Hydrol. Earth Syst. Sci. Discuss., 9, C1983–C1988, 2012
www.hydrol-earth-syst-sci-discuss.net/9/C1983/2012/

Hydrology and Earth System Sciences Discussions

Interactive comment on "The cumulative effects of forest disturbance on streamflow in a large watershed in the central interior of British Columbia, Canada" *by* M. Zhang and X. Wei

M. Zhang and X. Wei

adam.wei@ubc.ca

Received and published: 2 June 2012

We really appreciate two reviewers' constructive suggestions and great efforts in reviewing this paper. We have addressed all the questions raised by them and corrected editorial errors and improved the quality of all figures as suggested. Our responses to some of their comments are as follows:

1. 2862/06: should clearly identify which watershed ECA values there represent Authors' responses: The ECA values for each forest disturbances categories can be found in Figure 6. To make them clear, we have added more descriptions. "As shown in Fig-

ure 6, cumulative ECA was about 1% in 1975, which was then slowly increased to 10.4% and jumped from 22.4% in 2002 to 62.2% in 2009 due to salvage logging after the large-scale MPB outbreak in 2003. Up to 2009, the cumulative ECA of logging and salvage logging in response to MPB attack were 24.4 % and 22.6%, respectively. The cumulative ECA of MPB attack without logging was 14.8% (Figure 6)."

2. 2863/6&7: given the importance of these coefficients, can some detail be provided on them? Example why is eca $\sim$ 18% in year 1 for sbps/sbs and 78% in year 17? Is transpiration much less important than interception and sublimation in these forest types? How about understory? Authors' responses: We have provided more detailed information on these coefficients, MPB coefficient in particular since most readers may not be familiar with ECA and the hydrological impact of mountain pine beetle infestation. "For MPB infestation, Lewis and Huggard (2010) have developed a model to quantify the effects of MPB infestation on ECA calculation based on their monitoring in different biogeoclimatic zones. Based on their studies and inputs from local forest hydrologists, we also developed relationships between tree ages/height and hydrological recovery in SBPS, SBS and MS biogeoclimatic zones for the MPB killed forest stands. The hydrological impact of MPB infestation on forests is different from that of logging. Since dead trees remain in stands, the hydrological function of dead trees is not completely damaged as removal of trees by logging (Winkler et al., 2008). Moreover, the understory beneath MPB attacked stands and other trees not attached by MPB at overstorey can also intercept and transpire water. Thus, the alteration of hydrology due to MPB infestation was much lower than clear-cut, especially within 1-2 years after attacks. However, as dead trees lose their canopy over time, the hydrological effect of MPB attack is increased and then decreased with regeneration of young trees. For example, the ECA coefficient for the forest stand in SBS/SBPS zone is only about 15% one year after MPB attack and reaches the maximum of 75% in 18-20 years later and then drop to 10% after 60 years (Lewis and Huggard, 2010). Figure 4 provided time series of ECA coefficients for logging, fire and MPB, which was used to estimate ECA data series for each forest stand based on their disturbed area (i.e., annual clear-

cut area) derived from historic disturbance records." We understand transpiration is as important as interception and sublimation. However, there is a lack of long-term and complete information on hydrological alteration due to MPB even from stand-level studies. These ECA coefficients have taken into accounts of transpiration, evaporation, interception and sublimation. They are generated by stand-level experimental studies and professional judgements. Hopefully, with more long-term site studies on the hydrological changes after forest disturbances, especially mountain pine beetle infestation, we are able to have better extrapolation of the stand-level information to large watersheds. ECA coefficient for MPB has taken understory vegetation into accounts. More details can be found in Lewis and Huggard's (2010) paper. Lewis, D. and Huggard, D.: A model to quantify effects of mountain pine beetle on equivalent clearcut area, Streamline Watershed Manag. Bull., 13(2) , 42-51, 2010

3.2872/27, Is this true? Some of the earliest forest hydrology studies identified higher summer low-flow conditions after harvesting. Authors' responses: We understand low flows can be increased after harvesting according to some earliest studies. This can be the case in watersheds where soils are not severely damaged so reduced ET as result of harvesting can retain more soil water and thus higher low flows in low flow seasons (e.g., summer). However, low flows can be decreased after harvesting of cloud forests at higher elevations in some coastal mountains where fog drips intercepted by forest canopy from the air serve as an important source for precipitation in summers. Reduction in precipitation input accordingly decreases the runoff. More details are provided in the review paper by Bruijnzeel (2004). Moreover, for some rainfall-hydrology dominated watersheds where low flows occur in winters and peak flows in summers, low flows are expected to decline after forest harvesting (Calder, 2005). A case study in the Upper Minjiang River of Yangtze River basin can support this point (Zhang et al., 2012). In that watershed, low flow is maintained by groundwater discharge and soil water storage from wet seasons. During rainy seasons, reduction in forest canopy interception, evapotranspiration and soil infiltration after harvesting transferred more rainfall into surface and subsurface runoff and consequently more streamflow in rivers. The soil moisture was estimated to decrease by 36% after harvesting in that watershed. The dramatic decline in soil water storage in wet seasons greatly reduced available water for low flow in the dry season due to less groundwater recharging. That demonstrates the forest sponge effect that absorbs and holds huge quantities of wet season rainfall and releases the stored rainfall in dry seasons is expected to be damaged after harvesting. Accordingly, low flows were decreased after harvesting in the Upper Minjiang River of Yangtze River basin. Bruijnzeel, L.: Hydrological functions of tropical forests: not seeing the soil for the trees? , Agric. Ecosyst. Environ., 104(1), 185-228,2004. Calder, I.R.: Blue revolution – integrated land and water resources management, 2nd ed., Earthscan, London, UK, 2005. Zhang, M., X. Wei, P. Sun and S. Liu (2012), The effect of forest harvesting and climatic variability on runoff in a large watershed: the case study in the Upper Minjiang River of Yangtze River basin, Journal of Hydrology(in press)

4. 2876/02: given the variety of literature you provided and your own findings... what is the safe level? Is it for all watersheds? Authors' responses: The safe level varies among watersheds. Previous paired watershed studies suggest 20% is the threshold for detecting significant hydrological change in small watersheds (less than 100 km2). Currently, the safe level for large watersheds (>1000 km2) is very difficult to determine due to several reasons. First, large watershed studies are too limited to derive a forest disturbance threshold. Secondly, different studies use different indicators to express forest disturbance and normally focus on a single type of disturbance, which make it impossible to compare disturbance levels among different large watersheds. Third, the hydrological response of forest disturbances are watershed-specific, which can be affected by watershed attributes including geology, topography, vegetation, land use and land cover. According to our own findings, the safe levels for the Willow River watershed and the Baker Creek watershed in B.C. interior can be 20-25% while for the Bowron River watershed it can be above 30%. Thus, more case studies are needed to determine the thresholds of ECA for significant hydrological changes.

Please also note the supplement to this comment:
http://www.hydrol-earth-syst-sci-discuss.net/9/C1983/2012/hessd-9-C1983-2012-supplement.pdf

---

Interactive comment on Hydrol. Earth Syst. Sci. Discuss., 9, 2855, 2012.

HESSD

9, C1983–C1988, 2012

Interactive Comment

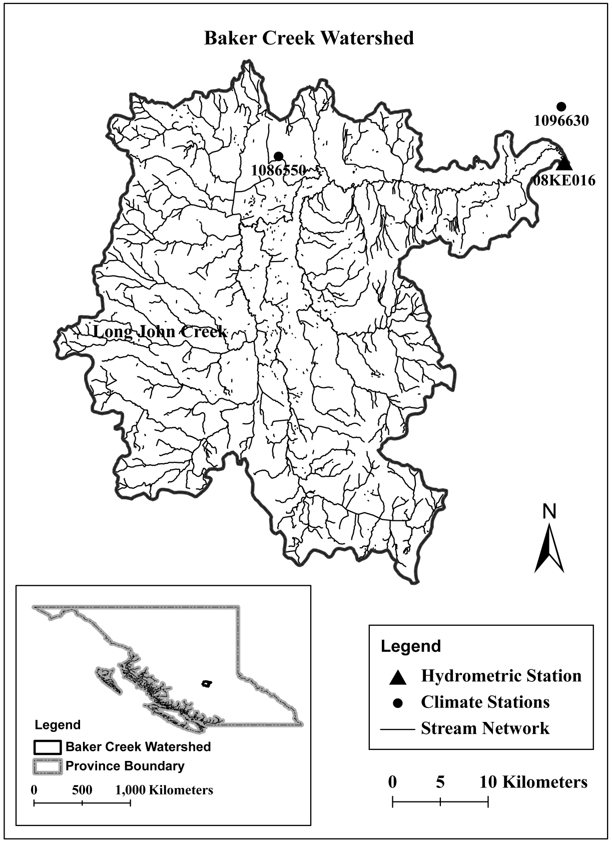

Fig. 1. Location of the study watershed in the central interior of British Columbia, Canada

HESSD
9, C1983–C1988, 2012