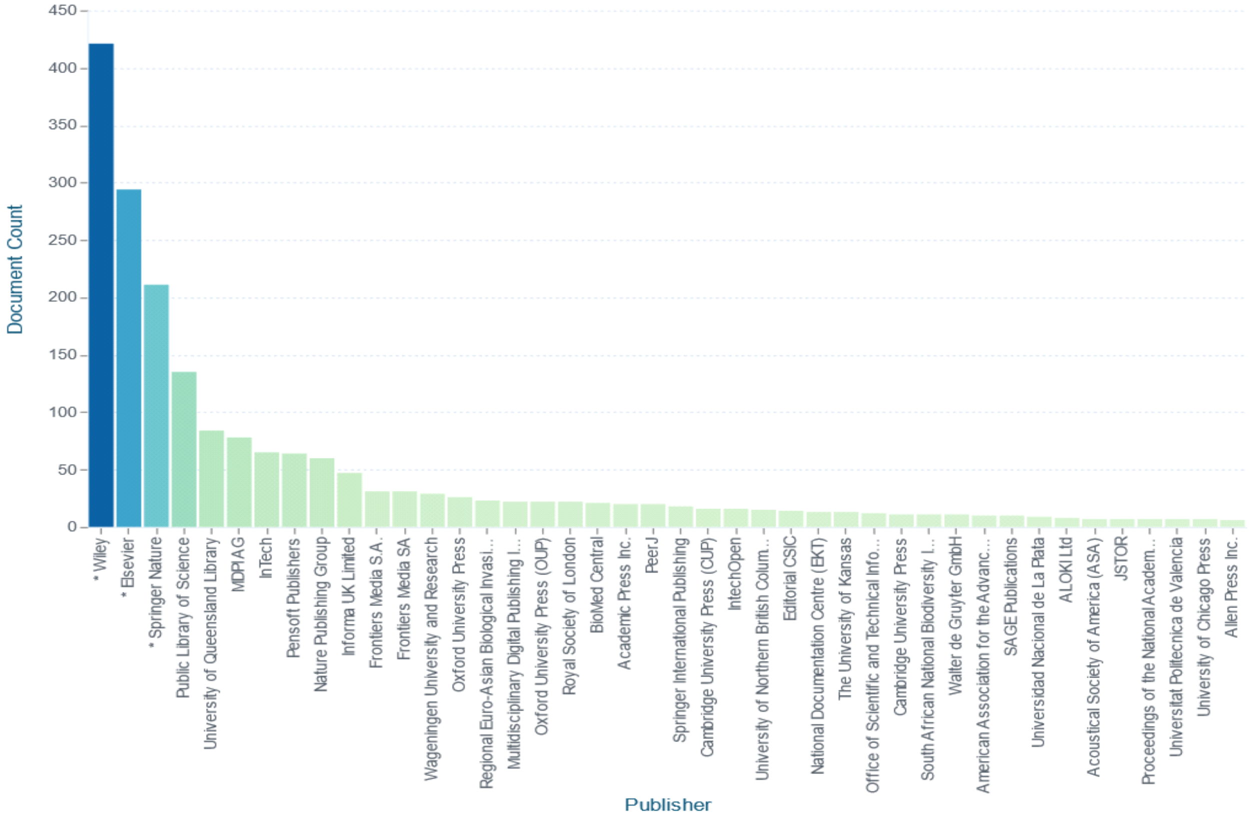

Figure 6. Leading publishers of the work on future distribution of invasive alien weeds

As far as high-risk regions are concerned, alarming situation will put forth the challenges for the policy makers, land resource managers and for other stakeholders to develop effective management plans in order to prevent the introduction, and further if it fails, then to control the further spread of this invasive species in High-Risk zones.

Limitations of SDM and future prospects

Many studies suggest that invasive alien species conquers climatic niches similar to those of its native places in some regions and such a resemblance in the climatic space between the native regions and invaded areas is considered to be critical factor for successful invasion in the non-native places (Becerra Lopez *et al.*

2017; Ficetola *et al.* 2007; Ahmad *et al.* 2019; Banerjee *et al.* 2019). Whereas, in some of the studies it is evident that the species when introduced into a new area, can simultaneously occupy climatic niches different from its native range, thereby it is necessary to reaffirm the fact that same species can exhibit variable invasion niche dynamics in an invaded regions (Wei *et al.* 2017; Becerra Lopez *et al.* 2017; Goncalves *et al.* 2014).

Many studies have successfully identified the invaded/hotspot areas and also determined the effect factors for the spreading of the invasive plants using climate factors (Welk *et al.* 2002; Kriticos *et al.* 2003; Tu *et al.* 2021), while others projected distribution scenarios and invasion trends of the plants in future (Van Wilgen *et al.* 2016; Tu *et al.* 2021). Although species distribution modelling plays a vital role in predicting the future potential distribution range of species under different climatic scenarios, such models are still relied on mainly abiotic factors. But, there are many other essential factors that affect the introduction and invasion process of invasive alien plant species and need to be considered in prediction (Coulin *et al.* 2019), for example, soil type, land use and biotic pressure, and especially anthropogenic factor (Zhu *et al.* 2017). Some biotic factors, such as competition, dispersal ability along with abiotic factors, also affect the potential distribution of species in future (Wisz *et al.* 2013*)*. Therefore, the future research challenge is to incorporate the biotic factors along with other factors such as land use and land cover changes in the SDMs to have a more sophisticated representation of the species distributions under changing climate (Bellard *et al.* 2016).

Currently, species distribution models (SDMs) are being widely used to predict distribution of IAWs at global (Guisan & Zimmermann 2000; Guisan and Thuiller 2005) as well as regional level. Though, one main challenge with the use of these SDMs is the selection of the most appropriate algorithm and suitable methodology among all available large number of modelling algorithms which are increasing at a rapid pace too (Elith *et al.* 2010). Recent studies revealed the difficulties in making the choice of the appropriate modelling algorithm due to varied performance of different algorithm. To avoid such situation, there is an emerging scientific trend to use several algorithms concurrently [*e.g.* ensemble modelling (Araujo and New 2007; Thuiller *et al.* 2009)] within a consensus modelling framework (Thuiller 2004, Marmion *et al.* 2009). By combining different algorithms for predictions, these ensemble modelling approaches accounts for uncertainties of using single algorithm (Buisson *et al.* 2010, Grenouillet *et al.* 2011) and hence increasing the predictive power of distribution modelling and projection (Marmion *et al.* 2009).

CONCLUSION

Climate change can cause huge impacts on the global ecosystem, change in areas of crop production and spread of weed species. An understanding the impact of climate change on weed species' future invasion is important for sustainable biodiversity conservation. This study summarized the important issues related to modelling weed invasion in future along with bibliographic analysis of the literatures related to weed invasion in future climate scenarios. The positive and negative economic and ecological consequences of species invasion everywhere are important concerns to all stakeholders of the society. The identification of areas where policies could benefit from synergies between climate, land use change and invasive species management is of prime relevance.

REFERENCES

Ansong M and Pickering C. 2015. What's a weed? Knowledge, attitude and behaviour of park visitors about weeds. *PLoS One* **10**(8): e0135026.

Adhikari P, Lee YH, Adhikari P, Hong SH and Park Y-S. 2022. Climate change-induced invasion risk of ecosystem disturbing alien plant species: An evaluation using species distribution modeling. *Frontiers in Ecology and Evolution* 10:880987.

Ahmad R, Khuroo AA, Hamid M, Charles B and Rashid I. 2019. Predicting invasion potential and niche dynamics of *Parthenium hysterophorus* (Congress grass) in India under projected climate change. *Biodiversity and Conservation* **28**: 2319–2344.

Allen J M and Bradley BA. 2016. Out of the weeds? Reduced plant invasion risk with climate change in the continental United States. *Biological Conservation* **203**: 306–312.

Amna M Al Ruheili, Thurya Al Sariri, Ali M. Al Subhi. 2022. Predicting the potential habitat distribution of parthenium weed (*Parthenium hysterophorus*) globally and in Oman under projected climate change. *Journal of the Saudi Society of Agricultural Sciences* **21**(7): 469–478.

Araujo MB and Guisan A. 2006. Five (or so) challenges for species distribution modelling. *Journal of biogeography* **33**(10): 1677–1688.

Araújo MB and New M. 2007. Ensemble forecasting of species distributions. *Trends in Ecology and Evolution* **22**(1): 42–47.

Bai F, Chisholm R, Sang W and Dong M. 2013. Spatial risk assessment of alien invasive plants in China. *Environmental Science & Technology* **47**(14): 7624–7632.

Banerjee AK, Mukherjee A and Dewanji A. 2017. Potential distribution of *Mikania micrantha* Kunth in India - evidence of climatic niche and biome shifts. *Flora* **234**: 215–223.

Banerjee AK, Mukherjee A, Guo W, Liu Y and Huang Y. 2019. Spatio-temporal patterns of climatic niche dynamics of an invasive plant *Mikania micrantha* Kunth and its potential distribution under projected climate change. *Frontiers in Ecology and Evolution* **7**: 291

Banerjee AK, Harms NE, Mukherjee A and Gaskin JF. 2020. Niche dynamics and potential distribution of *Butomus umbellatus* under current and future climate scenarios in North America. *Hydrobiologia* **847**(6): 1505–1520.

Barik SK and Adhikari D. 2012. Predicting geographic distribution of an invasive species (*Chromolaena odorata* L King & HE Robins) in Indian subcontinent under climate change scenarios. pp. 77–88. In: *Invasive Alien Plants: An Ecological Appraisal for the Indian subcontinent*. (Eds. Bhatt JR, Singh JS, Singh SP, Tripathi RS, Kohli RK), CABI, CPI Group (UK) Ltd, Croydon, UK.

Beaumont, LJ, Gallagher RV, Leishman MR, Hughes L and Downey PO. 2014. How can knowledge of the climate niche inform the weed risk assessment process? A case study of *Chrysanthemoides monilifera* in Australia. *Diversity and Distributions* **20**(6): 613–625.

Becerra Lopez JL, Esparza Estrada CE, Romero Mendez U, Sigala Rodriguez JJ, Mayer Goyenechea IG and Castillo Ceron JM. 2017. Evidence of niche shift and invasion potential of *Lithobatescatesbeianus* in the habitat of Mexican endemic frogs. *Plos One* **12**(9): e0185086. https://doi.org/10.1371/journal.pone.0185086

Bellard C, Thuiller W, Leroy B, Genovesi P, Bakkenes M and Courchamp F. 2013. Will climate change promote future invasions? *Global Change Biology* **19**(12): 3740–3748.

Bellard C, Leroy B, Thuiller W, Rysman JF and Courchamp F. 2016. Major drivers of invasion risks throughout the world. *Ecosphere* **7**(3): e01241.

Bradley BA. 2009. Regional analysis of the impacts of climate change on cheatgrass invasion shows potential risk and opportunity. *Global Change Biology* **15**(1): 196–208.

Bradley BA, Blumenthal DM, Early R, Grosholz ED, Lawler JJ, Miller LP, Sorte CJ, D'Antonio CM, Diez JM, Dukes JS and Ibanez I.. 2012. Global change, global trade, and the next wave of plant invasions. *Frontiers in Ecology and the Environment* **10**(1): 20–28.

Bradley BA, Curtis CA, Fusco EJ, Abatzoglou JT, Balch JK, Dadashi S and Tuanmu M-N. 2018. Cheatgrass (*Bromus tectorum*) distribution in the intermountain Western United States and its relationship to fire frequency, seasonality, and ignitions. *Biological Invasions* **20**(6): 1493–1506.

Braun M, Schindler S and Essl F. 2016. Distribution and management of invasive alien plant species in protected areas in Central Europe. *Journal for Nature Conservation* **33**: 48–57.

Buckley YM and Csergo AM. 2017. Predicting invasion winners and losers under climate change. *Proceedings of the National Academy of Sciences* **114**(16): 4040–4041.

Buczkowski G and Bertelsmeier C. 2017. Invasive termites in a changing climate: A global perspective. *Ecology and Evolution* **7**(3): 974–985.

Buisson L, Thuiller W, Casajus N, Lek S and Grenouillet G. 2010. Uncertainty in ensemble forecasting of species distribution. *Global Change Biology* **16**(4): 1145–1157.

Changjun G, Yanli T, Linshan L, Bo W, Yili Z, Haibin Y, Xilong W, Zhuoga Y, Binghua Z and Bohao C. 2021. Predicting the potential global distribution of *Ageratina adenophora* under current and future climate change scenarios. *Ecology and Evolution* **11**(17): 12092–12113.

Chauhan B and Johnson D. 2011. Growth Response of Direct-Seeded Rice to Oxadiazon and Bispyribac-Sodium in Aerobic and Saturated Soils. *Weed Science* **59**(1): 119–122.

Coulin C, de la Vega GJ, Chifflet L, Calcaterra LA and Schilman PE. 2019. Linking thermo-tolerances of the highly invasive ant, *Wasmannia auropunctata*, to its current and potential distribution. *Biological Invasions* **21**(12): 3491–3504.

Cunze Sarah, Leiblein MC and Tackenberg O. 2013. Range Expansion of *Ambrosia artemisiifolia* in Europe Is Promoted by Climate Change. *ISRN Ecology* **2013**: 1–9.

Dorji S, Lakey L, Wangchen T and Adkins S. 2022. Predicting the distribution of Parthenium weed (*Parthenium hysterophorus* L.) under current and future climatic conditions in Bhutan. *Journal of Environmental and Occupational Health* **12**(4): 169–181.

Duque TS, da Silva RS, Maciel JC, Silva DV, Fernandes BCC, Junior APB and Santos JBD. 2022. Potential Distribution of and Sensitivity Analysis for *Urochloa panicoides* Weed Using Modeling: An Implication of Invasion Risk Analysis for China and Europe. *Plants* **11**(13): 1761.

Elith J and Leathwick JR. 2009. Species distribution models ecological explanation and prediction across space and time. *Annual Review of Ecology, Evolution and Systematics* **40**(1): 677–697.

Elith J, Kearney M and Phillips S. 2010. The art of modelling range shifting species. *Methods in Ecology and Evolution* **1**(4): 330–342.

Elith J, Phillips SJ, Hastie T, Dudik M, Chee YE and Yates CJ. 2011. A statistical explanation of MaxEnt for ecologists. *Diversity and Distributions* **17**(1): 43–57.

Essa S, Dohai B and Ksiksi T. 2006. Mapping dynamics of invasive *Prosopis juliflora* in the Northern Emirates of the UAE: An application of remote sensing and GIS. In *ISPRS Commision VII Mid-term Symposium "Remote Sensing: From Pixels to Processes". Enschede, The Netherlands* (pp. 459-465): 24–29.

Fahad S, Hussain S, Chauhan BS, Saud S, Wu C, Hassan S, Tanveer M, Jan A and Huang J. 2015. Weed growth and crop yield loss in wheat as influenced by row spacing and weed emergence times. *Crop Protection* **71**: 101–108.

Ficetola GF, Thuiller W and Miaud C. 2007. Prediction and validation of the potential global distribution of a problematic alien invasive species-the American bullfrog. *Diversity and Distributions* **13**(4): 476–485.

Franklin J. 2010. *Mapping species distributions: spatial inference and prediction*. Cambridge University Press. **32**(6): 536–542.

Gharde Y, Kumar S and Sharma AR. 2019. Exploring models to predict the establishment of leaf-feeding beetle *Zygogramma bicolorata* (Coleoptera: Chrysomelidae) for the management of *Parthenium hysterophorus* (Asteraceae: Heliantheae) in India. *Crop Protection* **122:** 57–62.

Gharde Y, Singh PK, Dubey RP and Gupta PK. 2018. Assessment of yield and economic losses in agriculture due to weeds in India. *Crop Protection* **107:** 12–18.

Gholizadeh H, Friedman MS, McMillan NA, Hammond WM, Hassani K, Sams AV, Charles MD, Garrett DR, Joshi O, Hamilton RG, Fuhlendorf SD, Trowbridge AM and Adams

HD. 2022. Mapping invasive alien species in grassland ecosystems using air borne imaging spectroscopy and remotely observable vegetation functional traits. *Remote Sensing of Environment.* **271**: 112887.

Glenn NF, Mundt JT, Weber KT, Prather TS, Lass LW and Pettingill J. 2005. Hyperspectral Data Processing for Repeat Detection of Small Infestations of Leafy Spurge. *Remote Sensing of Environment* **95**(3): 399–412.

Goncalves E, Herrera I, Duarte M, Bustamante RO, Lampo M, Velasquez G, Sharma GP and Garcia-Rangel S. 2014. Global invasion of *Lantana camara*: has the climatic niche been conserved across continents? *PLoS One* **9**(10): e111468.

Grenouillet G, Buisson L, Casajus N and Lek S. 2011. Ensemble modelling of species distribution: the effects of geographical and environmental ranges. *Ecography* **34**(1): 9–17.

Guan BC, Guo HJ, Chen SS, Li DM, Liu X, Gong XI and Ge G. 2020. Shifting ranges of eleven invasive alien plants in China in the face of climate change. *Ecological Informatics* **55**: 101024.

Guisan A and Zimmermann NE. 2000. Predictive habitat distribution models in ecology. *Ecological Modelling* **135**(2-3): 147–186.

Guisan A and Thuiller W. 2005. Predicting species distribution: offering more than simple habitat models. *Ecology Letters* **8**(9): 993–1009.

Guisan A, Tingley R, Baumgartner JB, Naujokaitis Lewis I, Sutcliffe PR, Tulloch AIT, Regan TJ, Brotons L, McDonald Madden E, Mantyka Pringle C and Martin TG, Rhodes JR, Magini R, Setterfield SA, Elith J, Schwartz MW, Wintle BA, Broennimann O, Austin M, Ferrier S, Kearney MR, Possingham HP and Buckley YM. 2013. Predicting species distributions for conservation decisions. *Ecology letters* **16**(12): 1424–1435.

Hannah L, Midgley GF, Lovejoy T, Bond WJ, Bush MLJC, Lovett JC, Scott D and Woodward FI. 2002. Conservation of biodiversity in a changing climate. *Conservation Biology* **16**(1): 264–268. jstor.org/stable/3061423

Hellmann JJ, Byers JE, Bierwagen BG and Dukes JS. 2008. Five potential consequences of climate change for invasive species. *Conservation Biology* **22**(3): 534–543.

Hijmans RJ and Graham CH. 2006. The ability of climate envelope models to predict the effect of climate change on species distributions. *Global Change Biology* **12**(12): 2272–2281.

Hong SH, Lee YH, Lee G, Lee DH and Adhikari P. 2021. Predicting Impacts of Climate Change on Northward Range Expansion of Invasive Weeds in South Korea. *Plants* **10**(8): 1604.

Hoveka LN, Bezeng BS, Yessoufou K, Boatwright JS, Van der Bank M.2016. Effects of climate change on the future distributions of the top five freshwater invasive plants in South Africa. *South African Journal of Botany* **102**: 33–38.

Huang CY and Geiger EL.2008. Climate anomalies provide opportunities for large-scale mapping of non-native plant abundance in desert grasslands. *Diversity and Distributions* **14**(5): 875–884.

IPCC. 2014. Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assesment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, RK Pachauri and LA Meyer (eds).] IPCC, Geneva, Switzerland, 151 pp.

Ishii J and Washitani I. 2013. Early detection of the invasive alien plant *Solidago altissima* in moist tall grassland using hyperspectral imagery. *International Journal of Remote Sensing* **34**(16): 5926–5936.

Jarnevich CS, Holcombe TR, Barnett DT, Stohlgren TJ and Kartesz JT. 2010. Forecasting weed distributions using climate data a GIS early warning tool. *Invasive Plant Science and Management* **3**(4): 365–375.

Jimenez-Valverde A, Peterson AT, Soberon J, Overton JM, Aragon P and Lobo JM. 2011. Use of niche models in invasive species risk assessments. *Biological Invasions* **13**(12): 2785–2797.

Ju RT, Zhu HY, Gao L, Zhou XH and Li B. 2015. Increases in both temperatures means and extremes likely facilitate invasive herbivore outbreaks. *Scientific Reports* **5**(1): 1–10.

Kadioglu I and Farooq S. 2017. Potential Distribution of Sterile Oat (*Avena sterilis* L.) in Turkey under Changing Climate. *Turkish Journal of Weed Science* **20**(2): 1–13.

Kariyawasam CS, Kumar L and Ratnayake SS. 2019. Invasive Plants Distribution Modeling: A Tool for Tropical Biodiversity Conservation with Special Reference to Sri Lanka. *Tropical Conservation Science* **12**: 1–12.

Kariyawasam CS, Kumar L, Ratnayake SS. 2019. Invasive Plant Species Establishment and Range Dynamics in Sri Lanka under Climate Change. *Entropy* **21**(6): 571.

Katz TS and Zellmer AJ. 2018. Comparison of model selection technique performance in predicting the spread of newly invasive species: a case study with *Batrachochytrium salamandrivorans*. *Biological Invasions* **20**(8): 2107–2119.

Kearney M and Porter W. 2009. Mechanistic niche modeling combining physiological and spatial data to predict species ranges. *Ecology Letters* **12**(4): 334–350.

Kleunen van M, Dawson W, Essl F, Pergl J, Winter M, Weber E, Kreft H, Weigelt P, Kartesz J, Nishino M, Antonova LA, Barcelona JF, Cabezas FJ, Cardenas D, Cardenas Toro J, Castano N, Chacon E, Chatelain C, Ebel AL, Figueiredo E, Fuentes N, Groom QJ, Henderson L, Singh I, Kupriyanov A, Masciadri S, Meerman J, Morozova O, Moser D, Nickrent DL, Patzelt A, Pelser PB, Baptiste MP, Poopath M, Schulze M, Seebens H, Shu WS, Thomas J, Velayos M, Wieringa JJ and Pyšek P. 2015. Global exchange and accumulation of non-native plants. *Nature* **525**: 100–103.

Kriticos DJ, Sutherst RW, Brown JR, Adkins SW, Maywald GF. 2003. Climate change and the potential distribution of an invasive alien plant: Acacia nilotica ssp. indica in Australia. *Journal of Applied Ecology* **40**(1): 111–124.

Kriticos, D J, Yonow T and Mcfadyen R E. 2004. The potential distribution of *Chromolaena odorata* (Siam weed) in relation to climate. *Weed Research* **45**(4): 246–254.

Kwak TS, Ki JH, Kim YE, Jeon HM and Kim SJ. 2008. A study of GIS prediction model of domestic fruit cultivation location changes by the global warming-six tropical and sub-tropical fruits. *Journal of Korea Spatial Information System Society* **10**(3): 93-106.

Lee H.W. 2010. A study of methodologies assessing species susceptibility to climate change. *Issue studies of Korea Environment Institute* **13**(10): 1559.

Lemke D, Hulme PE, Brown JA and Tadesse W. 2011. Distribution modelling of Japanese honeysuckle (*Lonicera japonica*) invasion in the Cumberland Plateau and Mountain Region, USA. *Forest Ecology and Management* **262**(2): 139–149.

Manzoor SA, Grifths G, Iizuka K and Lukac M. 2018. Land cover and climate change may limit invasiveness of *Rhododendron ponticum* in Wales. *Frontiers in Plant Science* **9**: 664.

Marambe B and Wijesundara S. 2021. Effects of Climate Change on Weeds and Invasive Alien Plants in Sri Lankan Agro-Ecosystems: Policy and Management Implications. *Frontiers in Agronomy* **3**: 641006.

Maharjan S, Shrestha BB, Joshi MD, Devkota A, Muniappan R, Adiga A and Jha PK. 2019. Predicting suitable habitat of an invasive weed *Parthenium hysterophorus* under future climate scenarios in Chitwan Annapurna Landscape, Nepal. *Journal of Mountain Science* **16**: 2243–2256.

Marmion M, Parviainen M, Luoto M, Heikkinen RK and Thuiller W. 2009. Evaluation of consensus methods in predictive species distribution modelling. *Diversity and Distribution* **15**(1): 59–69.

Masum SM, Halim A, Mandal MSH, Asaduzzaman M and Adkins S. 2022. Predicting Current and Future Potential Distributions of *Parthenium hysterophorus* in Bangladesh Using Maximum Entropy Ecological Niche Modelling. *Agronomy* **12**(7): 1592.

McNeeley JA, Mooney HA, Neville LE, Schei PJ and Waage JK. 2001. Global Strategy on Invasive Alien Species. *IUCN: International Union for Conservation of Nature* **19**(3): 523–527.

Merow C, Bois ST, Allen JM, Xie Y and Silander Jr JA. 2017. Climate change both facilitates and inhibits invasive plant ranges in New England. *Proceedings of the National Academy of Sciences of the United States of America* **114**(16): 3276–3284.

Mitchell JJ and Glenn NF. 2009. Leafy spurge (*Euphorbia esula*) classification performance using hyperspectral and multispectral sensors. *Rangeland Ecology and Management* **62**: 16–27.

Moshobane MC and Esser LF. 2022. Ensemble modeling for the potential distribution of invasive weed *Verbesina encelioides* in South Africa from 2020 to 2090. *Management of Biological Invasions* **13**(4): 833-844.

Panda RM, Behera MD, Roy PS. 2018. Assessing distributions of two invasive species of contrasting habits in future climate. *Journal of Environmental Management* **213**: 478–488.

Panda RM and Behera MD. 2019. Assessing harmony in distribution patterns of plant invasions: a case study of two invasive alien species in India. *Biodiversity and Conservation* **28**(1): 2245–2258.

Parker C. 2012. Parasitic Weeds: A World Challenge. *Weed Science* **60**(2): 269–276.

Pearson RG and Dawson TP. 2003. Predicting the impacts of climate change on the distribution of species are bioclimate envelope models useful? *Global Ecology and Biogeography* **12**(5): 361–371.

Peterson AT and Anamza T. 2015. Ecological niches and present and historical geographic distributions of species: a 15-year review of frameworks, results, pitfalls, and promises. *Journal of Vertebrate Biology* **64**(3): 207–217.

Peterson AT, Papes M and Soberon J. 2015. Mechanistic and correlative models of ecological niches. *European Journal of Ecology* **1**(2): 28–38.

Peterson AT and Soberón J. 2012. Species distribution modeling and ecological niche modeling: getting the concepts right. *Natureza and Conservação* **10**(2): 102–107.

Phillips SJ, Anderso RP and Schapire RE. 2006. Maximum entropy modeling of species geographic distributions. *Ecological modelling* **190**(3-4): 231–259.

Poudel AS, Shrestha BB, Joshi MD, Muniappan R, Adiga A, Venkatramanan S and Jha PK. 2020. Predicting the Current and Future Distribution of the Invasive Weed *Ageratina adenophora* in the Chitwan–Annapurna Landscape, Nepal. *Mountain Research and Development* **40**(2): R61–R71.

Priyanka N and Joshi PK. 2013. Effects of climate change on invasion potential distribution of *Lantana camara*. *Journal of Earth Science and Climatic Change* **4**(6): 1000164.

Rao AN, Brainard DC, Kumar V, Ladha JK and Johnson DE. 2017. Preventive weed management in direct-Seeded Rice: Targeting the weed seedbank. *Advances in Agronomy* **144**: 45–142.

Reaser JK, Burgiel SW, Kirkey J, Brantley KA, Veatch SD and Burgos RJ. 2020. The early detection of and rapid response (EDRR) to invasive species: a conceptual framework and federal capacities assessment. *Biological Invasions* **22** (1): 1–19.

Roger E, Duursma DE, Downey PO, Gallagher RV, Hughes L, Steel J, Johnson SB and Leishman MR. 2015. A tool to assess potential for alien plant establishment and expansion under climate change. *Journal of Environmental Management* **159**: 121–127.

Romero-Alvarez D, Escobar LE, Varela S, Larkin DJ, Phelps NBD. 2017. Forecasting distributions of an aquatic invasive species (*Nitellopsis obtusa*) under future climate scenarios. *PLoS ONE* **12**(7): e0180930.

Rosenzweig C, Iglesius A, Yang XB, Epstein PR and Chivian E. 2001. Climate change and extreme weather events-Implications for food production, plant diseases, and pests. *Global Change and Human Health* **2**(2): 90–104.

Runquist Briscoe RD, Lake T, Tiffin P and Moeller DA. 2019. Species distribution models throughout the invasion history of Palmer amaranth predict regions at risk of future invasion and reveal challenges with modeling rapidly shifting geographic ranges. *Scientific Reports* **9**(1): 2426.

Sathischandra HGAS, Marambe B and Punyawardena R. 2014. Seasonal changes in temperature and rainfall and its relationship with the incidence of weeds and insect pests in rice (*Oryza sativa* L) cultivation in Sri Lanka. *Climate Change and Environment Sustainability* **2**(2): 105–115.

Seebens H, Blackburn TM, Dyer EE, Genovesi P, Hulme PE, Jeschke JM, Pagad S, Pysek P, Winter M, Arianoutsou M, Bachler S, Blasius B, Brundu G, Capinha C, Celesti-Grapow L, Dawson W, Dullinger S, Fuentes N, Jager H, Kartesz J, Kenis M, Kreft H, Kuhn I, Lenzner B, Liebhold A, Mosena A, Moser D, Nishino M, Pearman D, Pergl J, Rabitsch W, Rojas-Sandoval J, Roques A, Rorke S, Rossinelli S, Roy HE, Scalera R, Schindler S, Štajerova K, Tokarska-Guzik B, van Kleunen M, Walker K, Weigelt P, Yamanaka T and Essl F. 2017. No saturation in the accumulation of alien species worldwide. *Nature Communications* **8**(1): 14435.

Shrestha UB, Sharma KP, Devkota A, Siwakoti M and Shrestha BB. 2018. Potential impact of climate change on the distribution of six invasive alien plants in Nepal. *Ecological Indicators* **95**(1): 99–107.

Soberon J, Osorio-Olvera L and Peterson T. 2017. Conceptual differences between ecological niche modeling and species distribution modeling. *Revista Mexicana de Biodiversidad* **88**(2): 437–441.

Srivastava V, Lafond V and Griess VC. 2019. Species distribution models (SDM): applications, benefits and challenges in invasive species management. *CABI Reviews* **14**(20): 1–13.

Taylor S, Kumar L, Reid N and Kriticos DJ. 2012. Climate change and the potential distribution of an invasive shrub, *Lantana camara* L. *PloS one* **7**(4): e35565.

Taylor S. and Kumar L. 2013. Potential distribution of an invasive species under climate change scenarios using CLIMEX and soil drainage: a case study of *Lantana camara* L. in Queensland, Australia. *Journal of Environmental Management* **114**: 414–422.

Taylor S and Kumar L. 2012. Climate change and invasive weeds-Modeling distribution of *Lantana camara* (L.). The GSTF *Journal of Engineering Technology (JET)* **1**(1):56–60.

Thapa S, Chilate V, Rijal SJ, Bisht N and Shrestha BB. 2018. Underlying the dynamics in distribution of invasive alien plant species under predicted climate change in Western Himalaya. *PloS one* **13**(4): e0195752.

Thuiller W. 2004. Patterns and uncertainties of species' range shifts under climate change. *Global Change Biology* **10**(12): 2020–2027.

Thuiller W, Lafourcade B, Engler R and Araujo MB. 2009. BIOMOD–a platform for ensemble forecasting of species distributions. *Ecography* **32**(3): 369–373.

Tiwari S, Mishra SN, Kumar D, Kumar B, Vaidya SN, Ghosh BG, Rahaman SkM, Khatun M, Garai S and Kumar A. 2022 Modelling the potential risk zone of *Lantana camara* invasion and response to climate change in eastern India. *Ecological Processes* **11**.

Trethowan PD, Robertson MP and McConnachie AJ. 2011. Ecological niche modelling of an invasive alien plant and its potential biological control agents. *South African Journal of Botany* **77**(1): 137–146.

Tu W, Xiong Q, Qiu X and Zhang Y. 2021. Dynamics of invasive alien plant species in China under climate change scenarios *Ecological Indicators* **129**: 107919.

Van Wilgen BW, Fill JM, Baard J, Cheney C, Forsyth AT and Kraaij T. 2016. Historical costs and projected future scenarios for the management of invasive alien plants in protected areas in the Cape Floristic Region. *Biological Conservation* **200**: 168–177.

Wan JZ and Wang CJ, Tan JF and Yu FH. 2017. Climatic niche divergence and habitat suitability of eight alien invasive weeds in China under climate change. *Ecology and Evolution* **7**(5): 1541–1552.

Wan JZ and Wang CJ. 2019. Contribution of environmental factors toward distribution of ten most dangerous weed species globally. *Applied Ecology and Environmental Research* **17**(6): 14835-14846.

Wang CJ, Wan JZ, Qu H and Zhang ZX. 2017. Modelling plant invasion pathways in protected areas under climate change: implication for invasion management. *Web Ecology* **17**: 69-77.

Wei J, Zhang H, Zhao W and Zhao Q. 2017. Niche shifts and the potential distribution of *Phenacoccus solenopsis* (Hemiptera: Pseudococcidae) under climate change. *PloS one* **12**(7): e0180913.

Welk E, Schubert K and Hoffmann MH. 2002. Present and potential distribution of invasive garlic mustard (*Alliaria petiolata*) in North America. *Diversity and Distributions* **8**(4): 219–233.

Wisz MS, Pottier J, Kissling WD, Pellissier L, Lenoir J, Damgaard CF, Dormann CF, Forchhammer MC, Grytnes JA, Guisan A, Heikkinen RK, Hoye TT, Kuhn I, Luoto M, Maiorano L, Nilsson M-C, Normand S, Ockinger E, Schmidt NM, Termansen M, Timmermann A, Wardle DA, Aastrup P and Svenning J-C. 2013. The role of biotic interactions in shaping distributions and realised assemblages of species: implications for species distribution modelling. *Biological Reviews* **88**(1): 15–30.

Wisz MS, Hijmans RJ, Li J, Peterson AT, Graham CH, Guisan A and NCEAS Predicting Species Distributions Working Group. 2008. Effects of sample size on the performance of species distribution models. *Diversity and Distributions* **14**(5): 763–773.

Yan H, Feng L, Zhao Y, Feng L, Zhu C, Qu Y and Wang H. 2020. Predicting the potential distribution of an invasive species, *Erigeron canadensis* L. in China with a maximum entropy model. *Global Ecology and Conservation* **21**: e00822.

Yang C and Everitt JH. 2010. Comparison of hyperspectral imagery with aerial photography and multispectral imagery for mapping broom snakeweed. *International Journal of Remote Sensing* **31**(20): 5423–5438.

Yuan Y, Tang X, Liu M, Liu X and Tao J. 2021. Species Distribution Models of the *Spartina alterniflora* Loisel in Its Origin and Invasive Country Reveal an Ecological Niche Shift. *Frontiers in Plant Science* **12**: 738769.

Zhang X, Wang Y, Peng P, Wang G, Zhao G, Zhou Y and Tang Z. 2022. Mapping the Distribution and Dispersal Risks of the Alien Invasive Plant *Ageratina adenophora* in China. *Diversity* **14**(11): 915.

Zhu G, Li H and Zhao L. 2017. Incorporating anthropogenic variables into ecological niche modeling to predict areas of invasion of *Popillia japonica*. *Journal of Pesticide Sciences* **90**(1): 151–160.