



Statistical Downscaling of Future Precipitation Scenarios for Agusan del Norte, Philippines

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Abstract

General circulation models (GCMs) are essential tools for understanding climate behavior and projecting future global climate, but with limited applications for local vulnerability assessments, impact studies, and risk analyses. This study demonstrated the use of the statistical downscaling technique, which is computationally inexpensive and efficient in generating locally relevant data from GCMs. The 30-year records of daily precipitation data from 1981 to 2010 in Agusan del Norte, Philippines were considered to analyze the existing climatic condition of the province. Future precipitation magnitude, centered on 2020 (2006-2035), 2050 (2036-2065), and 2080 (2066-2095), were generated using a statistical downscaling technique under A1B climate scenario. Based on the analyses of annual 24-hour and 48-hour maximum precipitation, climatic conditions for present and future scenarios were analyzed. Precipitations with 24-hour duration are expected to increase by about 2-18%, 6-19%, and 15-51% for the period 2020, 2050, and 2080, respectively. Meanwhile, rainfall with 48-hour duration is projected to increase by about 7-17%, 7-18%, and 16-51% for the period 2020, 2050, and 2080, respectively. Future precipitation scenarios can help stakeholders from different sectors in the province evaluate impacts and identify tradeoffs towards implementing the most appropriate climate change adaptation strategies.

Keywords: statistical downscaling · precipitation scenarios · climate change · Agusan del Norte · Philippines

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Introduction

The Intergovernmental Panel on Climate Change (IPCC, 2013) has released a report that presents robust and significant findings about the science of climate change at a global scale, thereby enhancing our understanding of the climate system. The climate data in the report were generated using the general circulation models (GCMs), a complex mathematical representation of the major climate system components describing climatic condition at a global or continental scale. These data can be used to develop various climate scenarios capable of informing different stakeholders about the likely impacts of future climate. However, climate information at the local scale is needed to prepare and plan for the anticipated impacts and risks of projected climate change (Trzaska & Schnarr, 2014). Local-scale climate information is required in conducting sectoral analysis, for instance in the areas of agricultural production, food security, human health, local economy, and many others (Wreford, Moran & Adger, 2010; Asian Development Bank [ADB], 2011; Nelson et al., 2009).

Several methods and technologies have been developed and used to derive climate data at the local scale from the data produced with coarser resolution. Downscaling technique is now widely used to simulate climate data for a specific locality from global scale climate information supplied by GCM. This technique, which can be applied to define climate spatially and temporally, consists of several steps, assumptions to be satisfied, limitations, and advantages (Trzaska & Schnarr, 2014; Wilby & Dawson, 2007).

Downscaling has two main approaches to generate locally-relevant data from GCMs: statistical downscaling and dynamic downscaling approaches. Dynamic downscaling is used to produce a higher resolution Regional Climate Model (RCM) within a coarser resolution GCM, thereby simulating local conditions in greater detail. This approach requires intensive computing skills and high volume of data inputs to be able to generate local surface weather. Further, the approach has limited number of RCMs and model results are only available for some parts of the world (Trzaska & Schnarr, 2014; Department of Science and Technology – Philippine Atmospheric Geophysical and Astronomical Services Administration [DOST-PAGASA], 2011; Wilby & Dawson, 2007).

On one hand, statistical downscaling is efficient and does not require intensive computing skills. It uses various statistical analyses to establish an empirical relationships between local climate variables (e.g., local precipitation and surface air temperature) and large-scale atmospheric predictors (e.g., airflow strength), and the application of such relationship to the output of GCM to simulate future local climate (Wilby & Dawson, 2007; Sunyer, Madsen, & Ang, 2012). This allows

for generating climate data of different emission scenarios for a specific location.

Several provinces in the Philippines, including the province of Agusan del Norte, have experienced extreme rainfall^a events that caused massive inundation in the area as recorded by the National Disaster Risk Reduction and Management Council (NDRRMC). Many residents in the province suffered from low farm productivity and loss of lives and properties (International Labour Organization [ILO], 2011). This scenario has posed an alarming call to stakeholders since the occurrences of extreme events have now become dramatically more frequent and magnitudes have been more intense (Garrett & Müller, 2008; IPCC, 2012; IPCC 2014). To prepare for the anticipated impacts and risks brought by climate change, this study demonstrated the use of statistical downscaling approach in developing a location-specific climate scenario for Agusan del Norte, Philippines for periods 2020 (2006-2035), 2050 (2036-2065), and 2080 (2066-2095) using the Third Generation Coupled Global Climate Model (CGCM3) under A1B scenario.

Methodology

Study Area

The province of Agusan del Norte, which has a land area of 2,730.24 km², is located in the northeastern part of Mindanao Island in the southern part of the Philippines. According to the modified Coronas classification, it has a type II climate, which is characterized by the absence of a dry season but with a very pronounced maximum rain period from November to February. (DOST-PAGASA, 2011). On average, the province received an annual total rainfall magnitude of around 2,400 mm based on DOST-PAGASA historical records.

Due to its topography that lies on the eastern coast, the place is faced with the northeast monsoon, trade winds, and storms. Every year, the province is among those areas greatly hit by different typhoons that enter the country's area of responsibility according to NDRRMC. These typhoons, which commonly originate from the pacific coast (eastern part of the Philippines) and make landfall, carry heavy rains and strong winds.

Heavy rains have caused inundation in most areas of the province, especially when the water overflows from the lower sub basin of the third largest river in the country, the Agusan River, which is in Agusan del Norte (ADB, 2008). Further, hydrologic-related events such as landslides, flashfloods, and maritime incidents were also observed due to consistent heavy rains. This phenomenon has affected many people's lives and property, and posed an alarming call to different stakeholders to come up with actions addressing the impacts of flooding in the area.

^a A 300 mm daily rainfall is considered as "extreme" by the Department of Science and Technology-Philippine Atmospheric Geophysical and Astronomical Services Administration (DOST-PAGASA) (2011).

Data Collection

Thirty-year historical records (1981-2010) of daily precipitation of the province were obtained from PAGASA as baseline data to analyze the existing climatic condition. Two storm durations, the 24-hour and the 48-hour annual maximum precipitation, were considered. The weather station in the province, categorized as Airport and Surface Synoptic Station by PAGASA, is located at Bancasi Airport, Brgy. Bancasi, Butuan City, Agusan del Norte with latitude and longitude coordinates of $08^{\circ}56'48''$ N and $125^{\circ}32'36''$ E, respectively (Figure 1).

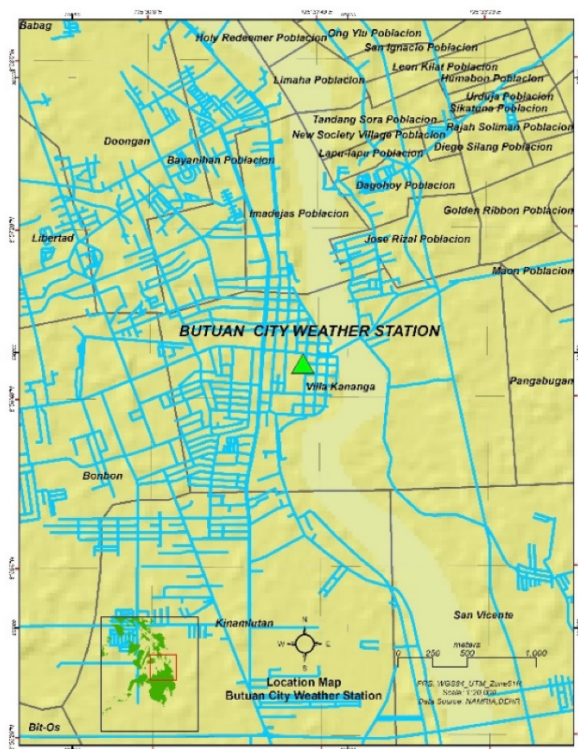


Figure 1. Location map of the airport and surface synoptic station of Agusan del Norte, Philippines.

Three time frames were considered for future climate predictions: 2020 (2006-2035), 2050 (2036-2065), and 2080 (2066-2095). Atmospheric predictor variables used were from the National Centre for Environmental Prediction (NCEP) re-analysis dataset for model calibration (Wilby & Dawson, 2007) and from CGCM3 (Flato, 2005) under a medium-range emission (A1B) climate scenario (DOST-PAGASA, 2011) for future climate modelling. They were requested and acquired from the Data Integration Access (DAI) Portal with latitude and longitude coordinates of 9.28° N and 123.75° E, respectively.

CGCM3 is a product of the Canadian Centre for Climate Modelling and Analysis (CCCma) with a new atmospheric

component, the Atmospheric Canadian GCM version 3 (ACGCM3). It was run at two resolutions: (1) the T47 version with a 3.75 degree grid cell size for atmospheric horizontal resolution and 1.85 degree resolution for the oceanic component; and (2) the T63 version which has a 2.8 degree atmospheric resolution subdivided into six oceanic grid cells (Flato, 2005).

Statistical Downscaling Process

The Statistical Downscaling Model (SDSM) version 4.2.9 software was used in this study (available at <http://co-public.lboro.ac.uk/cocwd/SDSM/>). SDSM is a free software used to produce ensembles of local climate change time series using a statistical downscaling technique (Wilby & Dawson, 2004; Wilby & Dawson, 2007). It is described as a hybrid of the stochastic weather generator and transfer function methods. It uses large-scale circulation patterns and atmospheric moisture variables to condition the local-scale weather generator parameters and utilizes stochastic technique to artificially inflate the variance of the downscaled data for a better representation of the observations (Wilby & Dawson, 2007). The statistical downscaling technique involves the following steps: variables screening, variable transformation (if necessary), model calibration, and weather and scenario generation (Wilby & Dawson, 2004; Wilby & Dawson, 2007).

In this study, a daily record of precipitation data from 1981 to 1992 (12 years) and from 1993 to 2003 (11 years) were used for model calibration and model validation, respectively.

Statistical Analysis and Evaluation of Data

Monthly mean, seasonal mean, and maximum values were computed to determine some statistical characteristics of the observed and simulated precipitation data.

Evaluation criteria between the observed and simulated data were also computed (Chen, Xu, & Gou, 2012; Batincila, 2012) such as the root-mean-squared error (RMSE) (Kelley & Keke, 2011; Makridakis & Hibon, 1995), Percent Bias (PBIAS) (Gupta, Sorooshian, & Yapo, 1999; Chen et al., 2012), Nash-Sutcliffe Efficiency (NSE), and RMSE-observations standard deviation ratio (RSR) (Moriassi et al., 2007).

Table 1 summarizes the general performance ratings for every statistic for a monthly time step established by Moriassi et al. (2007).

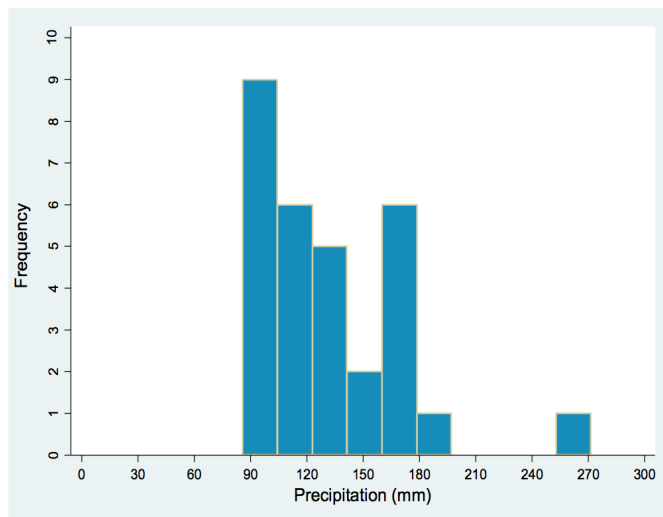
Results and Discussions

Current Climate Condition (1981–2010)

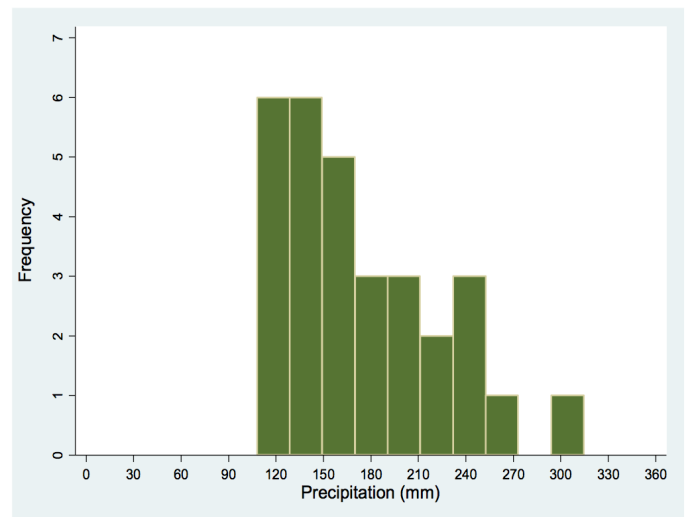
Figure 2 shows the frequency distribution from 1981 to 2010, focusing on the annual maximum 24-hr and 48-hr precipitation that occurred in the area. The annual

Table 1. General performance rating for model evaluation criteria

Performance Rating	RSR	NSE (%)	PBIAS (%)
Very good	$0.00 \leq \text{RSR} \leq 0.50$	$75 < \text{NSE} \leq 100$	$\text{PBIAS} \leq \pm 10$
Good	$0.50 \leq \text{RSR} \leq 0.60$	$65 < \text{NSE} \leq 75$	$\pm 10 \leq \text{PBIAS} \leq \pm 15$
Satisfactory	$0.60 < \text{RSR} \leq 0.70$	$50 < \text{NSE} \leq 65$	$\pm 15 \leq \text{PBIAS} \leq \pm 25$
Unsatisfactory	$\text{RSR} > 0.70$	$\text{NSE} \leq 50$	$\text{PBIAS} \geq \pm 25$



(a)



(b)

Figure 2. Frequency distribution of annual (a) 24-hr maximum and (b) 48-hr maximum precipitation data of Agusan del Norte from 1981 to 2010.

maximum daily precipitation ranges from approximately 90 mm to 270 mm for a 24-hr duration and around 100 mm to 320 mm for a 48-hr duration.

Table 2 summarizes the annual 24-hr and 48-hr maximum precipitation values recorded from 1981 to 2010. It was in 1985 that the province experienced the highest annual precipitation, which reached up to 271.6 mm and 314.6 mm for 24-hr and 48-hr durations, respectively. A La Niña event was also recorded that year, with an Oceanic Niña Index (ONI) value of -1.1 indicating a stronger La Niña event compared to other La Niña events recorded from 1981 to 2010 (Hilario, de Guzman, Ortega, Hayman, & Alexander, 2009). In contrast, it was in 1998 when the province experienced the lowest amount of precipitation of 85.8 mm rainfall within a 24-hr duration. One of the four most significant drought events recorded in the Philippines for the last two decades was in 1997 to 1998 (Hilario et al., 2009).

Statistical Downscaling Outputs

Screening of Predictor Variables

There are 26 predictor variables to choose from the NCEP

Table 2. Annual 24-hr and 48-hr maximum (max.) precipitation values (mm) in Agusan del Norte from 1981 to 2010 (Source of Data: DOST-PAGASA)

Year	24-hr max. (mm)	48-hr max. (mm)	Year	24-hr max. (mm)	48-hr max. (mm)
1981	175.8	207.6	1996	128.1	141.5
1982	110.0	139.2	1997	98.3	128.0
1983	108.8	119.2	1998	85.8	108.0
1984	127.8	149.2	1999	111.0	160.5
1985	271.6	314.6	2000	167.9	195.7
1986	147.0	244.5	2001	167.4	191.4
1987	130.3	150.3	2002	117.2	137.4
1988	191.4	211.9	2003	133.6	211.6
1989	96.3	111.8	2004	114.0	147.0
1990	93.9	122.8	2005	97.8	176.9
1991	98.2	108.6	2006	160.4	248.4
1992	94.6	169.6	2007	90.8	162.4
1993	171.8	237.4	2008	119.7	170.5
1994	168.0	189.9	2009	159.0	259.6
1995	131.8	139.8	2010	102.5	161.5

re-analysis and CGCM3, both of which were oriented to A1B scenario. Thorough assessment was done to determine the most conceptually and physically sensible predictor variables at the local weather site by performing these tasks: seasonal correlation analysis, partial correlation analysis, and scatter plots (Wilby & Dawson, 2004; Wilby & Dawson, 2007). Table 3 shows the list of the NCEP re-analysis and CGCM3 predictor variables for the precipitation data of Agusan del Norte as the predictand. The four predictor variables that gave the most desirable explained variance, correlation, and partial correlation coefficient values were selected: 850 hPa airflow strength (p8_f), 850 hPa zonal velocity (p8_u), specific humidity at 500 hPa (s500), and specific humidity at 850 hPa (s850).

Table 3. Selected NCEP/CGCM3 predictor variables for weather data generation and their description (Wilby & Dawson, 2004; Wilby & Dawson, 2007)

Code Name	Predictor Description	Precipitation
mslp	Mean Sea Level Pressure	
p_f	Surface Airflow Strength	
p_u	Surface Zonal Velocity	
p_v	Surface Meridional Velocity	
p_z	Surface Vorticity	
p_th	Surface Wind Direction	
p_zh	Surface Divergence	
p5_f	500 hPa Airflow Strength	
p5_u	500 hPa Zonal Velocity	
p5_v	500 hPa Meridional Velocity	
p5_z	500 hPa Vorticity	
p500	500 hPa Geopotential Height	
p5th	500 hPa Wind Direction	
p5zh	500 hPa Divergence	
p8_f	850 hPa Airflow Strength	✓
p8_u	850 hPa Zonal Velocity	✓
p8_v	850 hPa Meridional Velocity	
p8_z	850 hPa Vorticity	
p850	850 hPa Geopotential Height	
p8th	850 hPa Wind Direction	
p8zh	850 hPa Divergence	
s500	Specific Humidity at 500 hPa	✓
s850	Specific Humidity at 850 hPa	✓
shum	Surface Specific Humidity	
temp	Mean Temperature at 2m	
prcp	Precipitation	

Calibration and Validation of the Model

Model evaluation criteria. Three evaluation criteria were employed to assess the efficiency and accuracy of the model such as NSE (%), PBIAS (%), and RSR. These were matched with Table 1 to determine the general performance rating of each criterion. Table 4 shows the model evaluation criteria for calibration and validation processes using monthly maximum precipitation. (Chen et al., 2012; Moriasi et al.,

Table 4. Model evaluation criteria for calibration and validation processes using monthly maximum precipitation

Evaluation Criteria	Monthly Maximum		Remarks
	Calibration	Validation	
NSE (%)	99.97	79.94	Very Good
PBIAS (%)	-2.75	0.32	Very Good
RSR (%)	0.02	0.45	Very Good

2007). The model evaluated for both processes are all rated as “Very Good” in each of the three tests of accuracy used.

Figure 3 shows the closeness and intersection of observed and simulated series in the calibration process, which indicates a very good fit of the simulated data to the observation. All the tests employed in the analysis gave values that indicate that the model fitted the observed data well.

On one hand, the observed and simulated series are seen to be overlapping in the validation process as shown in Figure 4. It shows that there is an underestimation of the simulated data to the observed for the months of February, March, April, August, and September, and also an overestimation for the months of May, July, October, November, and December. However, these monthly biases are insignificant as reflected by its PBIAS (79.94%) which was rated as “Very Good” from the evaluation.

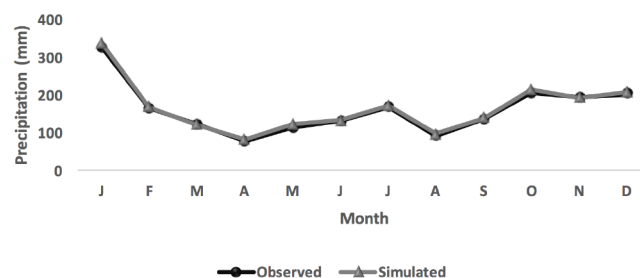


Figure 3. Mean monthly total precipitation of the observed and calibrated model for Agusan del Norte

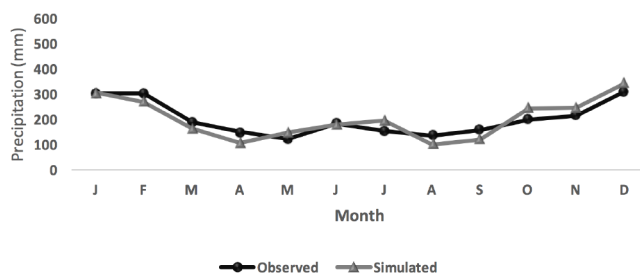


Figure 4. Mean monthly total precipitation of the observed and validated model for Agusan del Norte

Climate Scenario 2020 (2006-2035)

Table 5 lists precipitation values while Figure 5 shows the frequency distribution of the downscaled annual 24-hr and 48-hr maximum precipitation for 2020 climate scenario. It shows that for a 24-hr duration of rain, maximum precipitation could reach up to approximately 280 mm. More frequent rains with 100 mm scales are also expected in this scenario. For a 48-hr storm duration, rainfall projection could range from 90 mm to 320 mm. More frequent storm events are also projected to occur in 2006-2035.

Table 5. Annual maximum (max.) 24-hr and 48-hr precipitation values (mm) in Agusan del Norte for 2020 climate scenario (2006-2035)

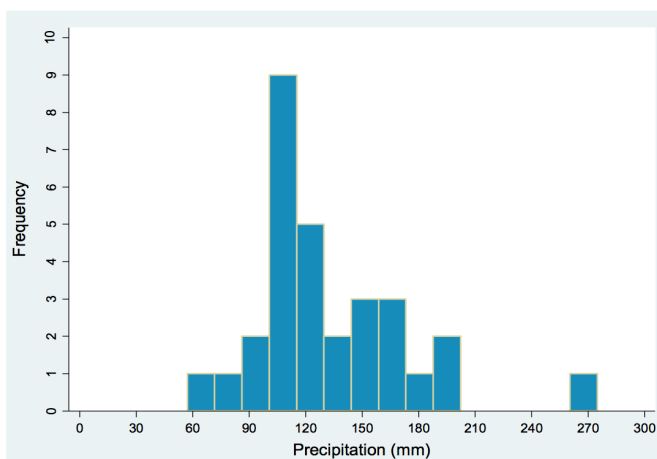
Year	24-hr max. (mm)	48-hr max. (mm)	Year	24-hr max. (mm)	48-hr max. (mm)
2006	110.2	119.5	2021	105.7	146.1
2007	164.4	210.6	2022	146.8	168.0
2008	57.2	80.1	2023	149.9	149.9
2009	102.8	156.6	2024	168.7	187.4
2010	80.1	80.1	2025	174.7	183.7
2011	87.3	140.6	2026	111.4	158.3
2012	138.4	161.5	2027	106.3	128.6
2013	140.4	151.5	2028	111.7	170.7
2014	123.3	123.5	2029	148.9	193.9
2015	89.5	100.9	2030	110.9	147.8
2016	105.7	126.6	2031	118.1	131.2
2017	163.7	217.9	2032	113.4	216.2
2018	190.3	217.3	2033	274.9	328.0
2019	192.1	212.2	2034	123.4	160.9
2020	128.6	128.6	2035	120.5	137.8

Climate Scenario 2050 (2036-2065)

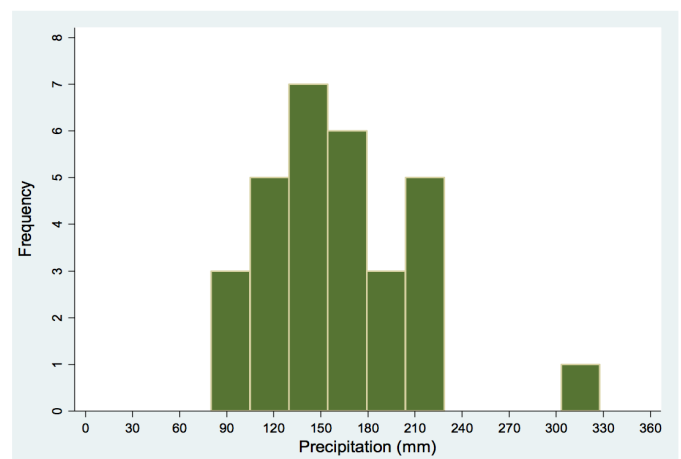
Table 6 indicates the precipitation values while Figure 6 shows the frequency distribution of the downscaled annual maximum 24-hr and 48-hr precipitation for 2050 climate scenario. It can be noticed that the distribution is concentrated within 80 mm to 160 mm rainfall magnitude, a bit higher than the 2020 projection. Precipitation magnitude in 2050 could reach up to 320 mm rainfall for a 24-hr duration, indicating more extreme events in the future. Annual maximum precipitation is projected to range from 110 mm to 330 mm for a 48-hr observation during this period.

Table 6. Annual maximum (max.) 24-hr and 48-hr precipitation values (mm) in Agusan del Norte for 2050 climate scenario (2036-2065)

Year	24-hr max. (mm)	48-hr max. (mm)	Year	24-hr max. (mm)	48-hr max. (mm)
2036	84.9	122.2	2051	86.2	122.7
2037	79.7	107.8	2052	125.6	160.4
2038	104.2	106.1	2053	103.8	126.5
2039	151.0	215.1	2054	126.0	146.7
2040	219.7	290.1	2055	182.5	198.7
2041	85.8	157.7	2056	320.8	327.4
2042	79.6	134.5	2057	151.7	151.7
2043	106.0	156.5	2058	245.0	249.6
2044	122.4	213.3	2059	131.8	135.1
2045	140.6	200.0	2060	148.8	189.0
2046	126.0	138.2	2061	204.6	242.2
2047	140.6	173.9	2062	153.6	211.7
2048	137.8	140.1	2063	98.5	121.1
2049	116.9	143.9	2064	82.6	177.3
2050	130.6	199.4	2065	145.9	209.1



(a)



(b)

Figure 5. Frequency distribution of annual maximum (a) 24-hr and (b) 48-hr precipitation in Agusan del Norte for 2020 climate scenario (2006-2035).

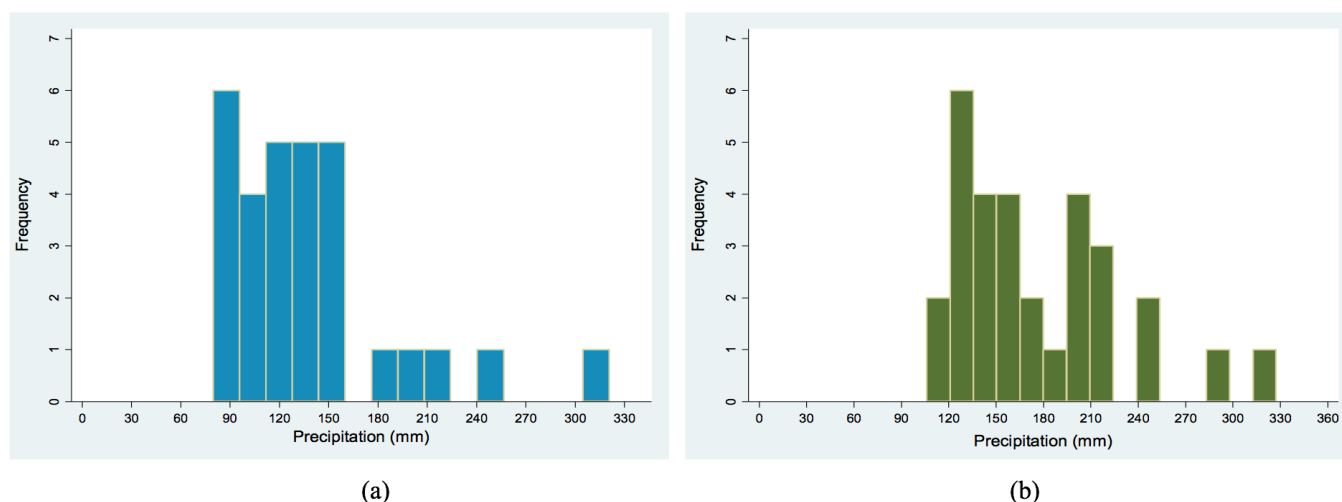


Figure 6. Frequency distribution of annual maximum (a) 24-hr and (b) 48-hr precipitation in Agusan del Norte for 2050 climate scenario (2036-2065).

Climate Scenario 2080 (2066-2095)

The magnitude and frequency distribution of the downscaled annual 24-hr and 48-hr maximum precipitation for 2080 climate scenario are shown in Table 7 and Figure 7, respectively. It can be seen that more extreme events are projected to occur. For this period, annual daily precipitation magnitude could range from 70 mm to 350 mm. If storm events last for 48 hours, they are projected to have up to 360 mm magnitude of rainfall. More concrete adaptation measures against the adverse impacts of the storm and/or flooding are required.

It can be observed that annual maximum precipitation projections from these models point to higher magnitudes compared to previous climate scenarios, affirming the existing studies about climate change projections in the Philippines (DOST-PAGASA, 2011).

Table 7. Annual maximum (max.) 24-hr and 48-hr precipitation values (mm) in Agusan del Norte for 2080 climate scenario (2066-2095).

Year	24-hr max. (mm)	48-hr max. (mm)	Year	24-hr max. (mm)	48-hr max. (mm)
2066	151.5	163.5	2081	185.3	256.5
2067	101.7	110.7	2082	115.7	115.7
2068	135.7	203.3	2083	177.3	189.4
2069	83.9	122.4	2084	123.2	146.1
2070	317.3	361.8	2085	88.7	143.4
2071	202.4	213.3	2086	210.6	230.3
2072	205.0	249.3	2087	83.8	95.6
2073	107.7	134.6	2088	239.2	362.0
2074	174.0	186.2	2089	130.0	196.5
2075	169.5	169.5	2090	221.0	327.1
2076	147.9	165.7	2091	120.3	124.2
2077	180.8	192.1	2092	120.6	227.4
2078	187.5	219.4	2093	118.2	153.2
2079	67.3	122.1	2094	346.9	346.9
2080	142.4	169.7	2095	89.7	106.3

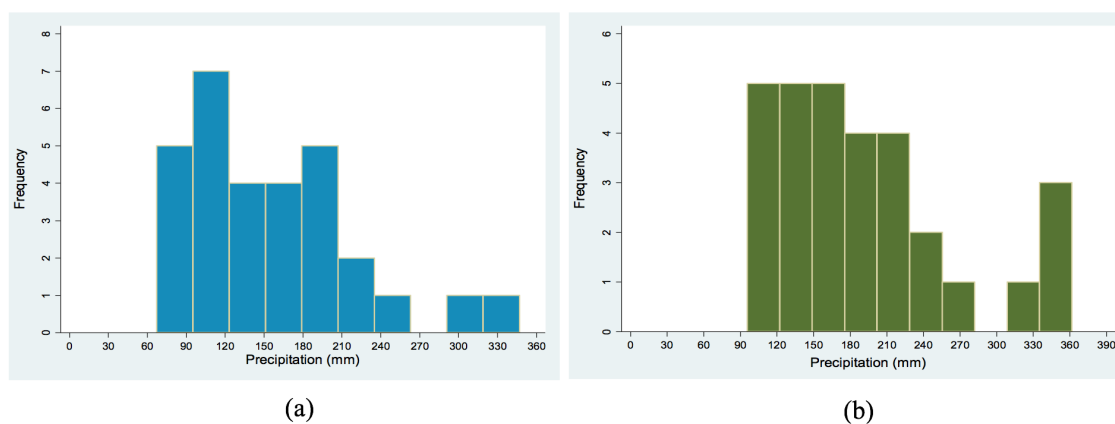


Figure 7. Frequency distribution of annual maximum (a) 24-hr and (b) 48-hr precipitation in Agusan del Norte for 2080 climate scenario (2066-2095).

Table 8. Seasonal rainfall change (in %) of different storm durations in Agusan del Norte in 2020 (2006-2035), 2050 (2036-2065) and 2080 (2066-2095)

Season	24-hr Duration				48-hr Duration			
	Observed Rainfall (mm) (1981-2003)	2020	2050	2080	Observed Rainfall (mm) (1981-2003)	2020	2050	2080
		% change				(% change)		
DJF	761.8	18.2	19.5	51.9	761.8	17.8	18.6	51.3
MAM	364.9	10.3	15.3	34.0	364.9	10.4	15.9	34.3
JJA	410.1	-3.8	11.0	20.3	410.1	-3.9	11.0	19.7
SON	527.1	7.3	6.4	15.3	527.1	7.9	7.2	16.4

Note: DJF (December-January-February); MAM (March-April-May); JJA (June-July- August); SON (September-October-November)

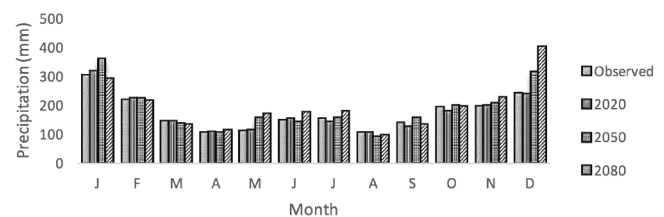
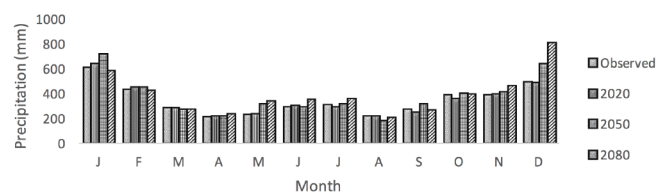
Comparison of Observed and Downscaled Data

Table 8 indicates the seasonal rainfall change (in %) of 24-hr and 48-hr storm durations in Agusan del Norte for future climate scenarios. It can be noticed that there is a projected increasing trend of precipitation magnitude in all seasons of future climates for 24-hr storm duration, except for the June-July-August (JJA) season in 2020 where there is a decreasing precipitation magnitude by about 3.8%. However, there is projected increase by about 11.0% and 20.3% in 2050 and 2080, respectively. In general, extreme storm events that could last for a day or 24 hours are projected to increase in the future.

Precipitation magnitude is expected to increase in the future, consistently among all scenarios and at different seasons with storm duration of 48 hours. Increasing precipitation magnitudes are projected during DJF season by about 17.8%, 18.6%, and 51.3% in 2020, 2050, and 2080, respectively. An increase of rainfall magnitude is seen during MAM season by about 10.4% in 2020, 15.9% in 2050, and 34.3% in 2080. A decreasing precipitation magnitude by about 3.9% is projected in 2020 during JJA season. This is projected to increase by about 11% and 19.7% in 2050 and 2080, respectively. Lastly, an increasing precipitation magnitude is projected during SON season by about 7.9%, 7.2%, and 16.4% in 2020, 2050, and 2080, respectively. These results imply that more intense and more frequent extreme events are expected to occur in the future.

From previous sections, it can be noticed that the higher frequency of maximum rainfall is toward higher magnitudes. Thus, the province is projected to experience more extreme rainfall events in the future. Figures 8 and 9 show the monthly total precipitation of Agusan del Norte across different climate scenarios according to a 24-hr and 48-hr durations of rainfall, respectively. For climate scenario 2020, an increasing magnitude of rainfall is projected for the months of January, February, April to June, and November. For climate scenario 2050, the months of January, February, April, May, July, and September to

December are anticipated to have the increasing intensity of rainfall. The months of April to July and October to December are projected to have an increasing magnitude of rainfall for climate scenario 2080.

**Figure 8.** Monthly total 24-hr maximum precipitation values in Agusan del Norte across different climate scenarios.**Figure 9.** Monthly total 48-hr maximum precipitation values in Agusan del Norte across different climate scenarios.

Conclusion and Recommendations

Through statistical downscaling technique, future precipitation centered on 2020 (2006-2035), 2050 (2036-2065), and 2080 (2066-2095) under A1B climate scenario were derived. The technique is more efficient and does not require intensive computing skills. Statistical downscaling involves selection of global scale atmospheric predictors that have significant relationship with the local climate variable. Model calibration and validation was done to

construct and validate the downscaling model given the daily precipitation data in the province and the outputs of NCEP A1B scenario. The validated model was used along with the output of CGCM3 to simulate future local climate data in the province.

In 2020, maximum precipitation is expected to reach up to 280 mm within a 24-hr duration of rain, and is expected to rise up to 320 mm if a storm would last for 48 hours. In 2050, projections showed that maximum precipitation could reach up to 320 mm and 330 mm of rainfall within 24-hr and 48-hr storm durations, respectively. In 2080, it is projected that the province will experience extreme rains with the magnitude of 70 mm to 350 mm within 24-hr storm duration and up to 360 mm if a storm will last for 48 hours.

Given the scope and limitations of the study, the same technique can still be employed for the province using the updated and new GCMs which will perform better than CGCM3. Also, four new greenhouse gas concentrations trajectories through representative concentration pathways (RCPs) have been presented by IPCC in their Fifth Assessment Report (AR5) (IPCC, 2014). It supersedes the emission scenarios considered in this study. These RCPs are used to describe four possible climate futures which depend on how much greenhouse gases are emitted in the years to come. Thus, projections of future climate in the province can also be simulated on the basis of these pathways.

Downscaled data for future precipitation scenarios are essential information for the local government unit of Agusan del Norte and for other agencies to conduct local studies such as vulnerability assessment and hydrologic modeling to understand hydrologic processes of some bodies of water in the area. This information is also an important input in updating the disaster risk reduction management plan of the province, and can be a basis for the formulation of suitable policies and programs addressing the climate conditions in the area.

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