Analysis of Sand Mining Impacts on Riverbed in the Downstream of the Progo River, Indonesia

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Abstract. The Progo River is a river that flows in the Province of Central Java and Yogyakarta Province in Indonesia. This river originates at Mount Sindoro with the main river length of about 138 km and has a watershed area of approximately 243,833,086 hectares. The Progo River is a natural river which has one of its upper reaches, which is sourced from Mount Merapi. This condition resulted in the Progo River being affected by the material carried by cold lava. The research method is carried out by analysing the amount of sand mining, social and economic impacts, sediment transport, degradation or aggradation at the point of review based on primary and secondary data from the results of laboratory measurements and tests. The location of the research was carried out at the point of the Srandakan Bridge to the Progo River Estuary. The results showed that at the Srandakan Bridge point to the Progo River Estuary the volume of sand mining was 459,576 m³/year, one of the social and economic impacts of sand mining was the opening of job opportunities for the community around the mining location, and degradation of the river bed, with a degradation value of 0.43 m/year.

1. Introduction

River sand and gravel have long been used as aggregate for construction of roads and building. Today, the demand for these materials continues to rise. In Indonesia, the main source of sand is from in-stream mining or river mining. Excessive removal of sand may significantly distort the natural equilibrium of a stream channel. By removing sediment from the active channel bed, in-stream mines interrupt the continuity of sediment transport through the river system, disrupting the sediment mass balance in the river downstream and inducing channel adjustments (usually incision) extending considerable distances (commonly 1 km or more) beyond the extraction site itself. The magnitude of the impact basically depends on the magnitudes of the extraction relative to bed load sediment supply and transport through the reach [1].

This issue poses a number of policy questions that are worth investigating. The strategies adopted so far have not been based on sound economic analysis and so have led to policy failures. Moreover, ad hoc and inconsistent policies have contributed to a short supply of sand, further degradation of the environment, and increased social upheaval. Therefore, there is an urgent need to identify appropriate policy guidelines that guarantee environmental protection with minimum regulatory costs and high levels of public cooperation [2].
Many river streams in Indonesia, rivers and their floodplains have abundant quantities of sand and gravel that is mined conveniently and economically for a variety of uses, for example is in Progo River. In recent years, rapid development has led to an increased demand for river sand as a source of construction material. This has resulted in a mushrooming of river sand mining activities which have given rise to various problems that require urgent action by the authorities. However, unregulated and unmonitored sand mining has taken place without a clear regulatory framework and this has aggravated environmental problems. Mining activities are often associated with environmental impacts including metal contamination of sediments and aquatic systems. These include river bank erosion, river bed degradation, river buffer zone encroachment and deterioration of river water quality. The Progo River is a river that flows in the Province of Central Java and Yogyakarta Province in Indonesia. This river originates at Mount Sindoro with the main river length of about 138 km and has a watershed area of approximately 243,833,086 hectares [3]. The Progo River has tributaries that have several tributaries, one of which is Mount Merapi, which still has an active volcano status. The tributaries that originate in Merapi include the Bedog River, the Krasak River, the Apu River, the Bebeng River, the Batang River, the Putih River, the Pabelan River, and the Blokeng River.

The Progo River is a natural river which has one of its upper reaches, which is sourced from Mount Merapi. These conditions resulted in the Progo River being affected by the material carried by cold lava. The flow of cold lava debris has the potential to change the morphology of the Progo River flow significantly. Not only did the flow along the river receive the impact of the cold lava flood, but the buildings along with the river flow also received it. Sedimentation can be defined as the transport, drift (suspension) or deposition of fragmental material by water.

Sand mining is the activity of taking river material in the form of sand carried out with or without assistive devices by residents around the Progo River and companies that aim to fulfil economic interests. Due to the increasing market demand for sand, it has an impact on the increasing number of sand miners in the Progo River area without paying attention to the impact of the surrounding environment. In river areas where material extraction is not carried out, it will generally experience aggradation or accumulation of river material on the bottom or bank of the river which will have an impact on silting the river, causing the river to overflow. However, the existence of an excessive amount of river material extraction activities will also cause other natural impacts, which are often referred to as degradation or erosion of river material due to several factors, namely by a large enough water discharge or by the sand mining activity itself. Examples of the impacts of aggradation and degradation that occur along the Progo River, especially in the downstream part, are such as the entry of sand material that has accumulated in the Mataram Canal area, the dysfunction of the Sapon Intake and the subsidence of several pillars on the Srandakan Bridge.

Reviewing the impact of aggradation and degradation, control and monitoring of sand mining activities is needed to maintain the stability of the river itself so that it does not have the potential to cause damage to water structures along with the river flow. The purpose of this study is to analyze the volume of sand mining, assess the socio-economic impact of sand mining, study sediment transport along the length and study the impact of sand mining on the stability of the bottom of the Progo River, from the centre at the point of the Srandakan Bridge to the Progo River Estuary.

2. Research methods
This research was conducted to determine the aggradation of the Progo River and to determine the amount of sediment transport that occurred after the eruption of Mount Merapi in 2010. To determine the amount of sediment transport of the Progo River bed using the Englund-Hansen (1967) formula [4]. The data collection technique is based on the type of data, namely primary data and secondary data. The primary data is obtained by direct research in the field and the laboratory. Secondary data is data obtained from agencies or agencies related to research.
2.1. Research location
The research location is along the Progo River from the middle of the river at the point of the Srandakan Bridge to the Progo River Estuary. The sand miner survey data were collected for four days, namely on 22, 26 February and 02, 06 March 2017 in the Progo River, the grading test was carried out on 20-21 March 2017 at the Civil Engineering Laboratory of UMY. The map of the research location can be seen in Figure 1.

![Map of the research location](image)

Figure 1. Location of the Downstream of Progo River

2.2. Research implementation
This research was conducted to determine data on sand miners, the amount of sediment transport, and the value of aggradation/degradation of the Progo River. To find out data on sand miners interview surveys were conducted with sand miners. Sediment transport is determined by Englund and Hansen's (1967) formula [4].

The types of data used are primary data and secondary data. Primary data is data from sand miners obtained from field surveys by interviewing sand miners and data on gradation tests of the bottom sediment samples of the Progo River, which is carried out in the laboratory. The data for sand miners includes mining volume per day, number of miners, mining methods, marketing of sand, the selling price of sand, and buying price of sand on-site. Secondary data obtained include AWLR data from the Serayu-Opak River Basin Research Center (BBWSSO), cross-sectional data and flow velocity of the Progo River from research conducted by several UMY students. In laboratory tests, data on aggregate grain gradation is obtained from samples taken at several mining locations.
2.3. Equipment and material

2.3.1. Sand mining survey
The equipment used in the sand miner survey are as follows:

1. Survey form
   The survey form serves to write down the results of interviews with miners.

2. Map of the Progo River
   The Progo River Map serves to mark mining locations.

3. GPS application
   The GPS (Global Positioning System) application is used to locate the mining location and the road to the mining location.

2.3.2. Gradation test
The equipment used in the grading test is as follows:

1. The plate
   The plates are used to place the sediment samples from the field for further insertion into the oven and to weigh the dried riverbed sediment samples.

2. Oven
   Ovens are used to drying riverbed sediments.

3. Filter
   A filter set consists of filter holes number 4, 8, 16, 30, 50, 100, and pan. The filter is used to filter riverbed sediment samples.

4. Shave Shaker Machine
   Shave Shaker Machine is used to sieve sediment samples from the river bed in a filter.

5. Digital scales
   Digital scales are used for weighing the riverbed sediment sample.

3. Result and discussion
This calculation will explain the steps for calculating the volume of sand mining, sediment transport volume, social and economic impacts as well as the impact of degradation/aggradation on the stability of the Progo River bed. Example of calculation is taken from the data at the point of the Srandakan Bridge.

3.1. Sand mining survey

3.1.1. Sand mining methods
There are three methods of sand mining in Progo River, namely:

a. Manual
   This method is done by plunging directly into the river and taking the sand that is on the riverbed using sand dug and placing the sand on a tire that has been covered with sacks so that the sand and water will separate.

b. Semi manual
   This method uses a diesel engine. Many traditional sand miners want to switch to use machine because it is more profitable in terms of time and the volume of sand dredged is greater than the traditional mining method.

c. Mechanic
   This method uses an excavator that directly lifts the sand to the tailgate that has been attached to a screen; the screen is useful for filtering the rocks that are also lifted by the excavator. Usually, this method is used by sand mining companies.
3.1.2. Sand mining impacts on social and economic aspects

Most of the sand miners at the Srandakan Bridge – the Progo River estuary site are native residents of the mining site. In the data obtained, the sand mining activity absorbs a workforce of about 275 people and is scattered at 12 points. The survey also revealed that the average price per trip was IDR 675,000, and the average price per cab was IDR 192,500. Therefore, miners can generate an average of around IDR 75,000 to IDR 100,000 net profit per day. This result is in line with research result from [5], that mining has a remarkable potential for production, employment, income distribution, socio-economic development [5].

![Sand mining methods in the Downstream of Progo River](image)

(a) (b) (c)

**Figure 2.** Sand mining methods in the Downstream of Progo River, (a) manual method, (b) semi manual method, (c) mechanic method

3.1.3. Analysis of sediment transport

Based on the sampling in the field, the size of the sediment grains at the Srandakan Bridge point on the Progo River, it is known that the value of D50 = 0.7 mm. So, it can be concluded that the dominant surface base material is sand with a size of approximately 0.7 mm.

When calculating sediment transport, monthly average discharge is used. The monthly average discharge data for the Srandakan Bridge was obtained from the discharge data at Sapon Station in 2015 because this station is the closest station to the Srunjuk Bridge and has sufficient data to find monthly sediment transportation. For 2015, the discharge data for Srandakan Bridge can be seen in the figure 3.

![Monthly discharge in the Saphon Station](image)

**Figure 3.** Monthly discharge in the Saphon Station
By using the Englund and Hansen equation, the bedload transport at the ridge of the Srandakan Bridge and the Progo River estuary can be analysed. If the base transport on the cross-section of the Srandakan Bridge as Qin and the base transportation at the estuary of the Progo River as Qout, then the sediment volume between the two cross-sections can be known so that the river bed can be estimated under conditions of degradation or aggradation. Figure 4 shows the Qin and Qout values.

![Figure 4. Bed load transport in the downstream of Progo River](image)

Based on Figure 4, it can be concluded that naturally in the downstream of the Progo River, there is always an aggradation phenomenon. This condition is due to the river's slope and low river flow velocity when it enters the sea. With these river characteristics, this zone is a zone of aggradation or sedimentation. This condition is following events in the field, that there has been aggradation from year to year, which causes the elevation of the river bed to increase. When the river bed has risen, this area often experiences floods.

3.1.4. Analysis of sand mining impact on riverbed

The number of sand miners in the Srandakan Bridge to the estuary is 12 location. If for one truck is estimated about 5 m³ and one small truck is estimated about 1.5 m³. After accumulating, the volume of sand mining per day is 1,473 m³. If in one week the sand miner works for six days and in one year there are 52 weeks, then six days × 52 weeks = 312 working days. So, we can get the volume of sand mining per year = 312 x 1,473 = 459,576 m³/year.

The impact of sand mining on riverbed conditions is analyzed by a formula as follows. $V = (\Sigma Q_s, \text{in} - \Sigma Q_s, \text{out})$ - the volume of sand mining. The result is as follows:

$$V = (254,617.469 - 200,431.971) - 459,576$$

$$V = 420,872.073 \text{ m}^3/\text{year}$$

By considering the width of the river at the point of the Srandakan bridge (157.7 m), the width of the river at the estuary point (125.92 m) and the distance of the Srandakan-estuary bridge (6881 m), the estimated degradation can be calculated as follows:

$$V = 420,872.073/(6,881 \times (157.7+125.92)/2)$$

$$V = -0.43 \text{ m/year}$$

Based on these results it can be concluded that the sand mining activity downstream of the Progo River has caused degradation of the riverbed by 0.43 m / year. This condition is because the volume of sand mining exceeds the capacity of the sediment resources at that location. If this condition continues, it will endanger the existing infrastructure in the downstream part of the Progo River, such as bridges, retaining walls, irrigation water intake and so on. This result is in line with the research result from [6] that sand mining has a negative impact on ecosystems and reduce river regulatory
safety [6-7]. Therefore, it is necessary to control the volume of sand mining. Based on this research, allowable sand mining is less than 459.576 m$^3$/year. The result is in line with the research from Ikhsan et al that allowable sand mining must be less than 1.44x10$^6$ m$^3$/year [8]. Sand mining does not need to be completely prohibited, because sand mining has benefits, such as providing materials for construction, providing jobs, increasing income for residents and as flood control.

4. Conclusion
Based on the results of the analysis in this study, several things can be concluded as follows. The social and economic impact of sand mining on the Progo River is that sand mining provides employment for the community around the mining site and also creates close cooperation between village communities to create a better economic level. The impact of sand mining on the stability of the bottom of the Progo River, from the centre at the point of the Srandakan Bridge to the Progo River Estuary is experiencing a tendency of degradation, with a degradation value of -0.43 m / year.

5. References

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Acknowledgement
The author would like to thank profusely to all those who have helped in carrying out the research. Special thanks to the Division of Research, Publication and Community Service (LP3M) UMY for providing research grants with a basic international collaborative research scheme with contract No. 034 / PEN-LP3M / 1 / 2020