A review of design and adaptation of embankment infrastructure built on permafrost under a changing climate

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Introduction

Climate change is causing permafrost thaw and alteration in the Arctic landscape, affecting northern communities, their infrastructure, safety, and prosperity. According to current air temperature prediction models (Masson-Delmotte et al., 2021), the ground mean annual temperature will continue to rise between 1-3.7˚C by 2100 (Bush & Lemmen, 2019), resulting in thawing permafrost, thickening active layers, and widespread settlement. As the frozen ground shifts and settles, infrastructure built on permafrost becomes highly vulnerable to damage, even collapse. In permafrost regions, transportation infrastructure is essential for the development of communities and industries (Regehr et al., 2013). Nevertheless, warming climate conditions lead to the failure of existing and future transportation infrastructure and costs millions of dollars by 2099 (Melvin et al., 2016).

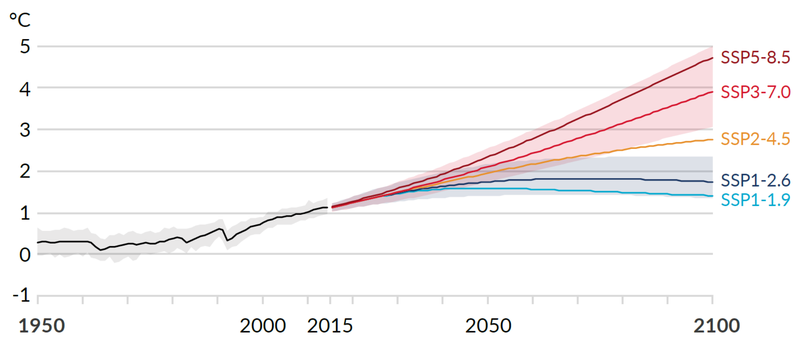

Figure 1: Global surface temperature change from 1.5 to 5˚C based on different scenarios by 2100 (Masson-Delmotte et al., 2021).

Figure 3: Settlement of the road due to the permafrost degradation (Batenipour et al. 2014).

Figure 4: Drainage condition along HBR (Oommen et al. 2017).

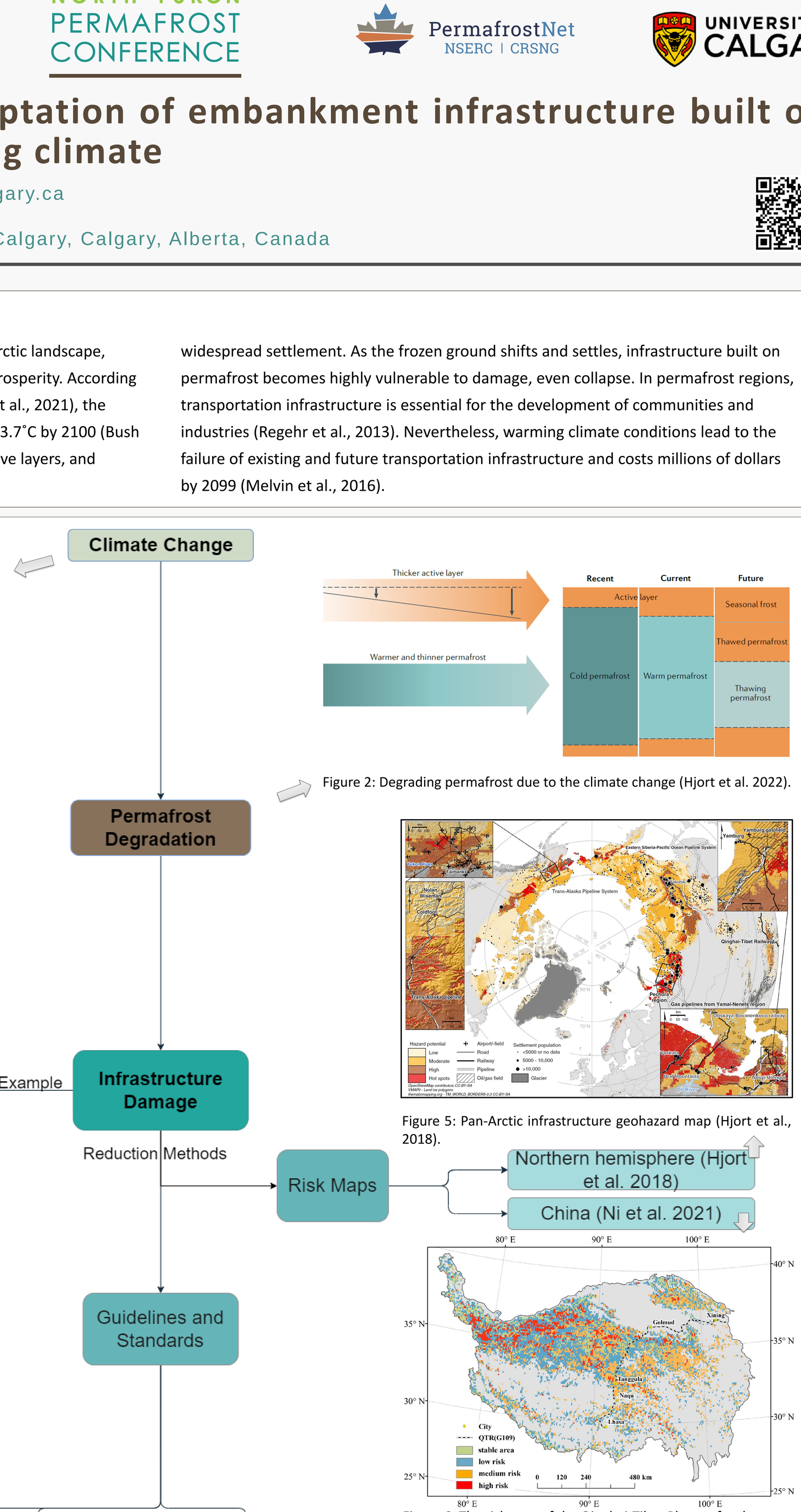

Figure 2: Degrading permafrost due to the climate change (Hjort et al. 2022).

Figure 5: Pan-Arctic infrastructure geohazard map (Hjort et al., 2018).

Figure 6: The risk map of the Qinghai-Tibet Plateau for the years 2061-2080 (Ni et al., 2021).

Conclusion and future work

Arctic regions are particularly sensitive to global warming trends, with preferential warming in the arctic at rates two times higher than the rest of the world. From unacceptable settlement to complete failure, the impact of permafrost thaw on transportation infrastructure must be considered. To decrease the costs of maintenance and replacement of infrastructure built on permafrost, qualitative and quantitate guidelines, frameworks and risk maps have developed in recent decades. However, each of them have limitations and there is still a lack of information regarding considering the long-term climate change effects on infrastructure. Thus, **the major goal of my PhD thesis is to provide a framework for analyzing the reliability of infrastructure built on permafrost embankment, with an emphasis on railways, for future climate scenarios**.