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Analysis of Channel Morphology and Large Wood Characteristics Through Remote Images in the Blanco River After the Eruption of the Chaitén Volcano (Southern Chile)

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Abstract

Volcanic eruptions drastically affect fluvial systems, modifying channel morphology and processes of supply and transport of sediment and wood material, destroying vegetation and reducing infiltration rates on hillsides. This work aims to study the morphological changes and the distribution of large wood (LW) material along the Blanco River after the eruption of the Chaitén volcano in May 2008 using aerial and satellite images. Four different images from pre and post-eruption conditions were used: a satellite image from 2005, an aerial one from 2009, and two satellite images from 2012 and 2013. To assess river morphology, the active channel was digitized in all the images; and LW assessment was carried out by digitizing every individual element as polyline and wood jams as polygons. Results showed a general increase in the channel width, being the most notable change between 2005 and 2009. The same occurred in the case of LW supply, both individual elements and wood jams within the active channel increased significantly between 2005 and 2009 but there were no statistically significant differences comparing 2009, 2012 and 2013 images. This drastic event provided an opportunity to study post-eruption situation in the Blanco River, and with the results obtained it was possible to verify that the shape of the channel and presence of LW were strongly affected by the volcanic eruption.

Keywords

Chaitén volcano • Channel morphology • Large wood • Remote images

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77.1 Introduction

The plinian eruption of the Chaitén volcano (Southern Chile) initiated on May 2nd 2008 (Lara 2009; Major and Lara 2013) severely affected the fluvial corridor and the riparian forests of the Blanco River (Major et al. 2013; Swanson et al. 2013). Pyroclastic flows, landslides and lahars caused by the partial collapse of the dome and the eruption column, and by the seismic activity (magnitudes between 3 and 5 Mw), generated volcanic material deposits which reached up to about 8 m high in the Blanco River valley, and damaged (destroyed) more than 400 km^2 of forest adjacent to the volcano. Precipitations after the eruption mobilized large volumes of material downstream, generating from May 11th 2008 an elevation of the bed of the Blanco River at Chaitén city that reached a height of 7 m on the 14th of that month. Subsequently, a new pyroclastic flow originated in February 2009 moved up to 7 km downstream from the volcano dome.

To date, the effects of natural disturbances and especially of volcanic eruptions have been little studied in forested watersheds of Southern Chile. Therefore, the vulnerability of these watersheds to the spectrum of disturbance processes and the hydrologic and geomorphic responses are not well understood.

Volcanic eruptions cause the most drastic changes in fluvial systems. They modify channel morphology, supply and transport processes of sediment and wood material, destruction of vegetation, and reduction of infiltration rates on hillsides. They also produce an increase of mass movement, which can fill the valleys with sediment, modify watershed divides, alter drainage patterns and change the size, shape and structure of the channel. After an eruption channels suffer complex filling cycles such as simplification of their structure, incision, aggradation and widening. Incision and aggradation processes can occur at scales of tens of meters, and changes in width at scales of hundreds of meters, in periods of time that can range from several months to very short cycles corresponding to a storm; whereas channel recovery involves morphological changes that can persist for decades after the eruption (Major et al. 2000; Hayes et al. 2002).

Large wood (LW) influences channel morphology and sediment transport. For instance, they increase channel roughness, generating a decrease in the energy required for sediment transport and riverbed and banks erosion, resulting finally in a greater stability of the channel (Piegay and Marston 1998). In large rivers wood can have important effects on shape and dynamics of the channel margin. In volcanic eruptions, the post-eruption adjustment of morphology, structure and channel shape in plan view in low order channels is governed mainly by the interaction between large wood and the channel. However, research on large wood effects on channels affected by volcanic eruptions is scarce, with the exception of the work carried out by Lisle (1995).

The aims of this study are to investigate the morphological changes and the redistribution of large wood (LW) along the Blanco River after the 2008 Chaitén volcanic eruption.

77.2 Materials and Methods

A segment of 6.5 km-long characterized by a low longitudinal slope (1.3 %) was divided into 7 individual reaches and numbered from downstream to upstream. Reach length ranges from 620 to 1,220 m, which correspond to lengths of approximately 15–40 times the width of the original channel.

Different aerial and satellite images were used: one from before the eruption (0.6 m spatial resolution) and three from 2009 (0.5 m spatial resolution), 2012 and 2013 (0.6 m spatial resolution). The research focuses on identifying and studying the evolution of the morphologic changes represented by the typology and channel geometry in a plan view, and the amount of large wood and its distribution along a 6.5 km-long segment of the main channel of the Blanco (or Chaitén) river basin. The Blanco River (total catchment area of ~70 km^2) flows into the Pacific Ocean through the city of Chaitén, which is located about 254 km south of Puerto Montt, capital of the Lakes Region, Chile.

The width of the active channel plus active floodplain was digitized in the four images. In the 2005 image, the width corresponds to the distance between the lines of the riparian forest in both sides of the channel. In the images of 2009, 2012 and 2013, the width of active channel plus active floodplain was delimited by terraces high enough to be inundated at the time the aerial images were collected (hereon active channel). Besides, the classification of channel types was carried out considering the sinuosity and braiding indices, according to Rinaldi et al. (2010).

Wood elements within the active channel along the 6.5 km-long river segment were identified in every image by digitizing every individual wood element as polyline and the wood jams as polygon. Subsequently, a comparison of the number of LW individual elements and jams observed in every image and an analysis of LW longitudinal distribution and morphologic changes were carried out. Given the resolution of the images, it was not possible to identify LW with lengths between 1 and 3 m, as it was not possible either to obtain diameter dimensions, so the volume of wood material was not calculated. For each year and each reach, the spatial density of wood material was calculated, in number of individual elements and number of jams per kilometer of channel length and per active channel area.

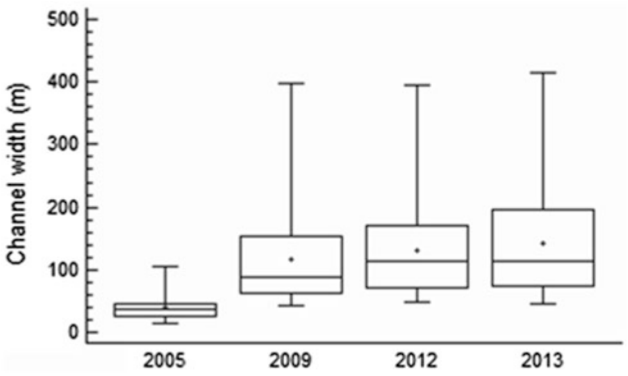

Fig. 77.1 Active channel width in the study segment for the four periods

Some relationships were also performed between morphological characteristics and evolution (active channel width and sinuosity) with LW redistribution variables (No. of large wood km^{-1} and No. of log jams km^{-1}).

77.3 Results

Considering the 6.5 km segment of low gradient, the Chaitén Volcano eruption resulted in significant changes in channel morphology. Channel width increased significantly ($P < 0.001$) between the 2005 pre-eruption period and the 2009 posteruption condition, increasing from 40 to 118 m respectively (Fig. 77.1). Then, between 2009, 2012 and 2013 there were no significant changes in the mean channel width, (mean width of 118, 131 and 142 m respectively). Minimum and maximum widths in 2005, 2009, 2012 and 2013 are 15, 43, 46 and 48 m and 105, 397, 399 and 414 m, respectively.

Before the eruption, the entire study segment featured a single channel, and 4 out of 7 reaches were wandering and 3 reaches were straight. In 2009, which is the closest photo available after the volcanic eruption, 3 reaches featured a braided (multiple channels) pattern. By 2012 and 2013, the channel geometry was more similar to the pre-eruption condition with the most reaches wandering, and the river returned to a single channel pattern (Table 77.1).

Pyroclastic flows and lahars caused the destruction of vegetation along the entire fluvial corridor, increasing the amount of dead wood in the Blanco River channel. As a result of this, the total amount of large wood elements within the active channel increased significantly ($P < 0.001$) between 2005 and 2009, which did not occur in the following periods. The total number of individual elements was 16, 512, 528 and 777 (5, 77, 81 and 112 in Nº km^{-1}) for the years 2005, 2009, 2012 and 2013 respectively. Considering that only LW longer than 3 m were identified, the amount of wood could have been underestimated. On the other hand, there were no jams in 2005 and the total number of jams was 271, 289 and 340 (42, 40 and 47 in Nº km^{-1}) for the years 2009, 2012 and 2013 respectively. Lisle (1995) also reports abundance of wood elements in channels affected by pyroclastic flows at Mount Saint Helens.

Table 77.2 shows the relations among LW distribution characteristics as dependent variables and channel morphology features as independent variables. Overall, the longitudinal distribution of LW and log jams is statistically significant related to channel sinuosity.

The distribution of large wood along the study channel was heterogeneous, being found, for example, between 17 and 150 individual elements and between 3 and 99 log jams per kilometre at reach level in post-eruption periods. Both individual elements and log jams showed positive and

Table 77.1 Morphologic characteristics of the study reaches

Reach	Length (km)	Slope (%)	Sinuosity index				Braiding index			
			2005	2009	2012	2013	2005	2009	2012	2013
1	1	0.76	1.04	1.06	1.05	1.04	1	1	1	1
2	1.2	0.58	1.22	1.32	1.36	1.52	1	1.8	1	1
3	0.7	1.71	1.05	1.01	1.02	1.10	1	2	1	1
4	1	1.12	1.29	1.26	1.31	1.28	1	2.3	1	1
5	0.7	1.28	1.28	1.7	1.38	1.33	1	1.1	1	1
6	1.2	2	1.45	1.09	1.2	1.21	1	1.1	1	1
7	0.6	2.5	1.07	1.17	1.07	1.09	1	1.2	1	1
Total	6.4	1.3	2.25	1.28	1.27	1.31	1	1.5	1	1

A positive yet not statistically significant relationship relates the change rates of channel width with sinuosity. Major changes occurred between 2005 and 2009 than from 2009 to 2012 and 2012 to 2013 (Fig. 77.2)

Table 77.2 Relations between variables of LW distribution by reach and morphologic channel variables

			Sinuosity			Channel width (m)		
			2009	2012	2013	2009	2012	2013
Number of Log jams	Nº Km^{-1}	2009	y = 109.9x + 93.1; R^2=0.6; P<0.04			R^2=0.12; ns		
		2012		y = 138.7x + 126; R^2=0.8; P<0.00			R^2=0.01 ; ns	
		2013			y = 141.4x + 125; R^2=0.7; P<0.02			R^2=0.0; ns
Number of LW elements	Nº Km^{-1}	2009	R^2=0.26; ns			y = 0.5x + 9.5; R^2=0.63; P<0.01		
		2012		y = 193.5x - 150.8; R^2=0.5; P<0.08			R^2=0.3; ns	
		2013			y = 177x - 104 R^2=0.45; P<0.09			R^2=0.1; ns

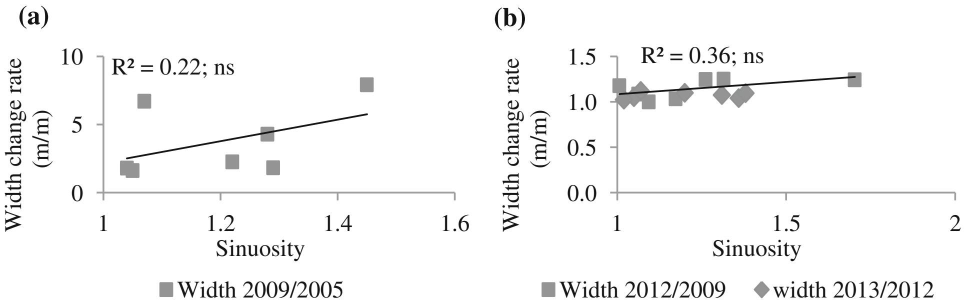

Fig. 77.2 Relations between change rates of the maximum channel width per reach and sinuosity, for the periods 2009–2005, 2012–2009 and 2013–2012. **a** shows channel width 2005/2009 v/s sinuosity 2005 and **b** shows channel width 2012/2009 v/s sinuosity 2009 and channel width 2013/2012 v/s sinuosity 2012. ns, indicates a non-significant relationship

significant relationships with channel sinuosity, width and cumulative area.

77.4 Conclusions

The Chaitén volcanic eruption provides a rare opportunity to study posteruption landscape adjustments in southern Chile. Through the analysis of a sequence of remote imagery it was possible to verify that the shape of the channel was strongly affected by the volcanic eruption. Overall, the greatest changes in terms of channel morphology and LW amount occurred between the eruption and year 2009.

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