Investigation of Sediment Characteristics Changes in the Lower Reach of Progo River Due to Debris Flows after Merapi Eruption in 2010

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1. Introduction

After Merapi eruption in 2010, huge produced material from the eruption was deposited in surrounding the volcano. When the high intensity of rainfall occurred, the material would be flowed down by debris flows. The debris flows took place frequently in almost rivers originated in the volcano and then, they flowed down to the Indonesian sea through main rivers. One of the main rivers is Progo River. River bed material in lower of Progo River would be affected by the debris flows. Therefore, it is important to investigate riverbed material condition due to debris flows after Merapi eruption in 2010. The aim of this research is to compare the characteristics of riverbed material in lower of Progo River, before and after Merapi eruption in 2010.

2. Method

The research compared grain size of riverbed material and changes on the river flow before and after the Merapi eruption in 2010 on several selected locations. Mean diameter of grain size was used to describe the riverbed material conditions. The selected locations are in Srandakan Bridge, Sapon, Bantar Bridge, Kebon Agung Bridge I, Kebon Agung Bridge II and Progo-Putih conjunction. The research location was shown in **Figure 1**.

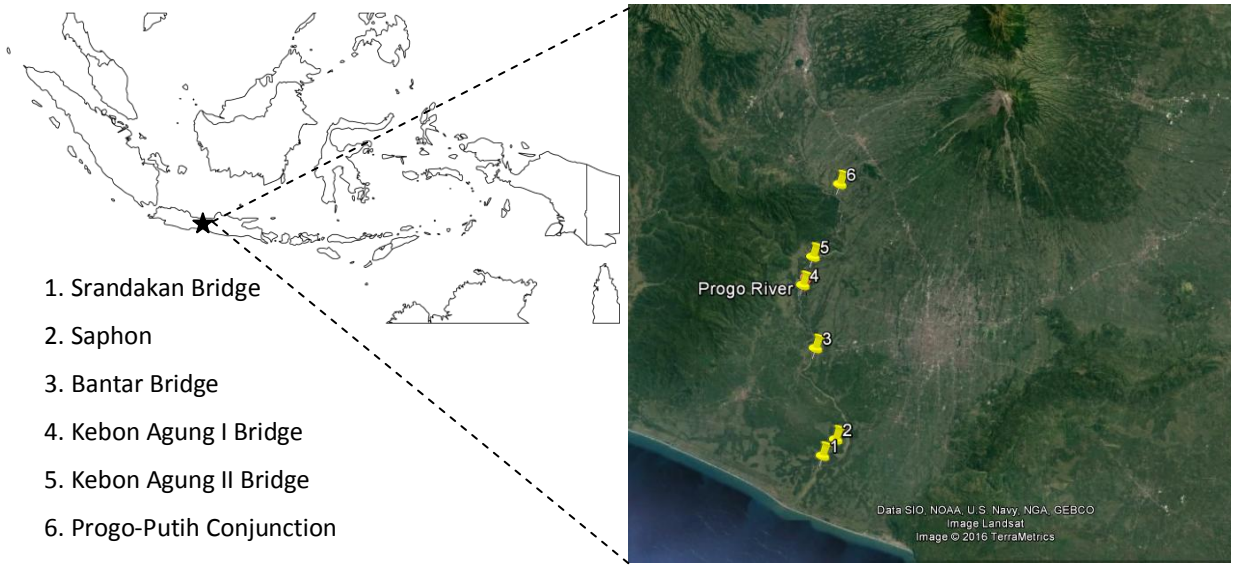

Fig. 1. The research location in Progo River, Indonesia

3. Results and Discussions

3.1. Grain Size of Riverbed Material

The grain sizes of riverbed material at the selected locations are shown in Table 1 as follows:

Tab 1. Mean diameters of riverbed material (D50) at the selected locations

Location	1999 (mm)	2009 (mm)	2012 (mm)	2013 (mm)
Srandakan Bridge	-	10.5	-	1.8
Sapon	1	10.9	-	0.7
Bantar Bridge	0.25	10.9	-	1.7
Kebon Agung I B.	4	10	-	0.5
Kebon Agung II B.	-	10.5	0.38	1.8
Progo-Putih Confluence.	0.43	10.2	0.25	-

From **Table 1**, it shows that in 1999, the mean diameters of the riverbed material at the selected locations are less than 1 mm, and it means that type of sediment is fine sand, except in Kebon Agung Bridge I. This condition is caused by several events of Mt. Merapi eruption in period of 1990-2000. In this period, almost directions of debris flows leaded dominantly to the western slope of Mt. Merapi. These eruptions were in 1992-1993, 1993-1994, 1996-1997 and 1998. Among these eruptions, the eruptions with large volume were in 1993-1994 and 1998. Due to the abundant sediment supply from the eruption of Mt. Merapi into Progo River, the type of riverbed material tended to fine sand, except at Kebon Agung I Bridge. At this location, the riverbed slope was quite steep, resulting in the riverbed material at this location to be coarser than other locations. In addition, the number of sediment control structures on the slopes of Mt. Merapi was still limited; so that the material from the eruptions of Mt. Merapi quickly reached to Progo River.

In the period of 2000-2010, eruption events of Mt. Merapi occurred in 2 times, namely the eruption in 2000-2001 and 2006. Direction of phyroclastic/debris flows in the 2000-2001 eruption leaded to the western slope of the Mt. Merapi slope. And the eruption in 2006 leaded to the southern slope of Mt. Merapi. Supply of materials from Mt. Merapi to Progo only took place in 2000-2001, after that almost no material supplied into Progo River. The eruption in 2006 did not affect on riverbed material conditions of the Progo River, because no tributary of Progo River which received sediment from the 2006 eruption. This situation resulted in armoring on riverbed material of Progo River. It was shown that the mean diameter of the riverbed material changed from fine sand with a diameter of less than 1 mm into the gravel with a diameter of 10 mm in 2009. This condition occurred in all locations reviewed.

In 2010, a big eruption of Mt. Merapi took place with a large volume of material eruption, which was estimated at more than 100 million cubic meters. Directions pyroclastic/ debris flow as a result of this eruption were dominantly flowed to the west and south slopes of Mt. Merapi. Due to the material supply from Mt. Merapi eruption in 2010, the type of riverbed material tended to become fine sand. This was indicated by changes in riverbed material diameter in the Kebon Agung II Bridge and Progo-Putih confluent, from 10 mm to less than 0.5 mm. Then, due to reducing fine material from Mt. Merapi, riverbed material diameter increased into sand type with a diameter of about 2 mm in 2013. The mean diameter of riverbed material at Sapon and Kebon Agung I Bridge in 2013 was still fine sand type, because in both locations were built the new groundsill causing a local sedimentation in the both areas.

3.2. Physical Condition of River Flow

The physical conditions of the river flow in the selected locations are shown in **Figure 2** and **Figure 3**, as follows.

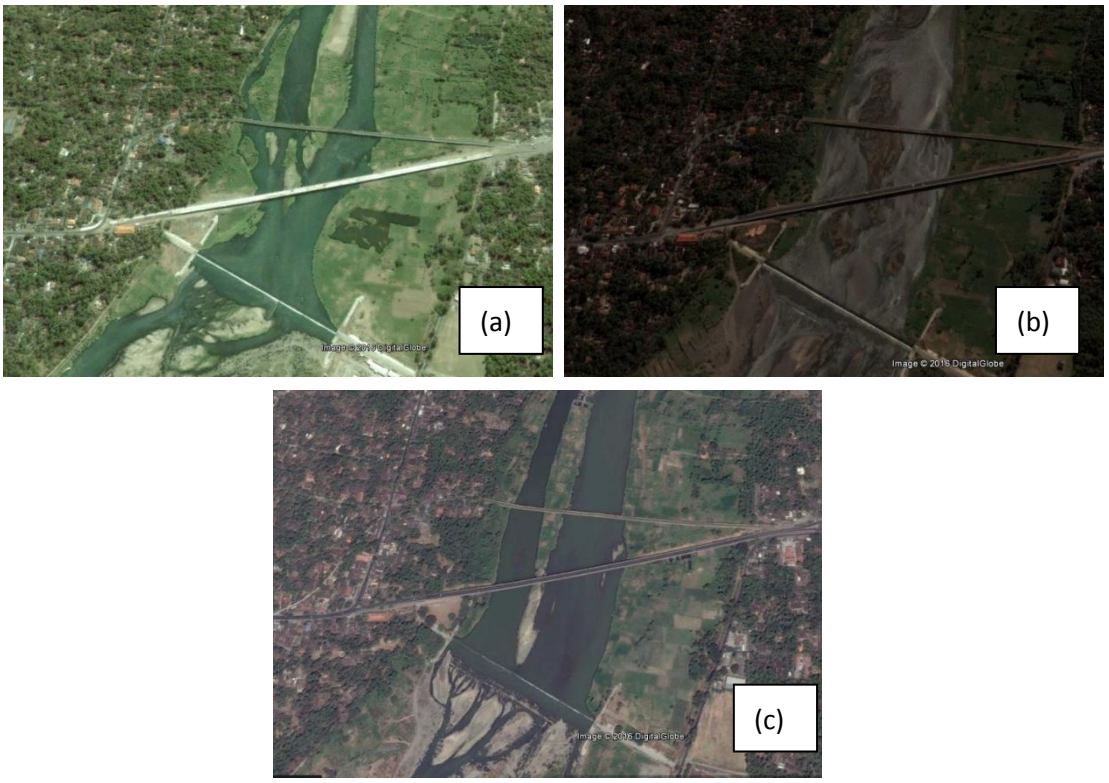

Fig 2. Physical condition of Progo River flow at Srandakan Bridge, (a) November 2006, (b) July 2012 and (c) September 2015

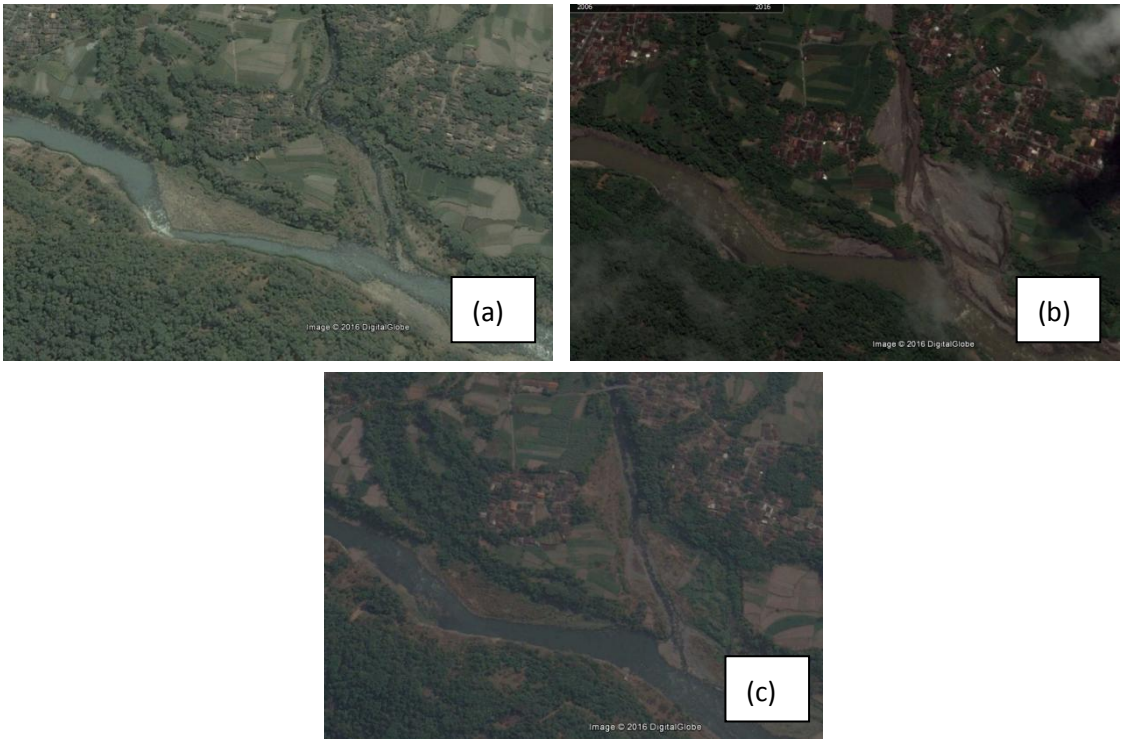

Fig 3. Physical condition of Progo River flow at Progo-Putih confluent, (a) September 2006, (b) February 2012 and (c) August 2015

From **Figure 2** and **Figure 3**, it shows that in 2006 there was no supply of material through tributaries of Progo River that originated at Mt. Merapi. This situation caused in the river flow was relatively stable, at Progo-Putih confluence and Srandakan Bridge locations. The river flow conditions of Progo River tributaries were very narrow, with a width of less than 10 meters, especially at the downstream of Putih River and also the at the downstream of Pabelan River. In the period of 2000 to 2010, the riverbed elevation of Progo River tended to be decreased by the natural transport of sediment and sand mining activities in channel of Progo River.

After the 2010 eruption, sediment flowed rapidly into Progo River through its tributaries originated on Mt. Merapi. The reasons why material from Mt. Merapi entered quickly into Progo River were, first was amount of sediment to be abundant, the second was changes of hydrological parameter causes run off to be greater and third was collapse of sediment control structures in Pabelan and Putih Rivers caused by debris flows in the both rivers. In the beginning of 2011, sediment had reached the Progo-Pabelan and Progo-Putih confluents. In addition to change in the riverbed material diameter, due to the sediment supply from Mt. Merapi, the width of Progo River tributaries were also increasing significantly, as shown in **Figure 3**. And also, the sediment supply caused in increasing of riverbed elevation. This condition occurred from 2011 to 2012. However, the sediment supply did not change Progo river flow conditions, significantly. But, the sedimentation occurred in the some locations. Due to reducing amount of material from Mt. Merapi that flowed into Progo River, tributaries of Progo River were going back narrow as condition before the 2010 eruption. Since 2013, river flow conditions began to narrow and the river flow conditions in 2015 were similar to conditions before the eruption. Likewise, the riverbed was degraded due to the limited of material supply from Mt. Merapi that flowed down into the downstream of Progo River.

4. Conclusions

The riverbed material of Progo River changed either its diameter or its elevation caused by materials from the eruption of Mt. Merapi. Besides that, the sediment transport gave impact on bank erosion in the Progo River tributaries, resulted in widening of the river channel. After the impact of material from the eruption reduced, the conditions of the riverbed material diameter and elevation were back to normal, as condition before the 2010 eruption.

Keywords: Mt. Merapi, the 2010 eruption, sediment, river bed, Progo River