Modeling Long-Term Effects of Riparian Restoration for Salmon Recovery in the Lower Tolt River

Collaboration

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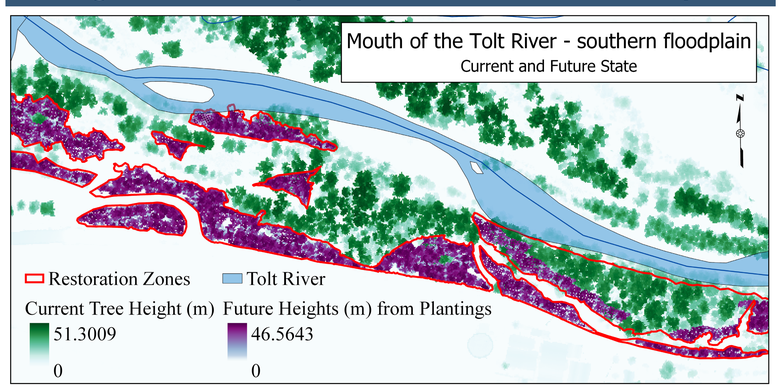
Introduction

The Snoqualmie Tribe and US EPA collaborated to use an established EPA landscape irradiance and shade model - Penumbra (Halama et al. 2018a) - to help inform habitat protection and restoration planning efforts for the Tribe's traditional lands in the Snoqualmie River Basin. Since 2013 the Tribe has been leading a community effort to restore degraded riparian habitat along both sides of the lower Tolt River in Carnation, WA. Habitat quality and quantity along the lower Tolt has been diminished due to impacts from logging, agriculture, urbanization and flood control resulting in increased temperature and sedimentation, decreased large woody debris, biodiversity, and altered flow regimes. Collectively, these changes have contributed to declines in riparian and stream habitat quality for multiple species of salmonids including key populations of ESA listed Puget Sound Chinook, Coho, and Steelhead. For this pilot study we used Penumbra to assess projected increases in riparian shading due to the Tribe's tree planting program.

Figure 1. Site Map for the Simulated Landscape



Current tree locations and heights are based on 2009 LiDAR data. Future trees are spatial copies of existing mature trees superimposed into the Tribe's restoration zones. Within the restoration zones some scattered trees already exist (Figure 1).

Methods

To assess effects of the Tribe's 20-acre riparian restoration site on the south side of the lower Tolt river, we used Penumbra to model projected increases in riparian shading from 2009 to 2100. Using 2009 1-m^2 LiDAR tree cover and height data, we first simulated reductions in ground-level irradiance (shading) due to present-day canopy cover. To estimate future gains in riparian shading by the year 2100, we superimposed projected tree heights of riparian plantings established during 2013-2019 (Figure 1).

Results

Figure 2 shows simulated shading (purple = max shading) by present-day riparian tree cover in the Tolt floodplain. In August, unshaded gaps (red = max irradiance) dominate large portions of the riparian area south of the river. Figure 3 shows a substantial increase in future (2100) riparian shading south of the river, due mostly to the fully-grown trees the Tribe planted during 2013-2019. Although much of the north half of the river is predicted to remain partially unshaded in the future, we hypothesize that the well-shaded riparian zone south of the river will reduce soil temperatures and, consequently, the temperature of groundwater flowing down-gradient into the river (e.g., Halama et al. 2018b) . *See Next Steps, below.*

Figure 2. Present-day (2009) Simulated Ground-level Irradiance

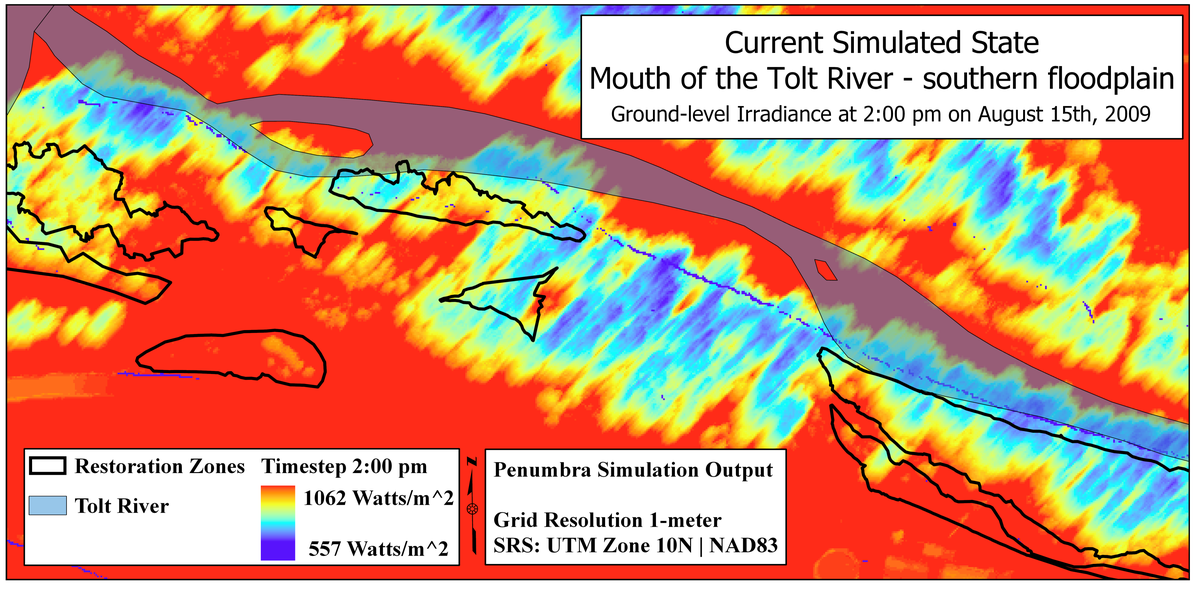
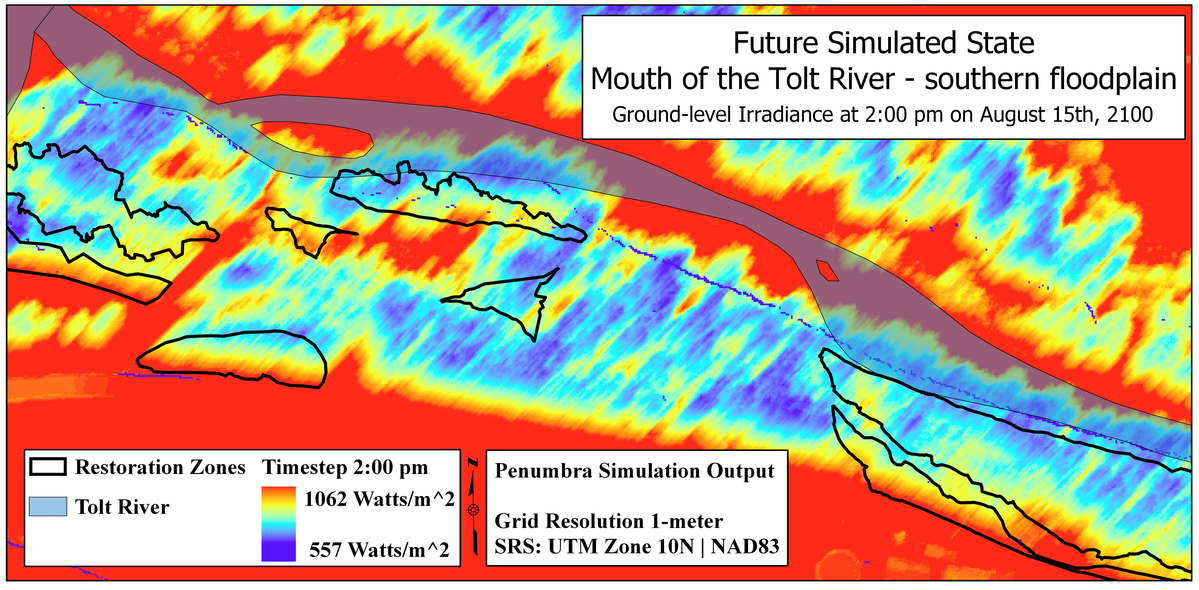


Figure 3. Future (2100) Simulated Ground-level Irradiance

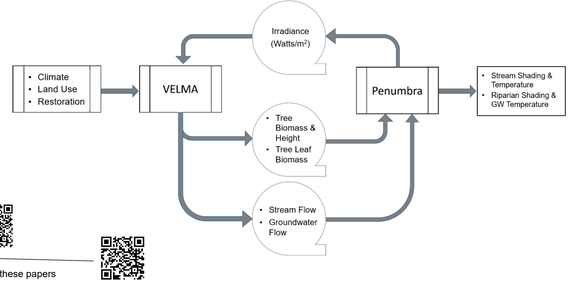


Next Steps

Next steps include running Penumbra coupled with VELMA – an EPA eco-hydrological watershed simulator (Abdelnour et al. 2011) – to dynamically simulate long-term changes in tree growth and shade, stream flow and stream temperature (Figure 4). VELMA-Penumbra simulations can potentially be used to help quantify the potential impact of tree plantings and other salmonid habitat restoration strategies on the following:

- Ground water cooling from expanded riparian zone
- Cooled ground water exchange with instream water
- Targeted establishment of cold water refuges
- Large woody debris recruitment during floods
- Synergistic effects of multiple floodplain and upland habitat restoration actions

Figure 4. VELMA-Penumbra linkage for dynamic stream shade and temperature modeling



The research presented here demonstrates the use of a landscape irradiance and shade model (Penumbra), and its integration with an eco-hydrological watershed simulator (VELMA), as a decision support tool for tribes, communities, states and others seeking to sustainably manage their shared watersheds. This modeling approach has drawn interest from various local stakeholders in the Snohomish River Basin. Recognizing that upstream land management and restoration actions can have downstream tradeoffs and benefits, it is hoped that further modeling work and collaboration will provide a basis for future applications in the broad context of Puget Sound recovery planning.

References:

Abdelnour, A. et al. (2011). Catchment hydrological responses to forest harvest amount and spatial pattern." Water Resources Research 47(9): 1-18.

Halama et al. (2018a). Penumbra: A spatially distributed, mechanistic model for simulating ground-level incident solar energy... PloS one, 13(12).

Halama et al. (2018b) Improved Soil Temperature Modeling Using Spatially Explicit Solar Energy Drivers. *Water* **2018**, *10*, 1398.

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