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Field Manual on Alien Flora of Kashmir Himalaya

Casual, Naturalised and Invasive Plants

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Biological Invasions represent one of those rare themes that cut across the disciplines of academic biology, while having profound environmental, philosophical, socioeconomic, and legislative implications at a global scale. There can be no doubt that biological invasions represent the single greatest threat to biodiversity past the activities of humankind itself. The implications are far reaching. Novel ecological and evolutionary forces are now directing the future expression of life itself, as native species and the communities that they comprise contend with invading species. The rules of the game have been suddenly and irrevocably changed.

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A panoramic view of plant invasion in the terrestrial ecosystem (Gulmarg)

A panoramic view of plant invasion in the aquatic ecosystem (Dal Lake)

Foreword

In the era of big data, large global consortia, open science, and sophisticated analytical tools, ecology has become fascinated by opportunities to search for general principles, ask questions that were hard to imagine a few decades ago and gain insights into processes that are applicable across taxa, scales and time. Research in biological invasions is no exception – the last decade has seen an outburst of papers exploring the mechanisms and processes determining the success of alien species at large scales, making use of dramatically improved information on alien species distributions, ecology, and traits. Such growing knowledge is paramount for better management and mitigation of the impacts of plant invaders. Still, it is good to be reminded that none of these achievements would have been possible without good old botanical field research. When it comes to real plants, you need to go to the field rather than just to databases and do some natural history.

The book **Field Manual on Alien Flora of Kashmir Himalaya: Casual, Naturalised and Invasive Plants** represents a brilliant example of such an approach where science meets practice. Authored by Ruquia Gulzar (a doctoral student), Anzar A. Khuroo (a botanist) and Irfan Rashid (a spatial ecologist) from the University of Kashmir, it provides profiles of the hundred alien plant species in Kashmir Himalaya with comprehensive information on their taxonomy, ecology, current invasion status, impacts, distribution map and photographs that are very helpful for field identification. Written to promote awareness among researchers, students, citizen scientists, stakeholders, and the general public on the threats invasive plants pose to the environment and biodiversity and encourage research and management, the book will be most beneficial for anyone interested in plant invasions in India and beyond.

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Preface

This ***Field Manual on Alien Flora of Kashmir Himalaya: Casual, Naturalised and Invasive Plants*** has been prepared with two main goals in mind: to promote awareness on the threats of invasive alien species and to encourage research on and management of the common casual, naturalised, and invasive alien plants in Kashmir Himalaya, India. The *Manual* contains concise information on taxonomy, ecology, invasion status, impacts and distribution of 100 alien plant species of this Himalayan region. To facilitate field identification, the *Manual* provides photographs of habitat, habit, leaves, flowers and fruits of each plant species. The *Manual* is organised into three chapters:

Chapter 1 provides a brief account on the discipline of invasion biology right from its genesis to the present status. The basic concepts of the invasion process, mechanisms of invasion, its impacts, options for management and policy issues are discussed. The role and interlinkages of invasion biology in contemporary global environmental challenges of climate and land use changes and biodiversity loss are also highlighted.

Chapter 2 guides the readers on how to use the *Manual*. It first provides an overview of the study region, including its location, geology, climate and vegetation. It then describes the methods used to conduct the study based on which this *Manual* is prepared. It also describes the terminology and definitions used in the chapter 3 (Alien Species' Profile).

Chapter 3 comprises the bulk of this *Manual* and contains information on 100 alien plant species of the study region. For each species, the scientific name, name of its family, English name, local name, taxonomic characters, ecological traits, current invasion status (casual, naturalised and invasive) in Kashmir Himalaya, native range of the species, its global distribution, a regional distribution map and photo illustrations portraying diagnostic field characters are provided.

The *Manual* is the outcome of extensive field work conducted by the authors across this Himalayan region. It is hoped that the *Manual* will increase awareness on the threats posed by plant invasions among all the stakeholders—researchers, land managers, policy makers, environmentalists, naturalists, citizen scientists, students and the general public. It will also help in promoting research, formulating policies and planning management actions to deal with invasive alien species.

Srinagar, India Ruquia Gulzar
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Acknowledgements

Writing a book is a teamwork, because it involves inputs and help from many individuals and institutions. Same is true for this *Manual* as well.

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On personal behalf, I (Ruquia Gulzar) feel that no words will suffice to express the immense gratitude and admiration for my beloved parents (Mr. Gulam Mohammad and Mrs. Sarwa) for their unconditional love, unwavering support and unflinching faith during the course of this work. I am highly grateful to my siblings (Mir Shahnawaz, Roohi) and niece (Sehrish) for their support and kind help during the field surveys. I am greatly indebted to my supervisor (Anzar Ahmad Khuroo) for his proficient guidance, unparalleled encouragement and timely help. I am also thankful to my co-supervisor (Irfan Rashid) for his valuable suggestions and timely help. I would also like to acknowledge the financial support received from CSIR-New Delhi during the present study.

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We are highly obliged to *Springer Nature* and their professional team, especially Eva Loerinczi, Anette Weiss, Rajeshree, Kayalvizhi for coordinating the manuscript processing, proofing and printing. Last but not least, no book can ever claim to be complete and free from errors (factual or typographical), and the same applies to this work as well. Therefore, it is our humble request to the esteemed readers of this book to share their valuable feedback with the authors.

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Ruquia Gulzar doctoral student in the Department of Botany at the University of Kashmir, is working on the 'Naturalised Flora of Kashmir Himalaya' for the last five years. In pursuit of her research, she has conducted extensive field surveys in this Himalayan region and laboratory-based studies. Recently, she has also published her research work in reputed scientific journals (see at https://www.researchgate.net/profile/Ruquia-Gulzar).

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Chapter 1
Invasion Biology

1.1 Introduction

We are currently living in an age of Anthropocene [1]. Amongst the dominant drivers of Anthropocene, biological invasions by alien species are recognised as the second greatest threat to global biodiversity after habitat loss [2]. In recent times, the rising global trade, travel and transport have accelerated the rate of species' introductions outside their native biogeographic ranges [3]. Worldover, a significant proportion of the introduced species pool has become naturalised and some of these spread as invasive in their non-native ranges, causing significantly high ecological and economic impacts affecting nature and nature's contribution to all life forms [4, 5]. In response, concerted efforts are being made across the globe to focus scientific research, strengthen biosecurity, formulate policies and implement management strategies to combat biological invasions [6–8].

Invasion biology—a scientific discipline that deals with the study of invasions by alien species—has its origin in the publication of Charles Elton's seminal book *The Ecology of Invasions by Animals and Plants* [9]. Since then, the discipline has emerged with global research efforts focussed on understanding the patterns and processes of biological invasions, impacts of invasive alien species on biodiversity and ecosystem functioning, and management and restoration strategies [10]. More specifically, a rapid expansion of the discipline over the last two decades reflects its increasing relevance in addressing the global crises of biodiversity loss, climate change and very recently the COVID-19 pandemic [2, 3, 11]. Invasion biology, as an interdisciplinary subject, has embraced a wide range of domains in ecology and related areas (e.g. biogeography, population biology, evolutionary biology, physiology and genomics) and also found interlinkages with divergent disciplines such as resource economics, epidemiology, risk analysis, vector science and biosecurity [12, 13]. More recently, the ongoing climate and land-use changes have contributed

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to the growing complexity of biological invasions and their ecological and economic fallouts [14]. Along with these new challenges, an ever-expanding connection with diverse disciplines has fostered the transdisciplinary growth of invasion biology [2, 15].

1.2 Biological Invasions: A Multi-stage Process

As a process, biological invasion involves a series of stages that all alien species may have to pass through along the invasion continuum. The main stages include import or introduction of alien species into a non-native range, its release or escape into the wild, propagation of its population without human intervention followed by its spread as invasive. These multiple stages can be characterised along a continuum known as introduction–naturalisation–invasion continuum [16, 17]. Recognising the status of an alien species at these stages is critical to comprehend how a variety of factors facilitate species transition over the continuum and what management action is suitable at each stage. Therefore, these stages of invasion process are reflected whilst characterising status of each species in alien inventories [18]. On entering into a non-native region, an alien species has to survive, reproduce, disperse and spread to be finally recognised as an invasive [16]. For instance, in case of plants, those alien species which grow outside the area of their cultivation but need human assistance directly or indirectly to survive are known as casual alien species. And, those alien species which form self-sustaining populations in the wild without human assistance are known as naturalised, and those species that spread widely across a region with impacts are known as invasive [19, 20].

Generally, there are three main mechanisms of introduction: importation of goods, influx of a transport vector and natural spread from an adjoining region where the species is an alien [15]. International trade and travel are considered the principal drivers of biological invasions in both terrestrial and aquatic ecosystems [21, 22]. The traded commodity can be an alien species (e.g. ornamental plants) in some cases but, most often, alien species (or their propagules) are introduced unintentionally as an impurity or contaminant of traded commodities, e.g. weed seeds in grain, parasites in livestock or as a runaway on transport vessels or other means of transportation [23], and ballast water and hull fouling are the main pathways/vectors for marine invasions.

After successful introduction and escape into the wild (human-dominated and/or natural ecosystems) in non-native regions, a proportion of the alien species successfully establishes and enters into the naturalised stage. The time to naturalisation can vary from years to decades depending upon the species' lag phase and pace of propagule pressure. Although majority of the imported species fail to establish long-term populations, a considerable proportion do so, and the number of such species is steadily growing globally [3]. Naturalisation is the most crucial stage in the invasion process because all naturalised species are potential future invaders. The naturalised species pool is often recognised as the most important proxy for estimating invasion debt in an area [24]. The number of naturalised species varies greatly throughout the world, and insightful biogeographical patterns have emerged [25]. Recent studies show that introduced species on islands are more frequently naturalised than those on the terrestrial lands [26]. The number of naturalised species on islands shows an increase with increasing temperature since it aids propagule establishment [27]. Similarly, the number of naturalised species in temperate zones is reported to decline with latitude whilst their geographical ranges increase. The final step for alien species is the transition from naturalised to invasive stage.

The stage-based approach in biological invasions has a fundamental and practical relevance in better understanding how alien species spread in non-native ranges, why some ecosystems are more susceptible to invasion, what factors determine invasive species impacts, and which species and sites/habitats are to be prioritised for management action [28]. Identifying each stage of the invasion process and recognising the status of alien species pool is thus crucial because each stage is mediated by a separate set of causes and factors, some of which may operate at multiple stages [27]. The importance of factors at each stage can vary, with socio-economic factors being the most important at earlier stages, followed by biogeographical, ecological, and evolutionary factors. But, all these factors can influence all stages of invasion along the invasion continuum [29]. Some of the factors can be ecological such as availability of a breeding partner, the need for specialised dispersers, obligatory mutualism, as well as plant traits (e.g. lifeform); likewise, the human-mediated factors include mainly introduction of the species.

1.3 Species Invasiveness and Habitat Invasibility

Species invasiveness and habitat invasibility are two fundamental conceptual pillars of invasion biology [30]. Species invasiveness is defined as the ability of an alien species to invade the recipient ecosystem and the major determinants include introduction history, species traits, evolutionary, and ecological factors [31]. On the other hand, vulnerability of the recipient ecosystem to the establishment and spread of an alien species is referred to as habitat invasibility. A number of hypotheses have been posited to investigate these twin concepts of invasion biology. One of the most extensively investigated mechanisms of alien plant invasions is the enemy release hypothesis (ERH), which hypothesises that, when plant species are introduced to a non-native environment, their control by herbivores and other natural predators is reduced, leading to a fast expansion in range and abundance [32, 33]. This hypothesis is built on a three-point argument: (1) natural enemies are significant regulators of plant populations; (2) enemies have a higher impact on native species than invasive species; and (3) plants can benefit from reduced enemy regulation, thereby leading to greater population expansion. Depending on the species under investigation, the reliability of these arguments and the likelihood for enemy release also varies [33].

In addition, there are several other factors that enable alien plants to spread quickly in introduced ranges which include: capability to reproduce both sexually and asexually, popularity as ornamentals, resistance to harsh environmental conditions, high regeneration, early maturation and effective seed dispersal modes. Depending upon the magnitude of human disturbance regimes and climate change, the adaptability and/or spreading potential of the alien plants may vary [34]. The evolutionary past of a species and its environment determine its ability to adapt to changing climates and dispersal in the non-native region. For instance, the floral diversity of the Western Himalaya has been shown to have a slower rate of colonisation and altitude-facilitated speciation, resulting in a predominantly native species composition in the high-altitude Himalaya [35]. The native plants are unable to survive in the altered environment or long-distance propagation to the new habitat as a result of this slower colonisation potential and climate-specific speciation. On the other hand, invasive alien plants with continental distributions may benefit from global environmental changes due to their physiological adaptability and possibility of acquiring new dispersal agents [36]. Also, land-use changes are responsible for altering native biodiversity patterns as novel ecosystems with combinations of alien and native species are becoming common throughout the world [37].

1.4 Impacts of Biological Invasions

Invasive alien species have the ability to inflict significant negative consequences on the environment, economy, and human health. These species are key drivers of change in recipient ecosystems, causing changes in ecosystem functioning and biodiversity [38]. Disturbed habitats like grazing pastures, open meadows, roadsides, and woodland openings are reported to be highly susceptible to invasive species worldwide [39, 40]. Also, these species pose a significant risk to the endemic biodiversity and life-supporting ecosystem services in the invaded biomes [41, 42]. In extreme cases, invasive alien species may cause extinction of native species through predation or competition for habitat and food [43]. Invasive species lead to a decline in species richness in both terrestrial and aquatic ecosystems. A global meta-analysis evaluated the role of invasive alien species in reducing native species richness and found that even a single invasive species can result in 16.6% reduction in native species richness [44]. The most significant effect on species richness and evenness is caused by tall invasive species that can establish populations with a cover noticeably greater than that of native dominating species [45]. Besides impacts on aboveground part of terrestrial ecosystems, plant invasions affect belowground soil system dynamics as well. Understanding the invasion impacts on belowground part of ecosystems is crucial for the effective management and restoration of invaded landscapes. The documented impacts of invasive alien species on soil systems are varied and include changes in cycling of carbon, nitrogen, and other nutrient pools, as well as modification of physio-chemical properties like soil pH, moisture, temperature, organic matter, and microbial activity [41, 42, 46]. Invasive alien species can also cause the transmission and spread of diseases in agriculture and forestry sectors [47, 48]. Therefore, management expenditures for the eradication of invasive alien species to mitigate damage can have considerable financial implications. The Generic Impact Scoring System (GISS) and the Environmental Impact Classification for Alien Taxa (EICAT) are uniform standardised approaches for evaluating, comparing, and eventually predicting the magnitude of various consequences of invasive alien species at a global scale [49].

Research attention has recently been focused on the economic costs of biological invasions, resulting in a rapid accumulation of evidence on invasion-related economic losses [50]. Based on a novel database viz., InvaCost, economic costs of biological invasions across the globe were recently estimated [4]. The study revealed that the global economic costs of invasive alien species amounted to at least US$ 1.3 trillion during the period 1970–2017, and the costs are increasing rapidly. The urgency of preventing and controlling biological invasions is highlighted by such huge costs, which are probably an underestimate, particularly for invasive alien plants [50]. The study by Diagne et al. [4] significantly underestimated the costs due to plant invasions compared to vertebrate and invertebrate invasions. It was estimated that, globally, between 1970 and 2017, invasive alien plants cost US$ 8.9 billion out of a total of US$ 591 due to plants, vertebrates, and invertebrates. However, the cost was more than US$ 8.9 billion for plants based on information available over the past 20 years [50]. For example, invasive alien plants are estimated to cost at least € 3.8 billion a year in Europe, accounting for 30% of the continent's total costs due to invasive alien species [51].

In an era of global environmental change, ecological novelty as an element of species redistribution is considered one of the effects of biological invasions [52]. Different dimensions of ecological novelty have been characterised and linked to range-expanding alien species in multiple ways. Ecological novelty can be quantified inversely as the eco-evolutionary process of interaction between native and alien species. [53]. The alien species with new weapons or other novel qualities that the native species is unfamiliar with (i.e. limited eco-evolutionary experience) are likely to have greater impacts on native species than those alien species that are comparable to native ones in these traits. The alien mammalian predators that were introduced into New Zealand (and other oceanic islands) had a highly deleterious impact on local flightless birds, with Kiwi and other soil-nesting bird species becoming easy targets for mustelids and cats since these predators were absent in the region previously [54]. Similarly, range-expanding plants that are spreading into biomes with colder climates in response to climate change can have significant effects on nutrient cycling and ecosystem functioning when alien plants with new growth forms unfamiliar to the region are introduced. For example, laurophyllisation occurs in temperate forests and shrubification in tundra ecosystems [53].

Whilst most of the research has focussed on the detrimental impacts of biological invasions [55], the possible advantages, though less known, pose formidable management challenges [56]. Therefore, assessing the impacts of alien species is crucial from a scientific standpoint for successful implementation of management strategies. To make objective management decisions, one must adopt a perspective that takes into account both ecosystem services and disservices due to invasive alien species.

1.5 Management and Policymaking

Globally, recent research has focussed more towards management of invasive alien species and ecological restoration of invaded landscapes. As already emphasised, targeting the stage of invasion is critical to the designing and application of successful management methods [57]. Invasive alien species management plans must include strategies related to prevention, early detection and rapid response (EDRR), containment and control at specific stages along the invasion continuum in order to be effective and efficient [58]. As majority of invasive plants are introduced intentionally, the most effective strategy to avoid future introductions is to prevent them from getting introduced in the first place. Robust tools of risk analysis (RA), which assess the biology of the species, the characteristics of the ecosystem into which it is being introduced, and whether it has been reported as invasive somewhere, help to select suitable species for introduction and prevent unsuitable species. If risk analysis fails to prevent the arrival of an invasive or potentially invasive species, it is vital that it be recognised early at the point of entry and removed before it gains entry. In EDRR, the term early detection is defined as the act of surveillance for already introduced alien species, and rapid response as any action that allows those organisms to be destroyed or stopped them from spreading further [59]. For a rapid response to be successful, eradication operations must be completed within weeks or at most 1–2 years, because each invasion scenario is different and the timescale for eradication varies [60]. Therefore, developing and implementing a proactive surveillance plan is critical. If monitoring does not result in the timely identification of a potentially harmful alien plant and removal is no longer an option, containment of the species is another option. If this also fails due to its vast and abundant distribution of the species, a control method must be implemented. Cultural, physical, chemical or biological control or a mix of some or all of these, could be used in a control plan, which should then be followed by restoration [61]. Of late, species distribution models (SDM) have emerged as commonly used tools to evaluate invasion risk and, in most cases, to predict species habitat suitability [41, 42, 62, 63]. However, applicability of SDMs to decipher patterns of abundance and impact may be limited [64]. Recently, citizen science has shown a huge promise in early detection of potential invasive species and map their occurrence thus helping in planning invasion management [65]. The use of smartphone-based apps for reporting and uploading photos and geospatial information of potential invasive alien species at their early stage of introduction has improved chances of early detection and rapid control of new invasive alien species [66].

Worldover, with nations having almost failed to meet the Aichi Biodiversity Target 2020, negotiations are being held under the aegis of the Convention on Biological Diversity (CBD) to develop a feasible and monitorable Post-2020 Global Biodiversity Framework. As per this Framework, to meet the 2050 Vision, where biodiversity is respected, maintained, and restored, we must reduce the significant and still rising impact of invasive alien species (IAS) on biodiversity. To achieve this, the IUCN Invasive Species Specialist Group (ISSG) has established a preliminary target that was formally presented to the CBD for discussion on Post-2020 targets [67]. The Aichi Target 9 of CBD related to IAS aimed to 'control all pathways for the introduction of invasive alien species, achieving by 2030 a 50% reduction in the rate of new introductions, and eradicate or control invasive alien species to eliminate or reduce their impacts by 2030 in at least 50% of priority sites' [68]. Reducing the effects caused by IAS has been identified as a priority area of action by various global environmental policies. The United Nations Sustainable Development Goals (SDGs) also include an IAS target that intends to 'avoid the introduction and considerably minimise the effect of IAS in terrestrial and aquatic ecosystems, as well as control or eradicate priority species'. The number of countries passing appropriate legislation and formally establishing institutional mechanisms for invasion management is used to gauge the progress.

Globally, significant progress has been made in gathering data and projecting alien species distributions [31, 69]. As a result, various alien species databases, ranging in scale from regional to continental, have been developed in the recent decade, with the goal of gathering data on alien species' status, distribution, pathways, impacts, and other characteristics [70]. For example**,** the European DAISIE project was ground-breaking in this respect since it included all important species and biomes for an entire continent and the data was collected using a uniform criterion [69]. Open access to data on the distribution of alien species, on the other hand, remains a challenge, particularly for countries that need to use such information for developing policies, plan management and surveillance. Also, the scientific literature on biological invasions is mostly available from developed nations, with relatively little known from developing nations. Global syntheses and inferences on the diversity and distribution of IAS and their impacts are often drawn based on the fragmentary datasets, though the huge knowledge gaps from developing countries are well known [71]. In fact, effective management measures for IAS, may be more necessary and advantageous for developing nations, where larger, and highly diverse natural ecosystems with greater biodiversity are more common [72]. Lack of skills and technical knowhow, little awareness about the scale of problem, inadequate policies and imperfect implementation of regulations are the main reasons why developing economies are not successful in combating IAS threats. Therefore, focussing on research and generation of appropriate knowledge products to inform policy and manage biological invasions in developing countries, particularly emerging economies like India, assumes immediate priority.

1.6 Relevance of the Manual

Mountains, with 12.5% of the Earth's land surface and covering 13.8 million km^2, are home to one-quarter of all terrestrial species [73]. Mountains are a natural treasure trove of precious ecosystem goods and services and progenitors of biodiversity and cradles of evolution [74]. Because of recent climatic and land-use changes, urban population growth, road construction, expansion of agricultural land and a host of unsustainable human activities, the natural habitats in mountains, across the globe, that were previously presumed to be resistant to biological invasion are now increasingly becoming susceptible to invasion by alien species [73, 75–77]. Amongst the mountain systems of the world, the Himalaya, endowed with a rich repository of biological diversity and recognised as a global biodiversity hotspot, occupies a prominent place [78]. The Himalaya is home to hydrological resources supporting nearly two billion human population in South Asia. Although spread across different countries in South Asia, the major portion of the Himalaya falls within India. The Kashmir Himalaya, located towards northwestern side of Indian Himalaya is also one of the most eco-fragile mountainous landscapes of the world [79]. Studies indicate that changing land-use patterns and rapidly warming climate have increased the risk of biological invasions in this Himalayan region also [80–82]. Although several studies on different aspects of plant invasions have been carried out in this region [39, 41, 42, 83], there is a dearth of information that could help rapid and reliable field identification and characterisation of alien plant species in the region. Against this background, publication of an illustrated *Manual* with a focus on field-based taxonomic characters, species traits and regional distribution is timely. It is expected to play a pivotal role in creating awareness on biological invasions, advancing research and planning management actions.

In fact, Ricciardi et al. [84] have recently highlighted that our capacity to assess and comprehend the spatiotemporal dynamics of invasions and their effects is critically hampered by the taxonomic barrier. A large portion of the current knowledge is based on secondary data syntheses and analyses using information from regional checklists and atlases of flora. In all such cases, the reliability of species identifications has substantially impeded their utility [85]. Misidentifications and inability to recognise cryptic species complexes have frequently prevented the development and use of effective control measures [86]. The present *Manual* is expected to function as a reliable source of information for developing invasion management, policy and practice [87]. Such manuals or field guides are available for some regions of the world, particularly in the developed world [88, 89]. However, to the best of our knowledge, there is no such field manual available for the Himalaya in particular and very few for the developing world in general.

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