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Disaster management: selections of evacuation routes due to flood disaster

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Abstract

A flood is a natural phenomenon that is difficult to avoid. Yet, it becomes problems in an urban area. Due to increase in population and high cost of land in urban areas, people have built their residential places in the areas at risk of inundation. In order to avoid great losses and fatality affected by flooding, a flood disaster management is needed. A study of non physical mitigation, i.e. to establish some alternatives of evacuation routes to some temporary shelters for the casualties was conducted. This research analysed and selected several evacuation routes that were effective and safe from flooding-based Geographic Information System (GIS).

The research was started by analysing the flood magnitude, inundation area, population density, settlement concentration, temporary shelter locations, topographic condition and existing road system. For this research, the Western Semarang District in Central Java was chosen as a case study area. The results can be used as a model of evacuation approach at the research location, for other flood areas and also for a dam failure.

Keywords: evacuation routes; flood disaster management; GIS; mitigation; model of evacuation.

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1. Introduction

1.1. Background

A flood is one of natural events that is difficult to avoid. In an urban area where populations always grow and residential areas become more expensive, settlements started developing in a flood risk area. The losses due to flooding can be in the forms of materials, damaged infrastructure, job opportunities and even can cause fatalities. These losses are even worse in dense populated areas [1]. This can be minimized by a better land-use planning, regulations, law enforcement, and non-physical mitigation management such as establishment of evacuation routes for casualties during flood event and proper socialization. Several selections of appropriate evacuation routes and eligible evacuation shelter locations are extremely helpful to reduce losses, especially lifesaving.

Data of rainfall, river morphology, administrative boundaries, population density and concentration, topography, are used to analyze the potential risks and the extent of flooding. In addition, based on analysis of roads condition and other infrastructure, it can be determined several alternatives of evacuation routes for casualties that are effective and safe.

It is not easy to determine correct evacuation routes and shelter locations. It needs a tool which has spatial detection ability. The use of Geographic Information Systems (GIS) is one tool that can be used, because GIS has an excellent capability in the mapping process [2]. By using GIS, the results of selection and determination of the evacuation routes due to flooding can be used directly in the research area. This also can be used as an evacuation model due to flood event in other places, as well as in the downstream area of a dam when the dam fails.

1.2. Research Location

This research was conducted in the West Semarang District, Central Java, Indonesia (Fig. 1), with an area of 21.74 km^2 and 158,668 populations [3]. West Semarang area is passed by three rivers, i.e. Siangker, Silandak and West Banjir Kanal. This district is chosen as a study case because floods are frequently occurred. It also has a high population and represents an urban area.

2. Research implementation phase

2.1. Research flowchart

Stages of research can be seen in Fig. 2. The required data includes: rainfall data, topographic maps (Catchment Area, inundation areas), longitudinal and cross section of the rivers, road network maps, settlement areas and population concentration, and temporary shelter locations. The next step is to determine flood discharge, hydraulics analysis, areas of inundation, and analysis of effective and safe evacuation routes to shelter locations.

2.2. Design flood

The HEC-HMS software was used to analyze Q_{100} design flood. There are 4 rainfall stations influence the catchment areas, i.e. Tugu, Mijen, Simongan and Ungaran, which cover three catchment areas of Silandak (14.35 km^2), Siangker (7.16 km^2) and Garang (205.77 km^2). Thiessen polygon method was used to measure the rainfall areas.

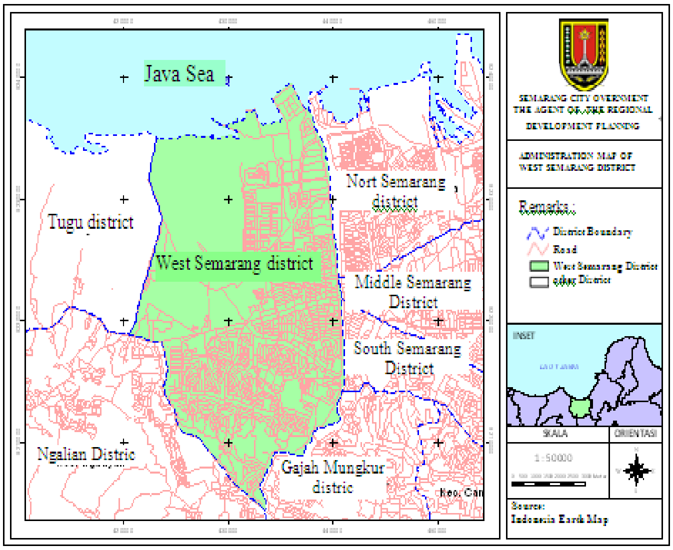

Fig. 1. The Research Location

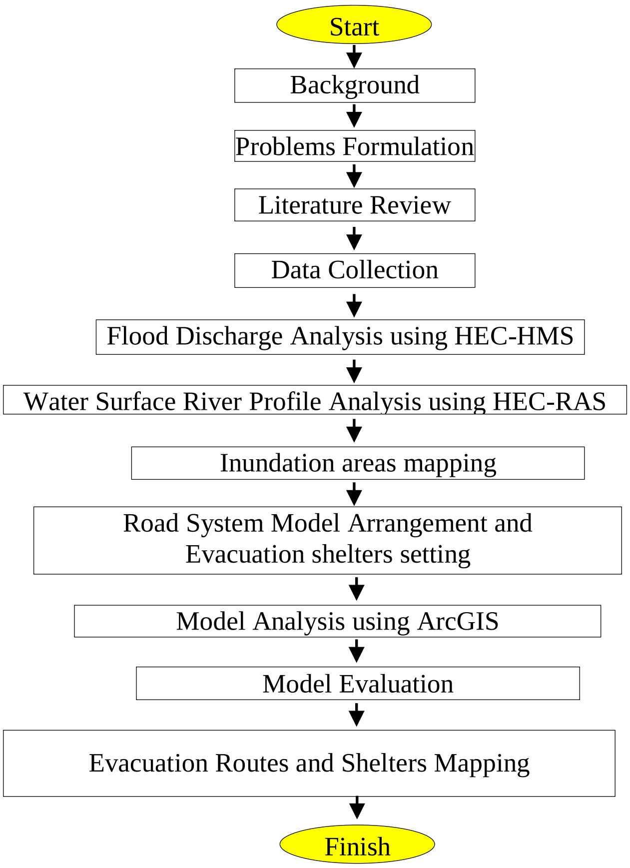

Fig. 2. Flowchart of Research

2.3. Water surface elevation and inundation area

A hydraulics analysis was carried out using HEC-RAS to find out the water surface elevation during flood events. RAS Mapper was then applied to detect the inundation area. Google Earth was used to find the flooded area and administrative boundaries accurately. The map showing potential flooded areas is a map that identifies the risk level of flood in an area at a certain period of time [4].

2.4. Evacuation routes

Based on the existing road systems, settlement location, and temporary shelter locations for the casualties, ArcGIS can identify the shortest and safe routes to the shelter locations [5]. The evacuation point is a temporary place for the casualties where they can stay, either in the shelters or in a family and/ or individual houses [6].

3. Results and discussions

3.1. Hydrology analysis

The regional design rainfall was analyzed based on rainfall data taken from four influencial stations for 23 year period. Thiessen Polygon method was used to calculate design rainfall, i.e. R100 = 322 mm (Silandak CA), 560 mm (Siangker CA) and 401 mm (Garang CA) respectively. The flood discharge was analyzed using HEC-HMS [7]. The amount of flood discharge for 100 year return period, Q100, are 258.50 m^3/s for Silandak CA, 285.20 m^3/s for Siangker CA and 3591.90 m^3/s for Garang CA. Fig.s 3(a), 3(b) and 3(c) show the Basin Model for each Catchment Area.

3.2. Hydraulics analysis

The river water surface was analyzed using the HEC-RAS software [8]. By using both HEC-RAS and RAS Mapper, it can be identified inundation areas that came from each river. Fig.s 4(a), 4(b), and 4(c) show the inundation areas. With the help of Google Earth, we can see accurately the inundation boundaries. It spread partly over the settlement areas and other areas for 10.80 km2.

3.3. Inundation map

The results of analysis using the HEC-RAS and RAS Mapper have produced two types of flood depth and velocity. Fig.s 5(a) and 5(b) are scenarios when the three rivers flood at the same time. This was done by overlaying inundation map on the administration map.

3.4. *Evacuation scenario*

The best and/ or the nearest evacuation route can be analyzed using ArcGIS [9]. Road capacity data was needed in order to select the nearest and safest route [10]. This research introduced four scenarios to evacuate people when flood event occurred. The scenarios are as follows:

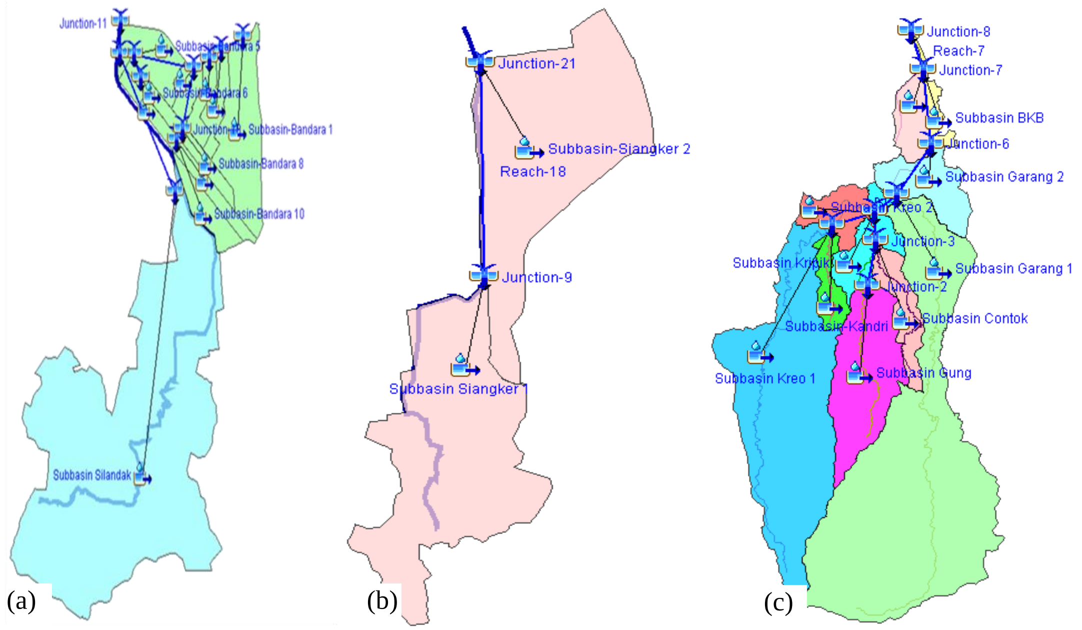

Fig. 3 (a) Basin Model Silandak CA, (b) Basin Model Siangker CA, (c) Basin Model Garang CA(West Banjir Kanal)

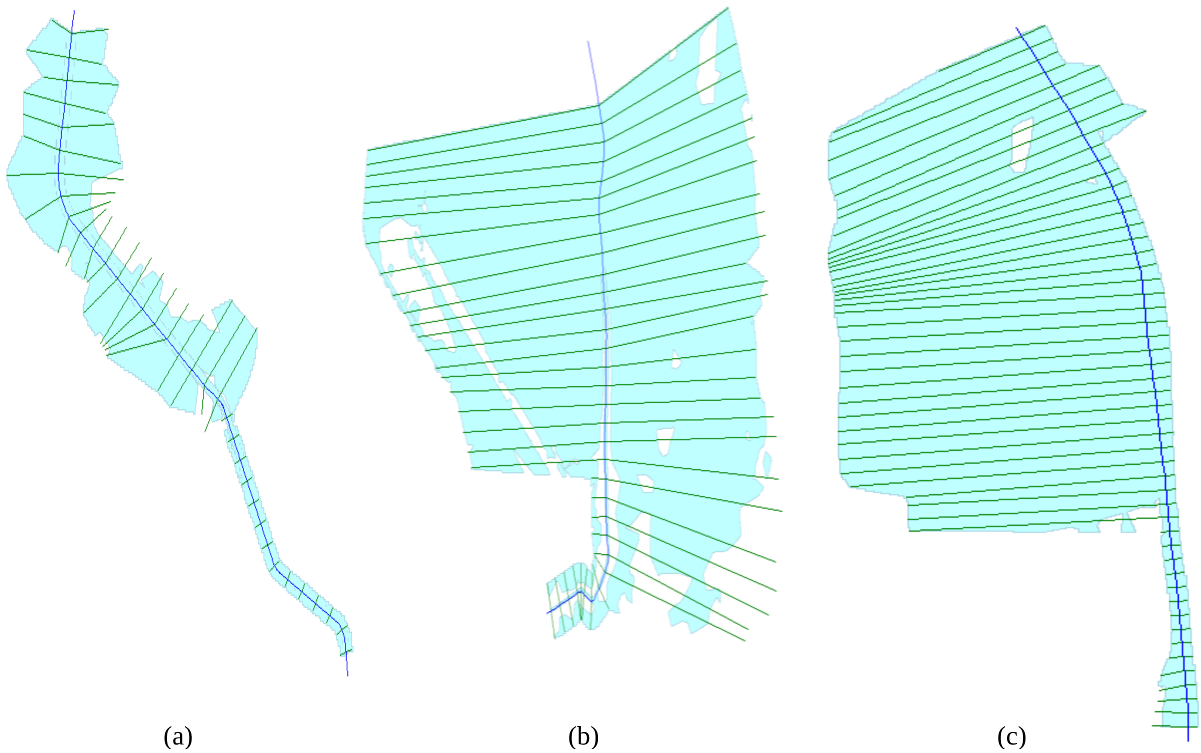

Fig. 4(a) The inundation spread of Silandak River; (b) Siangker River; (c) West Banjir Kanal

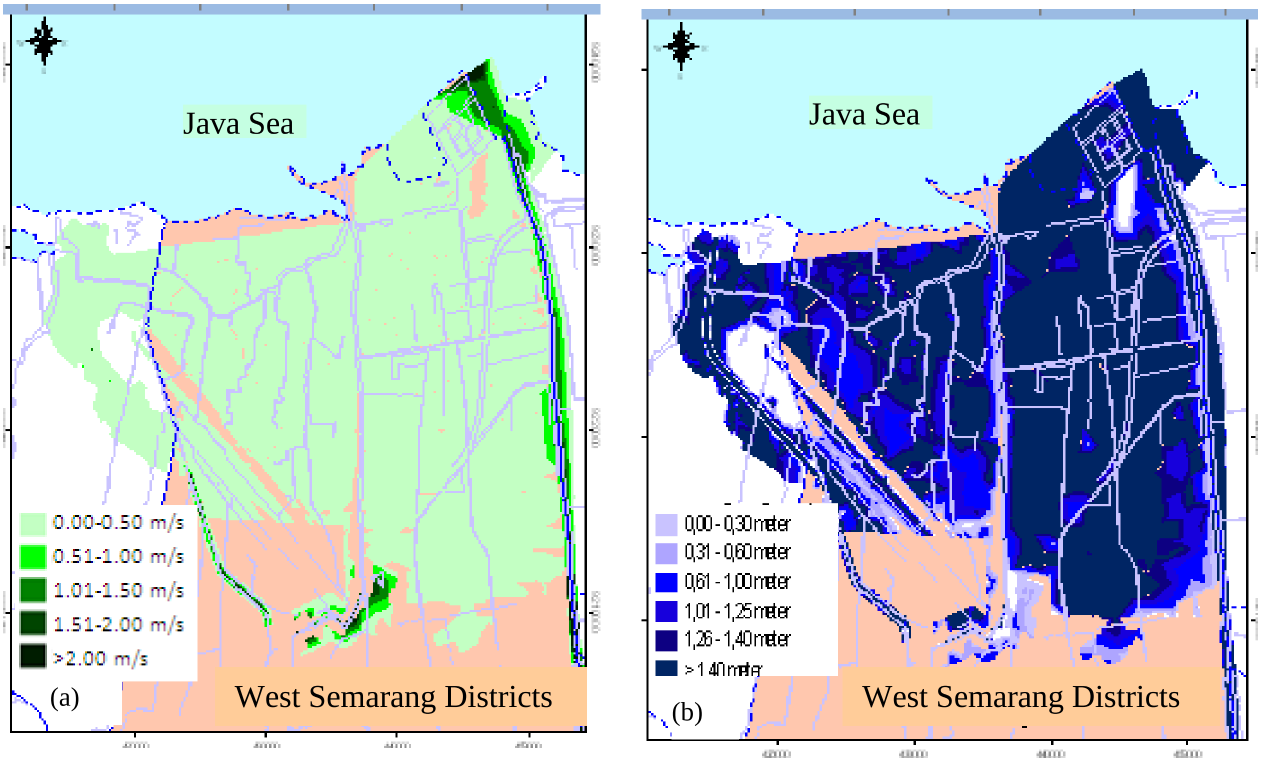

Fig. 5(a) Flood velocity Map; (b) Depth flood Map

1. Scenario A (Flooding in Silandak CA)

In A-scenario, it was determined that there are 3 evacuation points. All evacuation points had been surveyed and evaluated their infrastructure and facilities availability, and ensured that they met the criteria required for evacuation shelters [11]. Then, a road network analysis was conducted to identify the evacuation routes as shown in Fig. 6(a). It was followed by evacuation time calculation.

Evacuation time is the length of time required to evacuate the casualties from the collecting point to the evacuation point. The evacuation time was calculated from the beginning, i.e. when the flood reached the settlement and its vicinity until the flood reached the peak discharge (Q100).

The flood began when the river water overflew Silandak river bank at 209 m3/sec discharge. It occurred at 03:26. By running HEC-RAS, it was found that the maximum discharge of 258.50 m^3/sec occurred at 04:00. The evacuation time was the difference between 04:00 and 03:26, i.e. 34 minutes. The evacuation process from the collecting point to the evacuation point consists of preparation time, travel time and safety coefficient. Analysis from three locations showed that the maximum travel time was 36 minutes by walk, and 13 minutes by motorcycle. This 36 minute walk has exceeded two minutes from the time limit. Yet, this 2 minutes is still tolerable because the safety factor is 80%.

2. Scenario B (Flooding in of Siangker CA).

Based on the field survey, it was determined that there were 9 evacuation points (see Fig. 6(b)).

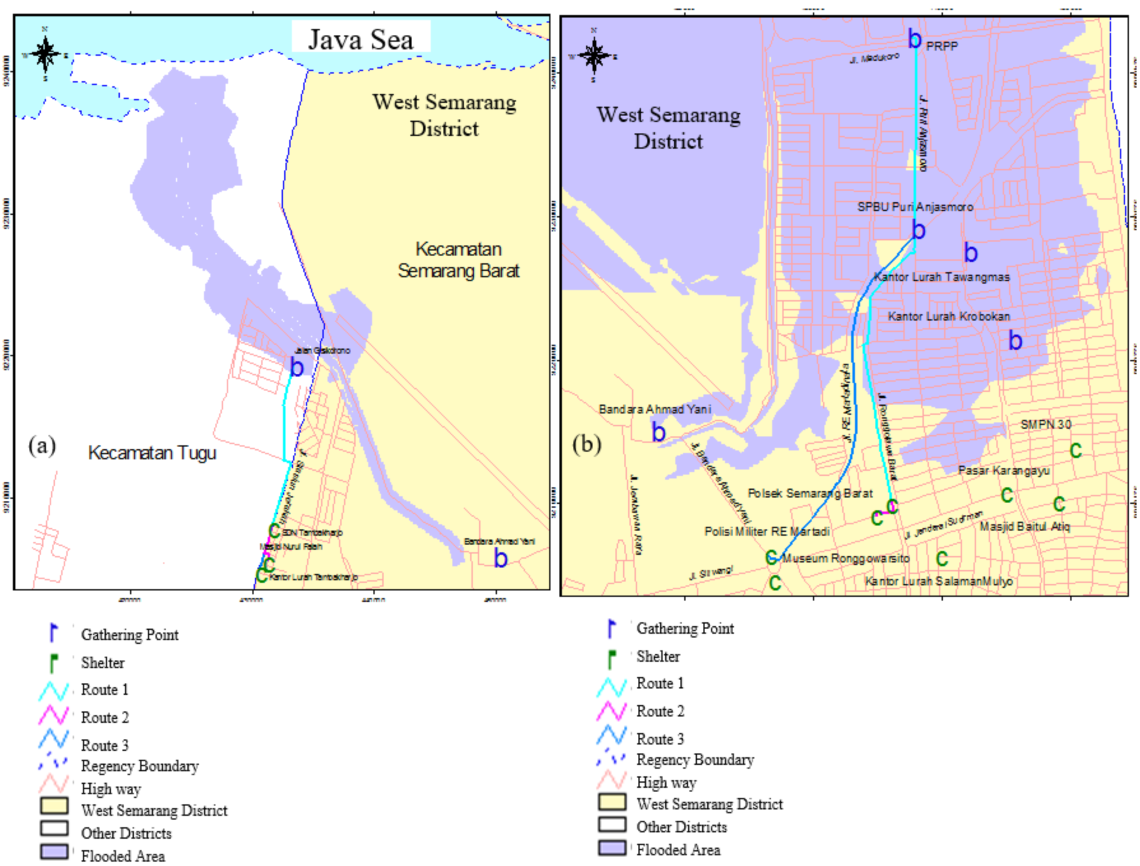

Fig. 6(a) Some fastest routes to the evacuation points in Scenario A, (b) Some fastest routes to the evacuation points in Scenario B

Then road network analysis was conducted and followed by evacuation time calculation. See Fig. 6(b).

The flood began at 01:49 when the discharge reached 170 m3/sec, while the maximum discharge of 285.20 m3/s occurred at 03:00. Thus, the evacuation time was 71 minutes. Research analysis showed that the longest evacuation time (from PRPP) was 70.21 minutes, reached by walk, and 20.04 minutes by motorcycle. Specifically, evacuation from PRPP area is obligated to use the motorcycle and/ or other vehicles. It is not safe by walk because it will exceed the maximum time limit.

3. Scenario C (Flooding in West Banjir Kanal).

In scenario C, it was determined six evacuation points as seen in Fig. 7. Then road network analysis and evacuation time calculation were conducted.

The flood began at 07:15 when the discharge reached 3000 m^3/sec, while the maximum discharge reached 3717.60 m^3/sec and occurred at 08:00. Therefore, the evacuation time is 45 minutes. From the travel time analysis it was found that the maximum evacuation time by walk from the farthest location, Krobokan, was 39.03 minutes, and it took 14.84 minutes by motorcycle. From the Krobokan location, both by walk and/ or by motorcycle to the evacuation point are considerably safe.

4. Scenario D (Flooding in Silandak, Siangker and West Banjir Kanal).

In scenario D, there are 12 evacuation points. All evacuation points are a combination of the previous three scenarios. Evacuation time for the area around Silandak River CA was 34 minutes referred to Scenario A result. Evacuation time for the area around Siangker River CA was 71 minutes, resulted from Scenario B (Siangker River flood). Evacuation time for the area around the West Banjir Kanal based on Scenario C was 45 minutes.

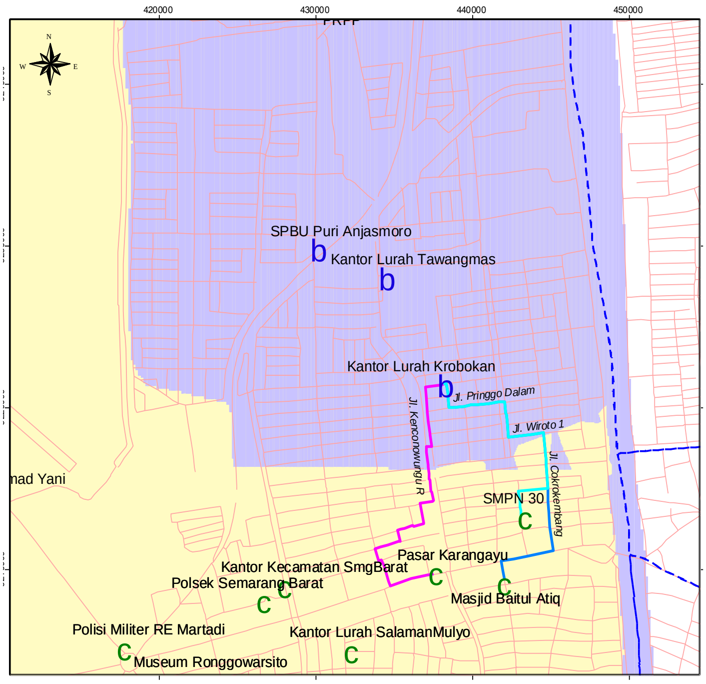

Fig. 7. Some the fastest routes to the evacuation point - Scenario C

4. Conclusions and recommendations

4.1. Conclusions

1 The capacity of the three rivers is not capable to hold the design flood (Q_{100}).
   a. Silandak River capacity = 209 m^3/sec, its design flood = 258.50 m^3/sec.
   b. Siangker River capacity = 170 m^3/sec, its design flood = 285.20 m^3/sec.
   c. West Banjir Kanal River capacity = 3000 m^3/sec, its design flood of 3717.60 m^3/sec.

2 The inundation covers the settlement and other areas of 10,80 km^2 (49.68%).

3 Based on the evacuation criteria and the field surveys results, there are 12 shelter points i.e. the State Elementary School of Tambakharjo, Tambakharjo Sub District Office, Nurul Falah Mosque, Kulon Kalibanteng Office, The RE Martadinata Military Police Office, Ronggowarsito Museum, Police Office in the West District Semarang, The West Semarang District Office, Salaman Mulyo Sub District Office, Karangayu Market, Baitul Atiq Mosque, and Yunior High School 30.

4 There are 18 evacuation routes identified, i.e.:
   a. From Gisikdrono Road to Tambakboyo Elementary School, Tambakboyo Sub District Office, and Nurul Fatah Mosque.
   b. From Ahmad Yani Airport to RE Martadinata PM Office, Ronggowarsito Museum, and the West Semarang District Office.
   c. From PRPP to the West Semarang Distict Office, the West Semarang Police Office, RE Martadinata PM Office.
   d. Tanjung Mas District to Yunior High School 30, West Semarang District Office, Karang Ayu Market.
   e. Anjasmoro Gas Station to the West Semarang District Office, the West Semarang Police Office, RE Martadinata PM Office.
   f. Krobokan Sub District Office to Yunior High School 30, Karangayu Market, Baitul Atiq Mosque.

5 Overall, the evacuation time by motorcycle is safe and does not exceed the time limit, i.e, the time required when the inundation reaches its peak. In several routes, the required evacuation time by walk has exceeded the inundation time (45 minutes):

from PRPP to The West Semarang District Office, to RE Martadinata PM Office and to the West Semarang Police Office. On average, it takes 70 minutes.

4.2. Suggestions

1. Some improvement is still required to apply this model to the research area and/ or other places by conducting some additional activities, i.e.:
   a. To validate the field condition that may affect upon the evacuation rate.
   b. To calibrate the real motor cycle speed to calculate the evacuation time.
2. Especially for PRPP, it is not permitted to evacuate people by walk because it will exceed the inundation time. It is obliged to evacuate people by motorcycle and/ or other vehicles.

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The initial step for developing sustainable urban drainage system in Semarang city-Indonesia

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Abstract

The objective of this study is to evaluate the impacts of the climate changes, land subsidence, and land use changes to flood in East Semarang Drainage System. Rainfall data from three stations in the period of 1990-2014 were used to describe the changes of rainfall characteristics, while sea level rise was analyzed based on sea level data in the period 1985-2008, combined with land subsidence data. The trend of rainfall characteristics changes were analyzed by statistical regression. HEC-MHS and HEC-RAS were used to estimate flood hydrograph and flood level. The results showed that during the last three decades, the annual rainfall and maximum daily rainfall is likely to increase by 22.64 mm/year and 2.56 mm/year consecutively, while the number of rainy days tends to decrease by 4 days/year. The rate of land subsidence is 5.34 cm/year, and SLR of 2.3 mm/year. Flooding and tidal inundation due to increasing rainfall and sea level rise is predicted to increase by 4.65% for a period of 17 years. Changes in rainfall characteristics contribute to increasing flooded area of 3.61%, while the SLR of 1.04%. Land subsidence is predicted to lead to an increase in flooding and tidal inundation by 23.59%. These three factors together combined with land use changes would increase the flood inundation of 26.69% for the period 2014 through 2031.

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Keywords: climate change; land subsidence; rainfall characteristics; sustainable urban drainage system

1. Introduction

Over the past two decades, the floods that hit major cities in Indonesia tend to increase, both in quantity and frequency. Much discussion is done to address this problem. Many expressed the opinion that the increase in floods is triggered or exacerbated by human activities, mainly related to land conversion. It cannot be denied, because the cities in Indonesia are still in the development stage. Other anthropogenic activities that are thought to contribute to flood are groundwater extraction that triggered land subsidence, and a greenhouse gas that causes global warming.

Urban flood that occurred was also compounded by the urban drainage system which is still conventional. It still uses the concept of discharging of water as quickly as possible from a protected location. Although, it has started to realize that this concept is no longer appropriate to be applied, but to leave it and shift to sustainable drainage system is not easy. As the existing is a mixed drainage system (storm water and waste water), while sustainable urban drainage system requires separate system. Sustainable urban drainage system is more emphasized how to manage rainwater instead of how to dispose of rain water as soon as possible. Rainwater is seen as a vital resource that must be managed appropriately and not as an enemy that must be removed.

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The most realistic step is to deepen understanding of the causes of the increased incidence of urban flooding, as an initial step in formulating a comprehensive and sustainable urban drainage system.

This study discusses the contribution of each of these causal factors, namely land use changes, climate change, and land subsidence to the increasing the flood inundation to support the development of sustainable urban drainage system. The case study is East Semarang Drainage System which includes Tenggang and Sringin catchment areas

2. Study area

The drainage system is an important issue in large cities, especially for cities in coastal areas, where the river is affected by tidal in the sea. The drainage system is also affected by changes in land use and human interaction because of urbanization [1, 2]. Semarang city is a good example to illustrate the problem. Semarang, capital city of Central Java Province, located in the northern coast of Java, Indonesia (Fig. 1). Geographically, it is located in 6º50'-7º10 'south latitude and 109º35'-110º50' east longitude, and covers an area of approximately 373.67 km^2, and inhabited by 1.57 million people in 2013 [3]. Semarang topography consists of two different landscapes, low-lying areas in the northern coast and the hills in the south. The northern part, where there is the center of the city, the port, the airport and the railway station is located, relatively flat topography with slopes ranging between 0 and 2%, and a height of between 0 and 3.5 m; while the south has a slope of up to 45% and a height of up to about 360 m above sea level. The northern part, which is called the old town, is a congested area, while the south is still relatively less dense and much open land.

The flood in Semarang in fact showed a tendency of increasing from time to time [4]. There are many causal factors, the dominant factors are land use alteration, climate change and land subsidence. The rapid development of the city in the last three decades, causing an impervious area increased, as a result of runoff higher and faster concentrated to the outlet. Climate change brings changes in rainfall characteristics. Based on rainfall data for 50 years (1960-2010), it was found that the maximum daily rainfall is likely to increase by 40.90 mm, with an average of 0.82 mm / year. The intensity of one hour rainfall duration is increased from 57 mm / hour in 1960 to 85 mm / hour in 2007. For two hour rainfall duration, it is increased from 35 mm / hour in 1960 to 55 mm / hour in 2007 [5].

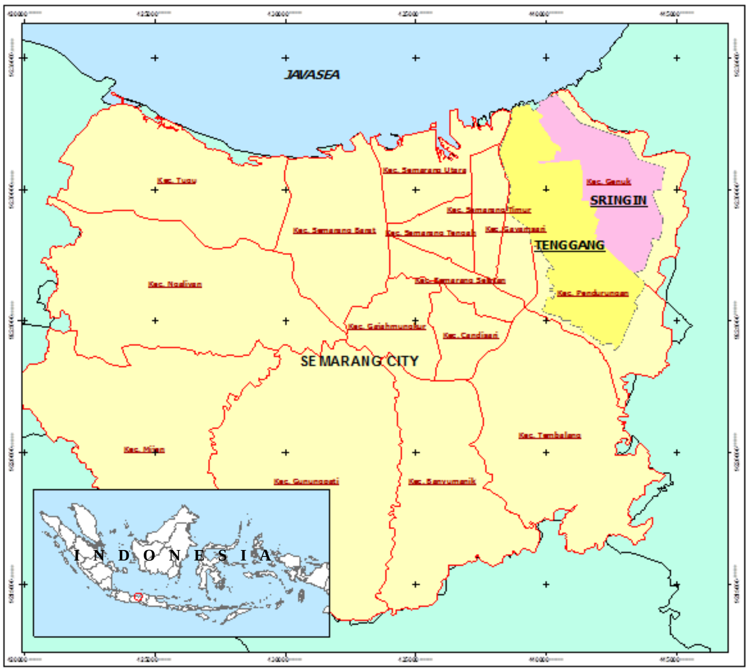


Fig 1. Study Area, Tenggang and Sringin Drainage System in Semarang, Indonesia

The land subsidence is not new to the city of Semarang. This incident has been known for more than 100 years ago [6]. There have been many studies conducted, with a variety of methods, including: leveling and tide data [7]; leveling and GPS [8], PSI with a network of fixed points [9]. The results obtained were relatively diverse, but generally concluded that the subsidence occurred in the area of Semarang low land (coastal) eastern part is at a rate of between 4 cm - 15 cm per year.

Semarang as part of the global community is also affected by sea level rise [10]. The current global sea level rise (SLR) is approximately 2 mm per year (1-3 mm / year in the coastal areas of Asia) and is projected to increase to about 5 mm per year over the next century [11]. These changes will have an enormous impact on tidal inundation in low-lying coastal areas of the city. The combination of the effect of land use, climate change, and land subsidence against flooding and tidal inundation led to the management of the drainage system in the city of Semarang yet to be completed. Development of drainage system that has been done is still conventional, not taking into account these factors comprehensively.

3. Methodology

Many studies that discussed about the potential impact of climate change on the hydrology of watersheds have been done [12, 13, 14]. The approaches are varied, ranging from the simplest to use statistical analysis to complex with general circulation models (GCMs). In this study, the changes of rainfall characteristics, annual rainfall and maximum daily rainfall, were analyzed based on data from three rainfall stations inside and/or around the watershed: Karangroto¸ Pucanggading, and Maritime rainfall stations. The trend of the change of rainfall characteristics were statistically analyzed with regression. The land subsidence was predicted based on analysis of data from several previous researchers. The predicted land subsidence was then added to DEM of 2014 to represent the DEM for 2031. While sea level rise was predicted based on the tidal recorded at Tanjung Emas Semarang between 1985 and 2008. Flood discharge was estimated by using the HEC HMS software. Two hour rainfall duration hyetograph of 25-year return period was used in this study, as it resulted the higest peak discharge compared with other rainfall durations [5]. Hydraulics analysis to estimate flood water elevation performed using HEC RAS software. Inundation area was based on the depth obtained from topographic maps by ArcGIS. The future flood discharge was predicted based the trend of rainfall characteristics changes as well as land cover change. Changes in land cover refers to the current state (2014) and the conditions that will come in accordance with the document Spatial Planning (RTRW). The flooded area was predicted by overlying among the map of land subsidence, sea level rise prediction, and flood water elevation. It was assumed that sea water can freely flowing to the low land area, either through the shoreline, channel, or river.

Analysis of the flood inundation changes carried out with five scenarios, each scenario was aimed to determine its contribution to the flood inundation, as follows:

- Scenario 1: illustrate the existing conditions, which do not take into account the effect of changes in rainfall characteristics, sea level rise, land subsidence, and land use, it was used as baseline;
- Scenario 2: taking into account changes in rainfall, other factors remain;
- Scenario 3: taking into account the changes in sea level rise (SLR), other factors remain;
- Scenario 4: taking into account the land subsidence, other factors remain;
- Scenario 5: taking into account the effects of changes in rainfall characteristics, sea level rise, land subsidence, and land use together.

4. Results and discussion

Characteristics of rainfall in the study area, which is represented by three stations: Karangroto (94), Pucanggading (98), and Maritime showed that in general the annual rainfall and maximum daily rainfall tend to increase, while the number of rainy day tend to decrease (Fig. 2). Mean annual rainfall increased 4.25% per year, the maximum daily rainfall increased an average of 1.39% per year, while the number of rainy days was decreased an average of 1.92% per year.

Land subsidence in the study area was analyzed based on measurement data by using leveling and GPS method carried out in 2008 and 2011. Based on these spot data, the land subsidence of point measurement can be known. The highest rate of land subsidence is 5.58 cm / year occurred at coordinate 06°58'18.65121" south latitude 110°26'31.71232" east longitude. Plotting of the results of measurements of the land subsidence rate was then overly with DEM (digital elevation model) map for the year 2014 to generate the future land elevation maps, assuming the rate of land subsidence is constant. Fig 3 shows a map of land subsidence (left) and DEM of Semarang City in 2014 (right). This land subsidence map can be projected to generate DEM map of existing and future conditions.

Sea Level Rise (SLR) was analyzed based on the tidal data recorded by PT. (Persero) Pelabuhan Indonesia III of Tanjung Emas Semarang. Data available for the year from 1985 to 2008 (Fig. 4). Plotting the data shows that the scatter water level in general tends to rise steadily, although the water level decreased between 1998 and 2003. Later revealed that the water level measuring devices (AWLR) in the period 1998-2003 has been modified, and the data is considered invalid, therefore the data is not used for analysis. It can be obtained that the sea level for the period of 1985-1998 increased 57.2 cm, with an average of 4.40 cm per year. While during the 2003-2008 period, sea level rise 33.36 cm or 6.672 cm per year. So that the average sea level rise during the period of 1985 - 2008 was 5.536 cm per year.

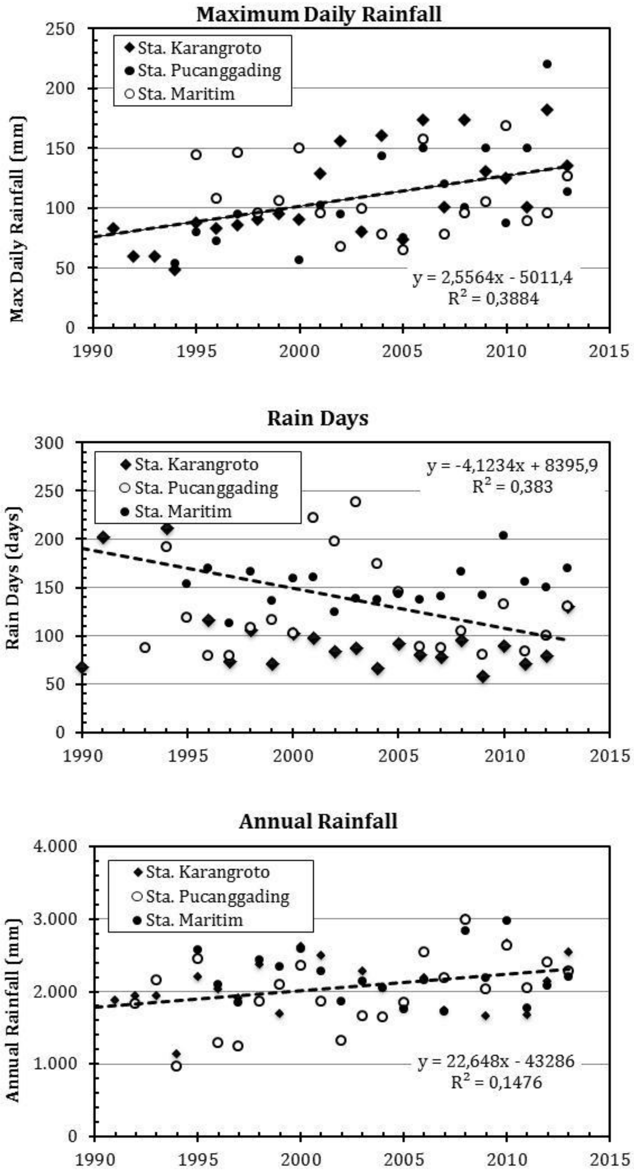


Fig 2. Changes in rainfall characteristics in the study area

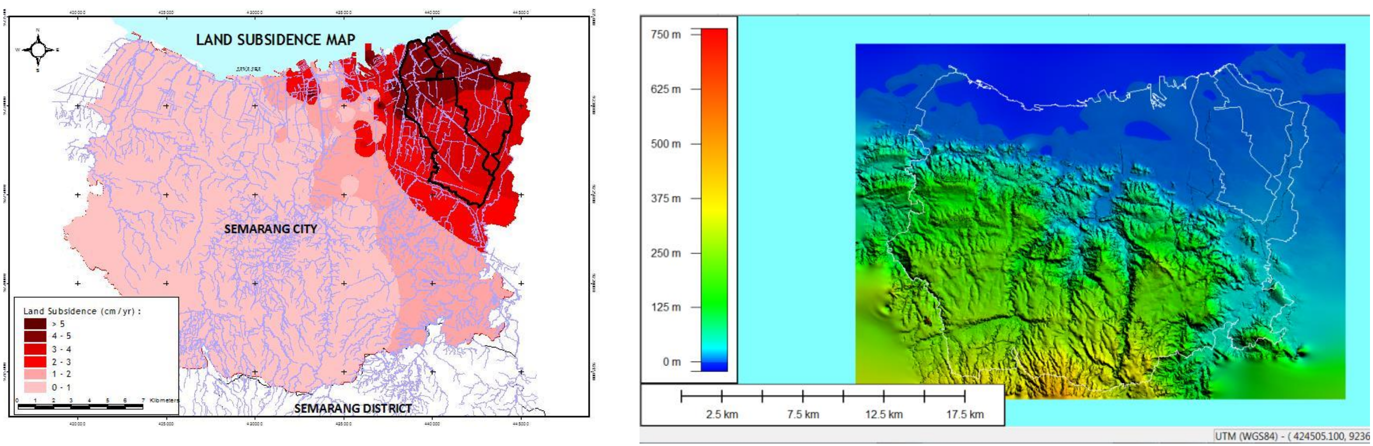


Fig 3. Map of the land subsidence rate (left) and DEM 2014 (right) of Semarang City

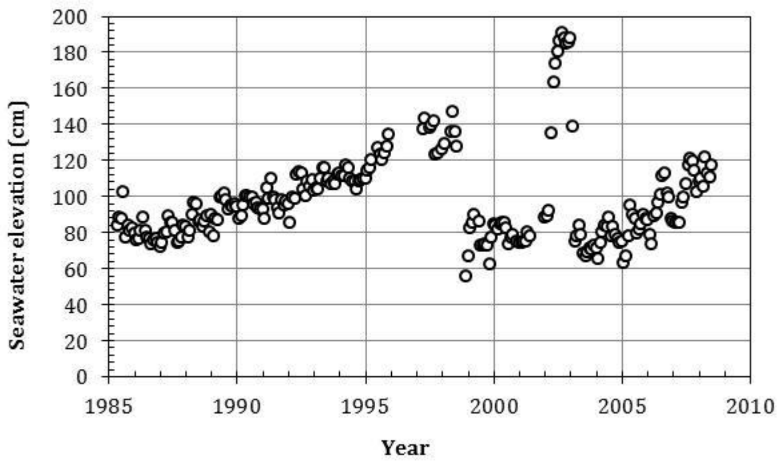


Fig 4. Sea level data at Tanjung Emas Semarang for the year 1985 - 2008

Facts show that the tidal station operated by PT. Pelindo III is going down together with land. The data of sea level rise recorded in the tidal station is basically a combination of actual sea level rise and land subsidence. Referring to the analysis of the land subsidence (Fig. 3), the land subsidence rate at the tidal station is 5.310 cm, slightly higher than the results of previous studies, i.e. 5.165 cm / year [7], and still be in the range of 5-6 cm/year [6]. By using the rate of land subsidence 5.310 cm per year, the rate of sea level rise in the study area is then equal to 2.26 mm/year. This result is consistent with the predictions of sea level rise in coastal areas Asia, ie in the range of 1-3 mm / year [11].

Land-use change occurs primarily of open land (rain fed rice field) into the settlement, then turned into urban area. The land cover for the year 2004, 2009, 2014, and spatial planning of the study area (2014-2031) is presented in Table 1.

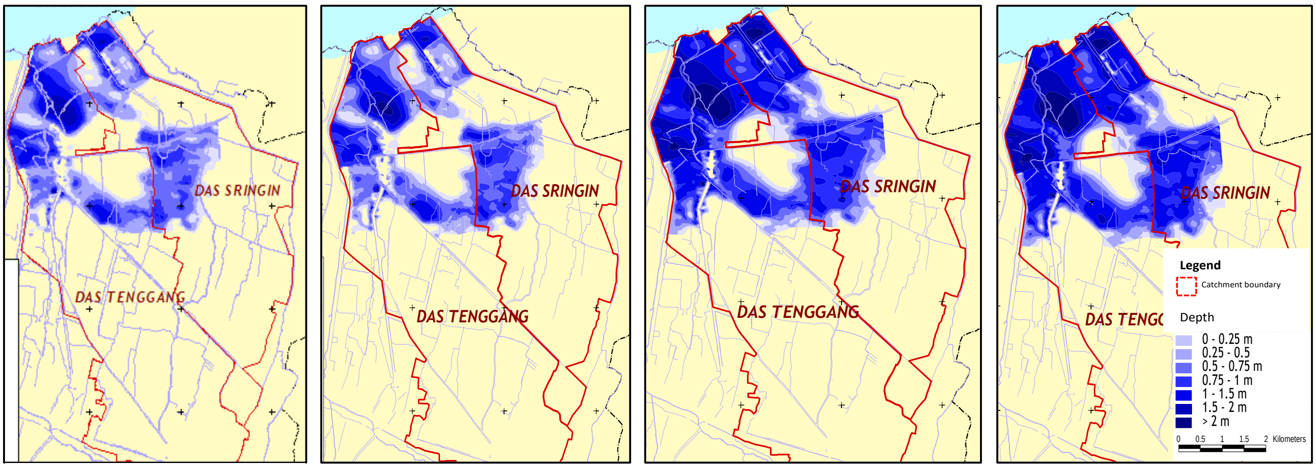
Table 1. Land use for the year 2004, 2009, 2014 and 2031 of the study area

Type of land use	area in percent			
	2004	2009	2014	RTRW**)
Rain fed rice field	34.06	7.75	0.00	0.00
Settlement	40.29	64.43	64.50	58.14
Urban area	15.73	17.90	29.51	34.14
Fishpond	9.92	9.92	5.99	3.73
Forest	0.00	0.00	0.00	3.99
Total	100.00	100.00	100.00	100.00

**) RTRW = spatial planning of the study area (valid for 2014-2031)

Design rainfall used in this study is 25-year return period. Flood hydrograph analyzed using HMS HEC program, and continued with hydraulic analyses with HEC RAS. The absence of the data record flood hydrograph in the study area, the hydrologic calibration cannot be done directly. The calibration is carried out by using flooded area, by comparing the observed flooded area and predicted flooded area.

Floodwater for each scenario was obtained by adding the elevation of water level to DEM, as shown in Fig. 5. The results are briefly summarized in Table 2. Table 2 it can be seen that the land subsidence to give the highest contribution to the increase in inundation and flooding, followed by the effect of changes in rainfall characteristics, land cover change, and the smallest is because of sea level rise. All these factors together, the flood inundation is predicted to increase 26.69% over a period of 17 years (2014-2031). The change of rainfall characteristics contributes 3.61%, and SLR of 1.04%. Thus climate change will account for 4.65%, and change in land use contributes 3.10% to the flood inundation of the study area.



(a) Existing condition (baseline)

(b) Climate change (Change of rainfall characteristics & SLR)

(c) Land subsidence

(d) Climate change, land subsidence, and land use changes

Fig 5. Inundation area for varoius scenarios

Table 2. Inundation area in the study area for each scenario

Flood depth (m)	Inundated area (ha)				
	Scenario-1 (Baseline)	Scenario-2 (Rainfall change)	Scenario-3 (SLR)	Scenario-4 (Land subsidence)	Scenario- 5 (Climate change, land subsidence, and land use changes)
> 2.00	1.34	5.82	5.77	46.58	53.01
1.50 – 2.00	25.93	27.03	26.96	153.87	171.50
1.00 -1.50	102.54	130.94	111.91	349.30	421.19
0.75 – 1.00	175.80	200.89	168.21	280.78	237.79
0.50 – 0.75	275.43	277.70	268.81	170.16	165.78
0.25 – 0.50	270.99	248.86	267.31	133.53	124.21
0.00 – 0.25	168.19	165.89	181.85	126.69	119.00
Total	1,020.23	1,057.11	1,030.83	1,260.91	1,292.49
Contribution to increasing flooded area (%)		3.61	1.04	23.59	26.69

Based on Table 2, it can be also known that the areas of inundation depth higher than 1.0 meters are increased markedly from 129.81 ha (based line) to 645.70 ha or increased 397.42% in 2031. Meanwhile, the areas of inundation depth less than 1.0 meters are reduced from 890.41 ha to 646.78 ha or reduced 27.36%. It may happen as the land subsidence rate does not occur evenly throughout the study area. Land subsidence occurs only in coastal areas with diverse rate. The highest land subsidence in coastal areas (northern), inland (south) land subsidence become smaller and approach zero at a distance of approximately 10 km from the coastline.

5. Conclusions and recommendations

The study concludes that flood inundation area in the study area tend to increase. The increasing of flooded are is proportional to the increase of rainfall, sea level rise, and runoff coefficient (due to land use conversion). During the period of 15 years (2015-2030) changes in rainfall characteristics influence of 3.61% or the average 0.28% per year, SLR of 1.04% or an average of 0.06% per year to the increasing flooded area. The land subsidence in the study area contributed 23.59% for the same period, or an average of 1.39% per year. Taken together of these three factors plus land use changes will cause flooding and tidal inundation rise of 26.69%, or an average of 1.57% per year against the baseline (2014).

The accuracy of the results of this study need to be further validated with field data, therefore it is recommended to perform measurements of the flood discharge continuously by installing automatic water level recording station (AWLR). The land subsidence has to be monitored regularly, and efforts to reduce it should be formulated seriously. As the influence of climate change, and land subsidence against flood and tidal inundation is high, then these factors should be taken into account comprehensively in the development of sustainable urban drainage systems in Semarang City.

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Proposed method to determine the potential location of hydropower plant: Application at Rawatamtu Watershed, East Java

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Abstract

Potential of hydroelectric plants depend on the availability of discharge and head flow. The steep slope of rivers and the abundant of water flow in rural areas are as potential locations of hydroelectric power plant site (HPPS). The lack of discharge data measurements on the tributaries are the main obstacles to determining the potential sites. This paper proposed a method to identify the potential sites for HPPS. The method based on two main information: (1) location of the steepest slope, and (2) discharge generation of tributaries. In this case, ASTER GDEM 2 was used to: delineate watershed boundary, determine river network, and derive slope. Then, long section of the selected tributaries was analyzed to obtain the location the steepest slope potentially to HPPS. Furthermore, generated discharges for selected sites were calculated using Clark UH running under HEC-HMS program. The model was calibrated using daily discharge data observed at the watershed outlet. The time series period used for calibration process is range from 2002 to 2014. Simulation model of rainfall-runoff at a variety of outlets were selected to obtain the dependable discharge assisted with hydro-office program. This result show that total potential of hydroelectric plants can reach up to 653 kW.

Keywords: hydrology, spatial, FDC, HPPS

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1. Introduction

The electrical energy is currently the most urgent needs correspond with current developments in both urban and rural areas. In urban areas, the electric energy supply is still constrained by the rotation outages. While in rural areas, the electricity supplies have not yet to serve entirely. Lack of sources of electrical energy is an issue that must be resolved in all regions. Various alternative energy sources such as PLTH, power plant, etc. have been developed. However, the electricity crisis is still unresolved.

Hydroelectricity is a small-scale alternative energy source which has the advantage to replace greenhouse gas emissions, which can contribute to sustainable rural development [1]. According to [2] where hydroelectric plants provide an important contribution to environmental protection of the local communities, and social cohesion (reduction of migration, etc.), because the method of run-off river does not require a large reservoir, so that the issue of the environmental impacts of dams was not feasible in this system. Run-off river systems provide an alternative power generation, and can be financed and owned by the local communities. The positive effect of these hydropower plants, the presence of potential sources should be sought as a power generator.

Potential source of Hydrolelectric affected by discharge availability and head flow that capable to change kinetical energy to become potential energy or power. Power, P, (kW) formulated by equation (1) [3] was influenced by the flow rate, Q, (m3 / sec); effective height, h, (m); the density of the fluid, ρ, (kg / m3); acceleration of gravity, g, (m3 / s).

$$P= Q.h.\ \rho.g.\eta \tag{1}$$

Based on these variables, Jember regency has the potential to build hydropower plants, because the area is mountainous and impassable by many tributaries that have a source of water with a fairly steep slope area. However, these potential locations are generally located in areas that are difficult to reach, thereby determining the location of optimal hydropower plants is hard to do in a conventional manner. Thus, the potential water resources are not fully utilized. Therefore a method for determining the potential of hydroelectric power plants efficiently and effectively in remote areas is needed.

Some researchers have determined the potential of hydropower plants to locate remote areas who generally have limited means of measuring discharge by using hydro-spatial approach. As performed, [4] are identifying potential hydropower plant in Uganda with spatial analysis found 250 potential locations, and once selected 14 locations turned out to only three locations available water discharge. [5] in Pohnpei, Federated States of Micronesia (FSM) determine the flow duration curve (FDC) using parametric curves of flow versus the average annual discharge selected for specific conditions on the percent exceedance. [6] is determining the height difference with the neighborhood and the statistical method in river discharge using SCS-CN equation in Kapuas upstream resulting in able to identify 18 sites with electric power of 100 kW to 5.2 MW.

Based on the success of the method in previous studies, the potential for hydroelectric power plants in the Rowotamtu watershed need to be developed. This paper integrates spatial analysis to determine the location of the height difference using Geographic information system (GIS), with rainfall-runoff modeling to generate a flow of data in locations that are not available discharge measuring tool to determine its FDC. The method used in the generation of discharge data differ from previous methods [6], Clark unit hydrograph is used due to a lack of land use recording data.

GIS is very supportive in hydrological modeling to facilitate the processing, management, and interpretation of hydrological data. One of the most useful capabilities of a GIS is the ability to describe the topography of the area [7]. This capability is used to develop a Digital Elevation Model (DEM). DEM is a digital representation of ground surface elevation. It is used for processing ground elevation values measured at the intersection of the horizontal grid lines [8]. Elevation data grid is a type of raster data, which is an array of values measured at uneven locations spatially across the region. DEM is required to generate a current, flow direction, flow accumulation, flow length, steepness of the slope and watershed [9]. DEM is the essential tool needed to research the hydrology and water resources.

HEC-HMS is a hydrological model that is able to model the rainfall data into the stream for single or continuous produced by the US Army Corps of Engineers hydrologic Engineering Center [10]. Rainfall runoff modeling process with HEC-HMS in a watershed can describe the loss of water when it precipitation (loss method comprises 4 methods), transformation of rainfall into streams (there are 6 unit hydrograph models include: Clark, ModClark, SCS, Snyder, User- specified S-graph, and User-specified), routing the flow in the river (there are 5 methods include: lag, Muskingum, Muskingum cunge, modifield puls, kinematic wave and straddle stagger), and baseflow (methods include constant, monthly-varying value models, exponential recession-linear models and reservoir volume accounting model)

The Clark unit-hydrograph (UH) is the transformation of rainfall into runoff models that exist in the watershed that represent two important processes. Movement of runoff water from the channel to the outlets, and the loss of the existing amount of discharge in the watershed. The principle of this model is similar to the linear reservoir models that have the continuity equation [10]. The model is a function watershed linear reservoir storage, S_t, watershed storage coefficient, R, and outflow, O_t, formulated in the equation:

$$St = R\,O_t \tag{2}$$

Clark UH method using the time of concentration (T_c) and storage coeficient (R) to build the shape function of time-area. This method is quite flexible and able to connect geomorphology in the form of hydrograph [11]. Therefore Clark UH has the advantage that it can performed to a watersheds that do not have AWLR. Time of concentration equation (3) is a function of the length of the main river (miles), L, and the slope of the river S (ft / mile).

$$Tc = 1{,}54 L^{0{,}875} S^{-0{,}181} \tag{3}$$

Storage coefficient (R) equation (4) is function of main river length (mil), L, and river slope (ft/mil), S, formulated as below:

$$R = 16{,}4 L^{0{,}342} S^{-0{,}790} \tag{4}$$

Muskingum method is performed for river routing. This method has been successfully applied by [12],[13], and [14] for river routing. This method is based on the assumption that there are linier relationship on channel storage, inflow and outflow discharge with all consequently introduced. This method is suitable for the channel-shaped prism with the high enough reservoirs. Towards the river downstream, the outflow can be calculated using equation (5) representing the mass balance, and the equation (6) expresses reservoirs volume (W) on the channel, which is a simple linear combination of discharge at upstream inflow (I) and outflow (Q) at downstream. The required parameters in Muskingum method is x and K. K is travel time (T) of flow through the entire channel and is called coefficient of reservoirs. x represents the weighting factor with a value ranging between 0-0.5 range depends on channel cross-sectional shape.

$$\frac{dW}{dt} = 1 - 0 \tag{5}$$

$$W = K[xI + (1 - x)Q] \tag{6}$$

2. Methodology

2.1. Data

The data used in this research is hydroclimatological and spatial data. Climatological data in the form of daily rainfall and discharge data. Rainfall data were obtained from the Department of Water Resources Jember for 12 years (2002-2014) from 20 rain stations include Dam Makam, Dam Pecoro, Rambipuji, Rowotamtu, Dam Sembah, Bintoro, Dam Arjasa, Kopang, Dam Pono, Tamanan, Sukokerto, Sukowono, Sumber Kalong, Sukorejo, Sumberjambe, Cempedak, Kotok, Jember, Ajung and Renes. While discharge data that used are from the Rawatamtu AWLR station result of 12 years records (2002-2014) obtained from UPT Bondoyudo-Mayang.

ASTER GDM 30 data (a spatial resolution of 30m x 30m) performed by Arc Gis 10 and ArcHydro 9 is used to generate the river network and create sub-watershed and watershed delineation accessed from the characteristics of the topography. Based on the GIS layer can be obtained length of the river, watershed area, and the slope is input from UH Clark. Layer land use is needed to determine its improvious value.

2.2. Rainfall-runoff modelling

Rainfall-runoff modeling process is intended to generate the long term discharge in the location of the planned hydropower plants. This generation process using two approaches aided by HEC-HMS 3.5 software. Model calibration is performed in the downstream Rowotamtu discharge station. The results of the calibration parameters on the tributaries is used to generate models of the long term discharge. Rainfall-runoff modeling process in the Rowotamtu Watershed for loss rate using initial loss, constant rate, and impervious transformation of rainfall into streams (direct runoff) using method of Clark unit-hydrograph, baseflow using bounded recession and for the search of flooding on the river using the Muskingum and gain / loss of his using constant. The sub watershed scheme with the required parameters in the model of HMS HEC program is shown in Fig 1.

2.3. Model evaluation

The evaluation process model is performed by calibrating the entire modeling on Rowotamtu AWLR station. Calibration is performed automatically by minimizing the objective function peak weight RMSE. Goodness of fit from model calibration is shown based on the efficiency of the resulting model (EEF) as performed by Ibbitt and O'Dannell, (1971) and Nash - Sutcliffe (1970). EEF value is affected by observation discharge (Q_{oi} m^3/det); average observation discharge ($\overline{Q_o}$ m^3/det); and discharge simulation results (Q_{si} m^3/det). If the total of observations discharge are similar to discharge simulation results, the EFF value equal to 1. The equation to evaluate the EEF is as follows:

$$EEF = \frac{\sum_{i=1}^{n}(Q_{oi}-\overline{Q_o})^2-\sum_{i=1}^{n}(Q_{oi}-Q_{si})^2}{\sum_{i=1}^{n}(Q_{oi}-\overline{Q_o})^2} \tag{7}$$

The calibrated parameters are include: for loss is Constant Loss Rate and Initial Loss, for Clark UH is R and T_c, for Baseflow is Initial Flow and Constant Recession, and for routing is K and X.

Fig. 1. Sub-watershed with Parameters

2.4. Potential river discharge

Potential river discharge can be determined based on the result of the generation of synthetic daily discharge from modeling rainfall into streams at a location that does not have the tools to measure the discharge. Considering the hydropower plan using runoff river it should be known that there is a dependable discharge in the river. Dependable discharge can be calculated by using method of flow duration curve assisted with hydro-office program.

2.5. Potential hydropower

Based on the equation (1), the potential energy generated by hydropower is influenced by two important factors that is the effective height difference and dependable discharge. Effective height difference can be determined with the GIS approach that is from generation riverbed topographycal profile. While the dependable discharge is the result of the FDC calculation.

3. Result and discussion

This research was performed in the Rowotamtu watershed. Based on the results of sub-watershed delineation are found the number of tributaries for order 3 is 10 tributaries that can be seen in Figure 1. The tributary have a variety of shapes, the slope of the riverbed and spacious. The total area of watershed is 667.82 km^2. The slope in this watershed can be classified into three parts, that is high (1157-3325), low (124-148 m), and medium (148-1157). Length, area, and the slope of the river bed are shown in Table 1, the longest tributary is Suger tributary and the next is Pakem tributary. Tributaries with a largest river slope is the Jompo tributary and that has the largest watershed area is Sumber Pakem tributary.

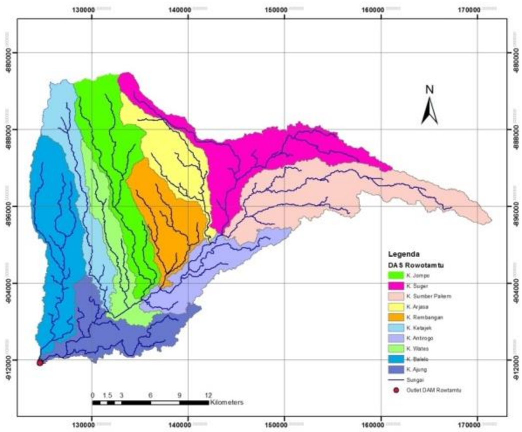

Fig. 2. Location of study

Table 1. Physical Condition of Rowotamtu Tributaries.

Sub-Watershed	Length (km)	Slope (%)	Area (km^2)
Balelo	80.542	26.269	85.140
Ketajek	83.670	31.277	51.297
Kaliwates	77.536	19.814	40.601
Jompo	85.081	42.273	82.326
Rembangan	53.183	22.070	53.481
Arjasa	61.833	34.635	50.300
Suger	120.476	17.507	91.380
Sumber Pakem	109.925	15.117	111.205
Antirogo	71.586	10.429	46.205
Ajung	82.198	9.120	55.887

The majority land use of Rowotamtu Watershed is the forest. Forest land use will have a positive impact on the existence of hydropower, because the forest will provide baseflow in rivers which makes continuous availability of water in the dry season [17].

Based on the results of hydrological modeling with outlets in Rowotamtu that have been optimized indicate that this modeling can respond baseflow well with EFF value of 0.99. Recession sensitive parameter is constant and constant loss rate. Generally the model has some similarities pattern that shows in figure 3, but has not been able to show a good response for extreme rainfall conditions. As a basis for planning Hydroelectric the main requirement is low flow, so that the model parameters can be used to predict the flow of water at a location that does not have the tools to measure the discharge.

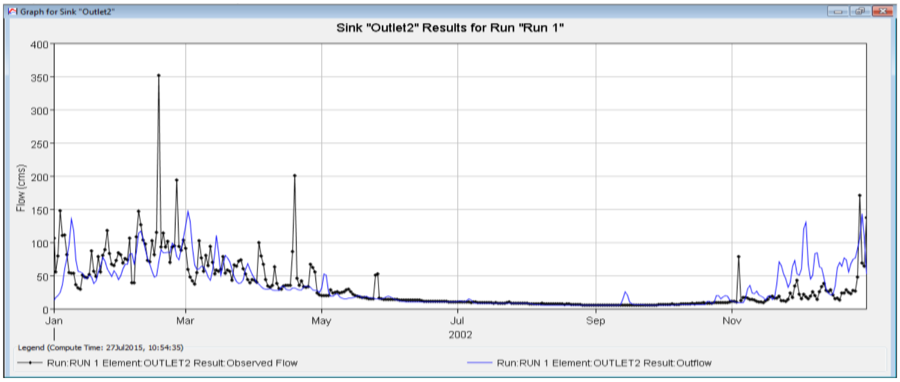

Fig.3. The result of model calibration.

Based on the results of generation discharge in nine locations in seven tributaries obtained FDC values for the reliability of 90% with a range of values between 0.3 m^3/s up to 1 m^3/s (Figure 4 and Table 2). The largest water source is from Sumber Pakem tributary, and the smallest is from Kaliwates tributary. Based on the results of running model showed that the value of dependable discharge and minimum discharge have a significant linear correlation value of respectively 0.9611 and 0.9272 with sub-watershed area (figure 5), while the maximum discharge had a fairly good correlation value of 0.6777 with river length and 0.6695 with percentage of slope. Therefore, this rain-flow modelling is more suitable for low-flow stream.

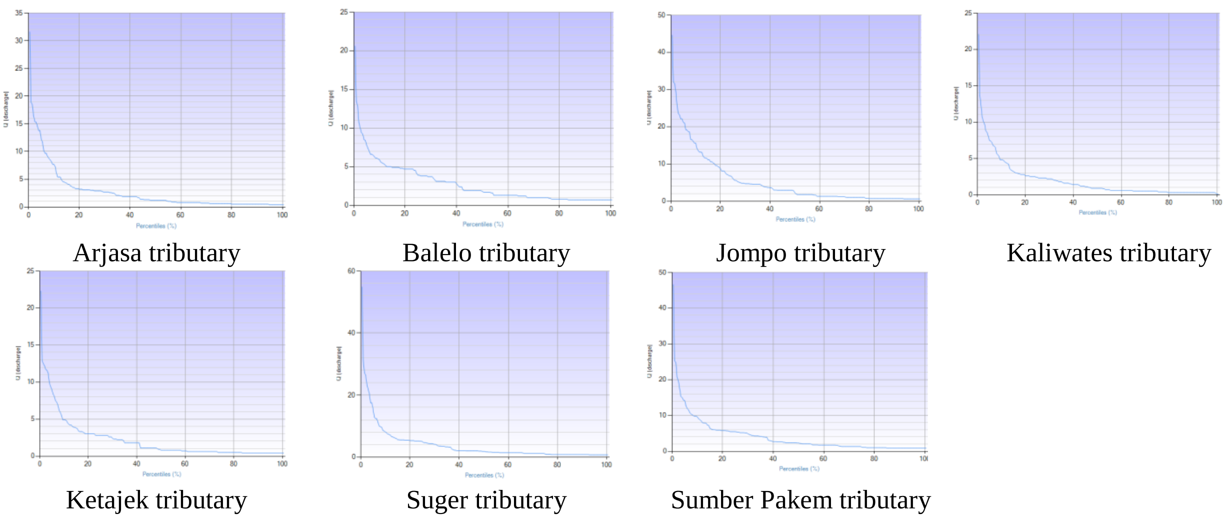

Fig. 4. FDC of Rowotamtu Tributaries

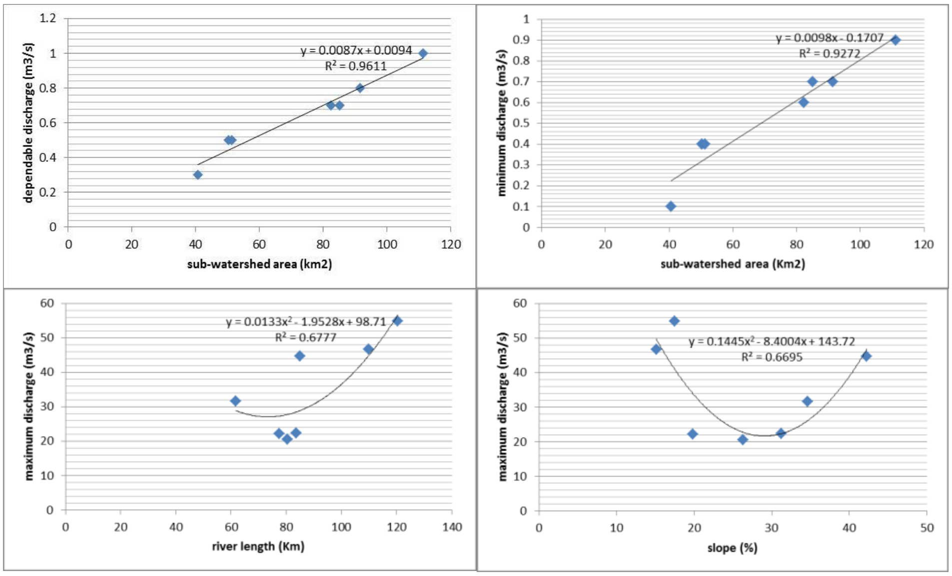

Fig. 5. Correlations between discharge, sub-watershed area, river length, and slope

The potential value of the generated electric power ranging from 24 kW up to 157 kW. The location of potential hydro power as shown in Figure 6. According to [18] , the capacity of hydropower can be classified into four classes, that is high (> 10,000 kW), medium / small-hydro (up to 1.000-9.999 kW), low / micro -hydro (100-999 kW), and small / mini-hydro (<99 kW). Therefore, the potential of hydropower in the Rowotamtu watershed classified as mini-hydro in Balelo and Ketajek tributaries and the remaining category is micro-hydro. Balelo and Ketajek tributaries and has a great potential for power generation because of their effective height difference is quite high.

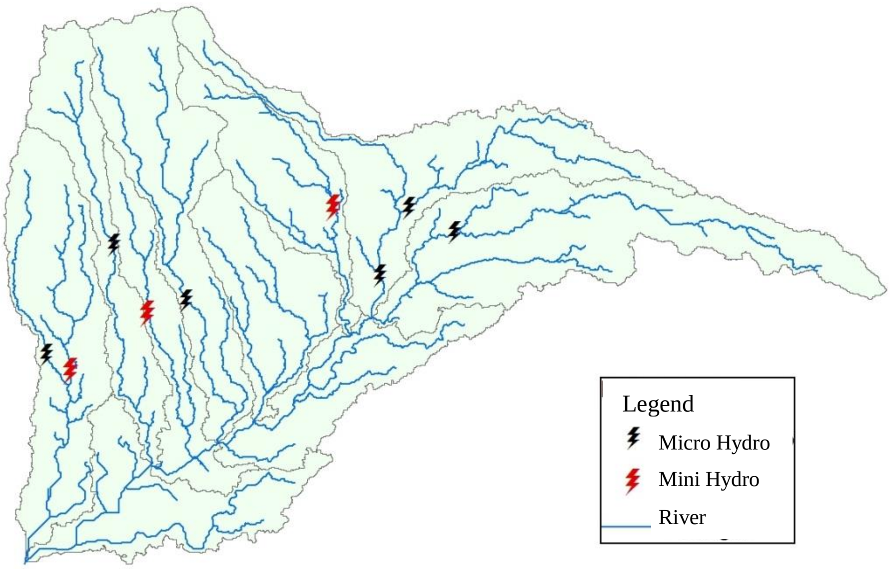

Fig. 6. Potential Hydropower Location

Table 2. Resulting Analysis of Potential Hydropower

Tributary	Q (90%)	H (m)	P (kW)	Information
Balelo	0.7	10	55	Micro-Hydro
Balelo	0.7	20	110	Mini-Hydro
Ketajek	0.5	40	157	Mini-Hydro
Kaliwates	0.3	10	24	Micro-Hydro
Jompo	0.7	15	82	Micro-Hydro
Arjasa	0.5	18	71	Micro-Hydro
Suger	0.8	10	63	Micro-Hydro
Suger	0.8	7	44	Micro-Hydro
Sumber Pakem	1.0	6	47	Micro-Hydro

4. Conclusion and recommendation

This analysis able to provide an initial estimate from the feasibility of developing hydropower plant project in a specific location. Rowotamtu watershed has the potential head and good enough water discharge to use as Hydropower. Hydropower potential in the Rowotamtu watershed found in nine locations with power ranging from 24 kW- 157 kW. There are two locations that are categorized as mini-hydro and 7 locations were classified as micro-hydro. Further research should be conducted ground checking for flow and slope data so it is expected to provide more accurate planning results.

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River erformance assessment model

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Abstract

The performance of a river is the capability of the river and river infrastructure efforts to achieve its planned objectives. River development objectives can generally be grouped into two areas, namely to drainage at high flow on the rainy season and to utilized flow reliability on the dry season. Question that should be answered is how much the performance of the river and how to determine the priority order of handling the improvement of the river performance. The method to assess the performance of the river was conducted in two groups: assessing the physical condition of the river, and the functioning of the river by using various indicators. The assessment of the river infrastructure functions carried out in accordance to the purpose of the infrastructure. The model of the assessment method which was developed is limited on the river function as a drainage infrastructure. Therefore the model is clarified to the physical condition, and drainage fuction in small rivers. They are Rivers Pepe, Dengkeng, Jlantah, and Samin which located in Surakarta, Sukoharjo, Karanganyar and Klaten districts. By knowing the value of the river performance indicator, it can be used to determine the river improvement priority sequence. The research result shows that that the river performance of Pepe is 73.87 % while the rivers Dengkeng, Jlantah, Samin are 60.53%, 77.31%, and 87.78%. It is clear that the first priority of river improvement is Dengkeng river.

Keywords: River performance; assessment.

1. Introduction

According to the United Nations Educational, Scientific and Cultural Organization (UNESCO) the Earth's freshwaters represent only 2.7% of the total water availability. Most part of that small value (77.2%) is found in

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polar caps, glaciers and icebergs, and the rest is distributed as: 22.4% stored in aquifers and groundwater; 0.36% in rivers, lakes and swamps, and 0.04% in the atmosphere [1]. Water on the river becomes crucial during wet and dry season. The problem during dry season consists of the quantity and quality of water. Both of them have strong relation to river ecosystem health [2]. In contrast during rainy season it always excesses of water.

River is a natural water flow or a place to storage the form of water drainage network along with water in it, from upstream to the estuary, with restricted right and left by a line of separation. River is the combination of river stream and water flow [3], while the definition of rivers infrastructure is the physical infrastructure constructed for river management including supporting facilities [4], such as: 1) Intake and water withdrawals structure, 2) Flood control structure, 3) Sediment control structure, 4) Protecting and strengthening riverbanks structure, 5) Regulating the flow direction structure, and 6) data monitoring structure.

Surface water such as water on the lake and swam is transported mainly flows on the river. Rivers play an important role on transporting of water [5]. They transport water by gravity, from headwaters to ocean. Topography of land surface becomes important part of transporting water on the river. The performance of the river system should be known exactly during the operation of the river and river infrastructure [6]. If the performance is well the river and river infrastructure will be operated normally and only need routine maintenance, but in contrast special maintenance or rehabilitation need to be done in worse river performance. The question is what the specific method to count the river and river infrastructure performance.

The assessment of river and rivers infrastructure performance in this study is specifically as a function of drainage purpose. River functions as a provider of water and as a water storage as well as purification of water quality is not reviewed in this research [4](4). Rivers infrastructure performance assessment conducted to measure the ability of streams and rivers infrastructures/facilities to serve its function. Assessment of river physical condition as mentioned above is a powerful tool to evaluate the initial condition before river restoration takes place [7].

The objective of this research is to prepare an assessment model to evaluate the river and river infrastructure performance. This study is intended to make the method for assessing the performance of the river and river infrastructure. The benefits of the performance assessment can be used to determine the priorities of river and river infrastructure maintenance order and the benchmarking of restoration existing condition. At this time no standardized criteria in Indonesia and is therefore the purpose of this research is to develop river performance assessment framework that can be used for the assessment of existing condition of the river and river infrastructure.

The research method in this study is the experimental method started with the preparation of the river performance assessment model. This study is an investigation in the field of getting a technique of assessing the performance of the river and river infrastructure. This field survey method begins by making the design criteria and making the assessment river streams method. River performance assessment is done by assessing the score.

Assessing river performance based on river condition and function is not developed formally in Indonesia. Some assessment methods develop based on the environment and ecological approach. Biological-based river performance assessment basically is developed on watershed and biological river area. Approach assessment condition mainly assesses the water quality and river levels of pollutants.

The methodology to assess river performance in Indonesia become importantt especially intended to make decision on maintenance priority scale on river and river infrastructure physical condition. In this moment a river and river maintenance priority scale is done by partial decision on a specific damage not systematic approach. This river performance assessment model later used to measure the performance of physical and functions condition of river. The application of this model will state the percentage of the performance by mean the function and condition of the river. In short by using an assessment results can be used to determine sequence of priority of rehabilitation or maintenance in case of limitation of funds condition.

2. Material and method

The study area is located in Central Java, Indonesia. It consists of four rivers which is a tributary of Bengawan Solo River. The selected river to be studied is a small river in the upstream of Bengawan Rolo River System. It’s composed of: (1) Rivers Pepe, a river which flows across Surakarta City, (2) Rivers Samin, a river which flows near settlement and industrial area at Karanganyar District, (3) River Jlantah, a river which is located on mostly agriculture suburb area at Sukoharjo District, (4) River Dengkeng, a rather big river in Klaten District.

Selection the river location is based on the variation of the river characteristic mainly on the river morphology, hydraulic and hydrology and the land use of river basin. The samples were also taken into consideration of river against chemical and biological context to consider the relation of river and watershed and also river disturbance. The river watershed and rural farmland will be very different from the river in urban areas and industrial sites. Expected populations studied represent the diversity of a natural river. Sample selected is on a segment of the river that does not have a reservoir to regulate the flow of water. All the rivers have the natural flow conditions without setting the flow rate from the reservoir.

This research is preparing an assessment model of river and river infrastructure performance. The research method is done with investigations on the field. River performance was good if all component of the river and river infrastructure functioning well and good physical condition. Otherwise bad river performance is all components of the river and river infrastructure is not functioning well and his physical condition was broken. In a simple stage of making the assessment model are as follows:

1. Identifying of variables that affect the river and river infrastructures performance on the fieds and literatures.
2. Analyzing the relation of those variables in point 1 and grouped in different major component.
3. Determining the variables (as indicator of performance) that are sensitive to changes in the performance of the river and river infrastructures.
4. Conducting field research on the performance of a river reach is observed.
5. Finding the magnitude of the effect of changes in the variables of the river and river infrastructures against performance index of rivers and river infrastructures.
6. Developing an assessment of river and river infrastructures.
7. Verifying developed method at point 6 to selected rivers.
8. Refining and concluding the method and the results of the verification of the assessment method.

The assessment of the performance of the river and river infrastructure is limited by specifying the criteria and indicators of functions and physical condition of the river and river infrastructures. The rate of river management such as the personnel, finance, facilities and method of river operation and maintenance do not assess.

The model is to determine the components of the river and river infrastructure. Each component has a performance indicator and criterion of rivers and river infrastructure that may perform well. Each component and sub component as the indicator then determined the specific criterion.

Assessment criteria of river physical condition are the assessing the structural condition based on the level of damage. If the damage is extensive or more 60% of new condition then the criterion is bad. If there is no damage or incidental damage about less than 20 % of new condition put in a good criterion, while the damage is lightweight or between 20-40 % of new condition is fair condition [8]

The criteria of river and river infrastructure according to function performed by examining the function of the river and river infrastructure based its functions as a drainage. If the river and river infrastructure functioning is reduced until less than 60 % of planned functioning is bad criterion, while if the function more than 80 % of planned function is good criterion. The criterion in fair if the river and river infrastructure functioning in between 80 – 60 % of planned function (4).

The performance of river and river infrastructure is as a result of combination between condition and functioning of the river or river infrastructure. In many cases of river or river infrastructure have bad physical condition but still good serve, in contrast a good physical condition of river or river infrastructure do not have good function. The combination of river and river infrastructure then are divided into nine criteria. River and river infrastructures combination indicator on physical condition and functioning of infrastructures as presented in Table 1.

Table 1. Combination score physical and functional condition.

No	Score	Criteria		Description of Physical and functioning condition
		Physical	Function	
1	1	Bad	Bad	degree of damage > 60 %, function of infrastructure < 60 %
2	2	Fair	Bad	degree of damage 20 – 40 %, function of infrastructure < 60 %
3	3	Good	Bad	degree of damage < 20 %, function of infrastructure < 60 %
4	4	Bad	Fair	degree of damage > 60 %, function of infrastructure 80 – 60 %
5	5	Fair	Fair	degree of damage 20 – 40 %, function of infrastructure 80 – 60 %
6	6	Good	Fair	degree of damage < 20 %, function of infrastructure 80 – 60 %
7	7	Bad	Good	degree of damage > 60 %, function of infrastructure > 80 %
8	8	Fair	Good	degree of damage 20 – 40 %, function of infrastructure > 80 %
9	9	Good	Good	degree of damage < 20 %, function of infrastructure > 80 %

The score is based on function, its intended that higher score on functioning than physical condition. For example a river structure which has bad physical condition but still has a good function, has higher score than the good physical condition but fair function condition.

The assessment method is done by giving score every component which is available on the field. Every component will contribute to the river performance based on the weight of the river and river infrastructure function mainly as a drainage system. Weights performance is calculated by the method of Analytical Hierarchy Process (AHP) [9]. The weight factor is calculated by comparing the size of the relative importance of components compared with the other components. Standard weighting based on a scale ranging from 1 (mean the two things are equally important) to 9 (indicate the activity is very much more important than the others) to be used in the pairwise comparison matrix. An evaluation sample consisting of n elements, with the pairwise comparison matrix is written as follows:

$$\begin{bmatrix} w_1/w_1 & w_1/w_2 & \dots & w_1/w_n \\ w_2/w_1 & w_2/w_2 & \dots & w_2/w_n \\ \dots\dots & \dots\dots & \dots & \dots\dots \\ w_n/w_1 & w_n/w_2 & \dots & w_n/w_n \end{bmatrix} \qquad (1)$$

Establishing priorities in the selection of AHP is done by calculating the eigenvector and eigenvalue through matrix operations. Eigenvector determines the ranking of the alternatives selected, while the eigenvalue provides a easure of the consistency of the comparison process. Calculation column vector (Vj) is performed by the following equation :

$$Vj = Kij \times Wi \qquad (2)$$

Where Kij is a matrix of the form :

$$\begin{bmatrix} w_{11} & w_{12} & \dots & w_{1p} \\ w_{21} & w_{22} & \dots & w_{2p} \\ \dots & \dots & \dots & \dots \\ w_{n1} & w_{n2} & \dots & w_{np} \end{bmatrix} \qquad (3)$$

with the purpose/objective i = (1,2,3 ... , p) , and w is an alternative weighting 1 for the purpose 1, p represents a number of alternatives, and n is the number of destinations. Column vector, V_j, stating the final ranking of the alternatives tested in the analysis

The performance assessment of river and river infrastructure is based on the function and physical condition. The assessment of the river is conducted by the four component groups. Each group components consists of several sub-components with the weight of each factor. The calculation of the performance assessment of the river is done by calculating the performance of each sub-component. Each sub-component is given a score and multiplied by the weight factor. An example calculations on the performance of the sub-components River Side Slope (RSS) is as follows:

$$RSS = \frac{\sum(\frac{SRSS_i}{MSRSS} * LRSS_i)}{TLRSS} * WRSS \quad \text{..........(4)}$$

Where:

RSS = Performance of River Side Slope (%)
$SRSS_i$ = Score of River Side Slope location i
MSRSS = Maximum Score of River Side Slope location i
$LRSS_i$ = Distance of River Side Slope Location I (m)
TLRSS = Total Distance of River Side Slope (m)
WRSS = Weight factor of River Side Slope (%)

The river performance assessment on one component carried by summing the performance of each sub-component, then the result is multiplied by the weight factor. If one sub-component is not exist in river systems assessed, the standardization of weights applied to make adjustments of weighting factor to get balance the weighting factor for its component. The equation of river performance calculations is as follows:

$$RSF = \frac{(RSS+RBS+RCD+RDt)}{(WRSS+WRBS+WRCD+WRDt)} * WRSF \quad \text{.......... (5)}$$

Where:

RSF = Performance of River Shortcut Floodway (%)
RSS = Performance of River Side Slope (%)
RBS = Performance of River Bad Slope (%)
RCd = Performance of Riparian Quality (%)
RDt = Performance of River Index Disturbance (%)
WRSS = Weight Factor of River Side Slope (%)
WRBS = Weight Factor of River Bad Slope (%)
WRCd = Weight Factor of Riparian Quality (%)
WRDt = Weight Factor of River Index Disturbance (%)
WRSF = Weight factor of River (%)

The assessment component of the river conducted by adding up all the components performance assessed. In another word performance calculations river infrastructure components should be performed for all sub-components. If the assessment component or sub-component is not completed then the performance value only takes into sub components by revised the weight factor. The overall assessment of the function and condition of the river is done by calculating the performance river/Shortcut/Floodway, river conservation infrastructures, utilization infrastructure and flood control infrastructure. The calculation is as shown in the following formula:

RIP = RSF + CsI + UtI + FCI .... (6)

where :

RIP = River and River Infrastructure Performance (%),
RSF = Performance of River/Stream/Shortcut/Floodway (%),
XsL = Performance of Conservation infrastructures (%),
UtI = Performance of Utilization infrastructures (%).
FCI = Performance of Flood Control structures (%).

The result of the assessment models can be one of these options: (a) if river and river infrastructure performance is very low (below 60 %) the river need to rehabilitated, (b) if the rivers and river infrastructure has moderate performance (60-80%) the river need special maintenance to restore the function and (c) if the river and river infrastructure performance can perform well (above 80%) its indicate only need routine maintenance.

3. Result and discussion

There are many varieties of river infrastructures in the field. Assessment should take into account the possibility of all the infrastructures or groups of infrastructures. Indonesian Government Regulation No. 38 (2011) classifies into 3 groups of rivers infrastructures: (1) conservation, (2) utility and (3) flood control. Assessing the component of river and river infrastructures in this research is grouped as follows:

1. River/shortcut/Floodway
2. River Infrastructures
    a. Conservation infrastructures
    b. Utilization infrastructures
    c. Flood Control Infrastructures

These models are made using four components river performance: (1) River/shortcut/Floodway (RSF), (2) Conservation Infrastructures (CsI), (3) Utilization Infrastructures (UtI), (4) Flood Control Infrastructure (FCI). All components above are an indicator of the performance assessment of the river and rivers infrastructures. Assessed component of river/shortcut/ floodway need sub component for detail of assessing. The purpose of making the sub-component are to describe the performance in more accurate. For example the sub component of the river/ shortcut/floodway consist of: (1) River side slope (RSS), (2) River bad slope (RBS), (3) Riparian Quality (RQt), River Index Disturbance (RDt). Component and sub-component which is rated the performance using a standard criterion as guidance. The explanation of the model components and sub-components as indicators and criteria in judging the performance of the river presented at Table 2. Indicator, Weight Performance and Criteria.

As mentioned on the methodology that the assessment of river and river infrastructure is done by giving a weight each component of river and river infrastructure. River and river infrastructure performance is the combination of the percentage of the weight of the function and the condition of both river and river infrastructure. The purpose of giving the weighting factor is to provide the level of interest in accordance with the judging measurement function of the river and river infrastructures. Weight of the river and river infrastructures can be different that depend on the degree of interest function of the river and river infrastructures. The method of calculating the weight using hierarchy analytical process provides the possibility to distinguish the level of importance of the indicator compared to other indicators.

Total weight for the entire assessment of performance as a function of the drainage river is 100 %. The result of the calculations of weights for each component is: (1) River/shortcut and floodway 39%, (2) Conservation Infrastructures 6%, (3) Utilization Infrastructures 11%, (4). Flood Control Infrastructure 44%.

The calculation results of weighted indicator in the model stated that the two indicators are dominant in the measurement of the river infrastructure performance as the drainage system. It indicates that the river/shortcut/ floodway and flood control infrastructure components is more important. Both of two components have high effect in the river as a function of the drainage system. Instead of two components that are not sensitive is the Conservation Infrastructures 6%, while Utilization Infrastructures is only 11%.

Calculation of weights for each component then detailed for sub components. A weighting factor in the component river streams/Shortcut/Floodway is grouped into 4 sub-indicators with the results weighted as follows: River Side Slope (7%), River bad Slope (9%), Riparian Quality (11%) and River Index Disturbance (12%). The weighting calculation in the model is described the Quality and River Riparian Disturbance Index states that more influence to the river functions. Weights calculation result for all components and sub-components in the model of the river assessment is presented in Table 2 coloum (3) and (5).

Table 2 Indicator, Weihgt Performance (WP) and Criteria

Reference Number (1)	Indicator (2)	WP (%) (3)	Sub-Indicator (4)	WP (%) (5)	Criteria (physical and function condition) (6)
1.	River/shortcut/flood way (RSF)	39			Draining properly and good physical condition
1.a.			River side slope (RSS)	7	Land slide stability of river and side slope in draining water
1.b.			River bad slope (RBS)	9	River bad stability and sediment transport
1.c.			Riparian Quality (RQt)	11	Riparian changes quality of natural condition
1.d.			River Index Disturbance (RDt)	12	Disturbance level by human and animal
2.	Conservation Infrastructures (CsI)	6			Flow conservation / erosion and sedimentation control at the river bad
2.a.			Sediment control structure (SCS)	2	Total volume erosion and aggradation
2.b.			River bad stabilization structures (RBS)	4	The stability of the slope of the river bad
3.	Utilization Infrastructures (UtI)	11			Retrieval and Utilization of river water
3.a.			Free Intake (Fin)	1	Service water discharge
3.b.			Weir (Wi)	3	Setting the water level and water discharge
3.c.			Supply Reservoir (SRv)	4	the amount of water supply
3.d.			Pumping installation (Pum)	3	Pumping of Water
4.	Flood Control Infrastructure (FCI)	44			Control of water damage
4.a.			Levee (Lev)	11	Protection of flood
4.b.			Revetment/Lining (Rev)	4	Strengthening Slope stability
4.c.			River banks Protection. (Masonry/ Concrete)	5	Protection of landslides and slide erosion
4.d.			Krib	4	Guiding the flow and protecting the slide
4.e.			Groins/Jetty (Gro)	4	The ability to guide the flow
4.f.			Side Spillway (SSw)	4	Dividing water
4.g.			Flow Regulation structure (FRS)	5	Regulating water
4.h.			Flood Control Reservoir/Detention/ Retention area (FCR)	6	Regulating peak discharge
4.i.			Hydraulic Monitor Equipment (HME)	3	Recording discharge
Total(%)		100		100	

The research result on four rivers shows that that the river performance of Pepe is 73.87 % while the rivers Dengkeng, Jlantah, Samin are 60.53%, 77.31%, and 87.78%. The result shows that the river performances do not have all similar components and sub components. River Pepe calculate score based on 4 components as a result of 9 sub components. The river dengkeng is assessed based on measured 4 components but not exactly similar in 9 sub-components. While Samin river only measured from 3 components of 8 sub-components, and the last is Jlantah rivers measured 3 components of 10 sub-components.

No one of 4 rivers that assessed using all standards sub components in the model developed. Jlantah and Samin rivers are only using 3 components. Jlantah and Samin used different sub components assessment indicator. With the difference in components and sub-components of the standard weighting in the model it is necessary to adjust the weight becomes relative weights. That particular weight is only valid in the rivers reach were assessed. The assessment was used the specific weight.

If one the component is not complete and needs correction of weights, the standard of weight should be distributed into the other component groups concerned. If the rivers assessed do not have the score of a component, the weight of these components is distributed proportionally to each sub-component. In accordance with the method of performance assessment, the final result of the 4 river as a river's are presented in Table 3.

Table 3 The River Assessment of Pepe, Dengkeng, Jlantah and Samin Rivers

No	Component	Sub Komponen	Standart Wight (%)		Pepe River					Dengkeng River					Jlantah River					Samin River				
					Avg Score	Relative Weight (%)		Performance (%)		Avg Score	Relative Weight (%)		Performance (%)		Avg Score	Relative Weight (%)		Performance (%)		Avg Score	Relative Weight (%)		Performance (%)	
1	2	3	4		5	6		7		8	9		10		11	12		13		14	15		16	
1	River (PoR)		38.9			38.9		25.4			38.9		27.6			41.2		33.1			43.8		37.5	
1.1.		River Side Slope (RSS)		7.1	2.0		7.1		1.6	3.6		7.1		2.8	6.7		7.5		5.6	7.4		8.0		6.5
1.2.		River bad Slope (RBS)		8.8	6.2		8.8		6.0	7.2		8.8		7.1	7.2		9.4		7.5	7.7		9.9		8.5
1.3.		Riparian Quality (RQt)		10.6	6.7		10.6		7.8	6.7		10.6		7.8	7.7		11.2		9.5	7.5		11.9		10.0
1.4.		River Index Disturbance (RID)		12.4	7.2		12.4		9.9	7.2		12.4		9.9	7.2		13.1		10.5	8.1		13.9		12.5
2	Conservation Infrastructure (Poc)		5.6			5.6		3.9			5.6		2.8			0.0		0.0			6.3		5.5	
2.1.		Sedimen Control Structure (SCS)		1.4																				
2.2.		River Bad Stabilization (RBS)		4.2	6.3		5.6		3.9	4.5		5.6		2.8					0.0	7.9		6.3		5.5
3	Utilization Infrastructures (PoU)		11.1			11.1		10.0			11.1		7.7			11.8		7.0			0.0		0.0	
3.1.		Free Intake (Fin)		1.3																				
3.2.		Weir (Wi)		3.3	8.1		11.1		10.0	6.2		11.1		7.7	5.3		11.8		7.0					
3.3.		Supply Reservoir (SRv)		3.9																				
3.4.		Pumping Station (PSt)		2.6																				
4	Flood Control Infrastructures (PoF)		44.4			44.4		34.6			44.4		22.5			47.1		37.3			50.0		44.8	
4.1.		Levee (Lev)		10.6	7.7		16.3		13.8	5.7		19.3		12.2	7.2		16.0		12.8	8.1		18.8		17.0
4.2.		Revetment/Lining (Rev)		4.0	7.1		15.1		11.8	5.9		7.3		4.8	6.0		13.4		8.9	7.9		7.2		6.3
4.3.		Riverbank Protection (RbP)		5.0	6.2		13.1		8.9	5.4		9.2		5.5						8.2		9.0		8.2
4.4.		Krib - (Kri)		3.7											7.9		17.6		15.5	8.1		6.5		5.9
4.5.		Groins/Jetty (Gro)		3.6																				
4.6.		Side Spillway (SSw)		3.9																				
4.7.		Flow Regulation structure (FRS)		4.8						4.8		8.7								8.0		8.5		7.6
4.8.		Flood Fontrol Reservoir (FCR)		5.8																				
4.9.		Hydologic Monitor Equipment (HME)		3.0																				
	Sum		100.0	100.0		100.0	100.0	73.87	73.87		100.0	100.0	60.53	60.53		100.0	100.0	77.31	77.31		100.0	100.0	87.78	87.78

By using the calculation in Table 3, it can be concluded that the first priority is the improvement in the river with weak performance is Dengkeng River. Priority repairs / maintenance in Dengkeng river can be seen from the low average scores on the respective sub-components. The lowest scores on the river Dengkeng is on the River side slope 3.6 of 9. The lowest score is because that the river bank is situated on black clay so that it is unstable and may not have function properly. Second lowest score is in the river bad stabilization score which only have 4.5 of 9. This score represents many groundsills at downstream of the bridge and the river bad is fail to protect river bad due to physical damage.

The performance assessment is useful in determining the ranking of repairing and maintenance of rivers and river infrastructure. Further analysis can be performed with scores determination to assess the sub-components as an indicator condition that requires improvement. The weakness of this model is the implementation of the assessment system is still highly subjective judgment in defining the scores. Assessment on the field by field personnel needs specific training to standardize the perception giving a score on each river infrastructure function and condition. Furthermore, in order to simplify the applied of assessment method, it needs to make cards describing the condition of river and river infrastructure which is appropriate with the capability field officers.

4. Conclusion

Based on developed model and trials assessment of river performance test at rivers Pepe, Dengkeng, Samin and Jlantah found that the river performance model that developed can help to make priority maintenance order. This result points out that the first priority of rehabilitation or a special maintenance program to restore the drainage function is Dengkeng River.

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Priority analysis of small dams construction using cluster analysis, ahp and weighted average method (case study: small dams in semarang district)

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Abstract

The Feasibility study potential of small dams in Semarang District has identified 8 (eight) urgent potential small dams. These potential dams must be constructed within 5 (five) years in order to overcome the problem of water shortage in the district. However, the government has limited funding source. It is necessary to select the more urgent small dams to be constructed within that limited budget. The purpose of the research is determining the priority of small dams' construction in Semarang District under limited budget condition. The method used in this study is Cluster Analysis, AHP and Weighted Average Method. The criteria used to determine the priority in this study consist of : vegetation cover in the inundated area, volume of embankment, land acquisition area, useful storage, reservoir's life time, water cost/ m³, access road to the dam site, land status at abutment and inundated area, construction cost, operation and maintenance cost, irrigation service area and raw water benefit. Based on results of Cluster Analysis Method, AHP Method and Weighted Average Method can be concluded that the priority, therefore the sequences, of small dams construction are : 1) Mluweh Dam (0,165), 2) Pakis Dam (0,142), 3) Lebak Dam (0,134), 4) Dadapayam Dam (0,128), 5) Gogodalem Dam (0,119), 6) Kandangan Dam (0,114), 7) Ngrawan Dam(0,102) and 8) Jatikurung Dam (0,096). Based on analysis of the order of priority of 3 (three) method showed that AHP Method is more suitable than Cluster Analysis and Weighted Average Methods, because the result of AHP Method is closer to the conditions of each dam in the field.

Keywords: AHP; Cluster Analysis; Priority selection; Weighted Average.

1. Introduction

One of the problem of water resources management is human behavior itself which increasing the change in land use for livings. Changes in land use may affect the availability of water resources. The land use change for people's activities will increase the need for water, reduced the water availability, increase the direct runoff thus incease the floodings, and increased the drought conditions.

District Semarang is one of the districts that alwayes experiencing high degree of land use change, which also experiencing the water resources severety problems. To overcome this problem, the Balai Besar Wilayah Sungai Pemali-Juana has identified 8 (eight) potential small dams (embung) in Semarang District, i.e., Dadapayam, Mluweh, Lebak, Pakis, Jatikurung, Gogodalem, Kandangan, and Ngrawan (Metana, 2010). To overcome the problem immediately, ideally these potential small dams must be constructed within 5 year term. However, the government cannot possibly build all these small dams within the 5 year period because of the financial constraints. So the government should determine the priority on which dams to constructed first during the period. The purpose of this study is to determine the sequence of construction of small dams in Semarang District which are more effective and efficient. It uses Cluster Analysis, AHP (Analytical Hierarchy Process), and Weight Average method.

The location of this research is in the administrative area of Semarang District, Central Java Province such as shown in the following figure.

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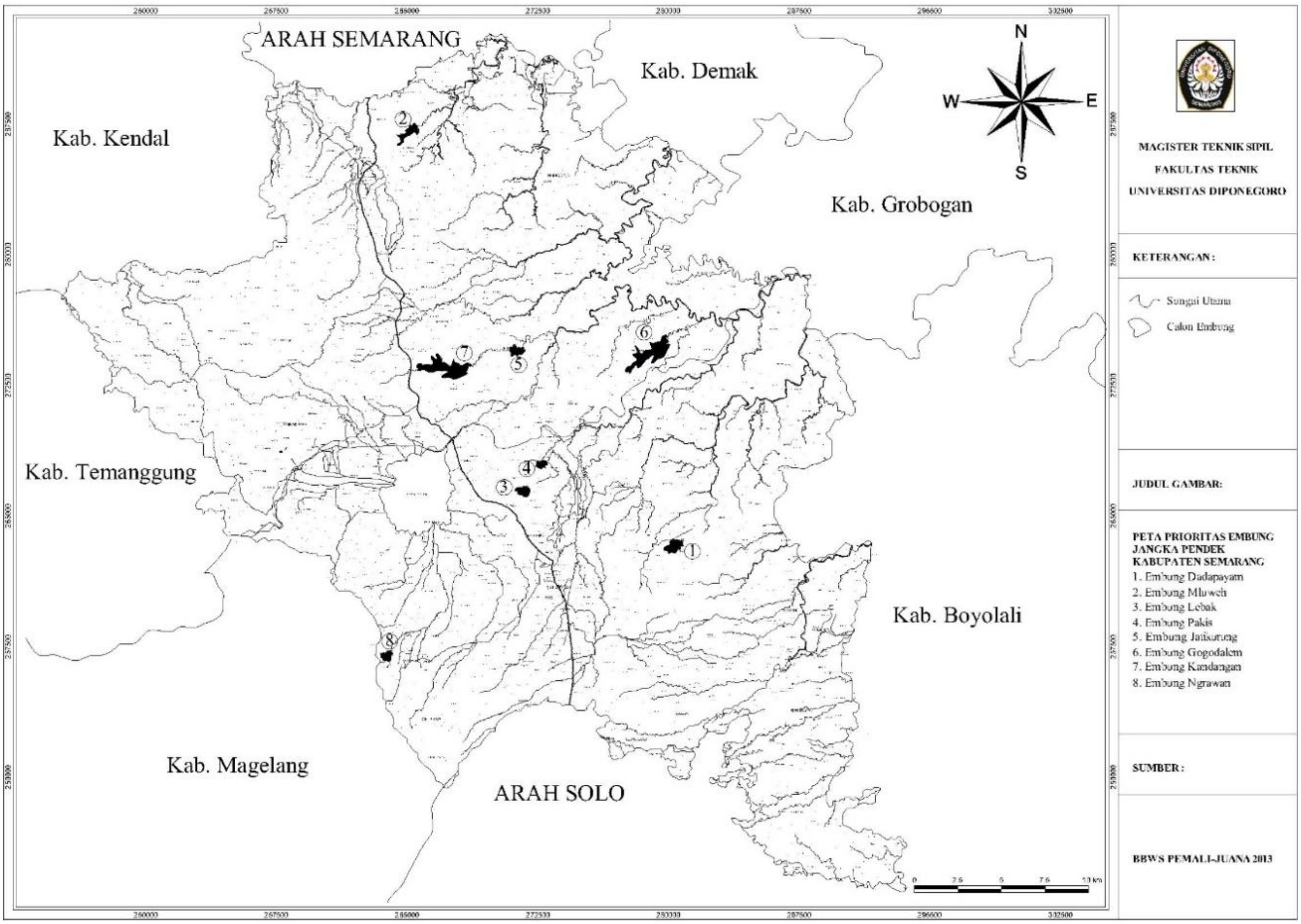

Fig. 1. Map Location potential small dams (Embung) In Semarang District.

The selection on which reservoir to be constructed first will require some criterias. The criterias whould reflect the efficient and effective construction. Therefore, some criterias should reflect both engineering and non-engineering factors. These criterias are selected based on some regulations, standards, and guidance for small dam construction such as SNI 03-1724-1989 (Planning Procedures for Hydrology and Hydraulics for building on the river), PP No. 37. Year 2010 about Dams, RSNI T-01-2002 (Procedure Design Dam Body Type of Pile), Public Work regulation No. 03/PRT/M/2009 (Code of Social Engineering Construction of Dams) and SK. Dams Safety No. 05/Kpts/2003 (General Design Criteria Manual Dam).

2. Research methods

Based on regulatory guidelines and regulations, some criterias for selecting the priority of small dams can be identified. Additional criterias is defined based on some consultation with experts and from review on the influence of criterias to the efficiency and effectiveness of small dams construction.

The following are some variables that will be used in the determination of priority for small dam construction. The variables that will be used in the analysis are : 1) Vegetation cover in the inundation area, 2) The slope and stability of the abutment, 3) Volume of embankment material, 4) The area to be acquired, 5) type of subgrade foundation, 6) design discharge Q50yr, 7) Effective storage, 8)

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Sediment storage, 9) catchment area, 10) Duration of operation, 11) Equivalent Cost of water/m³, 12) Distance of quarry from the site of the dam, 13) access road to the site of the dam, 14) the population needs to be evacuated, 15) Status of land in site, 16) Response from surrounding communities, 17) Infrastructure to be re-alligned/ re-placed, 18) Cost of land acquisition, 19) Cost of construction, 20) operating costs and maintenance, 21) Coverage of irrigation areas, and 22) The benefits of raw water. These variables are comprehensive and covering aspects of engineering, operational, economic, and social. Using these variables, it requires to collect data and information related to these variables for each potential small dams.

In principle, the research uses secondary dan primary data in order to quantify all the variables involved. The raw data for each variables are standardised and ranged into 5 category. Based on these standardized variables, the anaysis of cluster analysis is conducted to 1) the grouping of the variables and 2) the priority of the construction. Futhermore, based on the variables grouping, it can be determined up to nine selected representative variables. Based on these representative variables, it can be anlyse further using AHP and weighted method to determine the priority for the small dam construction.

2.1. Cluster analysis method

Cluster Analysis is an analysis to classify or to group "similar" elements such that the variables of the research can be grouped (clusterred) into less variables. It is useful to summarize the data with the grouping of objects based on certain characteristics in common between the objects to be studied. It is also usefull to "reduce" the variables in the research. Some variables which are in similar class or group, which therefore has similarity, can then be represented by one representing variable.

In cluster analysis, one class has principally similarity between the members in the class and has dis-similarity with the members from other class. The most commonly used similarity index is the Euclidian distant. The measure of dissimilarity between objects all objects i with j, can be symbolized by d_{ij} . The d_{ij} value obtained through the calculation of distance squared as follows:

$$d_{ij} = \sqrt{\sum_{k-1}^{p} \{x_{ik} - x_{jk}\}}^{2} \qquad (1)$$

Where :

d_{ij} = quadratic of distance Euclidian between object i with object j
p = sum of variable cluster
x_{ik} = value of object i on variable of k
x_{jk} = value of object j on variable of k

Based on this index, it can be used to determine which object is more belongs (similar) to which group. The analysis uses K-Means method as follow:

a) Determine the magnitude of k, namely from the amount of cluster and determine the centroid (average) in each cluster.
b) Calculate the distance of each object to every centroid.
c) Form a new cluster based on the calculated distances.
d) Recalculating the average (centroid) of the newly formed cluster.
e) Repeat step b) until no further transfer of objects between clusters.

2.2. Analytical Hierarchy Process (AHP) method

According to Saaty, 1993, the decision-making process is basically choose an alternative. The main equipment AHP (Analytical Hierarchy Process) is a functional hierarchy of human perception with its main input. With a hierarchy, a complex and unstructured problems resolved into their groups and then the groups are arranged into a form of hierarchy. Basically the steps in the method of AHP include:

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a) Define the problem and determine the desired solution.
b) Create a hierarchical structure that begins with a common goal, followed by sub-objectives, criteria and possible alternatives.
c) Make a pairwise comparison matrix that depicts the relative contribution or influence of each element on each criterion of interest or a level above it. Comparisons are made based on the judgment of the decision makers to judge the importance of an element compared to other elements.
d) Perform a pairing comparison in order to obtain judgment on n [(n-1)/2] results, where n is the number of elements being compared.
e) Compute eigenvalues and test consistency. If it is not consistence, then repeat from data retrieval.
f) Repeat steps c, d, and e for all levels of hierarchy.
g) Calculating the eigenvectors of each pairwise comparison matrix. Value eigenvector is the weight of each element. This step is to synthesize the judgment in the prioritization of the elements on the lowest hierarchy level to achieving goals.
h) Check the consistency of the hierarchy. If the value is more than 10 percent, the judgment should check the data.

2.3. Weighted average method

Weighted Average Method is a method by taking the average value based on the average calculation by giving weight to each value to be taken the average value. The weight of each are not the same, if all the weights are equal then the calculation is the average of ordinary arithmetic.

Average calculation with this method is with a few additions to the weight calculation. Similar to the calculation of average ordinary arithmetic. Data elements are taken into weight beforehand, in which the data has more weight will be more influential than the data with less weight. With the provision of the weights can not be negative, some of which may be zero, but it is impossible if all the weight is zero, because if it did so then the calculation is not possible to do. This method is widely used in the data analysis system, the calculation of differential and integral calculus.

In general, the calculation method of Weighted Average may be made to the existing data contents, $\{x_1, x_2, x_3, \ldots, x_n\}$, using weights, $\{w_1, w_2, w_3, \ldots, w_n\}$, to obtain the average with the formulation as following.

$$X = \frac{w_1.x_1 + w_2.x_2 + w_3.x_3 + \cdots + w_n.x_n}{w_1 + w_2 + w_3 + \cdots + w_n} \quad (2)$$

Rules of the use of variable / fittings that must be considered every element of data and weights :

$\{wi|i = 1,2,....,n\} > 0$

w is the weighting, on the basis of preference (interest/the preferred option) but the decision maker in this case using the results of the questionnaire.

In certain circumstances where the weights are normalized so that the accrual overall weight equal to one, then the formula above can be more concise becomes.

$$X = \sum_{i=0}^{n} w_i . x_i \quad (3)$$

3. Analysis and discussion

The data analyzed is the data of each reservoir to each of the variables that they are quantitative and qualitative. Where the data has been standardized or transformation of the relevant variables into scoring form of variable data. The scoring scale assessment data is put on a scale of 1 to 5 scale, where 5 is the scale with the highest weight value (most favourable), while 1 is the lowest weighting scale value (least favourable). A1 to A8 are alternatives for reservoir 1 to reservoir 8 (see Table 2.). The variables K1 to K22 are the variables used in the anlysis.

Table 1. Summary of Data Standards

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	A1	A2	A3	A4	A5	A6	A7	A8
K1	2	5	2	2	5	5	3	3
K2	5	2	2	3	2	3	4	2
K3	5	1	3	5	5	4	4	5
K4	4	5	5	4	3	2	5	4
K5	5	1	5	5	3	1	1	1
K6	2	2	4	3	2	3	5	3
K7	3	5	4	4	1	2	1	1
K8	2	3	2	3	5	3	5	1
K9	2	1	5	4	3	1	2	2
K10	2	5	2	2	1	3	1	1
K11	5	5	3	4	1	1	1	1
K12	5	3	3	3	3	3	3	1
K13	3	4	3	3	3	3	3	4
K14	5	5	5	4	5	5	5	4
K15	4	2	4	4	3	4	4	4
K16	4	5	4	4	4	5	5	4
K17	5	1	5	1	5	5	5	1
K18	3	5	4	4	3	1	3	4
K19	4	1	3	5	4	4	4	4
K20	3	1	2	1	4	4	4	5
K21	3	5	2	3	2	2	3	2
K22	2	2	5	5	2	3	5	1

Information:

K1=Vegetation cover in the inundation area, K2=The slope and stability of the abutment, K3=Volume of embankment material, K4=The area to be acquired, K5= Type of subgrade foundation, K6= design discharge Q50yr, K7= Effective storage, K8= Sediment storage, K9= catchment area, K10= Duration of operation, K11= Equivalent Cost of water/m³, K12= Distance of quarry from the site of the dam, K13= access road to the site of the dam, K14= the population needs to be evacuated, K15= Status of land in site, K16= Response from surrounding communities, K17= Infrastructure to be re-alligned/ re-placed, K18= Cost of land acquisition, K19= Cost of construction, K20= operating costs and maintenance, K21= Coverage of irrigation areas, and K22= The benefits of raw water.

3.1. Selection priority small dam (Embung) with non hierarchical cluster analysis method

This method starts with the process of determining the number of class, and the method used is non- hierarchical. After the standardization of data and have obtained the recapitulation of data of each reservoir, the next step is to enter the recapitulation data into the program Statistical Package For Social Science (SPSS) 17. Results of the analysis of non-hierarchical cluster method of SPSS 17 is in the form of each grouping of small dams and within each reservoir towards the center of the cluster.

Table 2. Distance to cluster center

No.	Small dams name	QCL_1	QCL_2
A1	Dadapayam	3	4,589
A2	Mluweh	2	0,000
A3	Lebak	3	3,816

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A4	Pakis	3	4,308
A5	Jatikurung	1	3,415
A6	Gogodalem	1	3,606
A7	Kandangan	3	5,706
A8	Ngrawan	1	4,619

QCL_1 is the cluster/grouping number, and QCL_2 is the distant between reservoir to the center's cluster.

- Cluster – 1 : Jatikurung , Gogodalem and Ngrawan.
- Cluster – 2 : Mluweh
- Cluster – 3 : Dadapayam, Lebak, Pakis and Kandangan
- To see if the variables have formed clusters are variables that influence the development of reservoirs it is necessary to test its validity using Variance Hypothesis testing. This test is used to determine the relative value of each variable and the usual more effective to test the number of variables and a population of more than one.

Additionally, from the F count it can be used as the determining more significant variables. From the 22 (twenty two) variables, there are twelve (12) variables whose Fcount > 2.747. They are 1) Vegetation cover in the inundation area, 2) Volume of embankment material, 3) The area to be acquired , 4) effective storage, 5) Duration of operation , 6) equivalent cost of water/m^3 , 7) access the entrance to the site of the dam, 8) Status of land at the site, 9) construction costs, 10) Cost of OM, 11) Coverage of irrigation areas and 12) Benefits of raw water. Therefore, it can be infered that in this case, these twelve variables are variables that has significant influence in the effeciency and effectiveness of construction of reservoirs. These 12 variables are then used in the AHP and Weighted methods.

3.2. Small dams priority selection method of AHP based questionnaire data

The process of priority selection using AHP (Analytical Hierarchy Process) aims to provide an assessment of the alternatives wich is more favourable compared to the others. It uses 12 selected variables to determine the priority. The comparison for each variables are obtained from questionaire. The result of AHP in the form of a ranking based on the assessment of priority weighting of each of the alternatives available.

1) Criteria Weighting Calculation for Purpose

From the results of the questionnaire obtained by the comparison results in a matrix form pairwise comparison between the criteria used in this study, as in Table 3 below.

Table 3. Pairwise Comparison matrix Criteria for Purpose

	K1	K2	K3	K4	K5	K6	K7	K8	K9	K10	K11	K12
K1	1,000	2,690	0,386	0,771	0,430	0,865	2,122	0,335	0,489	1,820	1,093	0,393
K2	0,372	1,000	0,627	0,779	0,792	0,578	1,000	0,541	1,000	1,000	1,364	0,590
K3	2,589	1,594	1,000	2,073	2,455	1,377	2,532	1,000	1,000	1,828	4,138	1,000
K4	1,297	1,283	0,482	1,000	1,000	1,000	1,093	1,062	1,000	1,000	1,000	1,000
K5	2,326	1,263	0,407	1,000	1,000	1,000	2,552	0,455	2,293	2,304	1,000	2,333
K6	1,156	1,730	0,726	1,000	1,000	1,000	0,498	0,399	1,000	1,000	1,000	1,000
K7	1,000	1,000	0,395	0,915	0,392	2,007	1,000	1,790	1,000	1,000	1,135	0,473
K8	1,849	1,849	1,000	0,942	2,196	2,504	0,559	1,000	2,539	2,422	2,541	0,272
K9	2,047	1,000	1,000	1,000	0,436	1,000	1,000	0,394	1,000	1,000	0,406	0,632

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K10	0,549	1,000	0,547	1,000	0,434	1,000	1,000	0,413	1,000	1,000	0,385	1,427
K11	0,915	0,733	0,242	1,000	1,000	1,000	0,881	0,500	2,462	2,600	1,000	1,000
K12	2,544	1,696	1,000	1,000	0,429	1,000	2,114	3,681	1,582	0,701	1,000	1,000

To model the Analytical Hierarchy Process (AHP) comparison matrix can be accepted if the value of a consistent ratio of not more than 10% or equal to 0.1. Because the value of CR = 0.0011 ≤ 0.1 the comparison matrix can be received / consistent.

Table 4. Recapitulation Criteria Weights

Kode	Criteria	Weight
K1	vegetation in the inundated area	6,950%
K2	volume of embankment	6,319%
K3	land acquisition area	12,228%
K4	useful storage	8,500%
K5	recervoir life time	9,431%
K6	water cost/ m³	7,709%
K7	access road to the dam site	7,593%
K8	land status at abutment and inundated area	9,284%
K9	construction cost	7,543%
K10	operation and maintenance cost	6,904%
K11	irrigation service area	6,862%
K12	and raw water benefit	10,678%

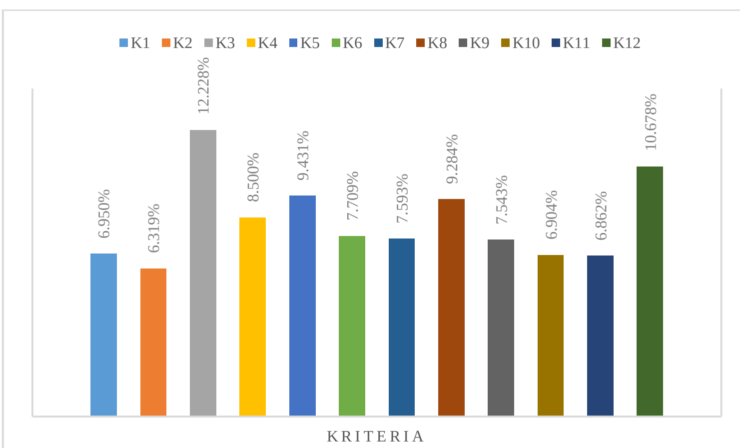

Fig. 3. Criteria Quality Towards Result Graph

2) Alternative Weighting Calculation Against Criteria

The process of calculating the alternative weighting of the criteria is to compare several alternatives to each criterion. Stages of the calculation is equal to the weighting of the criteria of the goal.

Table 5. Alternative Weight Recapitulation Against Criteria

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	K1	K2	K3	K4	K5	K6	K7	K8	K9	K10	K11	K12
A1	0,334%	1,353%	0,925%	0,558%	0,925%	1,941%	0,647%	1,589%	1,257%	1,335%	0,913%	1,043%
A2	1,391%	0,300%	3,058%	1,306%	2,667%	1,578%	2,328%	0,357%	0,349%	0,599%	1,794%	0,783%
A3	0,348%	0,382%	2,251%	2,044%	1,171%	1,207%	0,644%	1,428%	0,462%	0,342%	0,578%	2,505%
A4	0,351%	1,182%	1,415%	0,704%	1,234%	0,929%	0,633%	1,438%	1,703%	1,079%	1,323%	2,217%
A5	1,531%	0,795%	0,750%	1,037%	0,680%	0,575%	0,641%	0,411%	1,467%	0,695%	0,383%	0,619%
A6	1,556%	0,521%	0,566%	0,551%	1,809%	0,695%	0,622%	1,349%	0,826%	1,556%	0,604%	1,275%
A7	0,733%	0,690%	1,952%	1,557%	0,357%	0,442%	0,631%	1,347%	0,579%	0,441%	0,983%	1,647%
A8	0,707%	1,095%	1,311%	0,743%	0,589%	0,341%	1,447%	1,365%	0,899%	0,857%	0,286%	0,588%

Information :
A1 = Dadapayam A2 = Mluweh A3 = Lebak A4 = Pakis A5 = Jatikurung A6 = Gogodalem A7 = Kandangan A8 = Ngrawan

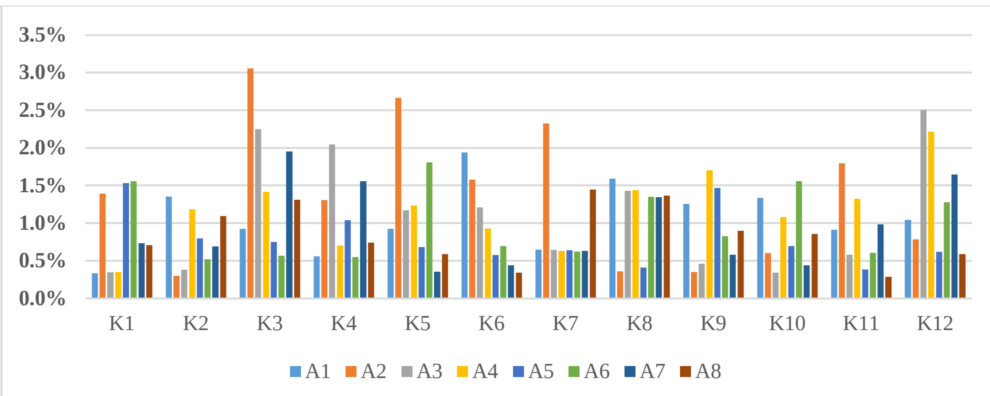

Fig. 4. Alternative Weight Graph Against Criteria

Table 6. Total Weight Alternatives

	Smalldams selection	Weight
A1	Dadapayam	12,820%
A2	Mluweh	16,510%
A3	Lebak	13,365%
A4	Pakis	14,208%
A5	Jatikurung	9,585%
A7	Gogodalem	11,929%
A8	Kandangan	11,357%
A9	Ngrawan	10,227%

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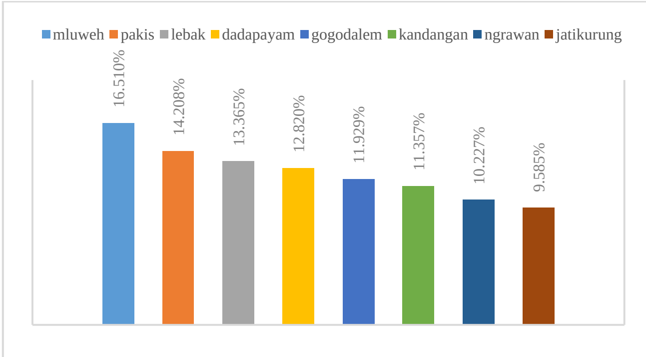

Fig. 5. Priority Ranking Chart Embung

3.3. Embung Priority Selection Method of AHP Based on Data Engineering

The decision making process with this method is to compare the technical data of each alternative against each criterion. The value of the interest rate is determined by dividing the interval of the result of each comparison matrix data. The division is divided interval of the level of interest of 1 (one) to 9 (nine). The final result of this method in the form of rankings based on the weighted votes of each alternative.

1) Alternative Weighting Calculation Against Criteria

The process of calculating the alternative weighting of the criteria is to compare several alternatives to each criterion. Stages of the calculation is equal to the weighting of the criteria of the goal.

Table 7. Alternative Weight recapitulation Against Criteria

	K1	K2	K3	K4	K5	K6	K7	K8	K9	K10	K11	K12
A1	0,020	0,271	0,061	0,141	0,127	0,136	0,049	0,227	0,157	0,103	0,139	0,052
A2	0,267	0,042	0,347	0,230	0,240	0,222	0,106	0,105	0,014	0,062	0,305	0,039
A3	0,020	0,065	0,242	0,147	0,127	0,143	0,060	0,129	0,025	0,079	0,104	0,234
A4	0,020	0,187	0,102	0,175	0,127	0,209	0,060	0,129	0,346	0,074	0,147	0,234
A5	0,267	0,124	0,028	0,066	0,094	0,062	0,060	0,026	0,235	0,163	0,049	0,071
A6	0,267	0,094	0,016	0,125	0,169	0,116	0,060	0,129	0,070	0,117	0,064	0,122
A7	0,070	0,094	0,158	0,066	0,028	0,059	0,060	0,129	0,048	0,172	0,144	0,234
A8	0,070	0,124	0,046	0,051	0,088	0,053	0,543	0,129	0,105	0,230	0,048	0,014

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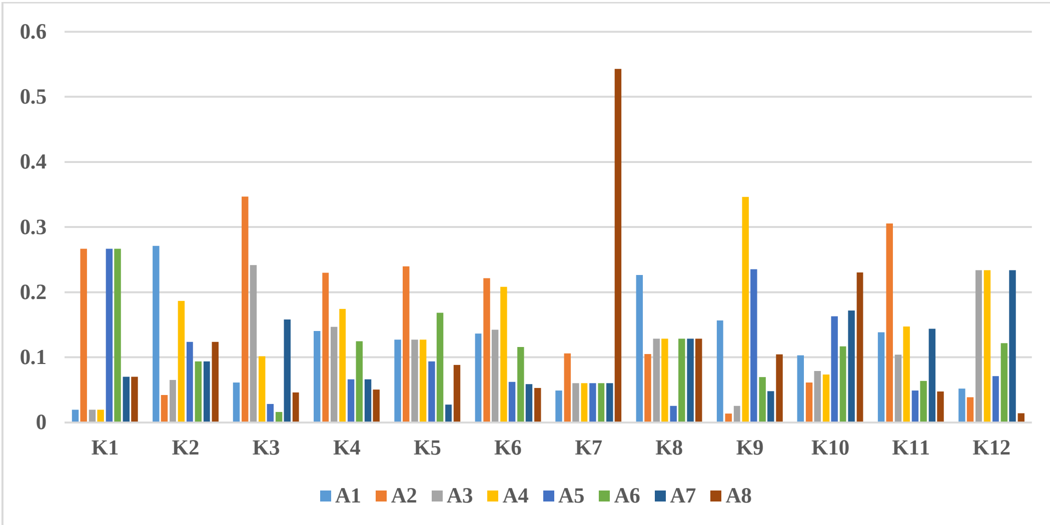

Fig. 6. Alternative Weight Graph Againts Criteria

Table 8. Alternative Weight Term

	Alternative	Weight
A1	Dadapayam	1,483
A2	Mluweh	1,978
A3	Lebak	1,375
A4	Pakis	1,808
A5	Jatikurung	1,246
A6	Gogodalem	1,347
A7	Kandangan	1,261
A8	Ngrawan	1,501

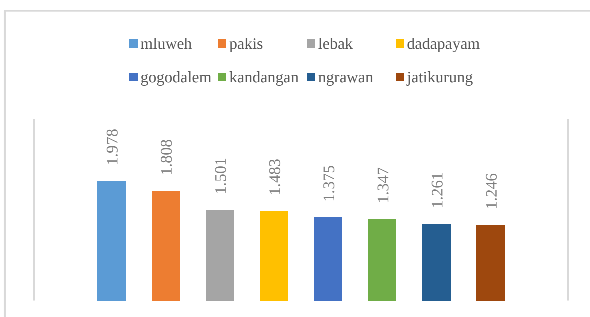

Fig. 7. Priority Ranking chart Embung

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3.4. Embung priority selection by the weighted average method

The weights of the criteria used is the questionnaire results have been analyzed using AHP questionnaire data. Weighting for alternative locations reservoir was made to all existing criteria. Alternative weighting criteria is based on secondary data from this study. Where data of each reservoir is given in accordance with the ranking of the value of scoring / standardization of data from the previous discussion. Where each alternative against the criteria with greater its value the greater the value of importance. Value ranking of alternatives is then multiplied by the value of the interests of criteria so that the value combinations then summed to obtain the overall value. The result of this final value which will be compared between the alternatives with other alternatives as the basis for determining the selection of priority reservoir.

Table 9. Total Weight Alternatives

	Criteria	Value Combination
A1	Dadapayam	2,674
A2	Mluweh	2,869
A3	Lebak	2,525
A4	Pakis	2,757
A5	Jatikurung	2,095
A6	Gogodalem	2,276
A7	Kandangan	2,230
A8	Ngrawan	2,247

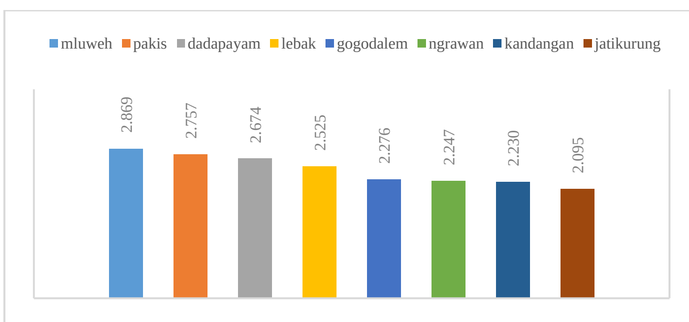

Figure 8. Priority Ranking Chart Embung

3.5. Results embung priority cluster analysis method , AHP questionnaire data , data engineering and weighted average

From the analysis that we can know the result of the difference between the reservoir prioritization to three (3) such methods.

Table 10. Results Embung Priority Cluster Analysis Method , AHP Questionnaire Data , Data Engineering and Weighted Average

	Smalldams selection	AHP Method		Method	Method	
		Cuestionnaire Data	Technique Data	Weighted Average	Analysis Cluster	
A1	Dadapayam	4	4	3	Cluster - 1	Jatikurung

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A2	Mluweh	1	1	1		Gogodalem
A3	Lebak	3	6	4		Ngrawan
A4	Pakis	2	2	2	Cluster - 2	Mluweh
A5	Jatikurung	8	8	8	Cluster - 3	Dadapayam
A6	Gogodalem	5	5	5		Lebak
A7	Kandangan	6	7	7		Pakis
A8	Ngrawan	7	3	6		Kandangan

4. Conclusions and recommendations

4.1. Conclusions

From the analysis that has been done in this study, several conclusions can be obtained as follows :

- Variables that influence in the construction of reservoirs using Cluster Analysis Method of non hierarchical method is : 1) vegetation in the inundated area (7,652), 2) volume of embankment (7,744), 3) land acquisition area (4,167), 4) useful storage (4,203), 5) recervoir life time (6,921), 6) water cost/ m³ (4,321), 7) access road to the dam site (3,125), 8) land status at abutment and inundated area (12,031), 9) construction cost (9,844), 10) operation and maintenance cost (4,559), 11) irrigation service area (22,500) dan 12) and raw water benefit (2,893).
- Based on the calculation method of Cluster Analysis, AHP questionnaire data , engineering data and Weighted Average , short-term reservoir development priorities are : 1) Mluweh (0.165) , 2) Pakis (0,142) , 3) (0.134) , 4) Dadapayam (0.128), 5) Gogodalem (0.119) , 6) Kandangan (0.114) , 7) Ngrawan (0.102) and 8) Jatikurung (0.096).

4.2. Recommendation

From the analysis that has been done with the above conclusions, some suggestions can be submitted as follows:

- In this study, administration of the class interval to gain weight at all variables have not been uniform. This means that there are several variables that have different class interval. Suggested for further research using uniform class intervals while providing a source elaboration grade interval of each of the variables to be analyzed.
- For optimal results , the determination of the data relied on respondents' assessment (through interviews / questionnaires), do increase in the number of respondents or experts with increasingly wide resources in order to maintain data consistency.
- To obtain a different result, in the process of standardizing data on Cluster Analysis method can be done by looking for better standards of raw or with standarization/transformation in SPSS.
- In this study, the scoring scale comparisons on AHP Method engineering data using standard scale of 1-9 according to the method of AHP questionnaire data. Suggested for further research could use a benchmark comparison with the scale of dividing the class interval on the comparative value of the largest and smallest.

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