The hydrological impacts of afforestation in Coldstream Creek, Canada

Source: Okanagan WaterWise, 2021

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Hydrological Modeling

Introduction

As development and expansion occurs near waterways, the hydrology of nearby areas may be affected. However, afforestation may mitigate these impacts. This study aims to analyze the impacts of changes in land use on streamflow in Coldstream Creek, Canada. This study investigates the impacts of afforesting all lawns in the Coldstream Creek area into young forest, and how it would affect hydrology at a hillslope scale. The RHESSys (Regional HydroEcological Simulation System) model of watershed Hydroecology will be used to model the potential changes.

Simulation Scenarios

Natural State

Coldstream Creek covers an area that has a strip of cropland that lays horizontally across the region, a cluster of development in the west, swaths of rangeland, a few patches of old forest, and a majority of young forest land use type (Fig. 1).

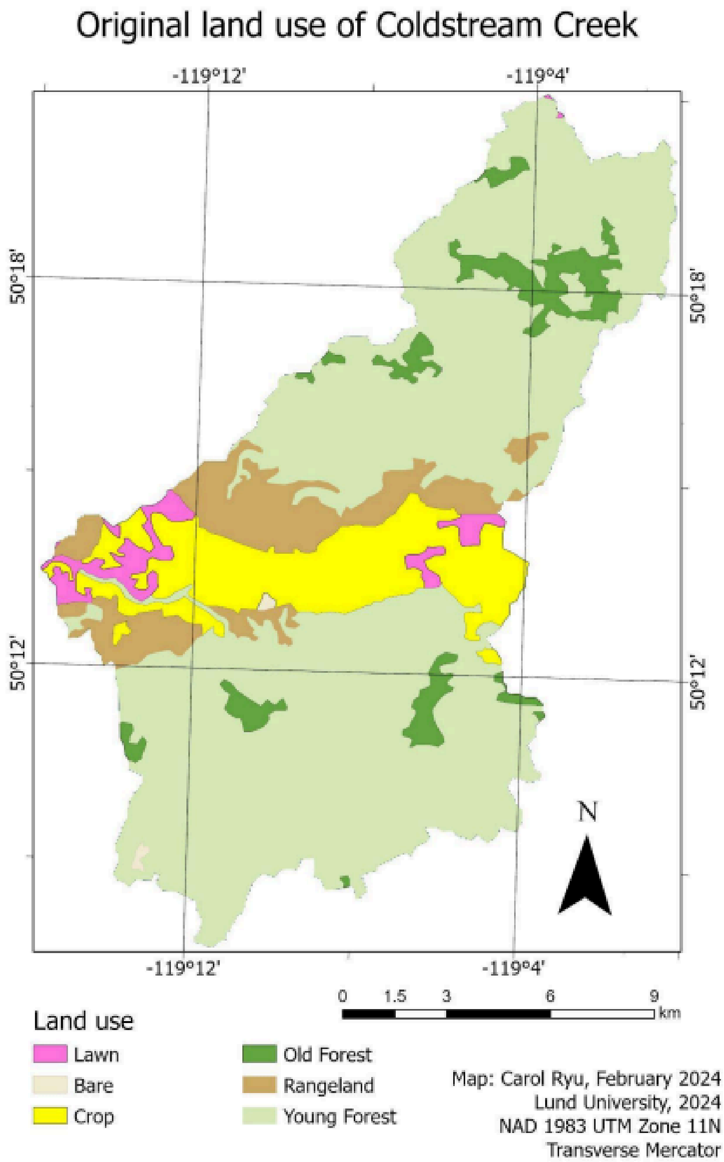

Figure 1. The natural state land use classification of Coldstream Creek.

69.8% of the area is classified as young forest, making up a total of 146 sq km (Table 1, Fig.2). Lawn area is much smaller by proportion, making up only 2.6% of the total area.

Table 1. The land use area of Coldstream Creek.

Land use class	**area (sq km)**
Bare	0.41
Crop	26.10
Lawn	5.37
Old Forest	11.56
Rangeland	19.90
Young Forest	146.11

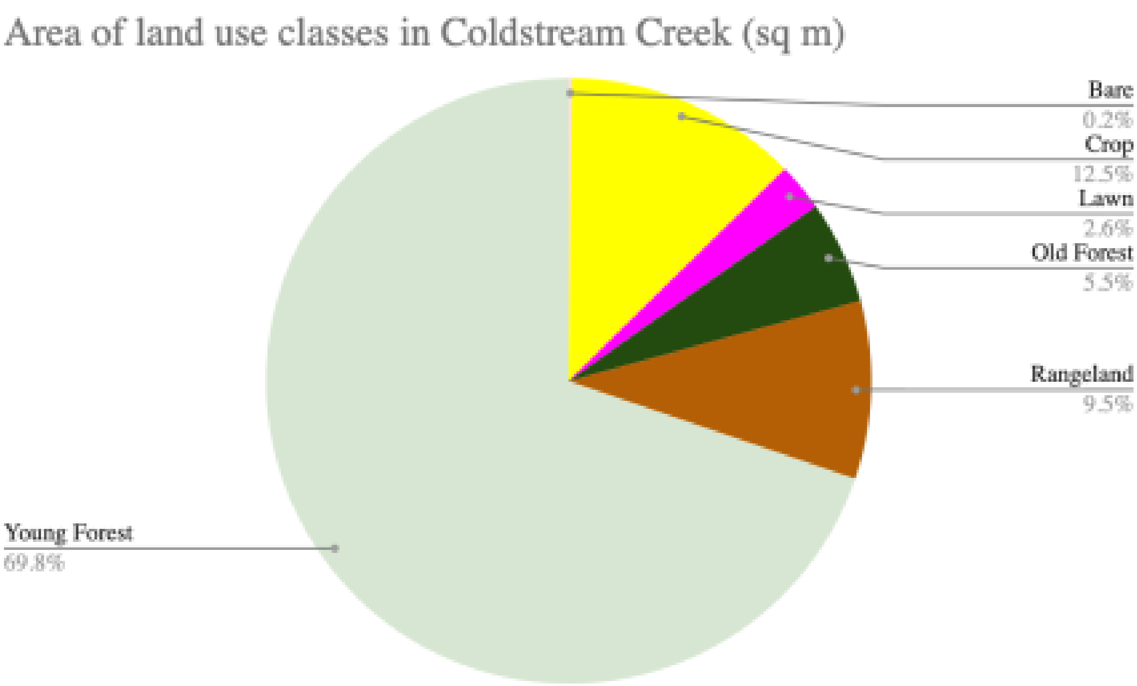

Figure 2. The proportion by area of land use classes in Coldstream Creek.

Alternative Scenario

The proposed alternative scenario is to convert all lawn area into young forest (Fig. 3).

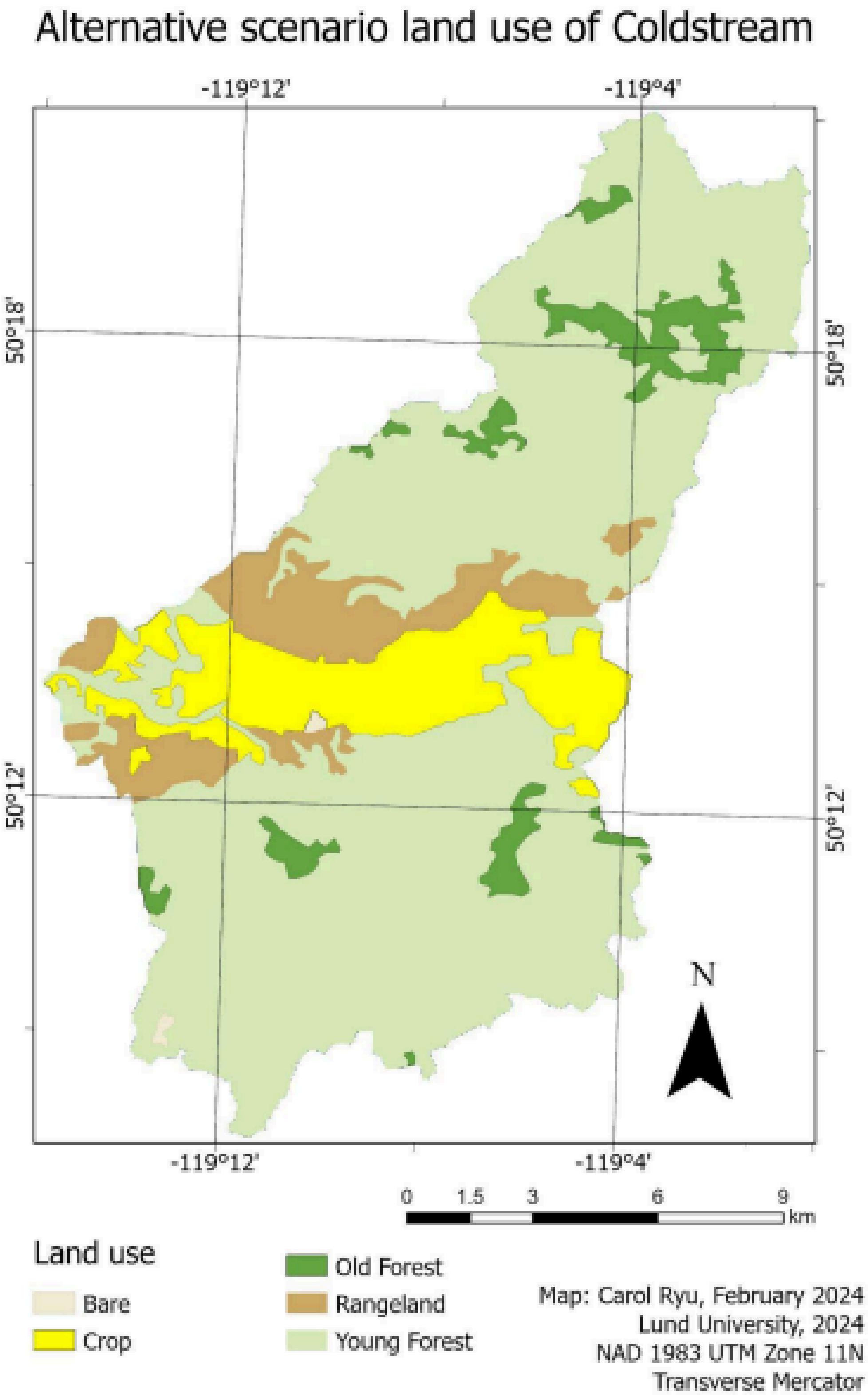

Figure 3. The land use classification of Coldstream Creek in the alternative scenario in which all lawn is converted into young forest.

Were the alternative scenario adopted, the land area of young forest would increase from 146.11 sq km to 151.48 sq km (Table 2). This would increase the proportion of area of young forest to 72.3% of the total area (Fig. 4).

Table 2. The area of land use classes in the alternative scenario.

Land use class Bare	**area (sq km)** 0.41
Crop	26.10
Old Forest	11.56
Rangeland	19.90
Young Forest	151.48

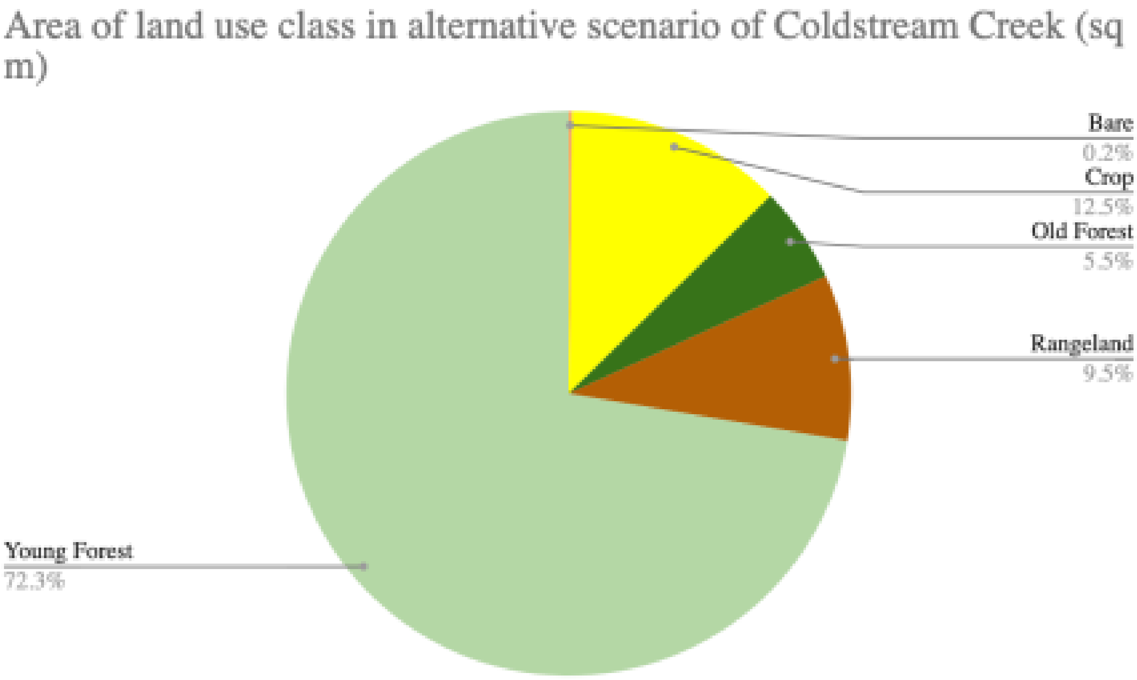

Figure 4. The proportion of the area of land use classes in the alternative scenario of Coldstream Creek were all lawn converted to young forest.

Methodology

Data

-template.coldstream - a RHESSys file used by the script
-DEM raster
-river outlet shapefile
-hillslopes raster
-sunrise and sunset angle DEM rasters
-stratdef, ludef, and vegclass files
-topographic moisture raster
-land use shapefile
-soil texture shapefile

-an ArcGIS toolbox containing a Python script

Spin up run

The RHESSys simulation was run using the worldfile.detcoldstream template file. The following command prompt was input into RHESSys:

> rhessys5.14.8.w32.exe -g -b -w worldfile.coldstream -t tec.coldstream

-*rhessys5.14.8.w32.exe* specifies which program should be run
-*g* specifies that the model should run in grow mode
-*b* specifies basin-level scale
-*w* worldfile.coldstream writes the worldfile
-*t* tec.coldstream specifies the name of the file to be used in the run
-the tec file specifies what period of time the worldstate should include

This simulation ran over 100 years of simulation, which created a new worldfile that has more realistic values than the worldfile.detcoldstream file does. A series of txt files were also outputted, some of which specify the output at the basin scale, since the script -*b* was used in the model.

Natural state run

The newly created worldfile was edited so that specific dates were commanded between 1971 and 1996. A different command was used:

rhessys5.14.8.w64.exe -g -b -h -z -p -c -w worldfile.coldstream -t tec.coldstream

-*h* specifies that hillslope scale
-*z* specifies the zone scale
-*p* specifies the patch scale
-*c* specifies the canopy stratum

Data from December 12, 1989 from the output hillslope.daily file were joined to features created from the run to create a shapefile of the natural state of the region at a hillslope scale. Then, all data from the hillslope.daily file were visualized in graphs.

Then, the model was run again using the newly created worldstate file from the last step with more realistic values. The output contains more realistic results of output in the area between 1971-1996.

Create alternative scenario

The land use shapefile was edited in the attribute table so that all lawn was converted into young forest. This new land use file was used to create stratdef, ludef, and vegclass files, which were used in the simulation to create a new worldstate file, just as before.

Lastly, the simulation was run on this newly created worldstate file to output hydrology values of the area using the new land use across the different scales specified in the command. The command used was:

rhessys5.14.8.w64.exe -g -b -h -z -p -c -w worldfilealtern.coldstream -t tec.coldstream

Data from December 12, 1989 from the output hillslope.daily file were joined to features created from the run to create a shapefile of the natural state of the region at a hillslope scale. Then, all data from the hillslope.daily file were visualized in graphs.

Results

The streamflow of Coldstream Creek from the first spinup run contains less realistic data than the outputs from the following simulations do. Further, the results of this first spinup run output only basin level data, thus are not accurate to compare with the hillslope level results of the following runs. Nonetheless, at the basin level, Coldstream Creek experienced peaks in streamflow roughly every 3 years in the 1970s, then after that, roughly every 10 years (Fig. 5).

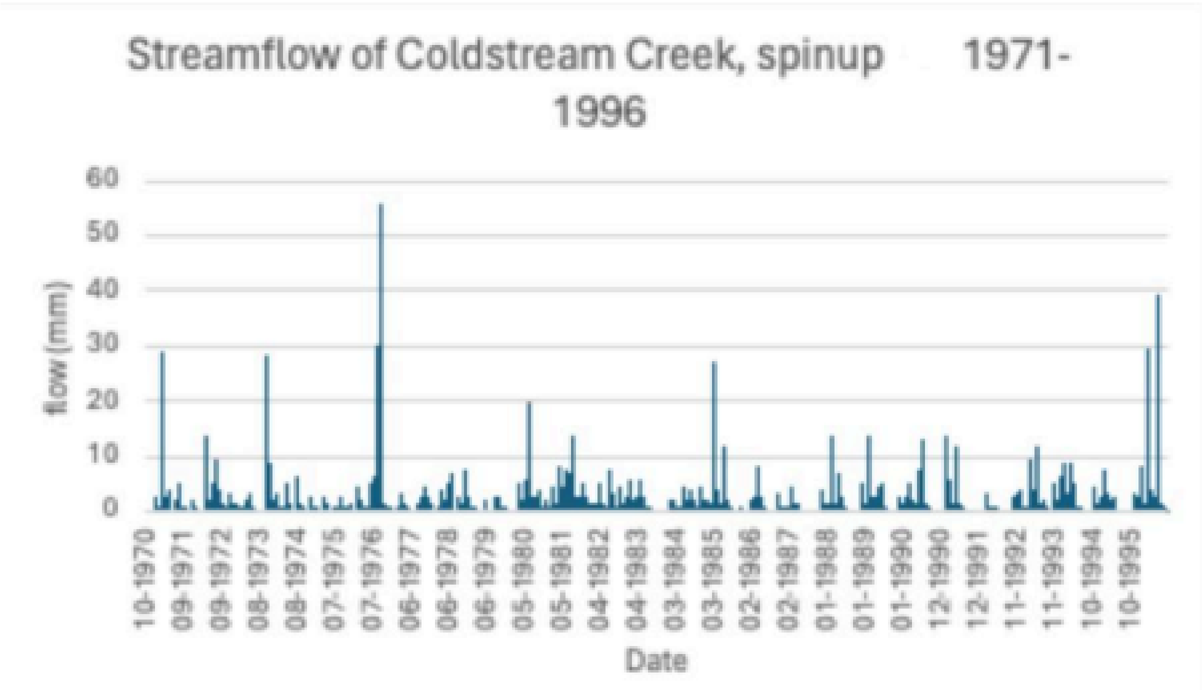

Figure 5. Streamflow of Coldstream Creek from 1971 to 1996 on basin scale from the first spinup run.

The streamflow of the natural state of Coldstream Creek is shown at the hillslopes level. There are peaks in streamflow in 1970, 1976, 1986, and 1995 (Fig. 6).

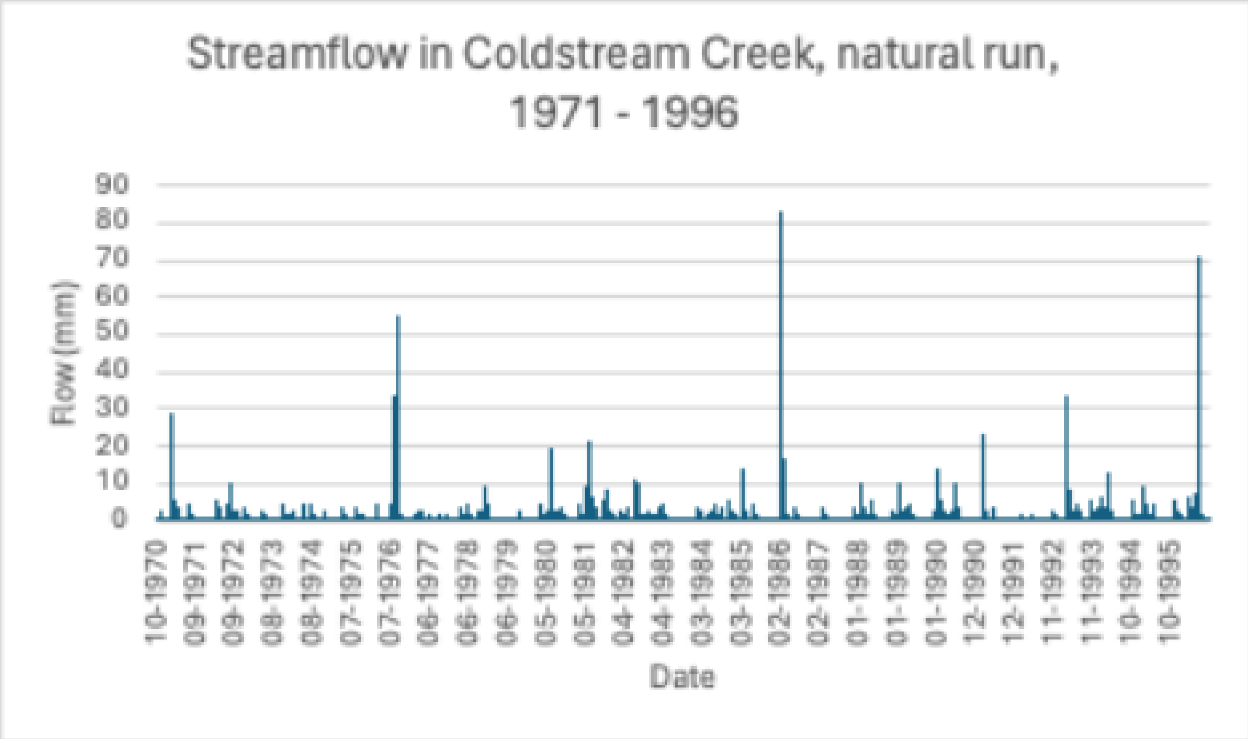

Figure 6. The streamflow in Coldstream Creek between 1971 and 1996 on a hillslope scale from the natural run.

When lawns were changed to young forest, the existing peaks in streamflow were increased in flow volume in 1971 and 1980. Some new peaks in streamflow were created, such as in 1996, while some peaks decreased in flow volume, such as in 1990 and 1992 (Fig. 7).

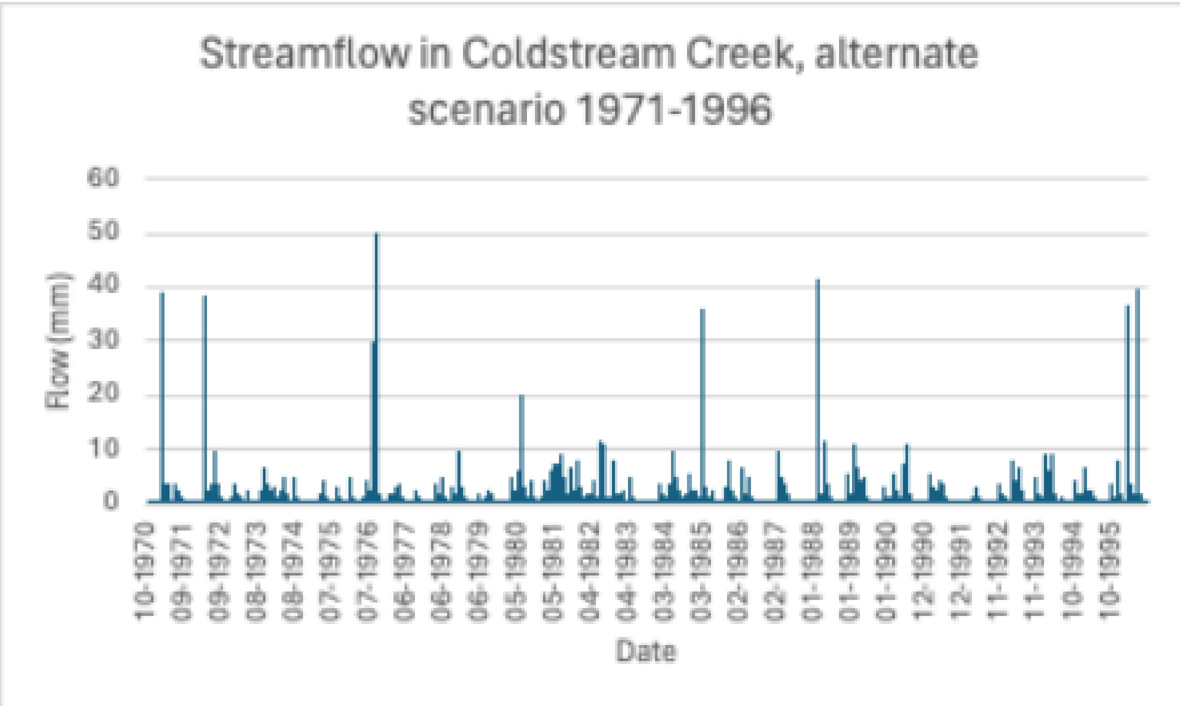

Figure 7. The streamflow of Coldstream Creek on the hillslope scale between 1971 and 1996 in the alternative scenario when lawns are converted to young forest.

The streamflow from the natural run in Coldstream Creek on December 12, 1989 at the hillslopes scale is visualized (Fig. 8). The areas that experience the highest volume of streamflow also are areas that have lawn, cropland, and rangeland. The patches of high streamflow levels in the north coincide with old and young forest areas. There is a small patch of high streamflow in the southern tip that contains an old forest area.

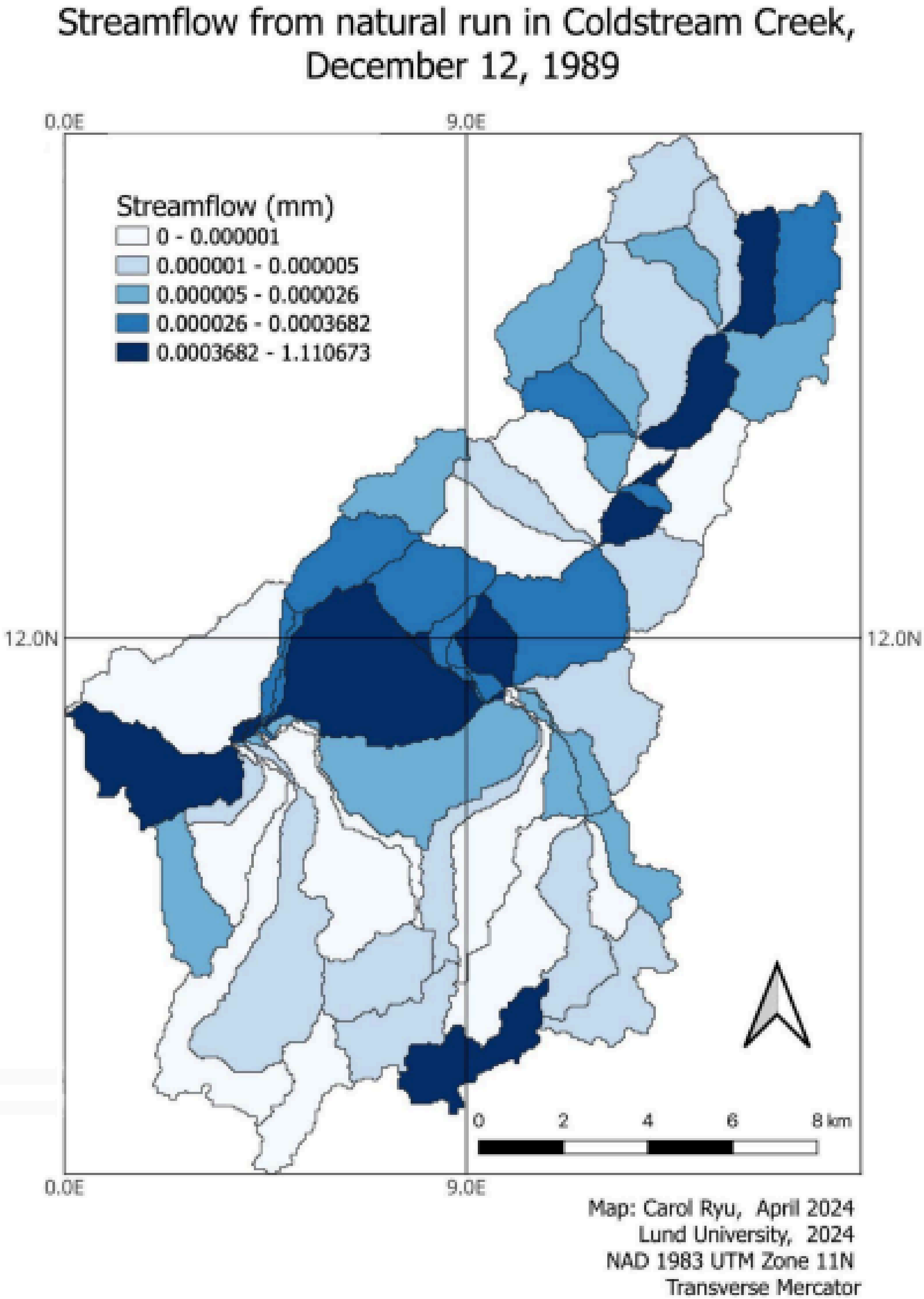

Figure 8. Streamflow from the natural run of Coldstream Creek on December 12, 1989 at the hillslopes scale.

When lawns were converted to young forest, the streamflow levels on December 12, 1989 at the hillslopes scale experienced changes (Fig. 9).

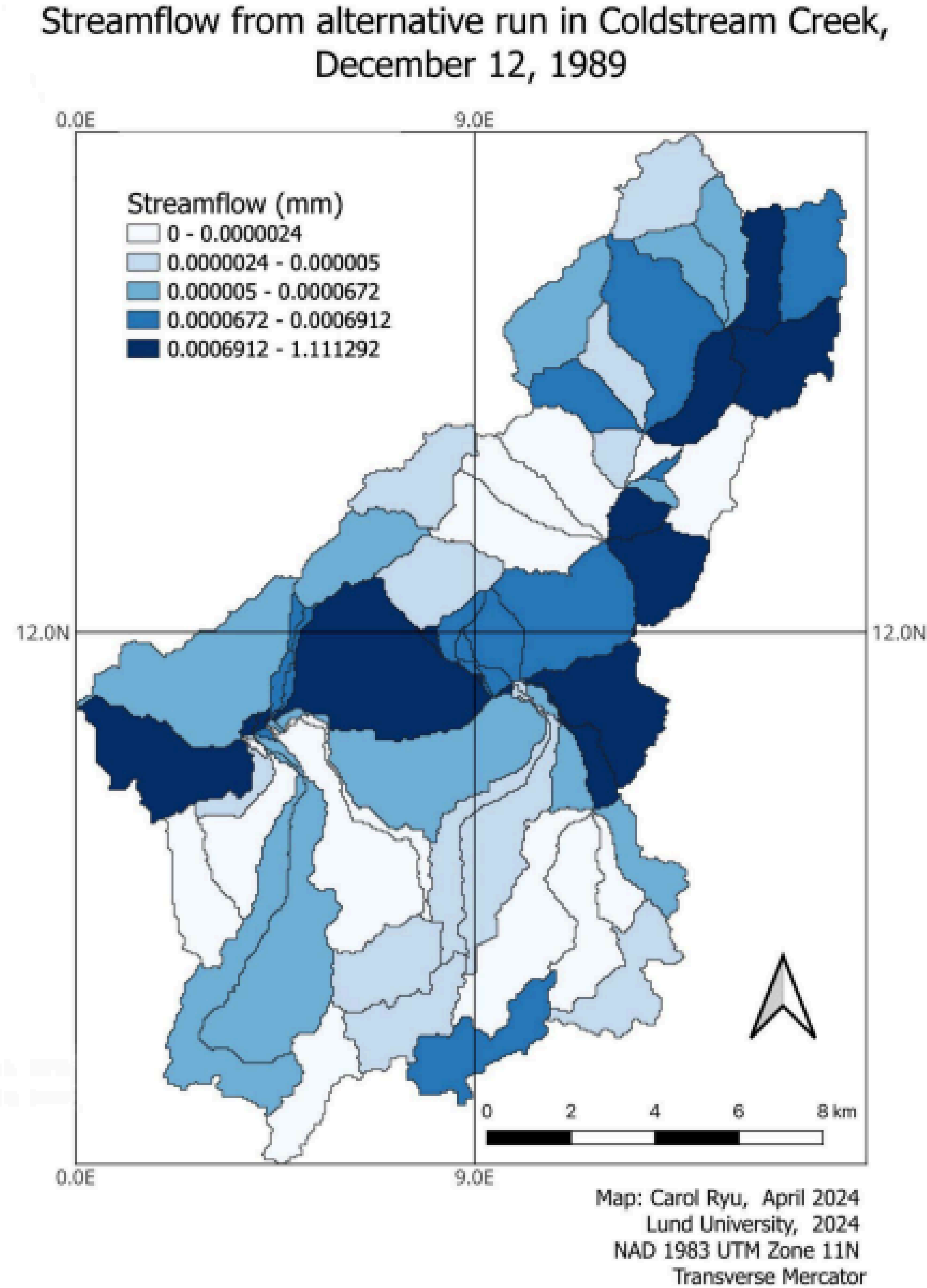

Figure 9. Streamflow from the alternative run of Coldstream Creek on December 12, 1989 at the hillslopes scale.

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The central region containing lawns, cropland, and rangeland, as well as a patch in the north of old forest, experienced the largest increase in streamflow volume when lawns were converted to young forest (Fig. 10).

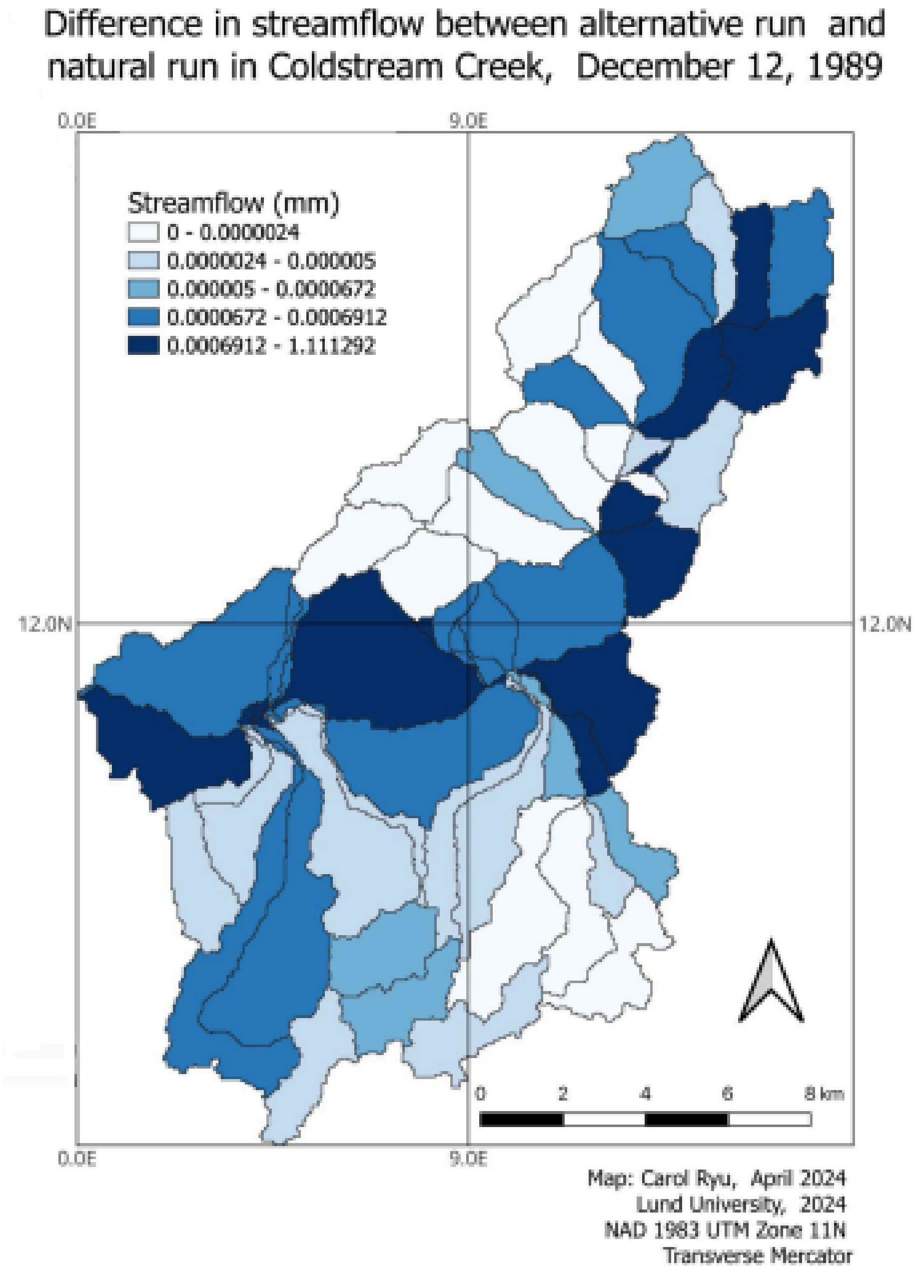

Figure 10. The change in streamflow when changing from the natural run to the alternative run in Coldstream Creek on December 12, 1989 at the hillslopes scale.

Discussion

Despite the small area that lawns inhabit in the region (5 sq km), there was a small increase in streamflow volume when they were afforested and converted into young forest. The increase was seen in all regions that contained lawns and even regions that did not, such as regions in the north. Furthemore, there was a general trend of more peaks of streamflow after the land conversion, though the peaks were less severe in volume. By assessing the output through a hillslope scale, the terrain of the region was taken into account. This is an important factor in hydrology as terrain impacts water transport.

There are several potential reasons for why this conversion may increase streamflow volume, even in areas that lacked lawns before the conversion. The hydrological dynamics of an area are connected, so the impacts are not only local. The increase in vegetation in young forests when converted from lawns can increase evapotranspiration and decrease runoff, impacting water availability (Trabucco et al., 2008). Higher evapotranspiration rates may contribute to water cycling and precipitation, which may contribute more water to the hydrological system. Additionally, an increased ability of forests to retain moisture but reduce surface runoff compared to lawns may contribute to increased streamflow generally, and cause more frequent though less severe peaks in flow volume, creating smoother streamflow patterns in the region.

Conclusion

Afforesting lawns in the Coldstream Creek region alters the hydrological dynamics of the region. After afforestation, the streamflow volume experiences more frequent but less severe peaks. Despite the small area afforested, the hydrological impacts highlight the consequences that even small-scale land use changes can have on local hydroecology.

References

Okanagan WaterWise (2021). Celebrating water wisdom from one of our partners @okwaterwise on this beautiful #waterwisewednesday [Instagram post]. Instagram. https://www.instagram.com/p/C5Y-8B2RsBc/

Trabucco, A., Zomer, R. J., Bossio, D. A., van Straaten, O., & Verchot, L. V. (2008). Climate change mitigation through afforestation/reforestation: a global analysis of hydrologic impacts with four case studies. *Agriculture, ecosystems & environment*, *126*(1-2), 81-97.