Sustainable water management: a review study on integrated water supply (case study on special district of Yogyakarta)

Yureana Wijayanti1, Markus Fittkow3, Kadarwati Budihardjo3, Purwadi3, Oki Setyandito1

1Civil Engineering Department, Faculty of Engineering, Bina Nusantara University, Jakarta, Indonesia 11480
2Hochschule Ruhr West University of Applied Sciences, Mulheim, Germany
3Faculty of Agriculture, Institut Pertanian Stiper (INSTIPER) Yogyakarta

Corresponding Author: yureana.wijayanti@binus.ac.id

Abstract. Yogyakarta Province development in the past decade has been attracting many investors, especially in tourism and education sectors. This growth resulted in increasing of population and water demand. An understanding of the water condition and possible solutions for this problem is very important in order to formulate an effective and sustainable water management. Therefore, this review paper aims to evaluate the key approaches for sustainable water management, using the case study of Yogyakarta Province. The method used in this study is a comprehensive literature survey about sustainable water management approach, such as efficient water use, expanding water supply, and managed aquifer recharge. This study also consist of information to present and support the stakeholder and policy makers to develop an integrated water supply management that in alignment with the integrated management goal of the Indonesian Government.

Keywords: Water supply, sustainable, water management, rainwater harvesting

1. Introduction
As the Indonesia economic situation is improving, so does the special district of Yogyakarta which can viewed by the increasing of per capita income [1]. The main sectors of development in Yogyakarta are tourism and education. The population is also growing very fast. As consequence, the water demand also increases [2]. Beside of its positive impact, it also causes new challenges in water availability issues in the future. At this moment, around 90% of the water sources are used in livestock and agriculture area, but this percentage will slightly reduce in the future development of the country [3]. The fast growth of tourism sector in Indonesia also impacted in higher water demand that need an immediate solution [4]. Yogyakarta province has set its tourism target for 10% increase [5]. A research calculated that the population in Yogyakarta province will grow from 3.7 million inhabitants in 2017 up to 4.3 million inhabitants in the year 2030, this means an increase of around 16% within 13 (thirteen) years which could arises many issues included water [3]. The statistics for the Yogyakarta area shows that there will be a decrease in agricultural land use by 0.3% per year due to landuse change for housing and other purposes. Also, the livestock and industry will increase by 0.62% and 5.6% per year, respectively [6]. As a result, water demand for both sectors is also increasing. Groundwater is one of the water sources. The uncontrolled abstraction of groundwater will increase the water stress in the upcoming years [7]. This condition should be taken seriously by the local
government and institutions through action under the national regulation no. 32 / 2004, that has the concept of an integrated water management scheme. Especially for the future development of the special district of Yogyakarta and the increase of industrial, livestock and populations. The key parameters are increase in industrial consumption, the population growth and increase in food consumption [8]. In the past decade, there is a significant shift of urbanisation in the city of Yogyakarta. Urbanisation has an impact of landuse changing that leads to reduction of infiltration of rainfall into the soil and aquifer. This landuse change is documented in Statistics of Yogyakarta province [6]. Besides the water quantity issue, the quality of surface water and groundwater are prone to contamination. As a result, these water sources do not meet the water quality standard for certain purpose, like as potable water, for irrigating the crops for agriculture [9,10,11]. If the government and local community are not taking action upon these condition, it can become worst and the livability in Yogyakarta area is in critical contition. The worst case scenario is that the water available will not be enough to fulfill the needs of all the domestic, industry, livestock and agriculture water demand. Furthermore, the climate change has impacted on the decline of rainfall intensity. This situation has worsened the negative impact, such as declining the surface and ground water table, within and surrounding area of Yogyakarta city. The increasing the salinity of the groundwater source, that causes saline soil and decreases the ability to grow crops on the surface area [12].

Considering these present facts and future challenges, we proposed 3 (three) key approaches for sustainable water management of Yogyakarta city that are reviewed further in this paper, they are as follows: 1. Reduction in demand, 2.Enlarging the supply (building new dams, rainwater harvesting and storm water management) and 3. Groundwater replenishment. These options can be combined to use the advantages of one to solve the disadvantage of one of the others.

2. Reduction of Water Demand

Previous study [3] on water balance in Yogyakarta province shows that, in year 2017 until 2030, there is water deficit in 3 (three) out of 5 (five) regencies. This study was conducted by evaluating groundwater as water source. So, the deficit term means that the rate of water demand is higher than the rate of groundwater recharge. However, we have been thinking to suggest a different approach for calculating the water demand, which is a conceptual water balance using virtual water [13]. Examples of how this concept applied are as follows: the production of one kilogram of beef needs around 15400 L of water, one kilogram of sheep or goat just needs around 8750 L and chicken meat needs around 4300 L of water per kilogram [14]. The virtual water concept enabled us to see the impact of producing goods at one location on water availability in that area.

In order to reduce water demand, another solution that we propose is implementing effective irrigation (e.g. drip irrigation) to avoid evaporation losses. According to Setyandito [3], 66% of rainfall is evaporating, in case study og special district of Yogyakarta. Drip irrigation allows water to irrigate the plants at a very close distant to directly infiltrate to the soil and root [15].

The advantage of reduction of water demand is assurance of present amount of water supply is sufficient for the increasing population and economic growth. Also, it prevents new investment and/or construction of new water resource infrastructure. Hence, the available fund can be used for develop other sectors such as education and health sector. The existing law and regulation regarding water management shall not be reviewed and implement it for now and in future. Other benefit of the reduction of water consumption is minimization of the influence of saline water towards the soil and the negative impacts of saline soil for agriculture [12].

There are also some disadvantages of water demand reduction, such as, some people might feel uncomfortable due to violation of their individual freedom of water consumption [16]. They could experience suspicion that there are other people, who prevent them to have economic success. Other shortcoming is there would not be a demand for new water sector investment, both in infrastructure and capacity building. The capacity building investment would be, to conduct an integrated project with other stakeholders in engineering, economic, social, policy and regulation aspect, in order to analyze the potential and options to solve water demand problem in this area.
The recommendations regarding the reduction of water demands are: 1) to analyze the livestock and agriculture and their habits towards water and consumption, because they are using around 90% of the water [3,17]; and 2) The drip irrigation offers a decrease of 56.4% of water needs, because the plants are watered close to the roots [3]. Another impact occurred, that the drip line irrigated crop increased the yield up to 22%. This irrigation reduces the losses in evaporation [18]. Industrial sector could use a recycling system [19], to reduce the quantity of raw water supply for their production and use the recycled water from their treated industrial waste water [20]. Also, it is important to train people and to educate the consumers about water saving habits [21].

3. Increasing The Water Supply

3.1. Development of New Dams

Building new dams is the key approach of obtaining sustainable water resource management in Indonesia [22]. Dams could store water during wet season, and using this water for dry season. The government continue the development of dams and store the surface water. This storage water would increase the water availability in this area and could reduce the water stress [23]. However, there is a disadvantage of building dams because it requires a large area of land, to store the water. If this required dam area is populated then it is necessary to resettle the people from that area towards another area [24,25]. High population density, social and economical costs of resettlement have become a problem in building dams [17]. Other disadvantage is that there is a negative impact on the ecology aspect, including its fauna and flora of the future dams [26]. In the tropical climate, a dam could lead to health issues, because the storing creates a habitat for diseases [27]. The storage of the water in a large storage facility also increases the amount of water that evaporates, because the sun can easily heat up the stored water, that increases the losses, that occur. The impact on the area if the dam breaks will be intense, because of the high density in this area [27].

There are advantages and disadvantages of new dams development. It also required a large amount of investment for a dam project which are related to the labor, the equipment. Therefore, a careful study and survey for the feasibility analysis must be conducted, that takes present and future circumstances into considerations [28].

3.2. Rainwater Harvesting

Rainwater harvesting type that is being discussed in this paper is, that each household collected the rainfall that is falling on their rooftops. This water then stored into a storage facility, for example into a rain water barrel or tank [29]. This water can be easily used for the inhouse and other domestic purposes. Figure 1 shows illustration of in house purposes such as, cleaning the house, showering, and laundyng. Furthermore, by implementing a filtration device in the system, this rainwater harvesting system could be produce drinking water [30]. Other domestic purposes of rainwater harvesting water are for watering the yard, cleaning the car, or any other water uses outside of the house [29,31].

The benefits of using rainwater harvesting would be, that according to the rainfall data there are options of 1900 mm/m²/year of rainfall in Yogyakarta [3]. This would create the opportunity of harvesting on an 50 m² roof top the amount of around 85,500 l/year [30]. This system could reduce the water stress on the groundwater, because the people could use the stored rain water instead of using the groundwater [29]. The system could also minimize the influence of flooding at the heavy monsoon time, by utilizing decentralized large capacity water storage. It could stored big volume of this heavy rainfall to prevent inundation in some areas of the city. Furthermore, the local water supply companies could gain the benefit by the house scale rainwater harvesting. Less water supply should be provided by these companies and as a result, they will decrease the implementation of large diameter pipe networks around the city of Yogyakarta [30]. The economic benefit is, that the rainwater harvesting systems are affordable and can be easily installed in the house or any buildings.
The roof top area is the largest sealed surface at a property, therefore, it is the best location to harvest the rain water. Rainwater treatment using a cartridge filter or a charcoal filter and a disinfection should be applied for drinking water purposes [33].

The disadvantage of rainwater harvesting is the inaccuracy of rainfall occurrence prediction. Therefore, during dry season, this system might not perform at its best. Another aspect is that the system needs regular maintenance to avoid health issues. Especially, when the rainwater is treated for potable use. It needs to be kept in storage tanks with cover and be secured from the breeding ground for insects and bacteria, that can be harmful to our health. The rainwater system has a limitation of water storage capacity [34].

![Figure 1. Rainwater harvesting system in a household level](image)

The local government and the legislative should promote this system to the people. The subsidy must be given for the poor people to cover the installation costs. For the household owners, the investment is applied to a storage tank [34]. The material of storage tank can be vary, from bricks, to compressed soil to plastic and other material, depending on the local condition. The availability of resources can have an impact on the costs of the water storage tank. The gutter and pipes usually made of metal or PVC. The system should have a first flush application to collect the rainwater from the rooftops. The first flush application helps to remove some dirt, insects, litter and other things on a roof. So, the rainwater will not be contain these material that could contaminate the tank and preserve the water quality [34,35]. A pump can be installed to the tank. This pump is connected to the pipe network in the house to supply the taps with the rainwater, instead of the groundwater [34].

The rainwater harvest investment costs could be reduced by a subsidy from the government or by introducing a water price. Hopefully, it will give the house owners an incentive to think about other water sources [36].

3.3. Storm Water Management

Storm water is the water that flowing on surfaces, in natural streams and as direct result of a rainfall event over the catchment [37]. Urbanization had affected the storm water because it changes the landuse [38]. Less open area and more impervious land surface (e.g roads, pavements, etc) increase storm water surface run off volume. A storm water drainage or sewage network is designed to transport the storm water out of an area. At the same time, it carries a lot of contaminants, like debris, litter, bacteria, chemicals and other contaminants. These pollutants can cause damage to environment [37]. Therefore, to prevent the deterioration of environment, a more sustainable solution in storm water management should be proposed. The Water Sensitive Urban Design (WSUD) approach is an alternative solution. According to the WUSD, the rainfall should infiltrate close to the rainfall event to decrease the impact of flooding and immediately recharge the aquifer [37]. This storm water management system enabled storm water to infiltrate into the ground without harming the
surrounding area. The alternative infiltration area could be in a form of a park, a rain water garden, a pipe network solution or storm drains [38]. Parks and gardens are function as natural filtration before the water is infiltrating to the soil. As a result, both groundwater quality and quantity are increasing, it supports the existing water resources conservation [37,38]. Yogyakarta could apply this approach, as it has a high intensity of rainfall, 1900 mm/ m²/year [3]. It could increase the water availability by providing more public open space to enable groundwater infiltration. This infiltration would reduce the water stress on the aquifer and replenish the aquifer close to the rainfall event [39]. Moreover, it minimize the impact of heavy rain events and decreases the occurrence of floods [37]. Other benefit of providing public open space such a park or greenery is that it would increase the recreation options for the residents and for the tourists. It also has a positive impact on the people’s health and stress level, because it can be a place to do exercise and relax. Open space also promotes environmental sustainability and makes the surrounding neighborhood attractive for investments [40]. The development, operational and maintenance of drainage infrastructure could be minimized, because less drainage systems are built or maintained [41].

According to the water balance for the special district of Yogyakarta could be the installation of storm water management be helpful to reduce the water stress in the area. The most water stressed areas are Kulonprogo, Bantul and Gunungkidul [3]. There are options to decrease the water stress significantly. The water balance approach is a simple tool to develop alternative solutions and to evaluate the best options. The utilization of storm water scenario was introduced to prevent water stress in 2 of the 3 regencies. It shows that this scenario could minimize the water stress in the most water stressed area, Kulonprogo regency, significantly. Other finding in Setyandito et al. [3] study is that the water balance would be an increase up to 95 % of infiltration or usage of the surface run-off be needed until 2030. In Bantul regency, it will be a storm water infiltration of ~55% be needed until 2020, that needs to reach 100% until 2030. In Kulonprogo, infiltration of storm water of 100% is needed until 2020 and it would still not be enough to fulfill all the water needs. In Gunungkidul regency, a ~80% infiltration be needed until 2020, that needs to reach 95% infiltration rate until 2030, to fulfill the water needs of the area.

In order to apply storm water management that required open surface, for instance, areas such as public open space of a park is needed. This will be a challenging issue in some densely populated area of Yogyakarta city where most surface areas consist of buildings or streets. Few available open space areas would be quite expensive [42].

The city of Yogyakarta area has still been developing up until now. Therefore, we recommend that the local authorities could create a regulation such as a restrictions of having an open space area around a neighborhood. This to allow the storm water to infiltrate to decrease the impact of flooding and allow the groundwater to replenish. It would be a cheap solution, because there is no need of pipes. The environment would be able to deal with a certain amount of contamination, that would not be needed to be treated, that means no needed investment and operation cost for a treatment facility. The implementation of planting trees would reduce the risk of flooding [30]. The main source of financial support is from the governmant or there are some possibilities of proposing financial assistance from international donors, such as The Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ), Asian Development Bank (ADB), etc. Therefore, the low cost small scale or decentralized waste water treatment plant (WWTP) [31] should be taken into consideration. Unlike the decentralized WWTP, the centralized treatment plant has difficulty to predict exact number of connection ratio in the future, so it is difficult to plan the investment, let alone to have a clear assessment of the tariffs. At present, the sewage tariff is charged within the drinking water (by PDAM) tariff, which is managed by the local government. The local government collects the money for water and waste water [30]. Furthermore, existing WWTP of the Sewon, located in Bantul regency, has a limited area, eventhough the wastewater that needs to be treated is increasing. The capacity enlargement is about 45000 m³/day. We propose that a study should be conducted to investigate the replacement of 4 (four) big treatment ponds into smaller basins with separated aeration and anaerobic treatment in order to reducing the
recidence time [43], so less area required in WWTP. Moreover, a further research of the possible use of the effluent for the discharge directly on paddy field or other crops [44] should be investigated.

4. Groundwater Replenishment using MAR
Shallow groundwater in Yogyakarta are vulnerable to contamination and over abstraction. Therefore, sustainable management of groundwater for the future should be thoroughly investigated. We propose artificially replenish groundwater known as managed aquifer recharge (MAR) in groundwater management of Yogyakarta. Confronted with climate change, MAR is a sustainable water management strategy to secure groundwater quantity and quality [45]. Preliminary study of applying MAR technologies in Yogyakarta indicates that aquifer recharge has a possibility to overcome high abstractions problem [46]. However, injection well trials should be performed in order to further determine groundwater recharge location, depth and size. Water source alternatives of replenishment could be from storm water [47] and/or effluent of wastewater treatment plant [48]. The recommendation for regulatory aspect is that the responsibilities of water management should be centralized under one institution. At present, there are 2 (two) institutions managed water management. They are surface water and ground water management by ministry of public work and housing, and ministry of energy and mineral resources, respectively. Another recommendation is to strengthen the local government and implementation of institutional arrangements [8].

5. Conclusions
The current water supply in Yogyakarta utilises groundwater bores, wells and piped water system (PDAM). The water security for the future is not sustainable, because of the over extraction of the water in the special district of Yogyakarta. The climate change and the economic development will change the water habits of the inhabitants and therefore, the water strategy needs to be adapted. The water strategy should be reviewed, because of the changes in climate, provincial and national level situation in order to develop long term and sustainable water management. The current water supply with the less infiltrating water into the aquifer are causing a serious water stress situation. Therefore, some options, like the reduction in demand, the enlargement of supply, storage the rainwater in dams, rainwater harvesting, and storm water management were discussed. There is a need of action and there are some alternative solutions available to support the current economic development, to make Yogyakarta become a livable area in the Central Java area. For the large scale study on the sustainability of these 3 key approaches and water policies that have been applied in Yogyakarta province, conceptual urban water balance using virtual water should be conducted.

6. References
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