Trends in wildfire burn severity across Canada, 1985 to 2015

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Supplementary Material 4

SM 4. Detecting post-fire salvage logging

The two z-score analysis were carried out as follows. First, we developed training and validation datasets based on 30 fires that occurred between 2002 and 2010 in which salvaged logging had been identified in the Landsat mosaic and was confirmed by the provincial database (Ministère des forêts de la faune et des parcs du Québec, https://www.donneesquebec.ca/recherche/fr/dataset/carte-ecoforestiere-avec-perturbations/resource/f7971e71-def1-4269-9536-d73517829d14). Within each fire, an analyst manually delineated five polygons that were salvage logged or not salvaged, for a total of 300 polygons with 50% of them salvaged and 50% not salvaged. We randomly selected polygons from 20 fires (59% of the pixels) for training and polygons from remaining 10 fires (41% of the pixels) for validation. We calculated the means and standard deviations for the salvaged pixels from the pre-and post-fire Landsat composites for bands 3, 4, 5, and 7 required to perform our two z-score analyses. An analyst then evaluated the best combination of threshold values based on his observation of Landsat imagery to be able to detect the areas where post-fire salvage logging had taken place. A positive classification corresponded to values of the two z-score below each selected threshold. The values of mean and standard deviation of reflectance were calculated across the pixels within the training set (Table S4.1).

The following Z-score formula was adapted from Huang et al. (2010) using Z value of each band:

$$Zbx = 0.25 * [(bx_v - bx_m)/Bx_s)]^2$$

Where Z value for a given Landsat band Bx, x =3,4,5, or 7, is calculated from the mean (m underscript) and standard deviation (s underscript) values as in Table S4.1 along with the actual pixel value (v underscript) of four Landsat bands B3, B4, B5 and B7. Z-score was calculated as follows:

Z-score= 10 * (Zb3 + Zb4 + zb5 + zb7)

Three thresholds of Z-score for each class were tested (5, 10 and 15) and evaluated by an analyst. The selected thresholds were of 15 for the non-salvaged pixels and of 10 for the salvaged pixels. A pixel was designated as salvaged if both z-score values were below those thresholds. The application of these thresholds provided an overall accuracy of 83% and a kappa of 66% based on the validation set (Table S4.2). In order to avoid any false detection of salvage in northern areas, where rocky areas could be confused with salvaged areas, a mask was manually delineated using the series of Landsat mosaics from 1985 to 2015 and *CanLaD* to locate harvesting activities with Landsat-based visual confirmation of new roads within fire perimeters.

<u>The following limitations in our approach apply:</u>

- Salvage logging is detectable mostly due to the disturbances to soil cover from harvesting machinery.
- Winter salvage could not be detected due to lack of such soil cover disturbance.
- Salvage mask only considers the year after the fire and may miss subsequent salvage operations.

Therefore, this mask layer should not be considered as salvage logging detection tool.

Table S4.1. Mean and standard deviation values used to compute the Z-score values for pre- and post-salvage conditions.

	Pre-salvage		Post-salvage	
Landsat 5-7 Band	**Mean (m)**	**Std (s)**	**Mean (m)**	**Std (s)**
B3	278.4841	121.1584	676.3447	169.6708
B4	1839.0676	365.3447	1456.5572	253.4981
B5	920.9541	332.3372	2316.8939	363.5138
B7	435.8769	195.7674	1855.5038	349.1989

Table S4.2. Number of pixels in the **Salvaged** and in the **Not salvaged** classes in the training dataset and in the prediction results. Also shown are the overall detection accuracy and the Kappa statistic.

		Predicted classes		
	NB pixel	**Not salvaged**	**Salvaged**	**Total**
Training	**Not salvaged**	2098	107	2205
	Salvaged	692	1803	2495
	Total	2790	1910	

Overall Accuracy : 83%

Kappa : 66%

REFERENCE

Huang, C., Goward, S. N., Masek, J. G., Thomas, N., Zhu, Z., and Vogelmann, J. E. 2010. An automated approach for reconstructing recent forest disturbance history using dense Landsat time series stacks. Remote Sensing of Environment **114**(1): 183-198.