Climate Change and Invasive Plants in Forests and Rangelands

Synthesis

There is considerable evidence suggesting that future climate change will further increase the likelihood of invasion of forests and rangelands as well as the consequences of those invasions. This is largely because of the potential for complex interactions between (1) the impact of warming and precipitation changes on population dynamics and species distributions; (2) increased ecosystem disturbance (e.g., wildfires, hurricanes); (3) the enhanced competitiveness of some invasive plants due to elevated CO2; and (4) increased stress to native species and ecosystems [1,2,3,4,5].

Invasive plants are introductions of nonnative (also referred to as exotic, alien, or non-indigenous) species that are or have the potential to become successfully established or naturalized, and spread into new localized natural habitats or ecosystems with the potential to cause economic or environmental harm [6]. Billions of dollars are spent every year to mitigate invasive plants or control their impacts [1]. Familiar examples include the invasive annual grass cheatgrass (Figure 1, Bromus tectorum), which has invaded significant areas of sagebrush-steppe and dry forests in the western U.S., and the invasion and spread of the non-native vine kudzu (Pueraria montana var. lobata) in the southeastern U.S. (Figure 2). While most delimiters of invasive plants only consider nonnative species, native species may be considered invasive by some [7]. For example, Juniper (Juniperus spp.) species in the western U.S. have historically expanded their range and are considered invasive in certain ecosystems [8,9]. We limit our discussion largely to nonnative invasive species, referring to these species simply as invasive plants.

In general, the detrimental effects of invasive plants in natural ecosystems may include a reduction in native biodiversity, changes in species composition, loss of habitat for dependent and native species (including wildlife), changes in hydrochemical cycling, and alteration of disturbance regimes. Most of the nonnative species in the United States have been introduced recently, and their actual invasiveness and possible future spread are unknown. The spatial extent of many invasive plants at any point in time can be difficult to determine, limiting assessment of their overall consequences. In addition, observed negative environmental effects can be later discovered to be more subtle or complex [10]. Not all consequences associated with invasives are viewed as detrimental. Some species have been found to help preserve ecosystem function or provide ecosystem services [11,12,13].

Table 1. Examples of non-native plants that have had significant spatial invasions in U.S. forests and woodlands.

<table>
<thead>
<tr>
<th>Species</th>
<th>Origin</th>
<th>Form</th>
<th>Region of Invasion</th>
<th>Common Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acer pseudoplatanus</td>
<td>Europe</td>
<td>Tree</td>
<td>Northeast</td>
<td>Norway maple</td>
</tr>
<tr>
<td>Alnus rubra</td>
<td>China</td>
<td>Tree</td>
<td>Southeast, East</td>
<td>tree of heaven</td>
</tr>
<tr>
<td>Alliaria petiolata</td>
<td>Europe</td>
<td>Biennial herb</td>
<td>Northeast, Midwest</td>
<td>garlic mustard</td>
</tr>
<tr>
<td>Barren's thimblebush</td>
<td>Asia</td>
<td>Shrub</td>
<td>Northeast, Midwest</td>
<td>Japanese barberry</td>
</tr>
<tr>
<td>Bromus tectorum</td>
<td>Eurasia</td>
<td>Annual grass</td>
<td>West</td>
<td>cheatgrass</td>
</tr>
<tr>
<td>Cakile edentula</td>
<td>Eastern Asia</td>
<td>Vine</td>
<td>Northeast, East</td>
<td>oriental bittercress</td>
</tr>
<tr>
<td>Campanula rotundifolia</td>
<td>Europe</td>
<td>Annual fork</td>
<td>West</td>
<td>yellow archangel</td>
</tr>
<tr>
<td>Campanulastrum</td>
<td>Europe</td>
<td>Biennial</td>
<td>West</td>
<td>spotted knapweed</td>
</tr>
<tr>
<td>Chrysanthemum</td>
<td>Europe</td>
<td>Perennial herb</td>
<td>West</td>
<td>Canada thistle</td>
</tr>
<tr>
<td>Cissus sicyoides</td>
<td>Europe</td>
<td>Shrub</td>
<td>Northwest</td>
<td>Scottish broom</td>
</tr>
<tr>
<td>Hedeoma holly</td>
<td>Europe</td>
<td>Vine</td>
<td>Northwest</td>
<td>English ivy</td>
</tr>
<tr>
<td>Impatiens cly描ths</td>
<td>East Asia or Southeastern Asia</td>
<td>Grass</td>
<td>Southwest</td>
<td>eggplant</td>
</tr>
<tr>
<td>Lignospermum</td>
<td>Southeast Asia</td>
<td>Shrub</td>
<td>Southwest</td>
<td>Chinese privet</td>
</tr>
<tr>
<td>Liriope japonica</td>
<td>Asia</td>
<td>Vine</td>
<td>Southwest, East</td>
<td>Japanese honeysuckle</td>
</tr>
<tr>
<td>Lyrurus japonicus</td>
<td>Asia &amp; Australia</td>
<td>Climbing fern</td>
<td>Southeast</td>
<td>Japanese climbing fern</td>
</tr>
<tr>
<td>Microstegum viride</td>
<td>Eastern Asia</td>
<td>Annual grass</td>
<td>East, Midwest</td>
<td>Japanese skunkbush</td>
</tr>
<tr>
<td>Pueraria montana var. lobata</td>
<td>Asia</td>
<td>Vine</td>
<td>Southeast</td>
<td>kudzu</td>
</tr>
<tr>
<td>Triadica pedata</td>
<td>China</td>
<td>Tree</td>
<td>Southeast</td>
<td>Chinese tallow, tallowtree</td>
</tr>
</tbody>
</table>
The success of invasive plants in native plant communities is highly influenced by factors related to environment (e.g., temperature, precipitation, CO2), propagule pressure or resource availability, prosaprobic pressure (p.g. seeds), and biotic resistance (from the native plants). These factors interact to influence the success of invasive species, even to the point of driving changes in the environment (e.g., increased CO2 levels can lead to more vigorous plant growth) [14,15,13]. While changes to any of these factors can influence plant invasions, a key issue in the future will be the complex interaction of these factors.

Environment: Scientists have known for over 20 years that enhanced levels of CO2 stimulate plant growth. Increased photosynthesis as a result of new and projected increases in CO2, is one of the most researched aspects of global change [16,17]. There is some evidence that elevated CO2 may favor woody plants [17].

In a hypothesis-driven response to warming, several studies have documented the movements of species poleward and/or upward in elevation, (e.g., 18-20). Although the trend has not been found universally [20], it is possible that species richness does not increase in response to rising temperatures, but rather increases in response to rising CO2 levels [21]. Species interactions and species’ local adaptability and dispersal ability and speciation flexibility, under competition, interact to influence these changes are also important to consider. Species’ performances such as growth, phenology, and productivity may also change in new conditions [22].

Disturbance: Future changes may be more influenced by climate-related shifts in disturbance regimes and altered land-use, rather than changes in a species’ environment. Natural and human-caused disturbances such as fire, landslides, volcanic activity, logging, road building, etc., are often resource available at the time for certain processes, leading to higher plant density and species diversity. These processes are key factors in the invasion process.

Prosaprobic pressure: A propagule is ecologically relevant unit of plant dispersal, defined as a colonizing organism or vegetative structure capable of establishing a self-sustaining population. For example, there is higher propagule pressure when an area already has a significant invasion and there are ample seed sources. Areas that are not subject to human disturbance and have dense tree cover, are likely to experience higher propagule pressure. Climate change will alter numerous aspects of propagule supply and pressure. Most invasive species reach new regions by accidental or accidental human-mediated (transport, tourism, commerce), and tourism and commerce are subject to be at risk from future climate change [23]. Factors associated with human and cultural activities (urban areas, roads, recreation) are positively correlated with plant invasions [24-26]. Atmospheric patterns that transfer seeds, such as hurricanes and wind patterns, will also change in the future. Climate change may also result in increased management activities and cause new disturbances, such as biofuel production or forest thinning.

Biotic resistance: The ability of the native plant community to resist an invasion may change in the future. For example, invasive plants may be exposed to above- and below-ground biotic interactions different from those in their current range or "new release" may occur [27]. In other words, invasive species in the invaded ranges often do not face the "exotics" such as diseases and competitors they have at home in native ranges.

Options for Management

Informed Management Decisions: how do scientists study climate change and invasive plants?

Experimental studies such as CO2 warming, and water deficit treatments, and field and observational studies are used to try to decipher the likely changes that climate change may have on invasive plant population establishment and spread. Scientists also use simulation modeling tools to assess the potential effects of climate change on invasive plants, including population and spread models, and "virtual reality" models. Such models can be critical in alerting us to the potential magnitude of the effects of climate change, considerable uncertainty remains about what the future may hold.

Fundamental research regarding invasion drivers and invasion biology is still needed, as are new tools that integrate invasion and climate change biology [28]. There is no limited data, particularly in field settings, about how plant invasions will be affected by different aspects of climate change. Understanding the response of the most problematic invasive plant species to climate change is critical. Therefore, much research, especially with multidisciplinary and collaborative efforts are strongly needed in the future [29].

Management Early detection and rapid response systems can consider how climate change may alter invasion patterns in the future. Because the window of opportunity for cost-effective and successful responses to plant invasions is small, the greatest chance for action is in the early phase of invasion. Close monitoring the rate and rate of introduced species under climate change could help identify the potential for future spread for the species. Increased monitoring with a relatively restricted distribution in their native range, coupled with predictive models for protecting and managing "hot spots" of entry along forest borders or in wildland urban interface areas, and limiting vector pathways (e.g. seed-borne, road) for many invasive species are key factors in the success of current threats to native species.

References


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