A REVIEW OF CLIMATE CHANGE EFFECT ON GROUNDWATER IRRIGATION IN INDONESIA

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ABSTRACT

Climate change is one of the biggest issues in the world and is stated as one of the United Nations Sustainable Development Goal the number 13. It has an impact on groundwater occurrence especially in groundwater use for irrigation. In some countries which use groundwater as source of irrigation, e.g. United States of America, Bangladesh, Bangkok, Pakistan, and Vietnam, the climate change has decreased the precipitation as well as the groundwater level. Groundwater for irrigation has been utilized in Indonesia since 1970. Until 2018, at least the total area of irrigated land by groundwater was 113,600 hectares in several provinces, i.e. West Java, Central Java, East Java, Yogyakarta, Bali, West Nusa Tenggara, South Sulawesi, and Central Sulawesi. Climate change has an impact on groundwater in terms of lowering of precipitation or rainfall which can affect the groundwater level declining. In Java itself, some rainfall analyses from Citarum, Cimanuk, Bengawan Solo, Progo, Serayu, and Citanduy watersheds indicate the declining trends, from -1.616 to -8.517 mm/year, and the turning point of climate change marked in the year 1960. Regionally, rainfall trends all over Indonesia are decreasing, except for the region of the Lesser Sunda Island and Eastern Java, whilst the highest decreasing of rainfall fall on Kalimantan and the less susceptible precipitation declining occurs in Java and Sulawesi. The declining sign of precipitation obviously threat the groundwater resources and food productivity from agriculture. To cope with this problem, the government should mitigate the probability of groundwater declining due to lack of rainfall. Some solutions are proposed: water harvesting to recharge back the aquifer, irrigation technology, and returning the irrigation flow back to the abstracted aquifer by installing artificial recharge wells or ponds.

Keywords: Climate change, groundwater, irrigation, recharge

1. INTRODUCTION

Irrigation in Indonesia has an important role in providing food security to the nation. Since the 1970s,the Government of Indonesia has been utilizing groundwater as one of the mainsources of groundwater(Tirtomihardjo, 2011). Until 2018, the irrigation area provided by groundwater has an area of 113,600 hectares from the total irrigation of 9,136,028 hectares, where the rests are provided by surface water, pump irrigation, swamp, and pond(Direktorat Irigasi dan Rawa, 2018). Since the groundwater is recharged by precipitation and surface water, the atmospheric condition, including climate, temperature, and rainfall also affect the groundwater recharge.

Climate change has effect to atmospheric condition and stated in UN Sustainable Development Goal 13: take urgent action to combat climate change and its

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impacts(United Nations, 2019). The climate change impacts to atmospheric conditions which affecting groundwater are most likely temperature rise, precipitation pattern, and droughts and heat waves (NASA, 2019a). Climate change itself is likely caused by forest fires and environmental degradation (Measey, 2010). In some countries which using groundwater as sources of irrigation, e.g. United States of America, Bangladesh, Bangkok, Pakistan, and Vietnam, climate change has clearly impacted the groundwater; it decreased the precipitation as well as the groundwater level(Shrestha and Yatsuka, 2008; Bertone Oehninger *et al.*, 2016).

The present paper attempts to review some evidence of the threat of climate change to groundwater security in providing irrigation in Indonesia. Some area with a lack of surface water still relies on groundwater to irrigate the paddy field, it is very important to discuss the effect. Besides the effect, the mitigation scenario is also discussed in order to mitigate climate change.

2. BASIC THEORY AND DATA AVAILABILITY

2.1 Climate Change and Groundwater Recharge

Climate change is defined as global phenomena in a broad range caused by fossil fuels burning; it increases temperature, sea level rise, glacier, and extreme weather (NASA, 2019b). The climate change results in changes in rainfall pattern and prolong the dry season. Some direct impacts of climate change to groundwater recharge, namely: intensity and amount of precipitation can increase or decrease, sea level rise causes saltwater intrusion to the fresh aquifer in a coastal area, CO_2 rise can affect carbonate dissolution (Shrestha and Yatsuka, 2008). Shrestha and Yatsuka (2008) also mentioned that land cover change, increase in groundwater extraction, and soil organic carbon content variations are likely to affect the infiltration.

2.2 Data Availability

The data were collected from several pieces of literature related to climate change in Indonesia and its impact on groundwater irrigation. The map showing the distribution of the availability of data is shown in Figure 1. The detail of data and its references are explained in Table 1.

3. RESULTS AND DISCUSSION

3.1 Climate Change Evidence

During 2004 to 2013, CO_2 was recorded at GAW (Global Atmospheric Watch) Bukit Koto Tabang Station, West Sumatra (Pawitan, 2018). The CO_2 concentration increase with a rate of 2.67 ppm year^{-1}, and it will reach 400 ppm level around the year 2020. Aldrian (2007) studied rainfall data from 63 rain gaugestations (Figure 2), generally ranged from 1950's to 1997 for Indonesia. The rainfall data were subjected to stastistical test to check outliers, artificial jumps, and trends including Kolmogorov – Smirnov test to comply with the normal distribution. To examine the increasing or decreasing trend of rainfall, Aldrian (2007) tested the data using Mann-Kendall test, and then the slope of the linear trend was calculated using the nonparametric Sen's method. From the 63 rain gauges data, it was concluded that overall rainfall trend showing negative trend except in five stations, i.e. Banyuwangi, Ampenan, Sumbawa, Walingapu, and Kupang stations in Lesser Sunda Island and Eastern Java.

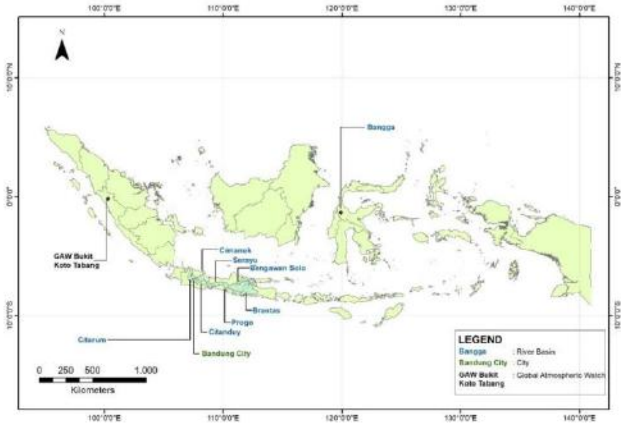

Figure 1. Map of data distribution, compiled from several works of literature.

Table 1. Data availability to assess effect of climate change on groundwater occurrences

No	Type	Location	Data	Reference
1	Global Atmospheric Watch	Bukit Koto Tabang	CO_2 concentration	(Pawitan, 2018)
2	Country	Indonesia	Rainfall trends over Indonesia, from 63 rain gauges	(Aldrian, 2007)
3	City	Bandung City	Distribution Groundwater Recharge	(Shrestha *et al.*, 2015)
4	River Basin	Brantas	Precipitation Rate	(Pawitan, 2010)
		Bengawan Solo		
		Cimanuk		
		Citanduy		
		Citarum		
		Progo		
		Serayu		
5	River Basin	Bangga	The trend of annual groundwater recharge	(Sutapa, 2017)

Aldrian (2007) also founded that Kalimantan is the most susceptible due to the decreasing trend of rainfall.

In Bandung City, Shrestha *et al.*(2015) predicted that the groundwater recharge would decrease by -2.9% to -10.0%. By 2100, the temperature of Bandung city will also rise by 3.1 °C, and the city will receive less rainfall than in the previous year.

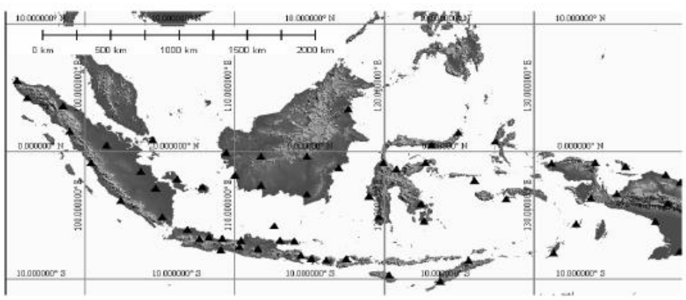

Figure 2. The 63 rain gauge stations, the rainfall data used by Aldrian (2007) to examine rainfall trend from the 1950s to 1997.

Pawitan (2010) examined hydrologic balance from seven main river basins in Java island, i.e. Citarum, Cimanuk, Bengawan Solo, Brantas, Progo, Serayu, and Citanduy. It is revealed that except for Brantas river basin, the annual rainfalls in the other basins were falling, ranged from -1.6 mm year^{-1} for Bengawan Solo and -8,5 mm year^{-1} for Progo.Pawitan (2010) also stated that the year 1960 is a remarkable year for climate change, where rainfall trends in all river basin except Brantas were changing rapidly.

Sutapa (2017) studied the effect of climate change on groundwater recharge in Bangga watershed, Central Sulawesi. The groundwater recharge was modelled using SWB (Soil – Water – Balance) model,which part of MockWyn-UB model considering climate change as correction factors in the form of rain and temperature correction factors. From the model result, it is obtained that there is a downward trend of annual groundwater recharge from early 1995 to 2011.

Almost all studies conclude that climate change in Indonesia causes decrease in annual rainfall rate. The decreasing tend also affected the groundwater recharge and the groundwater in the aquifer as well.

3.2 Mitigation Scenario

In order to cope with the climate change effect on groundwater recharge, some scenarios can be proposed, i.e. water harvesting, irrigation technology, and artificial recharge well.

(A) Water Harvesting

Rain harvest technology is an alternative water management technology by accommodating excess water in the rainy season and utilizing it in the dry season for irrigation purposes. Some rain harvesting technologies that have been widely applied are small dam and trench dam that do not require extensive land and are built around farms. Small dam functions as a catchment that can increase the storage capacity of groundwater and provide water for plants and livestock during the dry season.

The choice of small dam location needs to consider several things, including:

- Distance between small dam and water channels.
- Location of reservoirin land with a slope of 5-30%.
- Preferably on land that has clay and / or clay texture.

The benefits of small dam and dam ditches in an effort to anticipate drought are:

- Store abundant water in the rainy season, so that surface runoff, erosion, and flood hazards in the downstream area can be reduced and utilize water during the dry season.
- Support the development of farming in dry land, especially in the food crops, fisheries and livestock sub-sectors.
- Accommodating eroded soil so that it reduces sedimentation into the river, to fulfill household water needs a well can be made around the small dam.

Trench dam technology is a way to collect or stem water flow in a ditch (drainage network) in order to accommodate the volume of surface flow, so that besides being used to irrigate surrounding plants it can also reduce runoff erosion and sedimentation.

(B) Irrigation Technology

Various irrigation technologies have been developed to free plants from droughts, such as joint wells,capillary irrigation,drip irrigation,spray irrigation,ditch irrigation, rotating irrigation, and intermittent irrigation.

- The joint well is one of the most suitable plant irrigation technologies applied in areas with sandy textured soil. Land like this has the ability to pass very high water, so it cannot store water for a long time. Joint wells basically hold water for irrigation in a cylindrical reservoir that is connected to another reservoir through a capillary tube resembling a connected vessel.
- •Capillary irrigation is gravity irrigation technology that is suitable to be developed in areas that have steep topography with relatively limited water sources. The basic principle of capillary irrigation is to use water from sources of springs or rivers that are channelled into gravity reservoirs using PVC pipes. Furthermore, the water available in the reservoir is distributed to the planting area which will be irrigated using capillary plastic hoses.
- Drip irrigation is an irrigation technology that aims to utilize the very limited availability of water efficiently. This technology is suitable to be applied to dry land with a dry climate with a relatively sloping topography. The principle of the distribution of water in the drip irrigation system is to channel water from the reservoir tank which is placed in a position higher than the farm area. Plant water needs are supplied from the storage tank through a specially designed irrigation hose, so that the water can drip the roots of the plant with the same and constant discharge. This technique is very efficient in water use but only suitable for cultivation of plants that have a high economic value such as shallots.
- Irrigation fan spray sprinkler spray is a spray irrigation system in the form of a simple nozzle made of fan-shaped plastic spray. This technology has a low but constant watering discharge, suitable for application to plantation and horticulture plants. This irrigation technology is relatively cheaper, not easily clogged, easy to maintain, and the irrigation range can reach 1.5 m.
- Trench irrigation (furrow irrigation) is one of the irrigation technologies on dry land for crops (maize, soybeans, peanuts) or vegetables. Compared to conventional irrigation (submersion / inundation systems), this irrigation technique is more efficient in the use of water resources.

(C).Artificial Recharge

Artificial recharge can be in the form of well or pond. The well or pond can be infiltration media for rainwater so that the excess water from the irrigation system can be injected back to the aquifer. The quality of injected water should be examined first, whether it is appropriate with the baseline quality of the groundwater or not. Bear in mind that the aquifer may be utilized by local inhabitants for drinking water puroses too.

4. CONCLUSIONS

The study revealed that groundwater irrigation in Indonesia is threatened by climate change. The climate change resulting in lowering the rainfall rate in Indonesia, which is proven by decreasing trend of groundwater recharge in Bandung City and Bangga river basin, and decreasing trend of precipitation in the major river basin in Java Island too. To cope up with this threat some scenarios are proposed, i.e. constructing a small dam to harvest water, using irrigation technology to manage water for irrigation, and built some recharge media to recharge back excess irrigation water and rainwater.

5. REFERENCES

Aldrian, E. (2007) Decreasing trends in annual rainfalls over Indonesia: A threat for the national water resource?, J. Meteorologi dan Geofi sika.

Bertone Oehninger, E. et al. (2016) 'The effects of climate change on agricultural groundwater extraction', (August).

Direktorat Irigasi dan Rawa (2018) 'Pengenalan Program dan Kegiatan Direktorat Irigasi dan Rawa pada Pengarahan CPNS Formasi 2018'.

Measey, M. (2010) 'Indonesia: a vulnerable country in the face of climate change', Global Majority E-Journal, 1(1), pp. 31–45.

NASA (2019a) 'The Effects of Climate Change'. Available at: https://climate.nasa.gov/effects/.

NASA (2019b) 'What's in a name? Weather, global warming and climate change'. Available at: https://climate.nasa.gov/resources/global-warming/.

Pawitan, H. (2010) Global climate change and recent changes in Indonesia water resources.

Pawitan, H. (2018) 'Climate change impacts on availability and vulnerability of Indonesia water resources', in IOP Conference Series: Earth and Environmental Science. IOP Publishing, p. 12003.

Shrestha, S. et al. (2015) 'Climate change impact on groundwater recharge and suggested adaptation strategies for selected Asian cities', 8(1), pp. 41–51.

Shrestha, S. and Yatsuka, K. (2008) 'Groundwater and Climate Change: No Longer the Hidden Resource', p. Available at: http://www.iges.or.jp/en/pub/whitepaper.html.

Sutapa, I. W. (2017) 'Effect of the climate change on groundwater recharging in Bangga watershed, Central Sulawesi, Indonesia', Environmental Engineering Research, 22(1), pp. 87–94. doi: 10.4491/eer.2015.127.

Tirtomihardjo, H. (2011) 'Groundwater Resource Potential in Indonesia and their Management'. Available at: https://www.iges.or.jp/en/natural-resource/groundwater/PDF/activity20110602/S1-2_Mr.Haryadi-Indonesia.pdf.

United Nations (2019) 'Goal 13: Take Urgent Action to Combat Climate Change and its Impacts'. Available at: https://www.un.org/sustainabledevelopment/climate-change-2/.