Grasslands And Forests In Nebraska Are Vulnerable To Tree Invasion From Roadsides

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Abstract

Roadsides can be vectors for tree invasion within grasslands by bisecting landscapes and facilitating propagule spread to interior habitat. Current invasive tree management in North America's Great Plains focuses on reducing on-site (i.e., interior habitat) vulnerability through on-site prevention and eradication, but invasive tree management of surrounding areas known to serve as invasion vectors, such as roadsides and public rights-of-ways, is sporadic. We surveyed roadsides for invasive tree propagule sources in a southeastern Nebraska grassland landscape to determine how much of the surrounding landscape is potentially vulnerable to roadside invasion, and by which species, and thereby, provide insights into the locations and forms of future landcover change. Invasive tree species were widespread in roadsides. Given modest seed dispersal distances of 100-200 m, our results show that roadsides have potential to serve as major sources of grassland exposure to tree invasion, compromising up to 44% of grasslands in the Denton Hills. Under these dispersal distances, funds spent removing trees on grassland properties may have little impact on the landscape's overall vulnerability, due to exposure driven by roadside propagule sources. A key implication from this study is that roadsides, while often neglected from management, represent an important component of integrated management strategies for reducing grassland vulnerability to tree invasion.

Introduction

Invasion of North America's Northern Great Plains (NGP) grasslands by woody species reduces native biodiversity and ecosystem services, and is compounded by fragmentation from agriculture development and other human development (Spencer et al. 2009). Invasive tree management is therefore a priority for NGP natural resource managers, with the Natural Resource Conservation Service (NRCS) in Nebraska spending \$8.6 million from 2004 to 2013 on eastern red cedar (*Juniperus virginiana*) cost-share removal and prescribed burning (Simonsen et al. 2015). Invasive tree management tends to emphasize interior habitats while neglecting surrounding areas, such as roadsides (Donovan et al. 2018). However, roadsides can harbor invasive species, and facilitate invasion into remaining interior habitat (Tyser & Worley 1992; Gelbard & Belnap 2003), with single mature trees acting as potential sources of propagule exposure via vertebrate dispersal (Coulson et al. 2014). These invasive species have the potential to reduce the resilience of local ecosystem services in southeastern Nebraska, which include cattle production, public recreation, hunting, and wildlife habitat. In this study, we explore the potential for roadsides to function as a source of invasion risk in interior habitats.

The Denton Hills in Lancaster County, Nebraska is an ecologically distinct landscape embedded within a broader agriculturally dominated landscape. Unlike adjacent landscapes, the Denton Hills still contain relatively large grassland areas that serve as a repository for declining grassland species (Rosenberg et al. 2019). Remaining grassland in this region is largely due to cattle ranching, comparatively small-scale corn-soybean farms, and recently increasing residential development due to the proximity of the state's capital city of Lincoln with an approximate population of 289,000 in 2019 and an estimated population increase of 11.7% between 2010 and 2019 (U.S. Census Bureau 2021). Denton Hills soils are clay heavy

(NRCS Web Soil survey, SSURGO 2017), groundwater is limited, and average annual precipitation is approximately 75 cm (PRISM Climate Group 2020).

Since the presence of public transportation corridors is correlated with an increase in invasive species in native habitats (Tyser & Worley 1992) our objectives are to 1) determine the extent to which roadsides harbor invasive trees, and 2) model the extent of interior habitat exposure to roadside propagule sources based on seed dispersal scenarios.

Methods

We selected a 6278-ha area centered around Spring Creek Prairie, a relatively large grassland preserve in the Denton Hills owned by the National Audubon Society that serves as a key hotspot for regional biodiversity preservation. Next, we selected ten 500-meter transects along unpaved roadsides within the region by distributing random coordinates along unpaved roads and selecting 10 transect starting points. The prevailing road pattern in the Denton Hills is a one-mile cardinaly oriented road grid aligned with Public Land Survey System section boundaries; therefore, we randomly assigned a direction to each survey starting point in which researchers walked, resulting in ten 500-meter transects that were oriented either east-west or north-south.

From each sampling point, researchers walked 500 meters in the chosen random direction, searching for and counting individual trees between the right side of road and the right-of-way (ROW) boundary. We sampled for three species, autumn olive (*Elaeagnus umbellata*, ELUM), honey locust (*Gleditsia tricanthos*, GLTR), and eastern red cedar (*Juniperus virginiana*, JUVI), the most prevalent invaders in this region. To determine average ROW width and roadside acreage along each transect (Supplementary Table S1), we measured the distance in meters from the road edge to the edge of the ROW at six evenly spaced points along each transect. We identified the edge of the ROW as the location either directly under telephone lines or at the private property fence, whichever was closer to the road edge.

To calculate sampled roadside area for determining sampled invasive tree densities (objective 1), we took the average ROW width per transect, multiplied by 500 m (transect length). We also estimated total roadside area in the Denton Hills in hectares by taking the average ROW width from all 10 transects, multiplying by the length of public roads within the study area (Allen et al. 1997, Supplementary Table S1). To determine the sample distribution and density of roadside invasive trees, we calculated the number of trees per species and all tree species combined per hectare, plus summary statistics for abundance and densities. We computed these analyses in R 4.1.1 (R Core Team 2021).

For our second objective of quantifying the landscape area within the study area vulnerable to tree invasion from roadsides, we assumed that roadsides were potential propagule sources. Using the 2019 National Land Cover Database (NLDC), we calculated coverage of forests and rangeland within the study area boundary. From the 2019 NLCD land cover data, we selected the categories of “Herbaceous” and “Hay/Pasture” as rangeland, and “Shrub/Scrub”, “Mixed Forest”, “Evergreen Forest”, and “Deciduous Forest” as forest. All other categories (such as developed acreage, crop fields, and wetlands) were

excluded due to their negligible value as habitat for the invasive tree species in question. Forests and rangeland comprise 3,764 ha within the study region, including 3,347 ha of rangeland and 417 ha of forest (Figure 1).

We used seed dispersal scenarios to assess the extent to which grassland and forests are exposed roadside propagule sources. We buffered roads within the study region by 100 (Holthuijzen & Sharik 1985a), 200, 500, and 1000 meters. Five hundred and fifteen meters is the theoretical maximum dispersal distance for *J. virginiana* (Holthuijzen & Sharik 1985b), although recent data suggest *J. virginiana* seeds can disperse up to 1000 meters (Fogarty et al. *In prep*). We then clipped the forests and rangeland land cover layers by each road buffer and calculated the total areas for each within the study region. This represents the area and percentage of the total of each cover class that is vulnerable to roadside invasion for each scenario of seed dispersal (Table 3). These analyses were completed in ArcGIS Pro 2.8.0 (Esri 2020).

Results

Mean counts for all species combined, standard deviations, medians, and ranges are reported in Table 1. A Shapiro-Wilk test on abundance counts of all species per transect ($p = 1.009e-06$) indicates non-normality, which means that median count values may be more informative than means and standard deviations. Mean species density and total invasive tree density across all 10 transects, as well as the standard deviation, median, and range for each species are summarized in Table 2. A Shapiro-Wilk test on tree density per hectare returned $p = 8.201e-07$, suggesting tree densities are not normally distributed and median densities may be more informative than means and standard deviations.

J. virginiana was the most prevalent invasive woody species (per transect median count: 22, median density: 78.2 trees/ha), followed by *G. tricanthos* (median count: 2.5, median density: 9 trees/ha) and *E. umbellata* (median count: 0, median density: 0 trees/ha) (Tables 1 and 2). Median count for all species combined was 29 (Table 1), and total median density for all species combined was 109.4 trees/ha (Table 2).

Table 1
Tree species counts across transects ($n = 10$).

Species	<i>n</i>	Mean	SD	Median	Range
<i>Juniperus virginiana</i>	10	23	21.6	22	0-70
<i>Gleditsia tricanthos</i>	10	7.7	10.7	2.5	0-26
<i>Elaeagnus umbellata</i>	10	0.3	0.9	0	0-3
All Species	10	31	25	29	0-74

Table 2
Tree species densities (trees/ha) across transects (n = 10).

Species	<i>n</i>	Mean	SD	Median	Range
<i>Juniperus virginiana</i>	10	81.6	77.5	78.2	0-253.8
<i>Gleditsia tricanthos</i>	10	27.8	39.4	9	0-100.3
<i>Elaeagnus umbellata</i>	10	0.9	2.9	0	0-9.3
Total	10	110.3	87.9	109.4	0-268.3

We found that roadsides have a high potential to contribute to grassland and forest vulnerability, even at the conservative dispersal distance estimates of 100-200 meters. At these lower distances, 24-44% of grassland and 16-38% of forest in the Denton Hills landscape is exposed to roadside propagule sources from invasive trees (Figure 1). These numbers increase to 84-99% and 73-93% of rangelands and forests, respectively, under 500-1000 meters seed dispersal scenarios.

Table 3
Hectares and percentage of total Denton Hills landscape vulnerable to tree invasion, based on the contribution of roadsides.

Land cover type	Area vulnerable to roadside invasion							
	100 m		200 m		500 m		1000 m	
	ha	%	ha	%	ha	%	ha	%
Rangeland	803	24	1489	44	2807	84	3312	99
Forest	67	16	158	38	306	73	386	93

Discussion

Coordinated invasive tree management between properties (i.e., interior habitats) and surrounding ROWs could reduce the vulnerability of grasslands and forests to invasion and reinvasion. Nebraska roadsides are reservoirs for non-native species, and are permeable corridors for species dispersal within the surrounding landscape (Soper et al. 2019). While the Nebraska Department of Transportation (NDOT) actively manages for invasive woody species on state highways (Nebraska Department of Transportation, 2021), many rural roads in Nebraska are managed by counties or private landowners and receive sporadic invasive tree management, if any (for example, some are mowed regularly and some are not). The presence of permanent pasture fencing delineating ROW edges in the Denton Hills may further reduce the likelihood of invasive tree removal, either from counties deferring to pasture fencing owners, or private owners simply choosing not to remove trees from fences. Regardless, our results indicate that the longevity of grassland and forest management treatments could be compromised by roadside propagule sources. This interpretation of our results stems from one of the fundamental tenets of invasion biology, landscape ecology, and systems thinking—that ecological systems do not exist in isolation and therefore,

context (i.e., surroundings) matters. Under our seed dispersal scenarios, management treatment effects may be short-lived if invasive trees are removed only from interior pastures and not ROWs or ROW boundary fencelines, because a significant portion of the local landscape is within potential seed dispersal distance of ROWs. However, coordinated management efforts that consider interior pastures, ROWs, and ROW fencelines are more likely to reduce landscape vulnerability to invasion and reinvasion. In other words, landscape vulnerability to tree invasion depends not only on management of focal habitats, but on whether or not management is able to remove sources of seed exposure from neighboring lands.

Our dispersal scenarios show that roadsides have potential to drive grassland exposure across a majority of the Denton Hills landscape suggesting that roadsides, while often neglected, are an important component of the landscapes overall vulnerability to tree invasion. We further demonstrate the potential for the long-term efficacy of conservation action to be affected, in part, by the degree of coordination with management of grasslands and adjacent roadways. Grasslands are globally threatened by woody species invasions; therefore, management should be strategically and spatially targeted based on components that drive risk and vulnerability, including exposure from public ROW.

The Denton Hills is a unique, grassland-dominated landscape with high susceptibility to tree invasion, which continues to occur throughout the State of Nebraska (Fogarty et al. 2020), North America, and the world (Nackley et al. 2017). We recommend that invasive tree management on interior properties and public ROWs be coordinated for increased treatment efficacy, reduced landscape vulnerability, and enhanced resilience in the delivery of ecosystem goods and services, including cattle production, public recreation, hunting, and wildlife habitat.

Declarations

Data Availability

The datasets generated and analyzed during the current study are available from the corresponding author on reasonable request.

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Competing Interests

The authors have no relevant financial or non-financial interests to disclose.

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Figures

Figure 1

Study area map indicating landscape vulnerability to tree invasion from roadsides under the three most conservative dispersal estimates.

Supplementary Files

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- [SupplementaryInformation.docx](#)