Optimizing winter weather mitigation for transportation applications with a novel living snow fence design and geospatial suitability analysis

Jenni Kerns

Department of Earth and Atmospheric Sciences, Metropolitan State University of Denver

JHowart1@MSUDenver.edu or Kernsjenl@gmail.com

Introduction and Background

Despite state-wide efforts toward reducing and eliminating vehicular-related fatalities, Colorado saw 745 deaths related to traffic incidents in 2022. Finding solutions to lower this terrible statistic, which represents the highest number of traffic-related deaths since 1981, requires a multi-faceted approach. Living snow fences can be utilized to address winter weather related incidents, as they are proven solutions for transportation related maintenance, safety, and environmental issues.

Figure 1. Juniper living snow fence

The Eastern Plains of Colorado can experience extreme winter weather with intense winds that cause drifting snow across roadways, increasing the need for maintenance as well as chances for accidents and road closures. While conventional living snow fences can help to reduce and alleviate these problems, the species of trees required for traditional living snow fences – typically Rocky Mountain Junipers - do not naturally grow in eastern Colorado.

The potential solution to this challenge is the use of native shrubs as snow fences on the Eastern Plains.

The Minnesota and New York Departments of Transportation have put effort behind determining the effectiveness of utilizing shrubs alone as snow fences. In both states, willow shrub species were found to be effective at snow capture by the second year after installation at a fraction of the cost of traditional snow fences. While willows are not native to the eastern plains of Colorado, appropriate shrub species have been identified as sustainable options.

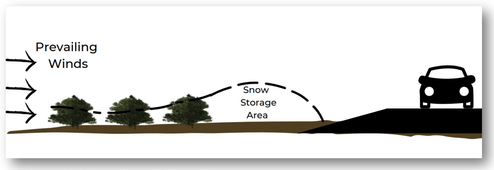

Figure 2. Snow fence illustration

Rather than collecting snow behind the fence, snow fences interrupt air currents, causing blowing snow to be deposited in front of the fence (leeward side). It is important to leave sufficient space for snow storage.

Because of the unique factors that contribute to the effectiveness of snow capture, fence design should be specific to each site needing snow control. Information such as topography, land use, soil and climate data, and crash frequency are just some factors that are imperative in determining an appropriate fence type and design. GIS suitability analyses can incorporate many of these factors, be utilized to identify strategic placement of snow fences, and can inform appropriate snow fence design.

This study utilized GIS tools and processes to identify strategic locations for living snow fence installations along highways in Colorado Department of Transportation (CDOT) engineering regions two and four that are within Colorado ecoregions with few to no native trees. The broader research also presented a site proposal as a case study to determine the feasibility of using shrubs as snow fences in Colorado.

Acknowledgements

I would like to extend my heartfelt appreciation to Dr. Parr for his unwavering support and guidance in developing my foundational GIS skills through instruction and mentorship. Dr. Parr's invaluable feedback and encouragement on several projects have been instrumental in shaping my research abilities.

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I would also like to acknowledge the invaluable support of my co-workers, whose input and assistance were critical to the success of this project. Without their support and contributions, this research project would not have been possible.

Methods

A mixed-method approach was used for this study that included both quantitative and qualitative methods. A variety of databases and GIS layers were gathered to inform the suitability analysis. Input from CDOT maintenance staff provided qualitative data that informed the lived experience of those dealing with the impacts of winter weather on transportation.

The suitability analysis utilized ArcGIS Pro to look at topography, crash density and frequency, ecoregions, native plants, current snow fence placement, parcel data, and wind power and direction. EPA descriptions of ecoregions were used to identify ecoregions in Colorado with no native trees that are suitable for living snow fences.

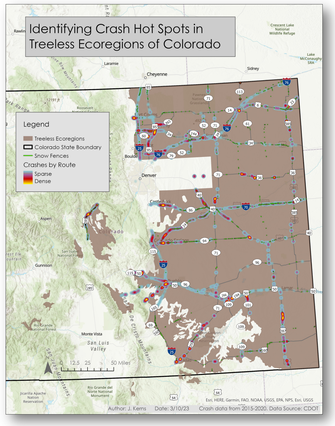

Figure 3. Initial map looking at crash density and existing snow fences

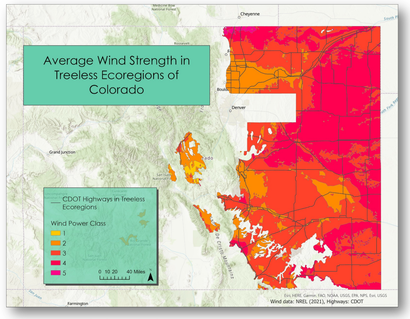

Figure 4. Wind strength map

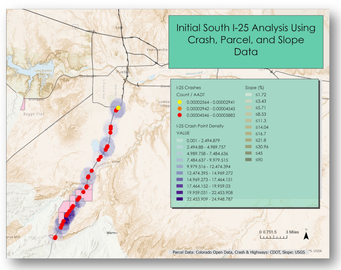

Figure 5. Example results from a partial suitability analysis on a segment of I-25 in Southern Colorado

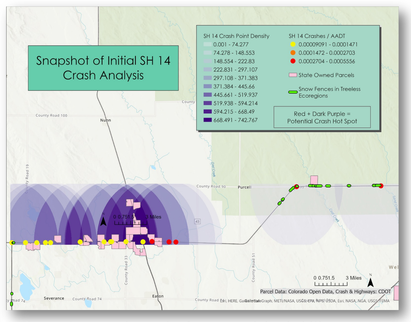

Figure 6. Example results from a partial suitability analysis on a segment of SH-14 in Northern Colorado

Data Sources

CDOT. 2015-2020 Crash Data. Acquired Feb. 01, 2023
CDOT. 2019 Fence Database. Acquired Feb. 01, 2023
CDOT. 2022 Engineering Regions. Acquired Feb. 01, 2023
CDOT. 2022 Highways. Acquired Feb. 01, 2023
CDOT Maintenance. 2023 Trouble Areas. Acquired Mar. 01, 2023
CDPHE. 2022 Colorado Counties. Acquired Feb. 01, 2023
Colorado Information Marketplace. 2020 County Parcel Data. Acquired Feb. 01, 2023
EPA. 2020 Level IV Ecoregion. Acquired Feb. 01, 2023
NREL. 2020 Colorado Wind Power. Acquired Feb. 01, 2023
Prism Climate Group. 1990-2020 Precipitation. Acquired Feb. 01, 2023
USGS. 2020 DEM. Acquired Feb. 01, 2023

Results

Out of 27 CDOT Highways considered in this analysis, 13 were identified as having potentially appropriate sites for novel living snow fence installation. Along these 13 highways are 46 possible sites.

Figure 7. Results showing potential ideal snow fence locations

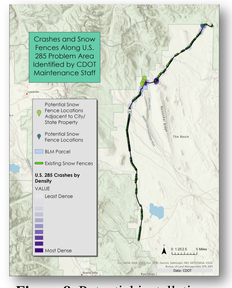

Figure 8. Potential installation locations on US-285

View the StoryMap related to this research!

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Conclusion

GIS tools can provide key insights when determining strategic placement for living snow fences. This initial research project utilized broad categories and limited crash data to identify suitable locations, and future analyses could build on this research with more detailed information to improve the site determination processes.

The effectiveness of living snow fences has strong backing in a variety of research, and their benefits can include accident reduction, road closure reduction, reduced maintenance costs and increased safety for maintenance staff, increased wildlife and pollinator habitats, increased soil health and stability, increased biodiversity, and roadside carbon sequestration.

To better understand if shrubs can function as effective snow fences that provide the above benefits in Eastern Colorado, the novel living snow fence design that uses native shrubs should be utilized at research sites and monitored for their contribution to the mitigation of winter weather-related transportation incidents. If successful, this is a replicable and sustainable environmental solution to annual winter issues.

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