The effect of climate and land cover changes on water resource sustainability in the Similkameen River watershed

(Progress Report 3, 2014-1)

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1. Introduction

Forest disturbance (e.g., logging, wildfire, Mountain Pine Beetle infestation (MPB)) and climatic change are recognised as two major drivers influencing water resources in forested watersheds. Understanding how forest disturbance and climate change interactively affect hydrology is critical for managing and protecting water resources. The Similkameen River watershed has been undergoing significant forest disturbances mainly due to MPB infestation and salvage logging. The impacts of this large-scale forest disturbance and climate change on future water supply in the watershed is an important question for water managers and the communities. Our ultimate goal of this project is to assess relative contributions of climate variability and forest disturbance or land cover change to hydrology in the Similkameen River watershed based on historic data, and predict the impacts of future climate and land use changes on water supply. The main objective for Report 3 is to calculate and analyze cumulative equivalent clear-cut area (CECA) for the entire Similkameen River watershed from 1960 to 2011 for subsequent hydrological analyses. The CECA has been recognized as a useful indicator for representing forest disturbance over space and time with consideration of hydrological recovery following any types of land cover changes or disturbances.

2. Progress

a. Annual disturbed area and the cumulative equivalent clear-cut area (CECA) for the whole Similkameen River watershed have been calculated. The detailed calculation method is provided in the Appendix.

b. The logging was the dominant disturbance type in the Similkameen River watershed. The largest logging year happened in 2010 with 1.2% of the total watershed being harvested. The annual average logged area (including areas disturbed by logging, logging+ fire, and logging+ MPB) was 33.8 km^2 (0.44% of the total watershed area) from 1960 to 2011. The large-scale MPB infestation broke out in 2003. The highest annual MPB infested area (MPB and MPB + logging) was 0.47% (35.3 km^2) of the total watershed area in 2005. The wildfire took place occasionally. The largest fire (including fire and fire + logging) occurred in 1998 affected 33.7 km^2, which is 0.45% of the total watershed size.

c. Up to 2011, the CECA for all disturbance types were 42.1% of the total Similkameen River watershed area (3185 km^2). The CECA of logging alone was 19.4% of total watershed area until 2011. The CECA of MPB infestation was largest disturbance type since 2009 with 21.9% of the entire watershed area in 2011. The CECA of MPB was relatively small before 2003 with an average of 0.02% from 1986 to 2002 and then extensively increased to an average of 12.7% for the period of 2003 to 2011. The CECA of fire was relatively small with 0.98% of the entire watershed until 2011.

3. Next steps

a. CECA calculation for sub-watersheds

As the CECA has been calculated for the entire Similkameen River watershed, the next step is to calculate the CECA for all sub watersheds (e.g., Hedley Creek watershed).

b. Hydrological data analysis

The forest disturbance has been analyzed from 1960 to 2011. The relationship between forest disturbance and hydrology will be assessed. The

next report will focus on the effects of forest disturbance on mean flows in selected sub-watersheds in the Similkameen River watershed.

Appendix

1. Biogeoclimatic ecosystem classification in Similkameen River watershed

According to the biogeoclimatic ecosystem classification (BEC) system, the most of the Similkameen River watershed locates in the Interior Douglas Fir (IDF), Engelmann Spruce Subalpine Fir (ESSF) and Montane Spruce (MS) biogeoclimatic zones. Ponderosa Pine (PP) zone can also be found in the watershed. IDF dry cold (IDFdk), IDF very hot (IDFxh), and EESF moist warm (EESFmw) zones are located in the lower elevation of the Simikameen River watershed. With the elevation increasing, the areas are featured with MS dry mild (MSdm), MS moist warm (MSmw), ESSF dry cold (ESSFdc) and ESSF very dry cold (ESSFxc).

The dominant tree species in this watershed include lodgepole pine (*Pinus contorta*), hybrid white spruce (*Picea engelmannii x glauca*) and interior Douglas fir (*Pseudotsuga menziesiiinterior*). Ponderosa pine persists as a climax species on drier sites at the lower elevations. Mixed stands of interior Douglas fir and lodgepole pine are extensive on drier sites at moderate elevations. Lodgepole pine commonly dominates the landscape in the driest regions due to crown fires, while Engelmann spruce, hybrid white spruce (*Picea engelmannii x glauca*), and subalpine fir (*Abies lasiocarpa*) are the dominant climax tree species on the wetter sites at the higher elevations. Trembling aspen (*Populus tremuloides*) is also a widely distributed seral species (BC Ministry of Forests, Lands and Natural Resource Operations, 2012).

2. Calculation of cumulative equivalent clear-cut area (CECA)

2.1. H60 calculation

In the BC interior, H60 elevation is defined as the elevation of snowline when the upper 60% of a watershed is covered with snow. It has been applied to evaluate the hydrological impact of forest harvesting (IWAP, 2006). Snow cover above H60 area

contributes significantly to high flows in the late spring. As such, forest harvesting above H60 are normally recognised to be more influential impacts on high flows in the BC interior (Gluns, 2011; Whitaker et al., 2002). As suggested from IWAP, the disturbed areas above H60 are multiplied by a weighted factor of 1.5 for CECA calculation. As shown in Figure 1, the H60 elevation is 1442 m for the Similkameen River watershed.

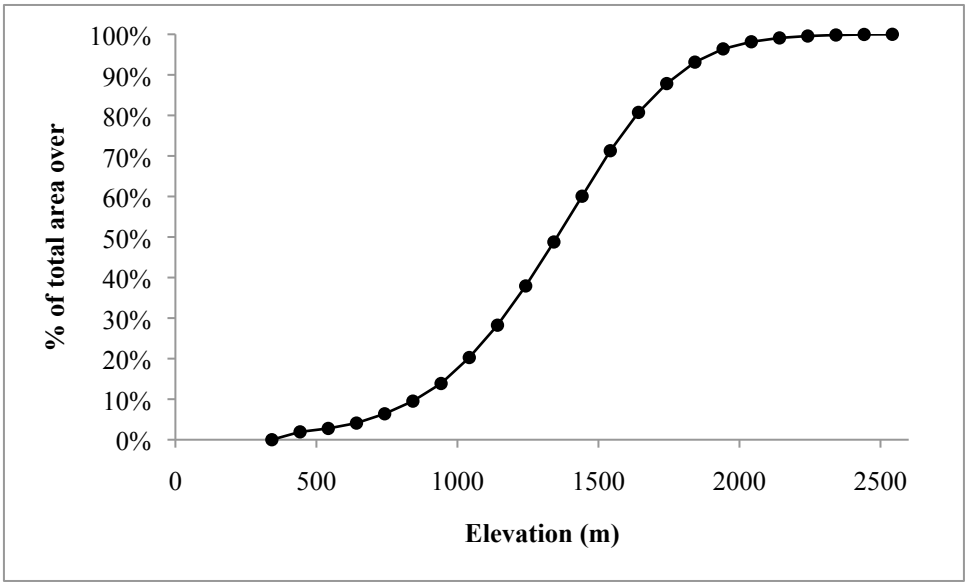

Figure 1 Hypsometric curve in the Similkameen River watershed

2.2. Hydrological recovery and ECA coefficients

Equivalent clear-cut area (ECA) is defined as the area that has been clear-cut, fire-killed or infested by MPB, with a reduction factor (ECA coefficient) to account for hydrological recovery due to forest regeneration. The ECA coefficient of 100% means no hydrological recovery in a disturbed area, while the ECA coefficient of 0% indicates a full hydrological recovery. The cumulative clear-cut area (CECA) is the sum of the annual ECA. However, hydrological recovery of forest stand is determined by various factors, mainly including disturbance type, climate, and tree species. Site index is the most common measure of forest site productivity and forest growth used in British Columbia. The relationship between vegetation growth (expressed by ages and tree height) and hydrological recovery rate was generally used to estimate ECA after logging for different tree species, mainly spruce, lodgepole pine, and Douglas fir forests in the

watershed assessment (BC Ministry of Forests and Rangeland, 1999). Thus, the relationship of the hydrological recovery according to age and height of major tree species were developed based on the site index for the Similkameen River watershed with the dominant site index of 13 (Tables 1 to 3). Then, the ECA coefficients time series for different tree species after logging or fire disturbance and MPB infestation were estimated based on the Interior Watershed Assessment Procedure Guidelines (Figure 2).

Table 1. Hydrological recovery according to age (year) and height (m) of Lodgepole pine forests

Average height of the main canopy (m)	Corresponding age (years)	Hydrological Recovery (%)
0-<3	0-13	15
3-<5	14-19	30
5-<7	20-26	50
7-<9	27-34	70
9-11	35-41	80
11-13	42-51	90
13-15	52-61	95
>15	>72	100

Note: The heights of lodgepole pine are 3, 5, 7 and 9.1m at ages of 5, 13, 20 and 25 years (based on the site index of 13), respectively.

Table 2. Hydrological recovery according to age (year) and height (m) of Spruce forests

Average height of the main canopy (m)	Corresponding age (years)	Hydrological recovery (%)
0-<3	0-25	15
3-<5	26-33	30
5-<7	34-39	50
7-<9	40-45	70
9-11	46-54	80
11-13	55-61	90
13-15	62-70	95
>15	>70	100

Note: (based on the site index of 13)

Table 3. Hydrological recovery according to age (year) and height (m) of Douglas fir forests

Average height of the main canopy (m)	Corresponding age (years)	Hydrological recovery (%)
0-<3	0-11	15
3-<5	9-19	30
5-<7	17-27	50
7-<9	23-33	70
9-11	28-40	80

11-13	34-51	90
13-15	41-62	95
>15	>63	100

Note: Based on the site index of 13

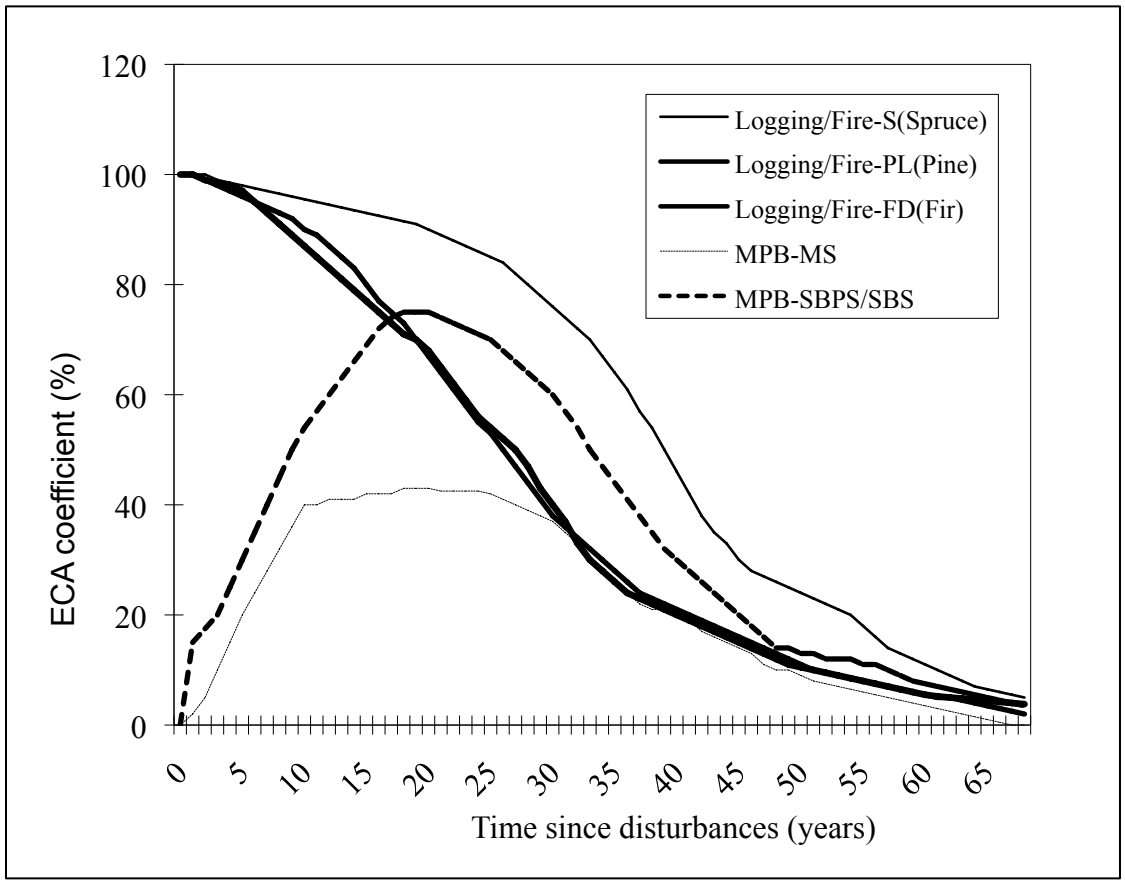

Figure 2. ECA coefficients of different forest disturbance types for the Similkameen River watershed

2.3. Annual disturbed area for Similkameen River watershed

GIS-based data on forest disturbance history for the Similkameen River watershed were obtained from two provincial databases: Cutblocks and Vegetation Resource Inventory (VRI). Both are developed and maintained by the BC Ministry of Forests, Lands and Natural Resource Operations. The Cutblock data includes complete

records of cutblock sizes and logged years, but detailed vegetation information was not recorded. The VRI databases records various disturbances information (e.g., fire, MPB infestation and logging) and detailed vegetation descriptions. However, the logging records are incomplete due to delayed submissions from forestry companies. As such, the overlaid two datasets are complementary to generate complete records on quantitative forest disturbance history for the Similkameen River watershed.

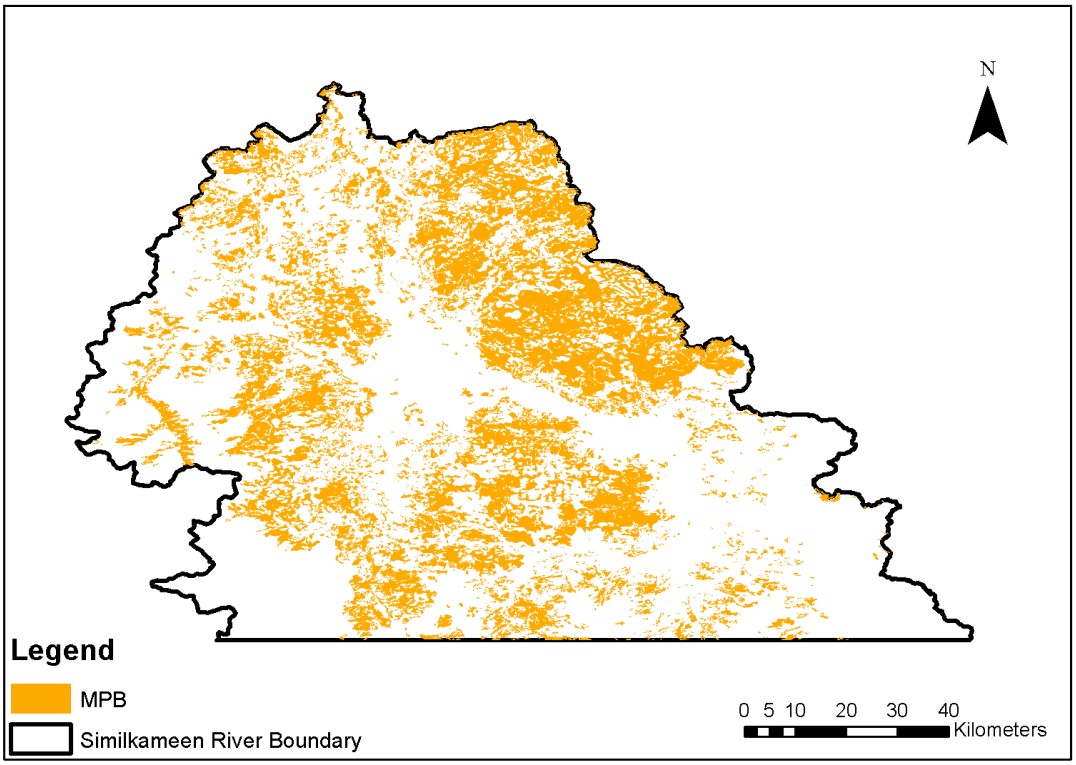

Figure 3. Mountain pine beetle (MPB) infestation in the Similkameen River watershed from 1960 to 2011.

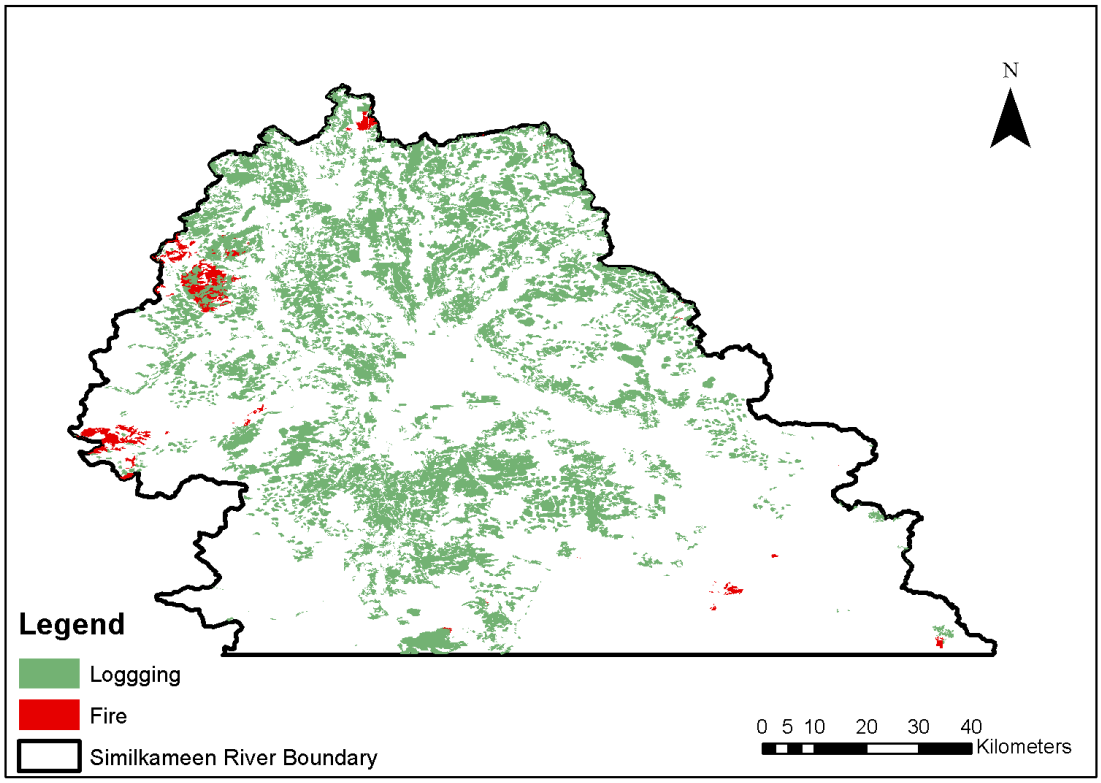

Figure 4. Logging and wildfire in the Similkameen River watershed from 1960 to 2011.

Logging, MPB infestation, and wildfire are considered as three major forest disturbance types in the Similkameen River watershed (Figures 3 and 4). Based on the Vegetation Resource Inventory (VRI) data, a forest stand in the Similkameen River watershed was disturbed by either one type (e.g., logging or fire or MPB) or two types of disturbances (logging + fire or logging+ MPB). Two types disturbances are defined as a forest stand which is first disturbed by one type and then disturbed by another one. For instance, a forest stand disturbed by wildfire first followed by salvage logging. In this case, it is defined as logging + fire. The annual average disturbed area is 36.5 km^2, which is 0.48% of the total watershed area. As shown in Figure 5, logging activities are the leading forest disturbance type with a steady increase. The annual average logging (including logging, logging + fire, and logging + MPB) area is 0.44% (33.4 km^2) of the whole watershed with the largest logging area (1.17%, 89 km^2) in 2010 and lowest logging area (0.08%, 6 km^2) in 1972. The MPB infestation is the second leading disturbance type. The MPB infested area was small before 2003. The highest MPB

infestation occurred in 2005 with the rate of 0.47% (35.7 km^2). The three major fire events (fire and logging + fire) took place in 1984, 1998, and 2001 with the disturbed areas of 0.24%, 0.44% and 0.13%, respectively.

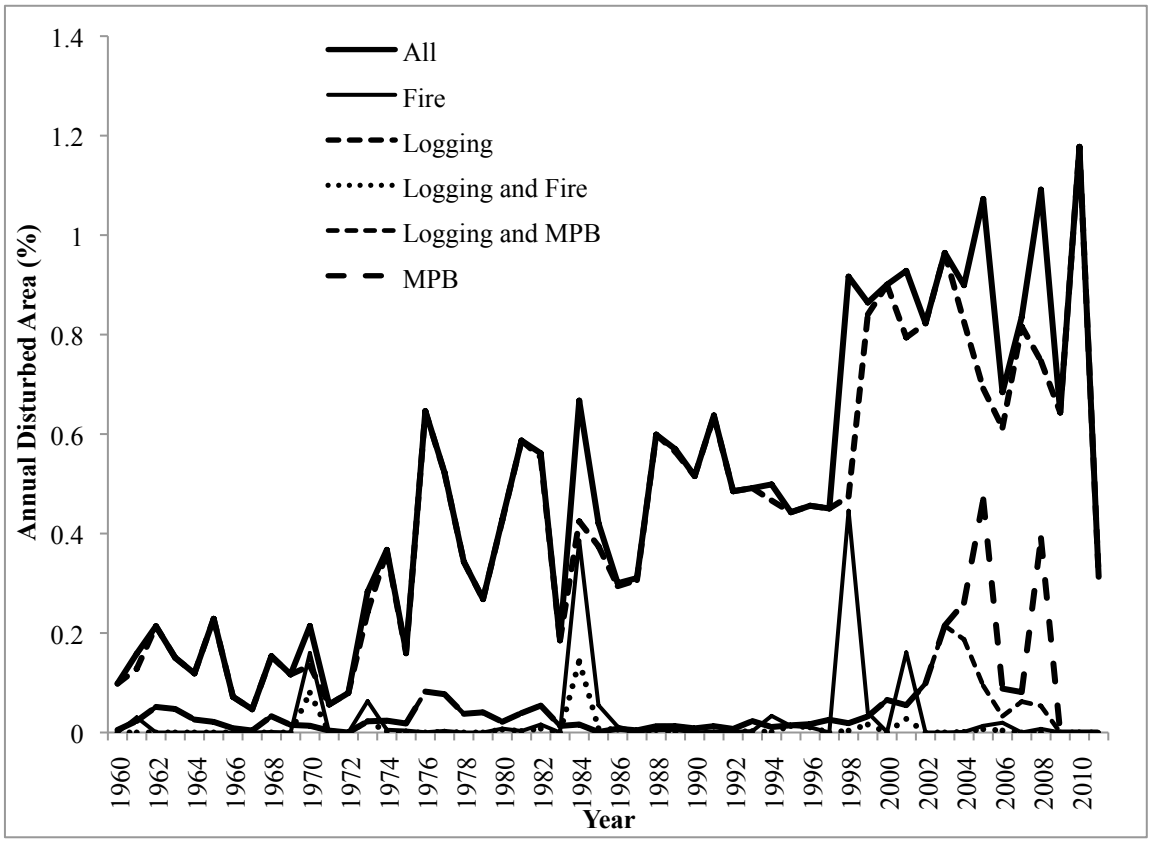

Figure 5. Annual disturbed area of the Similkameen River watershed from 1960 to 2011.

2.4. CECA for Similkameen River watershed

As shown in Figure 6, the cumulative equivalent clear-cut area (CECA) of all disturbance types was 42.1% (3185 km^2) in 2011. The annual average CECA for all disturbance types was 10.8% of the entire watershed from 1960 to 2011. The logging is the leading disturbance type before 2009. Until 2011, the CECA of logging in the Similkameen River watershed was 1431 km^2 (18.9% of the whole watershed area). The average CECA of wildfire was 0.52% from 1960 to 2011. The major three fire events made the CECA jumping from 0.21% in 1980 to 1.21% in 2002. The average CECA of MPB was 2.2% from 1986 to 2011. The large intensive MPB infestation broke out in

2003 with the CECA of 0.05%, and then became the dominant disturbance type after 2009 with the CECA of 18.8%. Up to the 2011, the CECA of MPB was 1655 km^2, which is about 21.9% of the total watershed area. Prior to 2011, the CECA of two types of disturbances (e.g., logging + fire and logging + MPB) are relative small with their CECAs of 0.32% and 0, respectively.

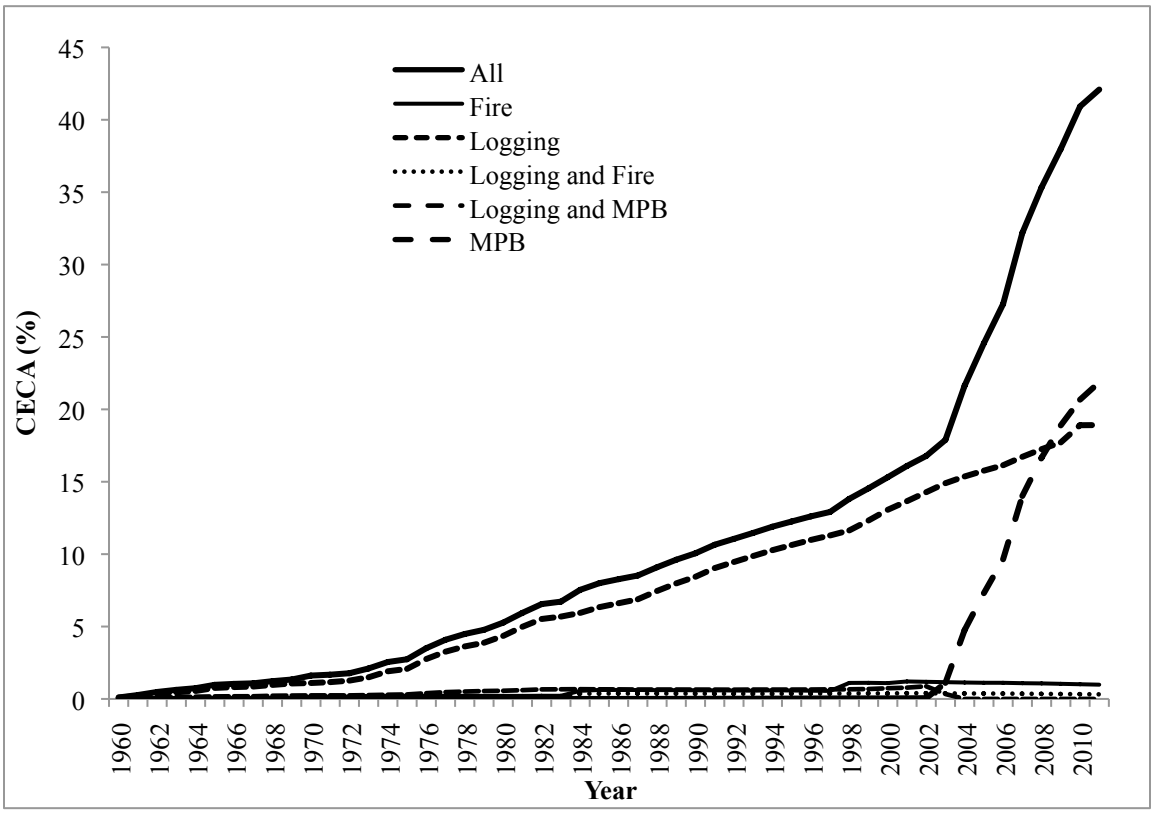

Figure 6. Cumulative Equivalent Clear-cut Area (CECA) in the Similkameen River Watershed from 1960 to 2011.

2.5. Discussion

The CECA of the Similkameen River Watershed is 3185 km^2 in 2011 which accounts for 42.1% of the total watershed area. The uncertainty in association with the CECA calculation may be resulted from the definition and application of H60 snowline for the Similkameen River watershed. It should be noted that the disturbance areas above H60 line were multiplied by the ECA weighted factor of 1.5 in our CECA

calculations. However, for large watersheds like the Similkameen River watershed with total area of 7566 km^2, using the entire watershed to calculate the H60 may lead to some errors. As shown in Table 4, the CECA above H60 line accounts for the large portion (65.7%) of the total CECA. The H60 line for the Similkameen River watershed is calculated as 1442 m. According to the preliminary results, the respective H60 lines of the Tulemeen, Hedley, and Ashnola are 1300, 1705, and 1800m, respectively. This indicates that disturbed areas in Ashnola and Hedley watersheds might be overestimated, while the disturbed areas in the Tulemeen River watershed might be underestimated if the snowline of 1442m was used. This also suggest that an alternative approach is to estimate the CECA from all sub-watersheds and then sum them up for the entire watershed.

Table 4. Summary of CECA and CECA above H60 in 2011 (% of total watershed area).

	Fire	Logging	MPB	Logging + Fire	Logging + MPB	All
CECA	0.98	18.92	21.87	0.32	0.00	42.09
CECA above H60	0.62	10.51	16.86	0.23	0.00	27.61
CECA above H60/Total (%)	63.37	55.58	77.09	72.71	-	65.59

References

BC Ministry of Forests, Lands and Natural Resource Operations, 2012. Biogeoclimatic Ecosystem Classification Program-BEC zone and subzone descriptions.

BC Ministry of Forests and Rangeland,1999. Interior Watershed Assessment Guidebook (Appendix 8) 2nd edition, Victoria, British Columbia, Canada.

Interior Watershed Assessment Procedure (IWAP). 2006. Interior Watershed Assessment Guidebook. Ministry of Forests and Range: Victoria, BC Canada.

Gluns DR. 2001. Snowline pattern during the melt season: evaluation of the H60 concept. In Toews DAA, Chatwin S (eds). Watershed assessment in the Southern Interior of British Columbia: Workshop Proceedings, Pencticton, March 2000. BC Ministry of Forests Research Program: 68–80p.

Whitaker A, Alila Y, Beckers J, Toews D. 2002. Evaluating peak flow sensitivity to clear-cutting in different elevation bands of a snowmelt-dominated mountainous catchment. Water Resources Research 38(9): 1172.