Assessing the risk of alien plant invasions to the developing world: Bhutan a case study

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Abstract

Humans have benefited from alien plant species since moving from a hunter-gatherer lifestyle to one based on farming and agricultural production. Most, if not all, staple food crops have been moved, bartered and traded around the globe. This trade and transport of plant material has increased the risk that potential invasive alien plant species could be imported for a variety of uses (food, fodder, ornamentals, landscaping, energy, timber and soil conservation) or be accidentally introduced with less invasive crops.

Biological invasions are a serious threat globally, but particularly to developing countries. The rapid growth of horticulture and livestock industries in developing countries coupled with insufficient or non-existent management of plant introductions among the major contributing factors to biological invasions in these countries.

Bhutan is unique among South Asian countries. It has a low biological invasion research quantum, but is a part of the Eastern Himalayan biological hot-spot and is highly vulnerable to invasive alien species. Bhutan is a strong advocate of biological conservation, giving individual citizens the ‘sacred’ responsibility of protecting the environment and conserving native biodiversity (Article 5 of The Constitution of the Kingdom of Bhutan). However, there is a mismatch between government policy on environmental conservation (i.e. strong emphasis on native biodiversity protection) and implementation (e.g. overlooking potential threats from deliberate introductions of alien plant species for agriculture, pasture and horticulture). There is no concise, comprehensive or current list of alien species introduced into Bhutan. The initial component of this research was to create the first comprehensive inventory of alien plant species across all sectors in Bhutan and to identify the major introduction pathways.

This baseline inventory was created using diverse sources including publications, reports, global online resources, and personal contact and/or correspondences with international/national experts and individuals associated with or who worked on alien plants in Bhutan. Much of the data were held in private, personal archives as there is no central repository for this information in Bhutan and as such much of this information eventually is
lost. Importantly, the baseline inventory provides the date of introduction or the first reported date of the alien plant species in Bhutan and their presence or absence in 20 districts of the country, which is now available for future research studies to build on.

The amount of alien flora in Bhutan is under reported. Prior to this research it was believed that only 6% (n = 336 species) of the total flora (N = 5600) were introduced. A total of 964 alien plant species however were identified here in the baseline survey as having been introduced into Bhutan since rice, *Oryza sativa*, the first alien plant species, was recorded in 747 AD. Prior to 1960, Bhutan was a closed country and isolated from the rest of the world. From 1961 onwards, the borders were opened and Bhutan embarked on a period of economic development. Only 94 species of alien plants were identified as being introduced before 1961.

Field survey was undertaken across Bhutan to test the representativeness of the inventory and to validate the baseline. The field survey was undertaken using the convenience sampling method and revealed an additional 159 alien species for which there were no records of them being introduced into Bhutan; given a revised total of 1123 alien plant species that have been introduced into Bhutan).

This research was able to identify the introduction pathway for more than 99.7% (n = 1120) of alien plants in Bhutan. Among these deliberate introduction pathways, ornamental (50%, n = 501) and pasture (20%, n = 228) species were the dominant alien plants introduced, followed by forestry species (2.8%, n = 32). The agricultural sector was responsible for the least alien plant introductions (2%, n = 18).

Horticulture was identified as one of the pillars of economic development in the 1999 ‘Vision 2020’ document of Bhutan. This led to the growth of the ornamental industry from one single nursery in 1990 to 79 registered private nurseries and many unregistered, family run nurseries today. Since 1999, more than 375 alien ornamental species have been introduced by this sector.

The livestock sector introduced over 96% of the total pasture species recorded in Bhutan (n = 228) in three decades from 1970 to 2000. These were dominated by species in the Fabaceae (n = 144) and Poaceace (n = 69); families that dominate the weedy flora of the world. Similar to global trends, fodder species selection in Bhutan were based on biomass and production under minimal external inputs and marginal management practices (i.e. mostly weedy characteristics). This means there is a high potential for those species to become invasive.
Given the majority of alien plant species in Bhutan were deliberately introduced and traditional pre-border screening is problematic in a land-locked country like Bhutan, I developed a decision tree framework that incorporates a hybrid pre-border screening and post-border weed risk management approach to help manage the problem. This approach can minimise the risks posed by the introduction and establishment of alien plant species in countries with open and porous borders. The first component of this hybrid model (pre-border) is based on the premise that even limited pre-emptive pre-border screening can reduce the potential of introducing high risk alien plants. The outcome of ‘off-the-shelf’ models, like the Australian Weed Risk Assessment (AWRA) system screens alien plant species proposed for introduction pre-border and/or those new alien species intercepted at the border, for regulatory action, i.e., to accept or deny entry of that species. Thereby this weed screening process can be used to create new lists of permitted/prohibited plant imports for the country; albeit such lists can be produced through other processes. The creation and the use of such lists forms the basis of the first (pre-border) component of the decision tree.

The second (post-border) component of the hybrid model applies management action for alien plants already in the country or those introduced or dispersed accidentally (e.g. by vehicles, contaminants, animals, birds, water and wind). My research found that many existing alien plant species that were not previously recorded in the country could be readily detected post-border through a rapid survey or early detection method at or near the borders and through targeting sectors identified as the main importation pathways. The status (accept or evaluate further or reject) of the alien plant species detected post-border could then be retrospectively assessed and outcome updated on the permitted/prohibited lists and/or plant regulatory action imposed. Concurrently, the permitted/prohibited list from the pre-border screening process could be used post-border to regulate internal movement of invasive plants from one district to another, or for use in early detection or incursion management processes. Management of invasive alien plant species detected post-border is dependent on capability. This decision tree framework, using the hybrid system, may be the first of its kind, incorporating both the principles of proactive (preventive) and reactive (early incursions) management of invasive alien plant species under one approach, which has significant benefits for countries constrained by resources or with open and porous borders.

There are some arguments that an ‘off-the-shelf’ model designed by a developed country is not suitable for developing countries and, additionally, that pre-border screening of potential alien
plants cannot be effective for countries that are open and porous. To test these assumptions, I used the AWRA system that has been tested predominantly in developed countries. I also created a new model appropriate for Bhutan in which I modified the AWRA to meet the local conditions and constraints of Bhutan (Bhutan WRA). I used AWRA results of the Tasmanian Government, Australia, as a training dataset (n = 499 species) to compare the applicability of the AWRA to Bhutan (n = 400 species) following similar global testing procedures. I used the risk rating from the ‘Global Compendium of Weeds’ as a proxy for a Bhutan experts’ rating or a-priori lists, to compare and validate the Bhutan weed risk assessment outcomes (Bhutan WRA). The results from the Bhutan WRA were comparable to those obtained from using the training dataset where all high-risk alien plants were rejected.

I used the full AWRA model as the training dataset to test two simplified models. The first model used the full 49 AWRA questions divided into four group variables (independent variables). These were biogeography (BG), biology and ecology (BE), dispersal mechanisms (DM) and undesirable traits (UT). The model based on these four group variables did not converge in SPSS multinomial logistic regression analysis due to quasi-complete separation. The two suggested solutions were to obtain more data or to simplify the model. I opted for the second solution by using the combination of three group variables that yielded the best result in the training dataset and Bhutan WRA. Among the different combinations of group variables, the combination of BG, BE and DM gave the best overall predictive power in both the training dataset and the Bhutan WRA. Alternatively, the scores from the group variable, with the exception of the UT group variable, could be used for rapid assessment and decision making based on the minimum (accept) and maximum (reject) scores of the group variable. The individual group variable with the greatest predictive power was BG, indicating that a plant being weedy elsewhere is an important parameter to discriminate the status of an alien plant species.

The second model trimmed nine selected questions from the full Bhutan WRA model. These questions were less able to be answered in developing countries due to lack of information, or were likely to be scored positively (e.g. herbicide control), despite land managers in developing countries not being able to afford or obtain the appropriate management tools. Only 9% (n = 37 species) of the total (n = 400) plant species examined changed their category of which 12 species (3%) in the ‘evaluate further’ category were accepted. This is not recommended for
developing countries where post-border management is generally poor because of lack or resources.

This research has shown that alien plant species management pre-, at- and post- border is possible in developing countries like Bhutan. However a thorough baseline inventory is also needed to underpin such a system, by documenting the current post-border status of alien plants for the country. Implementation of a decision tree framework that incorporates a hybrid pre-border screening and post-border weed risk management approach allows this, even with the capacity and resourcing constraints, and open and porous borders that many countries have. Further, it is applicable to developed countries as, globally, we all seek to manage the impacts of invasive alien plant species on the environment, primary production and society.