A Study on the Effects of Climate Change on the Availability of Water and Kalangkangan Watersheds

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ABSTRACT

Introduction: Climate change has a huge impact on the availability of water resources. Based on the case, this research is deemed necessary to do. Water availability is an essential issue related to climate change. The most perceived impacts due to climate change are climate anomalies; the rainy season lasts shorter with increasing intensity and the dry season lasts longer than usual conditions. The body of water cannot accommodate high-intensity rainwater, so it flows quickly into the sea. Relatively, a long dry season results in drought. The vulnerability of the availability of water sources in the Kalangkangan watershed, Tolitoli Regency was indicated through the reduction in river discharge. These changes in discharge had the potential to be difficult in meeting the needs of irrigation or clean water. If there is no attempt to protect and repair the water sources, it is believed that the reduction in discharge will continue until it hits a critical condition. The availability of water from the rain - discharge simulation model in the Kalangkangan watershed for wet conditions (Q20%) had a maximum discharge of 20.62 m³ / sec in June (decade II), and an average discharge of 13.59 m³ / sec. For normal conditions (Q50%) the maximum discharge was 19.47 m³ / sec in June (decade I), the minimum discharge was 5.35 m³ / sec in June (decade I) and the average discharge was 11.13 m³ / sec. For dry conditions (Q80%), the minimum discharge was 5.18 m³ / sec in May (decade I) and the average discharge was 9.05 m³ / sec.

1. Introduction

The issue of clean water crisis as one of the impacts of climate change has long been discussed. However, the depiction of our water conditions is even more disappointing. Relatively, as the human population increases, the availability of clean water decreases due to the increasing need for water. The most perceived impact due to climate change is climate anomaly. This phenomenon causes the duration of the rainy season shorter with the increasing intensity and the dry season lasts longer than usual conditions [1].

Climate change is a global phenomenon that has had a significant impact lately. The characteristics of the phenomenon of climate change occur globally including the average water vapor and projected rainfall. Moreover, the most visible feature of climate change recently is global warming causing the ice at the north and south poles to melt and resulting in rising sea levels [2]. The impact of climate change is the water crisis and flooding. The residents may need more clean water since the availability remains low. More importantly, clean water is a highly valuable component of their daily needs [3]. Water availability is an important issue related to climate change. Water issues occur because of an increase in the population of the earth, thereby increasing the water demand [4]. Increasing needs will further depress global water systems related to the effects of global warming. The rise in population and economy is the main driver of water demand; meanwhile, its availability is affected by the augmentation in evaporation due to an increase of the earth surface temperature [5].

Climate Change is an event that changes the elements of climate in a very long time. It needs long-term climate element data to observe climate change for at least 20 years lately.

In the long term, climate change has the potential to affect water availability [6]. Climate change itself is a long-term process that will change climate elements such as air temperature, rainfall, and air pressure. The First Assessment report from the City Climate Change Research network states that climate change affected water. Based on the literature studies, groundwater balance was influenced by water availability, precipitation, and evapotranspiration. Therefore, rainfall data are needed as a supporting factor.

People who live in coastal areas generally feel the greatest impact. Groundwater will decrease accompanied by rising sea levels. That triggers seawater intrusion into the mainland and polluting water sources for daily use and irrigation [7]. In a journal with a case study in West Bank, Palestine, groundwater was the main water source with a per capita water supply of around 63 m^3. The increase in air temperature was related to the decrease in precipitation and groundwater discharge in the West Bank [8].

In addition to air temperature, an increase in population will also affect the increased demand for water. Increasing the value of evapotranspiration, changes in groundwater recharge and changes in water demand are estimated to be factors that influence changes in climate towards water availability. Many previous studies stated climate change would increase temperatures and harmed water availability [9]. The increase in air temperature due to global warming in climate change causes more rapid evaporation so that groundwater decreases faster.

Aspects of climate change include modification in temperature, changes in rainfall patterns, and extreme weather phenomena such as drought and floods. Specifically, the climate shows significant changes. This is evidenced by changes in average temperature and changes for patterns of extreme weather intensity such as drought and floods [10].

2. Method

The Kelangkangan watershed is in the Galang District, Tolitoli Regency. The river originates in the villages of Malangga and Kinapasan with 7 tributaries, which then merge into the Kalangkangan River. Some villages in the Kalangkangan watershed are Lalos Village, Tende Village, Tinigi Village, Kalangkangan Village, Lantapan Village, Lakatan Village, Malangga Village, Kinapasan Village, and Ogomoli Village. Water availability was calculated using the MockWyn-UB method by entering monthly rainfall data and other physical parameters, which also occurred monthly in nature. Hence, it produced a monthly flow simulation discharge. This model used 4 (four) parameters, namely: soil storage (SS), soil moisture capacity (SMC), infiltration coefficient (I), and groundwater flow coefficient (k). The MockWyn-UB model included climate change, canopy interception, rainfall distribution based on land use, soil type and soil characteristics.

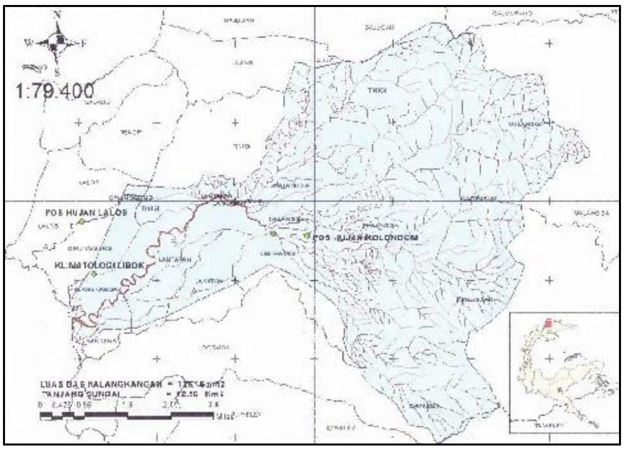

Fig 1. Kalangkangan Watershed

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3. Results and Discussion

3.1 Canopy Interception

The process of analyzing water loss due to interception in the canopy used Dunne and Leopold's research study, as depicted in Figure 4. for forest plants. The calculation of the interception of mixed garden plants applied < 5% of forest plants. Next, a linear regression equation was made between the amount of annual rainfall and rainwater falling to the ground surface by dripping and propagating on plant stems as in Figure 2 and Figure 3. The results obtained indicate that :

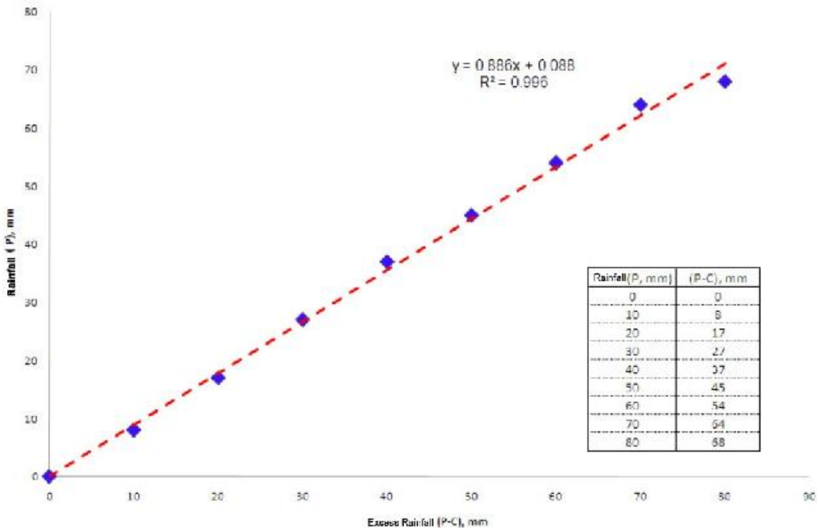

Fig 2. The Relationship Between Mean Rainfall In The Watershed And Excess Rainfall In Forest Plants

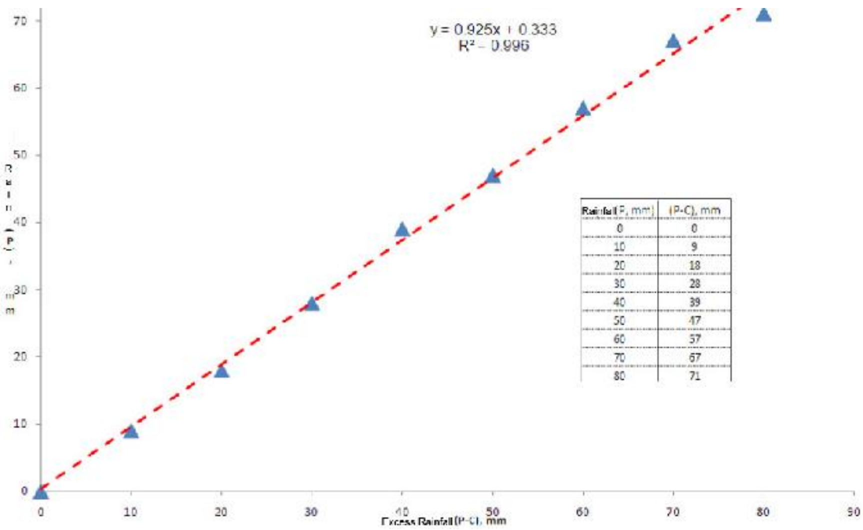

Fig 3. The Relationship Between Mean Rainfall In The Watershed And Excess Rainfall In Mixed Garden Plants.

Table 1. Area of land covers in the Kalangkangan sub-watershed

No	Year	Forest Area (km^2)	Fixed garden area (km^2)	Open land area (km^2)	Total area (km^2)
1	2011	75.78	27.81	24.57	128.16
2	2017	72.33	30.66	25.17	128.16

3.3 Excess Rainfall

Excess rainfall is based on monthly average rainfall data, the area of the Kalangkangan watershed, land cover maps, and canopy interception. Here is the example of the calculation of excess rainfall in January of 2009:

- Monthly average rainfall (PDAS) : 572.00 mm
- Watershed Area (LDAS) : 128.16 km2
- Forest land area (LLH) : 72.33 km2
- Mixed plantation area (LKC) : 30.66 km2
- Open land area (LLT) : 25.17 km2

1. Rain on forest land (PLH) = (LLH / LDAS) x PDAS = (72.33/128.16) x 572.00 = 268.98 mm
2. Rain in mixed gardens (PKC) = (LKC / LDAS) x PDAS = (30.66/128.16) x 572.00 = 114.02 mm
3. Rain on open land (PLT) = (LLT / LDAS) x PDAS = (25.17/128.16) x 572 = 93.60 mm
4. Excess rain on forest land (PNLH)= 0,886 PLH + 0,088 = (0,886 x 268,98) + 0,088 =238,40 mm
5. Excess rain in mixed gardens (PNKC) = 0,925 PKC + 0,333 = (0,925 x 114.02) + 0,333 =105.80 mm
6. Total excess rain (TPN) = PNLH + PNKC + PLT = 238,40 + 105,80 + 93,60= 437.80 mm

In the same way, it can calculate excess rain for other months and years.

3.4 Groundwater Content

Measurement of soil water content utilized soil samples for surface layers, root layers, and soil moisture. Soil sampling was conducted in three locations namely representing land cover in the form of dry fields & mixed gardens (test pit 1, TP1), the right mountain slope of the watershed in the form of forest (test pit 2, TP2) and the left slope of the mountain in the form of forest (pit test 3, TP3). In total, undisturbed soil samples were 9 (nine) samples. Each soil sample was analyzed in a laboratory to check the soil moisture content. The results were then used as input to the research model as well as initial soil storage. Laboratory analysis results for the nine soil samples. Initial groundwater content was calculated based on a comparison of the amount of rainfall from the available initial data (2007) to the start of the research model (2009) with the amount of rainfall from the initial data (2007). The data was then multiplied by the thickness of the soil water content in each soil layer. If written in mathematics, the results are as follows equation (1):

$$\text{Initial deposit} = \frac{C.H.of.2017 + C.H.of.2018}{C.H.2008 + C.H..2017} \text{ X thickness of soil water content} \quad (1)$$

Rainfall data for 2007 and 2008 were 5768.8 mm. Rainfall data for 2008 to December 2017 were 21506.07 mm. So, the initial deposit of groundwater content for the calculation of the 2010 research model was (5768.8 / 21506.07) x 283.57 = 37.64 mm. Deposits of maximum soil water content in the research model were determined based on the pore percentage and water content in the composition of the soil volume that was 40% - 60%; in this case, 40% of the composition of the soil determined.

3.5 Simulation Model Of Water Availability In The Kalangkangan Watershed

Land use-map data, rainfall data-processing results, potential evapotranspiration, soil moisture content, and maximum soil moisture were used as input data for the research model. The recapitulation of input data for the research model is as follows:

1. Watershed area based on the land use
2. Average monthly rainfall starting in 2009 - 2017
3. Potential evapotranspiration began in 2009 - 2017; processed from climatology data using CropWat 8 software
4. The initial groundwater deposit for the initial calculation of the research model (in 2009) was 37.64 mm
5. Maximum soil moisture was 351.55 mm

Based on the data for the research model input, monthly simulation river flow can be calculated. Below is an example of calculation of river discharge simulation on a MockWyn-UB model in January 2009.

Table 2. Calculation of the 2009-2017 water discharge in Kalangkangan watershed

	Jan		Feb		Mar		Apr		May		Jun		Jul		Aug		Sep		Oct		Nov		Dec	
	I	II	I	II	I	II	I	II	I	II	I	II	I	II	I	II	I	II	I	II	I	II	I	II
Q20	14.20	13.03	11.67	9.31	11.58	9.89	13.71	10.23	8.31	14.44	20.62	18.53	18.29	6.92	8.47	7.01	10.89	18.07	18.57	19.33	18.69	15.12	13.39	15.81
Q50	12.68	12.54	11.39	8.70	11.39	7.04	10.23	8.93	5.35	14.07	19.47	18.53	14.23	6.92	8.08	6.68	10.49	7.69	6.52	13.70	14.18	14.44	11.78	12.03
Q80	11.75	12.20	9.62	7.30	10.49	7.04	8.77	8.93	5.18	7.57	19.19	6.44	8.90	6.90	7.06	6.35	7.95	5.74	6.34	9.44	10.35	12.22	11.07	10.49
Q95	5.04	4.62	4.47	4.88	4.47	2.74	3.94	4.25	2.94	2.46	2.29	2.21	2.26	2.23	2.32	2.31	2.32	2.36	2.31	2.47	2.07	2.12	2.14	2.14

4. Conclusion

The availability of water from the rain-discharge simulation model in the Kalangkangan watershed for wet conditions (Q20%) is at maximum discharge of 20.62 m^3 / sec in June (decade II), and an average discharge of 13.59 m^3 / sec. For normal conditions (Q50%), the maximum discharge is 19.47 m^3 / sec in June (decade I), the minimum discharge is 5.35 m^3 / sec in June (decade I) and the average discharge is 11.13 m^3 / sec. For dry conditions (Q80%) the minimum discharge is 5.18 m^3 / sec in May (decade I) and the average discharge is 9.05 m^3 / sec.

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