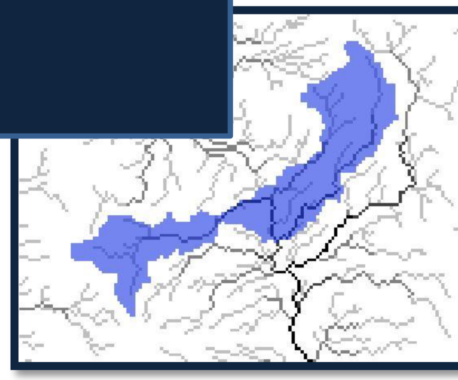
Analysis of Climate Change Impacts on Stream Discharges using STREAM

STEP 1: Hydrological Model



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1. Introduction

1.1. Climate Change in the Philippines

Climate change poses a serious threat on agricultural production systems and areas due to increased incidence and intensity of droughts, floods and storms. Developing countries are especially vulnerable, as they have limited resources to cope with the negative effects of climate change. Recently, a Global Climate Risk Index was published ranking the country's vulnerability to climatic change wherein the Philippines ranked fifth among the countries that are most affected due to its archipelagic geography (Harmeling and Eckstein, 2012).

For the Philippines, projected changes in climate include drier summer months, excessive rainfall during the rainy season and an increase in the average temperature. This is predicted to negatively affect crop yields and therefore poses a great risk for the country's economy, as rice and corn alone contribute to almost half of gross value added to the country's economy in 2007 (PCARRDSTA, 2012). Water availability is a major concern here, as rice production takes up 95% of the water volume dedicated to the agricultural sector (Greenpeace, 2007). Accurate predictions for water availability are therefore required in order to cope with the negative effects of climate change.

A range of different tools and models is available to study the effect of climate change. One of these tools is the Modeling System for Agricultural Impacts on Climate Change (MOSAICC), which was developed to assess the impacts of climate change on agriculture and food security. The toolbox is based on a generic methodology - defined to assess the impact of climate change on climate, river runoff, crop yields and the economy. This framework was used in the Analysis and Mapping of Impacts under Climate Change for Adaptation and Food Security (AMICAF) Project of the Food and Agriculture Organization of United Nations. Due to its high vulnerability to climate change, The Philippines is one of the study areas of the project.

The hydrological model that was incorporated to MOSAICC is the Spatial Tools for River basins and Environment and Analysis of Management options (STREAM). It is a grid-based spatial water balance model which describes the hydrological cycle of a catchment as a series of storage compartments and flows (Aerts et al., 1999). In this project, calibrations and simulations were done using a stand-alone version of STREAM as there are still components yet to be installed in the MOSAICC version.

The goal of this study is to use the hydrological module of the MOSAICC toolbox to estimate river runoff projections under different scenarios of climate change for the major river basins in the Philippines. Historical datasets on climate and river runoff are used for model calibration.

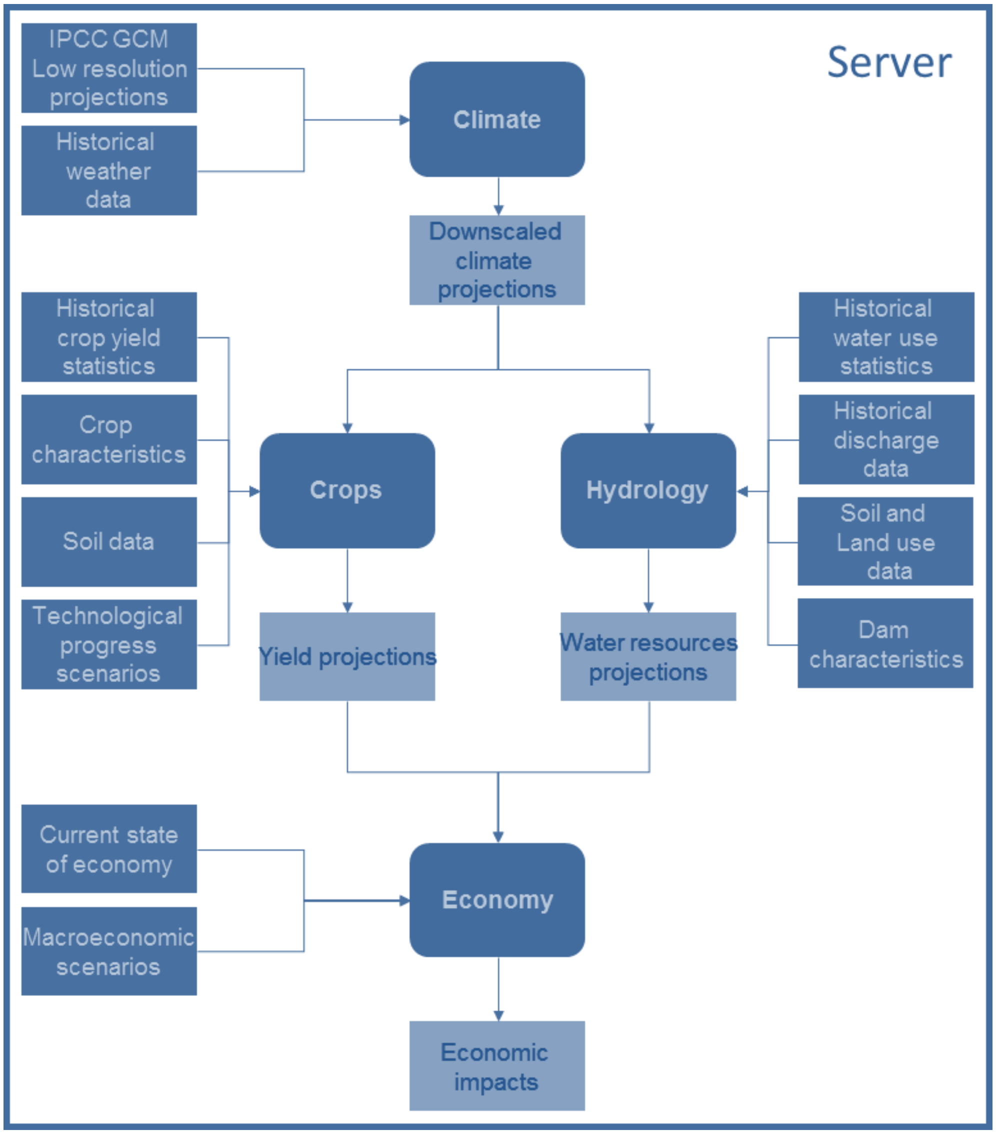


Figure 1. Overall flow of data in MOSAICC.

1.2. Specific Objectives

As stipulated in the Letter of Agreement between the Food and Agriculture Organization and UP National Institute of Geological Sciences (UP NIGS), the following are the tasks of the team from UP NIGS. A summary of the various outputs from this component is also included:

** Collect available national input data on historical water use, historical discharge, soil and land use, and dam statistics and format it for MOSAICC.*

- The three volumes of historical stream discharge data (20 years) were acquired from the Bureau of Research Standards (BRS-DPWH). The entire data were digitized to produce soft copies of the measurements.

- The watersheds were delineated by the Environment Monitoring Laboratory in UP NIGS using the ArcHydro software.

- The dam data were acquired from the National Water Resources Board.

** Participate in the trainings for MOSAICC system and its hydrological component.*

- Al trainings for STEP 1 Partners were attended:
    a. Statistical Climate Downscaling Workshop for PAGASA
    b. WABAL Workshop for PhilRice
    c. STREAM Workshop for UP NIGS
    d. PAM Model Workshop for NEDA

- Training in Wageningen University and Research Centre, Netherlands for STREAM with Ate Poortinga.

** Participate in the design of an integrated climate change impact study.*

- Interpolation of the downscaled climate data was also done since the climate data output will be used as input for the STREAM model.

** Calibrate the hydrological component of MOSAICC against historical data.*

-The stream discharges produced by STREAM for each river were calibrated using the measured data from the BRS.

** Run the hydrological component of MOSAICC for the study to simulate future projections. Analyze the results of the simulations, making sure the links between upstream/downstream models within MOSAICC, and that the results contribute to the overall study.*

-The downscaled climate data has been run for three climate change scenarios in 8 river basins in the Philippines.

1.3. Project Team Composition

The hydrological modeling component was performed by scientists from Environment Monitoring Laboratory of the University of the Philippines National Institute of Geological Sciences:

Name	Designation
Carlos Primo C. David, Ph.D.	Project Leader
Pamela Louise Tolentino	Principal Researcher
Justine Perry Domingo	Researcher
Maria Teresa Lorenzo	Researcher
Peter A. Cayton (Statistician)	Statistician

2. Materials and Methodology

2.1 Study Area

The Philippines is an archipelago in Southeast Asia. It is composed of 7,107 islands which has a total area of 299,764 square kilometers (sq. km) (Porcil, 2009). There are three main island groups, Luzon (141,000 sq. km), Visayas (57,000 sq. km) and Mindanao (102,000 sq. km). The country is divided into 80 provinces, 143 cities and 1491municipalities (NCSB, 2012). The Philippines has 421 principal river basins, 18 of which are considered as major river basins with at least 1400 sq. km watershed area (Figure 2) (RBCO, 2013). These river basins are important freshwater resources for agriculture, commercial and domestic demands. Three of the major river basins are included in the current study.

Selection of the rivers to be calibrated is based on their geographic location so that various parts of the country are represented and the availability of the discharge data of the stream. Fourteen rivers were selected for the study. Table 1 shows information of each river and Figure 2 shows the location of the rivers. The discharge locations are based on the established gauging stations of the Bureau of Research Standards (BRS). The basin maps are generated from STREAM as one of the base maps for the discharge simulations.

Table 1. List of rivers used in STREAM.

No.	Irrigated Province	River	River Basin	Location of the River			N	E	Year		Record
				Barangay	City	Province			Start	End	Status
1	Ilocos Norte	Laoag	Laoag	Poblacion	Laoag City	Ilocos Norte	18-12-12	120-35-18	1984	1994	Fair
2	Cagayan	Pared	Cagayan	Baybayog	Alcala	Cagayan	17-54-22	121-41-00	1984	1990	Good
3	Nueva Vizcaya	Magat	Cagayan	Baretbet	Bagabag	Nueva Vizcaya	16-35-02	121-15-06	1985	1992	Good
4	Isabela	Ganano	Cagayan	Ipil	Echague	Isabela	16-41-56	121-33-06	1987	1992	Good
5	Pampanga	Gumain	Gumain	Sta. Cruz	Lubao	Pampanga	14-55-00	120-34-08	1985	1996	Fair
6	Nueva Ecija	Rio Chico River	Pampanga	Sto. Rosario	Zaragosa	Nueva Ecija	15-26-44	120-45-02	1986	1997	Poor
7	Oriental Mindoro	Pangalaan	Pangalaan	Pangalaan	Pinamalayan	Oriental Mindoro	13-18-9	121-11-45	1990	1999	Good
8	Camarines Sur	Yabo	Yabo	Yabo	Sipocot	Camarines Sur	13-47-54	122-56-54	1980	1990	Fair
9	Capiz	Panay	Panay	Poblacion	Panitan	Capiz	11-23-36	123-46-17	1984	1989	Fair
10	Leyte	Das-ay	Das-ay	Sto. Nino II	Hinunangan	Southern Leyte	10-22-15	125-09-56	1986	2000	Fair
11	Zamboanga del Sur	Tukuran	Tukuran	Tinotongan	Tukuran	Zamboanga del Sur	7-52-46	123-35-56	1986	2000	Fair
12	Bukidnon	Agusan Canyon	Agusan Canyon	Damilag	Manolo Fortich	Bukidnon	8-19-22	124-48-26	1990	1999	Fair
13	Sultan Kudarat	Allah	Cotabato	Impao	Isulan	Sultan Kudarat	6-40-30	124-34-00	1980	1994	NA
14	Agusan del Sur	Wawa	Agusan	Wawa	Bayugan	Agusan del Sur	8-49-04	125-42-23	1985	1990	Poor

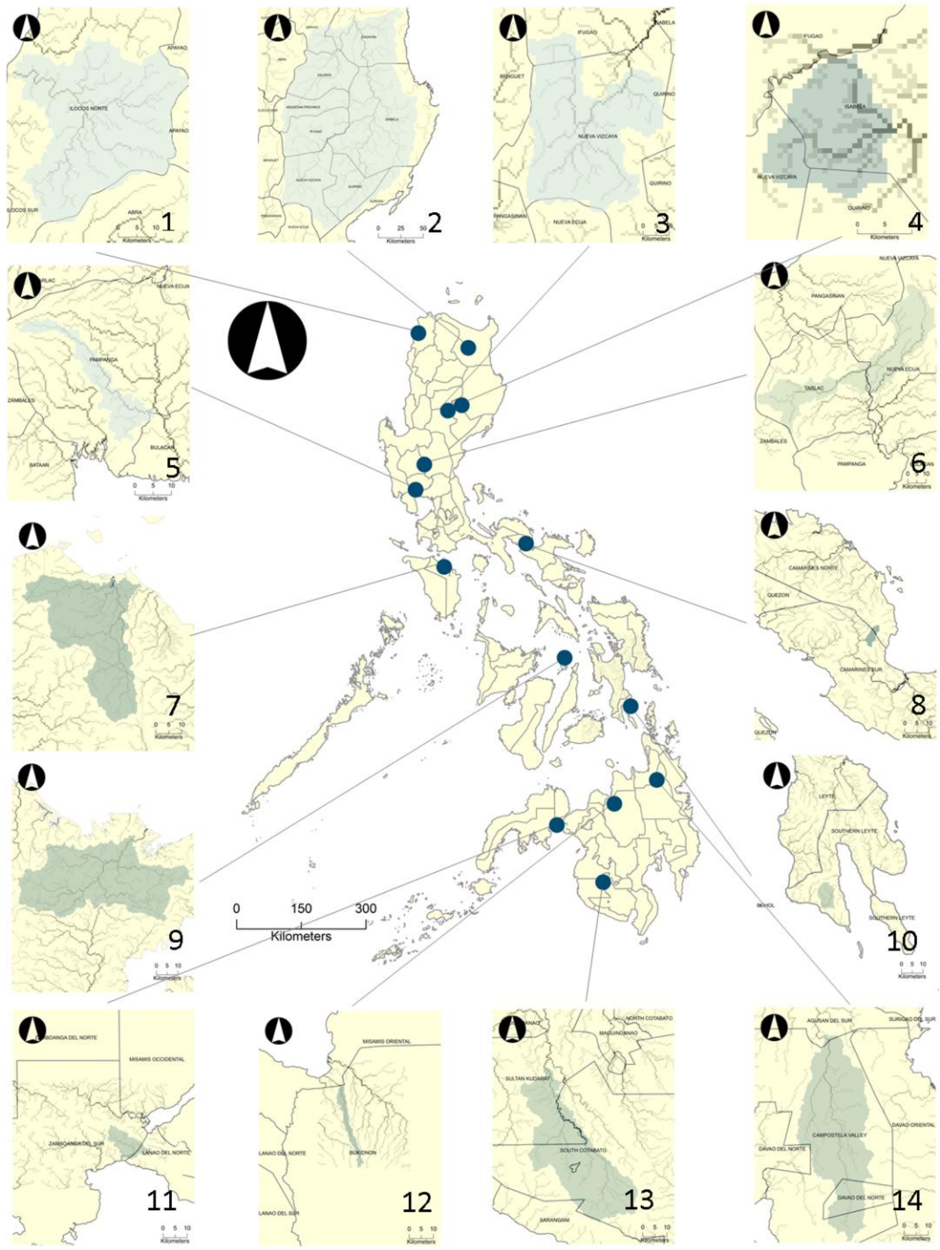


Figure 2. Upstream maps of the discharge points and their locations in the Philippines.

2.2 MOSAICC

The MOSAICC toolbox is based on a generic methodology defined to assess the impact of climate change on agriculture, including statistical downscaling of climate data, crop yield projections, water resources estimations and economic modeling. The primary input of the model is low resolution climate data, which serves as an input for the whole model structure. This climate data is used to produce the downscaled climate scenarios, which in turn serves as input data for hydrological modeling and crop growth simulation modules along with other basic information on elevation, land cover and soil. The outputs of the hydrological and crop model may then be used as input for the economic model, which calculates the economic impact. Details of data transformation and analysis for the hydrological component of MOSAICC are detailed in the succeeding sections.

2.2.1. Climate Downscaling

FAO-MOSAICC utilizes low-resolution projections generated from General Circulation Models (GCMs) for future climates, similar with most climate change impact assessment methods. Due to the coarse resolution of GCMs, downscaling is necessary in a regional or country scale. Projections are statistically downscaled onto particular weather stations for a specific time period in order to obtain a more precise resolution.

The Santander Meteorology Group of the University of Cantabria, Spain has developed and incorporated into MOSAICC a statistical downscaling tool for coarse climate grids generated by GCMs. This tool has been designed to downscale weather variables (i.e. precipitation, minimum temperature, and maximum temperature) simultaneously for a weather station network. Three GCMs were used in downscaling climate data, the BCCR-BCM2.0 (BCM2), the CNRM-CM3 (CNCM3) and the ECHAM5/MPI-OM (MPEH5). Information on these GCMs are listed in Table 2. Three scenarios were used for the discharge simulations, (1) 20C3M which is the past climate data (1970-2000), (2) SRES scenario A1B, which assumes very rapid economic growth, a global population that peaks in mid-century and rapid introduction of new and more efficient technologies and (3) SRES scenario A2 which represents the negative extremes, high population growth, slow economic development and slow technological change. No likelihood has been attached to any of the SRES scenarios. A1B and A2 are future climate emission scenarios (2011-2050).

Table 2.Information on each GCM used for simulation (Randall et al., 2007).

	Model ID, Vintage	Sponsor(s), Country	Atmosphere Top Resolution(a) References	Ocean Resolution(b) Z Coord., Top BC References	Sea Ice Dynamics, Leads References	Coupling Flux Adjustments References	Land Soil, Plants, Routing References
1	BCCR-BCM2.0 2005	Bjerknes Centre for Climate Research, Norway	top = 10 hPa T63 (1.9° x 1.9°) L31 Déqué et al., 1994	0.5°–1.5° x 1.5° L35 density, free surface Bleck et al., 1992	rheology, leads Hibler, 1979; Harder, 1996	no adjustments Furevik et al., 2003	Layers, canopy, routing Mahfouf et al., 1995; Douville et al., 1995; Oki and Sud, 1998
2	CNRM-CM3 2004	Météo-France/Centre National de Recherches Météorologiques, France	top = 0.05 hPa T63 (~1.9° x 1.9°) L45 Déqué et al., 1994	0.5°–2° x 2° L31 depth, rigid lid Madec et al., 1998	rheology, leads Hunke-Dukowicz, 1997; Salas-Mélia, 2002	no adjustments Terray et al., 1998	layers, canopy,routing Mahfouf et al., 1995; Douville et al., 1995; Oki and Sud, 1998
3	ECHAM5/MPI-OM 2005	Max Planck Institute for Meteorology, Germany	top = 10 hPa T63 (~1.9° x 1.9°) L31 Roeckner et al., 2003	1.5° x 1.5° L40 depth, free surface Marsland et al., 2003	rheology, leads Hibler, 1979; Semtner, 1976	no adjustments Jungclaus et al., 2005	bucket, canopy, routing Hagemann, 2002; Hagemann and Dümenil-Gates, 2001

Notes:
a. Horizontal resolution is expressed either as degrees latitude by longitude or as a triangular (T) spectral truncation with a rough translation to degrees latitude and longitude. Vertical resolution (L) is the number of vertical levels.
b. Horizontal resolution is expressed as degrees latitude by longitude, while vertical resolution (L) is the number of vertical levels.

Spatial consistency can be maintained through different methods incorporated into the system (e.g. regression, weather typing). A weather generator is included to derive time series of the weather variables needed. Using both historical weather data and GCMs, the tool is able to construct climate scenario predictions. The downscaled climate data are subsequently subjected to different interpolation methods, in order to obtain an appropriate spatial resolution for hydrological and crop modeling.

2.2.2. Principal Component Analysis

After climate downscaling, the Principal Component Analysis (PCA) is the next step in order to prepare supporting data. The interpolation tools in MOSAICC have been designed to process large amounts of data with minimum user input. All interpolation methods integrated in the system require the following data: 1) digital elevation model (DEM) of the area of interest, 2) polygon shapefile of the interpolation area, and 3) point shapefile with the locations of the input weather stations and the input time series.

The main objective is to derive all the maps necessary in subsequent interpolation procedures. Using the grid data of the input files (DEM and administrative

boundaries/river basins), the area of analysis is selected as shown in Figure 3. The resolution of the interpolation grid can be manipulated through the *step* value. PCA analysis will be performed and produce the following grids: interpolation grid, mask of the interpolation area, grid of the distance to the sea, grids of the first principal components. These outputs will be the basis for all interpolation methods.

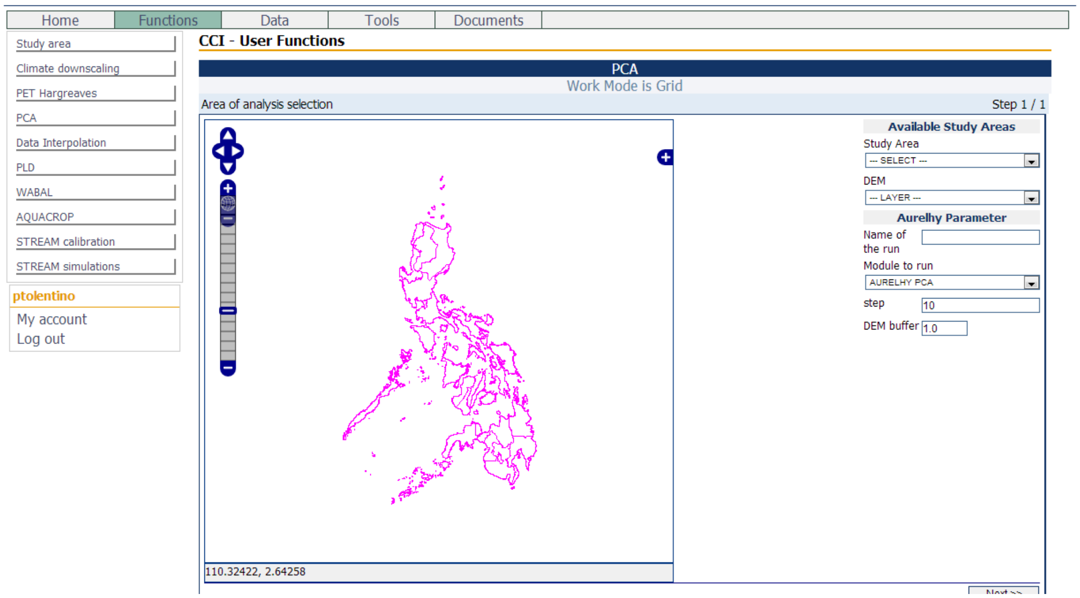


Figure 3.Principal Component Analysis in MOSAICC.

2.2.3. Preliminary Data Interpolation

In order to determine the regression models, Preliminary Data Interpolation (*Prelim*), as shown in Figure 4, is performed prior to other interpolation methods. This function provides additional processes to assist in the determination of the interpolation parameters. The elements considered for the analysis include geographical and temporal experiment specifications, stations, predictors and variogram model parameters. Using these data as input, *Prelim* executes the following analyses: 1) logarithmic transformation of the data; 2) stepwise selection of predicting variables for regression model and diagnosis; and 3) variogram fitting on median values of the regression residuals. Based on the initial results, the most relevant predictive parameters are selected and the variogram model values are adjusted for the next interpolation process.

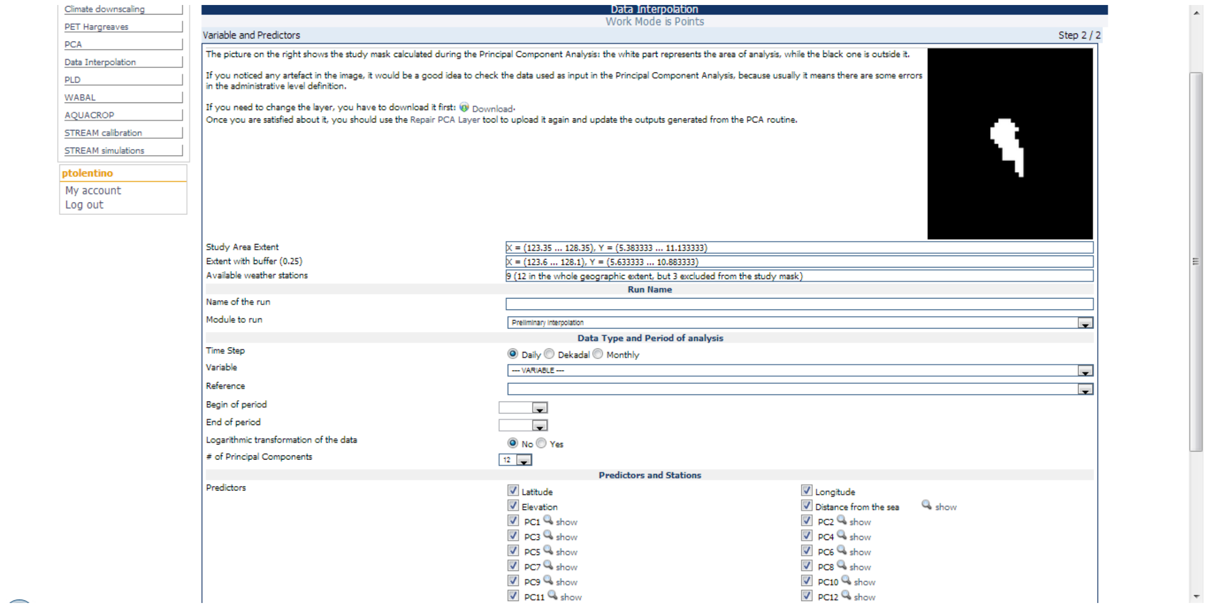


Figure 4.Preliminary data interpolation.

2.2.4. Kriging Interpolation

After performing preliminary interpolation, Kriging method would be used for automatic interpolation of data on selected time series, shown in Figure 5. The supporting data produced by PCA and the output from the Preliminary Data Interpolation are selected. The data type and time frame are both set accordingly. Variogram parameters are modified as necessary.

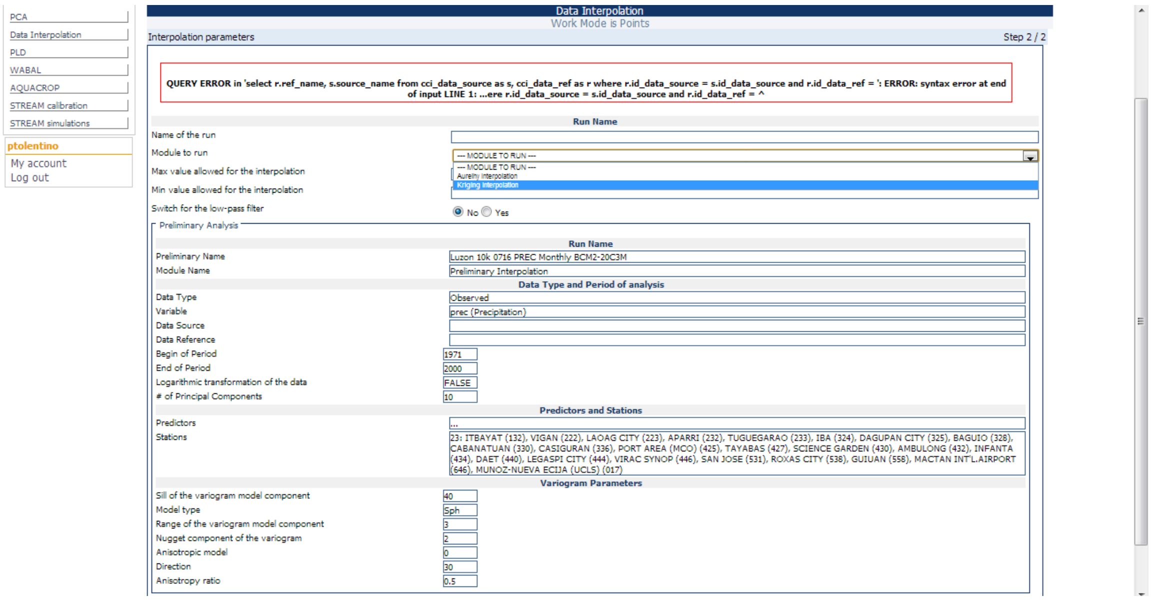


Figure 5. Data Interpolation through Kriging Method

2.3 STREAM

Calculation of forecasted stream discharge as affected by climate change is calculated through MOSAICC's hydrological model called STREAM. The Spatial Tools for River basins and Environment and Analysis of Management options (STREAM) is a grid-based spatial water balance model which describes the hydrological cycle of a catchment as a series of storage compartments and flows (Aerts et al., 1999). The model was developed to study the processes that impact water availability within a river basin with a specific focus on the effects of climate change and land use. STREAM has been extensively used for scenario analysis for a range of different spatial and temporal scales.

STREAM requires spatially explicit input on precipitation, temperature, land-cover and soil type (Figure 6). From the temperature the evapotranspiration is estimated using the Thornthwaite equation (Thornthwaite et al., 1957). Based on these parameters, the water balance is calculated for each grid cell. The former STREAM model uses a flow routing algorithm to calculate the total runoff, whereas in the new MOSAICC-STREAM it uses an upstream mask to sum the accumulated runoff. The latter significantly decreases calculation time and makes it easier to include dams/reservoirs and other compartments in the calculation.

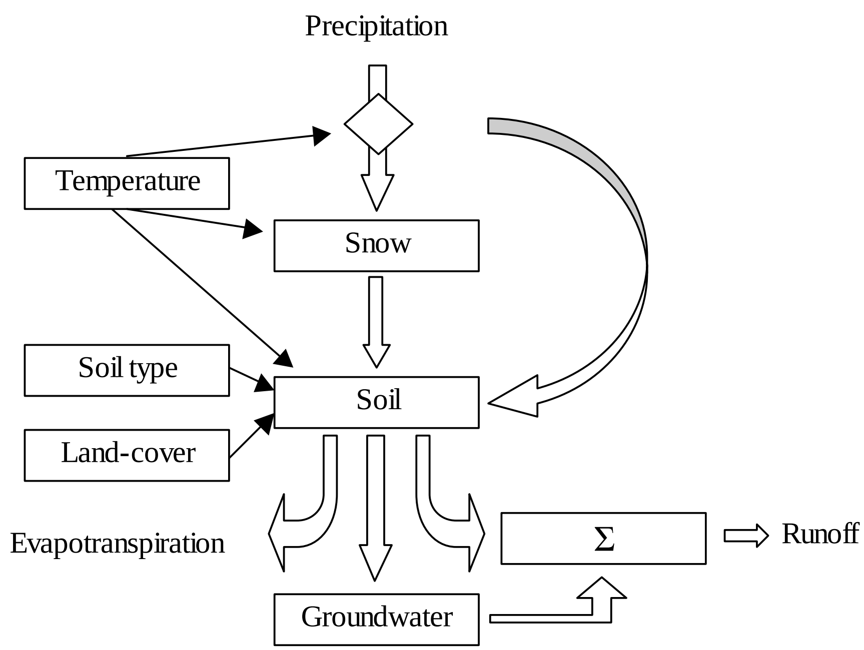


Figure 6. Flowchart of how STREAM model works.

2.3.1. Data requirements

The inputs used for the STREAM model are shown in Table 3.

Table 3: Inputs for the STREAM model

Input	Source
Digital Elevation Model (DEM) and basin delineation	
Climate Data: precipitation, evaporation or temperature.	MOSAICC Output (PAGASA/UP NIGS)
Land use map	BSWM
Soil data	BSWM

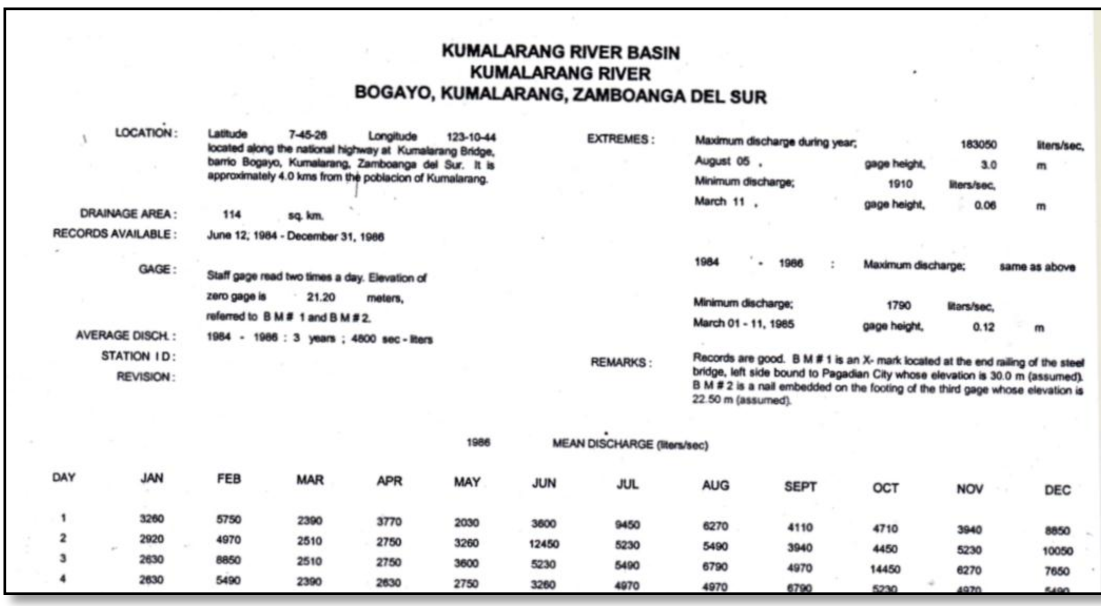
2.3.2. Model Calibration

The hydrological model output also includes a time range from 1979 to 2011 wherein the results can be compared to actual BRS discharge measurements which spans the years 1980-2000. The datasets' comparison represents the calibration procedure of the hydrological model. In the current model calibration scheme, three calibration parameters are used. These are shown in Table 4.

Table 4.Calibration parameters of STREAM.

Parameter	Description	Value
C	slow flow	>1
WATERH	water holding capacity	
TOGW	To groundwater fraction	0 – 1

Model calibration is done in two steps. The first step is done by visually comparing the actual hydrograph with the predicted hydrograph output, in order to get an estimate for the different parameters. The actual data is from the stream discharge data from the Bureau of Research Standards (BRS-DPWH) dataset. The data is presented in a tabulated form with daily and monthly discharges. The median of the daily measurements were calculated and compared with the modeled data. Figure 7 shows an example of a page containing the discharge data. The upper section contains information about the river and the lower section contains the daily discharge data.


KUMALARANG RIVER BASIN
KUMALARANG RIVER
BOGAYO, KUMALARANG, ZAMBOANGA DEL SUR

LOCATION : Latitude 7-45-26 Longitude 123-10-44 located along the national highway at Kumalarang Bridge, barrio Bogayo, Kumalarang, Zamboanga del Sur. It is approximately 4.0 kms from the poblacion of Kumalarang.

DRAINAGE AREA : 114 sq. km.

RECORDS AVAILABLE : June 12; 1984 - December 31, 1986

GAGE : Staff gage read two times a day. Elevation of zero gage is 21.20 meters, referred to B M # 1 and B M # 2.

AVERAGE DISCH. : 1984 - 1986 : 3 years ; 4800 sec - liters

STATION I D :

REVISION :

EXTREMES : Maximum discharge during year; 183050 liters/sec, August 05 , gage height, 3.0 m
Minimum discharge; 1910 liters/sec, March 11 , gage height, 0.06 m

1984 - 1986 : Maximum discharge; same as above
Minimum discharge; 1790 liters/sec, March 01 - 11, 1985 gage height, 0.12 m

REMARKS : Records are good. B M # 1 is an X- mark located at the end railing of the steel bridge, left side bound to Pagadian City whose elevation is 30.0 m (assumed). B M # 2 is a nail embedded on the footing of the third gage whose elevation is 22.50 m (assumed).

1986 MEAN DISCHARGE (liters/sec)

DAY	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC
1	3260	5750	2390	3770	2030	3600	9450	6270	4110	4710	3940	8850
2	2920	4970	2510	2750	3260	12450	5230	5490	3940	4450	5230	10050
3	2630	8850	2510	2750	3600	5230	5490	6790	4970	14450	6270	7650
4	2630	5490	2390	2630	2750	3260	4970	4970	6790	5230	4970	5490

Figure 7.Stream discharge data from the Bureau of Research Standards.

The second step is optimizing the parameters with Model-Independent Parameter Estimation software (PEST). PEST is a software for model calibration, parameter estimation and predictive uncertainty analysis. PEST runs the model as many times as needed adjusting the parameters until the difference between the model output and measured values approaches a minimum in terms of weighted squares (Doherty, 2004).

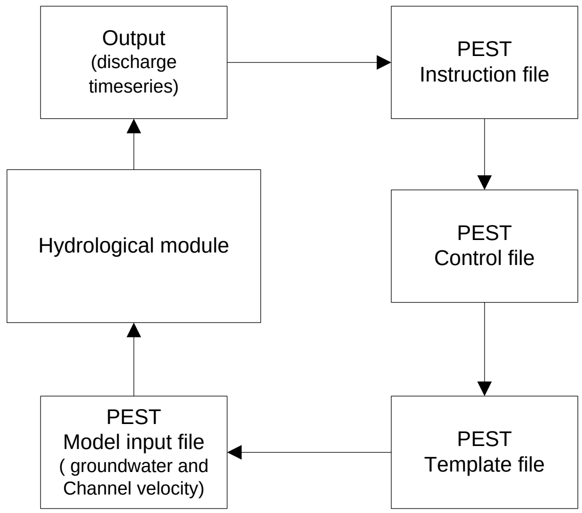


Figure 8: The PEST optimization scheme.

The PEST optimization routine consists of a control file, template file, module input file and instruction file as shown in Figure 8. The control file holds all the important information on parameters, parameter groups, settings and observed values. From a template file where the parameters are listed a model input file is created. This model input file can be read by the hydrological module after which the model is run. The output of the model, a time series of discharge data in this case, is read by PEST following an instruction file. The predicted data of the model is compared to the observer data, after which the parameters are adjusted. This process repeats itself until the Gauss-Marquardt-Levenberg algorithm has found an optimum. The theoretical description of PEST and the Marquardt-Levenberg algorithm can be found in the manual (Doherty, 2004).

2.4 Model Evaluation

To evaluate the model performance in quantitative terms, the Nash and Sutcliffe Efficiency (NSE) criteria is used. This method is typically developed for hydrological models. An efficiency of 1 indicates a perfect relation between the predicted and observed discharge. Negative values indicate a relation which is worse than when the predicted values would be replaced by the mean observed value. The NSE is defined below:

$$\text{Efficiency} = 1 - \left(\frac{\sum_{t=0}^{T} (p_i - o_i)^2}{\sum_{t=0}^{T} (o_i - o_{mean})^2} \right) \quad (1)$$

where,

o_{mean}	mean observed value
p_i	predicted (modeled) values
o_i	observed values

The median of actual discharge data from BRS are compared with the output discharge of the model using ERAINT using NSE. The ERAINT were then compared to the 20C3M of each GCM. The NSE between ERAINT and 20C3Ms may be used to determine the better GCM.

Criss and Winston (2008) discussed the disadvantages on using NSE as a measure of the model's efficiency. They reported that NSE tends to overemphasize large flows relative to other measurements due to squaring of various deviations. According to the them, it can be a problem since the flows that are more represented in the "goodness-of-fit" calculations are the least accurately measured. Large negative values may falsely indicate poor performance of the model, these values may be due to steady observed streamflow. Due to these problems, another equation was used to determine the efficiency of the model, the volumetric efficiency (VE). The VE (Equation no. 2) is claimed to be more useful for the comparison of similarly scaled, rainfall-runoff transfer functions and it treats every cubic metre of water the same as any other cubic meter, whether it be delivered during slow recession or during peak flow (Criss and Winston, 2008). VE values are shown in Table 7.

$$VE = 1 - \frac{\sum |Q_{calc} - Q_{obs}|}{\sum Q_{obs}} \quad (2)$$

To show the general trend of future discharge projections, the slope and p-value were computed. Positive value of slope indicates increase in discharge while a negative value corresponds to decrease in discharge. The p-value determines the significance of this trend, a value less than or equal to 0.1 indicates that the trend is significant while a value more than 0.1 indicates that the trend depicted by the slope is not significant.

3. Results and Discussion

3.1 Model Validation

The efficiency of the model was evaluated from the monthly discharges of the selected river produced by STREAM indicated by ERAINT(converted from cubic meters per month to cubic meters per second)and the observed monthly median (derived from the observed daily discharge), using the NSE equation. The ERAINT were also compared with the 20C3M scenario of each GCM. Table 6 shows the list of the NSE value for each province for different GCM comparison.

Table 6. NSE measures for each province.

GCM - 20C3M	Ilocos	Cagayan	Nueva Vizcaya	Isabela	Pampanga	Nueva Ecija	Bicol
Observed vs ERAINT	0.461293	0.3012	-2.015973035	0.319893148	0.2601508	0.780641408	-0.01963524
ERAINT vs BCM2	0.319351	0.154349	-0.734994203	0.462229126	0.7254823	0.678713054	-3.795062667
ERAINT vs CNCM3	0.227422	-0.40645	-1.858424226	-0.015632554	-0.017777	-0.033821002	-0.453815013
ERAINT vs MPEH5	0.723831	-0.54132	-1.858424226	-0.215816402	0.0306014	0.189180864	-0.453815013

GCM - 20C3M	Mindoro	Capiz	Leyte	Zamboanga	Bukidnon	Sultan Kudarat	Agusan del Sur
Observed vs ERAINT	-0.00839	-0.03447	-0.006521318	0.142565928	-0.325406	-0.196756787	-0.004566527
ERAINT vs BCM2	-0.98787	-0.36286	0.279729567	0.019121453	-0.266574	-0.20027947	-0.496905863
ERAINT vs CNCM3	-0.47812	-0.27239	0.279729567	-0.031846433	-0.226775	-0.20027947	-0.466111989
ERAINT vs MPEH5	-1.45665	-0.20881	-0.243752355	0.055726249	-0.590043	-0.420314446	0.009222558

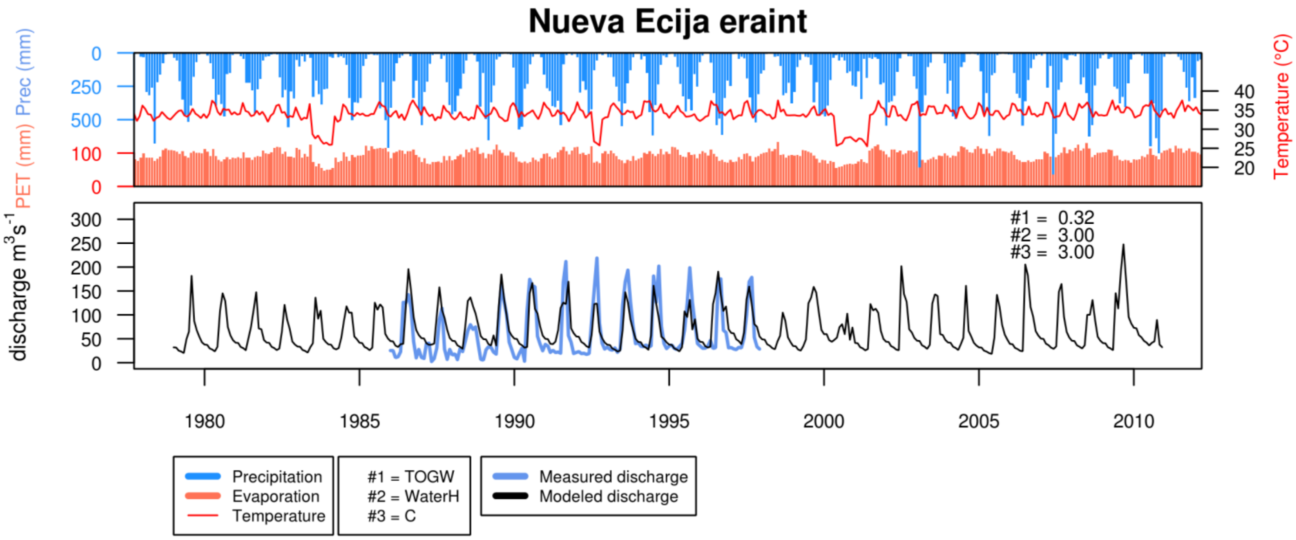
Table 7. VE values for each province.

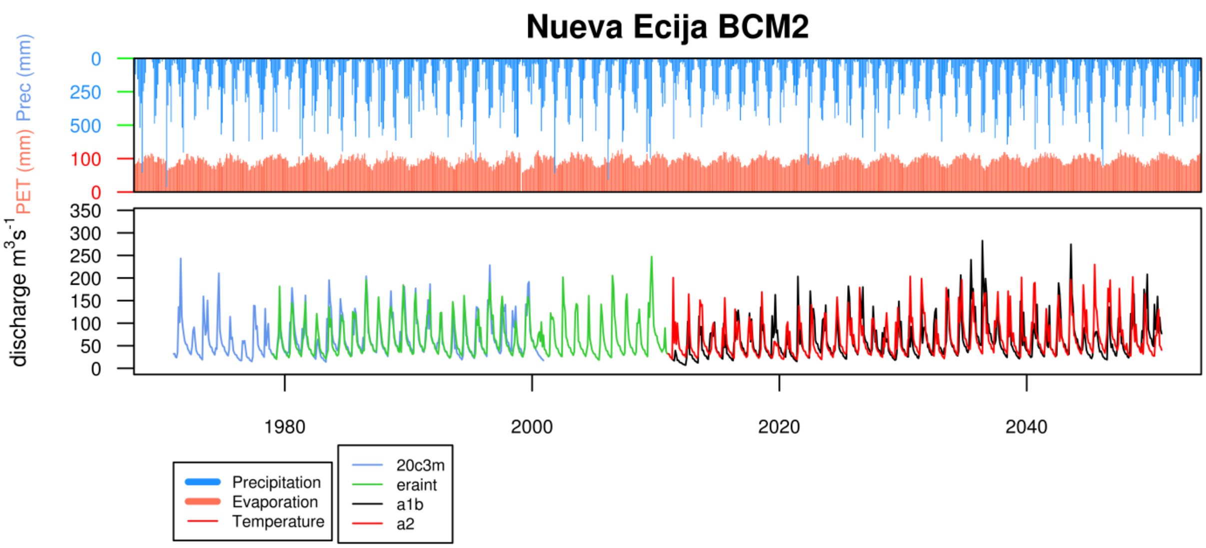
GCM - 20C3M	Ilocos	Cagayan	Nueva Vizcaya	Isabela	Pampanga	Nueva Ecija	Bicol
Observed vs ERAINT	0.77488	0.97130	0.04333	0.82026	-0.00094	0.78934	0.65752
ERAINT vs BCM2	0.91663	0.89395	0.00000	0.93751	0.87406	0.98063	0.00000
ERAINT vs CNCM3	0.95526	0.89801	-0.17202	0.95544	0.85047	0.99452	0.93509
ERAINT vs MPEH5	0.90037	0.93650	-0.17202	0.97683	0.94653	0.94322	0.93509
GCM - 20C3M	**Mindoro**	**Capiz**	**Leyte**	**Zamboanga**	**Bukidnon**	**Sultan Kudarat**	**Agusan del Sur**
Observed vs ERAINT	0.77842	0.97853	0.63853	0.59026	0.80078	0.66147	0.73951
ERAINT vs BCM2	0.85559	0.97255	0.97093	0.77151	0.92974	0.55872	0.90346
ERAINT vs CNCM3	0.82206	0.97423	0.97093	0.89734	0.94206	0.55872	0.87657
ERAINT vs MPEH5	0.27933	0.84459	0.95425	0.84852	0.87601	0.76963	0.99533

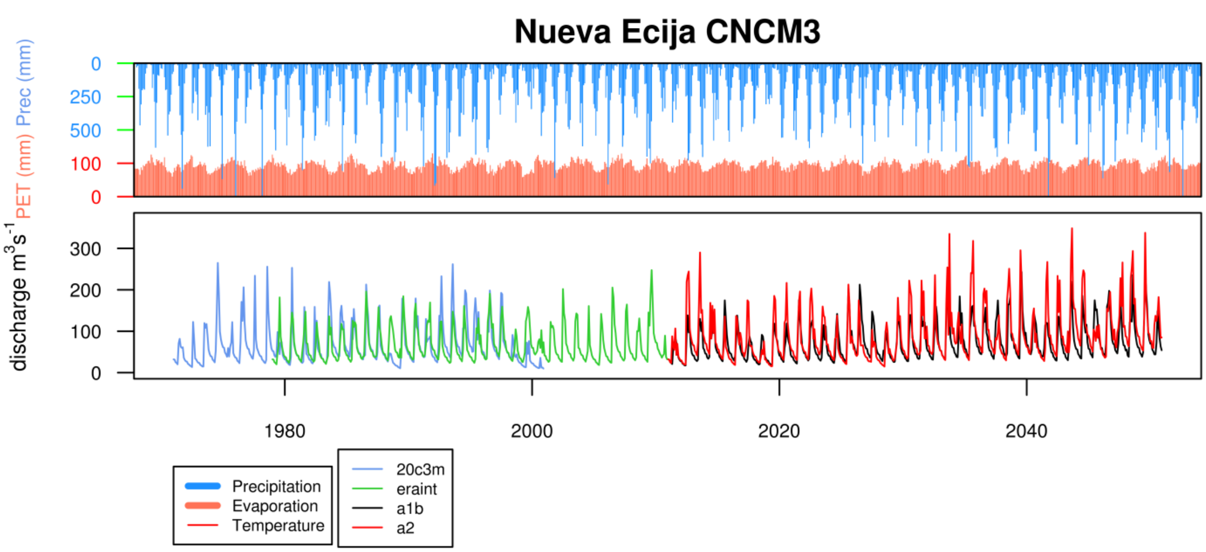
Most of the rivers used in the study for calibration showed negative NSE values but high VE values. The low to negative values of NSE indicate poor performance of the model to reproduce the discharge of rivers using historical climate data. Low efficiency values may be caused by one of the following reasons 1) the model was not able to capture the actual river setting due to coarse interpolation of climate data, or 2) errors in calibration due to incorrect measurement of the observed discharge data. The comparison of ERAINT with the 20C3M scenario of the GCMs also showed poor efficiency.

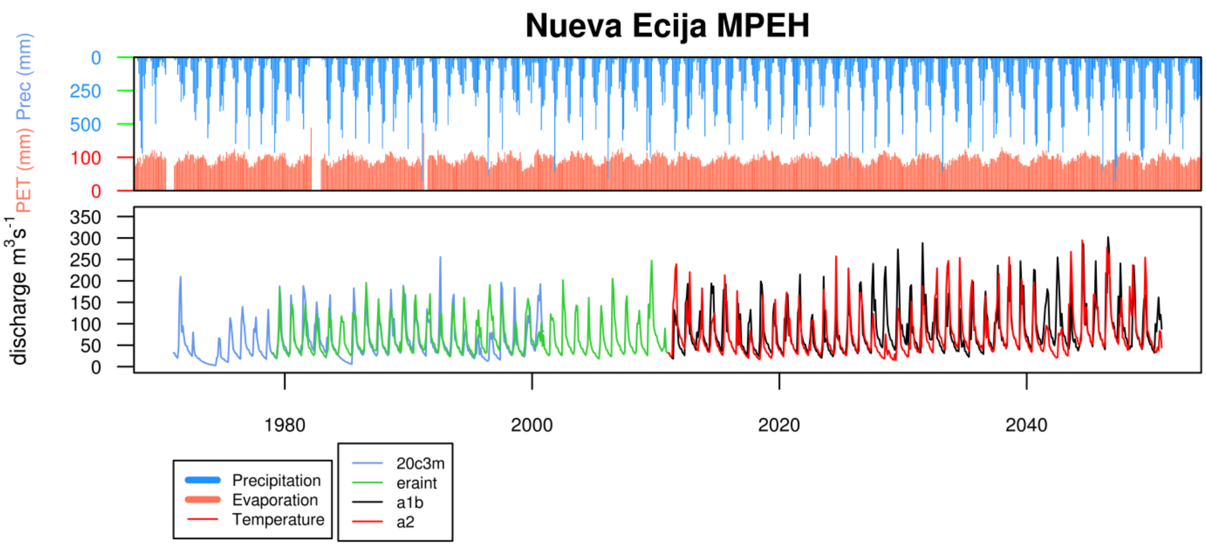
3.2 Discharge Projection

Ten hydrographs were produced for each river in this study as shown in Figure 8. The upper graph shows the precipitation (top), temperature (middle) and potential evapotranspiration (bottom), while the lower graph shows the hydrographs produced for each GCM. Figure 8a shows the hydrographs of the simulated past discharge using ERAINT (black) and the hydrograph of the median monthly observed data (blue). Figures 8b, 8c and 8d show the hydrographs of the simulations using ERAINT (green), 20C3M (blue), A1B (black) and A2 (red). Based from the hydrographs of the simulated and actual discharges, the model generally underestimated the peak discharges. Nonetheless, the model was able to capture the periods of peak discharges and simulate the relative changes in river discharges over specific time periods.


Nueva Ecija eraint
Prec (mm)
PET (mm)
discharge m³s⁻¹
Temperature (°C)
#1 = 0.32
#2 = 3.00
#3 = 3.00
Precipitation
Evaporation
Temperature
#1 = TOGW
#2 = WaterH
#3 = C
Measured discharge
Modeled discharge


Nueva Ecija BCM2
Prec (mm)
PET (mm)
discharge m³s⁻¹
Precipitation
Evaporation
Temperature
20c3m
eraint
a1b
a2


Nueva Ecija CNCM3
Prec (mm)
PET (mm)
discharge m³s⁻¹
Precipitation
Evaporation
Temperature
20c3m
eraint
a1b
a2

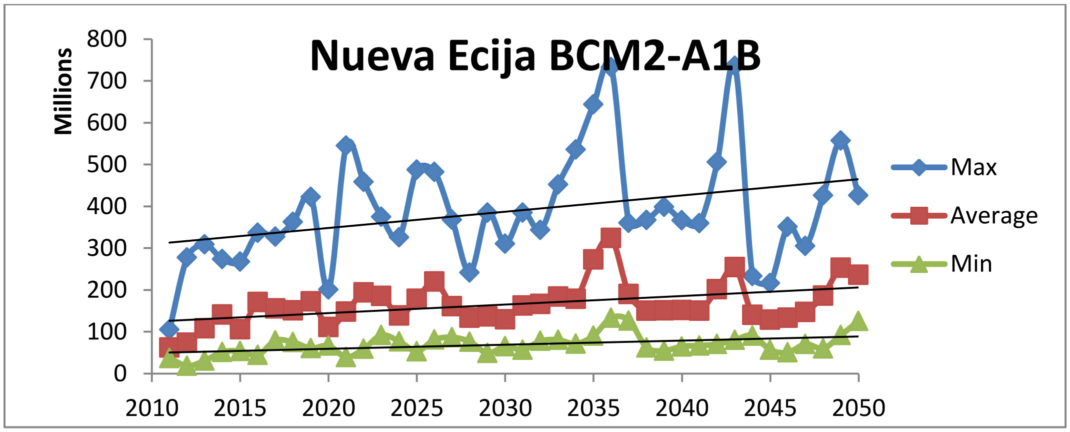


Figures 8a-d.Graphs of STREAM output.

3.3 Future Trends Observed

The maximum, average and minimum discharges were computed for the years 2011-2050 for both climate scenarios, A1B and A2.The general trends of the discharges were examined through slope computation. Figure 9 shows the discharge output of the model for Nueva Ecija BCM2-A1B. The trendlines of the graphs show that the discharge is generally increasing, as also implied by the positive slope. The observed increasing trend in the discharges is significant, as indicated by p-values less than 0.1. The results suggest that the long-term trend of increasing mean discharge will continue throughout the twenty-first century. The discharge steadily increases towards year 2050 and there is also an observed increasing variation in the min/max discharge. This is in accordance with a previous climate change vulnerability assessment by Jose and Cruz (1999), which suggested that the expected rise in temperature in the future may not be a significant factor in runoff variability in particular major reservoirs in the Philippines.

(a)



(b)

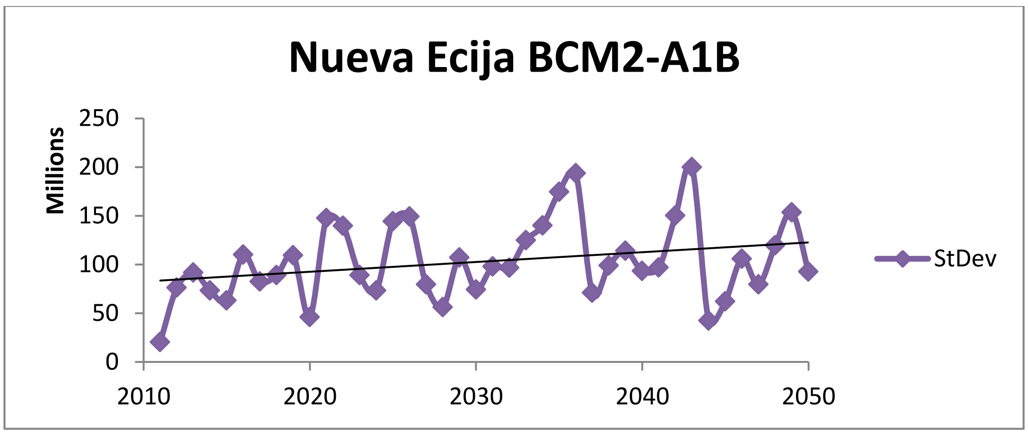


Figure 9.Plots of the (a) maximum, average, minimum discharges and the (b) standard deviation of Nueva Ecija BCM2-A1B.

Table 6.Computation of the general trend of projection of river discharge for Nueva Ecija using BCM2-A1B for years 2011-2050.

NUEVA ECIJA		slope	se(slope)	T stat	p-value
BCM2	A1B	3888360.04	1737978.8	2.23728853	0.03121072
		2039010.29	630540.333	3.23375077	0.00252929
		972062.542	294828.315	3.29704608	0.00212532
		1001414.81	532993.989	1.87884822	0.06795207

4. Conclusion and Recommendations

This study used STREAM to simulate projections of river discharge. The model was able to capture the trend of the peak discharges but the efficiency of the model was found to be below satisfactory. This suggests that the model can be useful in determining the discharge patterns for future climate projections. However, further adjustments should be made, i.e. modification of STREAM with respect to the Philippines' setting,in order to increase the robustness of the model and capture the actual discharge better. It could also be worth trying to calibrate STREAM using the 20C3Mscenarios of the GCMs. A better projection of the variations of monthly and future river discharges will be useful for the planning and management of agriculture, irrigation and hydropower production in the country.

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6. Appendix

Future Trend Statistical Analysis

ILOCOS							
			slope	STEYX	se(slope)	T stat	p-value
BCM2	A1B	Minimum	6085277	1.43E+08	1961420	3.102485	0.003611
		Average	1893265	35216991	482379.3	3.924846	0.000353
		Maximum	5747.095	330102.4	4521.527	1.271052	0.211436
		Standard Deviation	1891969	47883324	655874.4	2.884651	0.006422
	A2	Minimum	1869100	2.45E+08	3355915	0.556957	0.580823
		Average	707171.1	55355557	758224.2	0.932668	0.35688
		Maximum	-15443.8	854252.9	11701	-1.31987	0.194776
		Standard Deviation	894831.5	75044937	1027916	0.870529	0.389477
CNCM3	A1B	Minimum	3641727	1.22E+08	1665107	2.187083	0.034961
		Average	945515.7	32101487	439705.1	2.15034	0.037954
		Maximum	-7483.06	785134	10754.25	-0.69582	0.490774
		Standard Deviation	1162944	38387281	525803.8	2.211745	0.033072
	A2	Minimum	7198970	2.21E+08	3023691	2.380855	0.022389
		Average	1847604	56960372	780205.9	2.368098	0.02307
		Maximum	48953.94	4581416	62753.24	0.780102	0.440163
		Standard Deviation	2092357	74764661	1024077	2.043163	0.048016
MPEH5	A1B	Minimum	7198970	2.21E+08	3023691	2.380855	0.022389
		Average	1847604	56960372	780205.9	2.368098	0.02307
		Maximum	48953.94	4581416	62753.24	0.780102	0.440163
		Standard Deviation	2092357	74764661	1024077	2.043163	0.048016
	A2	Minimum	1036469	2.31E+08	3164611	0.327519	0.745073
		Average	657234.1	58741503	804602.6	0.816843	0.41911
		Maximum	-11815.6	945723.6	12953.9	-0.91213	0.367451
		Standard Deviation	658735.5	73605230	1008196	0.65338	0.517445

CAGAYAN							
			slope	STEYX	se(slope)	T stat	p-value
BCM2	A1B	Minimum	20433885	1E+09	13722770	1.48905	0.144728
		Average	18827209	4.64E+08	6355000	2.962582	0.005239
		Maximum	12473816	4.82E+08	6597826	1.890595	0.066322
		Standard Deviation	2761139	2.93E+08	4012350	0.68816	0.495532
	A2	Minimum	36652634	9.94E+08	13612134	2.692644	0.010487
		Average	24205246	6.5E+08	8900695	2.719478	0.009802
		Maximum	16437379	5.1E+08	6986258	2.352816	0.023911
		Standard Deviation	5552252	2.61E+08	3581553	1.550236	0.129374
CNCM3	A1B	Minimum	36350651	9.75E+08	13357006	2.721467	0.009753
		Average	21510845	5.77E+08	7897626	2.72371	0.009698
		Maximum	14783630	5.75E+08	7877689	1.876646	0.068262
		Standard Deviation	7368976	2.88E+08	3942000	1.869349	0.069295
	A2	Minimum	71207055	1.77E+09	24301203	2.930186	0.005704
		Average	47241563	7.46E+08	10222770	4.621209	4.3E-05
		Maximum	35664020	7.2E+08	9857700	3.617884	0.000861
		Standard Deviation	12195658	5.83E+08	7989885	1.526387	0.135195
MPEH5	A1B	Minimum	43970618	1.12E+09	15339595	2.866478	0.006732
		Average	28287339	6.83E+08	9358336	3.022689	0.004469
		Maximum	18936063	7.52E+08	10294517	1.839432	0.073674
		Standard Deviation	6723879	3.63E+08	4968686	1.353251	0.183972
	A2	Minimum	4533807	9.37E+08	12836873	0.353186	0.725901
		Average	12711614	6.42E+08	8790455	1.44607	0.156356
		Maximum	13420366	6.18E+08	8460722	1.586196	0.120982
		Standard Deviation	-1133786	3.25E+08	4445498	-0.25504	0.800066

ISABELA							
			slope	STEYX	se(slope)	T stat	p-value
BCM2	A1B	Minimum	665342.2	19753589	270571.7	2.459023	0.018598
		Average	516845.4	10077353	138033	3.744361	0.000598
		Maximum	298766.2	10899012	149287.5	2.00128	0.052541
		Standard Deviation	113787.6	7071335	96858.52	1.174781	0.247392
	A2	Minimum	1015113	19479147	266812.6	3.804593	0.000502
		Average	580392	12880606	176430.1	3.289643	0.002169
		Maximum	330073	10521347	144114.5	2.290352	0.027641
		Standard Deviation	192963.5	6944730	95124.36	2.028539	0.049556
CNCM3	A1B	Minimum	860558.6	19065277	261143.7	3.295346	0.002135
		Average	513841.7	12089938	165600.1	3.102908	0.003607
		Maximum	264119.6	13508341	185028.4	1.427454	0.161616
		Standard Deviation	190282.4	6473034	88663.38	2.146122	0.038312
	A2	Minimum	1629020	39201098	536951	3.033833	0.004339
		Average	1027697	15754365	215793	4.762423	2.78E-05
		Maximum	696315.3	13772782	188650.5	3.691033	0.000698
		Standard Deviation	337233.2	13624212	186615.5	1.807101	0.078669
MPEH5	A1B	Minimum	1121889	23758372	325426.6	3.447442	0.001398
		Average	685771.7	14751287	202053.5	3.394011	0.001623
		Maximum	379113	18296893	250618.9	1.512708	0.138627
		Standard Deviation	222640	9832227	134675.4	1.65316	0.106538
	A2	Minimum	251100.6	20808891	285026.6	0.880973	0.383871
		Average	343547.9	13651739	186992.6	1.837227	0.074006
		Maximum	311221.6	14256393	195274.7	1.593763	0.119274
		Standard Deviation	-35436.2	8439244	115595.2	-0.30655	0.760856

NUEVA VIZCAYA							
			slope	STEYX	se(slope)	T stat	p-value
BCM2	A1B	Minimum	9463001	1.82E+08	2496156	3.79103	0.000522
		Average	4270836	67919633	930318.7	4.590724	4.73E-05
		Maximum	1265304	37108431	508287	2.48935	0.017292
		Standard Deviation	2640307	74329485	1018117	2.593325	0.013424
	A2	Minimum	7814281	2.11E+08	2895553	2.698718	0.010328
		Average	3888126	88541412	1212782	3.205955	0.002729
		Maximum	1129152	43982702	602446.2	1.874278	0.068595
		Standard Deviation	2183378	78859761	1080169	2.021329	0.050331
CNCM3	A1B	Minimum	6702777	1.37E+08	1873279	3.578099	0.000965
		Average	3389474	65816808	901515.5	3.759752	0.000572
		Maximum	972154.4	51998813	712245.7	1.364914	0.180308
		Standard Deviation	1813700	49000870	671181.8	2.702248	0.010237
	A2	Minimum	15781598	2.59E+08	3549270	4.446435	7.35E-05
		Average	7372822	97805452	1339675	5.503441	2.73E-06
		Maximum	2860927	62159139	851415.2	3.360202	0.001784
		Standard Deviation	4219031	1.04E+08	1427149	2.956266	0.005327
MPEH5	A1B	Minimum	10575897	2.27E+08	3111774	3.398671	0.001602
		Average	5106827	83682394	1146227	4.455338	7.16E-05
		Maximum	1835302	77218581	1057690	1.735199	0.09081
		Standard Deviation	2901171	91134641	1248303	2.324093	0.025566
	A2	Minimum	2438020	2.22E+08	3041138	0.80168	0.427723
		Average	2336132	95911299	1313730	1.778243	0.083366
		Maximum	1189919	60220550	824861.7	1.442568	0.157335
		Standard Deviation	665867.2	78688227	1077820	0.617791	0.540398

PAMPANGA							
			slope	STEYX	se(slope)	T stat	p-value
BCM2	A1B	Minimum	1194600	83546925	1144371	1.043892	0.303131
		Average	684699.8	20167641	276243.1	2.478613	0.017745
		Maximum	102453	3352797	45924.42	2.230904	0.031667
		Standard Deviation	520288.4	24052136	329450.4	1.579262	0.122565
	A2	Minimum	1716334	64050367	877320	1.956337	0.057805
		Average	363863.6	13635598	186771.5	1.948175	0.058808
		Maximum	48392.88	2569704	35198.12	1.374871	0.177225
		Standard Deviation	529836.8	18129356	248324	2.133651	0.039387
CNCM3	A1B	Minimum	2660604	67755247	928067	2.866823	0.006726
		Average	880247.8	14452715	197963.8	4.446508	7.35E-05
		Maximum	128710.4	2232161	30574.68	4.209705	0.000151
		Standard Deviation	836267.4	19496098	267044.8	3.131563	0.003339
	A2	Minimum	2684459	1.01E+08	1385348	1.937751	0.060111
		Average	1049750	27065112	370720.2	2.83165	0.007365
		Maximum	168849.7	4216088	57749.21	2.923845	0.005799
		Standard Deviation	750091.2	36279496	496932.8	1.509442	0.139457
MPEH5	A1B	Minimum	2144327	70860220	970596.9	2.209287	0.033256
		Average	609148.7	21162496	289870	2.101455	0.042287
		Maximum	97849.61	3319217	45464.46	2.152222	0.037796
		Standard Deviation	564426.6	23001201	315055.4	1.791515	0.081177
	A2	Minimum	1455339	88648878	1214254	1.198545	0.238126
		Average	638044.9	25058910	343240.5	1.858886	0.070801
		Maximum	89502.51	3380540	46304.42	1.932915	0.060724
		Standard Deviation	487131.4	27734629	379890.8	1.282293	0.207507

NUEVA ECIJA							
			slope	STEYX	se(slope)	T stat	p-value
BCM2	A1B	Minimum	3888360	1.27E+08	1737979	2.237289	0.031211
		Average	2039010	46033763	630540.3	3.233751	0.002529
		Maximum	972062.5	21524486	294828.3	3.297046	0.002125
		Standard Deviation	1001415	38912212	532994	1.878848	0.067952
	A2	Minimum	3902711	88274602	1209128	3.227708	0.002571
		Average	1651231	27129323	371599.7	4.443574	7.42E-05
		Maximum	728470.9	11655735	159652.6	4.562849	5.15E-05
		Standard Deviation	863837.9	26371629	361221.3	2.391437	0.021838
CNCM3	A1B	Minimum	5751722	93386042	1279141	4.496551	6.31E-05
		Average	2567714	28250307	386954.2	6.635705	7.68E-08
		Maximum	1235314	14088199	192970.9	6.401554	1.6E-07
		Standard Deviation	1262129	28837215	394993.3	3.195316	0.002809
	A2	Minimum	6709741	1.7E+08	2327289	2.883072	0.006449
		Average	3633090	52341396	716938.2	5.067509	1.08E-05
		Maximum	1907492	27053147	370556.3	5.147645	8.36E-06
		Standard Deviation	1402845	57764622	791222	1.773011	0.084243
MPEH5	A1B	Minimum	4869032	1.13E+08	1543941	3.153638	0.003146
		Average	2146756	41509460	568569.4	3.775716	0.000546
		Maximum	1224746	21373835	292764.8	4.18338	0.000163
		Standard Deviation	947687	36991793	506689.3	1.870351	0.069152
	A2	Minimum	2494552	1.57E+08	2148833	1.160887	0.252929
		Average	2014662	55235789	756583.7	2.662841	0.011299
		Maximum	1166309	21950200	300659.5	3.87917	0.000403
		Standard Deviation	628427.2	48881356	669544.8	0.938589	0.35387

BICOL							
			slope	STEYX	se(slope)	T stat	p-value
BCM2	A1B	Minimum	2740.951	3434632	47045.34	0.058262	0.953845
		Average	-6708.2	1315527	18019.22	-0.37228	0.711753
		Maximum	-1306.68	987411.3	13524.91	-0.09661	0.923542
		Standard Deviation	-3577.06	891748.8	12214.59	-0.29285	0.771229
	A2	Minimum	67603.67	3054645	41840.53	1.615746	0.114423
		Average	41489.47	1297347	17770.21	2.334777	0.024939
		Maximum	31431.09	891558.9	12211.99	2.57379	0.014083
		Standard Deviation	12697.53	863033.8	11821.27	1.074126	0.28954
CNCM3	A1B	Minimum	71176.8	3118054	42709.06	1.666551	0.103827
		Average	36976.7	1265068	17328.07	2.133919	0.039364
		Maximum	20145.89	887988	12163.08	1.656315	0.105894
		Standard Deviation	18058.91	827638.3	11336.45	1.592996	0.119446
	A2	Minimum	-105009	4138556	56687.23	-1.85242	0.071745
		Average	2488.723	1108100	15178.03	0.163969	0.870625
		Maximum	6085.42	962917.9	13189.42	0.461386	0.647152
		Standard Deviation	-33781.4	1207401	16538.18	-2.04263	0.048072
MPEH5	A1B	Minimum	-38846.3	3459975	47392.48	-0.81967	0.417515
		Average	17666.74	1178073	16136.47	1.094833	0.280481
		Maximum	14043.26	943786.9	12927.37	1.08632	0.284181
		Standard Deviation	-11990.1	976146.8	13370.62	-0.89675	0.3755
	A2	Minimum	29241.82	3648741	49978.06	0.585093	0.561944
		Average	17556.23	1243277	17029.59	1.030925	0.309093
		Maximum	18055.74	1121414	15360.4	1.175473	0.247118
		Standard Deviation	3018.608	1082683	14829.88	0.203549	0.839792

MINDORO							
			slope	**STEYX**	**se(slope)**	**T stat**	**p-value**
BCM2	A1B	Minimum	2123536	72870417	998131.2	2.127512	0.039926
		Average	1615795	24497534	335551.2	4.815347	2.36E-05
		Maximum	708359.1	21796537	298554.7	2.372628	0.022826
		Standard Deviation	534831.3	26281213	359982.8	1.485713	0.145605
	A2	Minimum	2233445	1.52E+08	2081924	1.072779	0.290136
		Average	1738016	27791448	380669.1	4.565688	5.1E-05
		Maximum	904479.9	34642209	474506.3	1.90615	0.064215
		Standard Deviation	404396.9	56924236	779710.9	0.51865	0.607012
CNCM3	A1B	Minimum	1598441	1.33E+08	1816238	0.880084	0.384346
		Average	1682407	36162183	495325.9	3.396566	0.001612
		Maximum	990958.6	30304753	415094.7	2.387308	0.022052
		Standard Deviation	153453.9	47945489	656725.9	0.233665	0.816499
	A2	Minimum	2336000	1.52E+08	2085364	1.120188	0.269664
		Average	1798991	28602640	391780.2	4.591838	4.71E-05
		Maximum	921636.6	35314654	483717	1.905322	0.064326
		Standard Deviation	456544.6	57178628	783195.4	0.582926	0.563387
MPEH5	A1B	Minimum	2168816	83479652	1143450	1.896731	0.065484
		Average	1773271	28927547	396230.6	4.475352	6.73E-05
		Maximum	715905.6	22254294	304824.7	2.348581	0.024149
		Standard Deviation	600930.6	32457577	444582.6	1.351674	0.184471
	A2	Minimum	3167274	1.06E+08	1452267	2.180917	0.035448
		Average	2449222	24759131	339134.4	7.221983	1.23E-08
		Maximum	750878.5	19001112	260264.8	2.885056	0.006416
		Standard Deviation	1020654	42743472	585472.1	1.743302	0.089368

CAPIZ							
			slope	STEYX	se(slope)	T stat	p-value
BCM2	A1B	Minimum	1762530	66938524	916880.1	1.922312	0.062087
		Average	762744.2	22978496	314744.4	2.423377	0.020248
		Maximum	562027.6	15997976	219129.8	2.564816	0.014396
		Standard Deviation	275599.5	21546885	295135.1	0.933808	0.356299
	A2	Minimum	-1133152	1.09E+08	1494361	-0.75829	0.452958
		Average	-454020	33050623	452705.8	-1.0029	0.322251
		Maximum	-292.286	26265016	359761	-0.00081	0.999356
		Standard Deviation	-526167	37397527	512246.8	-1.02717	0.310833
CNCM3	A1B	Minimum	-1636606	1.04E+08	1430940	-1.14373	0.259891
		Average	-571286	27670976	379018.9	-1.50727	0.140009
		Maximum	-44547.7	24381525	333962.2	-0.13339	0.894588
		Standard Deviation	-673987	35775789	490033.3	-1.37539	0.177065
	A2	Minimum	-1044735	1.07E+08	1471792	-0.70984	0.482138
		Average	-365562	33445682	458117.1	-0.79797	0.429848
		Maximum	41963.43	26606265	364435.2	0.115146	0.908935
		Standard Deviation	-506182	37349935	511594.9	-0.98942	0.328717
MPEH5	A1B	Minimum	744255.9	83073469	1137886	0.654069	0.517006
		Average	1630289	29831430	408611.4	3.989828	0.000291
		Maximum	1203352	20836616	285406.3	4.216276	0.000148
		Standard Deviation	-6162.95	26399398	361601.7	-0.01704	0.986491
	A2	Minimum	1088569	97898920	1340955	0.811786	0.42197
		Average	1211799	22678809	310639.5	3.900981	0.000378
		Maximum	811287.9	18136749	248425.3	3.265722	0.002317
		Standard Deviation	190221.6	29613782	405630.2	0.468953	0.641782

LEYTE							
			slope	STEYX	se(slope)	T stat	p-value
BCM2	A1B	Minimum	-41060.5	3552118	48654.59	-0.84392	0.403997
		Average	-36704.3	1134100	15534.16	-2.36281	0.023358
		Maximum	-15315.1	1053401	14428.79	-1.06143	0.295196
		Standard Deviation	-7173.18	1159019	15875.49	-0.45184	0.653953
	A2	Minimum	-148084	3383176	46340.53	-3.19557	0.002807
		Average	-62008.1	1478861	20256.47	-3.06115	0.004034
		Maximum	-38824.4	1117110	15301.45	-2.5373	0.015396
		Standard Deviation	-33510.9	1142067	15643.28	-2.14219	0.038648
CNCM3	A1B	Minimum	18318.59	3313785	45390.06	0.403582	0.688783
		Average	-18272.7	1319264	18070.41	-1.0112	0.318319
		Maximum	-16645.5	1002132	13726.55	-1.21265	0.232749
		Standard Deviation	8312.334	970125.9	13288.15	0.625545	0.535353
	A2	Minimum	-150429	3438186	47094.02	-3.19422	0.002818
		Average	-61489.1	1492053	20437.17	-3.00869	0.004638
		;	-36517.7	1162940	15929.2	-2.2925	0.027504
		Standard Deviation	-34227.8	1151243	15768.97	-2.17058	0.036279
MPEH5	A1B	Minimum	-58691.8	3162176	43313.42	-1.35505	0.183403
		Average	-12468.7	1578939	21627.28	-0.57653	0.567659
		Maximum	-9617.7	1027350	14071.97	-0.68347	0.49846
		Standard Deviation	-15572.5	938819.4	12859.33	-1.21099	0.233378
	A2	Minimum	-98300.7	3164154	43340.5	-2.2681	0.029091
		Average	-30506.5	1408049	19286.53	-1.58175	0.121995
		Maximum	-7043.81	894458.8	12251.71	-0.57492	0.568731
		Standard Deviation	-28168.9	841002.7	11519.5	-2.44532	0.019218

ZAMBOANGA							
			slope	STEYX	se(slope)	T stat	p-value
BCM2	A1B	Minimum	-66420.5	5721179	78364.97	-0.84758	0.401979
		Average	-8890.75	958871.4	13133.99	-0.67693	0.502553
		Maximum	-3562.64	395054	5411.191	-0.65838	0.514261
		Standard Deviation	-10078	1792439	24551.65	-0.41048	0.683759
	A2	Minimum	-7158.52	10634853	145669.2	-0.04914	0.961063
		Average	-24135.8	1280298	17536.68	-1.37631	0.176784
		Maximum	-10343.1	816468.3	11183.45	-0.92486	0.360874
		Standard Deviation	-3362.88	3532476	48385.54	-0.0695	0.944955
CNCM3	A1B	Minimum	-174838	9136771	125149.5	-1.39703	0.17051
		Average	-65470.1	1209014	16560.29	-3.95344	0.000324
		Maximum	-13216.7	671562.3	9198.621	-1.43682	0.158953
		Standard Deviation	-53961.1	3070437	42056.83	-1.28305	0.207244
	A2	Minimum	-174838	9136771	125149.5	-1.39703	0.17051
		Average	-65470.1	1209014	16560.29	-3.95344	0.000324
		Maximum	-13216.7	671562.3	9198.621	-1.43682	0.158953
		Standard Deviation	-53961.1	3070437	42056.83	-1.28305	0.207244
MPEH5	A1B	Minimum	-174838	9136771	125149.5	-1.39703	0.17051
		Average	-65470.1	1209014	16560.29	-3.95344	0.000324
		Maximum	-13216.7	671562.3	9198.621	-1.43682	0.158953
		Standard Deviation	-53961.1	3070437	42056.83	-1.28305	0.207244
	A2	Minimum	-174838	9136771	125149.5	-1.39703	0.17051
		Average	-65470.1	1209014	16560.29	-3.95344	0.000324
		Maximum	-13216.7	671562.3	9198.621	-1.43682	0.158953
		Standard Deviation	-53961.1	3070437	42056.83	-1.28305	0.207244

BUKIDNON							
			slope	STEYX	se(slope)	T stat	p-value
BCM2	A1B	Minimum	1807.055	3516240	48163.15	0.037519	0.970267
		Average	-4872.04	923102.8	12644.06	-0.38532	0.702147
		Maximum	2909.54	487676.4	6679.872	0.435568	0.665614
		Standard Deviation	-2390.36	992636.7	13596.49	-0.17581	0.861379
	A2	Minimum	-175619	5270672	72194.21	-2.4326	0.019809
		Average	-84615.5	1451225	19877.93	-4.25676	0.000131
		Maximum	-29410	537532.4	7362.766	-3.99443	0.000287
		Standard Deviation	-37345	1437160	19685.28	-1.8971	0.065434
CNCM3	A1B	Minimum	-110900	4215165	57736.57	-1.92079	0.062284
		Average	-49453	1099648	15062.26	-3.28324	0.002208
		Maximum	-12025.5	494099.3	6767.849	-1.77685	0.083598
		Standard Deviation	-28790.4	1221557	16732.09	-1.72067	0.093446
	A2	Minimum	-174777	5356844	73374.55	-2.38198	0.02233
		Average	-86935.2	1513650	20732.98	-4.19309	0.000159
		Maximum	-30750.1	545779.5	7475.731	-4.11333	0.000201
		Standard Deviation	-37093.6	1436339	19674.02	-1.88541	0.067037
MPEH5	A1B	Minimum	-57462.9	3354093	45942.18	-1.25077	0.218667
		Average	148.3198	1382635	18938.43	0.007832	0.993792
		Maximum	12589.55	576617.5	7898.129	1.593991	0.119223
		Standard Deviation	-24290.1	1062245	14549.94	-1.66943	0.103251
	A2	Minimum	-17469.2	4182719	57292.14	-0.30492	0.762095
		Average	18502.13	1143533	15663.37	1.181235	0.24485
		Maximum	8099.436	584828.7	8010.601	1.01109	0.318369
		Standard Deviation	-9072.71	1377534	18868.56	-0.48084	0.633389

SULTAN KUDARAT							
			slope	STEYX	se(slope)	T stat	p-value
BCM2	A1B	Minimum	-493665	21431231	293551	-1.6817	0.100829
		Average	-224450	3523382	48260.98	-4.65075	3.93E-05
		Maximum	-21925.7	3475098	47599.62	-0.46063	0.647692
		Standard Deviation	-183171	8786094	120346.2	-1.52204	0.136279
	A2	Minimum	-416255	37803806	517811.8	-0.80387	0.42647
		Average	-191131	6499697	89028.59	-2.14685	0.03825
		Maximum	-65003	5456994	74746.33	-0.86965	0.389953
		Standard Deviation	-131487	13661479	187126	-0.70266	0.486548
CNCM3	A1B	Minimum	-748938	36033579	493564.4	-1.51741	0.13744
		Average	-275368	6958969	95319.39	-2.88889	0.006352
		Maximum	-62799.5	6408148	87774.62	-0.71546	0.478696
		Standard Deviation	-249951	12940058	177244.4	-1.41021	0.166612
	A2	Minimum	-443912	39085191	535363.3	-0.82918	0.412181
		Average	-204084	6870467	94107.16	-2.16864	0.036436
		Maximum	-74864.1	5619929	76978.11	-0.97254	0.336934
		Standard Deviation	-141509	14178735	194211	-0.72864	0.47069
MPEH5	A1B	Minimum	611595	40788894	558699.6	1.094676	0.280549
		Average	260258.7	6608706	90521.73	2.875096	0.006584
		Maximum	103167	5899767	80811.15	1.276643	0.209475
		Standard Deviation	138479.9	14138747	193663.3	0.715055	0.478946
	A2	Minimum	1109197	38828448	531846.7	2.085558	0.043786
		Average	517056.4	4500364	61643.04	8.387912	3.56E-10
		Maximum	159559.4	4528285	62025.48	2.572481	0.014129
		Standard Deviation	330139.5	12488959	171065.6	1.9299	0.061109

AGUSAN DEL SUR							
			slope	STEYX	se(slope)	T stat	p-value
BCM2	A1B	Minimum	-826621	24965672	341963.4	-2.41728	0.020543
		Average	-350132	6723190	92089.85	-3.80207	0.000506
		Maximum	-77762.5	4297981	58870.93	-1.3209	0.194435
		Standard Deviation	-233153	7556335	103501.7	-2.25265	0.030137
	A2	Minimum	-1136849	24858680	340497.9	-3.33878	0.001893
		Average	-442289	5890826	80688.68	-5.48142	2.93E-06
		Maximum	-204253	3739582	51222.35	-3.98757	0.000293
		Standard Deviation	-273253	7687786	105302.3	-2.59494	0.01337
CNCM3	A1B	Minimum	202774.9	26722899	366032.8	0.55398	0.582838
		Average	-143798	9813326	134416.5	-1.0698	0.29146
		Maximum	-88872.1	2563086	35107.48	-2.53143	0.015618
		Standard Deviation	53910.07	6522510	89341.07	0.603419	0.549815
	A2	Minimum	-1127689	25281416	346288.3	-3.2565	0.002376
		Average	-442435	10136200	138839	-3.18667	0.002876
		Maximum	-215292	3837976	52570.09	-4.09532	0.000213
		Standard Deviation	-273355	7714753	105671.6	-2.58683	0.01364
MPEH5	A1B	Minimum	-325716	28870501	395449.2	-0.82366	0.415272
		Average	-190158	10743702	147160.2	-1.29218	0.204098
		Maximum	-107845	3237650	44347.21	-2.43183	0.019845
		Standard Deviation	-81051.5	7238966	99154.62	-0.81743	0.418781
	A2	Minimum	-376548	29232707	400410.5	-0.9404	0.35295
		Average	-230299	11443920	156751.3	-1.4692	0.15001
		Maximum	-107845	5251402	71930.26	-1.4993	0.142059
		Standard Deviation	-81051.5	7238966	99154.62	-0.81743	0.418781

This report comes with a CD containing the following documents as part of the deliverables:

a. Observed streamflow data of the 14 river basins.

b. Discharge values from STREAM for the 14 river basins.

- ERAINT
- BCM2 (20C3M, A1B, A2)
- CNCM3 (20C3M, A1B, A2)
- MPEH5 (20C3M, A1B, A2)

c. Hydrographs of the discharge outputs.

AMICAF Analysis & Mapping of Impacts under Climate Change for Adaptation & Food Security