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Adaptation Strategy of Climate Change Impact on Water Resources in Small Island Coastal Areas: Case Study on Ternate Island-North Maluku

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Abstract

Observed of climate change on several decades has been linked to changes in the large-scale hydrological cycle and give the impacts to all areas include small island. Higher water temperatures and changes in extremes, including floods and droughts, are projected to affect water quality and quantity. This study was conducted to explain the condition of precipitation at Ternate Island related to climate change, to assess the saltwater intrusion in coastal area as impact of decline of groundwater and suggest several options as strategic adaptation plan could be done by government. Precipitation data had been collected from *Badan Meteorologi, Klimatologi dan Geofisika* (Meteorological Climatological and Geophysical Agency) and analysis of groundwater conditions were done by taking the geo-electric method and the measurement of physco-chemical parameters of groundwater. The result shows that precipitation pattern at study area during the last 10 yr have fluctuated and the peak of the dry season occurs in 2014 to 2015. The groundwater analysis found that below 20 m at study area, the freshwater had not found and intrusion of saltwater had been occuring. It was supported by result of groundwater quality where the condition at low tide and high tide shows that salinity and conductivity values obtained above the normal concentration for freshwater. The conditions show the region around Akegaale has been intrusion by seawater.

Keywords: Climate Change, Groundwater Quality, Saltwater Intrusion

1. Introduction

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Climate change due to increase of carbon dioxide at atmosphere has been influence various factors of life and one of the most is its impact on water resources. This changes could be characterized by alteration in climate elements such as surface air temperature, precipitation, humidity, wind speed, evaporation, and transpiration. This condition will impact directly or indirectly on the hydrological response of the region, which in turn determines the availability of water for various needs.

Climate change also can lead to shifts in the seasons in different regions. For example, long dry season and droughts. The rainy season will take place in a short time with the tendency of rainfall intensity is higher than normal rainfall. This is related to La Nina and El Nino that impacting on excess of rainfall on one side (flooding) and water shortages on the other side (drought). At the time of drought occurred in a long period, will encourage the growing the freshwater demand by consumers. Thus causing a decrease in the quantity of groundwater.

Groundwater is an important natural resource that ensures the survival of living creatures, especially humans. The main factor determining that the groundwater becomes important is the quality. But water scarcity, water pollution, floods and droughts are the current challenges that could get worse due to climate change. Therefore, changes in precipitation lead to changes in water resources [1], thus affecting all sectors that use water as essential requirement such as communities, agriculture, and industry.

As a small island, Ternate at the moment, faced the several problems related to water resources. **Firstly,** decrease of groundwater quantity. Ternate Island rely on groundwater as a source of drinking water because surface water are not founded in this island. Bandung Geological Agency in their publication in 2011, show that the potential of groundwater in Ternate Island has been declining in quantity caused by overload uptake by the community. **Secondly,** increase of population in Ternate city had encouraged rise of the clean water need [2]. The population number of Ternate City based on Statistical Bureau are 202 728 people on 2015, where the water consumption level approximately 150 L/persons/d thus the total water consumption reached 536 295 $m^3 \cdot yr^{-1}$. **Thirdly,** saltwater intrusion. Decrease of groundwater debit and increase of water demand by all sectors led to PDAM (Local Drinking Water Company) of Ternate attempt to pumping the groundwater in order to service the costumers. As a consequence, the groundwater had been empty and saltwater will exchange to the freshwater position.

A great number of studies and investigations of climate change effects for water resources have been published in different international reports and scientific journals [3–7]. But, this studies tend to focused on decline of water resources in Small Island as the effect of changing of precipitation. Therefore, the aims of this research are to explain the condition of precipitation at Ternate Island related to climate change, to assess the saltwater intrusion in coastal area as impact of decline of groundwater and suggest several options as strategic adaptation plan could be done by government.

1.1. Study site

Ternate is a small island with the Gamalama Mountain in the middle of the island. This mountain is still quite active. the size from East to West of Ternate Island around 10 km, and from north to south about 13 km. Ternate island with an area of ± 64.17 km^2, is geologically formed by Holocene volcanic rock composed of volcanic breccia, lavas, tuffs and volcanic ash.

Topography, Ternate is a mountainous area and hilly area with altitude that varies greatly from 0 to more than 1 000 m. Altitude 0 m to 100 m is the most dominant and is located on the coastal side area. The lowest elevation located on the east around the coast and towards the west the higher. Ternate City area, slope highly variable, ranging from 0 % to 60 %. The main area of the city is generally a plateau with a slope of 2 % to 5 %. Meanwhile, there are also areas with a slope of more than 60 % are located on the western of Gamalama.

Hydrogeology Understanding the geological processes is an important thing in order to study the water resources in the volcanic islands [8]. In general, based on the geology and physiography of North Maluku, Halmahera could be divided into two parts, namely western parts and eastern parts of Halmahera. The western part of Halmahera was dominated by young volcanic belt composed of volcanic rocks and sedimentary rocks tertiary until quarter, which is extended of Morotai through the West Halmahera district, Ternate Island and Tidore Island until heading Bacan Island. Otherwise, the eastern part of Halmahera, which is extending towards the east through the Gebe Island and the northern part of the Papua. This section consists of a sleeve Halmahera the northeast and southeast beyond the arc which is composed of rocks ultramafic, tertiary sediments and sediments in coastal parts of the quarter.

The initial permeability of young volcanic terrains affects dramatically the behavior and typology of islands' water resources. In Ternate Island, the aquifer system which is controlled by rock fissures and the space between granular materials of volcanic sediment closely corresponds to the free groundwater pattern of Ternate Island. The space between fissures gaps of igneous rocks and the space between granular materials of volcanic sediment becomes the space and the way for the water to flow [8]. Therefore, groundwater is essential resources at this island as a source of drinking water because the limited of surface water resources.

1.2. Preview of climate change in Indonesia

Climate change is expected to make a threat against the Indonesian security of water resources. Indonesia has experienced an increase in air temperature [9] noted that the air temperature at ground level around 0.5 °C in the 20th century, or 0.3 °C since 1990. Average temperatures are projected Indonesia an increase of 0.8 °C to 1.0 °C between the years 2020 to 2050. Meanwhile, Downscaled modeling specific for Indonesia projects that the rate of warming will rise relatively uniformly across all of Indonesia from about 0.1 °C to 0.3 °C per decade for the next 100 yr [10]. A more recent study suggests that the rate of warming for Indonesia will be slightly greater from 0.2 °C to 0.3 °C per decade [11]. Modeled precipitation changes are not as uniform; it is projected that annual rainfall will increase across the majority of the Indonesian islands, with the possible exception of southern Indonesia (including Java), where is it projected to decline by up to 15 % [10]. However, there is considerable variance in rainfall for different climate models, regions of Indonesia and times of the years. For example, during the December to February season, parts of Sumatra and Borneo become 10 % to 30 % wetter by the 2080's. In contrast, rainfall changes during the June to August season are generally negative; Jakarta for example, is projected to become 5 % to 15 % drier depending on the emissions scenario [10].

Impacts of observed changes in climate are already evident in Indonesia and will likely worsen due to further human-induced climate change. Rising concentrations of greenhouse gases will continue to raise the surface and ocean temperatures, change precipitation patterns, increase sea levels, and cause various other impacts from more frequent forest fires to increased health risks. Climate change will also continue to affect the natural climate variability, such as El Niño, and may lead to more frequent and more intense weather events.

The study long-term observation data (historical) that has been done by [12] showed that rainfall in the rainy season to the southern part of Indonesia (West Java, Central Java and Lampung) and most of eastern Indonesia tends to increase the amount of rain or is wetter, while rainfall in the dry season tends to be dry except for eastern Indonesia are experiencing wet dry season. Conversely, for the part of Indonesia north (North Sumatra, northern Borneo, North Sulawesi) rainfall rainy season will decrease, while rainfall in the dry season will tend to be higher, especially the northern part of Borneo.

2. Material and Methods

Precipitation data had been collected from Meteorology and Geophysics Agency (BMKG) of Ternate City for the period 1990 to 2015. Furthermore, the alteration trend of precipitation patterns will use to predict the availability of groundwater through the recharge potency at study area. This prediction applied the calculation of static and dynamic reserves related to the hydrogeology condition of study area [13]. Subsequently, this study also collect the number of customers and the total distribution of water by PDAM during 10 yr. Those information used to drawing the availability of water in this time. Then, statistical analysis used to predict customer requirements and water distribution till 2030 by PDAM. Afterward, to analyze the saltwater intrusion, analysis of groundwater conditions used geo-electric method and the measurement of physical and chemical parameters of groundwater from shallow wells. Geo-electric method was intended to look at the vertical profile of groundwater conditions and data was collected from two tracks at coastal area close to PDAM pumping wells. Two dimension of geo-electric configuration based on Winner-Schluberger used to explain the condition of groundwater. To measurement the physical and chemical parameters, water samples form shallow wells were collected from 13 sites since March to August 2015 and the parameters measured by Horiba water quality checker

3. Result and Disscussion

3.1. Precipitation pattern at study area

Precipitation is the main driver of variability in the water balance over space and time, and changes in precipitation have very important implications for hydrology and water resources. Hydrological variability over time in catchment area was influenced by variations in precipitation over daily, seasonal, annual and decadal time scales. Indonesia including Ternate Island—North Maluku, separated by the equator has an almost entirely tropical climate. The extreme variations in Precipitation are linked with the monsoons. The graphic on Fig.1 and Fig.2 shows the condition of precipitation monthly and annually on Ternate Island throughout the period of 1990 to 2015.

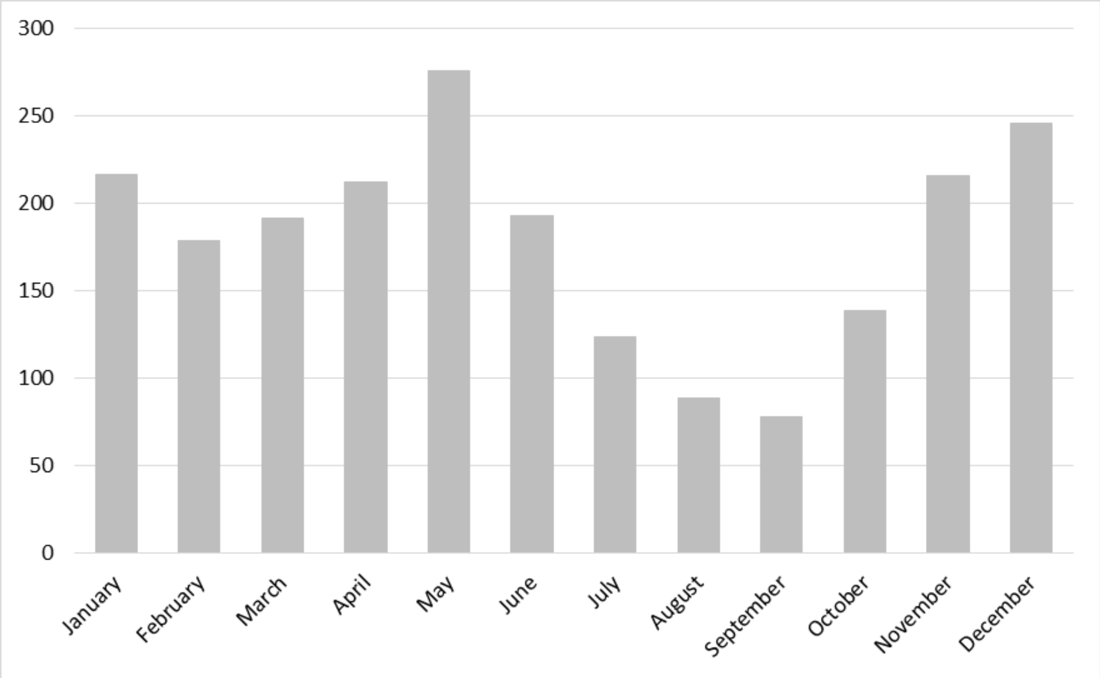


Figure 1: The Average of Precipitation (mm) in Ternate Island from 1990 to 2015 [14].

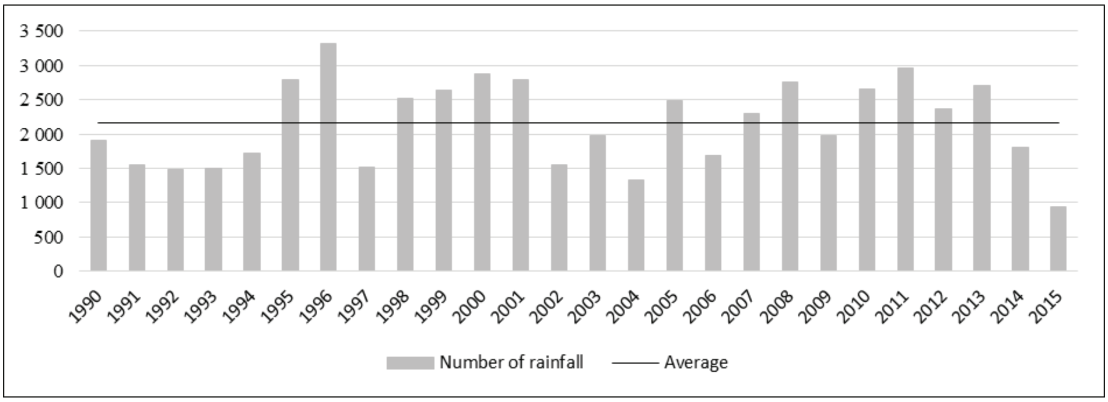
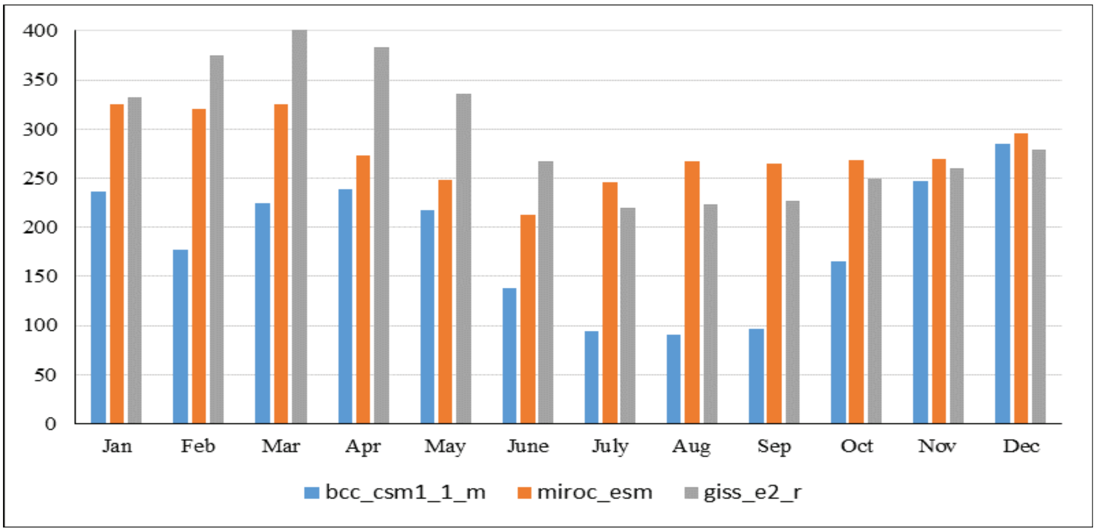


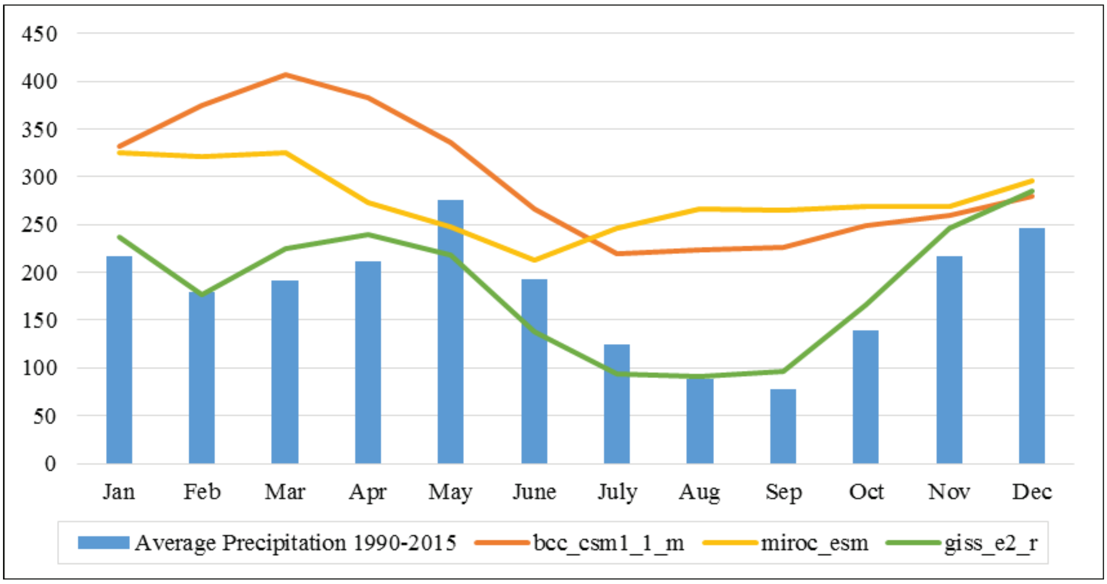
Figure 2: The Total Number of Rainfall (mm) Annually in Ternate Island from 1990 to 2015 [14].

In Fig.1, it could be seen that for the period February to May, the precipitation was increased thus May is known as the peak of the rainy season. In contrary, the precipitation was decreasing rapidly on period May to September, where September was the lowest time of Precipitation or the climax of the dry season. Furthermore, precipitation will rise up till December. Therefore, It could be said that in Indonesia as well as Ternate Island there was three seasons, dry season (June to September), and rainy season (December to March). And others months are transitional seasons.

Similar to Fig.1, Fig.2 shows the total amount of precipitation during the period of 1990 to 2015, where the average of total amount of precipitation around 2 161 mm. On this graph, it could be explained that on the period 1990 to 1994, the amount of



(a)



(b)

Figure 3: (a) Mean Projected of Precipitation (mm) in Indonesia from 2020 to 2039. (b) Comparison of Mean Projected of Precipitation (mm) from GCM Models and Average Precipitation (mm) in Study Area from 1990 to 2015.

precipitation was below the average value. On the other hand, the number of precipitation above the average occurs for periods 1995 to 1996 and 1998 to 2001. Thereafter, during the periods 2002 to 2015 the precipitation was moves fluctuate and there was an extraordinary year (2015), where it has the lowest number of precipitation (934 mm).

The global climate models had been used in this study where three of the 16 identified models by Climate Change Knowledge Portal (CCKP) created by World Bank: BCC_CSM1_1_M Beijing Climate Center, China Japan's Meteorological Research Institute's Japan's MIROC3.2 (MIROC), and GISS_E2_R Goddard Institute for Space Studies, USA. Those models could be projecting future conditions and translated into packets of information useful for decision-makers.

Fig. 3a illustrate precipitation trends of all climate scenarios and models. The variability across the climate models was relatively small compared to the difference between historical data and GCM predictions; thus, compared From Fig. 3a, could be explain that all models predict that throughout the period 2020 to 2039 the precipitation in Indonesia as well as Ternate Island have the similar fluctuation trend. On January to February, all models shows the precipitation tend to decrease but February to April, the trend tends to rise up and come down till August to September. However, all model disclose the different mean value of projected precipitation. BCC_CSM1_1_M model point out the mean projected of precipitation below two other models. Conversely, GISS_E2_R model shows the high elevation of projected precipitation from January to June and the mean value will below the MIROC_ESM model from July to December.

3.2. Groundwater availability and water demand

In order to study the water resources in the volcanic islands is necessary to understand geological processes and structures involved in the hydrological cycle. The initial permeability of young volcanic terrains affects dramatically the behavior and typology of islands' water resources [15]. The availability of groundwater from storage in Small Island is influenced by the size of the island, recharge patterns and a wide spectrum of geological conditions and recharge processes on small islands are largely influenced by rainfall, evapotranspiration, vegetation, and soil [16].

The potential of groundwater in study areas could be predicted with the calculation of static and dynamic reserves as well as recharge potency. Dynamic groundwater reserves were calculated based on the amount of water in the aquifer that affected by that horizontal flow through the aquifer. While, recharge potency calculated based on precipitation annual average (Rf), Wide area of each rock outcrop (A), and the percent of groundwater trapped in every type of rock (%Rc). This percentage (%Rc) appropriate on kind of rocks where the water through. On volcanic rock (30 % to 50 %), mixed volcanic and sediment (15 % to 25 %), Sand rocks (15 %), very fine sediment (5 %) and limestone (30 % to 50 %).

Based on previous research, the static reserve of groundwater in Ternate reach 158 604 887 m^3 and dynamic reserve of groundwater around 2 978 334 $m^3 \cdot d^{-1}$[13]. Hereinafter, related to the average of annual precipitation during periods 1990 to 2015, the recharge potency that had been calculated approximately 8 361 066 $m^3 \cdot yr^{-1}$ [13]. As a volcanic island with limited of surface water, PDAM of Ternate relies on groundwater as a source of freshwater. Source of freshwater taken from groundwater located in various locations in this island. Those locations were considered viable quality, quantity and continuity. It consists of shallow wells and wells in broncaptering (spring intake) with total capacity 446 $L \cdot s^{-1}$ and production capacity 398 $L \cdot s^{-1}$. Seven pump used by operation and service of each Operations Center (PO) applied to pumping from the water source to the reservoir.

PDAM Ternate as the one company who manage water resources and distribution services to the customers, hence the majority of the population rely on PDAM as a source of drinking water. Consequently, the amount of water demand increases rapidly as increase of customers. The clean water demand in Ternate could be calculated based on the number of customers and the demand of each person. In an assumption, if each family consists of 6 person and an average water consumption (16 to 30) $m^3 \cdot mo^{-1}$ or (88.89 to 166.67) L/people/d, so the average of water demand for each people a day approximately 127.78 L/people/d. Meanwhile, based on data from PDAM that the number of customers till 2015 reach 25 905 consumers which is growth 1 180 annually.

On the other side, PDAM continue to intensify the supply of drinking water to their customers. On 2006, the total drinking water that had been distributed by PDAM to costumers reach 4 515 509 m^3 and in 2015, it was increases gradually close to 8 492 101 m^3, with growth annually around 441 844 m^3 (Fig. 4). Clearly on Fig. 4, that the growth of water demand by costumer are not proportional with decline of groundwater available since 2014. This situation led to intrusion by saltwater into surface wells at coastal area.

3.3. Saltwater intrusion at study area

Seawater intrusion is the movement of seawater into fresh water aquifers due to decreases in groundwater levels or by rising in seawater levels. Saltwater intrusion into freshwater aquifers is also influenced by factors such as tidal fluctuations, long-term climate and sea level changes, fractures in coastal rock formations and seasonal changes in evaporation and recharge rates [3]. To measure the seawater intrusion, conductivity and salinity are a very good indicator of chloride content. Based on the

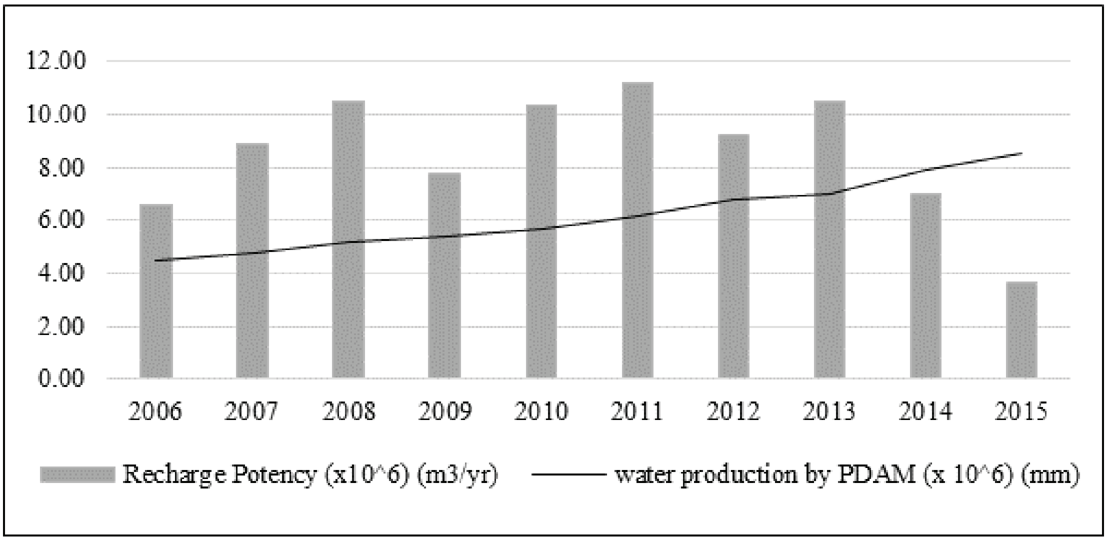


Figure 4: Recharge Potency of water and water production by PDAM of Ternate City during 2006 to 2015.

study result, which the value of conductivity and salinity measured had been show high value that indicate the seawater intrusion had been occurring.

The result of geo-electric measurement of groundwater depth shows the illustration of study area topography. Groundwater level was getting away from the coastline will deeper, and vice versa, it was shallow when near the coastlines. This is typical of a small volcanic island. In general, the groundwater flow pattern of a small volcanic island, flowing to a low plateau with a radial pattern.

The measurement results on line 1 and line 2 could be explained that until 20 m depth, the freshwater have has gone. It could be seen from the distribution of resistivity values between 4.2 Ωm and 19 Ωm (brackish to salt water; light blue color), which dominates the subsurface aquifer. At a depth from 3 m to 12 m in two "spot" (the electrode to 4–7 and the electrodes 12 and 13) shows the presence of salt water lens (resistivity values between 0.9 Ωm and 2.5 Ωm; dark blue). Furthermore, the distribution of 33.5 Ωm resistivity values (red color) on the surface till 4 m depth (between electrodes 9 to 22) and at a depth of 12 m to 20 m (between the electrodes 12 to 15) was indicate that fresh water till saltwater allegedly trapped in clay rocks (Fig. 5 and Fig. 6).

3.4. Physical and chemical characteristic of shallow wells

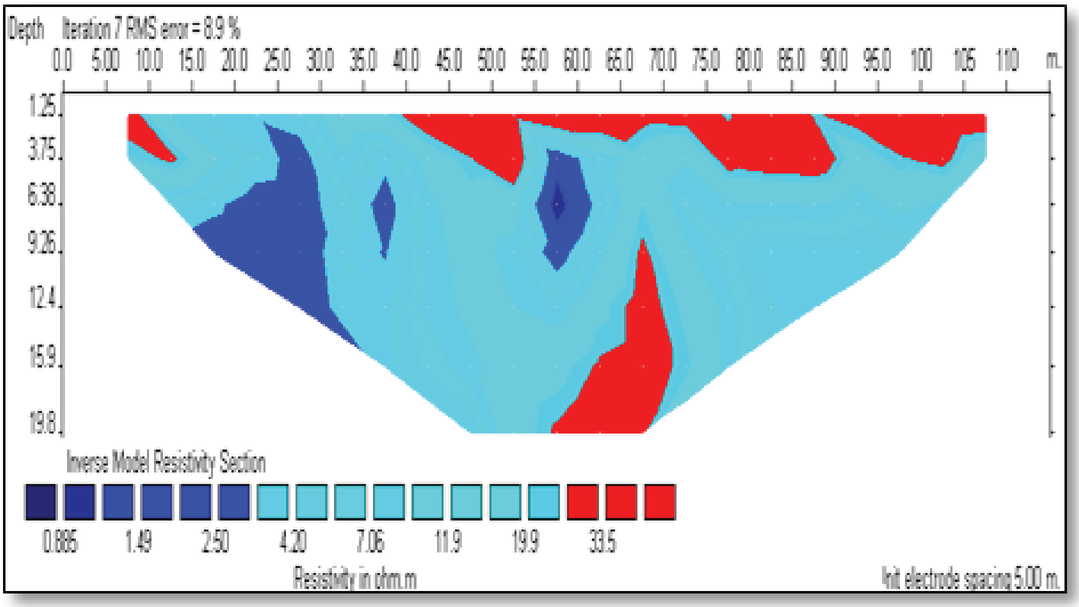


Figure 5: Geo-Electric Result in Line 1.

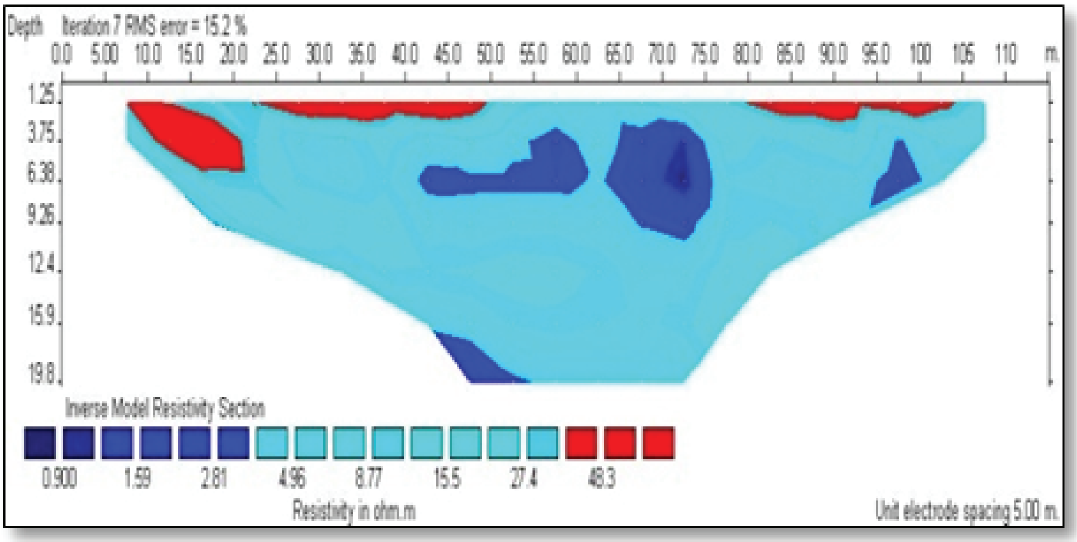


Figure 6: Geo-Electric Result in Line 2.

3.4.1. Conductivity

Electrical conductivity (EC) is water's ability to deliver electrical current. In pure state, water is a poor conductor or insulator. But, the availability of dissolved ionic substances in water make it's a conductor. Several values of EC indicated the kind of water e.g. rainwater from (5.0 to 30) $\mu S \cdot cm^{-1}$; groundwater (30 to 2 000) $\mu S \cdot cm^{-1}$ and seawater (45 000 to 55 000) $\mu S \cdot cm^{-1}$.

EC measurement results in all sampling sites showed that the values ranging from (1 230 to 29 200) μS · cm^{-1}. However, based on the results observed that EC high value generally can be at the time of measurement with the tide conditions compared with the low tide conditions (Table 1). These results indicate that in some wells already contains ions are especially high e.g. at 1, 3 and 12 sampling sites.

Table 1: EC (x 1,000 μS · cm^{-1}) of water sample at study area.

Site	March		April		May		June		July		August	
	Low tide	High Tide	Low tide	High Tide	Low tide	High Tide	Low tide	High Tide	Low tide	High Tide	Low tide	High Tide
1	14	10.6	23.5	22.34	26.3	18.6	19.23	29.2	24.4	22.8	18.6	26.3
2	9.12	8.59	5.14	4.56	3.17	2.44	3.34	5.64	6.02	4.47	2.44	3.17
3	9.96	9.93	5.39	27.89	4.62	1.96	2.19	6.24	5.34	27.8	1.96	4.62
4	1.66	1.86	1.82	2.78	2.2	1.99	2.95	2.19	1.81	2.78	1.99	2.2
5	1.47	1.51	1.56	1.53	1.81	1.68	1.89	1.86	1.56	1.53	1.68	1.81
6	1.56	1.6	1.85	3.45	1.95	1.91	1.9	2.01	1.86	3.13	1.91	1.95
7	1.69	1.67	1.68	1.23	1.73	1.6	1.56	1.81	1.65	1.23	1.6	1.73
8	2	1.95	2.33	3.2	2.44	2.34	2.43	2.66	2.34	2.03	2.34	2.44
9	1.52	1.51	1.78	1.75	2.02	1.98	1.89	1.96	1.78	1.75	1.98	2.02
10	4.62	4.61	3.52	4.7	3.33	3.56	4.3	3.93	3.54	4.7	3.56	3.33
11	5.31	5.19	5.71	4.9	5.46	4.74	4.74	5.46	5.73	4.9	4.74	5.46
12	2.51	7.33	18.4	22.23	21.5	10.9	10.9	28.2	18.45	20.1	10.9	21.5
13	5.87	6.09	8.99	9.78	6.56	5.57	5.57	7.42	8.99	8.5	5.57	6.56
min	1.47	1.51	1.56	1.23	1.73	1.60	1.56	1.81	1.56	1.23	1.60	1.73
max	14.00	10.60	23.50	27.89	26.30	18.60	19.23	29.20	24.40	27.80	18.60	26.30
average	4.71	4.80	6.28	8.49	6.39	4.56	4.84	7.58	6.82	8.13	4.56	6.39

3.4.2. Salinity

Salinity is the total weight of all salts dissolved in one liter of water. Value of salinity in freshwater ranged from 0.5 ‰ to 5.0 ‰, brackish waters between 5.0 ‰ to 30.0 ‰, while the ocean waters ranging between 30.0 ‰ to 40.0 ‰. The salinity values of wells at sites location received grades ranging from 0.6 ‰ to 18.10 ‰. The highest salinity value is generally obtained at 1, 3 and 12 sites (Table 2). Those sites are adjacent to small streams and directly related to the high ocean salinity. These values indicate that those sites have been intrusion by seawater into the groundwater aquifer. The result of salinity measurements at low tide and high tide period shows little difference where at high tide, the value of the salinity in some wells showed higher values compared at low tide.

Table 2: Salinity (‰) of water sample at study area.

Sites	March		April		May		June		July		August	
	Low tide	High Tide	Low tide	High Tide	Low tide	High Tide	Low tide	High Tide	Low tide	High Tide	Low tide	High Tide
1	8.1	6	14.3	14	11	16.1	12	18.1	15.56	17.65	10.21	17.5
2	5.1	4.8	2.8	2.4	1.3	1.6	1.4	3	3.23	4.3	1.45	1.6
3	5.6	5.6	3.1	17.3	1	2.5	1.5	3.4	4.32	17.3	1.34	2.5
4	0.8	0.8	0.9	1.3	1	1.1	1.2	1.1	0.9	1.3	1.2	1.1
5	0.7	0.6	0.8	0.8	0.8	0.9	0.8	0.9	0.8	0.8	0.87	0.9
6	0.8	0.8	0.9	1.4	1	1	1	1	0.9	1.4	1.78	1
7	0.9	0.8	0.8	0.6	0.8	0.9	0.8	0.9	0.8	0.6	0.8	0.9
8	1	1	1.2	1	1.2	1.3	1.2	1.4	1.3	1	1.2	1.3
9	0.8	0.8	0.9	0.9	1	1	1	1	1.23	0.9	1	1
10	2.5	2.5	1.8	2.5	1.9	1.7	1.9	2.1	1.8	2.5	1.9	1.7
11	2.9	2.8	3.1	2.6	2.5	2.9	3.4	2.9	3.1	2.6	2.5	2.9
12	4.1	4	10.9	12	6.1	12.9	6.7	17.3	11.45	14.56	7.5	13.65
13	3.2	3.3	5	4.7	3	3.6	4.21	4.1	5	4.7	3	4.5
min	0.70	0.60	0.80	0.60	0.80	0.90	0.80	0.90	0.80	0.60	0.80	0.90
max	8.10	6.00	14.30	17.30	11.00	16.10	12.00	18.10	15.56	17.65	10.21	17.50
average	2.81	2.60	3.58	4.73	2.51	3.65	2.85	4.40	3.88	5.35	2.67	3.89

3.4.3. Temperature

Temperature affects chemical reactions and also the water solubility of various substances in the water, therefore the temperature measurement is required. The results of temperature measurements between the low tide and high tide do not show a significant difference. The ranges of temperature from all sites are between 25.09 °C to 28.12 °C with an average temperature 26.34 °C (Table 3). This result shows that the water temperature is still within the normal range in accordance with environmental quality standards.

Table 3: Temperature (°C) of water sample at study Area.

Site	March		April		May		June		July		August	
	Low tide	High Tide	Low tide	High Tide	Low tide	High Tide	Low tide	High Tide	Low tide	High Tide	Low tide	High Tide
1	25.96	26.24	27.02	26.81	25.96	25.51	25.9	25.13	28.08	26.81	25.45	25.45
2	26.44	26.52	27.11	26.8	26.20	25.83	26.21	26.1	28.12	26.8	26.21	25.84
3	27.32	27.33	27.55	28.05	26.88	27.03	26.6	27.3	27.89	28.05	26.34	27.45
4	26.26	26.59	27	27.14	26.18	25.31	26.18	26.26	27.6	27.14	26.34	25.21
5	26.55	26.76	26.96	27.26	26.88	26.58	26.88	26.84	26.45	27.26	26.86	26.34
6	26.5	26.68	27.11	27.19	26.49	25.87	26.49	26.34	26.78	27.19	26.49	25.34
7	25.75	25.62	25.99	26.41	25.96	25.09	25.96	25.21	25.67	26.41	25.96	25.45
8	25.92	26.06	26.33	26.55	26.89	26.36	26.89	26.21	26.45	26.55	26.83	26.63
9	25.66	25.93	26.09	26.28	25.91	25.55	25.91	25.43	26.54	26.28	25.34	25.35
10	26.07	26.15	26.53	26.86	25.74	25.31	25.74	25.55	26.53	26.86	25.54	25.45
11	25.96	26.20	26.42	26.94	26.12	25.34	26.12	25.63	26.56	26.94	26.12	25.85
12	26.41	26.41	26.62	26.7	26.37	26.16	26.37	25.8	26.62	26.7	26.45	26.23
13	25.7	25.79	26.15	26.46	25.95	25.52	25.95	25.37	26.15	26.46	25.95	25.52
min	25.66	25.62	25.99	26.28	25.74	25.09	25.74	25.13	25.67	26.28	25.34	25.21
max	27.32	27.33	27.55	28.05	26.89	27.03	26.89	27.3	28.12	28.05	26.86	27.45
average	26.19	26.33	26.68	26.88	26.27	25.80	26.25	25.94	26.88	26.88	26.14	25.85

3.4.4. pH

pH is an important indicator for determining water quality. The pH value indicates the relative amount of free hydrogen atoms and hydroxyl contained in water. The water will be acidic when it contains many free hydrogen ions and is alkaline when hydroxyl contains many ions. Normally, the neutral of pH value ranging between 6,0 to 8.00. The results of pH value from all sites found that the pH value ranging between 4.22 to10.71. These results shows that some sites already contain many hydrogen ions and hydroxyl ions, and there was no significant difference among pH value at high tide and low tide (Table 4).

Table 4: pH of water sample at Study area.

Sites	March		April		May		June		July		August	
	Low tide	High Tide	Low tide	High Tide	Low tide	High Tide	Low tide	High Tide	Low tide	High Tide	Low tide	High Tide
1	7.04	7.4	6.45	6.17	7.33	8.69	7.34	7.13	7.45	6.57	7.34	8.69
2	8.19	9.18	4.36	8.35	5.75	7.9	5.67	7.04	5.46	8.35	5.45	7.23
3	4.77	7.15	7.74	4.72	5.85	5.34	5.6	4.22	7.54	4.72	5.21	5.41
4	5.72	6.69	9.04	8.85	6.47	5.83	6.47	5.58	8.65	8.85	6.56	5.43
5	7.86	8.59	9.64	9.57	8.31	7.62	8.21	7.03	9.56	9.35	8.56	7.56
6	8.25	8.92	9.49	10.71	8.87	8.22	8.34	8.07	8.54	10.32	8.32	8.23
7	9.4	9.72	9.34	9.36	8.99	8.68	8.79	8.42	8.65	9.34	8.12	8.56
8	9.65	10.02	9.57	9.37	9.97	9.93	9.1	8.88	8.43	9.37	9.43	8.21
9	9.29	10.11	9.53	9.49	8.52	10.29	8.53	9.25	9.65	9.49	8.21	8.54
10	10.13	10.43	9.57	8.29	8.22	9.18	8.22	8.11	8.54	8.29	8.56	8.45
11	10.24	9.14	9.34	8.21	7.51	8.82	7.51	7.09	9.54	8.21	7.32	8.21
12	8.93	10.03	9.61	8.71	7.55	8.58	7.45	7.05	9.23	8.71	7.32	7.98
13	8.32	8.64	8.92	8.01	8.11	8.07	8.11	7.13	8.92	8.01	8.11	8.07
min	4.77	6.69	4.36	4.72	5.75	5.34	5.60	4.22	5.46	4.72	5.21	5.41
max	10.24	10.43	9.64	10.71	9.97	10.29	9.10	9.25	9.65	10.32	9.43	8.69
average	8.29	8.92	8.66	8.45	7.80	8.24	7.64	7.31	8.47	8.43	7.58	7.74

3.4.5. Adaptation strategies

In the future, dry season estimated length while the rainy season is shorter, but heavier, so the risk of drought, flooding and erosion increases significantly. Therefore, the Ternate City government should have the mechanisms to strengthen the capacity of PDAM and civil society organizations to assess the impact of climate variability and change on integrated water resources management, and assists the formulation of adaptation strategies to integrate these impacts into local development planning.

Several actions could be taken by government in order to adaptation and mitigation strategy related to impacts of climate change. Short term adaptation, such as: i) Inventory of raw water sources; ii) Conduct research to determine the groundwater basin; iii) Monitoring land use changing in the catchment area; iv) recovery the catchment area; v) Makes the rainwater harvesting and build the recharge wells. Meanwhile, long term adaptation, such as: i) Raise awareness of water and climate issues and integrate climate change consideration into water governance reform; ii) makes the policy to protect water resources and catchment areas; iii) campaign and educate the community to save the water, iv) Manage the water supply infrastructure.

4. Conclusions

Measurement results of groundwater conditions with geo-electric method shows that at a depth of 20 m, the freshwater has gone. Possibilities in the study area have experienced intrusion of seawater showed with high salinity and conductivity. Therefore, climate change has given impact to small island particularly Ternate Island. The changing of rainfall recently and in the future had been influence the availability of groundwater and led to saltwater intrusion at coastal area, whereas around 75 % of Ternate population stay in this area. This condition tend to declining of water quality slowly in the future if the government doesn't have strategy and action plan.

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