Review on Invasive Alien plant species (IAPS) of Bhutan and its Geographical Distribution Within Country.

Abstract

Invasive Alien Plant Species (IAPS) is non-native, naturalized plants with high potential to spread over large area at considerable time and distances. Considering its driving factor and adverse effect on biodiversity loss and species extinction globally, the current study was aimed to document the IAPS of the Bhutan and its geographical distribution in the country. The total of 136 plant species were enumerated, including 22 major IAPS and 25 IAPS through desktop literature review. There are 9 IAPS in the country from the list of worlds 100 worst IAS. Fabaceae (24) constitutes maximum IAPS followed by Poaceae (20) and Asteraceae (19) respectively. IAPS in Bhutan are mostly herbs (73), followed by grass (23) and tree (15). IAPS were commonly found on disturbed sites, roadsides, fallows, cultivated areas and margins of wetland and forest. Still then, there is need of further IAPS documentations, determination of invasive status and its impact assessment in the country along with its geographical distribution within country.

Key words: *Invasive Alien Plant Species (IAPS), biodiversity loss, geographical distribution, invasive status.*

INTRODUCTION

The Kingdom of Bhutan is a small south Asian country, situated between longitude 88° 54' and 92° 10' East and latitude 26° 40' and 28° 15' North. It is a landlocked country, bordered by Tibetan autonomous region of China in the North and North-West subsequently and India in South, East and South-West (Wangda, 2017). The total geographic area of the country is 38,394 square kilometers with about 300 km long and 170 km wide. Virtually, geographical area of Bhutan is mountainous with little flat plain limited to southern parts of the country (NSB, 2020; The World Bank, 2019).

The elevation of Bhutan ranges from 100 meter above sea level (m.a.s.l.) in south to as high as 7700 m.a.s.l in north, stretching country from sub-tropical to arctic like alpine conditions. The country is geomorphologically divided into three lateral zones from South to North; i) Subtropical zone or The Himalayan foothill (100m-1200m), which is enclosed with dense deciduous forest, alluvial lowland river valleys, and mountains that descend into the subtropical plains of India. ii) Temperate zone or the inner Himalaya (1200m-4000m) and is southward spurs of the Great Himalayan Range. Here, lies the Black Mountain range between 1,500 meters and 2,700 meters above sea level. The woodlands of the central region provide most valuable forest production in the country. Eastern part of country is divided by, yet another southward spur and western Bhutan has fertile, cultivated valleys and terraced river basins. iii) Alpine zone or the greater Himalaya (above 4000m). It consists of an arc of glaciated mountain peaks with an arctic climate at the highest elevations and provides pasturage for livestock of high landers (Dorji, 2014;NSB, 2020).

Climate in Bhutan is generally dominated by monsoon with high precipitation during the summer and dry winters (Wangda, 2017). The wide range of altitudinal zones and micro-climatic conditions of the country have created a complex climatic pattern (BMCI, 2016). It has three distinct climatic zones, conforming largely to the three main geographical divisions; i) The southern belt with subtropical climate with hot, humid, temperatures remaining even throughout the year (15°C-30°C) and precipitation (2,500 and 5,000 mm). ii) The central inner Himalayas with cool, temperate climate, with annual average precipitation of about 1,000mm. iii.) The northern region with an alpine climate and annual precipitation of around 400mm (BMCI, 2016; NSB, 2019). Bhutan is positioned on the southern slope of the Eastern Himalaya (EH), one of the ten global biodiversity hot sport of the world. Spanning two major Indo-Malayan and Palaearctic biogeographic realms, Bhutan is the only country which shares all its land area as the Eastern Himalayan region. It occupies 7.60% of the total EH area and is comprised of 23 important bird areas, 8 ecoregions, important plant areas and wetlands, with three Ramsar sites – Trashiyangtse and Wangdue (Banerjee & Bandopadhyay, 2016).

Status report, (2021) maintained by National Biodiversity Centre of Bhutan mentioned that Bhutan is home to 11,248 species of flora and fauna. Floristically, country harbors around 5,603 species of vascular plants under 220 families and 1415 genera. It is comprised of 105 endemics, over 300 medicinal plant species and around 46 rhododendron species in the protected areas. Faunal diversity consist of 770 bird species and 200 mammals of which 18 bird species

and 27 species are globally threatened and also includes 125 fishes, 158 amphibians and reptiles (Dorji, 2014; Banerjee & Bandopadhyay, 2016; *Status Report* , 2021).

According to Article 5:3 of The Constitution of the Kingdom of Bhutan: 'The Government shall ensure that, in order to conserve the country's natural resources and to prevent degradation of the ecosystem, a minimum of sixty percent of Bhutan's total land shall be maintained under forest cover for all time.' The country has 71 percent of the total area under forest cover in accordance to the definition of forest cover given by National Forest Policy of Bhutan (NFP, 2011; FRMD, 2016). Forest in Bhutan is segregated in eleven different forest types and in general, broadleaf forests constitute about 65 % and conifers about 35 % of the forest area of the country (FRMD, 2016). The 51.44 percent of the total country's area is secured as protected areas and biological corridors (FRMD, 2016; *Status Report* , 2021). Bhutan has five national parks, four wildlife sanctuaries, one strict nature reserve, and seven biological corridors (MoAF, 2021).

Although, Bhutan is devoted to a high level of environmental protection and conservation activities, the rich biodiversity of the country is in the verge of decreasing in number. According to ICMOD (2016), as a least developed, mountainous and landlocked country, Bhutan's population and ecosystems are vulnerable to climate change. Over the past few years, urban areas have experienced environmental degradation and will likely further experience the impacts of global climate change (BMCI, 2016; The World Bank, 2019).

In Bhutan, loss of biodiversity is caused by several driving factors like climate change, fragmentation of natural habitats, changes in land use, urbanization, industrialization and developmental activities such as road and infrastructure construction, resource over exploitation, human wildlife conflict, hydropower development and forest fire (Tshewang et al., 2021). One of the important factor includes introduction of invasive alien species at accelerating rate of invasion along with the climate change in the country (Dorji, 2014; Thiney et al., 2019; Tshewang et al., 2021). The report on impacts of these species in the country are lacking, however most have been reported to reduce crop productivity, some encroaching the forest understory (Thinley et al., 2019), invasion in natural grasslands and pastureland (Wangchuk et al., 2013) and caused decline to economic status, environmental harm and harm to human health (Dorji, 2014).

To the current issue on the impact of alien invasive plant, the governmental and non-governmental organizations are working hard to assuage these factors and come to appropriate resolutions. Under the collaboration of NBC of Bhutan with other environmental agencies and researchers in the country are taking extensive studies in finding approximate number of invasive species, future prediction of their invasion and their impacts are under process. There are over 200 invasive species including both plants and animals in the country, belonging mostly to Asteraceae and Poaceae families (Dorji, 2014).

The knowledge on invasive plants in the country are still new and very few numbers of systematics, scientific studies and literatures are available in the country so far. These limits one's knowledge on invasive plants of Bhutan. Consequently, lack of detailed studies on

invasive plant species in the country will bring greater harm to the natural environment and its biodiversity, the economics of local communities and the country as a whole in future (Dorji, 2014). Therefore, this report attempts to compile all the invasive plants documented, recorded and studied in the country and to determine its current geographical distribution in the country. Furthermore, study aims to report the ecosystems invaded by IAPs and the status of invasive plants in Bhutan.

LITERATURE REVIEW

i. Definition of Invasive species: concepts and different terminologies

For many years the term ' Invasive species' has been used by ecologist, conservationist and others involved in biology and environment related fields (Wijesundara, 2021). The ability of invasiveness and distribution of those species in geographically new areas has drawn attention of different people including scientists, ecologist, conservationist, the general public and even policy makers (Kim et al., 2021; Szumańska et al., 2021; Wijesundara, 2021). Within past few decades, the studies on Invasive species have gained great momentum and started to document the spatial distribution of those species and assess its impact on biodiversity and ecosystems functioning (Reynolds & Aldridge, 2021; U.S. Department of Interior, 2021). Studies recognized Invasive species as one of the primary cause for global biodiversity loss (Rai, 2021) and species extinction (Dueñas et al., 2021).

Many definitions of Invasive species have been proposed by various workers during the last few decades (Wijesundara, 2021) and different terminologies like Invasive species, Invasive Alien Species (IAS) and Invasive non- native species (INNS) are commonly used (Reynolds & Aldridge, 2021; Szumańska et al., 2021). Invasive species is defined as non-native species with conspicuously high colonization rates and have the potential to spread over long distances (Ricciardi, 2017). According to IUCN, (2021), species is considered invasive, if alien species becomes problematic in the area.

To current study, the term invasive alien species (IAS) is used and adopt the definition according to Szumańska et al., (2021), in line with that proposed by the National Invasive Species Council (NISC) and the Invasive Species Advisory Committee (ISAC), the United States (2006). IAS is defined as non-native species, introduced accidentally or deliberately and has established itself in ecosystems or habitats that are either natural, semi-natural, or man-made. Its introduction in particular ecosystem causes or is likely to cause environmental or economic harm through harmful impacts on human, animal, or plant health (Szumańska et al., 2021; U.S. Department of Interior, 2021).

In plant ecology, the term "invasion" best describes the invasive plants where the distribution and abundance of plants changes as a result of human activities (Wijesundara, 2021). Several terminology in the literature on invasive plant species has been defined by Pysek et al., (2006) including native plants, aliens, aliens casual plants, naturalized plants, invasive plants, weeds and transformers. Accordingly, invasive plants is defined as a subset of naturalized plants, which has

potential to spread over large area with the production of very large numbers of reproductive offspring at considerable distances from the parent plants (Pysek et al., 2006). Therefore, the term Invasive Alien Plant Species (IAPS) and definition provided by Pysek et al., (2006) will be used throughout the paper.

ii. Historical progression of studies in Invasive Alien Plant Species (IAPS)

The phenomenon of non-native species was observed as far back as the 18th century by many naturalists including A. P. De Candolle and Charles Darwin (Richardson & Pyšek, 2007). Nevertheless, its deleterious effect on habitats and ecosystems of biological invasion became aware to scientist only after 1950s (Pysek et al., 2006; Richardson & Pyšek, 2007). Charles Elton the 'father' of invasion biology, defined biological invasions as 'ecological explosions' which means 'the enormous increase in number of some organism' in newly invaded ranges (Richardson & Pyšek, 2007; Gentili et al., 2021). Hereafter, different studies related to biological invasions became a branch of systematic ecological science (Gentili et al., 2021; Pysek et al., 2006).

The new recordings of invasive alien species (IAS) continually increased worldwide during the last 200 years (Richardson & Pyšek, 2007; Gentili et al., 2021). Over the last 30 years, studies were confined in assessing IAS effects and numbers of studies confirmed the negative effect of IAS on native biodiversity, its ecosystem and the landscape. Today, biological invasion is regarded as one of the main drivers that cause biological loss and species extinctions of plants and animal taxa (Pysek et al., 2006; Rai, 2021; Reynolds & Aldridge, 2021).

With the advance in scientific knowledge and technology, different branch of sciences is integrated to study the biological invasion, which includes ecological modelling and future predictions of IAS (Szumańska et al., 2021). The different methods of effective management of invasive plants is regarded as one of top priority of ecology management and environment conservation (Ricciardi, 2017). Therefore, according to Gupta et al., (2021), recent progression in the GIS and Remote sensing technologies can assist in studying and management of those invasive species with the impact of climate change.

iii. Invasive Alien Plant Species across the globe

Globally, the frequency and magnitude of introduction of alien species across the globe are changing more rapidly at present than ever before (Moodley et al., 2020). Global Invasive Species Database listed 100 worst invasive species based on two criteria: their serious impact on biological diversity and/or human activities, and their illustration of important issues surrounding biological invasion. Invasive plant species accounts 36% of the total invasive species among 100 worst invasive species of the world with 9 aquatic plants and 32 terrestrial plants (Lowe et al., 2000; Luque et al., 2014).

Though the numbers of invasive species vary widely, researchers estimate the current invasive species across the globe. There are approximately, 50,000 non-native species in United States and approximately 4300 species have been considered invasive species (Corn et al., 2002). According to Demarco, (2015), American Association for the Advancement of Science listed alien (1201), or invasive (755) using the U.S. Department of Agriculture (USDA) PLANTS database out of 13,575 plants in the continental United States. Currently there are 36 invasive plants and 30 invasive animals under European list of IAS of Union concern, which is regularly updated (JRC, 2021). Similarly, over 1650 alien plant species have become established in New South Wales of Australia, with at least 300 of these weeds considered as invasive (Frances et al., 2018). In addition, there are 427 invasive species in Korea according to data from the Korea National Arboretum (2016) (Kim et al., 2021).

The first catalogue of invasive plant species of India was compiled by Reddy (2008) with the total of 173 invasive alien species belonging to 117 genera under 44 families. In following years, many studies carried out on alien invasive plants and reported 1599 alien plant species belonging to 842 genera and 161 families with their native ranges and invasion status from India (Khuroo et al. (2012) cited in (Gupta et al., 2021). Inderjit et al., (2018) compiled about 471 invasive plant species in India and Pathak et al., (2019) reported a total of 297 naturalized alien plant species belonging to 65 families in the Indian Himalayan Region (IHR).

Among several invasive species *Chromolaena odorata*, *Ageratina Adenophora* (Inderjit et al., 2018), *Lantana camara*, *Parthenium hysterophorus* and *Ageratum conyzoides*have been reported from most IHR which are among worst IAPS of world (Pathak et al., 2019). Furthermore, plants like *Rubus niveus*, *Sapiumsebiferm*, *Cassia tora*, *Argemone mexicana* and *Anthemis cotula* have also been reported as noxious plants from Indian Himalayan states(Ivanova et al., 2016;Gupta et al., 2021). The above-mentioned invasive plants are also considered by many studies as one of the concerned invasive alien plants among many across the globe (Bradshaw et al., 2021; Gupta et al., 2021).

iv. Status and distribution of Invasive Alien Plant species in Bhutan

Biological invasions are considered as a serious threat globally, but particularly to developing countries like Bhutan (Dorjee et al., 2020; Dorji, 2014). The swift biological invasions in those developing countries are due to rapid growth of horticulture and livestock industries coupled with insufficient or non-existent management of plant introduction. There is limited number of comprehensive and systematics studies being carried out in the Bhutan with regards to exotics plants and invasive alien plant species, however Bhutan is part of Eastern Himalayan biological hotspot and is highly vulnerable to invasive alien species (Dorjee, 2018). Thus, studies regrading to alien or exotics species and biological invasions are very essential.

With the rapid biological invasions and importance in environmental management strategies in the country, numerous studies are following up with time. The collaborative works of environment conservation organization in Bhutan like National Biodiversity Centre (NBC), National Plant Protection Centre (NPPC) with other agencies across the world and enthusiastic

researchers in the country are studying on invasive plants of Bhutan and have made some publications so far. However, most of information regarding alien invasive plant is limited to different sectors, agencies and limited persons (Dorjee, 2018). There is still need of more intensive studies on IAS in the country like assessment of its economic, environmental impacts and its future predictions on biological invasion (Chhetri & Tenzin, K, 2012; Dorjee, 2020, 2021).

Before 1950s, the "Flora of Bhutan" was mostly compiled by few botanists and horticulturist from British and later undertaken by different taxonomist from Royal Botanic Garden, Edinburgh, London (Grierson & Long, D, 1983). Flora of Bhutan consist of three volumes and nine parts. It is the key reference guide for the identification of plants found in Bhutan. First studies related to invasive plants and weeds was studied by (Parker, 1992). He documented 187 species of weeds that are commonly found in Bhutan and mentions around 14 weed species that was introduced in Bhutan (Dorjee, 2018; Parker, 1992).

Study conducted by Dorji, (2010) documented 247 exotic plant species that are commonly found in pastures, roadsides and human settlement areas. It accounts about 5.6% of the total recorded plant species in the country. The numbers of exotic species from different plant families documented in the study is as follows; Poaceae (43 species), followed by Asteraceae (32 species), Fabaceae (26 species), Solanaceae (13 species) and Euphorbiaceae (12 species). More than 300 species of exotics plants in Bhutan includes ornamental plants, fodder species, agricultural crops, fruits and vegetables available in the country (Dorjee, 2018).

Dukpa, (2012) documented 216 total plant species, with 34 alien plant species and 30 invasive alien plants during the study period. The study also found out that *Ageratinaadenophora*, *Mikania micrantha, Chromalaenaordorata, Ageratum conyzoides, Saccharum spontaneum, Crassocephalumcrepidoides, Laportea dioica*, *Paederiafoetida, Poa annua, Sidarhombifolia, Alternanthera sessilis,* and *Solanum torvum* were the most common species constituting more than 90 % of the exotic species in subtropical region. Similarly, study conducted by Tshering (2012) recorded 44 alien plant species out of which 36 species were invasive alien plants among 237 plants documented throughout study in temperate region of the country. Furthermore, study revealed that about 79% of IAPS were herbs and others were shrubs, climbers, grasses and ferns.

According to National Biodiversity Centre, Bhutan has numerous invasive plant species, and some are even among the world's worst IAPS. About 201 invasive species (NBC, 2014) and 200 invasive species were identified in the country, including both plants and animals (Dorji, 2014).Around 34 plant species were known to be naturalized in the country and with 14 species being invasive (NBC, 2009) and 30 invasive plant species in the county as of 2014 (NBC, 2014). IAPS mostly belongs to Asteraceae and Poaceae family (Dorji, 2014).

Global Invasive Species database recorded 46 Invasive Species from Bhutan out of which 11 are alien and NBC recorded more than 30 invasive plant species, out of which eight were categorized as major invasive plant species (NEC, 2015). *Ageratinaadenophora* (Spreng.) R. King & H. Rob., *Chromolaena odorata* (L.) R. King & H. Rob., *Eichhornia crassipes* (Mart.)

Solms, *Lantana camara* L., *Mikania micrantha*Kunth, *Opuntia monacantha* (Willd.) Haw., *Parthenium hysterophorus*L. and *Robinia pseudoacacia* L.) are considered as the major invasive alien plants in Bhutan (NBC, 2014; NEC, 2015;Thiney et al., 2019).

Environmental Impact Assessment (2017) listed eight noxious invasive plants including *Cardamine flexuosa, Commelinabenghalensis, Chromolaena odorata, Lantana camara, Melilotus alba, Caesalpinia decapetal, Senegalia catechu, Mikania micrantha, Imperata cylindrica* from the buffer zones of Amochhu Land Development and Township Project (EIA, 2017). The National Biodiversity Centre published a "A Pictorial Guide to Major Invasive Plant Species of Bhutan" to address concerns over invasive plant species in the country (BBS, 2018). The book contains sixteen major alien invasive plant species with its geographical distribution in country and some of the commonly practiced control measures of IAPS management in country.

Due to rapid expansion of those invasive alien plants in the country with the globalization and climate change, ecological niche modeling has become essential to predict its invasion and distribution. Thus, study conducted by Thiney et al.,(2019), showed that IAPS like *Ageratina Adenophora* (Sprengel) King & Robinson, *Ageratum conyzoides*(L.) L.*Chromolaena odorata* (L) King & Robinson., *Lantana camara, Mikania micrantha* in Bhutan will have the potential increase in the areas of invasion, whilst *Parthenium hysterophorus* will experience a northerly shift and decline in distribution (Thiney, Banterng, Gonkhamdee, et al., 2019).

According to study on alien plant flora including cultivated taxa in Bhutan comprises the total of 964 plant species belonging to 545 genera and 139 families. Of these, 626 species only occur in cultivation, whereas other 388 species were found spontaneously in the wild; 131 (39%) casuals, 103 (31%) naturalized and 101 (30%) invasive (Dorjee et al., 2020).

v. Route of Invasive plant introduction in the country

The process of species invasion in the area comprises a sequence of events which involves transport, introduction, establishment, and spread of organisms into a new region (Ricciardi, 2017). Many studies suggest that human is one of the important vectors and key contributing factor for spreading IAPS across the globe. People introduce alien plants purposely with intention or unintentionally (Bacaro et al., 2015; Szumańska et al., 2021). According to Richardson & Pyšek, (2007), a combination of colonial rule, swift economic development and global trade exchanges across borders and continents are the key role in human-mediated distribution of IAS in new regions outside their natural range.

Many exotics species have been intentionally introduced for beneficial uses like food production, landscape restoration or for ornamental purposes in parks, along communication routes, and into home gardens (Bacaro et al., 2015; U.S. Department of Interior, 2021). Furthermore, promotion of tourism and increasing roads networks passing through forest have had led to alien plant invasion in forest and alpine ecosystems in Himalaya (Richardson & Pyšek, 2007).

In Bhutan too, rapid globalization, constant movement of people and goods with increase in trade and travel, intensive agriculture practices, constructions of roads in forest and infrastructure in natural habitats are the considered as main route of IAPS introduction in the country (Dorji, 2014; Dorjee et al., 2020). IAPS were concentrated in human settlement areas and decrease as altitude increases with less human settlements (Tshering, 2012: Chhetri & Tenzin, K, 2012). According to Dorjee et al., (2020),The majority of naturalized alien plants in the country were introduced as pasture species (32%), ornamental (24%) and from intentional sources (22%). Whereas major of invasive species were introduced unintentionally (76%), as ornamental (15%) and pasture species (3%). Literatures also suggest that climate change is viewed as a cause in accelerating the rate of invasion by IAS in addition to the globalization of anthropogenic activities (Gentili et al., 2021;Peter et al., 2021; Szumańska et al., 2021). Similarly, it is also regarded as a cause in accelerating the rate and establishment of IAPS in the mountainous countries of Himalaya like Bhutan (Thiney, Banterng, Gonkhamdee, et al., 2019).

vi. Impacts of Invasive Alien Plant Species

Biological invasions are considered as one of the main drivers causing biodiversity loss and species extinctions in the major plant and animal taxa across the world (Richardson & Pyšek, 2007). Over the last 100 years, rigorous invasion of IAS has decreased the average abundance of native plants, animals and insects by at least one-fifth across many ecosystems (Moodley et al., 2020). For an instance, within Australia there are about 1533 threatened plant and animal species that was affected by invasive species (*Australia ' s 10 Worst Invasive Species*, 2019). In Europe, IAPS are considered as the second greatest threat to protected area (Bradshaw et al., 2021). The plant invasion is one of the progressively important environmental challenges across the globe with significant impact on native biodiversity (Kariyawasam et al., 2019). IAPS can alter ecosystem functioning and structure, affecting native biota and abiotic conditions (Reynolds & Aldridge, 2021). IAPS affects the soil, its microbial association, and thus affect the native plants, often leading to displacement of habitat and ecosystem. Therefore, IAPS affects both floral and faunal diversity of the affected area. It disturbs the normal functioning of the ecosystem and deprive its beneficial ecosystem services (Gentili et al., 2021;Peter et al., 2021; Szumańska et al., 2021).

Besides biodiversity loss, literatures on IAS mentioned that IAS have negative impacts on agriculture, forestry, ecosystem services and on human health, eventually causing serious economic losses (Kim et al., 2021). Economic losses due to IAS includes the costs related to the direct damage caused by the species as well as those to be credited to their prevention, control and management (Richardson & Pyšek, 2007). IAS poses a threat to both natural ecosystems and crops, human health, and some branches of industry, such as tourism. Therefore, considerable financial resources are often required for IAS control and management activities (Gentili et al., 2021;Peter et al., 2021; Szumańska et al., 2021). For instance, Australia itself spent or suffered losses tallying at least US$298.58 billion or AU$389.59 billion from invasive species since the 1960s (Bradshaw et al., 2021).

In Bhutan, too the invasive plant species are reported to be posing problems to agriculture, human and animals' health and invasion of forests land (BBS, 2018). According to NBC, (2018), IAPS have negative impacts on ecosystem as well as agriculture system in the country. IAPS compete with the crops and affects the crop yield and some species are also known to be hazardous to human health. Farmers in the country have reported that along with climate change, invasive plants have started to colonize highland pasture and prevents fodder grass regeneration (Thiney, Banterng, Gonkhamdee, et al., 2019). Similarly, according to Wangmo et al., (2018), the grassland conditions in the subtropical region of country has degraded over the years due to the invasion by IAPS. However, further extensive and systematic study regarding the impact of IAPS in the country is found to be essential to know the economic losses incurred by IAPS in the country.

Method

The study on "Invasive Alien plant species (IAPS) of Bhutan and its geographical distribution" was carried out by reviewing the literatures available on IAPS within the country. The data on IAPS of the country was listed from sources like published literatures, books, national reports produced by National Biodiversity Centre (NBC) of Bhutan, Weeds of Bhutan (Parker, 1992), Invasive Species in Ecological Habitats of National Parks in Bhutan (Dorji, 2014) and accessed online websites such as Global Register of Introduced and Invasive Species-Bhutan (GRIIS), Invasive Alien Species of Bhutan-INaturalist, Bhutan Biodiversity Portal (BBP), Invasive Plants of Bhutan (Google sites) and Invasive Species Compendium maintained by Centre for Agriculture and Bioscience International (CABI).

RESULTS:

a. Invasive Plants in Bhutan

Table 1: Invasive Alien plant species of Bhutan and its geographical distribution, threat and status in the country.

Sl. No.	Species	Common /Local name	Habitat	Distribution	Threats	Bio Status
1	*Acacia melanoxylon* R. Br.	Australian blackwood (Eng.)	Forest margins, roadsides, river and stream banks, grassland	JDNP, JSWNP, RMNP, TNP, WCP, BWS, JWS, PWS, SWS, JKSNR	Agriculture, forest	Alien Invasive
2	*Acacia farnesiana* L. (Willd).	Huisache (Eng.)	Pastures, grasslands, wastelands	Punakha	Degrade pastureland, hazard to livestock	Less common
3	*Acanthospermu mhispidum* DC.	Bristly starbur (Eng.)	Arable land, pastures, roadsides, wastelands	Mongar, Punakha, Trashigang, Wangdue (upto 500m).	Hazard to livestock	Alien Invasive
4	*Achyranthes aspera* L.	Devils horsewhip (Eng.)	Cultivated land, grassland, forest, forest trial, roadsides, wastelands	Punakha	Crops, landscape	Common Weed
5	*Acmellauliginosa (SW). Cass*	March para cress (Eng.); Heydonam (Dzo.)	Disturbed area, roadsides, cultivated fields, marshes, streams, pasture, meadows, forest	Chhukha, Mongar, Punakha, Samchi, SamdrupJongkhar, Trashigang, Thimphu, Trongsa (upto 2500m).	Agriculture crops, native plants	Alien Invasive
6	*Ageretinaadenophora* (Sprengel) King & Robinson	Croftonweed (Eng.)	Forest margins, Grasslands, agriculture lands, roadsides, wastelands	Chukha, Sarpang, Trongsa, Punakha, Mongar, Lhuntse, Trashigang, Trashi Yangtse, Samdrupjongkhar, Gasa, Pema Gathsel, Tsirang, Wangdue, Dagana, Paro.	Degrade pastureland, hazardous to animal and human health	AlienInvasive
7	*Ageratum conyzoides* (L.) L.	Billy goat weed (Eng.); Elamey (Nep.); Rogpu-ngon (Sha.)	Grassland, pasture, roadsides, wasteland, forest, riparian, wetland	All districts (mainly at lower altitudes up to 2000 m).	Reduce crop yield	Common dryland weed
8	*Albizia julibrissin*Durrazz.	Silk tree (Eng.)	Roadside slopes, disturbed area, stream banks	JDNP, JSWNP, RMNP, TNP, BWS, JWS, PWS, JKSNR	Native plant	Native Invasive
9	*Albizia lebbeck*(L.) Benth.	Indian seris (Eng.)	Disturbed area, natural forest, riverbanks	Trashigang (300-900m).	Native plant	Less Common
10	*Albizia saman* (Jacq.) Merr	Rain tree (Eng.)	Deciduous forest margins, disturbed areas, roadsides,		Native plant	Less Common

			riverbanks			
1 1	*Alternanthera pungens*Kunth.	Khaki weeds (Eng)	Roadsides, footpaths, forest	Trashi Yangtse, Trongsa	Native plants	Alien Invasive
1 2	*Alternanthera sessilis* (L.) R. Br. ex. DC.	Sessile joyweed (Eng.)	Roadsides, pathways, wastelands, irrigation canals, wetlands, fallows	JDNP, JSWNP, RMNP, TNP, WCP, BWS, JWS, PWS, SWS, JKSNR (mainly below 2000m in all districts).	Agriculture crops: rice weed	Native Invasive
1 3	*Amaranthus hybridus* L.	Smooth pigweeds (Eng.); Ludeyjhar (Nep.); Lasomo (Sha.)	Cultivated fields, wastelands, roadsides, riverbanks, disturbed habitats	Bumthang, Lhuntshi, Paro, Trashigang, Thimphu, Wangdi (mainly above 1200 m).	Agriculture crops	Common
1 4	*Amaranthus spinosus* L.	Spiny amaranth (Eng.); Naumoth (Dzo.); Ludeyjharkadey (Nep.)	Weeds in agriculture field, orchards, pasture, secondary forest	Chukha, Lhuntshi, Mongar, Punakha, Trashigang (Mainly below 1500 m).	Unpalatable, Agriculture; Widespread dryland weed	Alien Invasive
1 5	*Anagallis arvensis*L.	Scarlet pimpernel (Eng.)	Disturbed area, Agriculture field	Punakha, Trashigang (between 1000 -2000m).	Agriculture crops	Less Common dryland weed
1 6	*Arceuthobium minutissimum*Hook. f.	Himalayan dwarf mistletoe (Eng.), Lamteka (Dzo).	Host plants: *Pinus* sp., (forest), orchard fruit tree	Temperate Blue pine forest (2000-3000m)	Forest, orchard tree parts	Common in coniferous pine forest
1 7	*Arundo donax*L.	Giant reed (Eng.)	Riparian habitats of stream, ditches, river	Chhukha, Punakha, Wangdue, Trashigang (1220-2000m).	Riparian plant ecosystem	(World's worst AIPS).
1 8	*Argemone mexicana* L.	Mexican poppy (Eng.); Satya nasi (Nep.)	Arable land, pastures, roadsides, wastelands, fence rows, construction sites	Trashigang, Mongar (below 1000m).	Agriculture crops	Alien Invasive
1 9	*Avena fatua*L.	Wild oats (Eng.); Jangali jar (Nep.)	Cereal field, wastelands, pastureland	Bumthang, Chhukha, Haa, Mongar, Punakha, Trashigang, Thimphu, Wangdue (over 1000m)	Cereal crops	Common
2 0	*Axonopuscompressus*(SW) P. Beauve.	Carpetgrass (Eng.)	Roadsides, gardens, waste areas, plantations	Trongsa	Agriculture crops, forest plantations	Alien Invasive
2 1	*Bacopa monnieri* (L.) Wettst	Water hyssop (Eng.)	Wetlands, streams, ditches, riverbank	Southern parts of country; Chukhha (below 1000m).	Deleterious to native plants and animals, deteriorates water quality	Native Invasive Less common
2 2	*Bidens Pilosa* L.	Blackjack (Eng.); Khaedu (Dzo); kuro (Nep.),	Roadsides, disturbed area, fallow lands, forest margins.	All districts (up to 2400 m).	Agriculture crops	Alien Invasive
2 3	*Borreria latifolia* (Aubl.) K. Schum.	Broadleaf buttonweed (Eng.)	Roadsides, agriculture field, riverbanks		Weeds of agriculture field	

24	*Brachypodiumsylvaticum* (Huds.) P. Beauv.	Slender false brome (Eng.)	Forest, meadows	Wangdue Phodrang	Forest (coniferous)	
25	*Bryophyllumpinnatum* (Lam.) Oken	Cathedral bells (Eng.)	Disturbed sites, roadsides, slope dry forest		Island ecosystem	
26	*Caesalpinia decapetala* (Roth) Alston	Mysore thorn (Eng.)	Open area, grassland, forest edges	JDNP, JSWNP, RMNP, TNP, BWS, JWS, PWS, SWS, JKSNR	Native plants	Native Invasive
27	*Casia tora*	Sickle Senna	Roadsides			Alien Invasive
28	*Calotropis procera* (Aiton) Dryand.	Apple of sodom (Eng.)	Arid, semiarid area fallows, roadsides, grasslands		Pasturelands native plants	
29	*Cardamine flexuosa*With.	Wavy bittercress (Eng.)	Cultivated areas, wastelands, forest field (common weed)	JDNP, JSWNP, RMNP, WCP, BWS, PWS, SWS, JKSNR	Agriculture, forest	Alien Invasive
30	*Chenopodium album* L.	Fat hen (Eng.); Hethu (Dzo.); Bathu, Bethe (Nep.); Bethu (Sha.)	Cutivated areas, wastelands, pasturelands, roadsides, riverbanks	All districts (mainly above 1000 m).	Agriculture winter crops	Common weed
31	*Chromolaena odorata* (L) King & Robinson	Siam weed (Eng.); Achame (Nep.); nayra-ngon (Sha.)	Roadsides, wastelands, fallow lands, grasslands	Chukha, Samtse, Sarpang, Punakha, Tsirang, SamdrupJongkhar, Pema Gatshel, Trashigang, Trashi Yangtse, Mongar, Lhuntse, Trongsa, Dagana, Wangdue, Zhemgang (200-1450 and upto 1511m).	Plant displacement, Reduces regeneration of trees.	Alien Invasive (World's worst IAS)
32	*Commelinabenghalensis*L.	Spreading dayflower (Eng.); Kaney jhar (Nep.); Humbatenang (Sha.)	Roadsides, wastelands, grasslands, rice fields	JDNP, JSWNP, RMNP, TNP, PWS. Lhuntse, Mongar, Punakha, Trashigang, Thimphu, Trongsa (up to 2300 m).	Agriculture crops; Common weed of lowland areas	Native Invasive
33	*Convolvulus arvensis* L.	Bindweed (Eng.)	Open area, cultivated area, pastures, roadsides		Agriculture and horticulture crops	
34	*Conyza bonariensis* L. (Cronquist)	Hairy fleabane (Eng.)	Wastelands, fallows, roadsides	Mongar, Thimphu (wide range of altitudes and probably in most districts).	Weeds in protected area	Invasive
35	*Conyza canadensis* L. (Cronquist)	Canadian fleabane (Eng.)	Wastelands, fallows, roadsides	Chhukha, Paro, Trashigang, Thimphu, Wangdue (restricted to higher altitude, mainly above 2000 m).	Weeds in protected area	Invasive
36	*Conyza sumatrensis* (S.F.Blake) Pruski & G.	Sumatran fleabane (Eng.)	Orchards, plantations		Native Plants	

	Sancho					
37	*Cosmos bipinnatus*Cav.	Garden cosmos (Eng.);	Roadsides, fallows	Bumthang, Paro, Trashigang, Trashiyangtse, Thimphu. (Mainly above 2000 m).		Alien Invasive
38	*Crassocephalumcrepidioides* (Benth.) S. Moore	Redflower ragleaf (Eng.); Dhadungphuley (Nep.)	Roadsides, riverbeds, wet sites, open areas	Chhukha, Lhuntshi, Mongar, Punakha, Trashigang, Trashiyangtse, Tongsa (mainly at lower, wetter altitudes up to 2000 m).	Native plants	Common
39	*Cryptomeria japonica* (Thunb. Ex L.f.) D. Don	Japanese cedar (Eng.)	Roadsides, forest plantations	All districts	Forest, hazardous to animal health	Alien Invasive
40	*Cuscuta campestris*Yunck	Field dodder (Eng.)	Parasitic	Lhuntshi, SamdrupJongkhar, Trashigang, Thimphu.	Crops	Sporadic parasitic plant
41	*Cuscuta europaea* L.	European dodder (Eng.)	Parasitic		Crops	
42	*Cuscutareflexa* Roxb.	Dodder (Eng.); Roba-je (Dzo.); Swarnlata, Amar lata (Nep.)	Parasitic	All districts (widespread at higher altitudes, over 600 m).	Crops	Common weed
43	*Cynodondactylon* L. Pears	Bermunda grass (Eng.); Rampa (Dzo.); Dubo (Nep.); Saram (Sha.)	Pasture, fallows, waste areas	All districts (below 2500 m).	Crops	Serious weed.
44	*Cyperus compressus* L.	Annual sedge	Wasteland, rice field	Trashigang district	Crops (rice)	Less common
45	*Cyperus iria* L.	Rice flatsedge (Eng.); Guchen, Ochumani, Chow (Dzo.); Mothey (Nep.)	Riverbanks, ditches, rice field	All districts (from 500 up to 2500 m).	Crops (rice)	Common weed
46	*Cyperus rotundus* L.	Purple nutsedge (Eng); Guchen (Dzo.); Mothey (Nep.)	Cultivated areas, wasteland, roadsides, pastures, riverbanks, sandbanks, irrigation channel, natural area.	All districts (from 500 to 2300 m).	Crops (vegetables, ornamentals)	Common weed
47	*Dalbergia sissoo* DC.	Shisham (Eng.)	Riverbanks	RMNP, PWS, TSNR (Phuntsholing, Sarpang, Gelephug, 300m)		Native Invasive
48	*Datura stramonium* L.	Jimson weed (Eng.); Dhaturo (Nep.); Nyangmo-throkchang (Sha.)	Roadsides, disturbed lands, wastelands, pasturelands, woodland gap	Trashigang, Trashiyangtse, Paro, Thimphu, Wangdue (mainly above 1000m).	Agriculture crops, plants	Invasive
49	*Delonix regia* (Hook.) Raf.	Flam boyant (Eng.)	Roadsides, disturbed areas, ornamental garden	Mongar, Trashigang, Trashiyangtse	Prevents regeneration of	

					native plants	
50	*Digitariaciliaries* (Retz.) Koeler	Southern crabgrass (Eng.); Tampula (Dzo.); Chittreybanso (Nep.)	Disturbed open area, roadsides, wasteland	All districts (mainly above 1000m).	Agriculture crops (cereals)	Common
51	*Digitarialongiflora* (Retz.) Pers	False couch grass (Eng.)	Disturbed open area, roadsides, wasteland	Trashigang	Agriculture crops	
52	*Dioscorea bulbifera*L.	Air potato (Eng.)	Cultivated, forest	Subtropical forest of country	Forest (displace native plants)	Native Invasive
53	*Drymaria cordata* (L.) Wild. ex Schult.	Tropical chickweed (Eng.); Ovizalo (Nep.)	Damp roadsides, gardens	Bumthang, Chhukha, Mongar, Punakha, Sarbang, Trashigang (2600 m).	Agriculture crops	Invasive
54	*Echinochloacolona* (L.) Link	Jungle rice (Eng.); Jam, Jama (Dzo.); Sama, Molera (Nep.)	Gardens, pasture, roadsides, disturbed area, water ways	All districts (upto 2000m).	Agriculture crops (paddy)	Common weed
55	*Echinochloa crus-gallii*(L.) P. Beauv.	Banyard grass (Eng.); Jam, Jama (Dzo.); Sama, molera (Nep.)	Field (paddy), wetlands, grassland, disturbed area	All districts	Crops, high nitrate content can poison livestock	Common weed
56	*Ecliptaprostrata* (L.) L.	Eclipta (Eng.)	Damp places, near swamps and rivers, ditches	Chukha, Punakha, Samtse, SamdrupJongkhar, Trashigang, Trongsa, Wangdue (upto 1800m).	Crops (rice)	Common weed
57	*Eichhornia crassipes* (Martius) Solms	Water hyacinth (Eng.)	Freshwater ponds, rivers	Chukha, Sarpang, Gelephu, Wangdi Phodrang	Water ecosystem	Alien invasive in country. (World's worst AIPS)
58	*Elaeagnus umbellata*Thunb.	Autumn olive (Eng.)	Hillside wastelands, roadsides, forest edges, river sides		Animal, native plants	
59	*Eleusine indica* (L.) Gaertn.	Goose grass (Eng.); Cholep (Dzo.); Dadey, Kode jhar (Nep.)	Forest margins, grassland, marshes, stream banks, fallows	All districts	Native plants	Common weed
60	*Erigeron karvinskianus*DC.	Karwinsky'sfleaban (Eng.)	Open areas, hillsides, cliffs, open forest	Trongsa (Mangdichu).	Native plants	High risk weed
61	*Euphorbia heterophylla* L.	Wild poinsettia (Eng.)	Waste place, cultivated area	Mongar, Trashigang, Wangdue (between 700 and 1700m).	Agriculture crops	Invasive
62	*Euphorbia hirta*L.	Garden spuge (Eng.)	Cultivated area, roadsides, fallows, wasteland s, ditch banks	Probably in all districts (1500 m).	Agriculture crops	
63	*Ficus microcarpa*L.f.	Indian Laurel tree (Eng.)	Roadsides, forest	RMNP, PWS, TSNR	Invades pine rock-lands and	

					hardwood forest	
64	*Galinsoga parviflora* Cav.	Gallant soldier (Eng.); Jagyouma, Jagasuju (Dzo.); Udasoy (Nep.); Yurungpa (Sha.)	Gardens, roadsides, disturbed area, water ways	All districts	Agriculture crops	Invasive
65	*Gliricidia sepium* (Jacq.) Steud.	Gliricidia (Eng.)	Disturbed area, roadsides, fallows, near cultivation area	Manas National Park	Invade road sites	
66	*Hedychium gardnerianum* Sheppard ex Ker Gawl.	Kahili Ginger (Eng.)	Undisturbed areas, forest, forest margin, roadsides	Broad leave oak forest (910-2130 m).	Native plants	World's worst AIPS.
67	*Houttuynia cordata* Thunb.	Chameleon plant (Eng.); Dachu (Dzo).	Fallow, forest margins, roadsides	JDNP, JSWNP, RMNP, TNP, WCP, BWS, JWS, PWS, SWS, JKSNR	Native plants	Common weed
68	*Hygrophilapolysperma*(Roxb.) T. Anderson	Indian swamp weed (Eng)	Lakes, ditches, wetlands, swamps, water canals	JDNP, JSWNP, TNP, WCP, BWS, SWS	Native plants, water ecosystem	
69	*Hyptis suaveolens* (L.) Poiteau	Pignut (Eng.)	Streamside, fallow lands, open and rocky forest	Samtse, Chukha, Sarpang, SamdrupJongkhar	Native plants	Major invasive
70	*Imperata cylindrica* (L.) Raeusch.	Cogon grass (Eng.); Becho (Dzo.); Khar, Sirru (Nep.)	Roadsides, fallow lands, grasslands, deforested areas, river margin	JDNP, JSWNP, RMNP, TNP, WCP, BWS, JWS, PWS, SWS, JKSNR	Crops, native plants	Major invasive in country. (World's worst AIPS)
71	*Ipomoea hederifolia* L.	Scarlet creeper (Eng.)	Roadsides, scrub, open forest	Chukha, Mongar, SamdrupJongkhar (200-600m and upto 964m)	Crops, native plants	Major invasive
72	*Ipomoea purpurea* (L.) Roth	Tall morning glory (Eng.)	Roadsides, fallows, disturbed areas, fence lines	Thimphu, Paro, Trashigang	Agriculture crops	Invasive
73	*Jatropha curcas*L.	Jatropha (Eng.); Zhoshing (Dzo)	Disturbed sites, roadsides, open woodlands, pasture, abandoned garden	Trashi Yangtse, Trashigang, Wangdue, Punakha	Native plants	
74	*Lantana camara* L.	Lantana (Eng.)	Roadsides, wastelands, open forest	Chukha, Sarpang, SamdrupJongkhar, Samtse, Wangdue	Native plants, crops, poisonous to livestock	Major invasive (World's worst AIPS).
75	*Lemna perpusilla*Torr.	Duckweed (Eng.)	Paddy fields, lakes, irrigation and drainage canals	Thimphu, Paro, Punakha, Trashigang (1000-2400m).	Crops (rice), water ecosystem	
76	*Lespedeza cuneata* (Dum.	Sericeae lespedeza (Eng.)	Rangelands, grasslands, roadsides, disturbed sites	JDNP, JSWNP, RMNP, TNP, WCP, BWS, JWS, PWS, SWS, JKSNR	Pasturelands native plants	Invasive

	Course) G. Don.					
77	*Leucaena diversifolia* (Schltdl.) Benth	White leadtree	Wastelands, roadsides, disturbed sites		Native plants	
78	*Leucaena leucocephala* (Lamarck) de Wit.	Leaucana (Eng.); Tsashing (Dzo.)	Roadsides, disturbed sites	Samtse, Chukha, Punakha, SamdrupJongkhar, Wandue, Trashigang (500-1500m).	Native plants	Major invasive (World's worst AIPS).
79	*Limnophila sessiliflora* (Vahl.) Blume	Asian marshweed (Eng.)	Paddy fields, irrigation and drainage canals	JDNP, JSWNP, RMNP, TNP, BWS, JWS, PWS, SWS, JKSNR	Crops (paddy), clogs water canals	Common plant
80	*Lepidium virginicum* L.	Virginian pepper cress (Eng.)	Roadsides, field	Paro, Trashigang, Thimphu	Agriculture crops	Invasive
81	*Lotus corniculatus*L.	Bird's-foot treefoil (Eng.)	Old fields, grassy places, roadsides	JDNP, JSWNP, RMNP, TNP, WCP, BWS, PWS	Native species	
82	*Ludwigiahyssopifolia* (G. Don) Exell	Water prim rose (Eng.)	Paddy field, wetlands		Crops (paddy), wetland native plants	
83	*Lygodium japonicum* (Thunb.) Sw.	Japanese climbing fern (Eng.)	Swampy disturbed area, marshes, floodplain forest, timber plantations	JDNP, JSWNP, RMNP, TNP, WCP, BWS, JWS, PWS, SWS, JKSNR	Plantation forests	Common
84	*Marsilea minuta*L.	Pepper wort (Eng.)	Ponds, pools, ditches, swamps, low land paddy field	Punakha, lower altitudes of southern districts (below 1500 m).	Crops (paddy)	Common weed
85	*Melilotus alba* Medik.	Honey clover (Eng.)	Meadows, disturbed sites, riparian areas	JDNP, JSWNP, RMNP, TNP, WCP, BWS, JWS, PWS, SWS, JKSNR	Agriculture, native plants	
86	*Melia azedarach* L.	Chinaberry (Eng.)	Roadsides, forest margins, forest, marshes	Trashi Yangtse, Trashigang, Wangdue, Punakha, Paro, Thimphu (probably in all districts)	Native plants	Common
87	*Melinisminutiflora*P. Beauv.	Molasess grass (Eng.)	Roadsides, forest margins, woodlands, disturbed sites, pasture	Trongsa	Agriculture, pasture,	
88	*Mikania micrantha*Kunth	Bitter vine (Eng.); Titaylaharo (Nep.)	Roadsides, wastelands	Chukha, Samtse, Sarpang, Punakha, Tsirang, SamdrupJongkhar, Pema Gatshel, Trashigang, Mongar, Lhuntse, Trongsa, Dagana, Wangdue Phodrang, Zhemgang	Agriculture crops, forest, plantations	Major invasive in country. (World's worst AIPS)
89	*Mimosa pudica* L	Sensitive plant (Eng.)	Roadsides, agriculture lands, construction sites	Samtse, Chukha, SamdrupJongkhar, Mongar, Sarpang (below 1000 m).	Agriculture crops, native plants	Major invasive
90	*Monochoria vaginalis*	Pickerel weed (Eng.); Damperu, Olasam	Wetlands, streams, ditches, swampy areas, rice field	All districts	Crops (rice)	

	(Burm.f.) C. Presl	(Dzo)				
91	*Murdannianudiflora* (L.) Brenan	Doveweed (Eng.)	Wetlands, streams, ditches, swampy areas, rice field, wet pastureland	Trongsa, SamdrupJongkhar	Agriculture crops (rice), water ecosystem	
92	*Myriophyllum spicatum* L.	Spike watermilfoil (Eng.)	Waterbodies; marshes, wetlands, ditches		Water ecosystem	
93	*Neyraudiareynaudiana* (Kunth) Keng ex Hitchc.	Burma reed (Eng.)	Warm subtropical; moist soil, stream and river sides, roadsides, disturbed area.	Warm subtropical region of the country; JDNP, JSWNP, RMNP, TNP, WCP, BWS, JWS, PWS, SWS, JKSNR.	Forest, agriculture crops	Invasive
94	*Nicandra physalodes*(L.) Gaerten	Apple of Peru (Eng.)	Wastelands, roadsides	Chhukha, Lhuntshi, Punakha, Trashigang, Thimphu, Wangdue (above 1000m)	Native plants	Invasive
95	*Opuntia vulgaris* Miller	Pickly pear (Eng.); Gewringa (Dzo),	Hillsides in dry valleys, roadsides.	Chukha, Punakha, Trongsa, Wangdue, Trashigang (250-1500m).	Native plants, animal	Major invasive
96	*Oxalis latifolia* Kunth	Sorrel (Eng.)	Orchards, plantations, gardens.	Paro, Trashigang, Thimphu, Wangdue, Trashigang (900 to 2700 m).	Plants	Invasive
97	*Paederiafoetida* L.	Skunkvine	Sunny disturbed area, deciduous forest, woodlands, roadsides.	JDNP, JSWNP, RMNP, TNP, WCP, BWS, JWS, PWS, SWS, JKSNR	Agriculture, forest	Invasive
98	*Parthenium hysterophorus* L.	Parthenium weed (Eng.), Dushing (Dzo)	Roadsides, fallow lands	Punakha, Mongar, Wangdue, Trashigang, Trongsa, Chukha, Tsirang, Dagana, Lhuntse, Sarpang, Pemagathsel, Trashi Yangtse, Zhemgang, Thimphu.	Agriculture crops, animal and human health.	Major invasive
99	*Paspalum conjugatum* P.G. Berguis	Buffalo grass (Eng.)	Disturbed area, roadsides, forest margin, pastures and grassland	Below 1000 m in all low-altitude districts of southern Bhutan.	Pasture, grassland, agriculture, forest	Invasive
100	*Paspalum distichum* L.	Knotgrass (Eng.); Jagarampa (Dzo.); chittrey (Nep.)	Wetlands, wastelands, grasslands, rice field	Lower altitudes and up to 2500 m in all districts.	Crops (rice)	Invasive
101	*Paspalum scrobiculatum* L.	Rice grass paspalum (Eng.)	Wastelands, field	Southern parts of country	Native pant s	Common wetland weed
102	*Pennisetum clandestinum*Hochst. Ex Chiov.	Kikuyu grass (Eng.)	Roadsides, agriculture lands, orchards, wastelands	Bumtang, Gasa, Chukha, Mongar, Punakha, Samtse, SamdrupJongkhar, Sarpang, Thimphu, Trashigang, Trashiyangtse, Trongsa, Lhuntse, Zhemgang (mostly over 1000 m).	Agriculture, forest, pasturelands	Major invasive
103	*Pennisetum pedicellatum* Trin.	Deenanath grass (Eng.)	Cultivated fields, fallows, grassland	Trongsa	Agriculture crops	Rarely abundant
104	*Phalaris minor* Retz.	Littleseedcanarygrass (Eng.)	Irrigated conditions	Punakha, Wangdue, Trashigang (1200-2300m).	Agriculture crops	Localized weed

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105	*Phyllanthus urinaria* L.	Leafflower (Eng.)	Cultivated fields, roadsides, wastelands	Punakha, Trongsa	Agriculture crops	
106	*Pithecellobium dulce* (Roxb.) Benth.	Manila tamarind (Eng.)	Forest, roadsides, urban area	Trashigang, Trashigang to Samdrupjongkhar highway	Pasture grass and native plants	
108	*Plantago lanceolata* L.	Ribwort plantain (Eng.)	Grasslands, wastelands	Haa, Bumthang (Ura)	Agriculture crops, pastures	
109	*Poa annua* L.	Annual meadow grass (Eng.)	Grasslands, pasture,	All districts (mainly above 2000 m).	Agriculture crops, native plants	Common winter weed
110	*Polygonum aviculare* L.	Prostrate knotweed (Eng.)	Irrigated conditions	Paro, Thimphu, Wangdue (above 1000m).	Irrigated crops, native plants	Common winter plant
111	*Persicariabarbata (L.)* H. Hara	Knot grass (Eng.)	Irrigated conditions; marshes, ditches, streams, paddy field		Crops (rice), native plants	Less common
112	*Persicaria hydropiper* (L.) Delarbre	Marsh pepper (Eng.); Piprejhar (Nep.)	Wherever moist soil and standing water; wetlands, roadsides	Phuntsholing, Chukkha, Haa, Punakha, Trashigang (200-2750).	Agriculture crops, native plants	Common wetland weed
113	*Persicarianepalensis* (Meisn) Miyaba	Nepal persicaria (Eng.); Shido (Dzo.); Berkheyratnaulo (Nep.); Gangchuma (Sha.)	Cultivated area, disturbed area	All districts (above 1000m).	Agriculture crops	Common and dominant
114	*Persicaria maculosa* (Raf.) Gray	Redshank (Eng.); Pirat (Dzo.)	Moist areas; wastelands, roadsides, disturbed sites, meadows, croplands	Mongar, Punakha, Trashigang, Thimphu (mainly between 1000 and 2000 m).	Agriculture crops, native plants	Common but rarely dominant
115	*Pueraria montana* var. *lobata* (Wild.) Sanjappa& Pradeep	Kudzu (Eng.)	Plantation forest, along river and roads, field margins, abandoned		Native plants	
116	*Pteridium aquilinum* (L.) Kuhn	Bracken (Eng.); Unew (Nep.)	Pastureland, deciduous and coniferous forest, hillsides	All districts (higher altitudes, above 1000 m).	Native plants	Serious weed of grassland
117	*Robinia pseudoacacia* L.	Black locust (Eng.)	Forest margins, disturb dry slopes	Thimphu, Paro, Chukha, Dagana, Punakha (1200-2500m).	Hazardous to animals, native plant displacement	Major invasive

118	*Rubus ellipticus*Sm.	Yellow himalayan raspberry (Eng.)	Slopes, sparse forest, thickets, roadsides and forest edges	Warm subtropical region of the country; JDNP, JSWNP, RMNP, TNP, WCP, BWS	Hazardous to animals, native plant displacement	Major invasive. (World's worst AIPS)
119	*Rubus niveus*Thunb.	Mysore raspberry (Eng.)	Agriculture land, forest, grasslands, riparian land	JDNP, JSWNP, RMNP, TNP, WCP, BWS, JWS, PWS, SWS, JKSNR	Hazardous to animals, native plants displacement	Major invasive
120	*Scoparia dulcis* L.	Sweet broom weed (Eng.)	Dryland field margins	Chhukha, Mongar, Samtse Sarbang, Thimphu, Trongsa. (Below 1500m).	Agriculture crops	Invasive
121	*Senna obtusifolia* (L.) H. S. Irwin & Barneby	Sicklepod (Eng.)	Agriculture land, wastelands, roadsides, woodlands, natural grasslands		Agriculture crops, native plant displacement	
122	*Senna occidentalisI*(L.) Link	Coffee senna (Eng.)	Roadsides, arable lands, degraded pasture, wasteland	Punakha	Agriculture crops, forest plantations	
123	*Senegalia catechu* (L. f.) P. J. H. Hunter & Mabb.	Black cutch (Eng.)	Mixed deciduous forest, hills, riverbanks, watersheds		Native plants	
124	*Sida acuta* Burm. fil.	Sida (Eng.); Balu jhar, Cannaino, Jaharu, Khareto (Nep.)	Pastures, rangelands, roadsides, fallow lands	Samtse, Chukha, Sarpang, Trashigang, Dagana, Trashi Yangtse, Punakha, Mongar, Lhuntse, SamdrupJongkhar (200-1200m).	Pasturelands, rangelands	Major invasive
125	*Solanum viarum*Dunal	Tropical soda apple (Eng.)	Drought affected pasture, forest, riverbanks, roadsides	Thimphu, Wangdue, Paro, Trashigang, Trashiyangtse, Lhuntse	Agriculture crops, forest, pastureland	Common plant
126	*Spergula arvensis* L.	Corn spurry (Eng.)	Disturbed area, roadsides, farmlands, forest	Bumthang, Haa, Punakha, Trashigang, Trashiyangtse, Thimphu, Wangdue (Mainly above 1000 m).	Agriculture crops, native plants	Semi-dominant
127	*Stellaria media* (L.) Vill.	Common chickweed (Eng.)	Cultivated fields, gardens, pasture, lawn, roadsides, wasteland	Chhukha, Mongar, Punakha, Samtse, Trashigang, Thimphu, Wangdue (Mainly at high altitudes but also down to 600 m).	Agriculture crops, native plants	Invasive
128	*Striga asiatica* (L.) Kuntze	Witch weed (Eng.)	Grasslands, cultivated field	Punakha, Wangdue.	Agriculture crops	Less common
129	*Syzygiumcumini* (L.) Skeels	Black plum (Eng.)	Moist riverine area, riverbanks		Native plants	
1	*Tagetes*	Stinging Roger (Eng.)	Pasturelands, roadsides,	Thimphu, Paro (1000-1500m)	Agriculture crops	Invasive

130	*minuta*L.		stream and river sides		Native plants	
131	*Thlaspi arvense* L.	Field penny cress (Eng.)	Cultivated field, wasteland	Bumthang, Chukkha, Mongar, Trashigang, Punakha, Thimphu (mainly above 1800m).	Agriculture crops	Common
132	*Tithonia diversifolia* (Hemsl.) A. Gray	Mexican sunflower (Eng.)	Roadsides, disturbed areas	Chukha, Samtse, Sarpang, SamdrupJongkhar (350-1500m).	Native plants	Major invasive
133	*Trifolium repens* L.	White clover (Eng.)	Roadsides, agriculture lands, pastureland	All districts (2000-2700m).	Native plants	Major invasive
134	*Urochloapanicoides* P. Beauv.	Liver seed grass (Eng.)	Pastureland, grasslands, cultivated fallows		Agriculture crops, poisonous to cattle	
135	*Verbascum thapsus* L.	Common mullein (Eng.)	Roadsides, forest clearing, meadows, pastures, open disturbed area		Native plants	
136	*Xanthium strumarium*L.	Common cocklebur (Eng.)	Roadsides, field edges, wastelands, cultivated area, fallows	Chhukha, Lhuntshi, Mongar, Trashigang, Thimphu, Trongsa, Wangdue.	Agriculture crops, native plants	Occasionally dominant

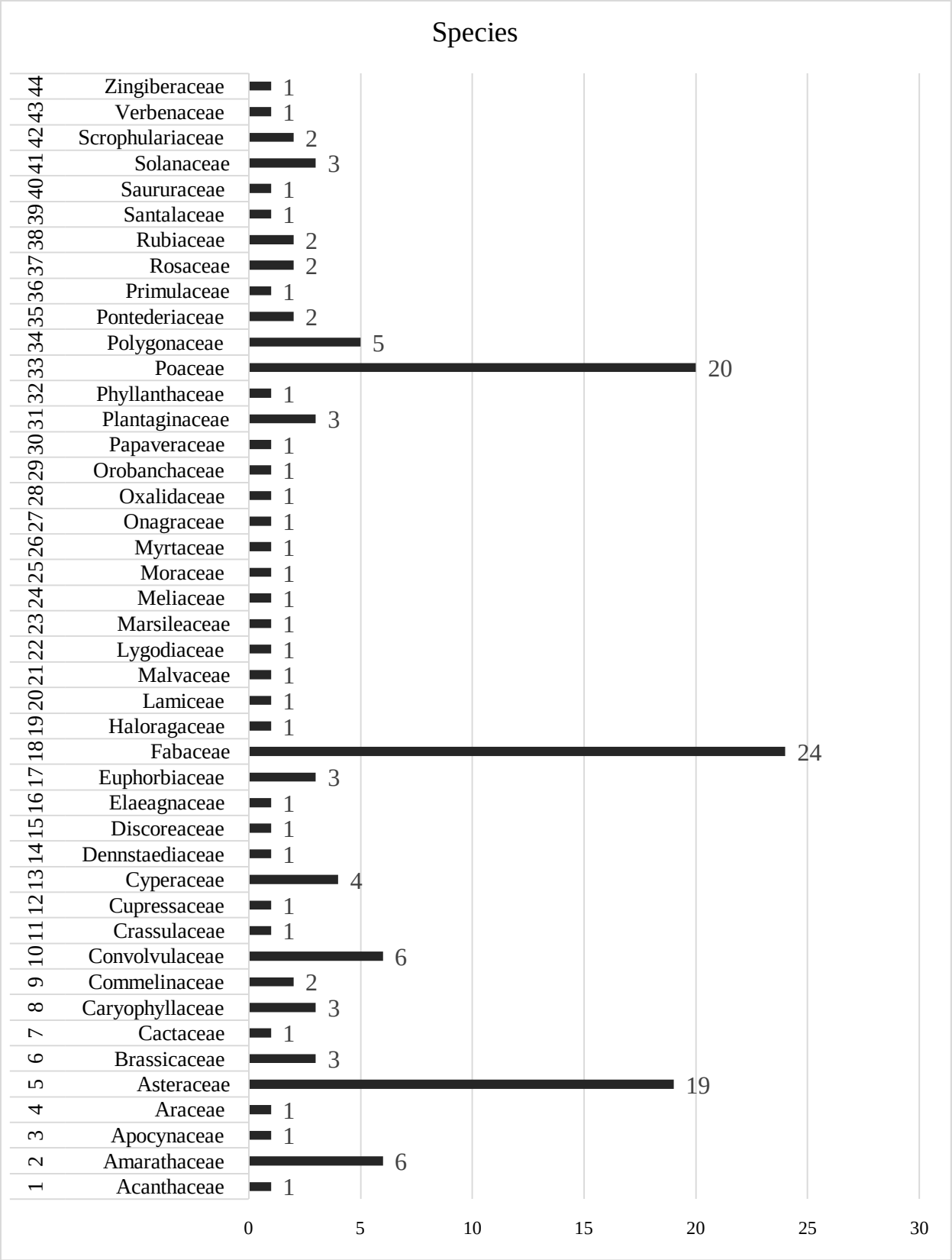

Figure 1: IAPS list from different plant families recorded in Bhutan.

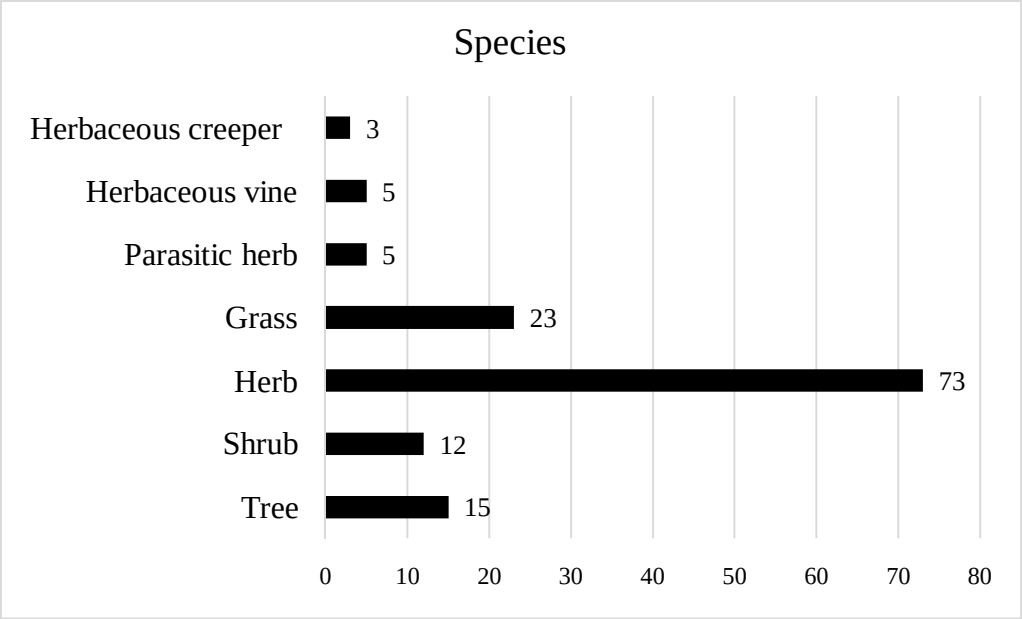

Figure 2: Different lifeforms of the IAPS recorded in Bhutan.

DISCUSSIONS

The current study on documentation of Alien invasive plant species of Bhutan listed a total of 136 IAPS in the country. It includes plants species that are considered as IAPS in literatures, National Biodiversity reports of NBC from 2009 to 2014. Besides, it also includes those commonly distributed alien plants which were considered as weeds in the country. The botanical name, common or local name, habitat, its geographical distribution, its threat and its invasive status are presented in the Table 1.

Out of 136 plants enumerated in the current list, 47 plant species were assigned with status of its invasiveness in the country as invasive plant species or major invasive plant species. There are 22 plant species which are considered as major invasive plant in the country posing serious environmental threats and found commonly distributed across the country with reference to NBC report, 2014. The total of 9 major AIPS including *Arundo donax*L., *Chromolaena odorata* (L) King & Robinson, *Leucaena leucocephala* (Lamarck) de Wit., *Eichhornia crassipes* (Martius) Solms., *Lantana camara* L., *Imperata cylindrica* (L.) Raeusch., *Mikania micrantha* Kunth. and, *Rubus ellipticus*Sm.,and *Hedychium gardnerianum* Sheppard ex Ker Gawl are among the world's worst invasive species found in the country (Lowe et al., 2000). Furthermore, 25 plant species were cnsidered as invasive palnt in the country.

The other IAPS found in the country are distributed in different districts of the country with different bio-status of invasiveness. Most of listed plants are considered as common weed of cultivated field, open disturbed areas, grasslands and pastureland, river banks and wetlands across the country. Therefore, currently their invasive status were not assigned by National Biodiversity of the country. However, different studies conducted in the country considered other

above listed plants in their respective study as AIPS in reference to other reports and online resources like Global Register of Introduced and Invasive Species-Bhutan (GRIIS), Invasive Alien Species of Bhutan-INaturalist, Bhutan Biodiversity Portal (BBP), Invasive Plants of Bhutan (Google sites) and Invasive Species Compendium maintained by Centre for Agriculture and Bioscience International (CABI). Therefore, present study listed all IAPS considered by different studies accounting total of 136 IAPS in the country as of now. However, the enumerated list will change, and its invasive status will keep on updating with further validation with National Biodiversity center of Bhutan.

IAPS has posed threat to natural environments, forest and wetland ecosystems, grasslands and pasturelands, native plants and native animals. Besides it has adverse impact of agriculture yield as a serious and compitive weeds of the crops. Some are even considered as hazadrous to animal and humna health. However, country still lacks the comprehensive study on impacts of all the AIPS and its invasive status in the country. Furthermore, the geographical distribution of all IAPS in the country couldnot be well documented due to lack of proper documentations of IAPS and its current distributiion in the country. Therefore, geographical IAPS will expand with its invasiveness in near future. IAPS in the country consitutute maximun for Fabcaeae (24), followed by Poaceae (20) and Astercaee (19) species, similar to finding of Dorji, (2014). Most of IAPS in the country are annual or perennial herbaceous plants.

CONTROL AND MANAGEMENT STRATEGIES OF IAPS

The management and control of IAPS causes huge economic losses once it is established or naturalized in the area (Richardson & Pyšek, 2007). However, prevention of IAPS is environment friendly as well as an economically sound. Therefore, prevention of introducing IAPS is vital in IAPS management strategies (U.S. Department of Interior, 2021). Broadly management of IAPS are categorized into two phases; preventive measures before introduction of IPAS and control or eradication measures after establishment IAPS in the particular area (CABI, 2021).

A. Preventive measures:

Some of the important preventive measures are as follows:

- Create mass awarness and sensitizaion programs on negative impacts of IAPS on environment and agriculture.
- Follow strict plant quarantine and plant sanitation regulations during plant imports.
- Early detection of IAPS in the country: conduct surveys, documentations, research and assessment of potential risk of plant invasion in the area.

B. Control and management strategies:

- **Initial assessment and prioritization:** assesst invasive status and impact of IAPS and proiritize major invasive plants with adverse effect for management.
- **Eradication and containment**: scientifically based eradication and population conatinment methods must be followed to ensure its longterm succes.
- **Follow control measures**: IAPS popluations are controlled by mechanical methods (Slashing, uprooting, clearing and burning), chemical methods (application of approved weedicides and herbicides) and biological control (identifyying and introducing natural enemies like herbivores, insects and native plants).
- **Habitat management:** traditionally practiced environment managements strategies like prescribed burning and agriculture practices must be continued to favour suitable habitat for native plants.

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APPENDIX

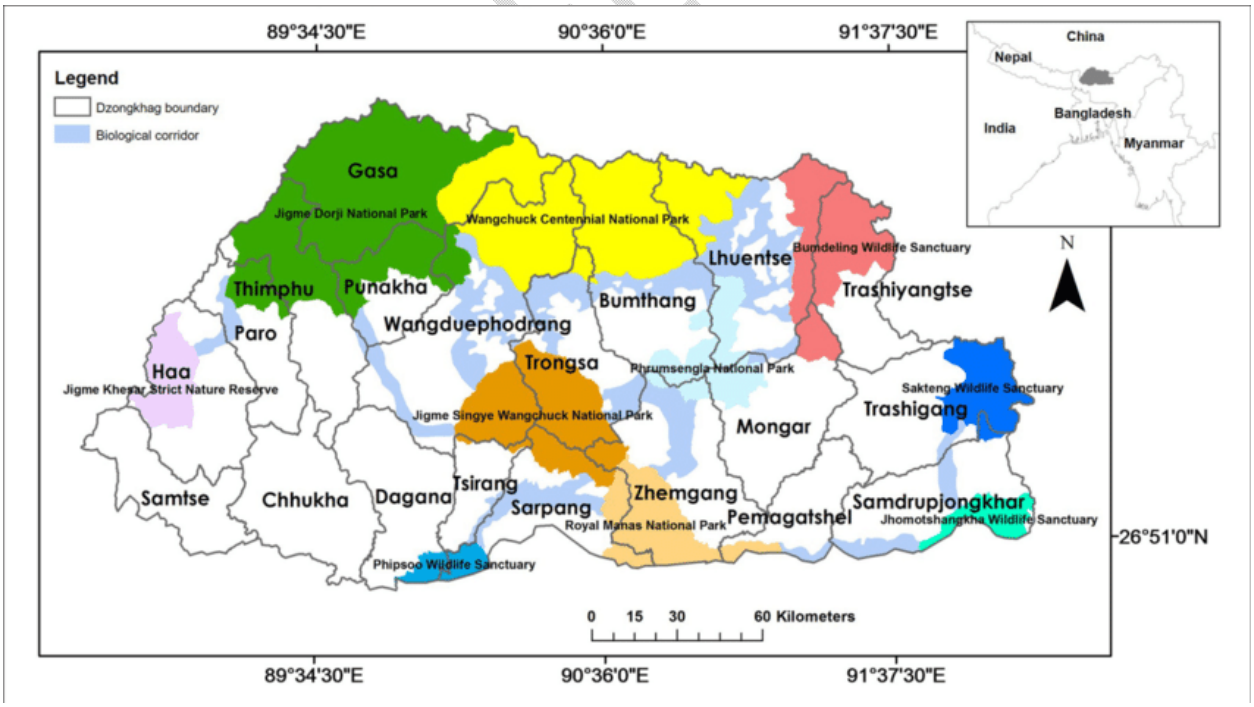

Figure 3: Protected areas of Bhutan. (Thinley et al., 2021).

- **Jigme Dorji National Park (JDNP):** Gasa, Paro, Punakha, Thimphu, Wangdue Phodrang.
- **Jigme Singye Wangchuk National Park (JSWNP)**: Sarpang, Tsirang, Trongsa, Wangdue Phodrang, Zhemgang.
- **Thrumshingla National Park (TNP)**: Bumthang, Lhuntse, Mongar, Zhemgang.
- **Wangchuck Centennial National Park (WCNP)**: Bumthang, Gasa, Lhuntse, Trongsa, Wangdue Phodrang.
- **Royal Manas National Parks (RMNP):**Pemagatshel, Sarpang, Zhemgang.
- **Bumdeling Wildlife Sanctuary (BWS)**: Lhuntse, Mongar, Trashiyangtse.
- **Phibsoo Wildlife Sanctuary (PWS)**: Dagana, Sarpang.
- **Sakteng Wildlife Sanctuary (SWS)**: Trashigang, SamdrupJongkhar.
- **Jomotsangkha Wildlife Sanctuary (JWS)**: SamdrupJongkhar.
- **Jigme Khesar Strict National Reserve (JKSNR)**: Haa district