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Modeling of Climate Change Impact on Water Availability in Metropolitan Mamminasata, Indonesia

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Modeling of Climate Change Impact on Water Availability in Metropolitan Mamminasata, Indonesia

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Abstract. Metropolitan Mamminasata is a National Strategic Area in South Sulawesi Province, Indonesia enacted based on Presidential Regulation Number 55 of 2011 on the spatial plan of Makassar, Maros, Sungguminasa, and Takalar urban areas. The development of these areas as central urban areas makes these areas are very prone to issues of water resilient. Eleven watersheds are affecting the water system in these areas: Jeneberang, Tallo, Maros, Bonelengga, Tabaringan, Lepa-Lepa, Paleko, Saro, Galesong, Pamukkulu, and Cikoang watersheds. The impact of climate change coincides with the change of land use affecting the availability of water in the area. Therefore, this study was conducted to find out the impact of climate change and land use on the availability of water at watersheds affecting the Metropolitan Mamminasata areas. The analysis was done by using Soil model and Water Assessment Tools (SWAT software). The data on climate was analyzed by using data on global weather climate of the 1987-1996 period (past condition) and 2004-2013 period (actual condition) and climate change projection of the 2035s period using RCP 4.5 Model CSIRO Mk3.6.0. Moreover, the data on land use analyzed was of 1996 and 2015. The results of the study indicate that land use in the study area had changed a lot from 1996 to 2015. This change decreased total forest area in watersheds in Metropolitan Mamminasata around 2,000 hectares (42,803.02 ha become 40,815.85 ha) and improved established areas such as settlement, agriculture, mining, and paddy field to 84,79% of the total watershed areas. The change of land cover has an interesting interaction with the climate change condition especially related to the availability of water in the study area. The SWAT model results explain the availability of water in 1987-1996 period as much as 1,682.55 million m3/year and in the 2004-2013 period decreased as much as 11.2% that is 1,485.30 million m3/year. The results of future water availability in the period of 2035s projected total potential water increased, but the potential increased in the wet month and decreased significantly in dry months, comparing to the actual condition of availability of water. This condition illustrates the change of land use, and climate contributes to the level of the quantity of water availability in several watersheds in Metropolitan Mamminasata. The planning of land use in the spatial plan is necessary to be applied so that the continuity of water availability is sustained every year to satisfy the need for water to fellow the increasing number of communities.

Keyword: Climate change, land use change, SWAT Model, water availability

1. Introduction

The natural resource is needed in the development of the area to satisfy the need of various human activities. One of the natural resources always needed and limiting factor in development is water. One side water is needed in area development, and on the other side, the development itself can damage the natural resource if it is done without paying attention to the environment. The potential for clean water availability decreases from year to year almost all over Indonesia. The decrease of water availability is assumed due to the degradation of carrying capacity of the watershed by deforestation, especially at the upstream. The other factor causing the decrease of clean water availability is environmental pollution as a byproduct of development resulting in the decrease of carrying capacity of watersheds [1]. This phenomenon also occurs in South Sulawesi including Metropolitan Mamminasata (Makassar, Maros, Sungguminasa, and Takalar).

1.1. Metropolitan Mamminasata

Metropolitan Mamminasata, as is reflected from its name, is an area of an urban characteristic of which the area consists of Makassar city and Maros, Gowa, and Takalar regencies. However, Gowa regency is only represented by Sungguminasa. Mamminasata urban area was established based on the Decree of South Sulawesi Province Governor in 2003 in the area of 246,230 ha. Metropolitan Mamminasata was inaugurated as National Strategic Area and enacted through the Government Regulation Number 26 of 2008 on National Area Spatial Plan. The location of Metropolitan Mamminasata can be seen in Figure 1.

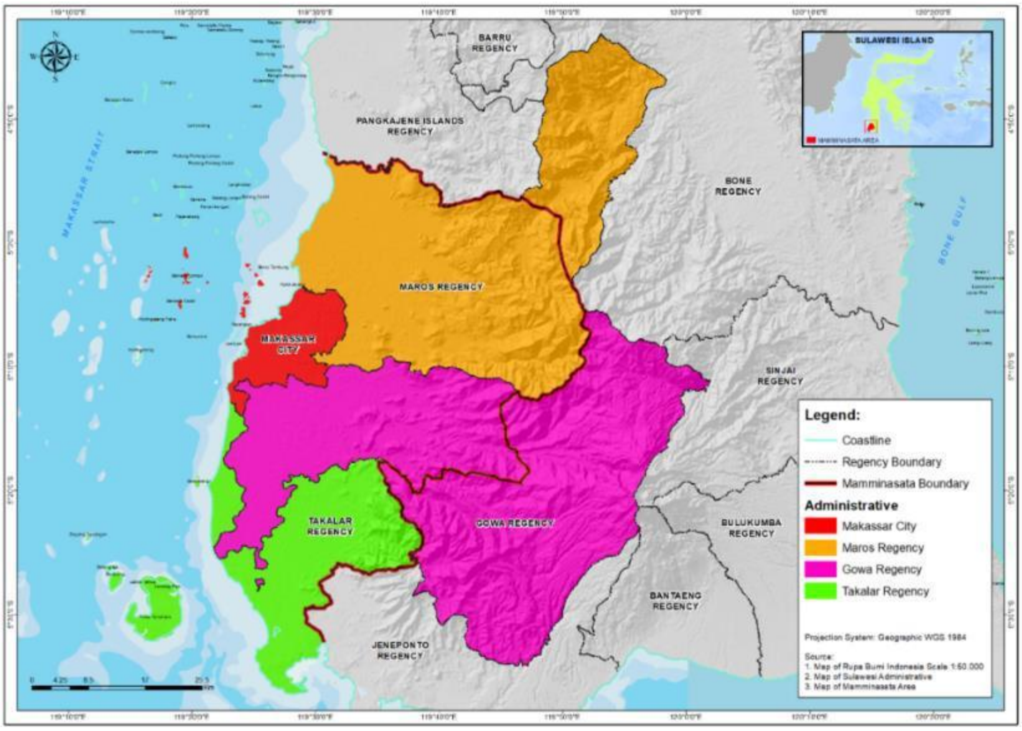

Figure 1. Map of Metropolitan Mamminasata and Its Established Regencies and Towns

Nationally, the national strategic area has a significant impact on state sovereignty, defense, and security, economy, social, culture, and environment including areas in it set up as world heritage. Mamminasata urban area is an area established due to the rapid development of Makassar town causing agglomeration with the other three principal towns. In general Makassar, town dominates all activities in Mamminasata urban area. Makassar town also develops now as a gate of development in Eastern Part of Indonesia is a representation of Mamminasata urban area.

Mamminasata vision is the realization of the urban area with the green urban program, comfort, beautiful, and hygienic which can bring in investors and can be equalized with metropolitan towns in the world as a prominent and foremost metropolitan area in the Eastern Part of Indonesia which has the universal concept and based on local wisdom. To realize the vision and goal of the Mamminasata national strategic area, so spatial plan for Mamminasata urban area is necessary as stipulated in

Presidential Regulation Number 55 of 2011. More detailed policies are necessary to reach the goal of the establishment of urban Metropolitan Mamminasata. They are:

1. Development of economy, social, culture, defense and security, and environmental conservation as a unity.
2. Development of Mamminasata urban area as a central orientation for international scale services and main motivator for Eastern Part of Indonesia.
3. Development of Mamminasata urban area as a center for growth and process of products of core urban area development and urban areas around it, and
4. Improvement of accessibility between areas and dissemination of service area.
5. To realize all the things that have been mentioned above, the support of sufficient water resource is necessary.

1.2. Water Crisis and Development

The indication of problem-related to water resource in Mamminasata has been noticed today. It is stated in Presidential Regulation Number 55 of 2011 article 40, Mamminasata area is integrated with network system of the water resource to guarantee the availability of clean water from the Jeneberang River, the Maros River, the Tallo River, the Pappa River, and the Gamanti River. Areas set up to be Metropolitan Mamminasata do not match fully with watersheds of the five rivers. Therefore, the available water resources for Metropolitan Mamminasata are not only affected by the development in this area, but also by the upstream condition of the five watersheds of which the development was based on the spatial plan of Maros, Gowa, and Takalar regencies.

The conditions as illustrated above cause conflict of interests, for example, between the need for drinking water and industry in Mamminasata and the need for agriculture in the three regencies. Besides that, flood in the downstream is also affected by the interest of development in the upstream of the five watersheds. The management of water resource will always be confronted with limited water availability and the increase of water need. Soil and Water Assessment Tools (SWAT) model is one of the tools that can be used in the management of water resources in Metropolitan Mamminasata. Moreover, many models for measuring water resources such as those developed by Li using the artificial neural networks [2] but the SWAT model can describe the condition of the water resources of a very complex region to be simple.

1.3. Water Crisis and Development

The availability of water in Metropolitan Mamminasata is not only affected by development in the area itself and watershed areas outside the area, but also by climate change. SWAT model can also be used to know the impact of climate change on the availability of water in Metropolitan Mamminasata.

There is strong scientific evidence about the existence of global warming and the potential of climate change system in various areas in the future. The climate affects all aspects of life including the availability of water so that it is vital to understand the variety of climate at present and in the future and its impact on water resources. Therefore, the government and community can anticipate the change. CSIRO report in 2012 provides various information on climate change in Mamminasata areas as follows [3]:

1. Based on data, there is strong evidence of the annual increase of average temperature as much as 0.27^0C per decade. Data on rain since 1950 indicate the tendency of rain decrease in the dry season.
2. Climate simulation in South Sulawesi area indicates that the increased temperature in Makassar will go on as much as $0.29\text{-}0.39^0$C per decade. Potential evaporation is projected to increase around 12%.
3. Projection of rain is uncertain, but most of the climate model identifies the decrease of rainfall in Makassar area in the future. The beginning of the wet season is thought to be unchanged but the end of the coming season will be earlier so that wet season is assumed to be shorter 12 days.
4. If the infrastructure in the future is similar to that in 2010, the lack of water will be familiar from 2020 especially for areas having water treatment installation from Somba Opu and Pannaikang.

About previous study results, understanding related to the impact of climate change on the availability of water in Metropolitan Mamminasata is necessary. CSIRO study results with Hasanuddin University recommend broadening the study of water resilient in the future to all Mamminasata area.

2. Research Methodology

2.1. Study Area

Area of Mamminasata is a part of several watersheds in the five management areas of the watershed in Mamminasata areas. They are namely management area of Jeneberang watershed comprises Jeneberang watershed, Tallo watershed management area, comprises Tallo watershed, Maros watershed management area comprises Maros and Bonelengga watersheds, Papa watershed management area comprises Pamukkulu and Cikoang watersheds, and Gamanti watershed management area comprises Tabaringan, Lepa-Lepa, Paleko, Sarod, and Galesong watersheds. The total watershed area is 283.594.77 ha. Administratively, the upstream and downstream areas in Mamminasata are in 4 regencies and 1 (one) town: Makassar, Maros, Gowa, Takalar, and Jeneponto. The relationship between Metropolitan Mamminasata boundary and its affecting watersheds can be seen in Figure 2.

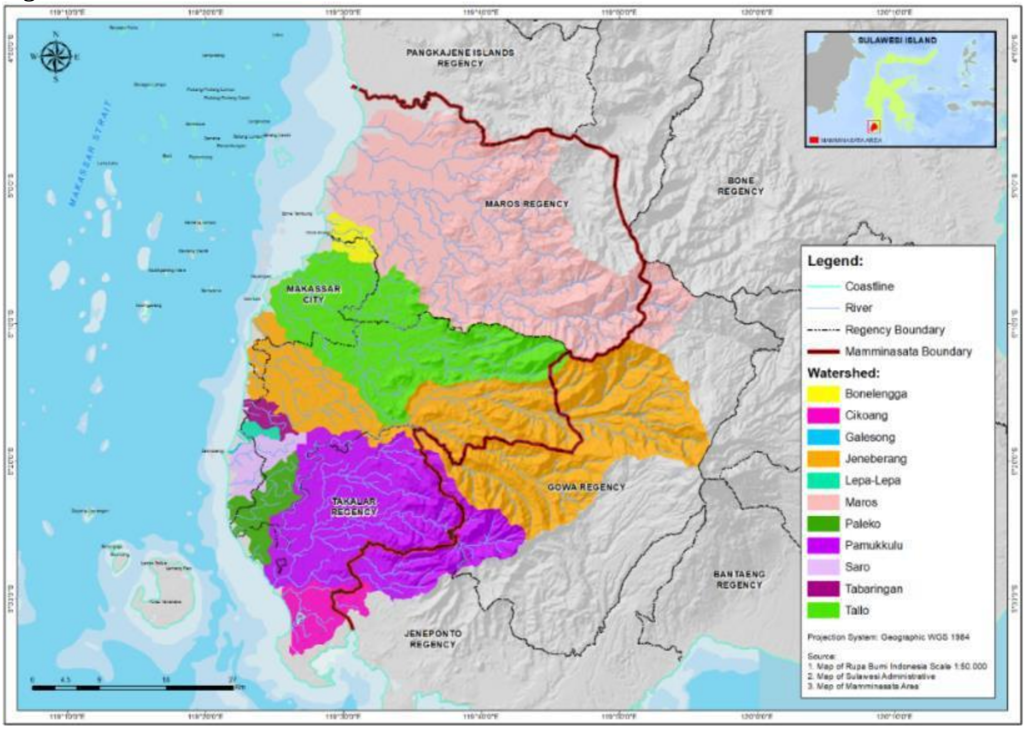

Figure 2. Watershed Boundaries and Metropolitan Mamminasata Areas

2.2. Data Acquisition for the SWAT Model

The model used in simulating this study was SWAT model to illustrate only the hydrologic conditions of watersheds affecting water resilience in Metropolitan Mamminasata, several inputs of data to be analyzed classified into spatial data and textual data. The data prepared in SWAT model simulation are:

1. Data on digital elevation model (DEM) made by GIS Interpolation Topo to Raster approach using shapefile data of study boundaries (5 watersheds), shapefile contour data with interval 10 meters extracted from data on ASTER DEM resolution 30 meters (http://gdex.cr.usqs.gov/gdex/) river network shapefile data from Indonesia Earth Shape (Rupa Bumi Indonesia) map. http://portal.ina.sdi.or.id/) and shapefile data of elevation point from Indonesia Earth Shape map.

2. Shapefile data of land cover of 1996 and of 2015 obtained from land cover data of time series from Ministry of Forestry and land cover data of Landsat 7 and 8 images interpretation results made with scale accuracy 1:50,000 and then the data were exported to become Raster format data for the SWAT model simulation need.
3. Shapefile data of land type from RePPProT (Regional Physical Planning Project for Transmigration) Map equipped with physical parameter and soil chemistry was obtained from database information of RePPProT Map and Web Soil USDA Natural Resource Conservation Service. Data of this land type then was export to Raster format data.
4. Data on daily global climate was obtained from Global Weather data (http://global weather.tamu.edu/) of 1987-1966 period (past time period) and of 2004-2013 period (actual time period) comprising data on daily rainfall (mm), daily air temperature (0C), air humidity (fraction), solar radiation (MJ/m2) and wind velocity (m/s).

2.3. Processing SWAT Model

Soil and Water Assessment Tool or SWAT Model is one of the models that can be used to predict the effect of land use on surface flow, lateral flow, groundwater flow, water availability, erosion, sediment, pesticide content, and agricultural yield chemistry enter the river or water body in a watershed. At SWAT model a response unit/hydrologic response or HRU (hydrologic response unit) as the smallest analysis unit is an overlay of the land cover map (land use), soil map specified with physical information and soil chemistry, and slope class map. The collection of adjacent HRU forms sub-watershed, and the combination of the sub-watershed is watershed. In general, the analysis was done both at the sub-watershed level and the watershed level.

The time series of the land cover map from 1996 to 2015 (20-year period) was obtained from interpretation of Landsat 7 and 8 and was validated through ground check. Land use map was fitted with database naming of land use of SWAT model. Land cover classification/land use which was used in the model can be seen in Table 1.

Table 1. Land Cover/Land Use Classification

No.	Land Cover/Land Use Class	SWAT Class	SWAT Code
1	Dryland Primary Forest	Forest-Mixed	FRST
2	Dryland Secondary Forest	Forest-Mixed	FRST
3	Secondary Mangrove Forest	Wetlands-Forested	WETF
4	Plantation Forest	Forest-Evergreen	FRSE
5	Dry Land Agriculture	Agriculture Land-Generic	AGRL
6	Mixed Dryland Agriculture with Shrubs	Agriculture Land-Generic	AGRL
7	Paddy Fields	Rice	RICE
8	Estate	Orchard	ORCD
9	Bushes	Range-Brush	RNGB
10	Wetlands Bushes	Wetlands-Mixed	WETL
11	Pasture	Pasture	PAST
12	Bare Land	Oak	OAK
13	Mines	Oak	OAK
14	Brackish Pond	Water	WATR
15	Water	Water	WATR
16	Settlement	Residential	URBN
17	Airport/Seaport	Transportation	UTRN

Soil map consist of soil data in the SWAT model are soil type, physical parameter and soil chemistry comprising the amount of soil layer, soil hydrologic group, depth of plant root, soil texture class, soil thickness, soil content weight, available water content, content of soil organic material, and content of sand, clay and dust, and rock content, soil albedo value, soil erodibility value, calcium carbonate and pH. Analysis to obtain the input of soil data parameter was done to comply with the SWAT parameter input needed. The analysis approach used was by extracting soil information from RePPProT map. The results of soil data analysis for watersheds in Metropolitan Mamminasata can be correlated later with user soil data which has been added to the SWAT model.

Slope class map was obtained from DEM analysis used in the formation of watershed boundaries and their network rivers. Slope class classification used can be seen in Table 2.

Table 2. Slope classes Used in SWAT Model

No.	Slope (%)	Explanation
1	0% - 8%	Flat
2	8% - 15%	Gently Sloping
3	15% - 25%	Undulating
4	25% - 45%	Rather Steep
5	> 45%	Steep

Hydrologic response unit produced from the overlay process was then combined with climate information in textual format. Climate data input in SWAT was daily rainfall (mm), daily maximum and minimum air temperature (0C), daily solar radiation (MJ/m2/day), daily air humidity (fraction), and wind velocity (m/s). The data was collected in PCP, TMP, SOLAR, RH, and WIND files with extension.txt. To doing verification on model simulation result, Water discharge data was used in txt format obtained from the Pompengan River Agency (Technical unit of Ministry of Public Works).

2.4. Working Mechanism

The working mechanism in the analysis of water availability in Mamminasata was done by simulation model which was able to illustrate phenomena and hydrologic characteristic of the watershed by paying attention to aspects of climate, soil, topography, river characteristic, and land cover. Stages in the simulation model consist of three working stages: (1) input parameter, (2) process running model, and (3) definition of output simulation model related to water availability analysis (Figure 3).

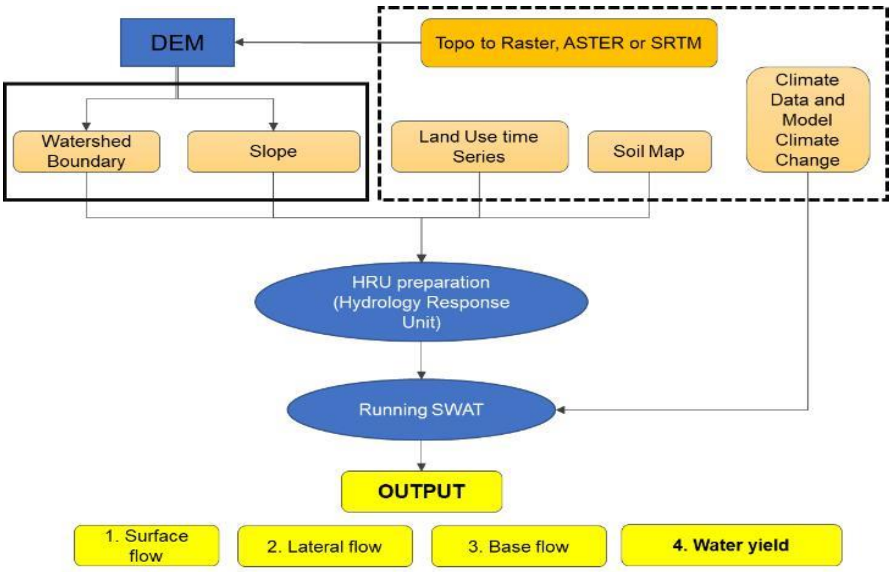

Figure 3. Working Mechanism in Water Availability Using SWAT Model

SWAT output model in each watershed affecting Metropolitan Mamminasata will produce data on water availability in 1987-1996 periods (past) and 2004-2013 periods (actual). Then this output was analyzed its change to obtain data on water availability in the 2035s period (future) related to climate change. The analysis of water availability is a stage to define output produced from the SWAT simulation model [4]. In the SWAT model, the water availability was termed water yield obtained in the watershed with the millimeter (mm) unit. The water yield was obtained from the following formula:

$$WYLD= SURQ+LATQ+GWQ-TLOSS\text{-pond abstractions}$$

In which:
WYLD: Effective amount of water available in the watershed (mm)
SURQ: Amount of surface flow reaching the main river (mm)
LATQ: Amount of water flow laterally under the surface contributed to the river discharge (mm)
GWQ: Amount of water flow at aquifer contributed to the river discharge (mm)
TLOSS: Total loss of water to the aquifer (mm)

2.5. Climate Change Scenario

Projection analysis of climate change in Metropolitan Mamminasata was done with the help of software Statistical Bias Correction for Climate Scenarios (SiBiaS) version 1.1. SiBiaS is software used to ease the use of GCM CMIP5 output data and the process of its bias correction. The statistic bias correction technique in this program consists of two choices that are by using the delta method and distribution correction method. Delta method was used in this study. Delta method is the simplest downscaling method and usually are used in the preparation of climate change scenario for local scale study. Delta method is a bias correction process through addition or multiplication approach of Δμta value and observation value at baseline period as in the following equation model:

$$X_{cor,i} = X_{o,i} + {}_{p} - {}_{b}$$

$$X_{cor,i} = X_{o,i} \times \frac{{}_{p}}{{}_{b}}$$

Xcor, i value is corrected model value and X0, i is observation value at baseline period. μ is the average value in which b and peach indicate simulation data of baseline period and projection of the model. Equation (2) is used for data on temperature, whereas equation (3) is used for rainfall data correction [5].

3. Result and Discussion

3.1. Landuse and Climate Change Analysis

3.1.1. Land Cover/Land Use Change. Intensive changes of the land function at the administrative region in which the 11 watersheds exist have an impact on the imbalance of the hydrologic system of the watershed in Metropolitan Mamminasata. The imbalance can be seen by the decrease of water availability in Mamminasata areas today. The analysis of the 1996 period to 2015 period indicates that in Mamminasata areas there have been changed of land function from forest to non-forest show an active area for agriculture compared to permanent vegetation land. The specification of land change in Mamminasata watershed areas is presented in Table 3, and the visualization of land cover change in Mamminasata watershed areas can be seen in the following Figure 4.

Table 3. Land Use Change in Mamminasata Watershed Areas for the 1996-2015 Periods

Land use	**Area on 1996**		**Area on 2015**		**The rate of Change (Ha)**
	(Ha)	**(%)**	**(Ha)**	**(%)**	
Primary Dryland Forest	34,360.86	12.12%	151.14	0.05%	-34,209.72
Secondary Dryland Forest	5,118.66	1.80%	36,805.46	12.98%	+31,686.80
Secondary Mangrove Forest	327.20	0.12%	226.03	0.08%	-101.16
Plantation Forest	2,996.30	1.06%	3,633.21	1.28%	+636.91
Pasture	3,417.75	1.21%	666.01	0.23%	-2,751.74
Settlement	7,887.14	2.78%	14,272.32	5.03%	+6,385.18
Mines	0	0.00%	206.84	0.07%	+206.84
Dryland Agriculture	1,185.83	0.42%	34,276.14	12.09%	+33,090.31
Dryland Agriculture with Shrubs	28,236.16	9.96%	82,755.40	29.18%	+54,519.23
Paddy Field	76,079.74	26.83%	73,610.59	25.96%	-2,469.15
Bushes	102,941.70	36.30%	21,562.10	7.60%	-81,379.60
Wetland Bushes	643.36	0.23%	41.33	0.01%	-602.03
Brackish Pond	9,532.93	3.36%	9,793.49	3.45%	+260.57
Bare Land	3,193.97	1.13%	744.94	0.26%	-2,449.03
Water	3,245.97	1.14%	4,161.61	1.47%	+915.64
Airport/Seaport	246.97	0.09%	688.15	0.24%	+441.17
Cloud	4,180.22	1.47%	0	0.00%	-4,180.22
Total	**283,594.77**	**100.00%**	**283,594.77**	**100.00%**	

The total change of forest area in Mamminasata watershed areas decreases around 2,000 ha (42,803.02 ha to 40,815.85 ha); whereas, the established areas such as settlement, agriculture, mining, and paddy field increase to 84.79% of the total watershed areas. The visualization of land condition in Mamminasata areas for the 1996-2005 periods is presented in Figure 4. The process of land change is caused by the human factor in which most of the land cover is converted into settlements and dryland farming [6]. It is due to the increasing population from year to year and the movement of the population from the village to the urban areas. As a result, land conversion for settlements and agriculture is inevitable where it has become the most significant income population in Mamminasata. Changes in land use from vegetated lands to built-up areas occur almost in all watersheds in the world along with increased human activity in the region. The results of the study by Butt et al. in Simle Watershed, Pakistan with an area of 5,000 ha has shown that from the analysis of the period 1992-2012 there has been a decline of forests and agricultural land into residential land respectively by 38.2% and 74.3% [7]. Land use monitoring in Oben Area, Niger River, Nigeria provide an overview of the high change of land use in some of the world's watersheds with the conversion of protected forests into industrialized areas within 28 years (1987-2015) [8]. Community activities cause most of the problems of land use change in watersheds in the world. Therefore, appropriate land use planning for the development of effective strategies in sustainable watershed is required [9]. Where in the planning of land use requires appropriate consideration through the analysis of spatial information so that that land use can be optimal [10].

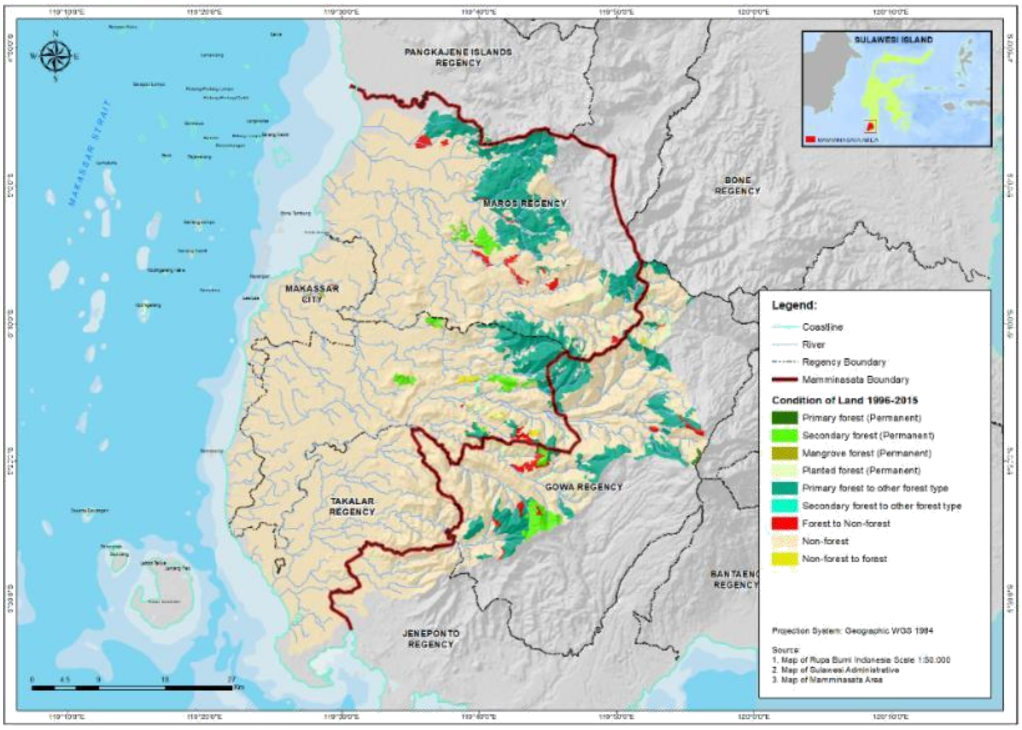

Figure 4. Map of Land Use Change in Mamminasata Watershed Areas for the 1996-2015 Periods

Study of land use change is often used in assessing hydrological responses in some watersheds especially in areas with rapid population growth. Land use is vital in a hydrological analysis because of its impact on population growth and economic growth and because of its role as a manageable watershed component. The results of the study by Nie et al. obtained information that the transformation of land use into residential areas during the 1973, 1986, 1992 and 1997 periods in the San Pedro Watershed, Arizona has reduced the flow of groundwater, resulting in a decrease in water availability in the region [11]. Land conversion in the catchment area also leads to an increase in runoff index, as well as increased flow concentration time. The change in the water system, causing phenomena with negative impacts on communities such as high intensity of floods and drought [12,13,14,15,16], as happened today in Mamminasata.

3.1.2. Climate Change

The impact due to climate change is something to be put into the account in the development of an area due to the impact of the condition such as improvement of hydrometeorology disaster is a barrier in the development of the area. Based on Global Weather data, there are eight climate stations used in analyzing climate change in Metropolitan Mamminasata (Figure 5). The Global Weather data is a baseline in analyzing climate change in Metropolitan Mamminasata areas. The scenario of climate change used was scenario Representative Concentration Pathways (RCP) 4.5 with CSIRO MK3.6.0 model which is a scenario of moderate climate offered by IPCC AR 5 [17]. The observation period was in 1989 up to 2013 and simulation period of climate change used is of 2018 up to 2039. The average analysis of rainfall obtained from the study of climate change in Mamminasata areas can be seen in Figure 6.

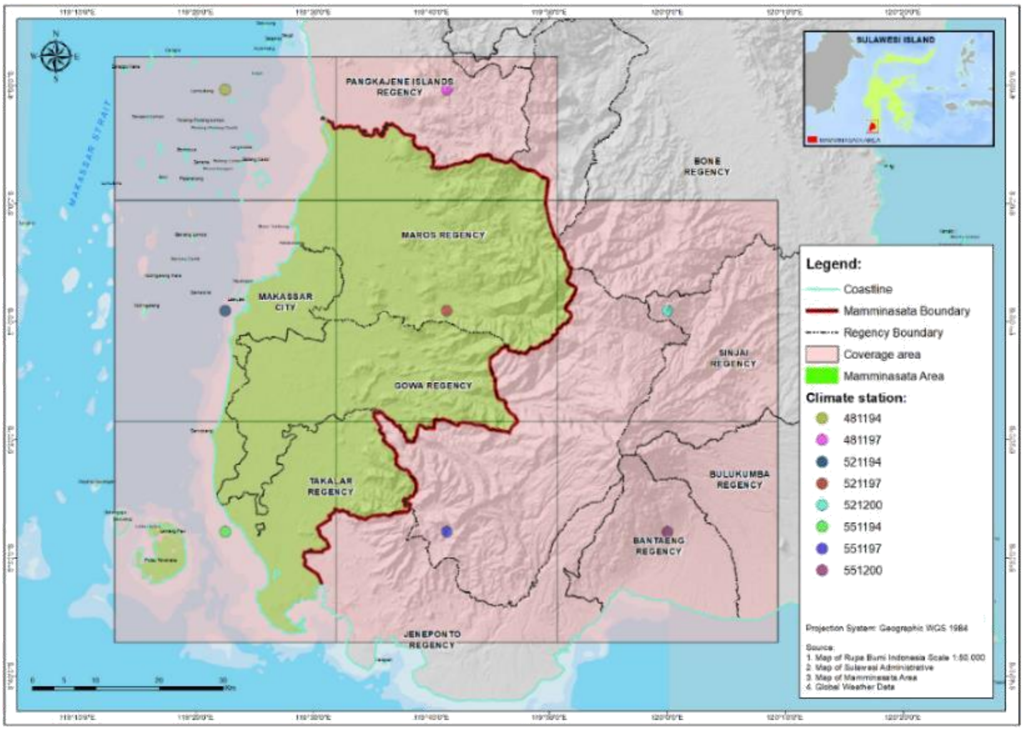

Figure 5. Global Weather Climate Station in Mamminasata Areas

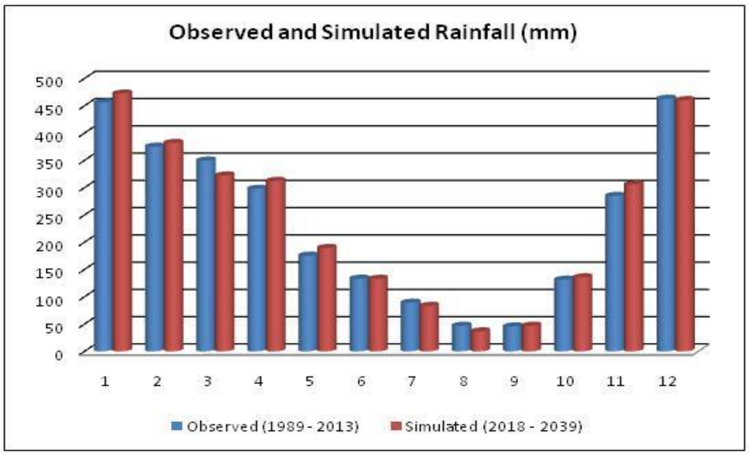

Figure 6. Average Rain Fall (mm) at Observation Period and Simulation Period

The results of CSIRO MK3.6.0 (Scenario RCP 4.5) climate model projected in the future is in the 2035s period of rainfall in Mamminasata areas at rainy season tends to increase and at dry season tends to decrease. The results of the analysis indicate that maximum increase of rainfall at rainy season is around 8 percent and the tendency for the decrease at dry season is around 22 percent. It indicates that in the future frequency and intensity of flood will increase more and more and the water supply will decrease more and more in Mamminasata areas. For the average temperature, it is known that in the future it tends to increase around 0.5-0.8^{0}C. The decrease of rainfall intensity in the future in Mamminasata areas corresponds to the study results of CSIRO Australia in 2012 in Makassar town in which by using six global climate models, namely CSIRO-MK3.5, GFDL 2.1, MPI-ECHAM5 and HADCM3 with analysis period of 1970 up to 2100. It is known that rainfall supply will decrease on the average around 36%, whereas the average annual temperature will increase as much as 0.29 to 0.39^{o}C per decade.

3.2. Water Availability Simulation

The cover land change from forest to agricultural land and established land and climate change condition is the occurrence of rainfall increase in the rainy season and decreases at dry season has an effect on the imbalance of water management system in Mamminasata areas. This condition is noticed by the decrease of water resource reserve in several water resource spots both declines in quantity and quality due to the land uses change in the upstream which increases land erosion, so that the dissolved sediment in water increases more and more. Based on the result of the analysis, it is indicated that from the past period to the present period water availability in Mamminasata areas decreases but for the future projection, total water availability will increase. However, the increase of water availability in the future show's affluence fluctuated availability in the rainy season and a decrease in the dry season. The results analysis of water availability in Mamminsata areas used SWAT model at 11 watersheds can be seen in Table 4.

Table 4. Water Availability in Mamminasata Areas

Month	Water Availability/Yield (million m^3/year)		
	Past Period (1987-1996)	**Actual Period (2004-2013)**	**Future Period (2035s)**
Jan	335.96	248.38	298.04
Feb	297.21	211.99	252.33
Mar	271.19	208.84	204.72
Apr	215.07	145.26	143.37
May	102.84	116.72	103.75
Jun	52.25	80.21	68.93
Jul	25.75	54.65	44.99
Aug	10.61	31.00	22.21
Sep	8.71	26.81	24.10
Oct	18.27	53.17	48.62
Nov	77.12	111.53	109.69
Dec	267.59	196.73	214.29
Total	**1,682.55**	**1,485.30**	**1,535.03**

Based on Table 4 above, it can be seen that total water availability at 11 watersheds decreases as much as11.2% from1,682.55 million m3/year at the 1987-1996 periods to 1,485.30 millionm3/year at the 2004 -2013 periods. However, the result of scenario in the future is predicted that water availability will increase if monthly analysis shows that in the specific month it increases around 20% (month of January) and decreases around 28% (month of August) from the present condition.

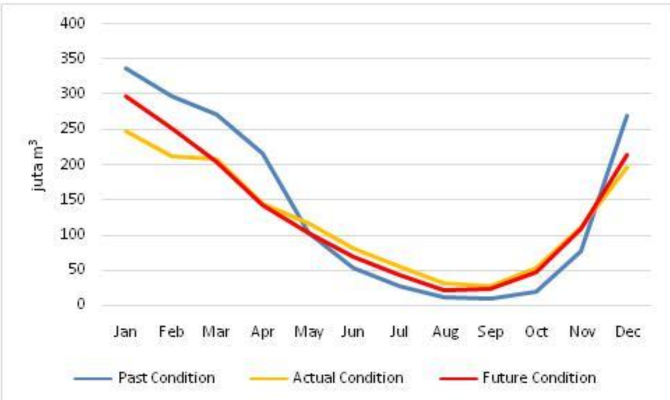

Figure 7. Water Availability Graph of 1987-1998 Period (past), 2004-2013 (present), and 2035s Period (future) in Mamminasata Watershed Areas

The comparison of water availability in each watershed of Mamminasata areas is presented in Table 5, and dynamic visualization of water availability in Mamminasata areas can be seen in Figures 8.

Table 5. Water Availability in Mamminasata Watershed Areas

Watershed	Water Availability/Yield (million m^3/year)		
	Past Period (1987-1996)	Actual Period (2004-2013)	Future Period (2035s)
Jeneberang	443.25	405.40	458.49
Tallo	302.40	254.96	254.06
Maros			
a. Maros	657.70	565.14	558.72
b. Bonelengga	8.49	7.78	7.84
Gamanti			
a. Tabaringan	12.26	11.07	11.14
b. Lepa-Lepa	6.12	5.52	5.10
c. Galesong	2.92	2.82	3.73
d. Saro	8.89	8,99	9.01
e. Paleko	12.12	11.38	11.40
Pappa			
a. Pamukkulu	178.20	159.48	162.45
b. Cikoang	50.21	52.76	53.07

The impact of vegetated land use change to established land was triggered by dynamic of climate causing several watersheds to decrease in water availability in the future such as Maros watershed, Tallo watershed, and Lepa-Lepa watershed. This decrease in water availability certainly has an impact on the fulfillment of water by the community live in the areas. Based on the actual condition in 2015, analysis of water need level in Mamminasata areas was 1,695.43 million m3. This need analysis was calculated based on SNI.6728.1 2015 on the preparation of spatial balance water resources [18]. The results detail can be seen in Table 6 below:

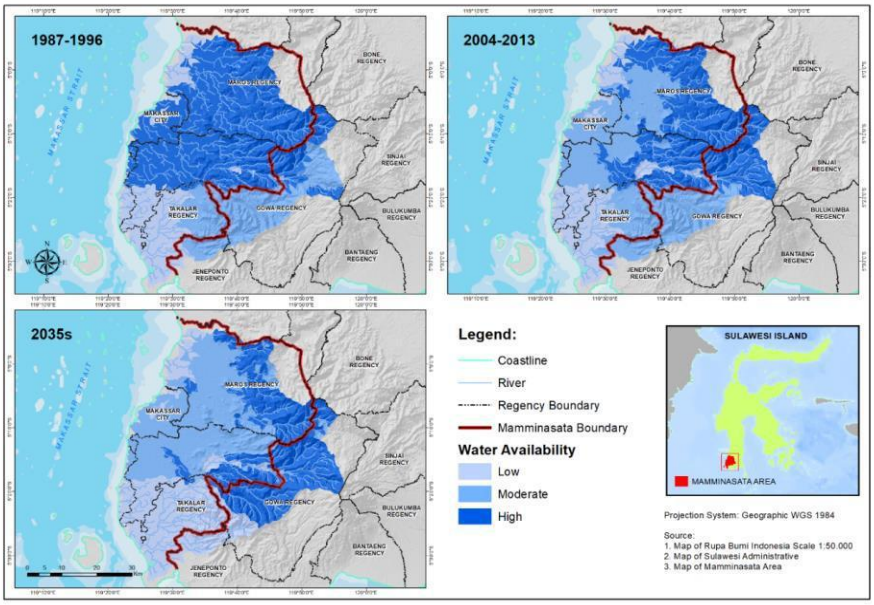

Figure 8. Map of Water Availability (Dark Blue Gradation: High; Light Blue Graduation: Low)

Table 6. Water Need Level in Mamminasata Areas in 2015

Regencies/City	Water Need (m^3)			
	Domestic	**Agriculture**	**Aquaculture**	**Total**
Makassar	59,162,782	275,787,556	448,831	335,399,169
Maros	13,333,623	45,765,181	107,062,301	166,161,105
Gowa	23,135,098	301,848,561	514,201,297	839,184,956
Takalar	12,021,777	238,529,629	104,134,287	354,685,693
Total	**107,653,280**	**861,930,927**	**725,846,715**	**1,695,430,923**

Total water needs in Mamminasata areas as shown in Table 6 if it is related to water availability at actual condition analysis indicates that Mamminasata areas are prone to water availability resources. This susceptibility can be seen from the relationship between water need and imbalanced water availability. The increase of population in the future is badly in need of water availability supply viewed from high water need at present, and it is certain that this area will lack water, although it is projected that in the future water availability will increase. However, the increase in water availability only occurs at rainy season, whereas it will decrease at dry season. The increase of water availability in the future illustrates that at the rainy season in Mamminasata areas have the affluence of water so that it is ascertained that in this condition water surface is high enough to cause flood overflow bigger and bigger. The surface flow analysis in all Mamminasata watershed areas used the SWAT model is presented in Figure 9 below:

Figure 9. Graph of Surface Flow of Mamminasata Watershed Areas between 2004-2013 (actual) Periods and 2035s Period (future)

4. Conclusions

Climate change both from CSIRO study results in 2012, and SWAT simulation model results have an impact on water resources in Metropolitan Mamminasata. Climate change does affect not only the change of amount and rainfall pattern but also the change of vegetation pattern. The climate change scenario in Metropolitan Mamminasata areas explains that the amount of water availability in the future per year will increase, but the dissemination pattern will change. The amount of water in the rainy season will increase, and it will decrease in the dry season. It indicates the increase of flood intensity in Metropolitan Mamminasata, especially in Makassar City and the lack of water availability in the dry season.

The management of water resources to support development in Metropolitan Mamminasata will be more complex, and it is assumed that development of dams is necessary to manage overflow of water in the rainy season and prepare water in dry season. Spatial plan which has been prepared accordingly for each regency/city and Metropolitan Mamminasata areas needs to be reviewed.

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