Analysis of land requirements of Temesi final disposal facility, Gianyar Regency with 3R waste management scenario

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Abstract. Based on waste generation projection in 2040, the total waste generation in Gianyar Regency was approximately about 1,208.88 m$^3$/day from a total occupant of 593,436 inhabitants in Gianyar Regency. The existing supporting capacity of Temesi Final Disposal (Temesi Landfill) was 51,500 m$^3$; meanwhile, the total waste generation in Gianyar Regency in 2020 is up to 146,356 m$^3$ consequently Temesi Landfill was overloaded by untreated solid waste since 2020. To reduce waste generation and decrease the treatment burden in Temesi Landfill, solid waste management using 3R methods from household clusters needs to be applied. Using 3R concept, eventually, the waste generation that is disposed into Temesi Landfill can be reduced significantly by 63%, from 1,208.88 m$^3$/day into 446 m$^3$/day with a total weight of 148 tonne/day in 2040. Within the 3R waste management from households, the land requirement could be reduced to only 1.08 Ha in 2020 and 14.35 Ha in 2040 from previously about 3 Ha and 39 Ha. Within the forecast results, it is concluded that the upstream 3R scenario has a significant impact on reducing waste generation; thus, it will also lead to fewer landfill area demands.

1. Introduction

Like any other regencies/cities in Bali, Gianyar Regency faces identical waste disposal and management problems that firmly pollute the surrounding environment. In particular, during the holiday season, the volume of wastes tend to increase about third folds. The district government has taken various steps related to handling this waste. In addition to increasing public awareness in managing waste, Gianyar Regency also optimizes Temesi Final Disposal in Temesi Village with a total area of 4.5 hectares. Temesi landfill has been adopting a sanitary landfill method in order to process the untreated waste. However, Temesi has suffered severe overload since 2018 due to a significant increase in waste disposal after a sudden closure of Suwung landfill, followed by limited land available to perform proper sanitary landfill operations. Along with establishing the Government Law 18 (2008) concerning Waste Management, every regency in Indonesia must undergo complete waste management from its source. Efforts to manage waste can be done through Reuse, Reduce, and Recycle (3R).

There have been several studies that had been researching the Temesi landfill. However, it did not specifically mention the waste generation and landfill capacity. The impacts of solid waste in the water...
body around the Temesi landfill but did not discuss the waste calculation and land capacity [1]. The leachate accumulation in the Temesi landfill and did not calculate the waste generation. The lack of data dan waste calculations in the Temesi landfill has been considered a notable urgency that leads to the establishment of this research [2]. Therefore, this research was aimed to provide a conceptual, theoretical framework based on literature studies and field observations to forecast waste generation and landfill capacity with and without 3R waste management in the Temesi landfill. Besides, the first aim was to forecast the waste generation in Gianyar Regency from 2020 to 2040. After forecasting the generated waste in Gianyar Regency, then the land requirement approximation for both the business-as-usual scenario (without 3R treatment scenario) and 3R scenario can be made to accomplish the second aim. This calculation was intended to emphasize the importance of 3R waste management. The efficiency of waste reduction and landfill area reduction can be determined as the third aim from those approximations.

2. Methodology

2.1. Literature studies
In this study, the first step that had to be attained was obtaining secondary data and literature related to the method of estimating landfill area. Also, a literature study was also conducted to determine the risk index for the Temesi landfill, whether the landfill is still feasible to develop or not. Existing condition data is also essential to determine which existing land area can still be operated and the potential area for further developing the Temesi landfill. Using the existing condition data, the total estimation of land requirements can be approximated. According to that calculation, the comparison between land availability at the Temesi landfill and the total required land to undergo impeccable waste treatment can be carried out. Furthermore, the comparison results would lead to a bigger image of how many land areas need to be prepared and how to minimize those superfluous land requirements.

2.2. Waste generation projection
Waste generation quoted from is the amount of waste generated per person per day in volume and weight units [3]. Determination of the amount of waste generation will be calculated based on the Indonesian National Standard (SNI) 3242:2008 concerning Waste Management [4].

According to SNI 3242:2008 the standard of waste generated by each person can be approximated as equal as 3 liters/person/day for large cities and 2.5 liters/person/day for small cities [4]. Gianyar Regency was included in the big city category because the population is more than 500,000 inhabitants. Therefore, the standard of waste generation used is 3 liters/person/day, assuming that the projected solid waste service level is in accordance with existing conditions, namely 48%, where every year, the service level is increased 1%. Non-household waste generation for Gianyar Regency is 12% of household waste generation.

2.3. Temesi landfill carrying capacity
In order to maintain waste management sustainability in a single city, only the untreated waste (residue) that would be allowed to be included in the final disposal of Temesi landfill [5]. Thereat, in order to meet that compulsory management standard, a 3R upstream method scenario should be assigned.

The 3R scenario in this study refers to several researches conducted prior to this study, whether in the area of Gianyar Regency or another area with identical waste characteristics shows the different number amidst the waste composition, in this case, organic to inorganic wastes, which obtained as much as 83.91% for organic waste and 16.09% for inorganic waste in the research area of Ubud Sub-District, Gianyar Regency [6], Several specific potentials proposed by each type of waste in Werdhapura Village [7]. According to that study, approximately about 25.36% of the wet waste/organic waste was compostable, 43.64% fed to livestock, and as much as 31% would be disposed to final disposal of the Temesi landfill. Meanwhile, the recyclable inorganic waste was estimated at around 32% of total inorganic waste and the rest 67.92% was the residue.
Due to the scarcity of waste data in Gianyar Regency; consequently, several assumptions were made in order to find the closest approach to the real condition. Firstly, data from Juniartha et al. (2019) were used to define the bigger picture of waste characterization in Gianyar since the research was conducted in Gianyar Regency [6]. Meanwhile, potential 3R treatment was provided by Wardiha et al. (2013) since Werdhapura Village's waste management has been a benchmark for integrated and sustainable waste treatment in Bali [7]. The 3R scenario can be seen in figure 1.

After the total waste generation over the years was calculated, the amount of land required to launch the utmost waste treatment in the Temesi landfill could be determined by dividing waste accumulation each year by the landfill's cell height. The landfill cell's maximum height should not be beyond 5 meters [8]. After acquiring landfill area based on a business-as-usual scheme, the 3R scenario, which was arranged by multiple literature studies, was applied to measure potential waste reduction caused by proper 3R management on the upstream of waste generation. The declining waste generation will spontaneously decrease the land’s requirements to perform final disposal.

**Figure 1.** The 3R scenario framework.

### 3. Results and discussion

#### 3.1. Waste generation of Gianyar Regency

After obtaining the calculation results of population projections for every 5 years, the projections of waste generation each year can be calculated. From table 1, it can be seen that from year to year, the waste generation originating from Gianyar Regency that enters the Temesi landfill continuously escalated. Until 2040, the total waste generation is 1,208.88 m$^3$/day, from 593,436 inhabitants of Gianyar Regency. In order to decrease waste generation, the 3R (reuse, reduce, recycle) concept, which starts from the place where the waste emerges, can be applied.

**Table 1.** Gianyar Regency’s waste calculations.

| Year | Total inhabitant | Household waste | Non-household waste | Total waste |
|------|-----------------|-----------------|---------------------|-------------|
|      | (m$^3$/day) | (kg/day) | (m$^3$/day) | (kg/day) | (m$^3$/day) | (kg/day) |
| 2020 | 515,322 | 749 | 174,879 | 90 | 74,948 | 840 | 249,828 |
| 2025 | 536,665 | 820 | 191,412 | 104 | 82,034 | 924 | 273,446 |
| 2030 | 553,001 | 888 | 207,300 | 118 | 88,843 | 1,007 | 296,143 |
| 2035 | 572,862 | 967 | 225,699 | 136 | 96,728 | 1,103 | 322,428 |
| 2040 | 593,436 | 1,053 | 245,732 | 155 | 105,313 | 1,208 | 351,045 |
According to the 3R scenario stated in figure 1, surprisingly, after processed using the 3R scenario, the waste volume was reduced up to 63% from its business-as-usual approximation. The comparison between the waste treated using the business-as-usual method and the waste that was appropriately handled using the 3R method can be seen in table 2.

Table 2. Waste comparison with and without a 3R scenario.

| Year | Total inhabitants | Waste generation without 3R scenario (Business-As-Usual) | Waste generation with 3R scenario |
|------|-------------------|--------------------------------------------------------|----------------------------------|
|      |                   | (m³/day) | (ton/day) | (m³/day) | (ton/day) |
| 2020 | 515,322           | 840.32   | 196.08    | 310.14   | 72.37    |
| 2025 | 536,665           | 924.84   | 199.65    | 341.33   | 73.69    |
| 2030 | 553,001           | 1,007.37 | 203.30    | 371.79   | 75.03    |
| 2035 | 572,862           | 1,103.39 | 207.01    | 407.23   | 76.40    |
| 2040 | 593,436           | 1,208.88 | 210.80    | 446.16   | 77.80    |

From the table 2, it can be noticed that in the year of 2020, the solid waste was boasted up to 840.3 m³/day in volume unit and 196 tonnes/day in weight unit if the 3R scenario were not executed yet. The numbers keep increasing over the year along with the increasing inhabitants population and finally will reach an all-time high of 1,208 m³/day in 2040. This number can be considered critical and can potentially be a further threat for waste management sustainability in Gianyar Regency. Meanwhile, when the waste treatment is equipped with a sustainable and appropriate 3R waste reduction method, the generated waste would have trimmed more than a half.

Despite the high waste generation, compared to some cities in a developing country, e.g., India, the waste generation in Gianyar Regency was way lower than it. The total waste generation in Ahmedabad, Bangalore, and Bhopal was 1,302 tonne/day, 1,699 tonne/day, and 574 tonne/day, respectively [9,10].

3.2. Temesi landfill land requirements
From the results of the calculation of the waste generation, it can be calculated that the capacity of the Temesi landfill from year to year is projected so that we will get the year when there is an overload at the Temesi landfill.

Waste that enters the landfill generally has undergone compaction many times due to shocks during the collection and delivery process. The waste will also be compacted at the landfill location with heavy equipment. Compacting factor in truck and landfill were taken from Damanhuri et al. (2015) [5]. The waste that discharges to the landfill block at the landfill will also reduce the composting facility in the Temesi landfill area. This calculation assumes that all organic waste that enters the Temesi landfill will be managed in the Integrated Waste Composting Facility and convert to become compost. According to the data acquired from the 2018 Gianyar Regency Solid Waste Report, Integrated Waste Composting Facility at Temesi landfill reduced up to 58.73% of the total waste in Gianyar Regency. Eventually, the total existing capacity compared to the accumulated waste over the years with a business-as-usual scenario (without 3R scenario) can be seen in table 3.

From table 3, it can be seen that with the maximum height of 5 meters and the total landfill volume of 51,500 m³, the Temesi landfill should have encountered waste overload starting in 2020 because waste generation in 2020 was up to 146,356 m³. In addition, based on the field observation, both landfill blocks were filled and could not be used anymore, so additional land was necessary. Overload occurred due to the landfill area being not adequately large. The permitted cell height was about 5 meters because the Temesi landfill was designed with the concept of Sanitary Landfill, where the height of the waste piles ranges from 1.5 - 5 meters. For 2020 it is estimated that an area of 2.93 hectares is needed to handle waste with the concept of a sanitary landfill, this land area does not include access roads, leachate treatment plants, and other facilities.
hectares, 3.96 hectares, 7.11 hectares, 10.56 hectares, and 14.35 hectares for 3R scenario,
landfill area required.
This research aim to forecast the waste generation in Gianyar Regency from 2020 to 2040, estimate landfill area required for both business-as-usual scenario (without 3R treatment scenario) and 3R scenario, and determine the efficiency of waste reduction and landfill area reduction according to the scenarios above. The volume of waste generation in Gianyar Regency in the research year of 2020, 2025, 2030, 2035, and 2040 were 840.32 m³/day, 924.84 m³/day, 1,007 m³/day, 1,103 m³/day, and 1,208 m³/day, respectively for the business-as-usual scenario. Meanwhile, by implementing the 3R scenario, the waste generation would be 310.14 m³/day, 341.33 m³/day, 371.79 m³/day, 407.23 m³/day, and 446.16 m³/day in the year of 2020, 2025, 2030, 2035, and 2040 respectively.

On the other hand, in 2020, the government plans an additional 4 hectares of landfill land. However, without the implementation of the 3R, the landfill expansion will only be able to process waste until 2025, while with the 3R scenario, the expansion of the land area of 4 hectares in Temesi landfill can afford waste processing until 2025, with the proper sanitary landfill treatment. So far, Temesi landfill has been prevailing open dumping practices since 2018 due to a significant increase in waste disposal after a sudden closure in Suwung landfill. The forecast results from this paper substantiate that the upstream 3R scenario has a significant impact on reducing waste generation and will also lead to fewer landfill areas required.

4. Conclusion
This research aims to forecast the waste generation in Gianyar Regency from 2020 to 2040, estimate landfill area required for both business-as-usual scenario (without 3R treatment scenario) and 3R scenario, and determine the efficiency of waste reduction and landfill area reduction according to the scenarios above. The volume of waste generation in Gianyar Regency in the research year of 2020, 2025, 2030, 2035, and 2040 were 840.32 m³/day, 924.84 m³/day, 1,007 m³/day, 1,103 m³/day, and 1,208 m³/day, respectively for the business-as-usual scenario. Meanwhile, by implementing the 3R scenario, the waste generation would be 310.14 m³/day, 341.33 m³/day, 371.79 m³/day, 407.23 m³/day, and 446.16 m³/day in the year of 2020, 2025, 2030, 2035, and 2040 respectively.

The total landfill area requirement in the previously mentioned year was 2.93 hectares, 10.73 hectares, 19.27 hectares, 28.62 hectares, and 38.87 hectares for the business-as-usual scenario, 1.08 hectares, 3.96 hectares, 7.11 hectares, 10.56 hectares, and 14.35 hectares for 3R scenario, respectively.
From the calculation results, it can be concluded that the 3R waste management scenario could perform waste reduction for up to 63% compared to the business-as-usual scenario.

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