Economic and environmental impacts of sand mining activities at sadang river Pinrang Regency, South Sulawesi

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Abstract. Sand is a material needed for various purposes such as construction materials and backfill materials so that the need for sand continues to increase. The economic potential in the form of generating income for both workers and companies has triggered increased sand mining activities in the Sadang River in Pinrang Regency. The research took place between September and November 2019 which aimed to determine the economic potential and environmental impact of the Sadang River sand mining in Pinrang Regency. The research area covers three districts included in the Sadang River sand mining area of Pinrang Regency namely Patampanua, Duampanua and Cempa Districts. A field survey was conducted to find out the amount of production volume, production costs, mining and transportation activities. The results showed that the Sadang River sand mining has considerable economic potential. In addition to direct economic benefits, it also provides indirect economic benefits for the community around the mining area. If the river sand mining has been deemed damaging to the environment and disrupting the function of the river, then the activities at Sadang River shows the opposite, namely that the Sadang River sand mining can help restore the hydrological function of the Sadang River to prevent siltation of the Sadang River due to sedimentation so as not to cause overflow and floods that can damage residents’ settlements and agricultural land in three districts.

1. Introduction

Rivers have several functions including the function of transportation, social economy, and the function of public spaces for cultural learning with all kinds of ideas and cultural products that developed around it [1]. Whereas Kodoatie and Sugianto (2002) mention rivers have ecological, economic and social functions [2].

Rivers have long been a source of construction materials such as sand and gravel. Sand is a very important material and is needed by the community on a large scale, for example a mixture of reinforced concrete cement aggregates for the construction of modern buildings, of roads, bridges, dams, housing, and so on [3]. Along with the rasing speed of development and economic growth the demand for sand and gravel has also increased which has led to increased sand and gravel mining activities in rivers. Naturally, sand is a granular material consisting of rock particles and fine minerals measuring between 0.06 mm to 2 mm. Sand is formed from decompoition of rocks due to mechanical strength where decomposed rocks form gravel and then sand.
Globally there are around 68% - 85% of 47-59 billion tons of material that were mined every year were sand and gravel (UNEP-GEAS, 2014). For the reasons of the abundance of sand and gravel resource reserves due to erosion and sedimentation from upstream areas and easy access to transportation, most of the sand and gravel mining is carried out in watersheds or rivers [4].

Suherman et al (2015) states that river sand mining can have a positive impact in the form of job creation and employment, foster business opportunities for the surrounding community and provide income for the region as a source of Regional Original Revenue (PAD) [5]. Ashraf et al (2011) also states that sand mining is very important for the economies of various countries [6]. The same thing was stated by Mattamana et al (2013) and Gunaratne (2016) that sand mining can provide economic benefits for the state and local communities directly or indirectly specifically in developing countries [7,8].

On the other hand, mining of sand and gravel in river streams causes serious damage to watersheds and is a major challenge especially in developing countries [7]. Studies conducted by Chevallier (2004) in South Africa and Wang et al (2012) in China showed that illegal sand river and gravel mining were increasingly worrying and damaging rivers [9,10]. Mining activities in rivers can damage public property and private assets and aquatic habitats, threaten the stability of slopes and river bank deformation [10], have negative consequences for the river and its surroundings [11,12].

Sadang River is one of the longest rivers in South Sulawesi and stretches for 185 km with an average width of 80 m, has an area of Watershed (DAS) about 6,446 km². The potential of Sadang River water resources is quite large with the amount of water availability ranging from 9.5 to 10.98 billion m³ / year, with the number of tributaries reaching 294. Characteristics of the Sadang River based on morphological analysis have relatively straight flow direction, steep slope, rectangular dendritic, with moderate flow rates ranging from 0.25 to 10 m/second, with discharges ranging from 35 to 3000 m³ / second (UPTD PSDA Sadang, 2019).

Along with the increasing demand for sand material for various purposes such as construction, the number of sand mining companies or people group operating in the Sadang River has also increased. Sadang River is the main source of sand construction material in Pinrang Regency and surrounding areas. Data shows that from 2015 to 2019 there were 80 mining companies operated in the study area.

The objectives of this study are: 1) To describe the mining activities and the volume of sand that mined in the study area; 2) calculate the real and potential economic impacts of mining activities, and 3) describe the environmental and social impacts that occured in the study area.

2. Research Methods
The research carried out in September to November 2019 covered the research area of Pincara Village, Patampanua District, Massewae Village, Duampanua District and Mangki Village, Cempa District. Direct observations were made to observe mining activities carried out by miners as well as changes in river morphology at five locations as shown in Table 1 and Figure 1.

Table 1. Observvation sites of study area.

| Atrribut | Latitude | Longitude | Subvillage Name |
|----------|----------|-----------|-----------------|
| SS1 – SS2 | 3°42'11.12"S - 3°42'9.29"S | 119°37'39.50"E - 119°37'54.65"E | Lome |
| SS3 – SS4 | 3°42'17.25"S - 3°42'10.04"S | 119°37'43.61"E - 119°38'7.04"E | Masolo |
| SS5 – SS6 | 3°42'15.41"S - 3°42'11.27"S | 119°37'37.57"E - 119°37'22.49"E | Pincara |
| SS7 – SS8 | 3°42'10.47"S - 3°42'0.80"S | 119°37'31.76"E - 119°37'18.69"E | Bulu Kae |
| SS6 – SS9 | 3°42'11.27"S - 3°42'5.50"S | 119°37'22.49"E - 119°36'54.89"E | Sali Salie |
To calculate sand production, a direct observation of the number of trucks and the volume of trucks transporting sand from the study area is carried out for 11 working days. Interviews were conducted with representatives from miners, local communities and representatives from the government. Reports on environmental impacts available at the Pinrang District Environmental Office were also used as literature study material.

In this study the economic, environmental and social impacts analyzed were only significant direct impacts from mining activities.

3. Results and Discussion
3.1. Sand Mining Activities and Sand Produced
The Sadang River sand mining activities has been going on since the 1980s which was originally only managed by four community groups led by local community leaders. Three groups managed sand mining on the north side of the river located in Lome, Massewwae Subvillage, in Duampanua District, while one group managed sand mining on the south side of the river of Pincara and Salisalie subvillage of Pincara Village, Patampanua District. These were what we referred to as the early generation who started and spearheaded the mining of sand and gravel in the Sadang River. The material that was mined from the Sadang River initially consisted of sand and gravel. Sand and gravel from the Sadang River are widely used for aggregate. But over time, until now, gravel is no longer a mining commodity that has a high selling value. This was caused by the substitute material that replaces gravel as a concrete mixture aggregate material, namely the use of coarse aggregates in the form of broken stones to replace the use of natural aggregates in the form of gravel.

The Sadang River sand mining activity initially used human labor to mine sand and gravel from the riverbed. The use of pumping machines to suck sand from the riverbed was introduced in the early 2000s by a miner who belongs to the second generation. Until now, all of the sand mining activities in the Sadang river have used mechanical means to use a pumping machine to suck sand from the riverbed. In 2019, there were 80 companies or mining groups operating in the study area. All mining activities were carried out without obtaining permission from the Pinrang District government so that it is considered illegal.

Based on observations of 11 working days, data collected the number and size of trucks that transport sand from the study area. The types of trucks that operate consist of trucks with a capacity of 4 m$^3$, capacity of 15 m$^3$ and 25 m$^3$. In Table 2 it can be seen that trucks with a capacity of 4 m$^3$ are the trucks most widely used to transport sand in the study area.
Table 2. Number of trucks operated and volume of sand transported in the research area.

| Day | Number of trucks | Total sand volume (m³) |
|-----|------------------|-----------------------|
|     | 4 m³ Cptcy | 15 m³ Cptcy | 25 m³ Cptcy |                      |
| 1   | 226         | 9           | 8           | 1,239                  |
| 2   | 260         | 6           | 15          | 1,505                  |
| 3   | 350         | 1           | 16          | 1,815                  |
| 4   | 320         | 17          | 17          | 1,960                  |
| 5   | 265         | 14          | 10          | 1,520                  |
| 6   | 312         | 2           | 9           | 1,503                  |
| 7   | 305         | 10          | 16          | 1,770                  |
| 8   | 292         | 11          | 15          | 1,708                  |
| 9   | 314         | 4           | 25          | 1,941                  |
| 10  | 242         | 13          | 27          | 1,838                  |
| 11  | 301         | 14          | 18          | 1,864                  |
| Total | 3,187    | 101         | 176         | 18,663                 |
| Average | 290      | 9           | 16          | 1,697                  |

Table 2 shows the average number of trucks transporting sand at the study site were 290 of 4 m³ capacity, 9 of 15 m³ capacity and 16 of 25 m³ capacity per day. Thus the volume of sand transported during the 11 days of observation was 18,663 m³ or an average of 1,697 m³ per day.

3.2. Economic Impact

Based on the volume of sand transported by trucks per day at 1,697 m³ and the price of sand at the location of Rp. 35,000 per m³, the sand value per day being mined is Rp. 59,395,000. If it was extrapolated to one year with an assumption of 300 working days per year, the total sand value was Rp. 17,818,500,000. Table 3 explains the economic value of sand that was mined, the amount of profits received by mining companies and the wages received by their workers.

Each mining company or group employed a sand suction machine operator and a sand regulator and loader to load sand into a 4 m³ truck. The wage received by the suction machine operator was Rp. 10,000, and loaders of Rp. 5,000 per m³ of transported sand. Taking into account labor costs and fuel costs for the suction machine, the total cost per m³ of sand was Rp. 21,000. Thus the profit received by the company was Rp. 14,000 per m³, or in total Rp. 23,758,000 per day and Rp. 7,127,400,000 per year.

Table 3. Sand value and economic impacts of sand mining

| No | Item                      | per day | Physical Value (Rp) | Total Value per Year (Rp) |
|----|---------------------------|---------|---------------------|--------------------------|
| 1  | Sand mined (m³)           | 1,697   | 59,395,000          | 17,818,500,000           |
| 2  | Profit to company         | 23,758,000 |                      | 7,127,400,000           |
| 3  | Direct worker's income    |         |                     |                          |
|    | - machine operator (Rp/m³) | 16,970,000 | 5,091,000,000       |
|    | - loading (Rp/day)        | 8,485,000 | 2,545,500,000       |
| 4  | Loading activities (local) | 660,000  | 198,000,000         |
| 5  | Potential fee to local govt |        |                     |                          |
|    | - Low fee (Rp/m³)         | 2,500   | 4,242,500           | 1,272,750,000           |
|    | - High fee (Rp/m³)        | 5,000   | 8,485,000           | 2,545,500,000           |

Local residents benefit from mining activities because they work as workers in mining companies and as casual laborers to load sand into large trucks (15 and 25 m³). The salary value of mining
company workers was Rp. 7,636,500,000 per year for all workers involved. Other unloaded workers who were not company workers also receive a wage of Rp. 198,000,000 a year. This value was much smaller than workers who work at the company because it was only used to load sand into large trucks.

One of the interesting things was that the local government of Pinrang Regency did not get any payment from mining activities in this area because it was done without permission from the government. On the other hand, miners were actually willing to pay a fee if the government gives permission to mine. From the results of interviews with miners, the amount of fees that miners willing to pay varies between Rp. 2,500 - up to Rp. 5,000 for each m³ of sand mined. If this value was submitted as a reference to the value of potential money that could be received by the government, then the value of money that could be accepted by the government ranges from Rp. 1,272,750,000 up to Rp. 2,545,500,000 (see Table 3).

3.3. Environmental Impact
Based on Google Earth satellite imagery data from 2006 to 2019 as can be seen in Figure 2, a very significant difference in the appearance of the stream pattern and the sediment distribution of the Sadang River is seen. Sediment deposits and river water flow patterns tend to shift from year to year. In 2006, for example, there was a large amount of sand sediment deposition in the SS1 to SS2 area. Satellite imagery data for 2019 shows sediment deposition in the SS1 to SS2 area tends to decrease, sediment deposition shifts to the SS3 to SS4 area. Likewise, the flow pattern of the Sadang River water flow has also shifted from the SS1 and SS2 areas to the SS3 and SS4 areas.

Changes in river water bodies, pint bars and channel bars from 2006 to 2019 can be seen in Table 4. This pattern of change can be observed by utilizing satellite data and information systems. One example was the change in the average depth of the riverbed which ranges from 1 m to 3 m. Changes in river depths that have become deeper were considered positive by the community because they reduced flooding at the study site. In addition to the changes and increases in average river depth, based on observations of satellite imagery data, it showed that in areas where there are mining stations, changes in flow direction and reduction of sediment deposits.

![Figure 2. Google earth picture of research area in 2006 (left) and 2019 (right).](image)

| Table 4. Change of river body, point bar dan channel bar in the research area. |
|-----------------------------------------------|
| **Items**                                      | 2006 | 2014 | 2017 | 2019 |
| River water body (ha)                         | 17   | 39   | 51   | 44   |
| Point Bar (ha)                                | 35   | 13   | 0    | 1    |
| Channel Bar (ha)                              | 4    | 3    | 3    | 8    |
Another significant environmental impact was damaged of the access road between the sand dump site and the Parepare - Pinrang main road. This road was actually an embankment and a primary irrigation channel inspection road from the Pekkabata dam that irrigates 5400 ha of rice fields. The road condition of 3 km long was quite bad because it was often traversed by 4 m³ capacity of trucks to transport sand. From the calculations, the cost of repairing and maintaining the 3 km long road was estimated Rp. 1,800,000,000 per year. Figure 3 shows the mentioned road conditions.

3.4. Social Impact

Conflicts among miners and between miners and surrounding communities were common in the mining area. Conflicts between miners were caused by competition for access and the right to mine in an area, especially if mining activities were carried out without permission. Conflicts between mining companies and local communities can occur because local communities do not received the benefits of the mining activities that occur.

Conflicts between fellow miners led by local community leaders were reported in the early 1980s. In 2019, a conflict between a company and the local community was reported so that it had to be resolved with the help of the police.

4. Conclusions and Suggestions

Sand mining activities in rivers can have positive and negative impacts on the environment. The positive impact comes from the availability of employment for local people, encouraging the local economy and encouraging development on a broader scale. At present the Pinrang Regency government does not obtain direct economic benefits in the form of fee payments from miners because mining activities at the study site are still considered illegal.

The negative impact arises from the change in river morphology that makes the river get deeper and wider, and the possibility of further impacts arising from changes in river morphology. Nevertheless, the community considered that changing the river bed has boomed deeper has positive impact because river water stays in its stream during the rainy season and reduces flooding in the area around the river.

Social conflicts have been reported between fellow miners and between miners and the surrounding community. Conflicts were caused by competition over access and the right to mine among fellow miners, while conflicts between miners and the community occurred because the community deemed did not receive the benefits of mining activities.

Mining activities should be legalized and regulated by the government so that the government can obtain economic benefits from fees that can be collected from miners, and can regulate and supervise activities to be carried out sustainably.

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