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Report

SWAT HYDROLOGICAL MODELING AND THE IMPACT OF CLIMATE AND LAND USE CHANGE ON THE YAQUE DEL NORTE, OZAMA, HAINA, AND NIZAO WATERSHEDS.

Riverside Technology, inc.
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FINAL REPORT:

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1.0 Executive Summary

1.1 Background

The Nature Conservancy (TNC) under the USAID-TNC Environmental Protection Program is implementing two Water Funds for the Nizao, Haina, and Ozama basins and the Yaque del Norte basin. The Water Fund is a financial mechanism to support the implementation of conservation practices in the basins to provide on a long-term basis, fresh, clean water to the end-users in the watersheds. In preparation for the establishment and development of the Water Funds in the Dominican Republic, TNC requested assistance from Riverside Technology, inc. (Riverside) to evaluate the impact of climate and land use changes in the water and sediment production in the Nizao, Haina, Ozama and Yaque del Norte basins. The results of this study will be used as guidance to propose changes in land use land cover that will improve the current hydrologic conditions of the basins and support adaptation for potential future climate changes.

1.2 Objective

The primary objective of this study was to analyze the changes in water and sediment production to potential future climate projections and land use land cover scenarios. The Soil and Water Assessment Tool (SWAT) was used to simulate the hydrologic and sediment response of the basins to different climate projections and land use land cover scenarios.

1.3 Approach

The approach taken to assess the impact of future climate and land use land cover changes was to:

- Select five climate change projections representative of the range of outputs from different climate models.
- Develop five future land use land cover maps representative of potential rules and conservation practices in the Dominican Republic.
- Calibrate the SWAT model using historical climate data and the most recent land use land cover map. The results from these models represent the baseline condition.
- Simulate the hydrologic and sediment response of each study basin using the calibrated SWAT model with the future land use land cover scenarios and the selected future climate projections.
- Compare the results of water yield, sediment yield, baseflow, and peakflow across all climate change projections and land use land cover scenarios including the baseline condition.

This approach led to the following four major tasks:

Task 1: Land Use Land Cover Modeling - This task was performed in collaboration with the stakeholders of the Dominican Republic. Riverside and TNC facilitated two on-site workshops to identify current concerns in the basins and propose rules to develop five future land use land cover scenarios. Riverside used the data gathered at the stakeholder workshops to simulate the spatial expansion of urban and agricultural lands over time. Additional rules were superimposed over the land use modeling results to reflect different management practices. The land use land cover scenarios modeled included Business-As-Usual, Best Management Practice, Conservation, Development, and Combination. The Combination scenario assumed conservation practices in the headwater sub-basins and development in the lower part of the basins.

Task 2 – Selection of climate model projections - Available climate model outputs for two emission scenarios (A2 and B1) and two future time periods (2046-2065 and 2081-2100) were assessed in this study. The assessment of the climate projections were performed by grouping all the available data into

a single population regardless of the emission scenarios and future time period. The main objective was to characterize the future climate over the next century understanding that some projections might occur sooner with greater greenhouse gas emissions or be more delayed with fewer emissions. A subset of FIVE climate change projections out of a population of 36 projections was used in this study to characterize the future climate. The selected projections belong to three climate zones representative of the change of climate conditions between the historical and the future periods. The climate zones are: Dry and Hot, Median, and Wet and Warm. The Dry and Hot zone represents a reduction of precipitation and increase in temperature on an annual basis while the Wet and Warm represents an increase in precipitation and a slightly lower increase in temperature. Two projections were selected in the Dry and Hot climate zone, one projection in the Median zone and two more in the Wet and Warm zone. The reduction of precipitation is expected to reduce the water yield, peak flow and sediment yield in the basins while the opposite effect is expected to occur with projections in the Wet and Warm zones. The Median zone represents an intermediate climate condition between the other two zones.

Task 3 – SWAT Model Calibration - Historical hydroclimatologic data available within and around the study basins were first quality controlled. The SWAT model was configured for each study basin using the most recent land use land cover and soil maps and the quality controlled climate data. The models were calibrated to match the long-term water volumes observed at the streamflow gages. The calibrated model parameters were used to project water and sediment production in the basins using the modeled land use land cover scenarios and the selected climate change projections as explained in Task 4.

Task 4 - Hydrologic Simulation Using Future Land Use Land Cover Scenarios and Climate Projections - Five different SWAT models were setup for each study basin to simulate the impact of climate change and land use in the water and sediment yield. Each model used a different land use land cover scenario. For the 2003 land use land cover, a total of five climate change projections were input. For the other land use land cover scenarios, the impact of climate change was evaluated with three climate projections. Each projection is representative of a climate zone (Dry and Hot, Median, Wet and Warm). The impacts of the future land use land cover scenarios and climate projections were evaluated through the analysis of the annual change in water yield, sediment yield, peak flow, and baseflow.

1.4 Findings

The land use land cover modeling results reflect the land use rules proposed by the stakeholders in the Dominican Republic. These rules do not represent current policies and regulations, but they do reflect hypothetical conditions that might occur under each of the scenarios. The conservation and development scenarios represent the most extreme conditions. For conservation, the main criterion was to impose conservation practices regardless of the potential urban growth and development in the basins. The opposite was assumed with the development scenario, where development was the major driver to build the scenario.

The pool of 36 climate change projections from which five projections were selected showed a broad variability in projected future precipitation and temperature in the study basins. All projections showed an increase in mean annual temperature from just over 1^{o} to 3.5^{o} Celsius with respect to the historical mean. Meanwhile, the average annual percent change in precipitation with respect to the historical varies from about -40% to +20%. The monthly percent changes in precipitation do not show a consistent seasonality among all the projections.

The calibration of the hydrologic models was limited to some extent by the availability and quality of the data. The lack of correlation between the streamflow and the precipitation data seems to be, in part,

the result of the sparse precipitation station network. Assumptions were made to account for irrigation in the basins. Reservoir modeling was out of the scope of the project.

The hydrologic response of the basins to the combined change of land use land cover and climate is the result of complex processes. The hydrologic responses are not a linear result of the inputs. Each basin has particular storage characteristics that are the result of the soil drainage properties and land cover type. The sequence and frequency of precipitation events significantly impact the results. The antecedence moisture conditions of the soil will affect the amount of water that will runoff in the basin due to a given precipitation event. Additionally, the timing of the events in relation to the stage of the vegetation canopy affects the erosion of the soil and the simulated sediment yield.

The land use land cover scenarios that produce more water and less sediment are considered the best scenarios to adapt to future climates. In general, the change of land use type from forest to agriculture produces more water yield and more sediment.

For the Haina basin, the Combination and Development scenarios tend to produce the largest amount of water yield. Meanwhile, the Conservation and Best Management Practice scenario tend to produce the least amount of sediment. In depth analysis of the land use land cover changes at the sub-basin scale can provide guidance to design an intermediate land use land cover scenario more favorable to an increase in water yield and a reduction in sediment together.

For the Nizao basin, the Combination scenario produces more water yield in the form of baseflow and the Conservation scenario produces the minimum sediment yield. As in the Haina basin, an intermediate scenario that combines the changes of the Combination and Conservation scenarios might be more appropriate to simultaneously increase water yield and reduce sediment.

For the Ozama basin, the Conservation land use land cover scenario is more favorable with respect to reductions in sediment yield and increases in water yield and baseflow under future climates.

For the Yaque del Norte basin, the Best Management Practice scenario produces the largest water yield in the form of baseflow and the lowest sediment yield.

It is recommended to extend this study to include models for irrigation diversions, return flows, and reservoir regulation. Regulation modeling will allow water users to assess the impact of land use and climate change on water availability at a specific time and point in the watershed.

2.0 Introduction

Riverside supported TNC under the USAID-TNC Environmental Protection Program to evaluate the impact of projected climate change and potential land use changes in the hydrologic and sediment regimes of the Haina, Nizao, Ozama, and Yaque del Norte watersheds in the Dominican Republic.

Land use and climate changes affect hydrologic regimes and sediment production. Assessing and quantifying the impacts of land use and climate changes are critical activities for many watersheds and water managers worldwide. This assessment requires complex modeling activities to simulate the future long-term effects of climate change scenarios and possible future land use land cover (LULC) projections that might mitigate and reduce the severity of the impacts of climate change on water production, water availability and sediment production.

Watersheds provide hydrologic services to society including water for human consumption, domestic use, irrigation, hydropower production, as well as plant and fish habitat. The potential effects of global climate change in the Dominican Republic are of concern to decision makers. This study provides scientific results to support the decision makers in the development of policies that will benefit the conservation of the basins and the water users of the watersheds. In this regard, the Dominican Republic is increasing its capacity to adapt to the impacts of climate change through the initiation of a Water Fund Platform. Water users will potentially invest in the conservation of the watersheds following the policies proposed by the decision makers. The results of this project will be used as guidelines to develop the Water Fund plans and activities.

The main objective of this project is to quantify the impact of climate and land use changes in the water yield and sediment load using the Soil and Water Assessment Tool (SWAT). The specific objectives of this project include:

1. To analyze and quality control the historical climate data in the Haina, Nizao, Ozama and Yaque del Norte basins for use in hydrologic models.
2. To configure and calibrate the Soil and Water Assessment Tool (SWAT) for the four study basins using the most recent land use land cover data and the quality controlled historical climate data.
3. To conduct a stakeholder workshop in the Dominican Republic to delineate the rules under which the land use land cover projections will be modeled.
4. To model five land use land cover scenarios based on the rules delineated by stakeholders in the Dominican Republic.
5. To select five climate change projections representative of the future climate to evaluate the effect of climate change using SWAT.
6. To evaluate the effects of the selected climate projections and the five land use land cover scenarios in the water yield and sediment production using the SWAT model.
7. To conduct training on SWAT modeling to local professionals.

This report summarizes the methodology and results of the project. ***Section 3.0*** describes the data collection and analysis task. ***Section 4.0***includes the description of the land use land cover modeling task. ***Section 5.0*** presents the results of the selection of the climate change projections used in this project. The configuration and calibration of SWAT is presented in ***Section 6.0***. The results and final analysis are included in ***Section 7.0*** and the conclusions and recommendations are presented in ***Section 8.0***.

2.1 Study Area

Figure 2-1 shows a map of the project region. The Haina, Nizao, and Ozama basin are located in the southern part of the Dominican Republic and surround the city of Santo Domingo. The Yaque del Norte basin is located in the north west part of the country and contains the city of Santiago, the second largest city in the country. ***Table 2-1*** lists the basin areas and the minimum, maximum, and average elevations.

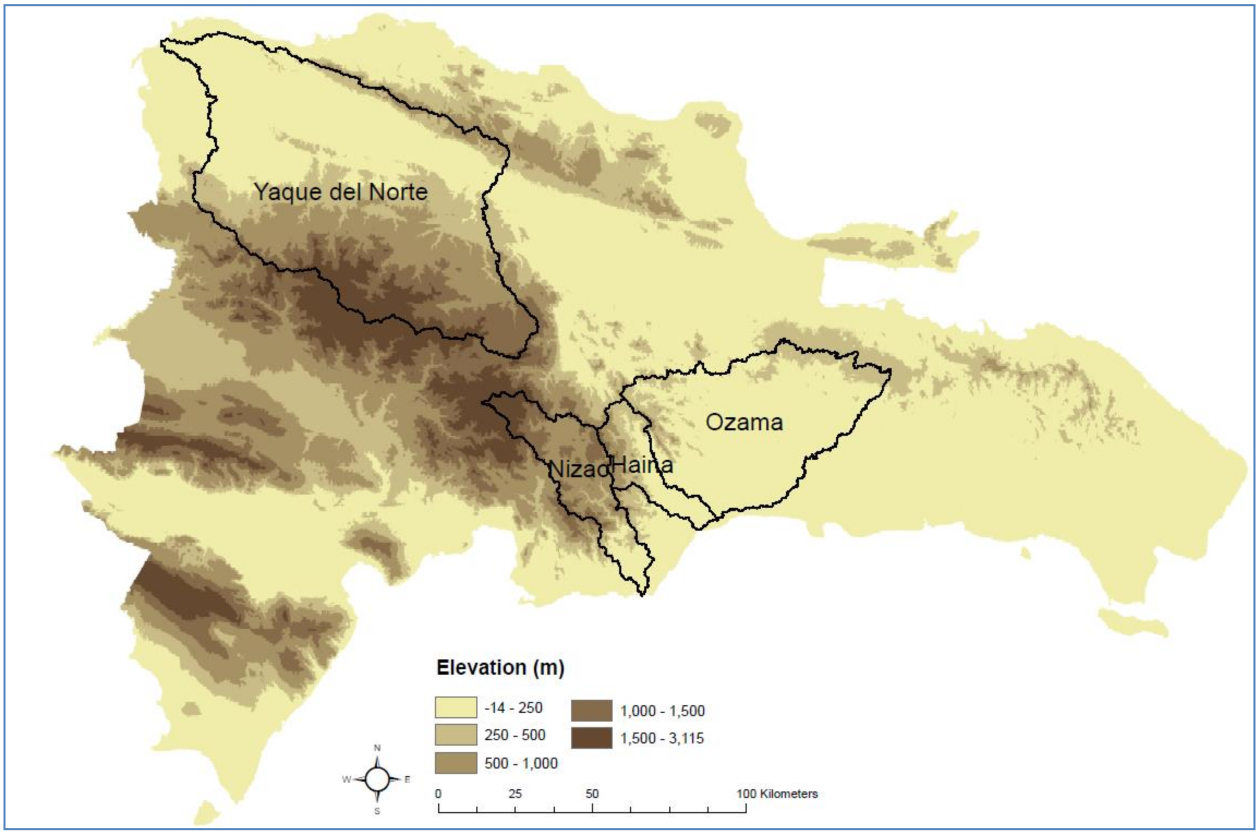

Figure 2-1. Location of the Nizao, Haina, Ozama and Yaque del Norte basins in the Dominican Republic

Table 2-1. Area and elevation of the Nizao, Haina, Ozama and Yaque del Norte basins

Basin	Area (sq-km)	Mean Elev. (m)	Min. Elev. (m)	Max. Elev. (m)
Yaque del Norte	6859	545	0	3104
Haina	561	337	0	1483
Ozama	2894	129	0	932
Nizao	1040	887	0	2835

3.0 Data Collection and Analysis

The data collection and analysis task consisted in gathering all the information available for the SWAT hydrologic modeling of the Yaque del Norte, Nizao, Haina and Ozama basins in the Dominican Republic. SWAT requires many inputs due to the broad application of the model. However, only a few inputs are required for particular modeling cases. The focus of this project was modeling water and sediment volumes. Therefore, climate, soil, and land use data were collected for these purposes.

Collected data were inventoried to assess the completeness of the data sets. Raw files were formatted into formats consistent with the different data analysis tools and with SWAT. This chapter summarizes the data collected for the project as well as the data analysis procedures and results.

Two data sets were received: spatial data sets that comprise several Geographical Information System (GIS) layers and climate data including point precipitation, temperature, streamflow, relative humidity, and wind speed.

3.1 Spatial Data Sets

Different spatial datasets for the entire country were provided by TNC. ***Table 3-1*** lists the data along with the original source file name or geo database, period of record and original projection.

In preparation of data inputs for SWAT, Riverside modified the original data as follows:

- DEM tiles were mosaiced into a single DEM and projected to UTM 19. A hill shade grid was developed.
- An Isoheytal map for the entire country for the 1950-2000 period was provided in hard copy by TNC. The source of the map is the Atlas Digital de Biodiversidad y Recursos Naturales de República Dominicana, Subsecretaría de Estados de Educación e Información Ambiental, Agosto 2006. Riverside digitized the isoheytal map and developed a digitized contour map and grid as shown in ***Figure 3-1***.

The most recent land use-land cover (LULC) dataset available for this project was the map developed in 2003. Each LULC type available in 2003 was mapped to the SWAT land use land cover types included in the SWAT database as shown in

Table 3-2.

Table 3-1. Summary of GIS data received from TNC indicating name of the file, period of record and original projections

GIS Data Processing	Input Sources	Period of Record	Original Projection
Recent (within the last 5 years) land use land cover (LULC), including cropland, vegetation, forest, urban areas in fine resolution (30 meter preferred).			
Farms	\PADRON_GEOREF.mdb\Fincas	Unknown	WGS UTM 19
uso_03		2003	WGS UTM 19
90mLc	\DR_July09.gdb\Dominican_Republic\nc_do_lc_use_04_90m_15feb05	2004	WGS UTM 19
Hydrography			
Basins	\Hydrography\Cuencas_RD.shp	NA	Nad27 UTM 19
Subbasins	\Hydrography\Subcuen_RD.shp	NA	Nad27 UTM 19
Rivers	\Hydrography\rios_nacional.shp	Unknown	Nad27 UTM 19
Lakes	\DR_July09.gdb\Dominican_Republic\nc_do_fw_lakes04_30m_15feb05	2005	WGS UTM 19
Roads/Transportation	\DR_July09.gdb\Dominican_Republic\xnc_do_infr_roads_09feb04	2004	WGS UTM 19
Political/Administrative boundaries			
Country	\LandUse_LandCover\rd.shp	NA	Nad27 UTM 19
Municipalities	\LandUse_LandCover\municipios.shp	NA	Nad27 UTM 19
Provinces	\LandUse_LandCover\provincias.shp	NA	Nad27 UTM 19
Wildfires	\Fires\puntos calor incendios 2005.shp	2005	Unknown
Wildlife/Biology			
Ecoregion	\DR_July09.gdb\Dominican_Republic\nc_do_terr_wwf_ecoregions_15feb05	2005	WGS UTM 19
Whales	\DR_July09.gdb\Dominican_Republic\nc_do_tgt_mar_humback_whales_13jul09	2009	WGS UTM 19
Manatee	\DR_July09.gdb\Dominican_Republic\nc_do_tgt_mar_manatee_13jul09	2009	WGS UTM 19
Seabirds	\DR_July09.gdb\Dominican_Republic\nc_do_tgt_mar_seabirds_13jul09	2009	WGS UTM 19
Turtles	\DR_July09.gdb\Dominican_Republic\nc_do_tgt_mar_turtles_13jul09	2009	WGS UTM 19
Mammals			
Marine National Parks	\DR_July09.gdb\Dominican_Republic\nc_do_pas_2000_marine_06oct00	2000	WGS UTM 19
Population predictions			
Municipalities	\DR_July09.gdb\Dominican_Republic\xnc_do_poli_municipals_15dec03	1993/1981	
All permits: mining, logging, etc.			
concessions	\mining\concesiones.shp	Unknown	Nad27 UTM 19
exploitation	\mining\explotacion.shp	Unknown	Nad27 UTM 19
Protected lands (private, public, gov't, easements)			WGS
SINAP (National System of Protected Areas)	\SINAP-ProtectedAreaSystem\SINAP.shp	Unknown	Nad27 UTM 19
Caribbean protected areas	\SINAP-ProtectedAreaSystem\car_prot_area_aug2011.shp	2011	WGS
DEM/Hill Shade	ASTER 30m tiles		

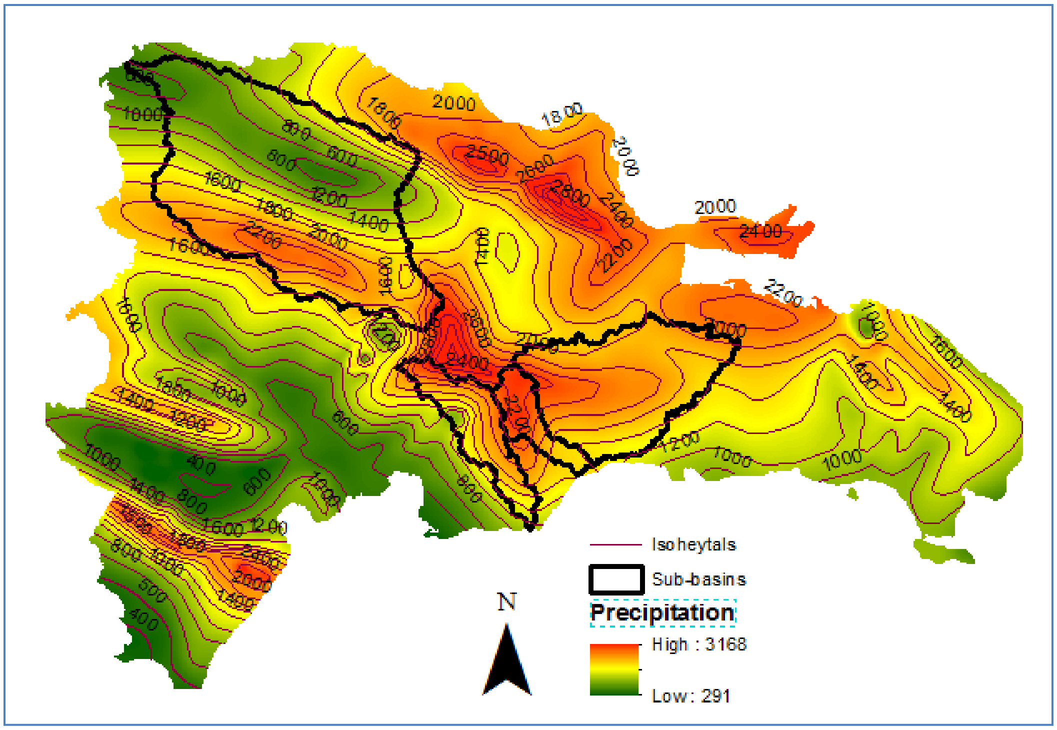

Figure 3-1. Isoheytal map for the 1950-2000 period for the Dominican Republic. Contour lines are every 200 mm.

Table 3-2. Percentage of Landuse Code by Basin

CODE	Description	Name in Original Landuse Grid file	Yaque	Haina	Ozama	Nizao
AGRC	Agricultural Land – Close-grown	Cultivos Intensivos	6.78%	1.28%	0.73%	8.63%
AGRL	Agricultural Land - Generic	Agricultura Mixta/Coco/Cacao	13.56%	6.18%	10.14%	22.33%
COFF	Coffee	Café	5.65%	0%	0%	1.26%
OILP	Oil Palm	Palma Africana	0%	0.31%	2.22%	1.34%
ORAN	Orange	Cítricos	0%	15.68%	0.01%	0%
SUGC	Sugarcane	Caña	0%	9.34%	36.98%	5.11%
RICE	Rice	Arroz	11.41%	0%	0.56%	0.02%
PAST	Pasture	Pasto	8.50%	11.97%	10.37%	5.74%
RNGB	Range - Brush	Matorrales Seco/Matorral Latifoliado	15.50%	2.66%	2.41%	2.08%
FRST	Forest Mixed	Bosque Latifoliado Nublado/Bosque Latifoliado Humedo/Bosque Latifoliado Semi Humedo/Escasa Vegetacion	13.00%	45.34%	31.43%	39.12%
FRSE	Forest Evergreen	Bosque Conifera Denso/Bosque Conifera Abierto	14.55%	1.20%	0.15%	11.76%
FRSD	Forest Deciduous	Bosque Seco	8.79%	0%	0%	0.87%
URBN	Urban	Zona Poblada	1.84%	5.97%	4.93%	0.15%
WATR	Water	Mar/Presas	0.38%	0.01%	0.01%	1.45%
WETL	Wetlands - Mixed	Sabana de Humedales de Agua Dulce/Sabana de Humedales Salobres/Eneal/Mangles	0.05%	0.05%	0.06%	0.14%

In addition to the data provided by TNC, Riverside retrieved soil data for the entire country from the Harmonize World Soil Database (HWSD) available online at http://webarchive.iiasa.ac.at/Research/LUC/External-World-soil-database/HTML/. This database is a compilation of four source databases for the entire world. The Dominican Republic soil dataset comes from the soil and terrain digital database for Latin America and the Caribbean at 1:5 Million scale, FAO Land and Water Digital Media series #5. FAO, Rome (Harmonize World Soil Database Documentation, February 2012). A soil shapefile that covers the entire country was retrieved along with an attribute table that includes the soil properties (***Figure 3-2***).

Table 3-3 lists the percentage of each soil type within the study basins.

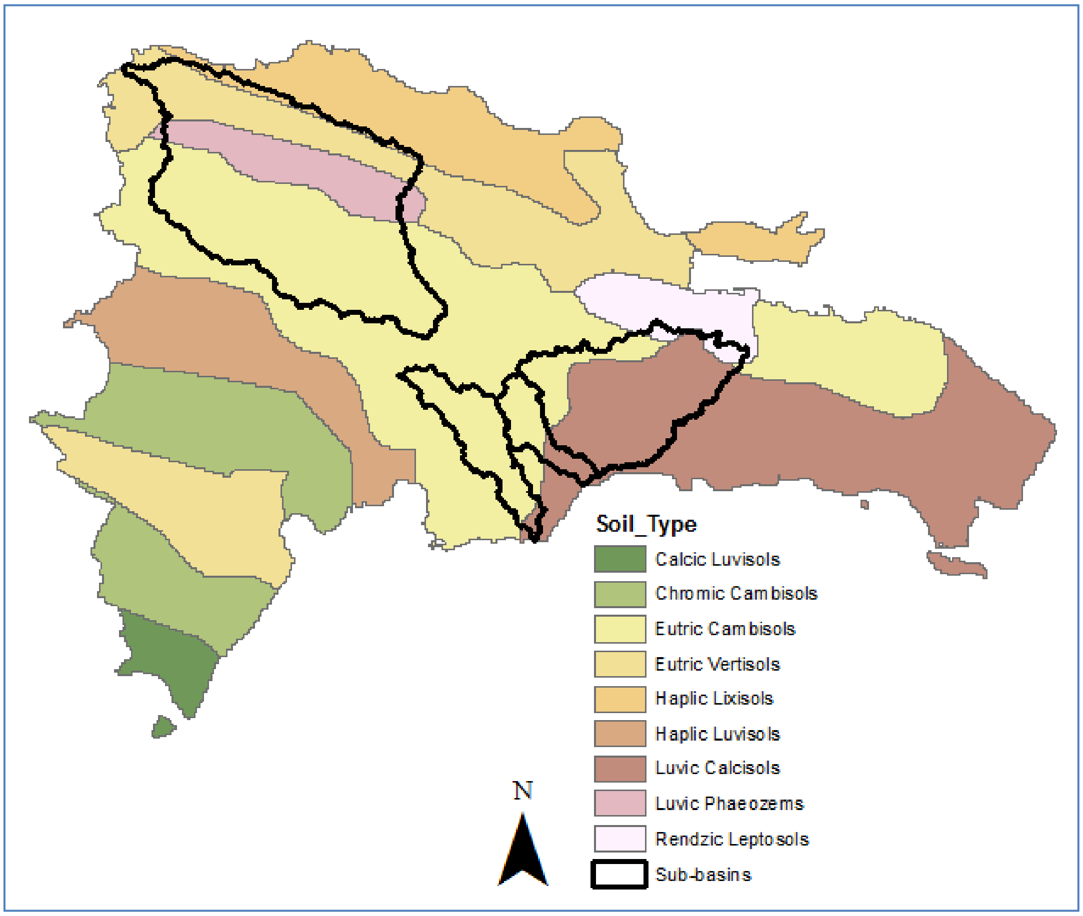

Figure 3-2. Dominican Republic Soil Data from HWSD

Table 3-3. Percentage of Soil Type by Basin

Basins	Eutric Cambisols	Eutric Vertisols	Haplic Lixisols	Luvic Calcisols	Luvic Phaeozems	Rendzic Leptosols
Yaque	55%	21%	3%	0%	20%	0%
Haina	70%	0%	0%	30%	0%	0%
Ozama	21%	0%	0%	73%	0%	6%
Nizao	95%	0%	0%	5%	0%	0%

SWAT requires more input soil parameters than the information included in the HWSD. Missing parameters were estimated based on known properties of the soils such as soil texture, hydraulic conductivity, drainage class, organic carbon content, etc. ***Table 3-4***, ***Table 3-5***, and ***Table 3-6*** summarize the initial parametric soil data input into SWAT.

The hydrologic groups of the soils were estimated with the soil texture and the drainage class. Rendzic Leptosols are characterized by imperfect drainage class. This implies that the soil is wet most of the time because water drains from the soil slowly in relation to supply (precipitation, groundwater, subsurface water). The soil texture classifies this soil in hydrologic group C. However, a class D was assigned based on the drainage class.

The depth of obstacle to roots (SOL_ZMX) is not available in the soil database. SWAT was setup to use the crop depth instead. The faction of porosity from which anions are excluded (Anion_EXCL) parameter is only used for nitrate transport that is not considered in this study. This parameter is not provided in the soil database. When missing, SWAT defaults it to 0.50. The potential or maximum crack volume of the soil profile expressed as a fraction of total soil volume (SCL_CRK) is used to compute the temporal change in soil volume, the formation of soil cracks and the infiltration through the cracks. The formation of cracks occurs in vertisols. These data are not available for the vertisols in the Dominican Republic and therefore, the routing that computes infiltration through cracks was not used in the model.

Table 3-4. Soil properties – Part I

Basin Name	Soil Name	NLAYERS	HYDGRP [1]	SOL_Z (mm)	Top Soil Depth (mm)	Subsoil depth (mm)	Moist Top SOL_BD (g/cm3) [2]	MoistSub SOL_BD (g/cm3) [2]	SOL_AWC (mm/m)
Yaque del Norte	Luvic Phaeozems	1	C	1000	0 to 300	300 to 1000	1.45-1.55	1.40-1.50	150
	Haplic Lixisols	1	C	1000	0 to 300	300 to 1000	1.45-1.55	1.45-1.55	150
	Eutric Cambisols	2	C	1000	0 to 300	300 to 1000	1.45-1.55	1.40-1.50	150
	Eutric Vertisols	2	D	1000	0 to 300	300 to 1000	1.40-1.50	1.35-1.45	125
Ozama	Luvic Calcisols	1	C	1000	0 to 300	300 to 1000	1.45-1.55	1.45-1.55	150
	Rendzic Leptosols	1	D	300	0 to 300		1.45-1.55	1.45-1.55	50
	Eutric Cambisols	2	C	1000	0 to 300	300 to 1000	1.45-1.55	1.40-1.50	150
Haina	Luvic Calcisols	1	C	1000	0 to 300	300 to 1000	1.45-1.55	1.45-1.55	150
	Eutric Cambisols	2	C	1000	0 to 300	300 to 1000	1.45-1.55	1.40-1.50	150
Nizao	Eutric Cambisols	2	C	1000	0 to 300	300 to 1000	1.45-1.55	1.40-1.50	150
	Luvic Calcisols	1	C	1000	0 to 300	300 to 1000	1.45-1.55	1.45-1.55	150

NLAYERS: Number of soil layers. HYDGRP [1]: hydrologic group estimated from soil texture and hydraulic conductivity (SWAT Input Output manual). SOL_Z: soil depth. SOL_BD: moist soil bulk density [2]: estimated from soil texture (http://www.mo10.nrcs.usda.gov/references/guides/properties/moistbulkdensity.html). SOL_AWC: soil available water content.

Table 3-5. Soil properties – Part II

Basin Name	Soil Name	Sub Soil SOL_CBN (% wt.)	Ksat top soil cm/h [3]	Ksat sub soil cm/h [3]	SOL_ALB (fraction) [4]	USLE_K [5]	Organic Matter [6]
Yaque del Norte	Luvic Phaeozems	0.36	0.43 cm/h	0.23	Using Sandy loam (0.10-0.19)	0.15	0.62
	Haplic Lixisols	0.32	0.43	0.43	Using Sandy loam (0.10-0.19)	0.15	0.55
	Eutric Cambisols	0.34	1.32	0.23	Using Sandy loam (0.10-0.19)	0.17	0.58
	Eutric Vertisols		silty clay = 0.09	clay (light) = 0.06	Using clay loam (0.10-0.14)	0.24	--
Ozama	Luvic Calcisols	0.20	0.43		Using Sandy loam (0.10-0.19)	0.16	0.34
	Rendzic Leptosols	0.05	1.32	0.06 (lowest K for clay)	Using clay loam (0.10-0.14)	0.17	0.09
	Eutric Cambisols	0.34	1.32	0.23	Using Sandy loam (0.10-0.19)	0.17	0.58
Haina	Luvic Calcisols	0.20	0.43	0.43	Using Sandy loam (0.10-0.19)	0.16	0.34
	Eutric Cambisols	0.34	1.32	0.23	Using Sandy loam (0.10-0.19)	0.17	0.58
Nizao	Eutric Cambisols	0.34	1.32	0.23	Using Sandy loam (0.10-0.19)	0.17	0.58
	Luvic Calcisols	0.20	0.43	0.43	Using Sandy loam (0.10-0.19)	0.16	0.34

Ksat: saturated hydraulic conductivity [3] estimated from Rawls et al, 1982. SOL_ALB: soil albedo estimated from http://agsys.cra-cin.it/tools/solarradiation/help/Albedo.html. USLE_K [5]: Universal soil equation erodibility factor estimated from Williams's 1995 equation in SWAT's manual. Organic matter [6]: estimated as 1.72*Organic content.

Table 3-6. Soil properties – Part III

Basin Name	Soil Name	Top soil CLAY (% wt.)	Top Soil SILT (% wt.)	Top Soil SAND (% wt.)	Sub soil CLAY (% wt.)	Subsoil SILT (% wt.)	Subsoil SAND (% wt.)	Subsoil ROCK (% wt.)
Yaque del Norte	Luvic Phaeozems	30	17	53	33	31	36	0
	Haplic Lixisols	22	15	63	34	13	53	0
	Eutric Cambisols	24	31	45	27	30	43	0
	Eutric Vertisols	52	41	7	47	40	13	0
Ozama	Luvic Calcisols	22	24	54	29	24	47	0
	Rendzic Leptosols	25	39	36	0	0	0	0
	Eutric Cambisols	24	31	45	27	30	43	0
Haina	Luvic Calcisols	22	24	54	29	24	47	0
	Eutric Cambisols	24	31	45	27	30	43	0
Nizao	Eutric Cambisols	24	31	45	27	30	43	0
	Luvic Calcisols	22	24	54	29	24	47	0

3.2 Climate Data

Climate data are available at hydroclimatologic stations within and around all four basins. The following historical data were quality controlled and processed as primary inputs into SWAT.

3.2.1 Precipitation Data

Precipitation is the primary driver of runoff; historical precipitation data at climate stations within and nearby the basins were quality controlled to identify potential data errors and inconsistencies. Then the point precipitation data were converted into mean areal precipitation (MAP) time series over each sub-basin. ***Section 3.2.1.1*** outlines the precipitation quality control completed prior to computing MAP time series, and ***Section 3.2.1.2*** describes the MAP algorithm implemented into the Community Hydrologic Prediction System (CHPS) to convert point precipitation to areal precipitation.

3.2.1.1 Precipitation Data Quality Control

The Oficina Nacional de Meteorología de la República Dominicana (ONAMET) and the Instituto Nacional de Recursos Hidráulicos (INDRHI) provided historical precipitation data from daily stations for the 1931-2012 period (***Figure 3-3***). Data analysis was performed from 1950 to 2000 because this is the period that overlaps with the period of record of the isoheytal map and with the streamflow data available for calibration.

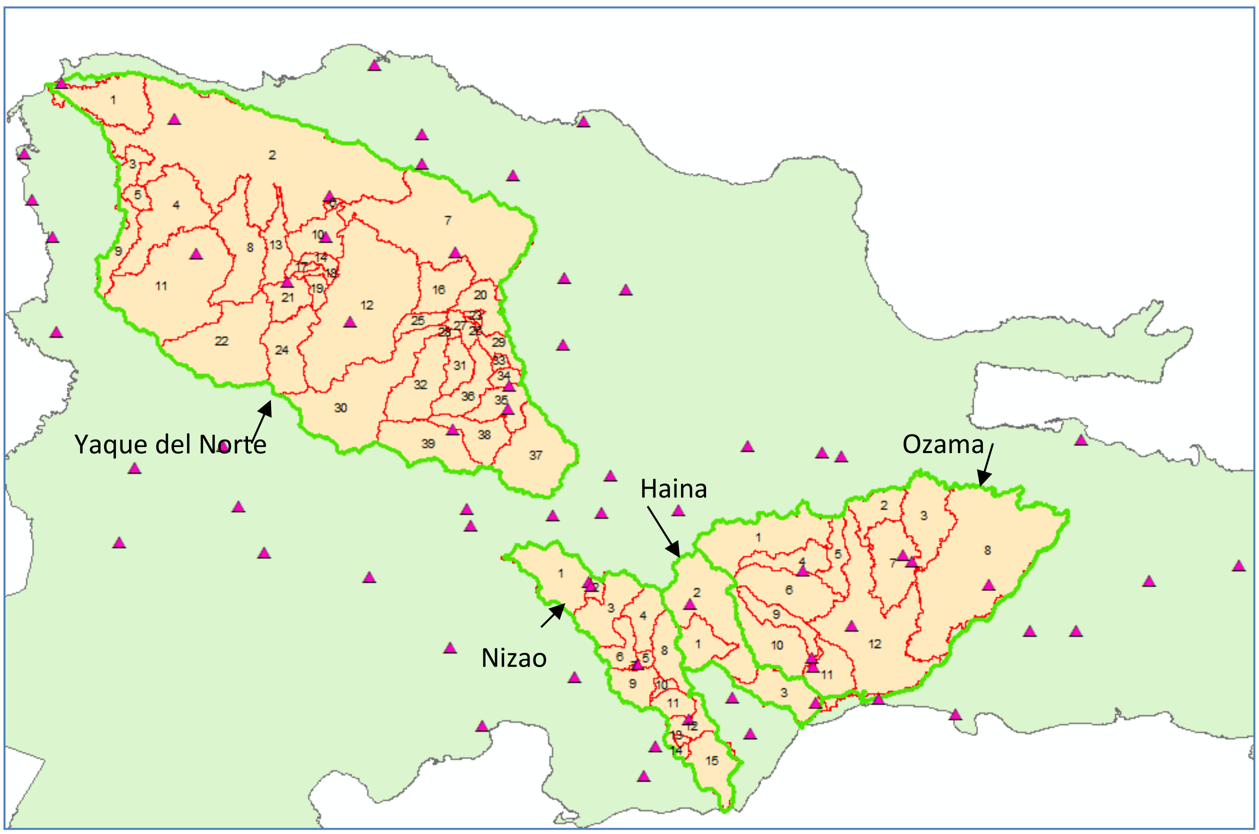

Figure 3-3. Location of precipitation stations (pink triangles). Major basins are outlined in green and modeling sub-basins in red. The sub-basins are identified by numbers within SWAT.

Stations with less than five years of record were not included in the analysis, because they do not provide enough information to estimate long term precipitation averages. A number of quality control checks were conducted to ensure a high quality dataset. During the quality control process, potentially

bad data values were flagged and reviewed to determine whether they should be removed from the dataset. In addition, the spatial and temporal consistencies of the historical data were checked among the stations.

Riverside reviewed the raw data using the TSTool software program (http://cdss.state.co.us/software/Pages/TSTool.aspx) to identify obvious data problems. A total of 15 groups of stations were analyzed with about 4 to 6 stations in each group. The stations were grouped based on their proximity to each other and their elevations. Periods were flagged if data patterns repeated from year to year, if extended periods showed no recorded precipitation, or if a particular measurement was not consistent with other measurements in nearby stations. To evaluate the potential of high precipitation totals, high precipitation amounts were validated against the occurrence of tropical storms and hurricanes in the region. ***Appendix A*** includes a summary of all flagged values and measures taken to resolve identified data problems. A list of all the precipitation stations inventoried that were not included in the MAP analysis and reasons for not using these stations is also included in ***Appendix A***.

The NWS Preliminary Precipitation Program (PXPP) (http://www.nws.noaa.gov/oh/hrl/nwsrfs/users_manual/part3/_pdf/37pxpp.pdf) was used to estimate mean monthly precipitation and to verify the long-term consistency of the records on a monthly time scale. The NWS Interactive Double Mass Analysis (IDMA) program (http://www.nws.noaa.gov/oh/hrl/idma/html/dma_home_frame.htm) was used to display the consistency plots. PXPP uses an inverse distance squared method to estimate missing data. These computations rely heavily on data from a base station, which is selected based on record completeness and how representative data from this station are of the area being analyzed.

Stations were categorized into one (1) group for PXPP/IDMA consistency analysis based on location and expected similarity in general hydrologic conditions. La Vega (LAV) station was selected as the base station for this analysis.

The PXPP analysis output was used to produce double mass plots. These plots show the deviation of accumulated precipitation at each station from the average accumulation of all stations within the group. A change in slope in the double mass plot may indicate changes in station location, instrumentation, collection methodology, or surroundings. Correction factors were computed using IDMA to adjust the data and improve the slope of the double mass plots (i.e. by increasing or decreasing the observed precipitation accumulation rate during a defined time period). In addition, erroneous data that may have been missed in the preliminary data quality checks may appear as unreasonable spikes or breaks in the double mass plots. Several breaks were identified in the double mass curves and correction factors were applied to maintain consistency of the data (***Appendix A***). Unfortunately, station history records were not available to verify the potential source of data problems.

The PXPP program computes monthly and annual average precipitation values (characteristics) for each station. As an additional consistency check, station characteristics were plotted so that the temporal distribution could be evaluated. It is presumed that stations within the same group should have similarly shaped annual distributions. Stations that indicate obvious erroneous distributions were investigated. ***Figure 3-4*** shows a comparison of the monthly characteristics of a group of six stations located within the same region. This plot shows two rainfall seasons in the region, where May and October have the largest monthly precipitation values.

For the CHPS/FEWS MAP processing (***Section 3.2.1.2***), only the station locations and the mean annual precipitation are required for every station. Riverside used the final station characteristics and quality-controlled precipitation data to compute mean areal precipitation estimates for input to the hydrologic models.

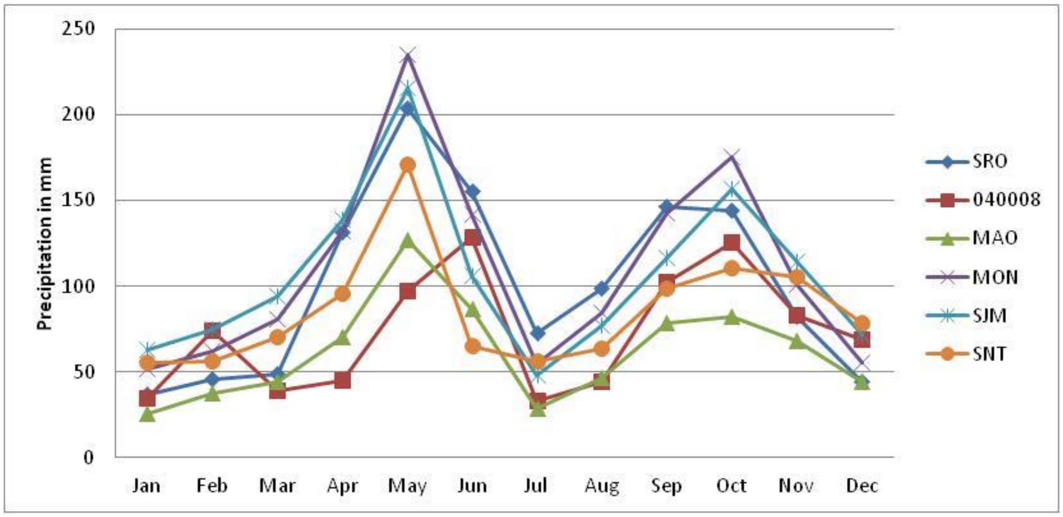

Figure 3-4. Comparison of monthly characteristics for a set of six precipitation stations.

3.2.1.2 Historical MAP Development

The CHPS/FEWS framework (http://publicwiki.deltares.nl/display/FEWSDOC/Home) was configured to compute historical MAP time series. The algorithm implemented within CHPS/FEWS accounts for the precipitation gradients across the watersheds. Quality controlled daily precipitation data, mean annual point precipitation amounts and a historical isoheytal map corresponding to the period 1950-2000 were input into the system.

Within the CHPS/FEWS framework, computations are completed using Workflows consisting of one or more Modules. Modules are operations that transform or process the data. The primary built-in computation module is the Transformation Module, which was used to convert point precipitation data into the mean areal precipitation amounts. The workflow consists of the following:

1. Compute daily precipitation grids over the period of record:
    a. Divide each observed daily value by the average annual precipitation at the station, yielding daily “anomalies” from normal;
    b. Spatially interpolate the anomalies using inverse distance weighting to yield daily grids of precipitation anomalies (a 900-m grid cell size was selected for the precipitation grids);
    c. Multiply the daily precipitation anomaly grids by the 900-km annual isohyetal map to yield daily precipitation grids.
2. Compute daily MAP for each sub-basin by overlaying the final daily precipitation grids with the sub-basin boundaries. These final time series are the precipitation input for SWAT.

The MAP time series were computed for each sub-basin delineated with SWAT. ***Table 3-7***, ***Table 3-8***, ***Table 3-9***, and ***Table 3-10***, include the mean annual precipitation per sub-basin for the Yaque del Norte, Ozama, Nizao and Haina basins. The Yaque del Norte has the lowest mean annual precipitation (1338 mm), while Haina has the largest (2124 mm). The locations of the sub-basins are shown in ***Figure 3-3***.

Table 3-7. Mean annual precipitation in the Yaque del Norte basin and sub-basins.

Basin Name	Sub-basin #	Streamflow Gage at Outlet	Mean Annual Precipitation per sub-basin (mm)	Mean Annual precipitation per basin (mm)
Yaque del Norte	1		637	1338
	2	PALO VERDE	894	
	3		827	
	4		1116	
	5		1065	
	6	PTE. SAN RAFAEL	765	
	7		1104	
	8		1085	
	9		1452	
	10		1452	
	11	RINCON	663	
	12		1614	
	13		1219	
	14		928	
	15		815	
	16		815	
	17		969	
	18		944	
	19	BULLA	1135	
	20	LAS CHARCAS	1014	
	21		1411	
	22		2026	
	23		1079	
	24		2042	
	25		1188	
	26		1147	
	27		1193	
	28	PINALITO	1264	
	29		1373	
	30		1910	
	31		1597	
	32		1911	
	33		1490	
	34	LOS VELASQUITOS	1632	
	35	BOMA	1764	
	36		1778	
	37	HATO VIEJO	1978	
	38	PINAR QUEMADO	1884	
	39	MANABAO	1913	

Table 3-8. Mean annual precipitation in the Ozama basin and sub-basins

Sub-basin #	Streamflow Gage at Outlet	Mean Annual Precipitation per sub-basin (mm)	Mean Annual precipitation per basin (mm)
1	DON JUAN	1945	1910
2	CACIQUE	1815	
3	EL CERRO	1868	
4		2118	
5		2038	
6		2286	
7		2011	
8		1827	
9	HIGUERO	2108	
10	PALMAREJO	1895	
11		1657	
12		1853	

Table 3-9. Mean annual precipitation in the Nizao basin and sub-basins

Basin Name	Sub-basin #	Streamflow Gage at Outlet	Mean Annual Precipitation per sub-basin (mm)	Mean Annual precipitation per basin (mm)
Nizao	1	ESTRECHURA	2090	1789
	2	BOCAINA	1881	
	3		1584	
	4		1896	
	5		1872	
	6	PALO DE CAJA	1501	
	7		1735	
	8	LOS CACAOS	2071	
	9		1617	
	10		1901	
	11	EL ERMITANO	1880	
	12		1851	
	13		1626	
	14		1516	
	15		1514	

Table 3-10. Mean annual precipitation in the Haina basin and sub-basins

Basin Name	Sub-basin #	Streamflow Gage at Outlet	Mean Annual Precipitation per sub-basin (mm)	Mean Annual precipitation per basin (mm)
Haina	1		2333	2124
	2	LOS COROZOS	2241	
	3		1707	

3.2.2 Temperature Data

3.2.2.1 Temperature Data Quality Control

SWAT requires complete maximum and minimum daily temperature time series to estimate evapotranspiration from the basins. Raw temperature data were provided by ONAMET and INDHRI (see ***Appendix B***). There were a total of 36 stations with maximum temperature data and 29 stations with minimum temperature. Before computing complete mean areal maximum and minimum temperature time series, the data were quality controlled with the same procedures used for the precipitation data (see ***Section 3.2.1.1***).

Maximum and minimum temperature data were plotted using TSTool. The stations were organized into 6 groups for comparison based on their proximity and elevations. ***Appendix B*** summarizes flagged values and actions taken to resolve data problems. Some potential data errors were not set to missing during the initial quality control step because the data problems were not obvious. These stations were evaluated later in more detail with a double mass analysis. Correction factors were applied to maintain consistency in the data when needed. The correction factors applied to the stations are summarized in ***Appendix B***.

3.2.2.2 Historical Maximum and Minimum Mean Areal Temperature Time Series

SWAT requires complete maximum and minimum temperature time series for modeling the evapotranspiration in the basins. The NWS Mean Areal Temperature Program (MAT) (http://www.nws.noaa.gov/oh/hrl/nwsrfs/users_manual/part2/_pdf/27calb_mat.pdf) was used to estimate mean daily maximum and minimum temperature time series for each basin.

The MAT program computes mean areal temperature time series based on maximum and minimum daily temperature data as well as station location and elevation. The MAT program estimates temperature data at locations where data are not available by weighting available data at surrounding stations. Since there are significant changes in elevation in the study basins, the weighting factor scheme for mountain areas was used. The weighting factors are a function of both, difference in elevation and distance between the estimated and the estimator station. The MAT program was configured to output maximum and minimum temperature time series at the centroid of each sub-basin. The period of record of this analysis was from 1955 to 2000.

3.2.3 Other Climate Data: Wind Speed, Relative Humidity and Solar Radiation

Wind speed and relative humidity data were received from ONAMET for the stations and periods of record listed in ***Figure 3-5*** and ***Figure 3-6***. SWAT requires complete daily wind speed and relative humidity time series to compute the evapotranspiration in the basins. In order to estimate continuous time series, mean monthly wind speed and relative humidity values were computed from the observed data at each station and then disaggregated into a complete daily time series from 1955 to 2100 for modeling purposes.

SWAT also requires complete daily solar radiation time series to compute the evapotranspiration in the basins. Observed solar radiation data were not available. Therefore, these data were estimated using the guidelines for computing crop evapotranspiration developed by FAO (Arnold, J.G et al. 1999). In these guidelines, the daily extraterrestrial radiation for different latitudes for the 15th day of each month is available in tabular format. A single daily solar radiation time series was created for all the basins for the period 1955 to 2100.

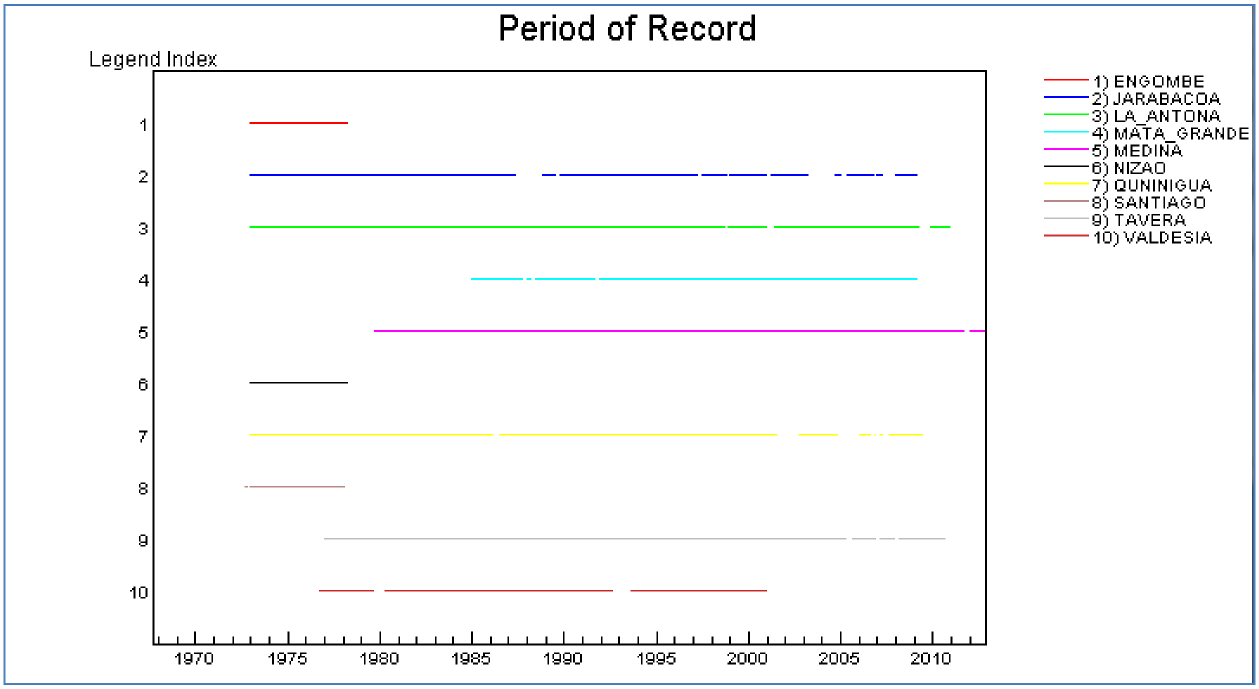

Figure 3-5. Period of record of relative humidity data from ONAMET stations

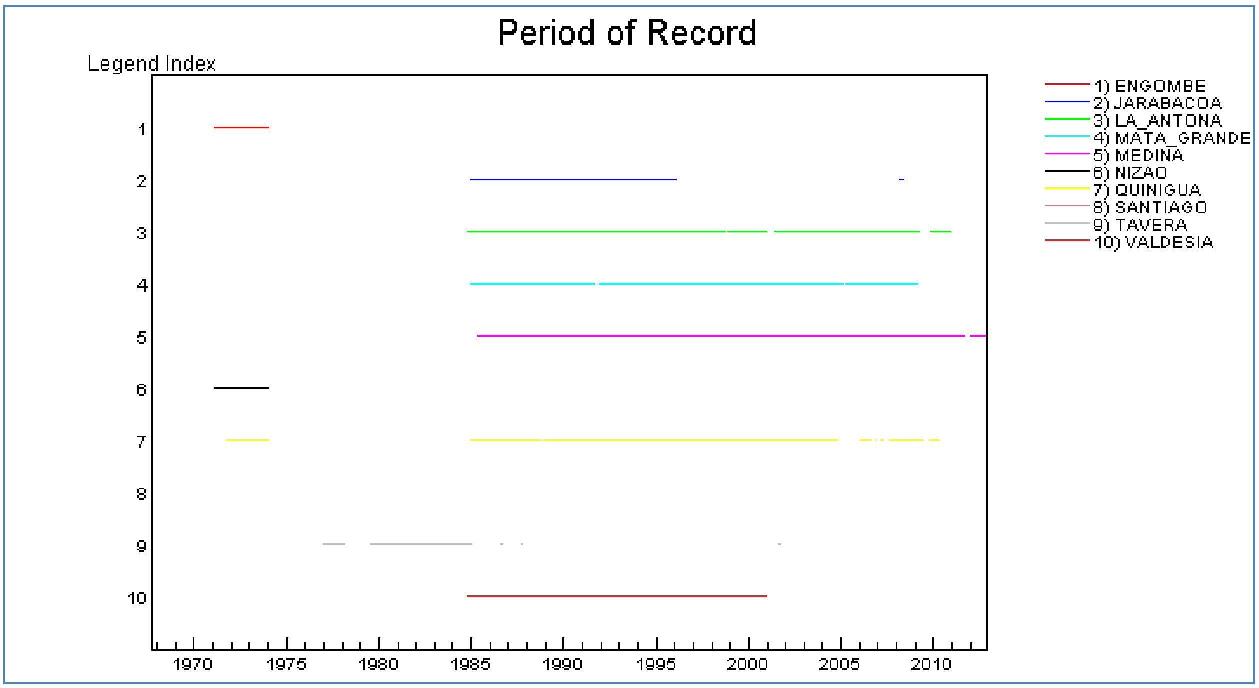

Figure 3-6. Period of record of wind speed data from ONAMET stations

3.3 Streamflow Data

Streamflow data were provided by INDRHI through the following web site http://byuhydro.byu.edu/Observational-Data/5. A total of 21 streamflow gages were identified within the study basins. ***Figure 3-7*** shows the period of record for all stations. The quality of the data was assessed during calibration as explained in ***Section 6.2*** of this report.

Most gages show a bimodal flow season. Largest peaks occur in May-June and September- October. This distribution coincides with the observed precipitation pattern as shown in ***Figure 3-4***.

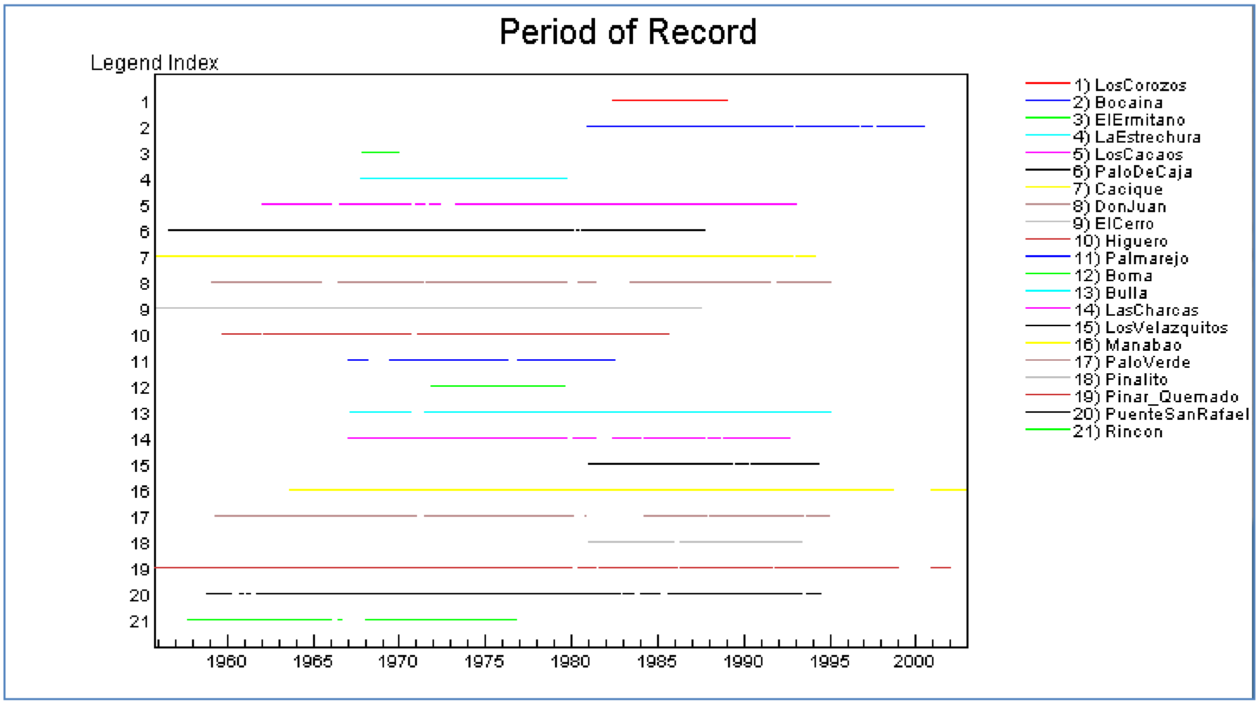

Figure 3-7. Period of Record o Streamflow Data

3.4 Regulation Data

The Haina, Nizao, Ozama, and Yaque del Norte flows are significantly altered by water diversions for irrigation and human consumption. A point shapefile dated February 13, 2013 with the location of water intakes for irrigation and water supply was provided by INDRHI. The maximum flow capacity of the intakes was provided as an attribute in the shapefile but not the duration or timing of irrigation to estimate irrigation volumes. In addition, the available data did not provide information about the location of canals to determine if the water is used within or outside the basins where the intakes are located. The location of the water supply intakes were compared against the streamflow gages used for calibration to evaluate if the diversion amounts could be used to correct the streamflow data at the gage for these diversions. Two water supply intakes were identified upstream from the station Los Corozos in the Haina basin. The flows from these two intakes were added to the streamflow data at station Los Corozos to estimate the natural flows in the basin. These two intakes are for water supply and the diverted flows are not returned to the basin upstream from the gage.

3.5 Climate Change Data

The Nature Conservancy (TNC), Global Climate Change Program, provided the climate change temperature and precipitation time series used in this project. These time series are the result of daily downscaled General Circulation Models (GCM) projections. The GCM projections were downscaled to 0.5 degree resolution (~50 km) and bias corrected with historical weather station data (Girvetz et. al. 2012). Riverside analyzed a total of 36 future projections for two different greenhouse emission scenarios (SRES A2 and B1) and for the time periods 2046-2065 and 2081-2100 (***Table 3-11***). Based on the contract for this project, a total of five future projections should be selected to characterize the future climate. A detailed description of the selection of the five climate change projections used in this project is included in ***Section 5.0*** of this report.

Table 3-11. Number of runs/outputs per emission scenario (B1 and A2) for the analyzed GCMs

GCM	B1	A2
cccma_cgcm3_1	3	3
cnrm_cm3	1	1
gfdl_cm2_0	1	1
gfdl_cm2_1	1	1
ipsl_cm4	1	1
miroc3_2_medres	1	2
miub_echo_g	2	3
mpi_echam5	3	1
mri_cgcm2_3_2a	1	5
Total	18	18

4.0 Land Use Land Cover Modeling

SWAT accounts for different types of land uses to model the water and sediment production. Five land use land cover scenarios were developed to evaluate the impact of the land use changes in the hydrologic and sediment regimes of the four study basins. As part of this task, Claudia León, Senior Water Resources Engineer from Riverside, Driss Ennaanay, Program Leader, Water Resources and Climate Change from Riverside, and Burak Guneralp, Research Assistant Professor, Department of Geography from Texas A&M University, travelled to the Dominican Republic on February 4 and 5, 2013 to facilitate two stakeholder meetings together with TNC. The meetings were attended by representatives from different socioeconomic sectors, including the Ministry of the Environment and Natural Resources, the Land Use Planning and Development Department, the National Institute of Hydraulic Resources, the National Office of Meteorology, National Institute of Water Supply and Sewerage, the Academia, ONGs, among others.

The objectives of these meetings were: 1) to identify current problems in the basins that alter the water and sediment production and 2) to propose potential solutions, rules and policies that might help mitigate the identified problems. The results from these meetings represent the basis for developing the five projected land use scenarios that will help evaluate the effects of climate change on sediment and water production in the basins.

Sections 4.2 and ***4.3*** summarize findings and conclusions from the stakeholder meetings and the methodology used to model future land use scenarios under the identified rules and policies.

4.1 Meeting Keynotes Speakers

Three keynote speakers participated in the stakeholder meetings. The following section summarizes the conclusions that are relevant in the design of the potential land use scenarios.

Omar Rancier, architect from the Land Use Planning and Development Department in the Dominican Republic (Dirección General de Ordenamiento y Desarrollo Territorial, DGODT), provided the following information about the current conditions of the Haina and Ozama basins:

- The Haina and Ozama basins have the largest population density in the country (total population in the two basins > 3 million). The Haina basin has a population density of 1,220 inhabitants per square kilometer.
- The main socio-economic activities in these basins include industry, agriculture, ports, hydrocarbon management, and hydropower generation.
- About 60% of the water supply for the city of Santo Domingo comes from the Haina and Ozama basins. Both surface and subsurface water sources are extensively depleted to supply water for the major urban centers in the basins.
- Water supply has decreased due to the reduction of groundwater recharge induced by urbanization and the increase in water demand.
- Groundwater supply is affected by saline intrusion.
- Urban development has occurred in a disorganized pattern. Irregular housing occurs in lands previously used for sugar cane cultivation or along major roads.
- Surface water is polluted due to the inappropriate disposal of wastewater and solid waste from urban areas and industries.

Pedro García Brito, Director of GTI from the Ministry of the Environment, addressed the status of the proposed policies and laws to dictate urban planning and territorial development.

A very important finding from this presentation is that the Dominican Republic does not have an urban planning and development law to regulate the land use in the basins. The lack of regulation has caused disorganized urban expansion in the country and deterioration of the environment. The Ministry of Planning and Development has been working for over a year on the development of a law to regulate the land use in the country.

Some of the efforts to improve current environmental conditions are:

Reforestation of the basins. Currently, reforestation is implemented in an unplanned fashioned. The government has not established a final goal for the forest cover in the entire country.

Establishment of a National Soil Conservation Service to preserve the integrity of the soils. This service will be created among the Ministry of Agriculture, the National Institute of Hydraulic Resources, and the Ministry of the Environment.

Establishment of payments for ecosystem services. This system consists of assigning value to ecosystem services and compensating the communities for the preservation of the environment.

Creation of protected areas. About 25% of the territory is assigned to protected areas. However, many of these protected areas are still subject to human activities at varying levels of intensity.

Bienvenida Cuevas, engineer and professor from the Center of Urban and Regional Studies (CEUR) at the Pontificia Universidad Católica Madre y Maestra (PUCMM) identified current environmental problems in the Yaque del Norte and Ozama basins and proposed solutions.

The major environmental problems include:

- Environmental degradation due to irregular housing development.
- Deforestation in the middle part of the Yaque del Norte basin
- Water pollution and inappropriate solid waste disposal from the major urban centers, Jarabacoa and Santiago.
- High concentrations of nitrogen and phosphorous in the middle and lower Yaque del Norte river.
- Erosion and sedimentation in the entire Yaque del Norte basin.

Proposed solutions:

The CEUR/PUCMM is working on a program created in 2003 to provide technical training and economic support to farmers to develop small-scale projects to reforest the basins. The main goals of this project are to protect the water sources/rivers in the basins, to improve air quality, and to provide jobs and incomes to the communities through the production and sale of forest products. This project is based on a sustainable development approach. The communities are able to sustain themselves by logging activities that provide the economic incentive to maintain the forest.

4.2 Meeting Methodology and Findings

Additional information related to water and sediment production problems in the basins were elicited from the rest of the participants. The participants of the meeting were organized into groups. Each group applied the DPSIR Framework developed by the Environmental Protection Agency (http://www.epa.gov/ged/tutorial/) with the objective of identifying the current concerns in the basins from each stakeholder point of view. This framework facilitates gathering information from stakeholders, the organization of the information, and integration of the gathered information into the decision-making process.

The following items were discussed within the DPSIR Framework:

DRIVING FORCES: Socioeconomic sectors and cultural factors that drive human activities in the basins.

PRESSURES: Human activities that place stress on the environment.

STATE: Current condition of the environment.

IMPACTS: Effects of environment degradation.

RESPONSES: Responses of society to the environmental situation.

The objectives of this exercise were: 1) to identify potential **RESPONSES** to build future land use scenarios and 2) to evaluate the **IMPACT** on sediment and water production in the basins. The following information was gathered from the DPSIR exercise:

DRIVING FORCES: agriculture, urbanization, industry, transportation, and mining.

PRESSURES: poor agricultural practices such as lack of contour barriers (live, dead, and mixed), cultivation on steep terrain, deforestation of steep terrain, excessive use of slash and burn, and unplanned urban and rural expansion.

STATE: excessive erosion in the upper parts of the basins, lower infiltration and recharge of aquifers, water quality degradation, and lack of land use regulations and laws.

IMPACTS: water scarcity, sedimentation in the lower part of the basins, degradation of sewage and wastewater from urban areas.

RESPONSES: The identified RESPONSES were organized into five potential land use land cover scenarios:

1) Business-as-usual, 2) Best Management Practices (BMPs), 3) Conservation, 4) Development, and 5) Combination (Middle-of-the-Road) Scenario.

After applying the DPSIR framework, the participants identified current areas of concern in maps and delineated areas where changes should occur under each scenario to mitigate the identified problems.

The conclusions from the DPSIR exercise, as well as the information from the maps from both meetings were used to build the following rules for each scenario (the maps for all scenarios except Business-as-usual are provided in ***Appendix C***):

1) Business-as-usual: this scenario assumes no changes in current practices and policies. To model this scenarios the following data were collected:
    - Historical and projected population in rural and urban areas by administrative unit.

Riverside used the data from the Oficina Nacional de Estadística (ONE) available in the following URL: http://www.one.gob.do/index.php?module=articles&func=view&catid=76 and in the excel spreadsheet "Poblacion total estimadas y proyectadas por año calendario y sexo, segun región y provincia 1990-2020.xls". Riverside extended the projections provided in these data out to 2055 to cover the time horizon of the land change model.

- Historical and projected agricultural production by crop type.

Riverside used the data from the Ministry of Agriculture available in the following URL: http://www.agricultura.gob.do/Estadisticas/tabid/86/language/en-US/Default.aspx). In particular, Riverside used the data from the entries under the *Estadísticas Agropecuarias.* These data do not

include the projections. Therefore, Riverside developed the projections based on the trends in the historical data. The agricultural production projections were developed for the following categories:

1. Rice
2. Crops for export (conventional crops): sugar cane, cocoa and coffee
3. Other crops: mixed agriculture, intensive agriculture, palm, coconut, and citrus.
    - Historical and projected GDP, total, by sector and by administrative unit

The GDP data used came from the following URL: http://www.bancentral.gov.do/estadisticas.asp?a=Sector_Real. Specifically, "Producto Interno Bruto (PIB) por sectores de origen, a precios corrientes y año de referencia 1991, anual" under Sector Real Referencia 1991.

1) BMPs: This scenario assumes best management practices for the main drivers: agriculture and urban expansion. BMPs were positioned in locations likely to produce the greatest benefit to ecosystem services related to sediment reduction and dry season water yield increases. The following rules were used to develop this scenario:
    - Sustainable (Compact) urbanization: Urban development will mostly grow vertically.
    - Reforestation on slopes > 60%.
    - Reforestation within 30-meter buffer area from main rivers.
    - Protected areas with category 1 and 2 will be reforested.
    - Agro forestry practices in areas with slopes < 60% and within protected areas with category 5 and 6.
    - Reforestation of areas upstream from reservoirs within a 250-meter buffer.
    - Silvopastoral practice in terrains with slope between 10% and 25%.
2) Conservation: This scenario assumes only rules that will conserve the environment from development. Other drivers will not have weight in this scenario. The following rules were used to model this scenario:
    - Reforestation in slopes > 45%.
    - Reforestation within 100-meter buffer area from main rivers.
    - Designation of additional protected areas.
    - Reforestation of the additional protected areas.

    In this scenario, it was assumed that there is no horizontal urban expansion. Thus, the growth will be vertical on the existing urban land.
3) Development: This scenario assumes only rules that will encourage development. Conservation of the environment is not at all an important issue in this scenario.
    - Urban expansion toward the areas identified in maps and based on the slope of the terrain as explained in the Methodology to Develop Scenarios section of this report.
    - Urban expansion along main roads.
    - Increase of mining exploration and exploitation in areas identified on maps.
    - Increase of tourism infrastructure in areas identified on maps.
    - Implementation of new industrial projects in the areas identified on maps.

Regarding the urban expansion along the road to the east of Santo Domingo, the road follows the coastline very well outside the Ozama basin. There is no room for development between the road and the coastline within the study basins. In general, it was not possible to keep development contained between the road and the coast. GEOMOD mostly allocated development along both sides of the road not extending too far inland within the polygon.

4) Combination: This scenario assumes a combination of conservation practices in the upper part of the basins and development in the lower parts. The following rules were used in the modeling:
    - Forest in areas with slope > 60%.
    - Forest in 30-meter buffer area from main rivers.
    - Forest in a 2 km buffer area from current national parks.
    - Urban expansion from current urban centers. The expansion will be dictated by the slope of the terrain as well as proximity to existing urban areas and roads as explained in the Methodology to Develop Scenarios section of this report.

4.3 Methodology to Develop the Scenarios:

Two future periods were evaluated in this project, 2046-2065 and 2081-2100. For the land use modeling, it is assumed that maturity of the land use changes is reached in the year 2055. Therefore, the land use changes were modeled from 2003 through 2055. The final 2055 maps were used in the SWAT model together with the climate data for both future periods: 2046-2065 and 2081-2100.

The maps used by the stakeholders during the two workshops were scanned and georectified. The areas that are delineated by the stakeholders on the maps as the areas of interest in the scenarios are digitized from these scanned and georectified maps. Those areas that are specified as having a particular slope or within a certain distance of a landscape feature (such as lands within 100 m of rivers) are determined by spatial operations in ArcMap. Because it is assumed that land use changes specified in the scenarios will have occurred by 2055, some of these areas are set aside as having a particular land-cover (e.g., forests on lands with slope > 45%); others act as masks that allow a particular land change to occur in certain places but not in others.

Riverside used GEOMOD to generate the land-use land-cover map for 2055. GEOMOD is a land use change model built in IDRISI, an integrated geographic information system and remote sensing software developed by Clark Labs at Clark University for the analysis and display of digital geospatial information. Riverside selected GEOMOD as the platform to build the land use change model because it can work with input maps from a single year. This functionality of the model is important for our purposes because the available land-cover maps of the four watersheds are from a single point in time, which is from year 2003. Absent a time-series of land-cover maps, Riverside used the GEOMOD framework to generate one land-cover map out to 2055 for each of the five scenarios.

4.3.1 GEOMOD Land Change Model

4.3.1.1 How GEOMOD Works

GEOMOD, a spatially-explicit grid-based land-use and land-cover change model has been fully described elsewhere (Pontius *et al.* 2001) and been applied extensively (Echeverria *et al.* 2008; Pontius *et al.* 2008). GEOMOD simulates the change between exactly two land covers, e.g., “urban” and “nonurban”. The input maps are an initial land-cover map, and several “driver” maps such as proximity to roads and elevation. Through statistical analysis of the empirical patterns created by the overlay of the initial land-cover map with the “driver” maps, a map that shows the overall suitability of each location for change is

generated. The model also reads from a text file the number of locations (cells) of each land-cover at a final time. Based on these inputs, the model allocates the net change in each land-cover between the initial and final time points across the study area and thus, simulates the spatial pattern of land change across the landscape.

GEOMOD's allocation algorithm prioritizes candidate pixels according to their suitability values. To this end, GEOMOD first creates a suitability map, which shows the suitability for the land change in question. With this rule, GEOMOD simulates land change by searching the landscape for the location of candidate locations that have the highest suitability value. Thus, starting from the pixels with the highest suitability value, GEOMOD allocates the projected land change until all pixels with that suitability value are converted. Then it proceeds to the pixels with the next highest suitability value and so on (Pontius *et al.* 2001). GEOMOD creates the suitability map empirically, by using several driver maps and the initial land-cover map. When a large number of locations that are candidate for change are tied (i.e., has exactly the same suitability value), GEOMOD allocates change among the tied locations in a uniform fashion.

GEOMOD's suitability map is created in two steps. First, GEOMOD reclassifies each driver map such that the locations of each category of the driver map are assigned a real number, obtained by comparing the driver map to the beginning time land-cover map. For example, if a slope map is one of the driver maps and urban land is the land cover of interest, GEOMOD reclassifies each category of slope to exactly one real number, which is the percent of the category that is urban according to the beginning time land-cover map. The percent-urban for each category in the slope map is computed as the ratio of the quantity of urban locations of that slope category to the quantity of all locations of that slope category. This step is repeated to reclassify all driver maps. In the second step, GEOMOD superimposes these reclassified driver maps and computes for each location a weighted sum of suitability to produce the overall suitability map. The weight given to each intermediate suitability map is determined by the user; the default is to use equal weights across all intermediate suitability maps.

GEOMOD requires the projected amount of change in the land cover of interest as an input. These projections were determined based on the available historical data on population change, agricultural output, and GDP as indicated in the Business-As-Usual (BAU) scenario section of this report. Specifically, Riverside generated the projected amounts of change in urban land and agricultural land. These projected amounts were entered as "Ending Time Quantities" in GEOMOD. Because GEOMOD simulates the change between exactly two land covers, for each scenario, Riverside used GEOMOD first to simulate the expansion of urban land according to the scenario rules. Then, using the resulting urban map, Riverside calculated the amount of agricultural land projected to be lost to urbanization and updated the projections for the change in the agricultural lands. These updated projected amounts of change in agricultural lands were input to GEOMOD, to determine where the changes in agricultural lands occurred. The rationale for this sequence of runs is that urbanization typically is irreversible (Seto et al, 2012) and agricultural land is lost to urban expansion (Nelson et al, 2010).

Riverside modeled the expansion of three agricultural land categories: rice, export crops, and other crops as indicated in section 3 of this report. Therefore, a total of three iterations (one iteration per category) were performed to simulate the agricultural expansion.

It is possible to determine the form of land change (e.g., compact versus spread-out urban expansion) in GEOMOD. For this, GEOMOD uses a neighborhood constraint rule to simulate the manner in which new development grows out of previous development. For example, if GEOMOD simulates change from non-urban to urban, then the neighborhood constraint mode restricts the search to only those locations of nonurban that are within a small square window around any urban locations. The width of the window, denoted by W, is called the neighborhood search width, and can be set by the user. The simulation re-computes the neighborhood at every time step because the land use state can change at every time

step. This functionality of GEOMOD is important to simulate land change according to the rules in each of the scenarios.

Detailed instructions for implementation of urban and cropland change simulations are presented in ***Appendix D*** at the end of this report. The instructions use Haina-Nizao-Ozama watershed as an example; however, the instructions have general applicability. ***Figure 4-1*** shows a flow chart of the iterations done within GEOMOD to simulate crop expansion in the basins.

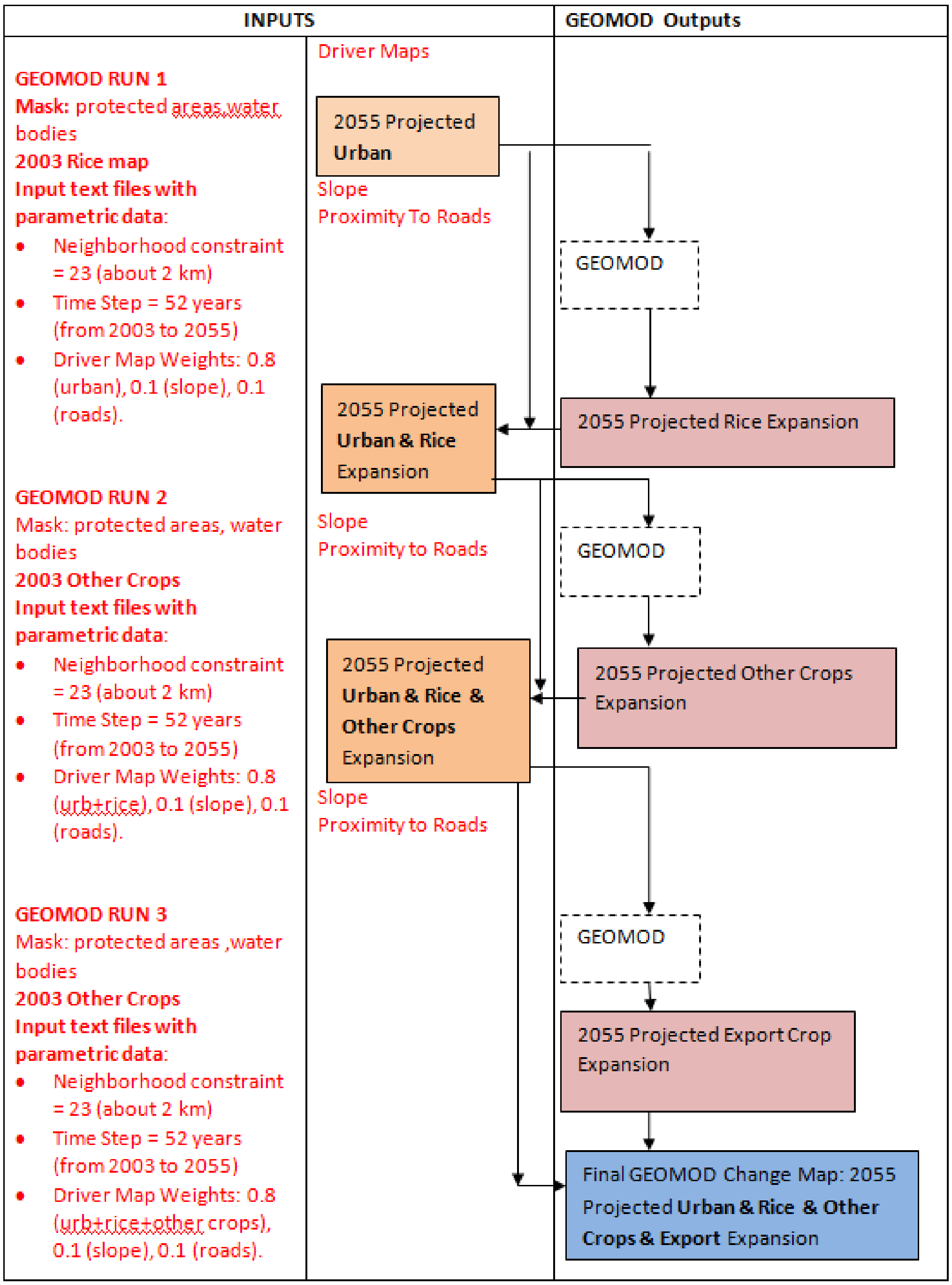

Figure 4-1. Flow chart of the iteratively procedure followed with GEOMOD to simulate the crop expansion in the study basins

4.3.2 Data Requirements

GEOMOD requires an initial land-cover map, a region map as well as an exclusion mask and driver maps. The justification, sources, and derivation of the exclusion masks and the driver maps are detailed below. Each input map must contain discrete (i.e., categorical) values. Therefore, continuous variables often expressed as real values, such as slope, must be reclassed into categorical bins, such as: category 1 = (0 degree - 1 degree), category 2 = (1 degree - 2 degrees), category 3 = (2 degrees - 3 degrees), etc.

Data Projection and resolution: All data used in the simulations and the subsequent analyses should be in an equal-area projection or in a projection in which areal distortions are negligible. Such distortion is negligible for the coordinate system WGS_1984_UTM_Zone_19N for the study sites. The resolution is 30 m to 90 m, dictated by the scale of the analysis, the overall level of accuracy of the maps used as drivers, and to a lesser degree, by the availability of computing resources in terms of time.

Population density: Riverside used population density maps from the Global Rural-Urban Mapping Project (GRUMP) to create the population density driver maps for each watershed (CIESIN, 2010). Riverside first reprojected the original GRUMP map to the coordinate system of the project. The resolution of the GRUMP map is 30" (approximately 1 km). Riverside resampled the data to 90m resolution to agree with the other spatial data used in the modeling.

Exclusion masks: In addition to driver maps, Riverside used several masks that direct land-cover change by preventing or encouraging certain types of land-cover changes in certain areas depending on the scenario. For example, no development was allowed within the protected areas and areas that are designated as additional conservation areas in the scenarios. In addition, for all scenarios, Riverside excluded inland water surfaces (consisting of lakes and reservoirs) extracted from the land-cover driver map. Thus, Riverside created a mask for each scenario to exclude the protected areas, additional conservation areas if any, and water from urban and cropland expansion. A few urban pixels in the initial land cover map may happen to fall into the protected areas and additional conservation areas. Riverside assumed no growth around those urban areas.

Riverside used the polygons drawn in the maps by the stakeholders as additional masks in GEOMOD to allocate land use and direct urban and agricultural land change (See ***Appendix C***). For example, urban expansion was not allowed beyond the polygons labeled "Sustainable Urbanization" under the BMP scenario and "Urbanization" under the Development and Combination scenarios. Likewise, agro-forestry under the Combination scenario in the Yaque del Norte was only allowed within the polygon labeled "Agro-forestry" and so on. On the other hand, no urban expansion or agricultural land change was allowed within polygons representing conservation or proposed conservation areas in respective scenarios.

Several rules under the scenarios dictate the presence of specific land covers at certain locations. Such rules tend to fragment the watersheds into several patches. For example, "Reforestation in slopes > 60%" rule under the BMP scenario means that all locations with slopes >60% will be forested in 2055. GEOMOD's neighborhood rule can only work with a single contiguous area; applying these rules would fragment the watersheds in at least some of the scenarios into more than one piece in which case the neighborhood rule could not be applied. Therefore, Riverside post-processed the simulated land cover maps to implement certain rules so that no urban or agricultural land change was allowed on these locations. In addition, a few rules such as "Agro forestry practices in areas with slopes < 60% and within protected areas with category 5 and 6" under the BMP scenario specify the type of agricultural practices. In implementation of this rule, Riverside first used GEOMOD to simulate agricultural land change; then Riverside post-processed the GEOMOD output to classify those projected agricultural lands that are in areas with slopes < 60% and within protected areas with category 5 and 6 to agro-

forestry. Note that all existing agricultural lands within protected areas with category 1 and 2 were assumed to be forested in 2055.

4.3.3 Driver Maps

GEOMOD requires a map of each one of the four factors that are the primary drivers of land change: slope, proximity to roads, population density, and land-cover.

1. Slope: Slope is generally accepted as a major factor influencing land change processes including urban land expansion. *Ceteris paribus*, gently sloped land is more preferable over land that is steeper. The slope map is derived from the DEM derived from ASTER imagery of the watersheds. Because GEOMOD uses input maps with discrete categories (i.e., integer values), Riverside reclassified the map to integer values as shown in ***Figure 4-2***.

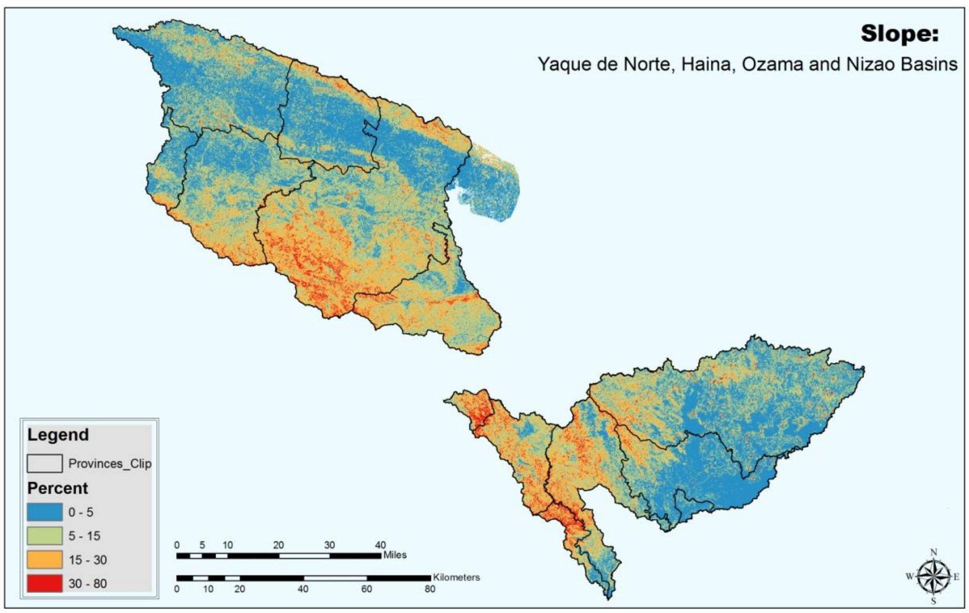

Figure 4-2. Slope map for Yaque del Norte, Nizao, Ozama and Haina Basin.

2. Weighted Distance to roads: This map is created using "Spatial Analyst>Distance>Cost-weighted…" in ArcGIS (***Figure 4-3***). The roads map was provided by TNC. In addition to the existing road network, Riverside also incorporated the roads that are planned or under construction assuming these will be in place by year 2055. The location of these roads were provided in the stakeholder meeting and included in the rule maps in ***Appendix C***. ***Figure 4-4*** shows the weighted distance to road maps. The red areas indicate greater road density.

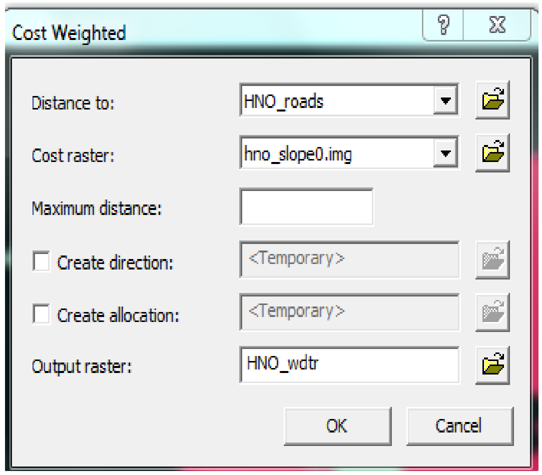

Figure 4-3. The Cost-weighted window with relevant inputs and output map name in ArcGIS

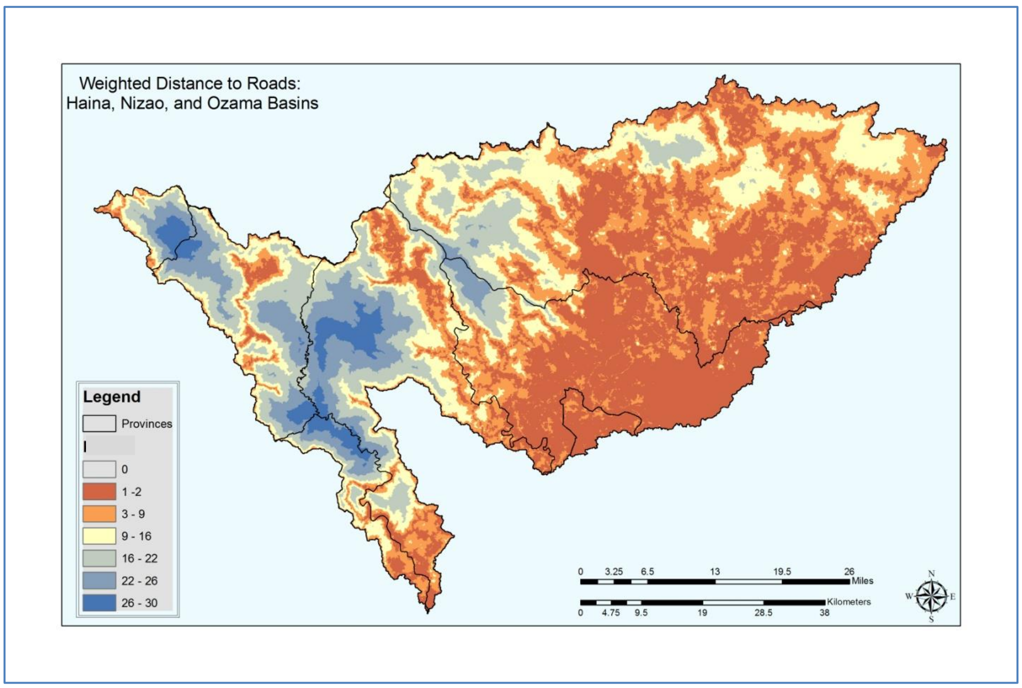

Figure 4-4. Weighed distance to road maps for Haina, Nizao and Ozama Basins.

3. Population density: Riverside used regional discretized population density maps based on the global map derived from the original GRUMP data. Riverside used these maps to track the spatial variation in population density across the watersheds. For population projections, Riverside used the demographic data pointed out under the Business-as-usual scenario above. Historical trends suggest that populations in the watersheds will increase approximately linearly and reach 7,374,298 and 3,273,606 in the Haina, Nizao, and Ozama watersheds and in the Yaque del Norte watershed, respectively, in 2055. The respective populations were 3,752,682 and 1,965,103 in 2003, the same year as the initial land cover map.

4. Land-cover: Riverside used the land-cover map provided by TNC and dated 2003 as the initial land cover in the watersheds.

4.3.4 Superposition of Rules

For the conservation and BMP scenarios, the outputs from GEOMOD included some gaps, which represent areas where the expansion of crops and urban classes did not take place. In these cases, the gaps were filled in with the initial 2003 LULC map. The outputs from GEOMOD were resample from 90-m to 30-m resolution to coincide with the original resolution of the 2003 LULC map. Additionally, the final outputs from GEOMOD for all scenarios were merged with the initial 2003 LULC map for the masked out areas (water bodies, protected areas, national parks). The rules defined by the stakeholders and listed in ***Section 4.2*** of this report were then superimposed on these maps.

For the BMP scenario, the following rules were applied:

- Reforestation in slopes > 60%. The new class is forest. If the underlying cell had a Bosque class, the new class was named "Bosque Type – Forest". This naming convention allows the policy makers to distinguish between new and old forest cells.
- Reforestation within a 30-meter buffer from main rivers. The new class is forest. If the underlying cell had a Bosque class, the new class was named "Bosque Type – Forest". This naming convention allows the policy makers to distinguish between new and old forest cells.
- Reforestation of protected areas with categories 1 and 2. The new class is forest. If the underlying cell had a Bosque class, the new class was named "Bosque Type – Forest". This naming convention allows the policy makers to distinguish between new and old forest cells.
- Agro forestry practice in areas with slopes < 60% and within protected areas with category 5 and 6. The new classes include the original LULC descriptor plus the new management practice (e.g. Bosque and/or Forest /agro forestry).
- Agro forestry practice in areas with slopes < 60%, original bosque type and within polygons delineated by the stakeholders. The new classes include the original LULC descriptor plus the new management practice (e.g. Bosque and/or Forest /agro forestry).
- Reforestation of a 250-meter buffer around reservoirs, but not downstream from the dam. If the underlying cell had a Bosque class, the new class was named "Bosque Type – Forest". This naming convention allows the policy makers to distinguish between new and old forest cells.
- Silvopasture practice in forested areas with slopes between 10% and 25% and outside protected areas. For the Haina, Nizao, and Ozama basins, this rule was also limited to within the polygons delineated by the stakeholders. The new classes include the original LULC descriptor plus the new management practice (e.g. Bosque, Forest/silvopasture).
- For the Haina, Nizao, and Ozama basins, the agro forestry practice was assigned to areas with slopes between 25% and 60%, with forest and/or bosque cover and within the polygons delineated by the stakeholders. As pointed out before, it was assumed that agro forestry practice is going to take place in areas with a forest or bosque class.

For the Conservation scenario, the following rules were applied:

- Reforestation in slopes > 45%. The new class is forest. If the underlying cell had a Bosque class, the new class was named "Bosque Type – Forest". This naming convention allows the policy makers to distinguish between new and old forest cells.
- Reforestation within a 100-meter buffer area from main rivers. The new class is forest. If the underlying cell had a Bosque class, the new class was named "Bosque Type – Forest". This naming convention allows the policy makers to distinguish between new and old forest cells.
- Designation and reforestation of additional protected areas delineated by stakeholders. If the underlying cell had a Bosque class, the new class was named "Bosque Type – Forest". This naming convention allows the policy makers to distinguish between new and old forest cells.

For the Development scenario, the following rules were applied:

- Mining class in the areas identified by the stakeholders. This simply delineates the general area where mining activities are expected to happen during the timeframe of the study, but no such development was forecasted by the land change model given the existing land use land cover map and other driver maps.
- Tourism class in the areas identified by the stakeholders. This simply delineates the general area where tourism activities are expected to happen during the timeframe of the study, but no such development was forecasted by the land change model given the existing land use land cover map and other driver maps.
- Tourism and industrial class in the areas identified by the stakeholders. This simply delineates the general area where tourism and industrial activities are expected to happen during the timeframe of the study, but no such development was forecasted by the land change model given the existing land use land cover map and other driver maps.
- Location of a new road in the Yaque del Norte basin. The road follows a slope between 0% and 10%.
- Location of projected reservoirs. The elevation of the projected dam was provided. New lakes were delineated following the contour line that corresponds to the given elevation.

For the Combination scenario, the following rules were applied:

- Forest in areas with slopes > 60%. This rule was also applied in the BMP scenario.
- Forest in a 30-meter buffer from main rivers. This rule was also applied in the BMP scenario.
- Forest in a 2-km buffer area from current national parks. The new class is forest. If the underlying cell had a Bosque class, the new class was named “Bosque Type – Forest”. This naming convention allows the policy makers to distinguish between new and old forest cells.
- Agro forestry was assigned within the conservation polygons delineated by the stakeholders and on cells with forest class.
- Tourism and industrial class was assigned to new areas delineated by the stakeholders.
- New reservoirs were placed within the locations identified by the stakeholders. The elevation of the projected dam was provided. New lakes were delineated following the contour line that corresponds to the given elevation.

4.3.5 Deliverables

The following results have been delivered in electronic format together with this report:

- Maps in pdf format for all basins and scenarios.
  - North_BAU.pdf: Business As Usual scenario for the Yaque del Norte basin
  - North_BMP.pdf: Best Management Practice scenario for the Yaque del Norte basin.
  - North_CONS.pdf: Conservation scenario for the Yaque del Norte basin.
  - North_DEV.pdf: Development scenario for the Yaque del Norte basin.
  - North_Mixed.pdf: Combination scenario for the Yaque del Norte basin.
  - South_BAU.pdf: Business As Usual scenario for the Nizao, Haina, and Ozama basins
  - South_BMP.pdf: Best Management Practice scenario for the Nizao, Haina, and Ozama basin.
  - South_CONS.pdf: Conservation scenario for the Nizao, Haina, and Ozama basin.
  - South_DEV.pdf: Development scenario for the Nizao, Haina, and Ozama basin.
  - South_Mixed.pdf: Combination scenario for the Nizao, Haina, and Ozama basin.

The following scenarios include new land use land cover classes:

Business As Usual:

Other crops: includes mixed agriculture, intensive agriculture, palm, coconut, and citrus.
Crops for export: includes sugar cane, cocoa, and coffee.

Best Management Practice, Conservation and Combination:

The following new classes represent the existing bosque areas with agro forestry and silvopasture practices:

Bosque Conífer Abierto – Agro
Bosque Conífero Abierto – Silvo
Bosque Conífero Denso – Agro
Bosque Conífero Denso – Silvo
Bosque Latifoliado Húmedo – Agro
Bosque Latifoliado Húmedo – Silvo
Bosque Latifoliado Nublado – Agro
Bosque Latifoliado Nublado – Silvo
Bosque Latifoliado Semi Húmedo – Agro
Bosque Latifoliado Semi Húmedo – Silvo

The classes named Bosque type - forest represent the existing bosque types that met the forest cover criteria from the rules. These areas (bosque type – forest) remain with the same cover type as the 2003 LULC map.

Bosque Conífero Abierto – Forest
Bosque Conífero Denso – Forest
Bosque Latifoliado Húmedo – Forest
Bosque Latifoliado Nublado – Forest
Bosque Latifoliado Semi Húmedo – Forest

The classes named Forest, Forest – Agro and Forest – Silvo are new areas that became forest class based on the imposed rules.

Development:

The following new classes were created for the development scenario:

Tourism
Tourism Industrial
Mining
Roads
Proposed reservoirs

Combination:

The combination scenario includes the following new classes:

Other crops: includes mixed agriculture, intensive agriculture, palm, coconut, and citrus.
Crops for export: includes sugar cane, cocoa, and coffee.

New bosque/forest classes were created and named with the same convention used in the BMP scenario.

Tourism Industrial

Potential reservoirs

4.3.6 Results

The predominant land use land cover classes are crops, forest and urban. In the Haina basin, Sub-basins 2 and 3 yielded most of the changes while sub-basin 1 remained almost the same. Urban and crop expansion were simulated for the Business-As-Usual (BAU), Development (DEV) and Combination (MIX) scenarios, while forest expansion and reduction of crops were simulated for the Conservation (CON) scenario (***Figure 4-5*** and ***Figure 4-6***).

The results are more variable for the Nizao, Ozama, and Yaque del Norte basins than for the Haina basin. As opposed to the Haina basin, the land use model forecasted an increase in crops and a decrease in forest for some sub-basins for all land use scenarios including conservation (***Figure 4-7***, ***Figure 4-8***, ***Figure 4-9***, ***Figure 4-10***, ***Figure 4-11***, ***Figure 4-12***, ***Figure 4-13***, ***Figure 4-14***). ***Table*** 6-3 includes a description of the land use type codes. The percents of each land type within each sub-basin area are summarized in ***Appendix E.***

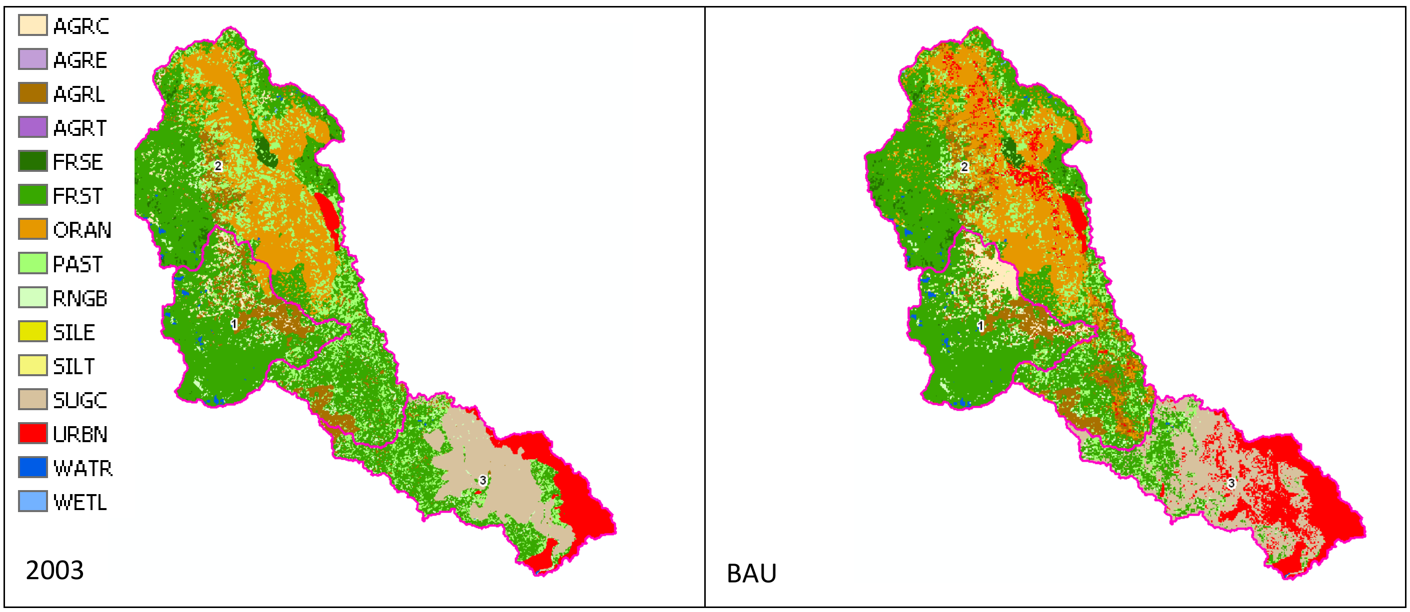

Figure 4-5. Haina 2003 LULC and BAU modeling results

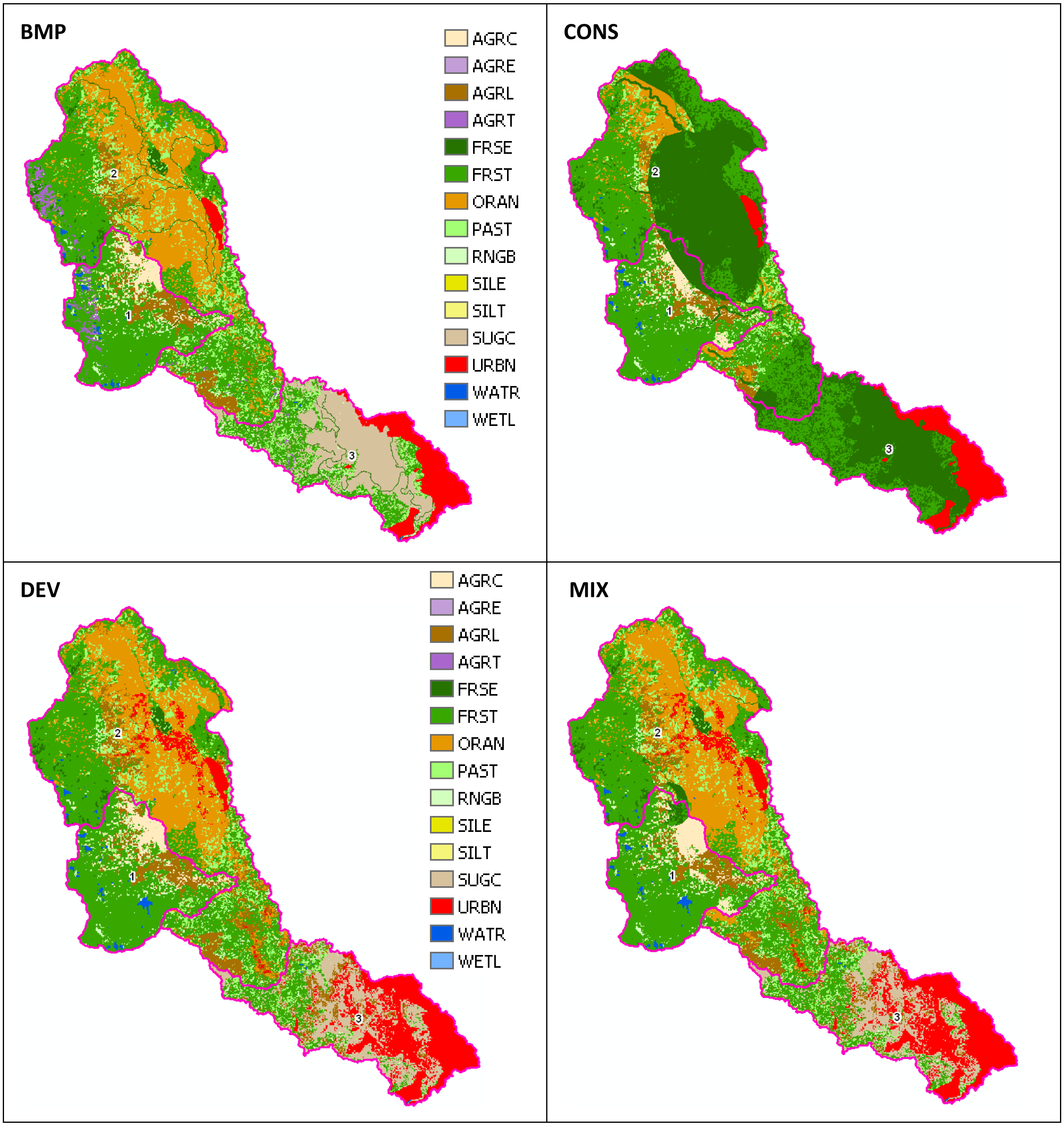

Figure 4-6. Haina LULC Modeling Results for the BMP, CONS, DEV, and MIX scenarios.

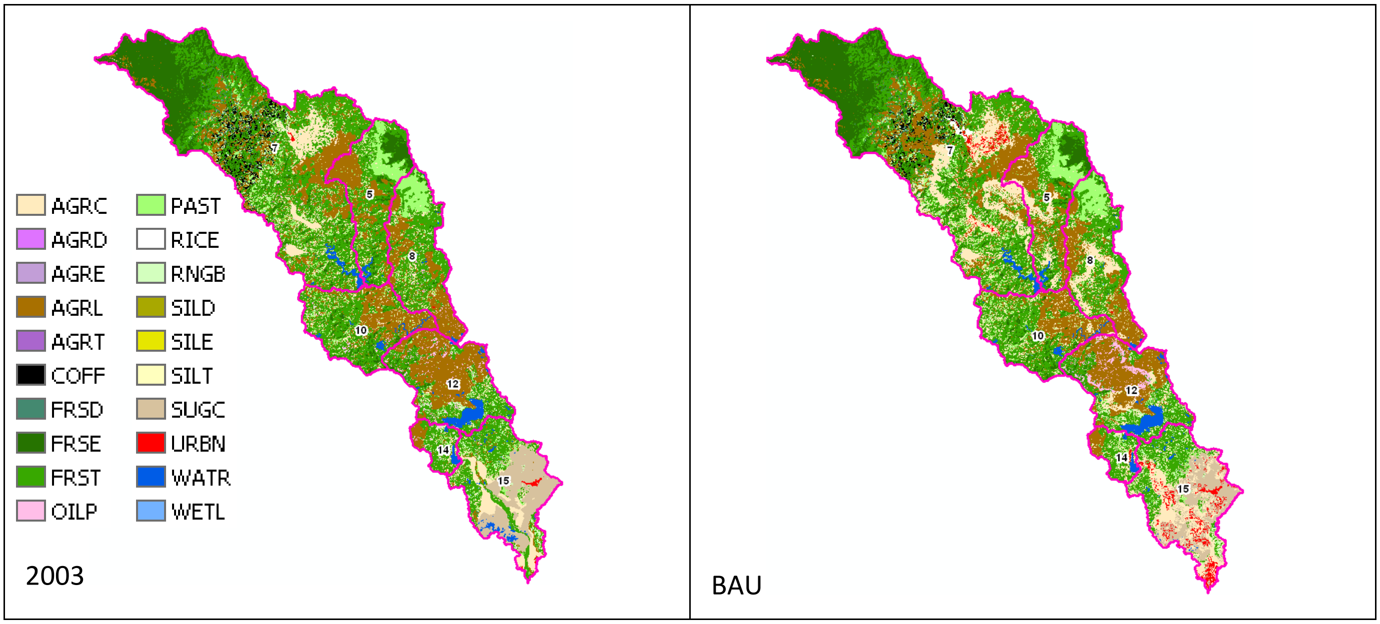

Figure 4-7. Nizao 2003 LULC and BAU modeling results

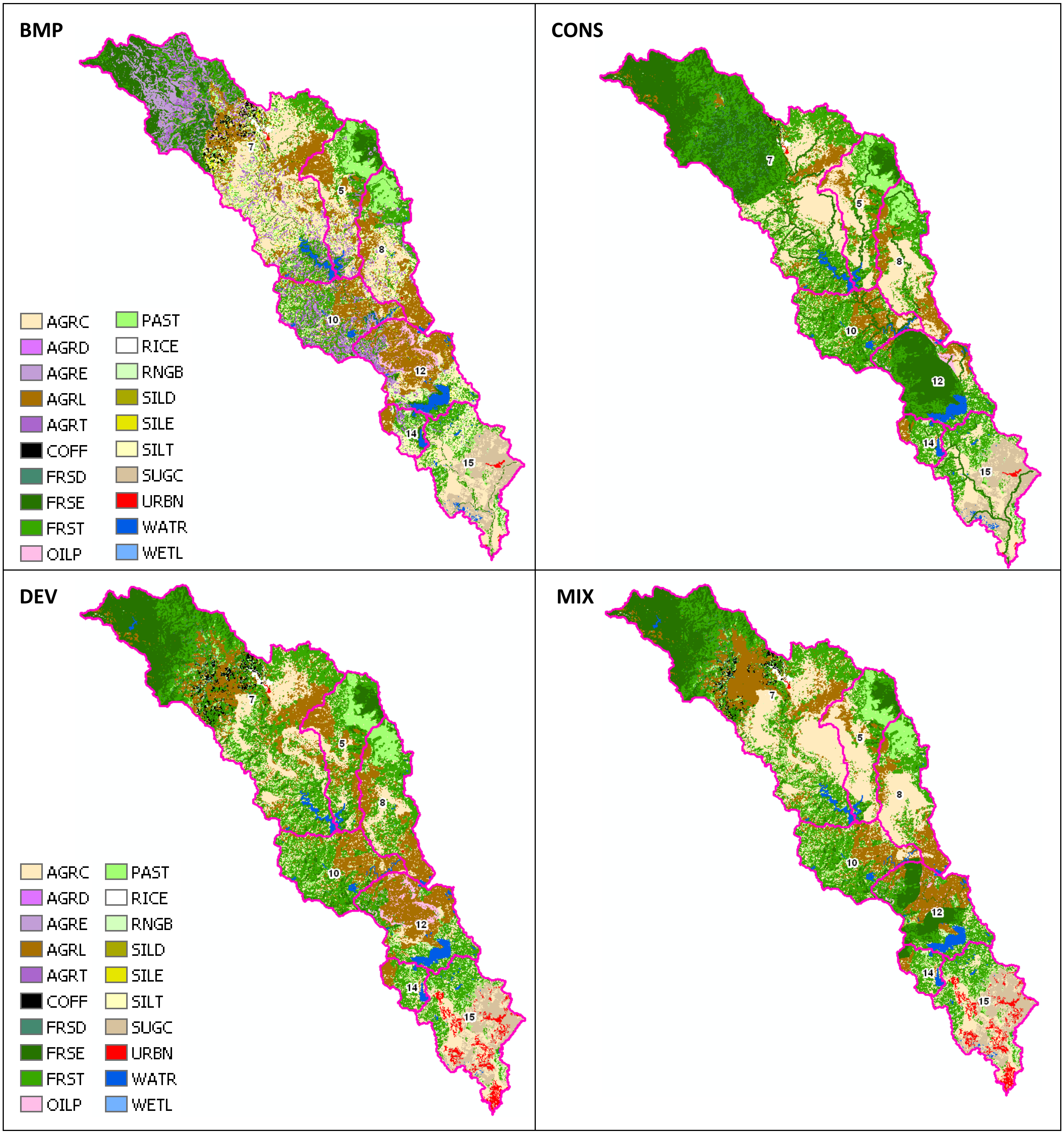

Figure 4-8. Haina LULC Modeling Results for the BMP, CONS, DEV, and MIX scenarios.

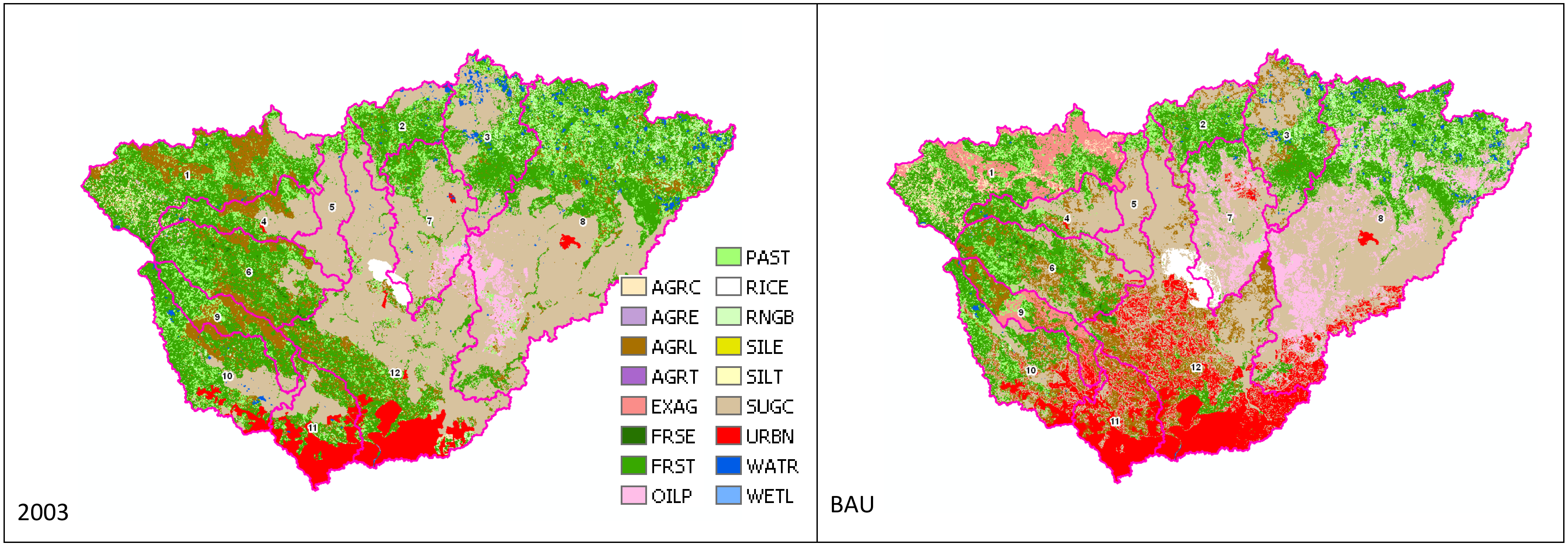

Figure 4-9. Ozama 2003 LULC and BAU modeling results

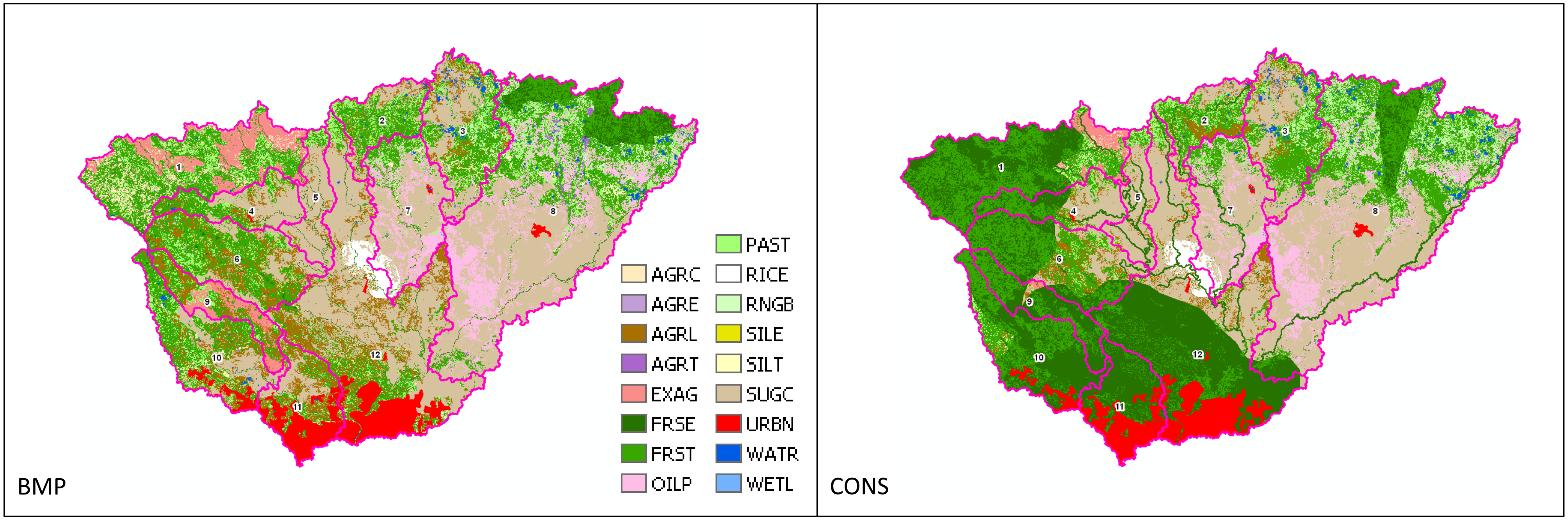

Figure 4-10. Ozama LULC Modeling Results for the BMP and CONS scenarios.

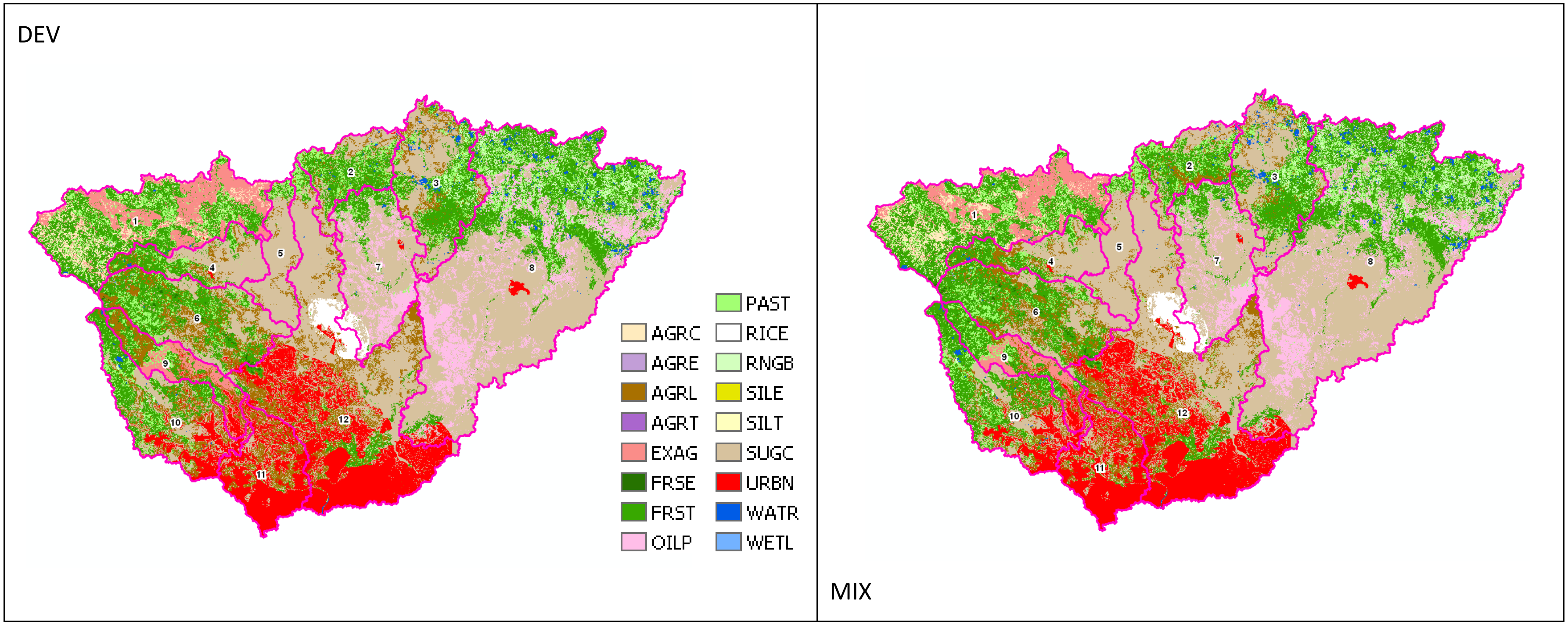

Figure 4-11. Ozama LULC Modeling Results for the DEV and MIX scenarios.

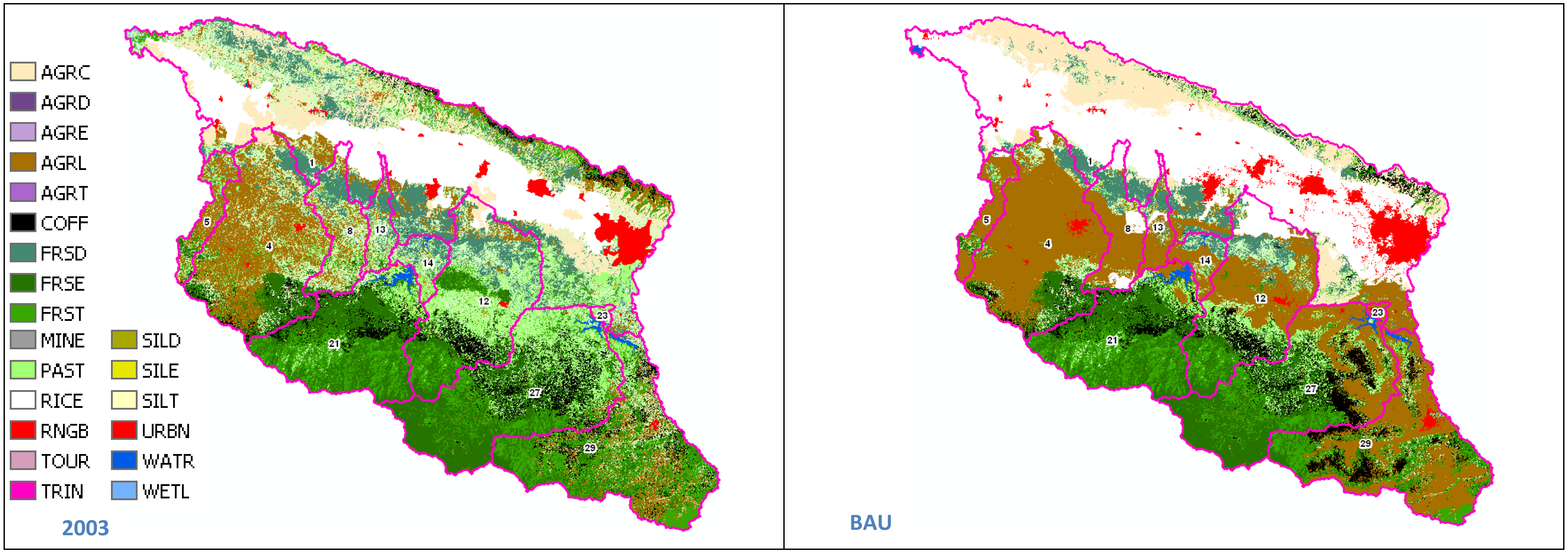

Figure 4-12. Yaque del Norte 2003 LULC and BAU modeling results

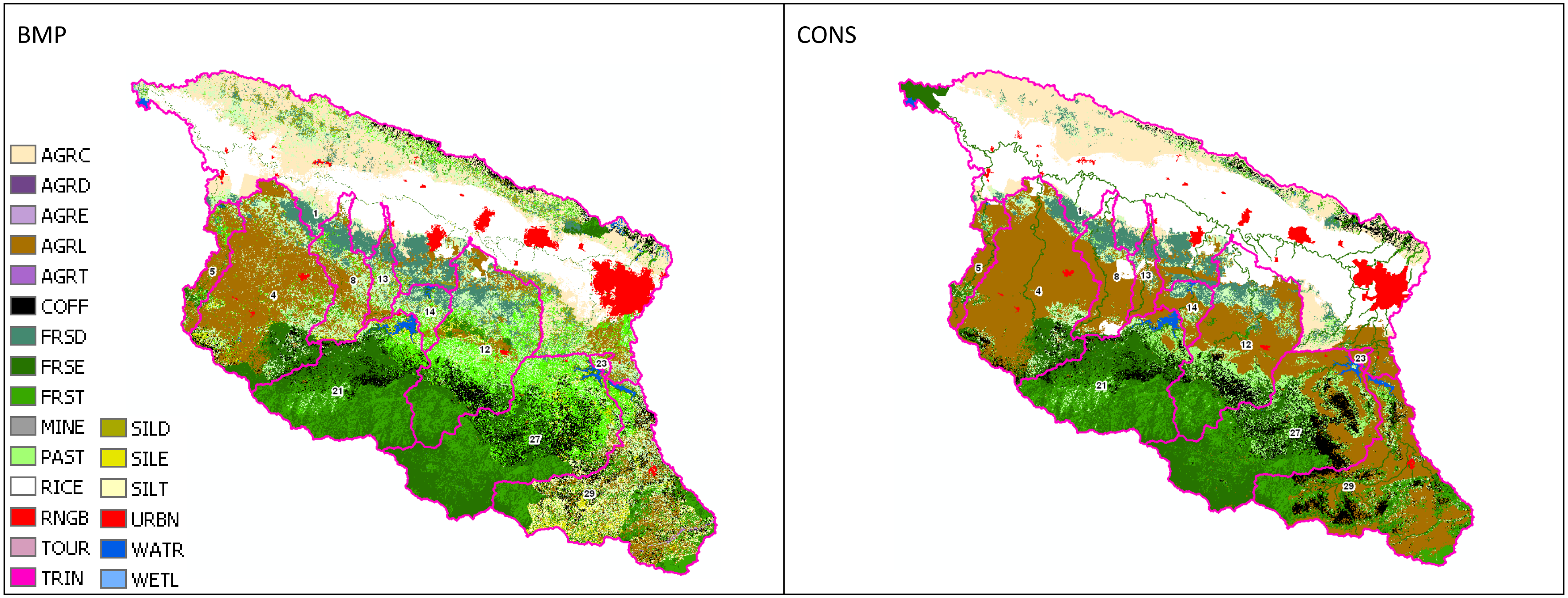

Figure 4-13. Yaque del Norte LULC Modeling Results for the BMP and CONS scenarios.

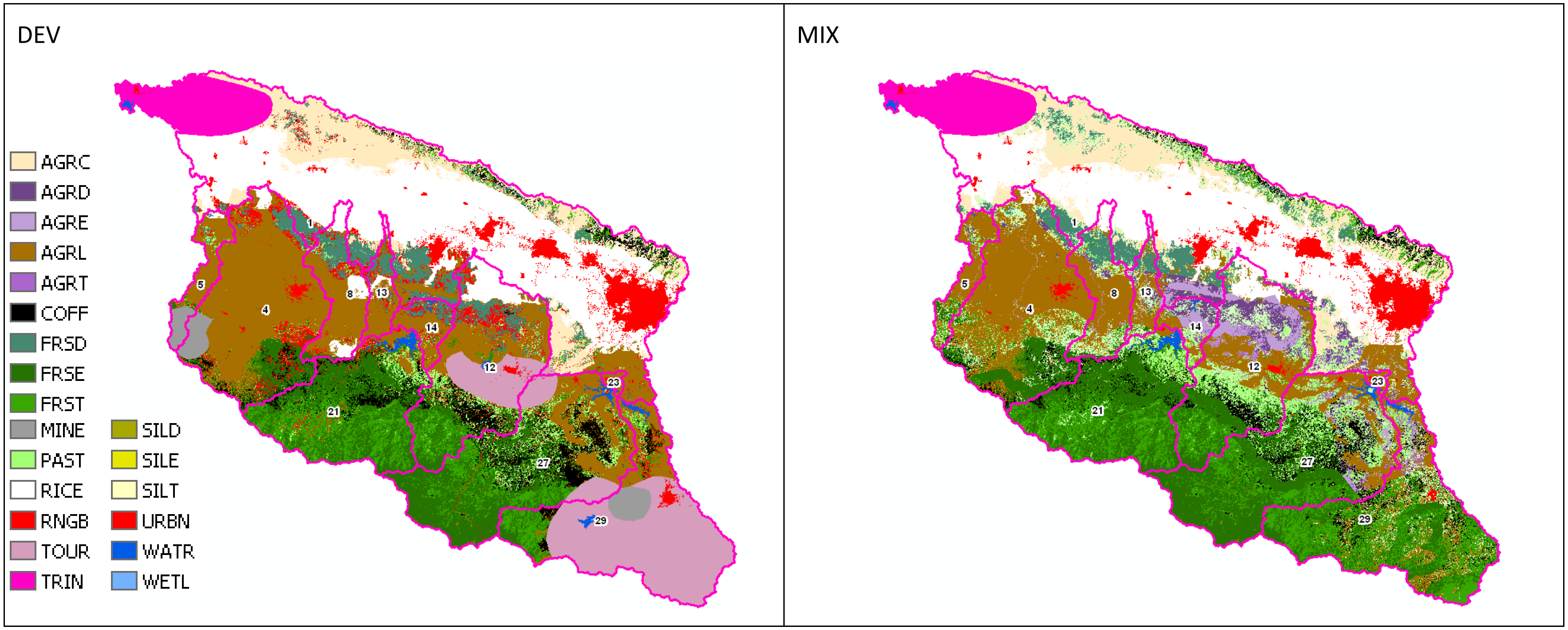

Figure 4-14. Yaque del Norte LULC Modeling Results for the DEV and MIX scenarios.

5.0 Selection of Climate Change Projections

Riverside reviewed the climate change data received from TNC. Historical precipitation and temperature quantiles were computed for all the time series for the time period 1961 – 1990. The results confirmed that the time series were bias corrected. Then, the annual change in temperature and the percent change in precipitation were computed and plotted to represent, on an annual scale, the range of results from the GCM projections. The delta plots among all four basins were similar. Therefore, the climate change selection was performed with the data from only one of the four basins.

Figure 5-1 represents the annual delta plot for the Haina basin. Three climate zones were identified in the delta plots: dry and hot, median and wet and warm (see red polygons in ***Figure 5-1***). A subset of 18 GCM projections was selected from all three zones for this analysis.

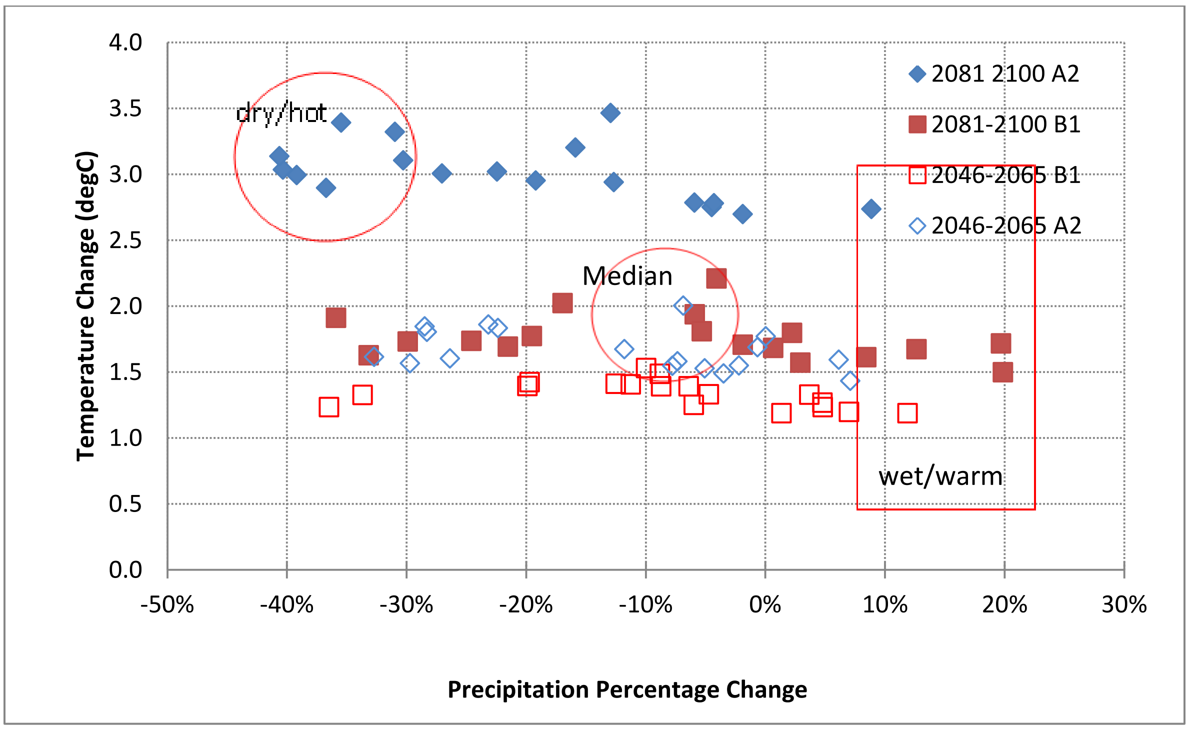

Figure 5-1. Annual delta plot for the Haina basin

The hydrologic response and storage characteristics of the basins are not a linear function of the climate inputs. Therefore, the SWAT model for the Haina basin and the 2003 LULC data was executed with the selected 18 GCM projections to assess the impact of the climate inputs on the water and sediment production of the basin.

Sediment, water yield, evapotranspiration, and potential evapotranspiration are direct outputs from SWAT. Peakflow, surface runoff, and baseflow were estimated based on the total streamflow output from SWAT. A Log-Pearson-Type III probability distribution was fit through the annual peakflow time series derived from the SWAT output because this type of distribution fitted very well the historical peak flow data and this distribution is widely used to describe this type of data. The 25-year peakflow (exceedence probability = 0.04) was selected to represent the annual peakflows in the sub-basins. The annual peak data fit this distribution well below the 25-year return period. For lower exceedence probabilities (< 0.04), there were very few data to fit the theoretical distribution and therefore less confidence in the estimated annual peakflows.

To characterize the baseflow and surface runoff components of the output flows, the streamflow results were processed through a baseflow filter that is available through the SWAT software website at http://swat.tamu.edu/software/baseflow-filter-program/ (Arnold J.G et. al, 1999). Then, the mean annual baseflow and surface runoff were computed.

It is presumed that wet and warm climate projections will produce more water yield, sediment, and larger peaks than the baseline or historical climate. Conversely, the dry and hot projections are expected to produce less water yield, sediment, and lower peaks than the historical climate. The results of this analysis demonstrated this general trend with some exceptions. Nonlinearities in the hydrologic models can produce some surprising results in some cases.

5.1 Climate Change Projections in the Hot-Dry Climate Zone

Figure 5-2 shows the values of peakflow, sediment, water yield, baseflow, surface runoff, and evapotranspiration (ET) at the outlet of the Haina basin for six dry and hot climate change projections and the historical mean areal precipitation and temperature. All projections produced lower water yield and evapotranspiration than the historical. Two projections (mpi_echam5_a2_r1_2046 and ipsl_cm4_a2_r1_2081) produced slightly larger peak flows than historical. In addition, all projections produced more sediment than the historical.

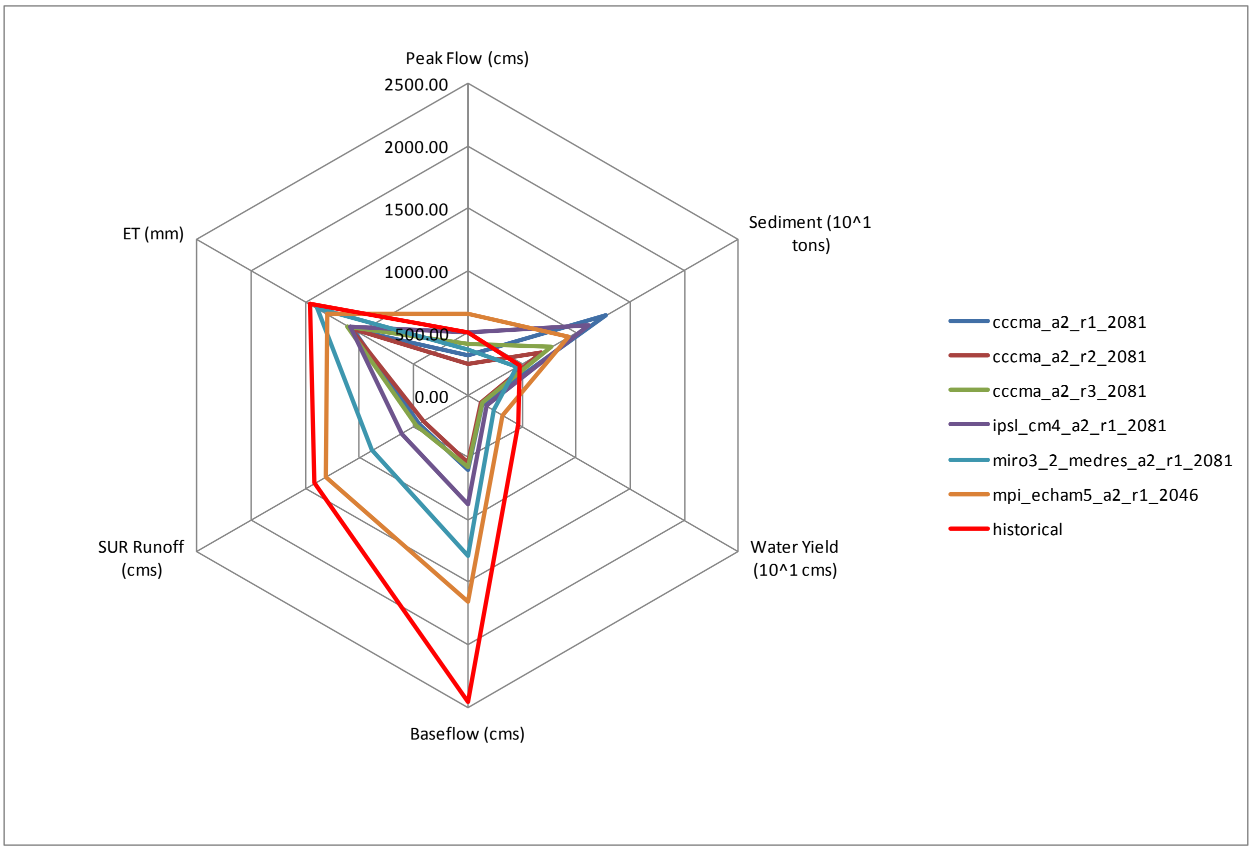

Figure 5-2. Comparison of mean annual peakflow, sediment, water yield, baseflow, surface runoff and evapotranspiration (ET) at the outlet of the Haina basin for six climate change projections representative of the dry and hot climate zone and the historical climate.

A closer analyzes of the data revealed that the timing of the occurrence of the peaks affects the sediment production in the basins. Upland erosion depends on peak flow rate, surface runoff volume, slope, an erodibility factor that was kept constant for all runs, a support practice factor that was also

constant for all runs and a cover and management factor which changes throughout the simulation and accounts for the development of the plant canopy. The plant canopy affects erosion by intercepting raindrops and reducing the effective rainfall energy available to detach soil particles.

For the climate change projections that predict lower flows and larger sediment, the peak flows in the future periods occur early in the year when the crops are not fully developed and the soil are more vulnerable to erosion. On the other hand, the historical largest peaks occur in mid May and August-September when the vegetation canopy is fully developed.

Figure 5-3 compares the hydrograph for the historical period and the future period for the climate projection ipsl_cm4_a2. Most peak flows are lower than the historical, except for one at the beginning of the record. This large peak in the future period occurs early in the year when the crop canopy is not dense enough to protect the soils from erosion (***Figure 5-4***). This peak flow produces the largest sediment load in the future record.

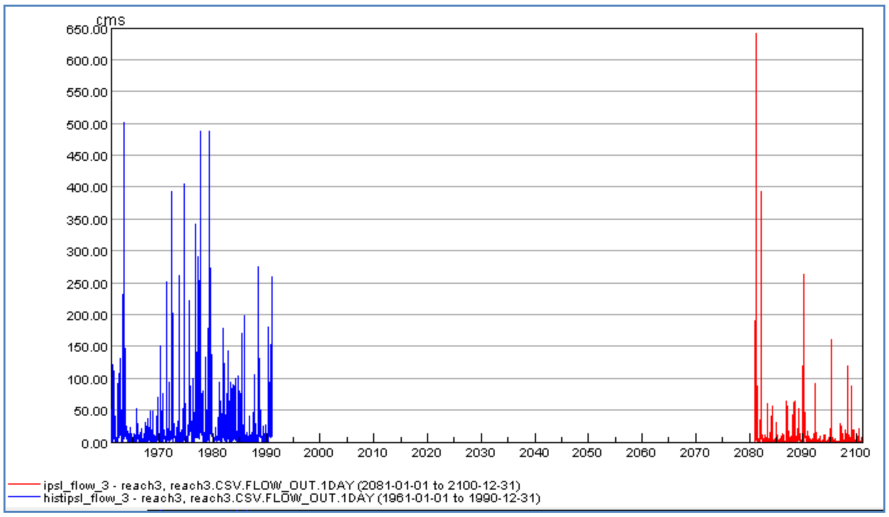

Figure 5-3. Historical and future hydrographs from ipsl_cm4_a2 climate change projection at the outlet of the Haina basin.

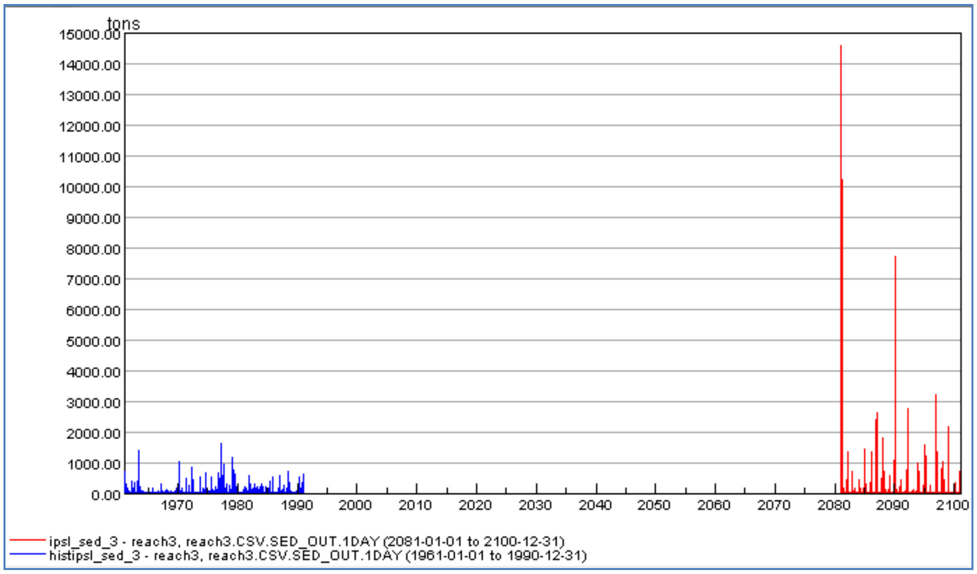

Figure 5-4. Sediment yield for the historical (blue) and future (red) periods for the ipsl_cm4_a2 climate change projection at the outlet of the Haina basin.

Similar results from the cccma_cgcm3_a2_run1_2081 projection are shown in ***Figure 5-5*** and ***Figure 5-6***. In this case, all peak flows are lower in the future period than in the historical period. However, the sediment yield is larger in the future period. ***Figure 5-7*** and ***Figure 5-8*** show a comparison of the sediment yield produced by a peak flow that occurs in January and a peak flow that occurs in late May. The sediment yield in January is much larger than the sediment yield in May, even though the peak flow is much lower in January than in May. This happens because the vegetation canopy is more dense in May than in January. The amount of sediment load produced in January (~1400 tons) represents less than 1 mm of soil depth over the entire Haina basin. Therefore, it is unlikely that the lower sediment peak produced in mid May is due to a lack of sediment in the basin.

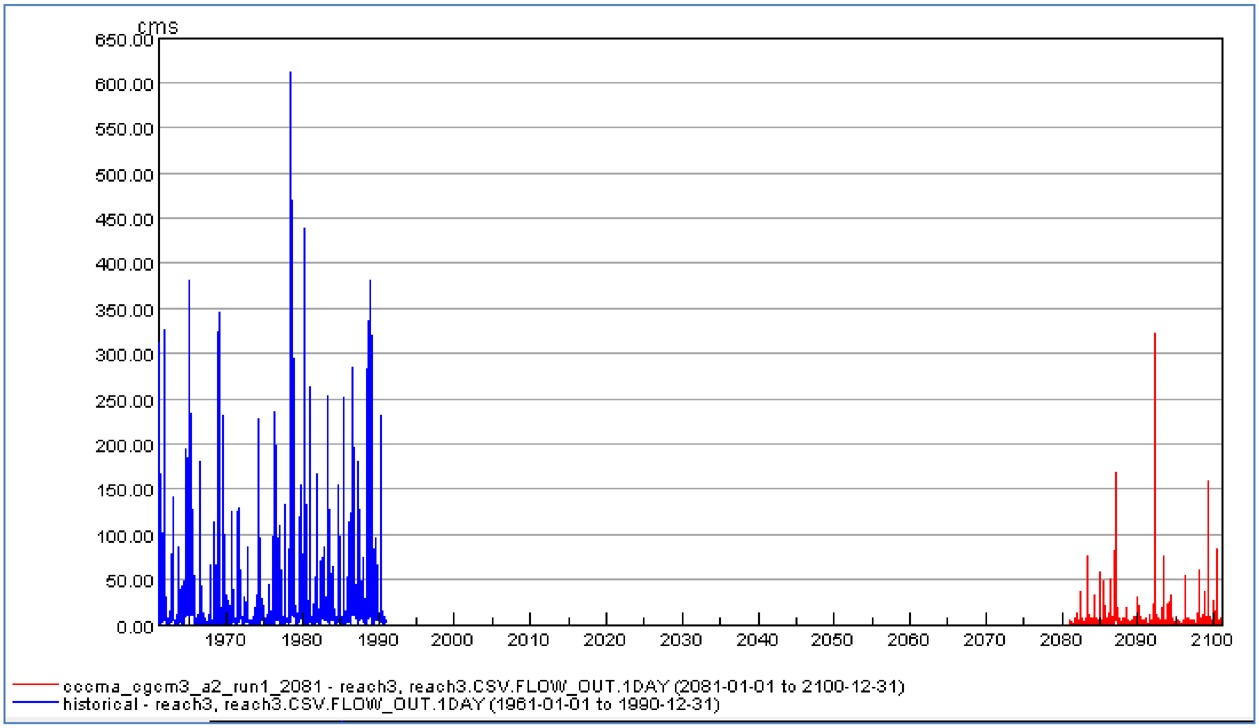

Figure 5-5. Historical and future streamflow from the miro3_a2_r1 climate change projection at the outlet of the Haina basin.

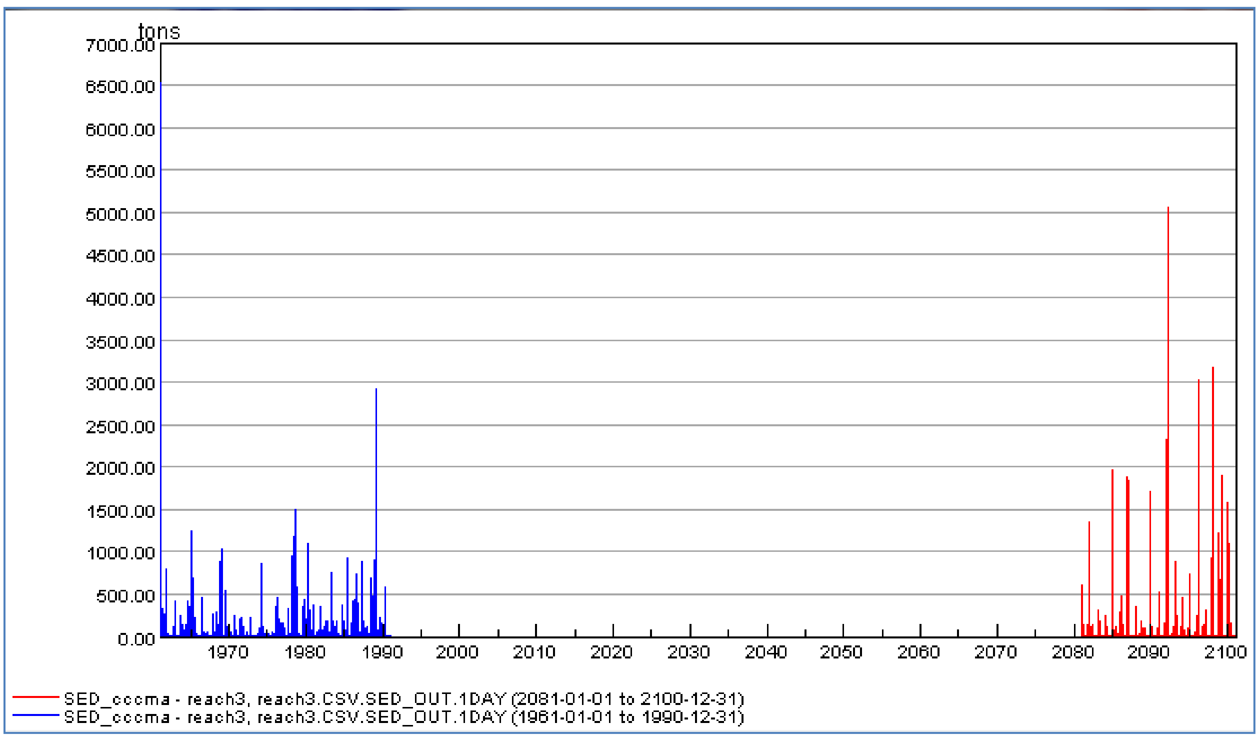

Figure 5-6. Historical and future sediment load (in metric tons) from the cccma_cgcm3_a2_run1 climate change projection at the outlet of the Haina basin.

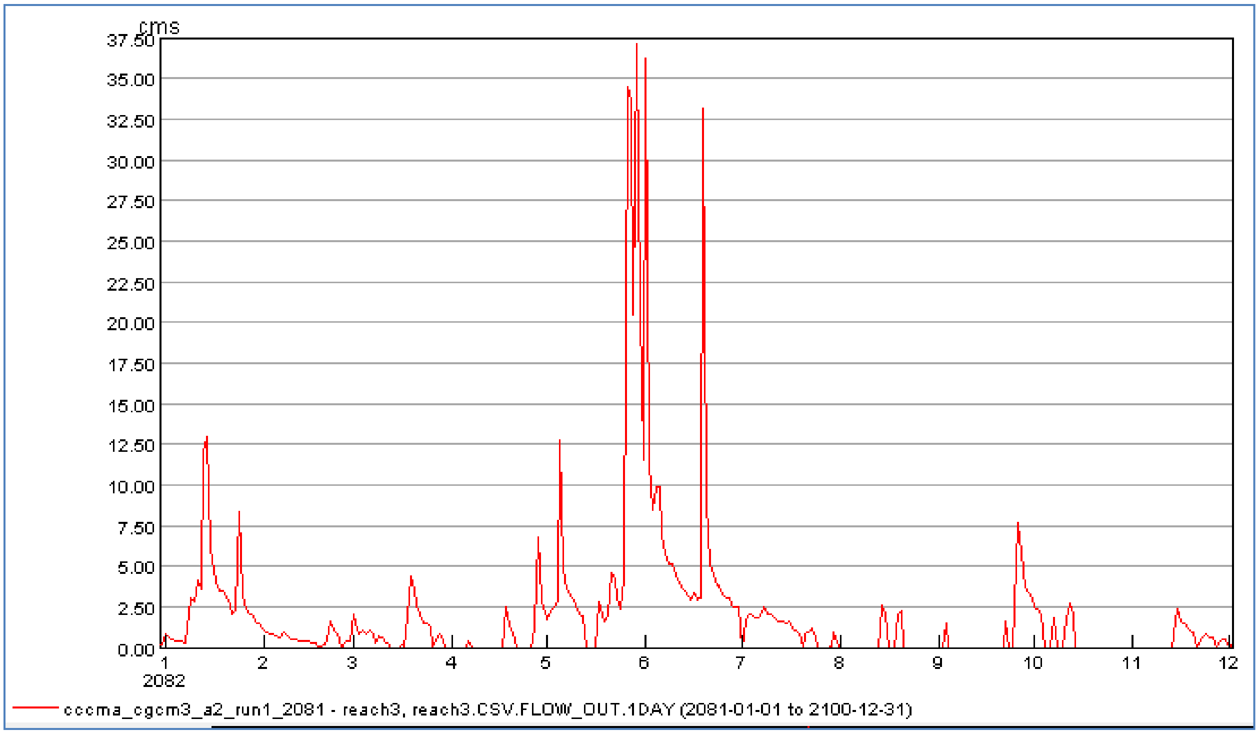

Figure 5-7. 2082 hydrograph at the outlet of the Haina basin from the ccma_cgcm3_a2_run1 climate change projection at the outlet of the Haina basin.

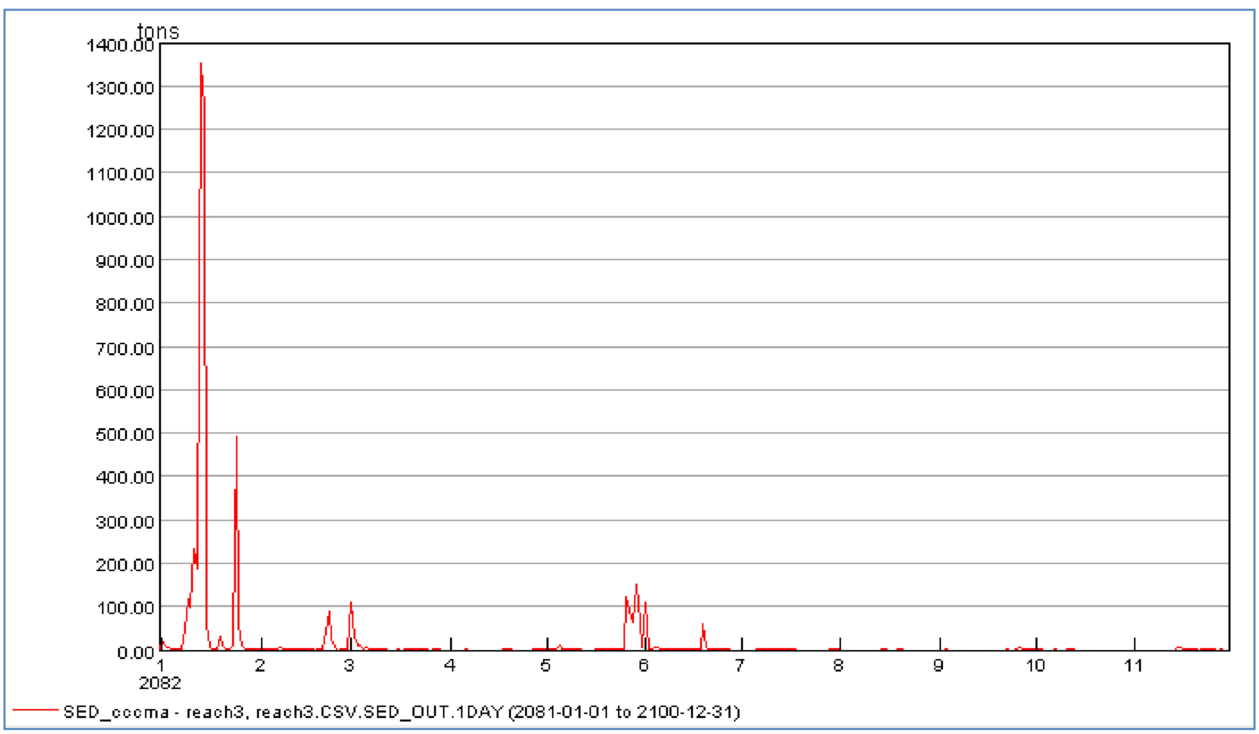

Figure 5-8. 2082 sediment yield at the outlet of the Haina basin from the ccma_cgcm3_a2_run1 climate change projection at the outlet of the Haina basin.

5.2 Climate Change Projections in the Wet-Warm and Median Climate Zones

Figure 5-9 and ***Figure 5-10*** summarize the SWAT results for the subset of climate change projections from the wet-warm and median climate zones. The wet-warm projections produced increases in flow and sediment as expected. The projections from the median zone yielded a combination of results some with more flows and sediment and some with less flows and more sediment.

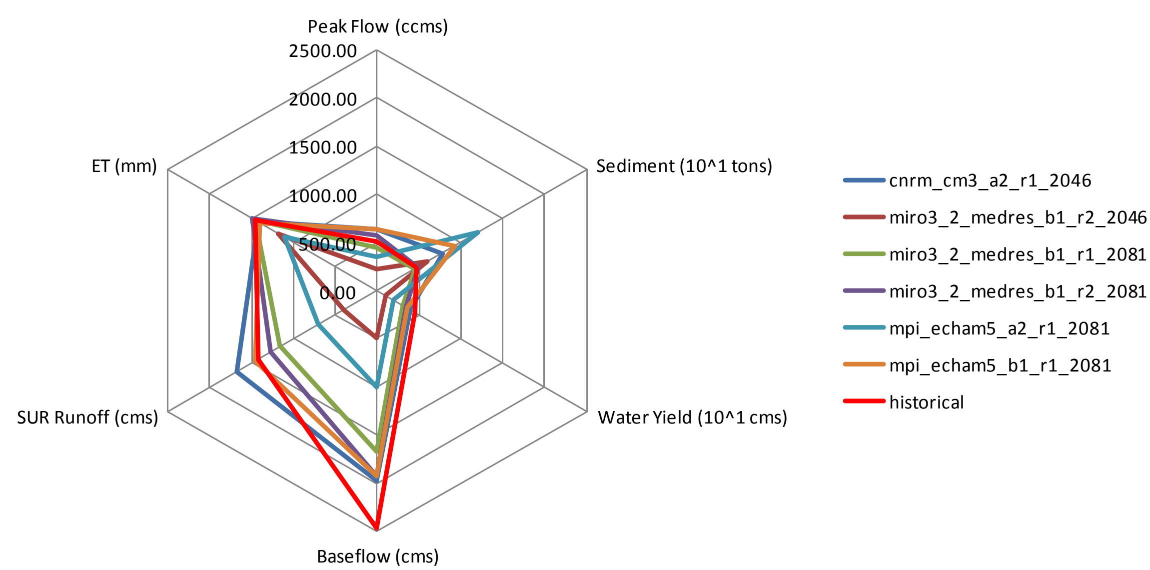

Figure 5-9. Comparison of mean annual peakflow, sediment, water yield, baseflow, surface runoff, and evapotranspiration (ET) at the outlet of the Haina basin for six climate change projections representative of the median climate zone and the historical climate.

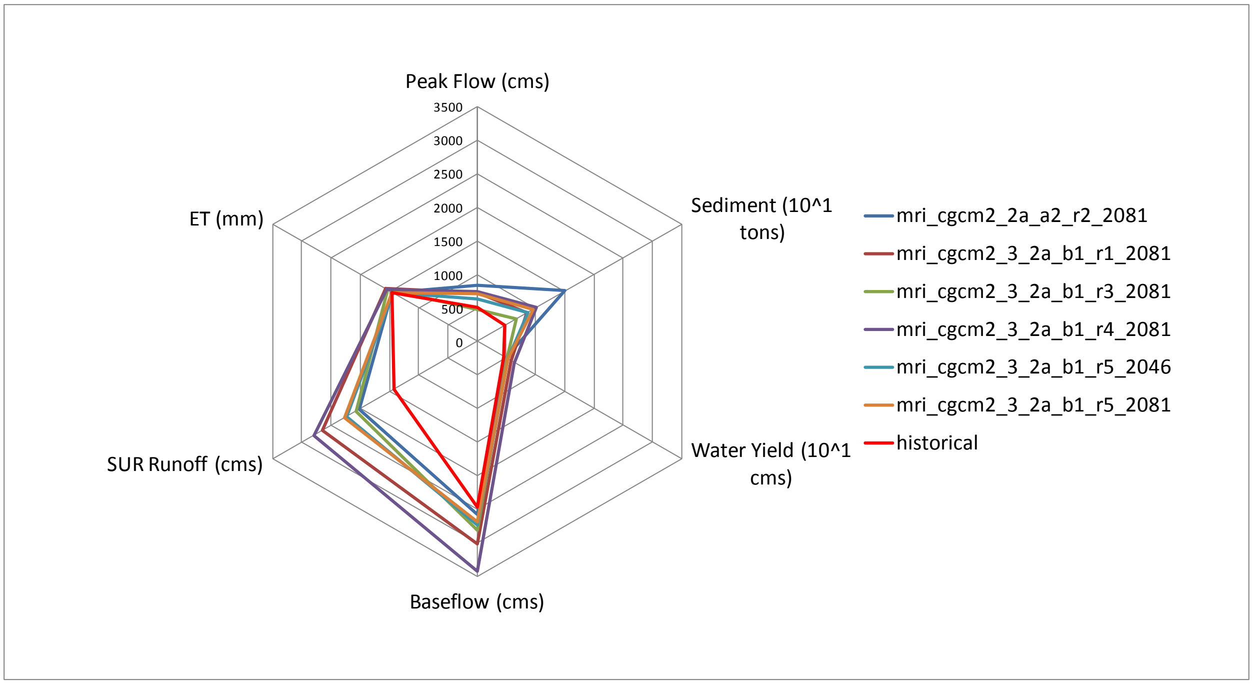

Figure 5-10. Comparison of mean annual peakflow, sediment, water yield, baseflow, surface runoff, and evapotranspiration (ET) at the outlet of the Haina basin for six climate change projections representative of the wet-warm climate zone and the historical climate.

Riverside in conjunction with TNC selected five climate change projections out of the 18 projections analyzed to characterize the potential future climate. ipsl_cm4_a2 and cccma_a2_run2 projections were selected from the hot-dry climate zone to account for the effect of the timing of the events in the analysis. cnrm_cm3_a2_r1, mri_cgcm2_2_2a_b1_run5_2081 and mri_cgcm2_2_2a_b1_run5_2046 were selected from the other two climate zones. These three projections produce results that plot in the middle of all other results and represent the average response from the projections in the wet-warm and median climate zones.

5.3 Seasonality of the Climate Change Projections

The monthly percent change in precipitation was plotted for all 18 GCM projections to assess the monthly variability of the data. ***Figure 5-11*** shows the results for the projections in the dry and hot climate zone. Even though these projections predict decreases in precipitation on an annual scale, some of them produce more precipitation than the historical in December through March (e.g. ipsl_cm4_a2_run1, cccma_cgcm3_1_a2_run1, cccma_cgcm3_1_a2_run2, cccma_cgcm3_1_a2_run3, mpi_echam5_a2_run1). The monthly variation in precipitation is not consistent among all the projections in the same climate zone. For example, miroc3_2_medres_a2_run1 tends to differ less from the historical from July through September compared with the other projections. The monthly variation in temperature is not as great as the variation in precipitation as shown in ***Figure 5-12.***

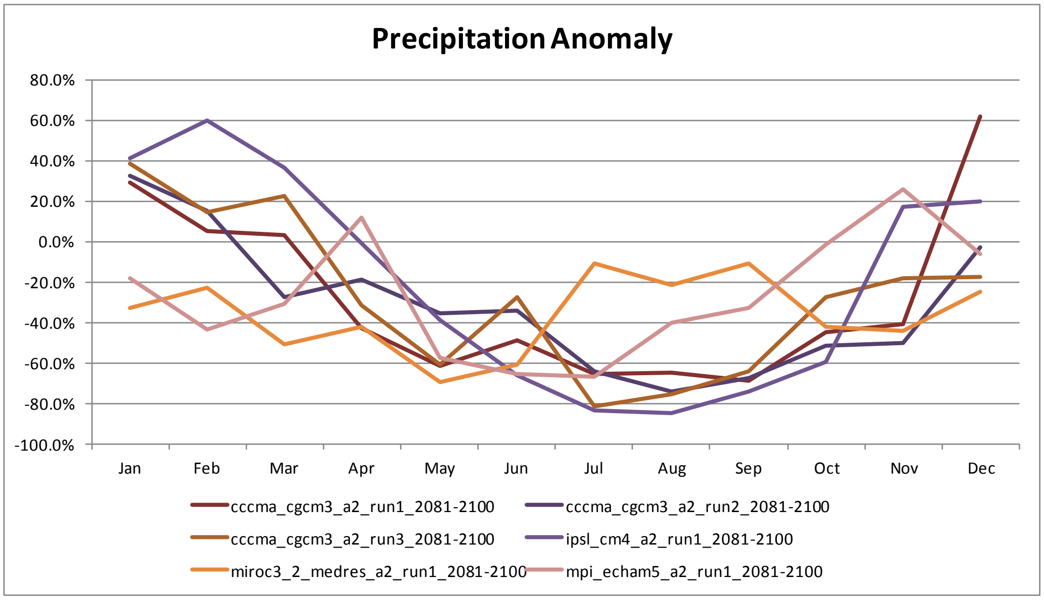

Figure 5-11. Monthly percent change in precipitation for the selected climate change projections in the hot and dry climate zone.

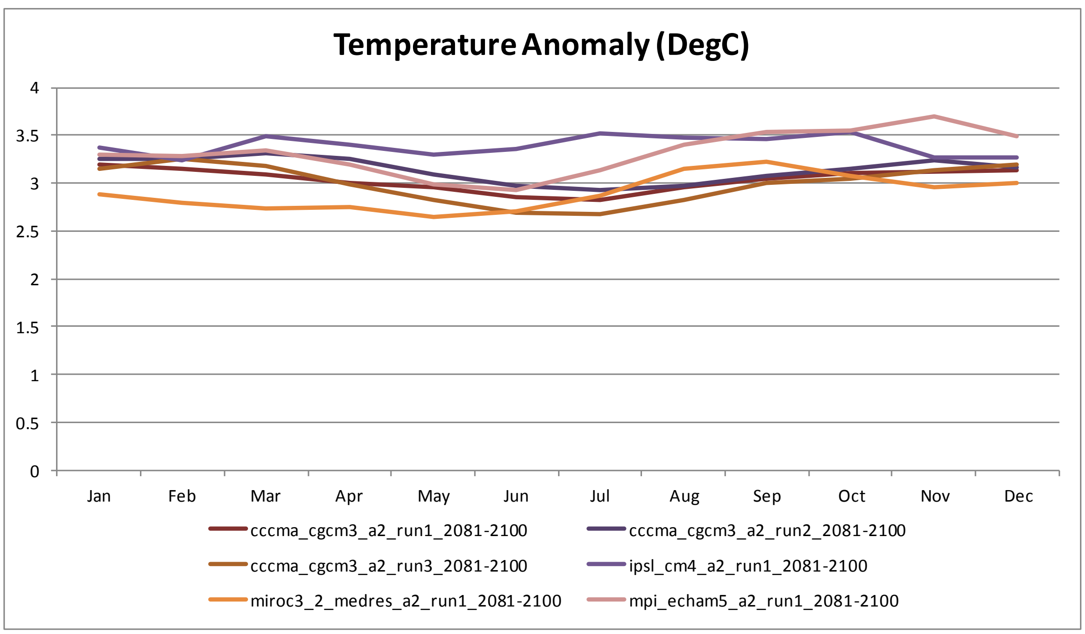

Figure 5-12. Monthly temperature deltas for the selected climate change projections in the hot and dry climate zone.

The results are more random for the other two climate zones and there is not a consistent seasonal pattern among the projections. In the dry and hot climate change zone, the projection ipsl_cm4_a2_run1 produces more precipitation in November through March and less the rest of the year, and the projection miroc3_2_medres_a2_run1 produces less precipitation year round. In the median zone, the projection cnrm_cm3_b1_run1 produces more precipitation in October, November, March, April and June. In the wet and warm climate zone, the projection mri_cgcm2_3_2a_b1_run5_2046 predicts increases in precipitation year round except for the months of

December and January and mri_cgcm2_3_2a_b1_run5_2081 predicts increases in precipitation for all months but January, March, May and June.

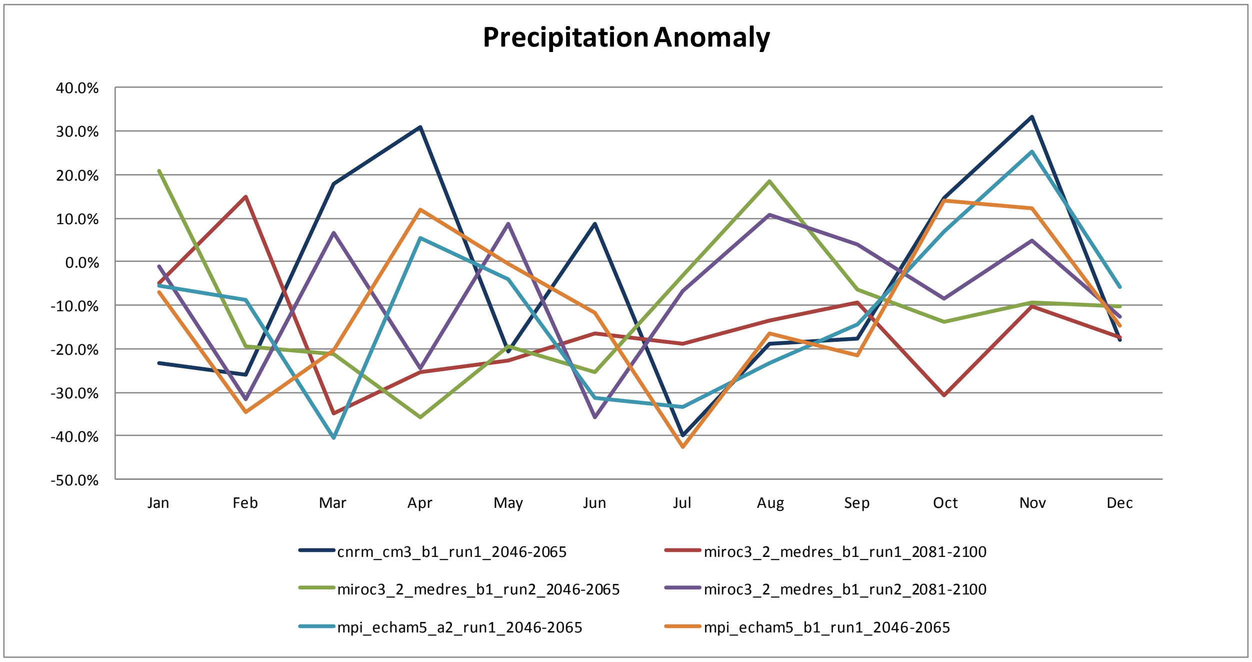

Figure 5-13. Monthly percent change in precipitation for the selected climate change projections in the median climate zone.

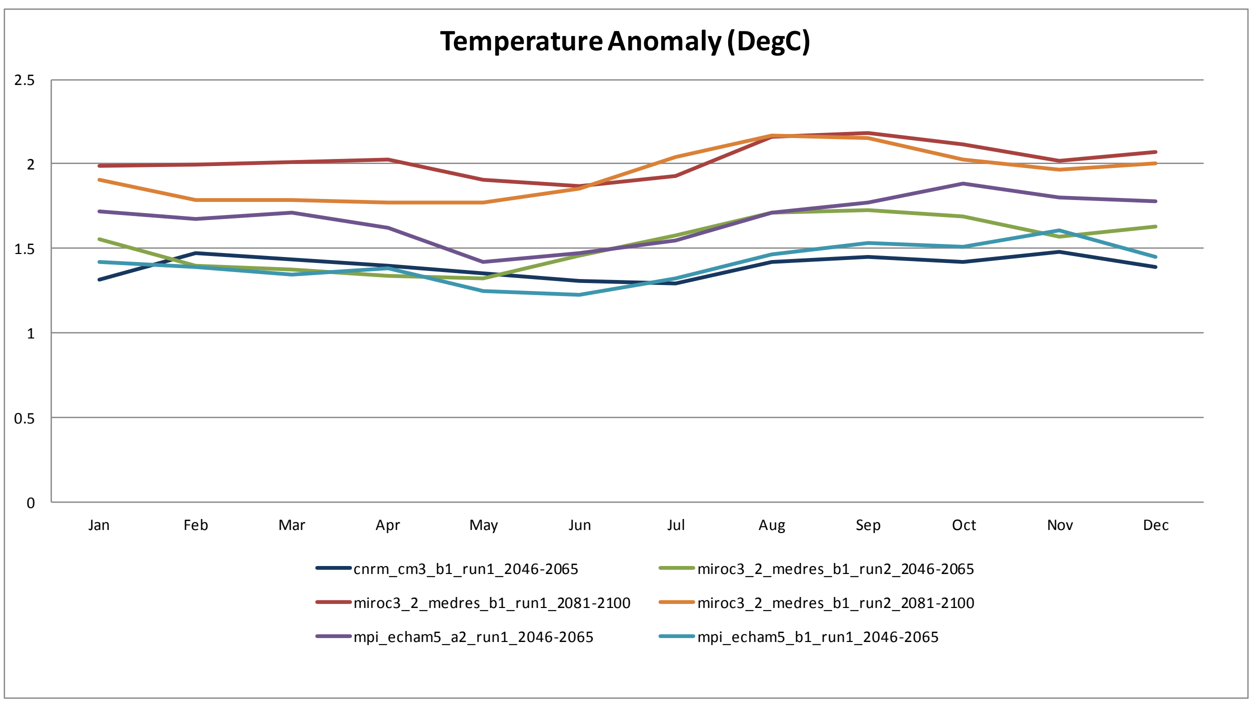

Figure 5-14. Monthly percent change in precipitation for the selected climate change projections in the median climate zone.

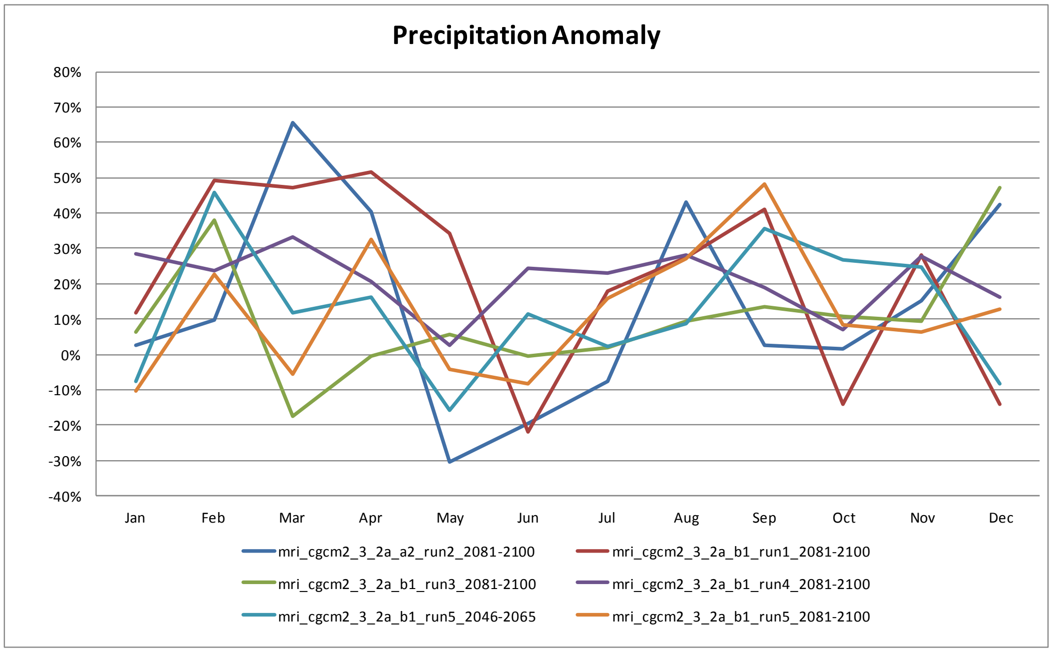

Figure 5-15. Monthly percent change in precipitation for the selected climate change projections in the wet and warm climate zone.

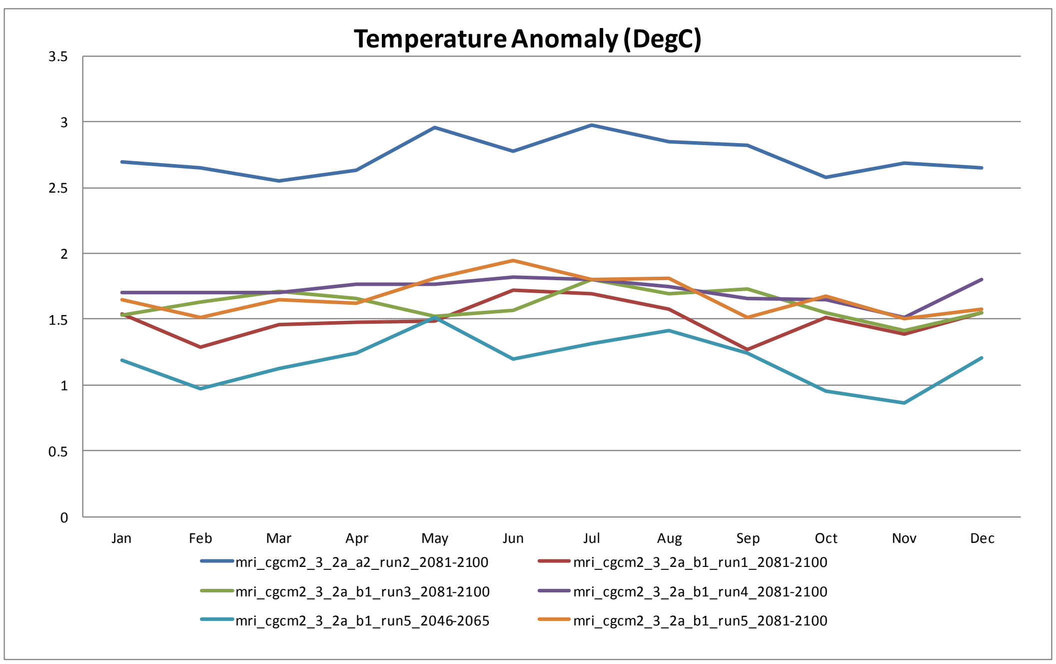

Figure 5-16. Monthly percent change in temperature for the selected climate change projections in the wet and warm climate zone.

6.0 SWAT Model

6.1 SWAT Model Setup

SWAT is a continuous hydrologic model built to quantify the impacts of land management practices in large, agricultural watersheds allowing the user to predict the effect of alternative land management decisions on water, sediment, nutrients, and pesticides yields with reasonable accuracy on large un-gauged river basins. It is a spatially semi-distributed model that operates on a daily time step. It has a user-friendly Graphic User Interface built in ArcGIS that eases the pre-processing of data inputs, model development, and post-processing of model's results.

6.1.1 Watershed Delineation

SWAT model setup required the DEM mentioned in ***Section 3.1*** to delineate the watershed. The rivers layer was used to "burn" channels into the DEM. A contributing source area of 1000 acres was used for defining the accumulated area needed before channel initiation begins.

Subbasins within the watershed are delineated in SWAT using the DEM and by defining the locations of the subbasin outlets. The Haina basin was delineated into three subbasins, using an outlet for the Isa River and another at the Los Corozos streamflow gage. ***Figure 6-1*** shows the basin configuration used for the Haina SWAT model.

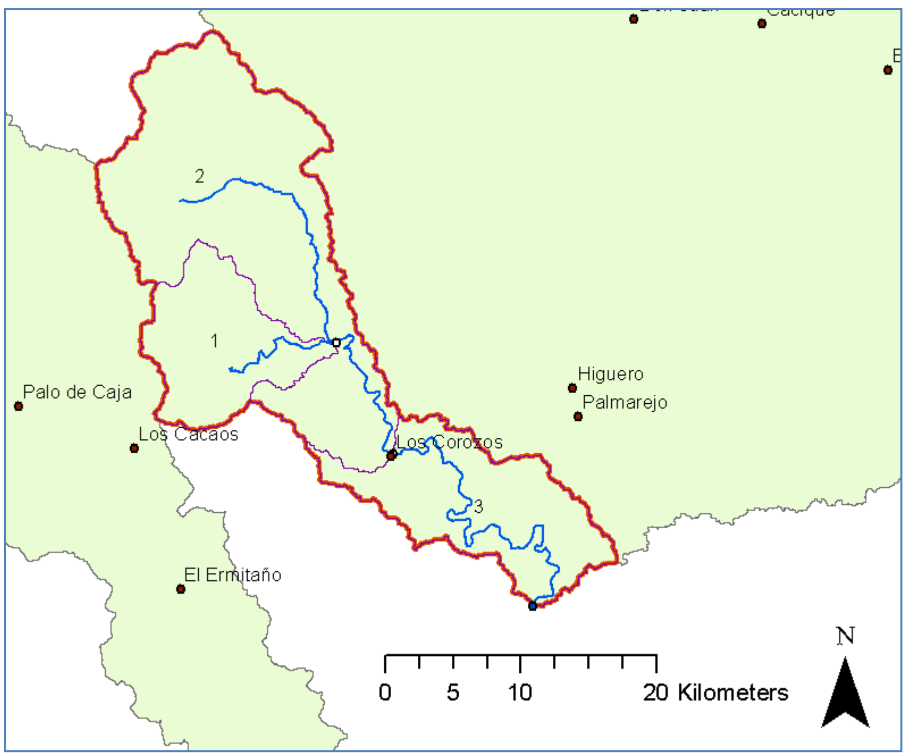

Figure 6-1. Haina SWAT Configuration

The Nizao basin was delineated into 15 subbasins, using outlets at streamflow gages and above and below the reservoirs. At the request of TNC, two subbasins were added to include the Mahoma River basin and to create the Mahomita River basin using the Los Cacaos station as its outlet. ***Figure 6-2*** shows the basin configuration used for the Nizao SWAT model.

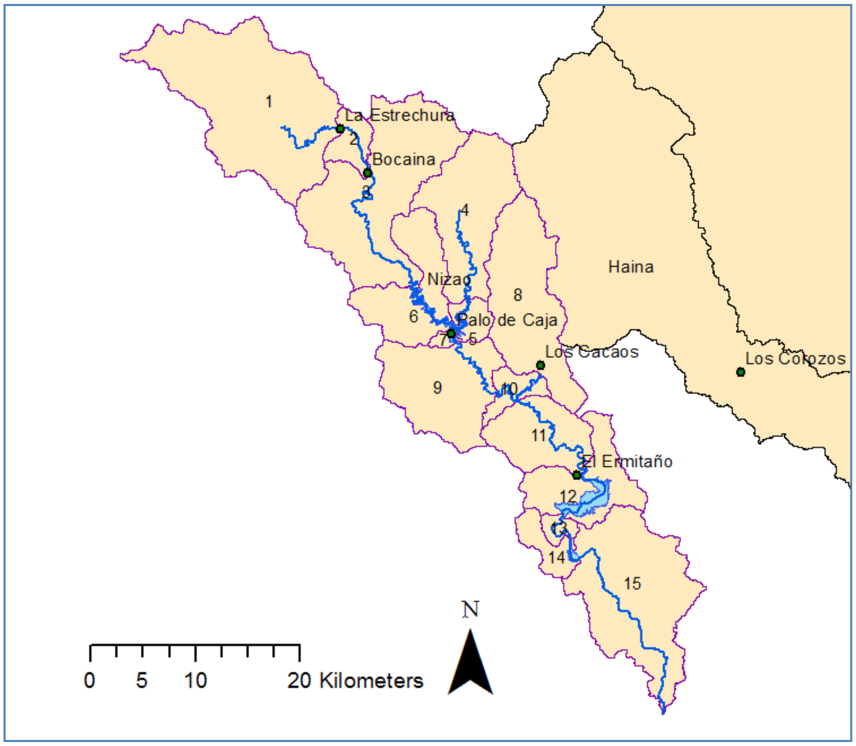

Figure 6-2. Nizao SWAT Configuration

The Ozama basin was delineated into 12 subbasins using the original boundaries for the basin provided by TNC. Originally, the SWAT delineation on the DEM defined a 13th subbasin, named Brujuela, to the northeast of the original Ozama boundary. According to TNC, the Brujuela basin drains outside of Ozama and, therefore, was masked out for the official modeling of the Ozama basin. ***Figure 6-3*** shows the final basin configuration used for the Ozama SWAT model.

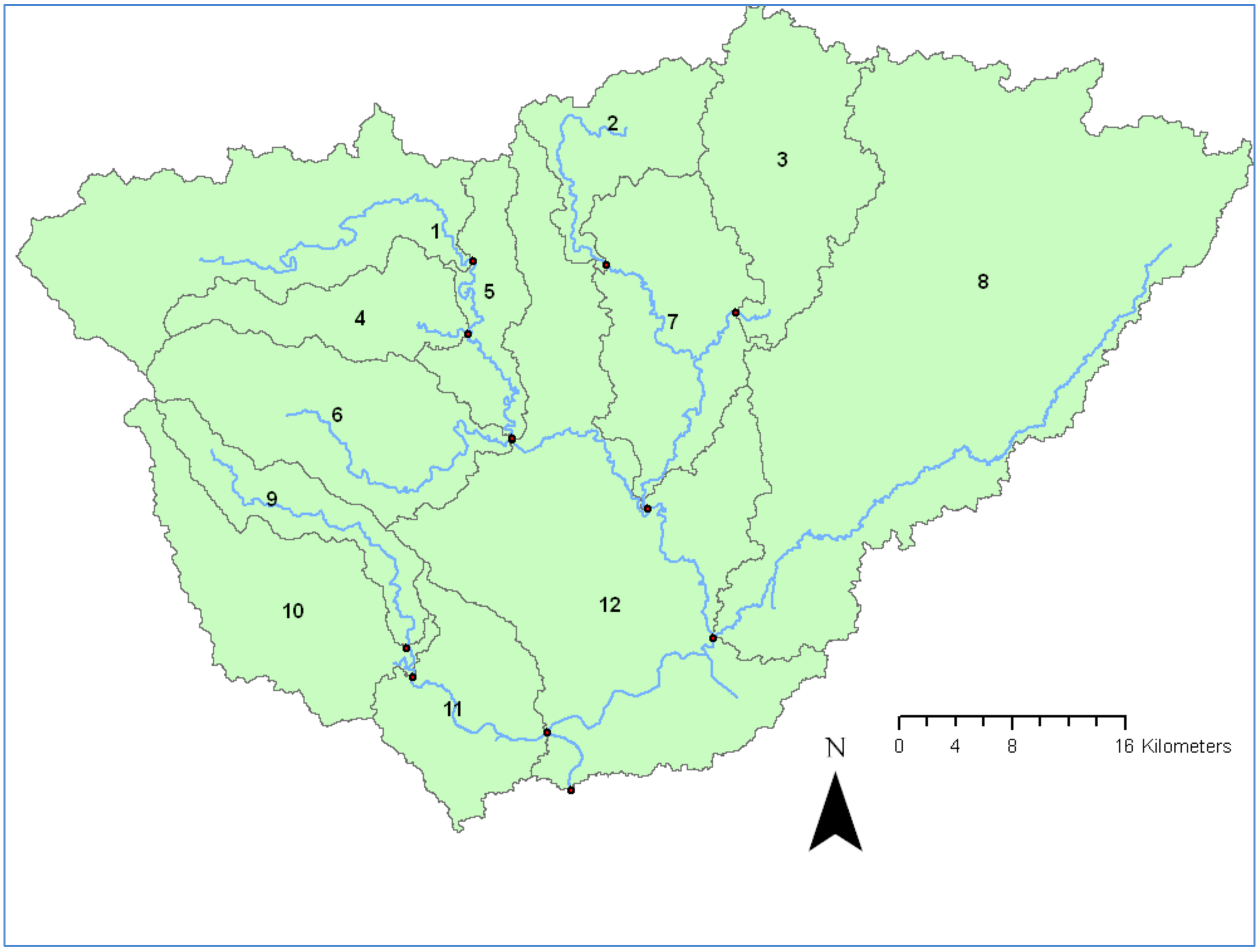

Figure 6-3. Ozama SWAT Configuration

The Yaque Del Norte basin was delineated into 39 subbasins, using outlets above and below the six reservoirs as well as the outlets of a few subbasins from the basin boundaries provided by TNC. ***Figure 6-4*** shows the basin configuration used for the Yaque SWAT model.

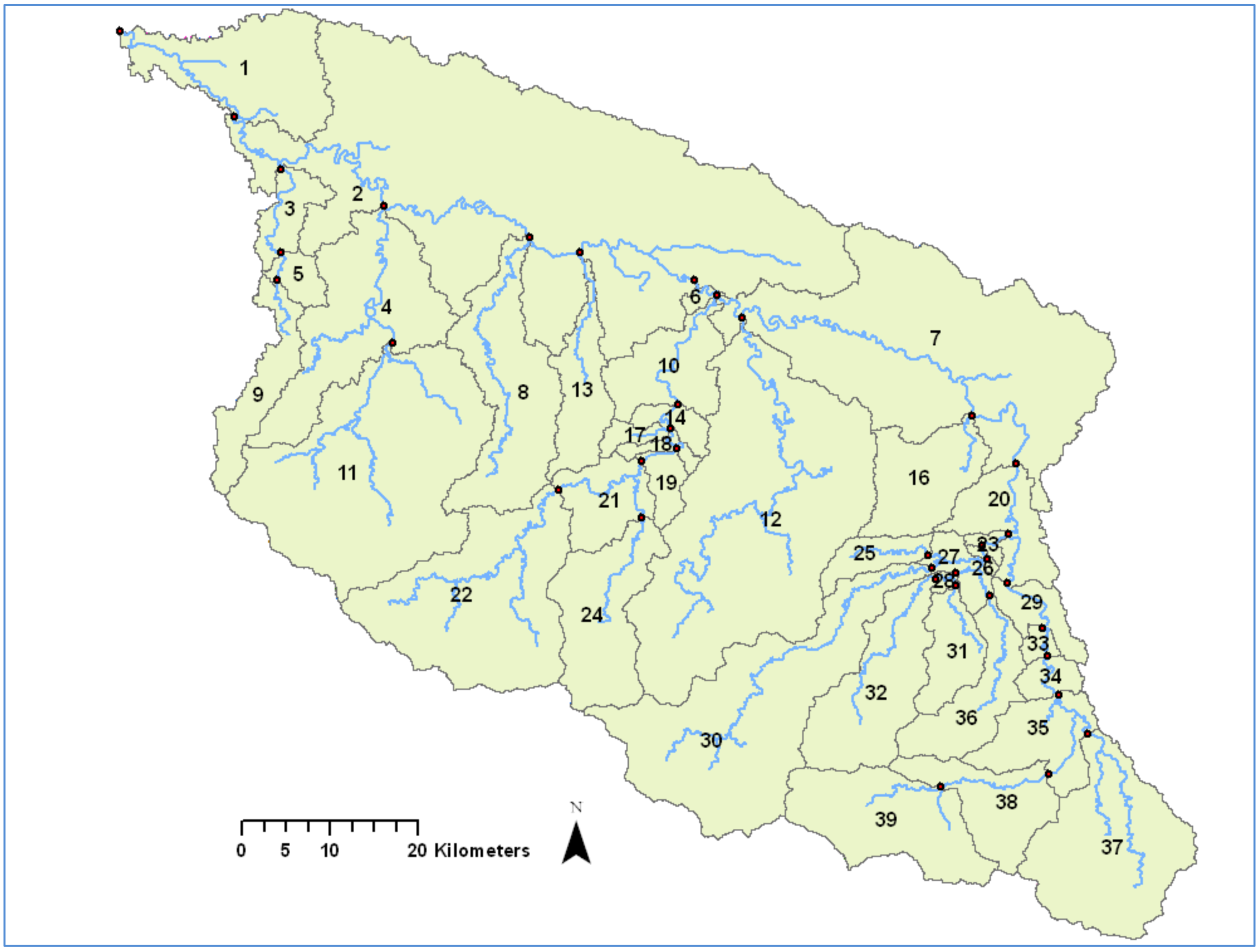

Figure 6-4. Yaque Del Norte SWAT Configuration

6.1.2 HRU Definition

All computations within SWAT are done on Hydrologic Response Units (HRU) level. The results are combined to obtain a total on the subbasin level. SWAT has internal databases that include the parameters related to the HRU components needed for the hydrologic modeling. SWAT determines HRUs by overlaying the LULC layer, soils layer, and a computed slope grid computed within SWAT. For this study, the LULC grids from the GEOMOD Land Use Model (***Section 1.0***), the Harmonized Soils data layer (***Section 3.1***), and the DEM from the Watershed Delineation step above were used for defining the HRUs. All three components of the HRU definition were set to a limit of 0% of the area, meaning that all possible unique combinations of the three would create an HRU.

6.1.2.1 SWAT LULC Database Edits

To be recognized by SWAT, LULC types must be classified by 4-letter codes pre-defined in the default SWAT database. This database includes parameters for the LULC type that affects the hydrologic modeling. Several LULC types were grouped under the same code; as an example, all the “Bosque Conífera” types were classified as the FRSE (evergreen forests) code. Other LULC types without an equivalent in the database, like “Cacao”, were classified into the class that most closely represented its landuse type. A few LULC types used in the study were already in the SWAT database and no direct equivalent had to be added manually to the database when developing the models.

The two new classes created to represent crops in the alternate LULC scenarios, “Other Crops” and “Crops for Export”, lumped several crop types with varying parameters. To estimate representative parameters for these new classes, the original 2003 LULC was used to determine what percentage of each original crop type made up the total landuse in each subbasin. The dominant crop type for each of the “Other” and “Export” classes was used for their respective class in a given subbasin. For example, a subbasin with a major crop of Caña (SUGC) in the 2003 LULC as compared to Café and Cacao was classified as SUGC for its “Export” class for that subbasin in all LULC alternative scenarios. The Curve Number (CN) and the Cover and Management Factor used in the estimation of sediment erosion (USLE C) values were weighted by the average of these percentages basin-wide. ***Table 6-1*** and ***Table 6-2*** show the original CN and USLE C values for the “Other” and “Export” crops, respectively.

Table 6-1. Original CN and C values for Other Crops

Code	Curve Number				USLE C
	A	B	C	D	
AGRC (cultivos intensivos)	58	72	81	85	0.03
AGRL (agricultura mixta)	58	72	81	85	0.2
OILP (Palma Africana)	67	78	85	89	0.001
ORAN (cítricos)	67	78	85	89	0.001

Table 6-2. Original CN and C values for Export Crops

Code	Curve Number				USLE C
	A	B	C	D	
SUGC (caña)	67	78	85	89	0.001
AGRL (cacao)	58	72	81	85	0.2
COFF (café)	62	71	78	81	0.001

Because “Cacao”, an “Export” crop, and Agricultura Mixta, an “Other” crop, were both being classified with the AGRL (general agriculture) code originally, a new code type called EXAG was created to differentiate when Cacao was the dominant “Export” crop. When Agricultura Mixta was the dominant “Other” crop the AGRL code was still used. The EXAG code was only needed in a few subbasins in Ozama.

The BMP and MIX LULC scenarios include agro forestry, silvo pasture, and tourism land cover types, not found in the default SWAT database. The agro forestry and silvo pasture types were classified using the same parameters as the forest types used before, but their CNs were slightly increased to represent an area with woods and grass combination. The new codes were defined as AGR- and SIL- with the last letter defining the forest type to it identifying: –E for Evergreens (Bosque Conífera), -T Mixed (Bosque Latifoliado), and –D Deciduous (Bosque Seco). The Tourism and Industrial Tourism LULC types were represented using the parameters from the URBN (urban) code but using CN values equal to the average of pasture and range, and the average of range and urban, respectively. ***Table 6-3*** shows the codes given to the LULC types for each scenario.

Table 6-3. LULC Types for SWAT

Landuse Land Cover	Code
Cultivos Intensivos	AGRC
Cacao	AGRL
Agricultura Mixta	AGRL
Café	COFF

Landuse Land Cover	Code
Bosque Seco	FRSD
Bosque Conífera Denso	FRSE
Bosque Conífera Abierto	FRSE
Bosque Latifoliado Nublado	FRST
Bosque Latifoliado Húmedo	FRST
Bosque Latifoliado Semi Húmedo	FRST
Escasa Vegetación	FRST
Palma Africana	OILP
Cítricos	ORAN
Pasto	PAST
Arroz	RICE
Matorrales Seco	RNGB
Matorral Latifoliado	RNGB
Caña	SUGC
Zona Poblada	URBN
Zona no Clasificada	WATR
Mar	WATR
Presas	WATR
Mangles	WETL
Sabana de Humedales Salobres	WETL
Mina	MINE
OTHER – Cítricos, Palma Africana, Cultivos Intensivos, and Agricultura Mixta	--------
EXPORT – Caña, Cacao, and Café	--------
User Created Categories	
AGRL Category when EXPORT category is predominantly Cacao (used in Ozama only)	EXAG
Agroforestry – Bosque Conífera types	AGRE
Agroforestry – Bosque Latifoliado types	AGRT
Agroforestry – Bosque Seco types	AGRD
Silvoforestry – Bosque Conífera types	SILE
Silvoforestry – Bosque Latifoliado types	SILT
Silvoforestry – Bosque Seco types	SILD
Tourism	TOUR
Industrial Tourism	TRIN

6.1.2.2 Management Operations Edits

SWAT assigns default United States management practices to the land use types. This includes just one growing season, and by default, no specified irrigation. Because agriculture occurs year round in the Dominican Republic, the management practices for all of the models were adjusted in the Management Editor within the SWAT model interface. Based on the Plan Hidrológico Nacional developed by INDHRI, the irrigated lands in the Dominican Republic are cultivated two or more times per year and the duration of each crop cycle varies from 110 to 365 days. Management operations were changed for all crop types being modeled to include two growing seasons, one from January through June, and another from July through December. An operation was added for the addition of elemental nitrogen fertilizer during each growing season. Because modeling the reservoirs and irrigation canals was beyond the scope of the project, an operation was added to irrigate the crops based on the plant-demand from the reach at the outlet of the basin. Including the irrigation in this manner helped ensure that the water balance for the basins was maintained. ***Table 6-4*** includes the parameters used for these operations. An

irrigation efficiency of 30% was estimated from the Plan Hidrologico Nacional developed by INDHRI. All other parameters were based on guidelines from the SWAT User Manuals.

Table 6-4. Management Operation Parameters

Management Operation	Parameter	Description	Value used
Fertilization	FRT_KG	Amount of fertilizer applied to the HRU	50 kg/ha
	FRT_Surface	Percent of fertilizer applied to the top 10 mm of soil, the rest is applied to the first soil layer below	0.2
Auto Irrigation	AUTO_WSTRS	Water stress threshold that triggers irrigation, as a fraction of potential plant growth	0.9
	IRR_EFF	Irrigation efficiency	0.3
	IRR_MX	Amount of irrigation water applied when auto irrigation is triggered	50 mm
	IRR_SCA	Auto irrigation source. A value of 1 indicates water is diverted from a reach	1
	IRR_NOA	Auto irrigation source location. When IRR_SCA, this number identifies the reach ID from which water is diverted	Reach ID at outlet of basin

As recommended in the SWAT manuals, slopes greater than 10% need to have larger CN values to simulate increased water runoff. The Adjust CN by Slope option was chosen in the management editor mode in the model to compute these values automatically.

The Support Practice Factor (USLE P) used in the estimation of soil erosion in the Modified Universal Soil Loss Equation (MUSLE) is affected by slope and was edited for all crops in the Management Editor within SWAT. For the 2003, BAU, and DEV LULC scenarios, USLE P values were adjusted to 0.5 for slopes less than 10%, 0.8 for slopes less than 20%, and 0.9 for slopes greater than 20%. For crops in the BMP, CONS, and MIX LULC scenarios, theses values were set to 0.25, 0.4, and 0.45 for the same respective slope classes (Julien, 1998).

6.1.3 Climate Input

SWAT requires user-defined daily climate data. A single precipitation timeseries per basin was available for each climate change scenario. For modeling within SWAT, this timeseries was split into a precipitation timeseries for each subbasin, so that when an area weighted sum is taken of each, it equals the total basin precipitation. A single temperature timeseries per basin was used for each climate change scenario. Limited historical data were available for relative humidity, solar radiation, and average wind speed data. For use in SWAT, the average monthly values was taken from each dataset and used as the daily value for that month for all time periods.

6.2 Model Calibration

The evaluation of SWAT model input parameters is based on the visual closeness of individual observed and simulated hydrographs, as well as overall simulation statistics. Which statistics are considered important depend on both the availability of data and the hydrologic complexity of the basin. Headwater sub-basins are not influenced by upstream sub-basins, therefore, there is generally a good fit between observed and simulated hydrographs. Sub-basins with diversions or other losses introduce complexity that causes additional uncertainty.

The configuration of management operations within SWAT such as planting, irrigation, and harvesting schedule are important to simulate the growth of crops, which affects primarily the evapotranspiration

and the erosion of the soils. The SWAT configuration accounts for irrigation of crops within the basins as explained in the previous section of this report. The simulation of the reservoirs was out of the scope of this project. For this reason, the basins were divided in sub-basins upstream from reservoirs. This configuration allowed the estimation of water and sediment contribution to the reservoirs, but does not account for the mass balance in the lakes.

Most basins have more than one streamflow gage. The streamflow record that correlated better with the observed precipitation was selected for calibration. Each basin (Nizao, Haina, Ozama, and Yaque del Norte) was calibrated to one single gage within its boundaries. Sediment data were not available for calibration. The following sections summarize the detailed calibration approach for each basin.

6.3 Calibration Approach

6.3.1 Nizao Basin

The Nizao basin is located to the west of Haina and drains an approximate area of 1,040 sq-km. The land use-land cover of the basin is comprised of approximately 52% forest, 31% agriculture, and 6% pastures. Sugar cane covers approximately 5% of the Nizao basin. The basin soil types are characterized as 95% eutric cambisols and 5% luvic calcisols. The Nizao basin is the steepest of the basins with 19% of the area at 10-20% slopes and 67% of the basin greater than 20% slopes.

There are a total of five streamflow gages and four reservoirs within this basin. Sub-basins were delineated at each gage and at the upstream end of each reservoir. This configuration resulted in a total of 15 sub-basins as shown in ***Figure 6-2***.

The period of record for the gages is shown in ***Figure 6-5***. Palo de Caja is located on the main stem and has the longest period of record. The Los Cacaos gage is located in a headwater basin and has a long period of record. However, the streamflow data are not very consistent from year to year with periods of large peaks followed by periods of sustained low flows. Calibration was performed for the Palo de Caja basin prior to the construction of the Jiguey reservoir in 1987. The calibration period was 1960-01-01 to 1985-12-31.

The La Guama irrigation diversion is located between the Bocaina and Palo de Caja gages and far from the main stem. The potential effect of this diversion was not considered in calibration because there is no information about return flows that might occur from the irrigated lands. Additionally, the irrigated area is small and it is presumed that the impact of this diversion is not significant.

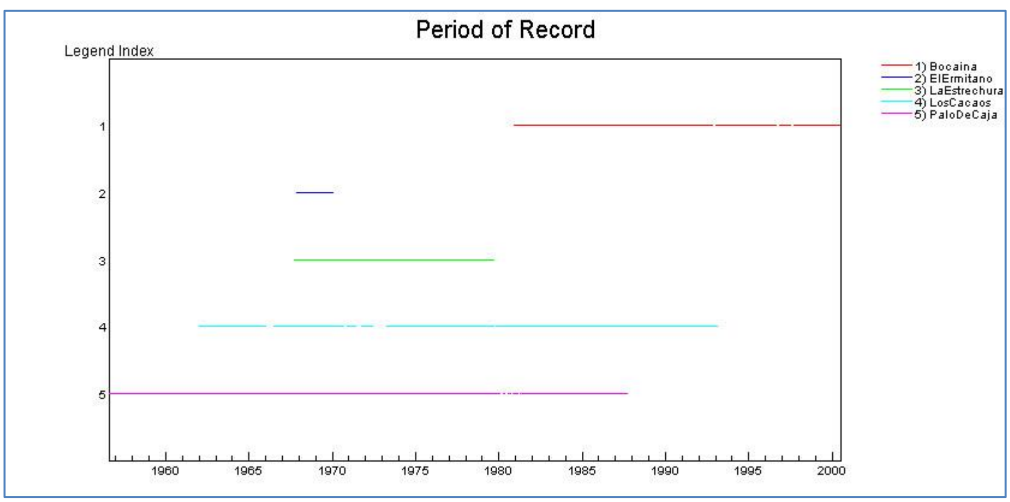

Figure 6-5. Period of record of streamflow gages within the Nizao basin

6.3.1.1 Nizao Calibration Strategy and Results

The initial parameter set produces a simulation that over simulates the peaks and under simulates the baseflow, yielding an annual bias of -38% over the period 1960 to 1985. The calibration focused on achieving a better balance between peaks and baseflow while reducing the annual bias.

The option ICN (parameter to define the type of method used to compute the initial retention with the SCS curve number) was changed to 1 to reduce the peaks. This option uses the evapotranspiration to compute the daily curve number. With this change the peak flows decreased significantly. The CNCOEF (factor to adjust the initial retention coefficient) was retained at 1.0. The Curve Number (CN) for the most predominant land use land cover types upstream from the Palo de Caja gage were increased to simulate more surface runoff. However, the model was not sensitive to these changes even with a high CNCOEF (of up to 1.5). The CN values were set back to the initial set. SURLAG (surface runoff lag coefficient) was reduced to 1. There was a minor improvement in the visual fit of the simulation with this change. The hydraulic conductivity of the soil for the Eutric Cambisols type was increased from 13.2 mm/h to 30 mm/h to allow more infiltration into the soil layer. The Eutric Cambisols in the Nizao basin are loam soils that can have saturated hydraulic conductivities ranging from 20 mm/h and 120 mm/h depending on the infiltration characteristics of the soil (Hazelton, P. et. al 2007). This change in the saturated hydraulic conductivity significantly increased the simulation of the low flows.

The initial baseflow parameters are all setup to allow maximum contribution to baseflow from the shallow aquifer and minimum losses through the deep aquifer. In addition, REVAP (factor that measures the amount of water that move from the shallow aquifer to the overlying unsaturated zone) is set to a minimum value. The groundwater delay time was increased to sustain baseflow year round. The model was sensitive to this change. The annual bias was reduced to -28% with parameter changes.

Plots of the simulated flows at the Estrechura and the Bocaina gages show under simulation of the observed flow as well. In order to reduce the annual bias, the mean areal precipitation (MAP) input in the model was increased by 15% for all the sub-basins upstream from the Palo de Caja gage. This change resulted in a simulation that produces a -4% annual bias at the Palo de Caja gage.

Figure 6-6 shows the simulated and the observed streamflow time series at Palo de Caja for a period of just over a year. The results vary with the observed peaks over, under or well simulated.

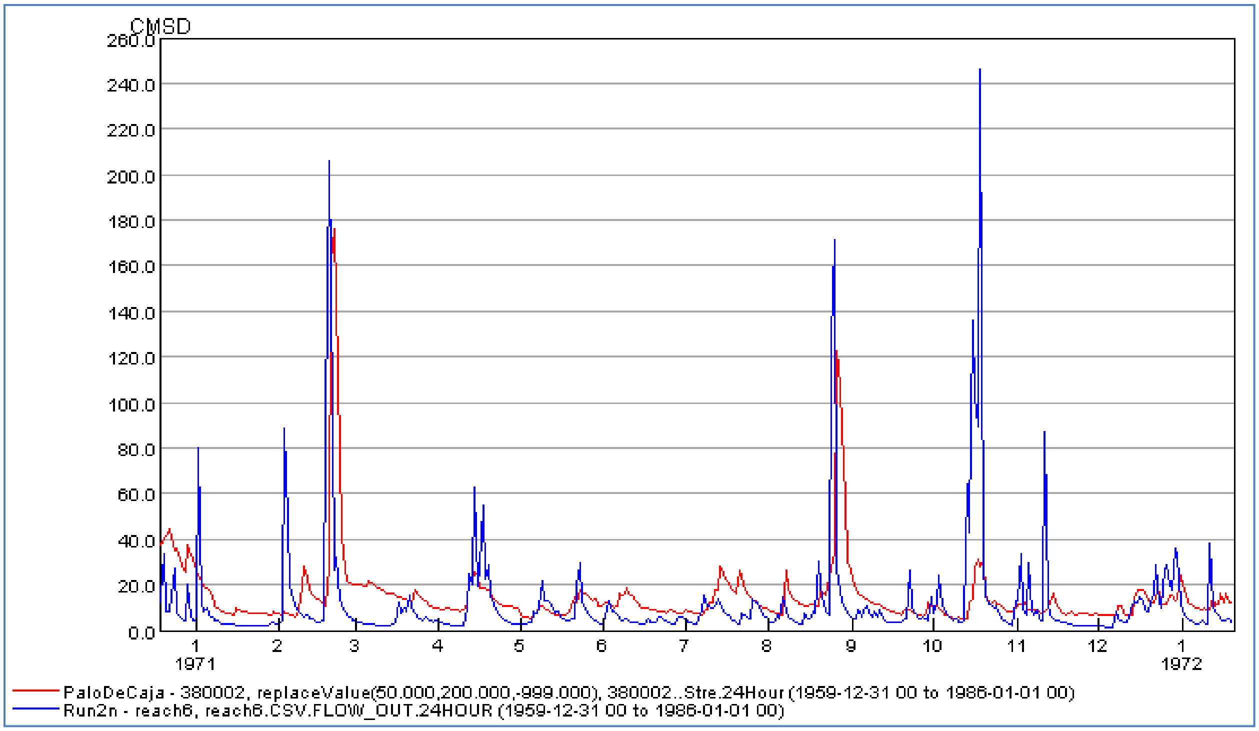

Figure 6-6. Palo de Caja observed (red) and simulated (blue) streamflow.

The final parameter set is included in ***Table 6-5.***

Table 6-5. Nizao final parameter set

PARAMETER	FINALVALUE
ICN	1
CNCOEF	1.0
SURLAG	1.0
EPCO	1.00
ESCO	0.95
RCHRG_DP	0.0
REVAPNM	1
GW DELAY	200
ALPHA_BF	0.05
GWQMN	0
GW_REVAP	0.02
SOL_K upper layer - Eutric Cambisols	30 mm/h

6.3.2 Haina Basin

The Haina basin is located between the Nizao and Ozama basins and drains an approximate area of 561 sq-km. The outlet of the basin is at the city of Santo Domingo. The land use land cover for the basin is comprised of approximately 47% forest, 12% pasture, and 7% agriculture. Major crop types within Haina

include orange and sugar cane, which are 16% and 9% of the area, respectively. The basin soil types are characterized as 70% eutric cambisols and 30% luvic calcisols. Haina is the second steepest basin with 15% of the area at 5-10% slopes, 21% of the area at 10-20% slopes, and 40% of the basin greater than 20% slopes.

There is one streamflow gage within this basin. Sub-basins were delineated at the Los Corozos gage and at the junction of the Isa and Haina rivers as shown in ***Figure 6-1***. The water supply diversions Isa-Mana and Duey are located upstream from Los Corozos gage. Together, they divert about 1.7 m^3/s. This discharge was added to the observed gage data prior to calibration to account for those losses in the basin. The calibration period was from 1983-01-01 to 1988-12-31.

6.3.2.1 Haina Calibration Strategy and Results

Unlike the Nizao, the initial parameter set produces over simulation with an annual bias of 10%. The largest peaks in the record are well simulated while medium to small peaks are significantly over simulated. Observed peak magnitudes are not consistent throughout the entire period of record. Peak flows in the last two years of record are about 3 to 4 times the peaks in the early years (***Figure 6-7***). It is not possible to simulate the correct magnitude for all peaks. Therefore, the goal of this calibration was to reduce the annual bias and achieve the correct simulated streamflow volume.

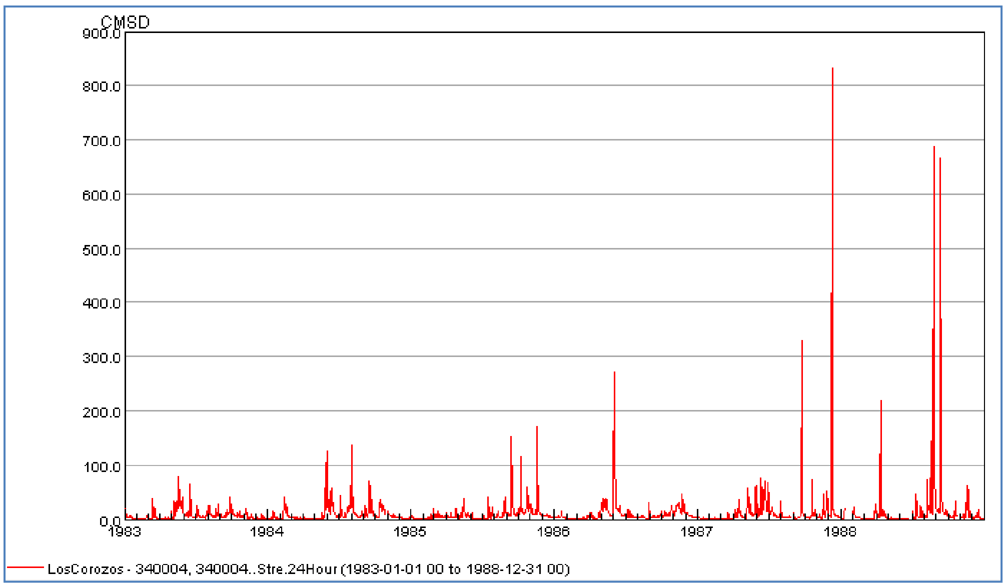

Figure 6-7. Los Corozos streamflow data

The excess volume was adjusted by changing ICN from 0 to 1. CNCOEF was set at 0.5 to reduce the peaks. The baseflow component of the hydrograph was decreased by allowing less water to move from the shallow aquifer to the stream (GWQMN = 10). SURLAG was lowered to 1 to better capture the shape of the recession of the hydrograph. The deep aquifer percolation fraction (RCHRG_DP) was set to 0.0 to reduce losses to the deep aquifer. This change helped to adjust the magnitude of the groundwater. Additional parameter changes were tried but not maintained.

The annual bias for this basin is -6%. The final simulation balances the over and under simulation of peaks (***Figure 6-8***).

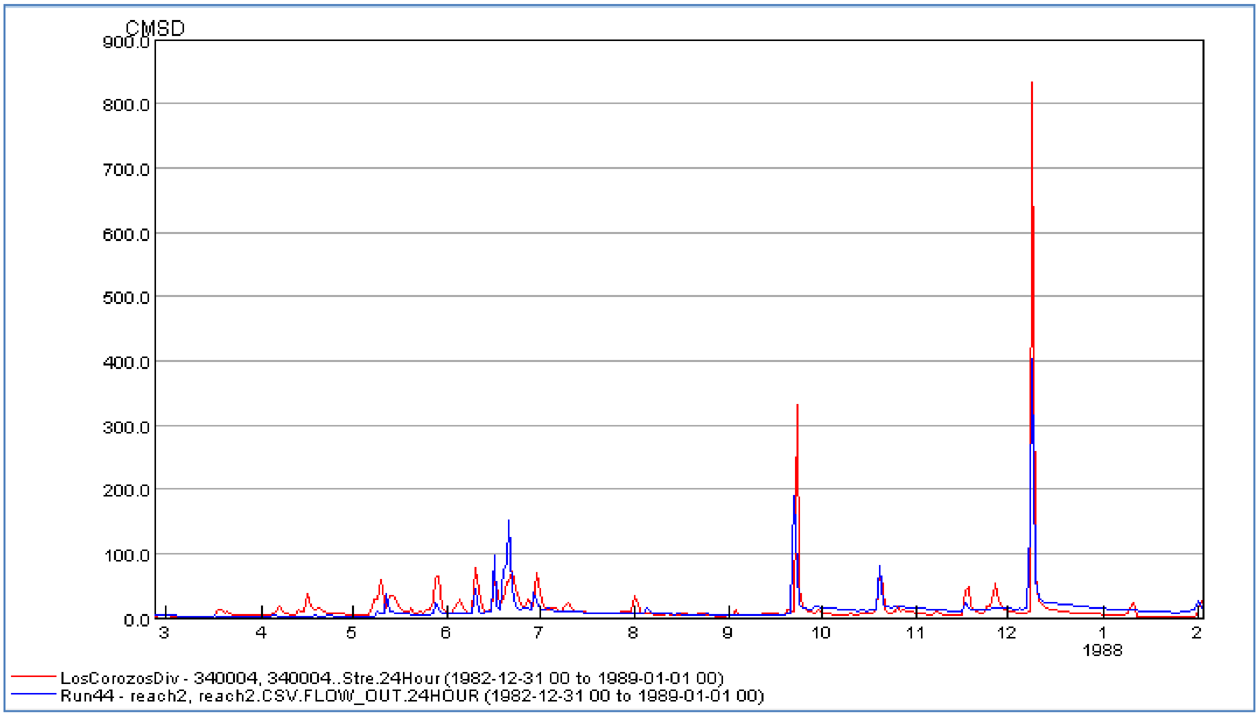

Figure 6-8. Los Corozos observed (red) and simulated (red) streamflow.

The final parameter set is included in ***Table 6-6***.

Table 6-6 Haina final parameter set

PARAMETER	FINAL VALUE
ICN	1
CNCOEF	0.5
SURLAG	1
EPCO	1.00
ESCO	0.95
RCHRG_DP	0
REVAPNM	1
GW DELAY	150
ALPHA_BF	0.5
GWQMN	10
GW_REVAP	0.02

6.3.3 Ozama Basin

The Ozama basin is located east of Haina and drains an approximate area of 2894 sq-km. The outlet of the basin is at the city of Santo Domingo. The land use-land cover of the basin is comprised of approximately 32% forest, 21% agriculture, and 10% pasture. Sugar cane covers approximately 37% of the area in Ozama. The basin soil types are characterized as 21% eutric cambisols, 73% luvic calcisols, and 6% rendzic leptosols. Ozama has 34% of the area at less than 5% slopes, 26% of the area at 5-10% slopes, 21% of the area at 10-20% slopes, and only 18% of the basin greater than 20% slopes.

There are a total of six streamflow gages within the Ozama. SWAT was configured with 12 sub-basins. The outlets correspond to the streamflow gages and the junctions of the main rivers (***Figure 6-3***). The calibration period was from 1956-01-01 to 1982-12-31.

6.3.3.1 Ozama Calibration Strategy and Results

Model simulations were compared against the observed streamflow at Cacique. This gage is at the outlet of a headwater basin and shows a good correlation with the precipitation data. The Cacique gage also has the longest period of record (***Figure 6-9***). Other gages do not seem to correlate as well with the precipitation data as Cacique. For example, the El Cerro gage, close to Cacique, and located in another headwater has a sequence of peaks that repeat periodically at about the same magnitude indicative of potential problems with the streamflow record. The final parameter set was compared against the Palmarejo gage, just downstream from Higuero.

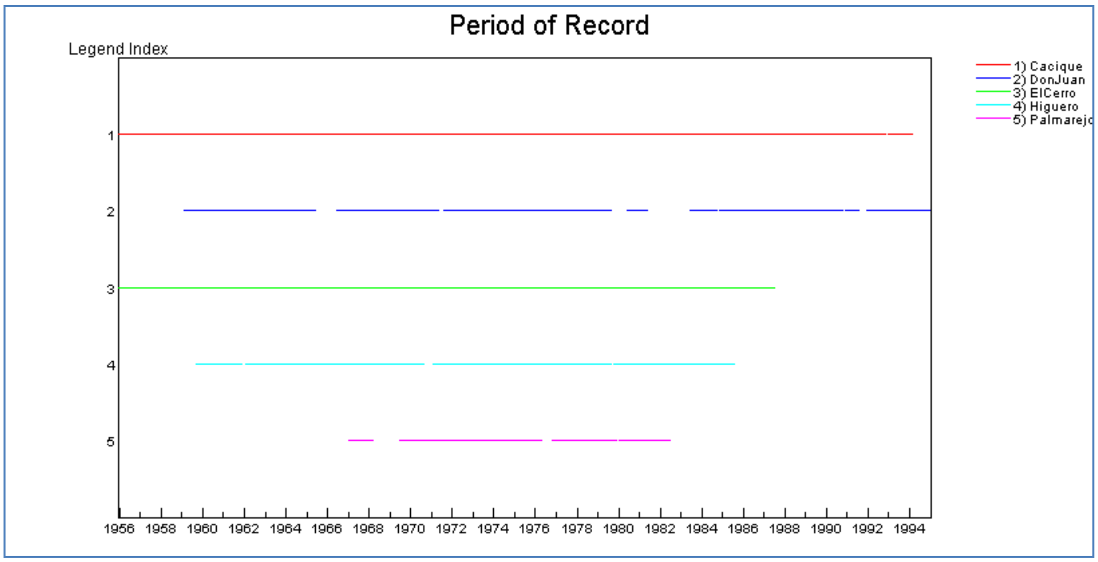

Figure 6-9. Period of record for streamflow gages within Ozama basin

There are 2 surface water supply intakes and 69 wells in this basin (Arq. Omar Rancier, Dirección General de Ordenamiento Territorial, personal communication, February 2013). Additionally, irrigation diversions exist in this basin. The Cacique water supply intake is located downstream from the streamflow gage. Therefore, there was no need to consider this diversion in calibration.

Baseflow was first adjusted by shifting more water to the sub-soil. CNCOEF was initially reduced and the groundwater delay increased. These changes produce a good fit for the baseflow but under simulated significantly the peaks. CN values for the predominant land type (Forest) were increased. The simulation of low flow periods improved but the peak flows were significantly over simulated. Therefore, the CNs were set back to their original values. CNCOEF was set to 1.5 to increase the simulation of peak flows and the ground water delay increased to 100 days to sustain the baseflow year round.

The final simulation yields an annual bias of 0%. ***Figure 6-10*** shows a comparison of the observed and simulated streamflow for a period of one year. Some peaks are missed in the simulation due to the lack of precipitation events. The station coverage in this basin is very sparse and probably unable to capture the spatial distribution of rainfall events over the basin. ***Table 6-7*** includes the final parameter set.

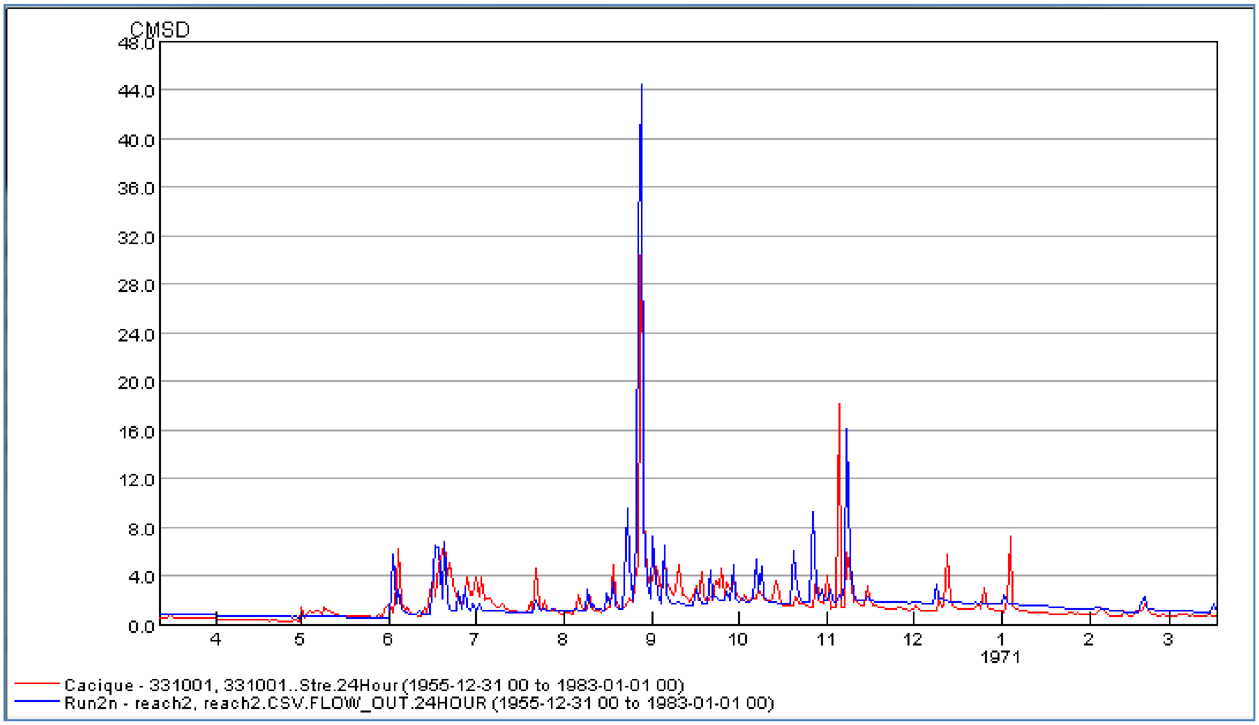

Figure 6-10. Cacique observed (red) and simulated (blue) streamflow.

Table 6-7. Ozama final parameter set

PARAMETER	FINAL VALUE
ICN	1
CNCOEF	1.5
SURLAG	1
EPCO	1
ESCO	0.95
RCHRG_DP	0
REVAPNM	1
GW DELAY	100
ALPHA_BF	0.05
GWQMN	0
GW_REVAP	0.02

The final parameter set produces a mean annual bias of -9% in the simulation of the Palmarejo sub-basin. In general, the baseflow is slightly over simulated and the simulation of peaks varies as shown in ***Figure 6-11***. The flows in the Ozama basin are significantly altered by water supply and irrigation diversions. No information is available to assess the impact of the diversions on the measured flows at the Palamarejo gage.

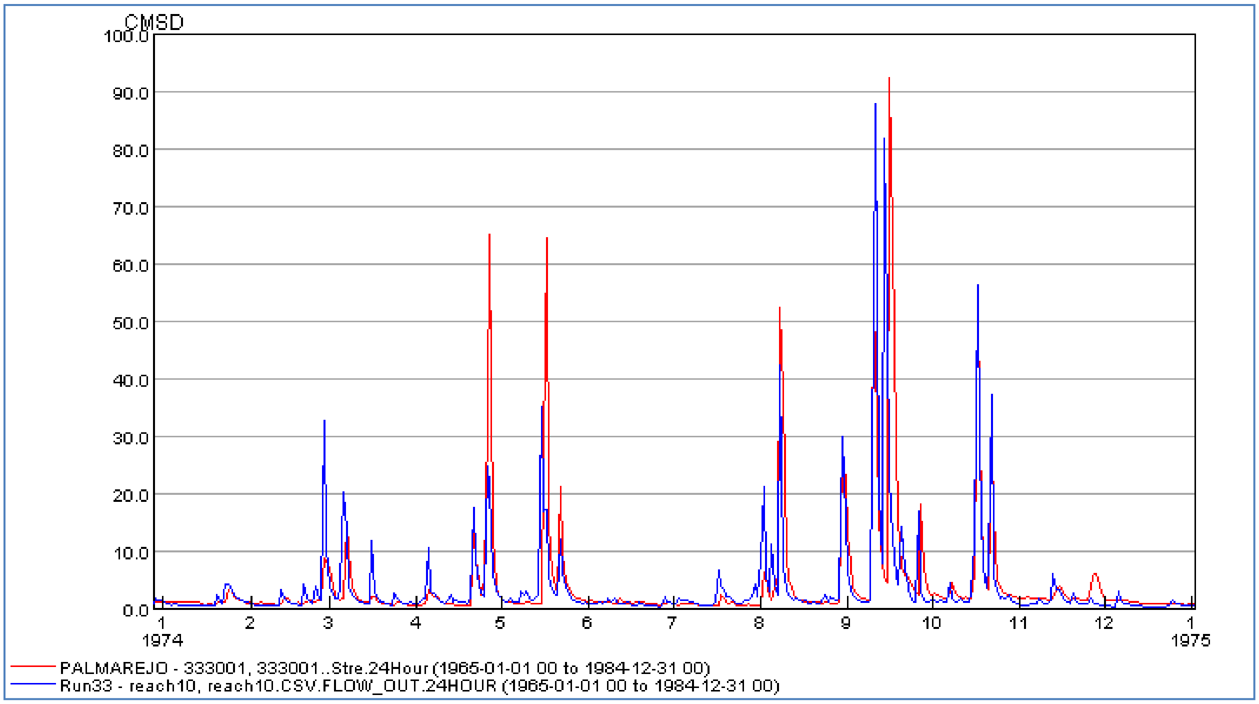

Figure 6-11. Palamarejo observed (red) and simulated (blue) streamflow

6.3.4 Yaque del Norte Basin

The Yaque del Norte basin is located northwest of the Nizao basin and drains an approximate area of 6859 sq-km. The basin is comprised of approximately 36% forest, 20% agriculture, 15% range, and 9% pasture. Major crop types within the Yaque del Norte include rice and coffee, which cover 11% and 6%, respectively. The basin soil types are characterized as 55% eutric cambisols, 21% eutric vertisols, and 20% luvic phaeozems. The Yaque has 19% of the area at less than 5% slopes, 21% of the area at 5-10% slopes, 24% of the area at 10-20% slopes, and 36% of the basin greater than 20% slopes.

There are 15 streamflow gages in this basin and six reservoirs. In addition, there are several irrigation diversions indicative of a highly regulated basin.

Sub-basins were delineated with outlets at all gages and upstream of reservoirs. A total of 39 sub-basins were defined within SWAT. Manabao, Pinar Quemado and Boma all have very consistent records where peaks occur at the same time and the hydrograph volume increases from upstream to downstream. The Baiguate irrigation district is just downstream of Pinar Quemado and the irrigation diversion, Arroyo Cercado, appears to be just upstream from the gage.

A comparison of streamflow data between Las Charcas and Puente San Rafael indicates that flows are retained in Presa Monción to let releases pass from Presa Bao and Lopez Angostura. The local contribution between Las Charcas and Puente San Rafael is not appreciable in the data. Based on the isohyetal map, the rainfall in this area (middle to lower basin) is less than the precipitation in the upper basin. In addition, water is diverted for irrigation in between the Las Charcas and Puente San Rafael gages.

The most upstream basin, Manabao seems to be the least regulated basin. The land use-land cover map shows a large portion of the basin covered with agricultural lands, but no irrigation diversions were identified. The SWAT model calibration was performed by comparing the simulated flows against the observed flows at the Manabao gage. The simulation period was from 1964-01-01 to 1997-12-31.

6.3.4.1 Yaque del Norte Calibration Strategy and Results

The Manabao sub-basin is located in the upper part of the Yaque del Norte basin, where rainfall is significantly larger than in the lower basin.

The initial parameter set significantly under simulates the observed streamflow with an annual bias of negative 49%. The soil parameters for Eutric Cambrisols in the Yaque del Norte basin were set to similar values used in the Nizao basin to increase the interflow. CNCOEF was set to 0.5 to reduce the peaks and simulate more groundwater flow. To increase the baseflow component, the recession rate (Alpha_bf) was increased to 0.5. Then the groundwater delay was increased to 200 days to sustain the baseflow year round. The CN for forest was increased, which reduced significantly the annual bias. A 15% increase in mean areal precipitation was required to reduce the annual bias even more. The final simulation yields an annual bias of -1% with monthly biases less than 10% from January through May and September through December.

The under estimation of the precipitation could be caused by the sparse station network around the area as shown in ***Figure 6-12***. The precipitation gage located at the outlet of the basin (Manabao) has data from 1983 to 2006. Therefore, for the first 20 years of calibration the precipitation was estimated from other stations located farther away from the basin.

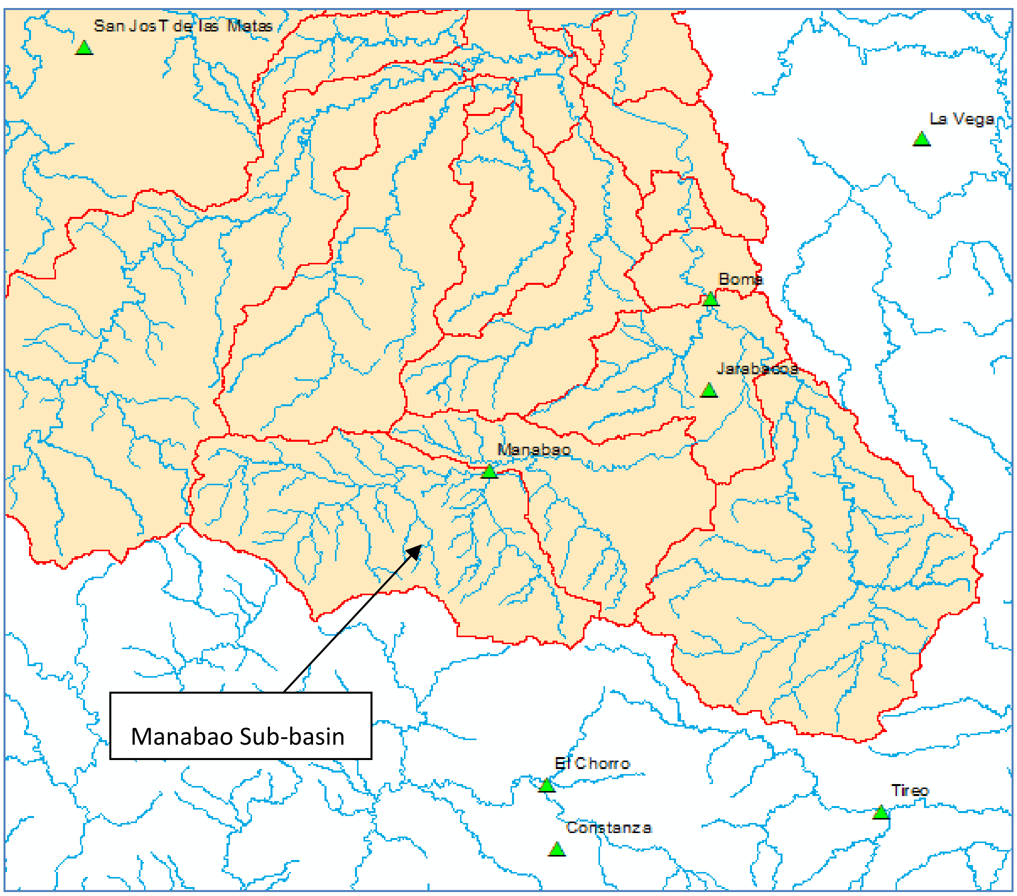

Figure 6-12. Precipitation stations (green triangles) within and around the Manabao sub-basin

The visual fit of the baseflow is very good. Peak flows are well simulated and some times over simulated (***Figure 6-13***). The observed streamflow is noisier than the rest of the record from about 1980 to 1982.

This could be the result of potential problems at the gage during this period or the presence of diversions. The final parameter set is summarized in ***Table 6-8***.

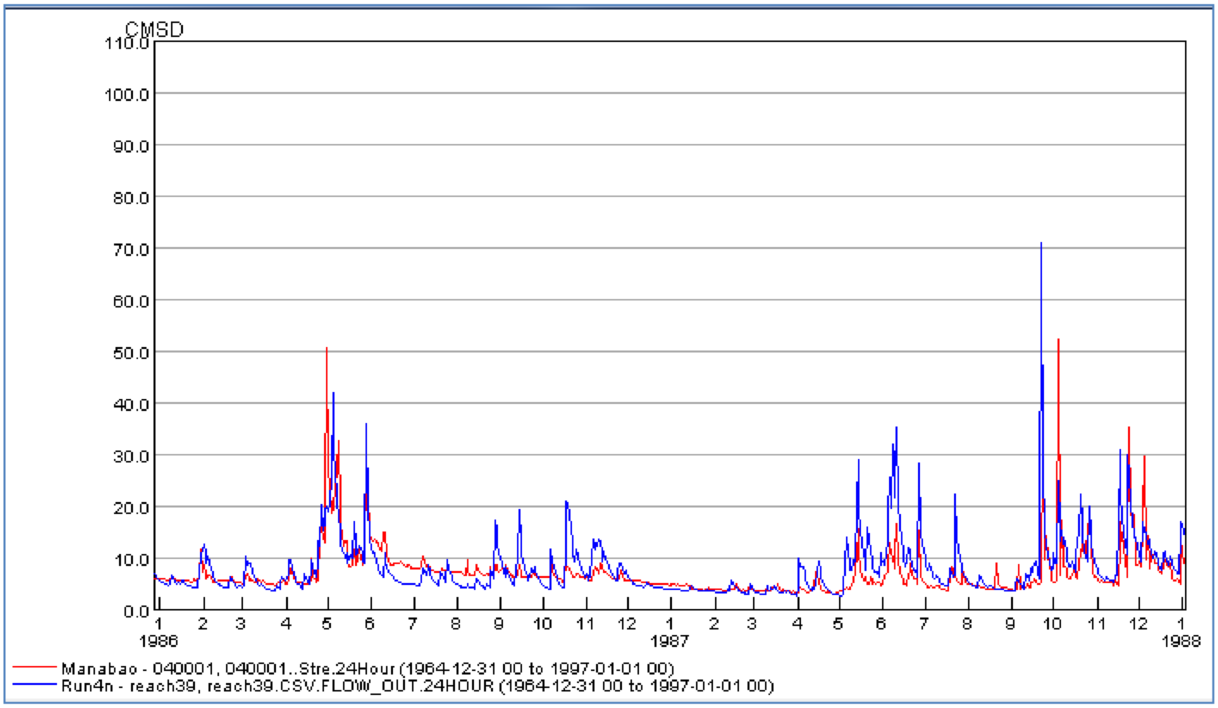

Figure 6-13. Manabao observed (red) and simulated (blue) streamflow

Table 6-8. Yaque del Norte basin final parameter set

PARAMETER	FINALVALUE
ICN	1
CNCOEF	0.5
SURLAG	4.0
EPCO	1.00
ESCO	0.95
RCHRG_DP	0.0
REVAPNM	1
GW DELAY	200
ALPHA_BF	0.5
GWQMN	0
GW_REVAP	0.02

The Rincon sub-basin is another headwater in the Yaque del Norte basin. The simulation for this sub-basin was compared against the streamflow record from the Rincon gage using the final parameter set. The baseflow matches very well. However, most peaks are not simulated (***Figure 6-14***). There is only one precipitation station within this basin. The spatial variability of the precipitation is not captured well with only one precipitation station in this basin.

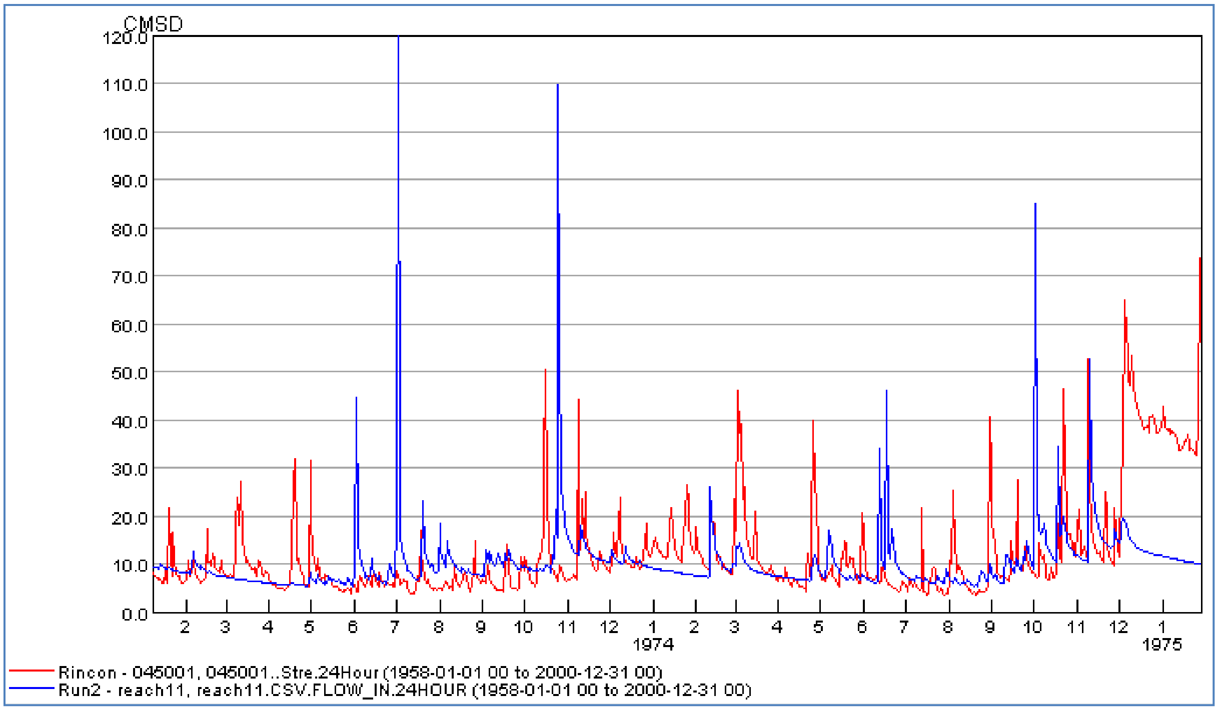

Figure 6-14. Rincon observed (red) and simulated (blue) streamflow

A previous study in the Yaque del Norte basin (Cuello, 2003) reports total sediment load over the entire Yaque del Norte basin of about 0.92 mm per year. The mean annual sediment load simulated in the Manabao sub-basin is 0.10 mm per year. The order of magnitude of these results are in good agreement.

6.4 Calibration Summary

There is uncertainty associated with both the input precipitation and the streamflow data. Streamflow records over the same stream network were compared when possible to assess the quality of the data. In general, if the upstream and downstream flows peaked at about the same time, then more confidence was given to the streamflow data than the precipitation. In all cases, if the water balance could not be achieved in the basin with parameter changes, an adjustment of the input precipitation was done.

All basins produce flashy responses with sustained baseflows year round. All basins have similar soil types. The Nizao and Ozama are simulated with more surface runoff while the Yaque del Norte and the Haina basins are simulated with more interflow and baseflow components.

The input precipitation data were increased in the Yaque del Norte and Nizao basins in order to achieve the water balance. In all basins, several peaks could not be simulated due to the lack of adequate precipitation. The precipitation station network is sparse in some areas such as in the northeast part of the Ozama basin and the southeast section of the Yaque del Norte basin.

Given the quality of the data, the approach of the calibration was to achieve the correct long-term water volume. This was computed as the annual percent bias between the observed and the simulated streamflows.

7.0 Modeling the Effect of LULC and Climate Changes in the Hydrologic Response of the Basins

After calibrating the SWAT models, new SWAT models were configured using the five land use land cover scenarios and the selected climate change projections. The calibration parameters were input into these models. The new LULC scenarios were parameterized as explained in ***Section 6.1*** of this report to accommodate the new modeled classes. The baseline model uses the 2003 LULC and the historical MAP and temperature data. This model was run with the selected five climate change projections. The other models corresponding to the BAU, BMP, CONS, DEV, and MIX LULC were run with three climate change projections.

Water yield was output from SWAT as a daily time series for each sub-basin. This time series was post-processed to compute the mean annual water yield in each sub-basin for this analysis. The sediment load was also output from SWAT as a daily time series. The mean annual sediment load was computed from the daily time series. The sediment load from SWAT is the total sediment accumulated at the outlet of each basin. Therefore, the difference between the sediment leaving each sub-basin minus the sediment coming into each sub-basin was computed to estimate the sub-basin upland erosion.

The streamflow time series from SWAT was post processed to develop an annual peak flow time series. A Log Pearson Type III probability distribution was fit to the annual peak flow data to estimate the 25-year return period peak flow as explained in ***Section 5.0*** of this report.

Mean annual baseflow was computed from daily baseflow time series. The baseflow time series was computed from the daily streamflow time series output from SWAT using a baseflow filter as described in ***Section 5.0*** of this report.

The sediment and water yield results are summarized by sub-basin rather than by basin wide totals. However, the baseflow and peakflows were estimated from the total outflow (total streamflow) at the outlet of the basin and not the local flows. The land use land cover is very variable across the basins and therefore, a lumped sediment and water yield result will not be useful for water managers to understand the relationship between the different land type changes and the hydrologic response in the basins. The model results were output at the outlet of the sub-basins indicated in ***Figure 7-1***, ***Figure 7-2***, ***Figure 7-3***, and ***Figure 7-4***.

Figure 7-1. Basin or reach numbers used to output the results for the Haina basin.

Figure 7-2. Basin or reach numbers used to output the results for the Nizao basin.

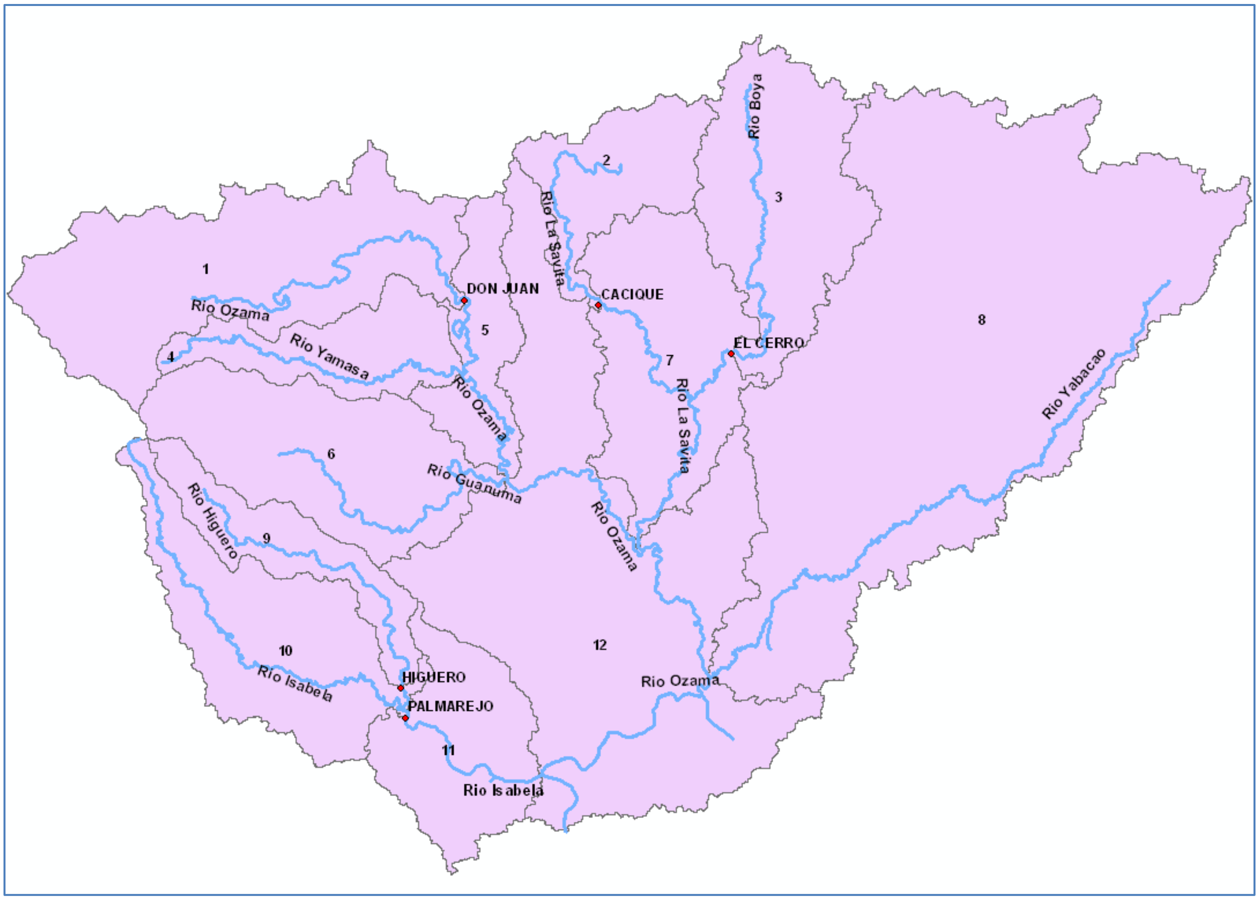

Figure 7-3. Basin or reach numbers used to output the results for the Ozama basin.

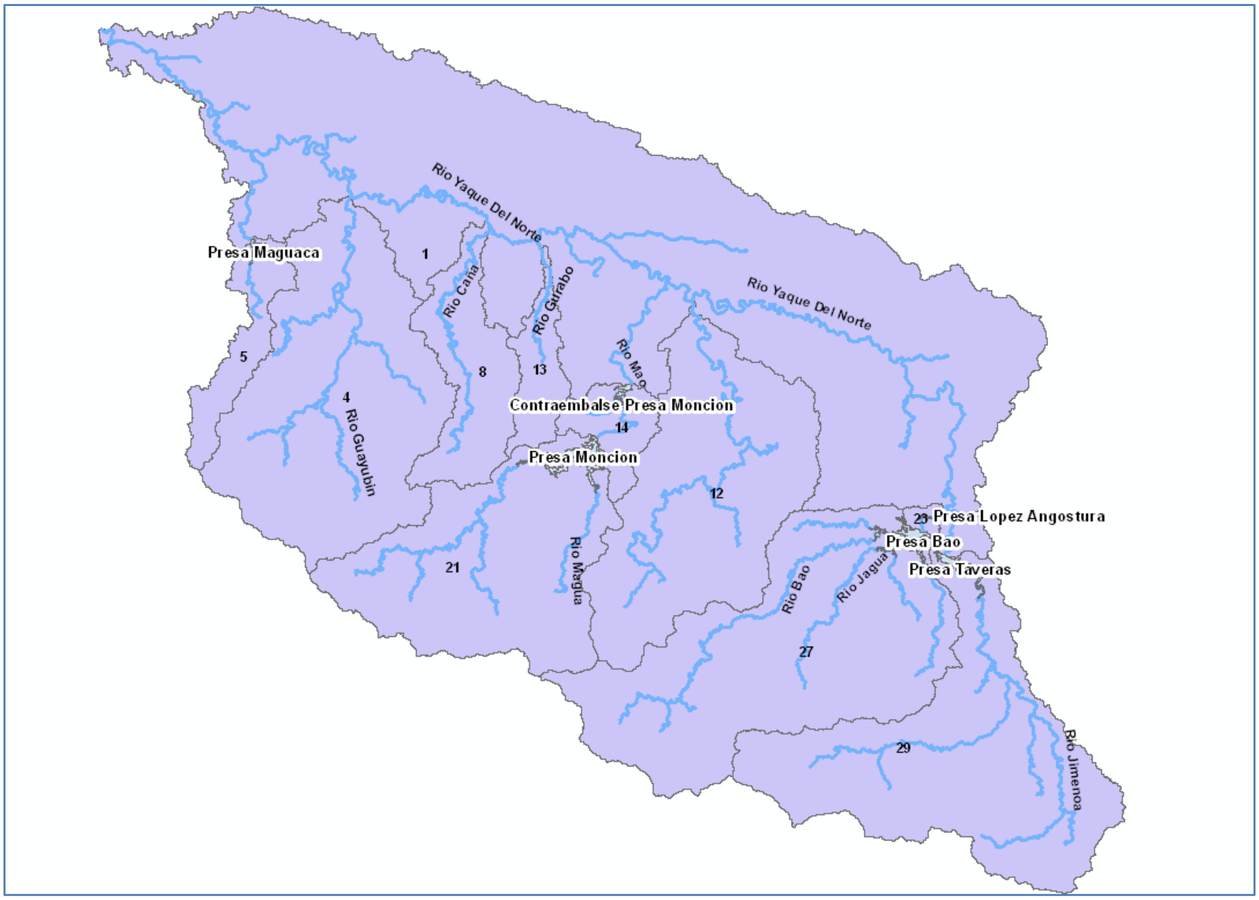

Figure 7-4. Basin or reach numbers used to output the results for the Yaque del Norte basin.

7.1 Results

The results are highly variable from basin to basin. The analysis included in this section highlights the major trends in water yield, sediment, baseflow and peakflow due to both land use and climate changes with the objective of identifying the land use land cover scenario that produces less sediment and more water yield in the basins. For the purpose of analyzing the impact of land use change, the results were compared across all LULC scenarios for a given climate scenario. Similarly, the impact of climate change was analyzed by comparing the results among all climate scenarios for a given land use. A final comparison between the baseline results (2003 LULC and historical climate) and each climate and land use scenario combination was also assessed. The following acronyms are used in the balance sheet tables presented in this section to identify the land use land cover scenarios: 2003 is the 2003 LULC, BAU is Business-As-Usual, BMP is Best Management Practice, CONS is conservation, DEV is development, and MIX is combination.

7.2 Haina Basin

7.2.1 Water Yield

Table 7-1 summarizes the mean annual water yield for each climate change and land use scenario modeled. For a given land use land cover scenario, the water yield increases from the dry and hot to the wet and warm climate projections for all three sub-basins.

For all climate change projections, the lowest water yield is predicted with the conservation and the largest water yield is produced some times by the combination scenario and sometimes by the

development but the difference between both scenarios is not significant. This means that the reduction in crops and the increase in forest cover produce less water yield in the Haina basin. Forest land types tend to evapotranspirate more than crop lands reducing the water yield.

The results for the wet and warm projection and across all land use land cover scenarios are larger than the baseline results.

7.2.2 Peak Flow

For a given land use land cover scenario, the peak flows increase as the climate data change from the dry and hot to the wet and warm climate zones as expected. The variation of peak magnitude is not significant for a given climate change projection and across all land use land cover scenarios. In general, the median and wet and warm climate change projections produce larger peaks than the baseline. ***Table 7-2*** shows the peak flow results for all climate change and land use models.

7.2.3 Sediment

The variation of sediment load in the basin among all modeled scenarios is greater than the variation of peak flows. For a given land use land cover, the sediment load does not change proportionally with the increase in precipitation. This is due to the fact that the erosion will be affected by the timing of the rainfall events in relation to the stage of the vegetation canopy.

For all climate change projections, the conservation scenario produces the least amount of sediment in sub-basins 1 and 2 while the best management practice produces less sediment in sub-basin 3.

With respect to the baseline sediment yield, the sediment yield increases under all climate change projections and across all land use land cover scenarios for the sub-basins 2 and 3, except for the conservation scenario in sub-basin 2 that reduces significantly the sediment yield under all three climate zones.

7.2.4 Baseflow

For a given land use land cover scenario, the baseflow is larger for the wet and warm climate change projections than for the dry and hot climate change projections. For a given climate change projection, the conservation scenario produces lowest baseflow. There is not a single scenario that produces consistently the largest baseflow. In general, the wet and warm scenario produces larger baseflows than the baseline simulation.

Table 7-4 summarizes the baseflow results.

Overall, under a wet and warm climate change projection the water yield, peak flow and baseflow tend to increase with respect to the baseline. The combination and development scenarios tend to produce more water yield. The conservation scenario produces the lowest water yield, and baseflow. The conservation and the best management practice scenarios tend to produce the least amount of sediment.

Table 7-1. Mean annual water yield in the Haina basin for all LULC and climate change projections modeled.

			Dry and Hot Climate Zone		Median	Wet and Warm Climate Zone	
Sub-basin		Historical	cccma_cgcm3_a2_run2_2081_2100	ipsl_cm4_a2_run1_2081_2100	cnrm_cm3_a2_run1_2046_2065	mri_cgcm2_3_2a_b1_run5_2081_2100	mri_cgcm2_3_2a_b1_run5_2046_2065
1	Baseline	960	266	384	807	1075	1080
1	BAU			394	826	1098	
1	BMP			391	826	1096	
1	CONS			370	796	1062	
1	DEV			396	830	1102	
1	MIX			389	842	1115	
Sub-basin		Historical	cccma_cgcm3_a2_run2_2081_2100	ipsl_cm4_a2_run1_2081_2100	cnrm_cm3_a2_run1_2046_2065	mri_cgcm2_3_2a_b1_run5_2081_2100	mri_cgcm2_3_2a_b1_run5_2046_2065
2	Baseline	2867	748	1094	2448	3242	3229
2	BAU			1173	2606	3396	
2	BMP			1108	2513	3297	
2	CONS			847	1980	2711	
2	DEV			1182	2575	3372	
2	MIX			1154	2594	3384	
Sub-basin		Historical	cccma_cgcm3_a2_run2_2081_2100	ipsl_cm4_a2_run1_2081_2100	cnrm_cm3_a2_run1_2046_2065	mri_cgcm2_3_2a_b1_run5_2081_2100	mri_cgcm2_3_2a_b1_run5_2046_2065
3	Baseline	764	182	280	650	880	890
3	BAU			374	830	1089	
3	BMP			280	661	886	
3	CONS			190	442	630	
3	DEV			386	810	1045	
3	MIX			382	807	1040	

Table 7-2. Annual peakflow in the Haina basin for all LULC and climate change projections modeled. Units are cms.

			Dry and Hot Climate Zone		Median	Wet and Warm Climate Zone	
Sub-basin		Historical	cccma_cgcm3_a2_run2_2081_2100	ipsl_cm4_a2_run1_2081_2100	cnrm_cm3_a2_run1_2046_2065	mri_cgcm2_3_2a_b1_run5_2081_2100	mri_cgcm2_3_2a_b1_run5_2046_2065
1	Baseline	112	62	124	143	158	148
1	BAU			117	140	155	
1	BMP			123	141	157	
1	CONS			125	143	159	
1	DEV			124	141	155	
1	MIX			125	140	158	
Sub-basin		Historical	cccma_cgcm3_a2_run2_2081_2100	ipsl_cm4_a2_run1_2081_2100	cnrm_cm3_a2_run1_2046_2065	mri_cgcm2_3_2a_b1_run5_2081_2100	mri_cgcm2_3_2a_b1_run5_2046_2065
2	Baseline	418	219	445	526	583	525
2	BAU			412	502	570	
2	BMP			452	528	580	
2	CONS			446	561	623	
2	DEV			448	527	575	
2	MIX			449	522	584	
Sub-basin		Historical	cccma_cgcm3_a2_run2_2081_2100	ipsl_cm4_a2_run1_2081_2100	cnrm_cm3_a2_run1_2046_2065	mri_cgcm2_3_2a_b1_run5_2081_2100	mri_cgcm2_3_2a_b1_run5_2046_2065
3	Baseline	509	253	509	632	706	636
3	BAU			498	607	685	
3	BMP			517	636	702	
3	CONS			488	647	766	
3	DEV			528	644	697	
3	MIX			528	635	706	

Table 7-3. Annual sediment load in the Haina basin for all LULC and climate change projections modeled. Units are tons.

			Dry and Hot Climate Zone		Median	Wet and Warm Climate Zone	
Sub-basin		Historical	cccma_cgcm3_a2_run2_2081_2100	ipsl_cm4_a2_run1_2081_2100	cnrm_cm3_a2_run1_2046_2065	mri_cgcm2_3_2a_b1_run5_2081_2100	mri_cgcm2_3_2a_b1_run5_2046_2065
1	Baseline	1319	131	289	1194	1675	1584
1	BAU			269	1104	1526	
1	BMP			140	597	867	
1	CONS			102	467	699	
1	DEV			286	1181	1638	
1	MIX			142	377	667	
Sub-basin		Historical	cccma_cgcm3_a2_run2_2081_2100	ipsl_cm4_a2_run1_2081_2100	cnrm_cm3_a2_run1_2046_2065	mri_cgcm2_3_2a_b1_run5_2081_2100	mri_cgcm2_3_2a_b1_run5_2046_2065
2	Baseline	2346	905	2721	2523	4580	3257
2	BAU			7651	5734	9273	
2	BMP			2195	1743	3217	
2	CONS			916	1169	1893	
2	DEV			6790	5396	8544	
2	MIX			5014	2553	4317	
Sub-basin		Historical	cccma_cgcm3_a2_run2_2081_2100	ipsl_cm4_a2_run1_2081_2100	cnrm_cm3_a2_run1_2046_2065	mri_cgcm2_3_2a_b1_run5_2081_2100	mri_cgcm2_3_2a_b1_run5_2046_2065
3	Baseline	1070	5712	8186	4037	3433	3877
3	BAU			15482	8851	7479	
3	BMP			8085	4053	3318	
3	CONS			8206	4150	3390	
3	DEV			17872	10157	8538	
3	MIX			17624	9332	7367	

Table 7-4. Mean annual baseflow in the Haina basin for all LULC and climate change projections modeled. Units are cms.

			Dry and Hot Climate Zone		Median	Wet and Warm Climate Zone	
Sub-basin		Historical	cccma_cgcm3_a2_run2_2081_2100	ipsl_cm4_a2_run1_2081_2100	cnrm_cm3_a2_run1_2046_2065	mri_cgcm2_3_2a_b1_run5_2081_2100	mri_cgcm2_3_2a_b1_run5_2046_2065
1	Baseline	487	179	256	424	531	550
1	BAU			274	475	597	
1	BMP			264	453	566	
1	CONS			246	420	522	
1	DEV			269	457	573	
1	MIX			262	486	600	
Sub-basin		Historical	cccma_cgcm3_a2_run2_2081_2100	ipsl_cm4_a2_run1_2081_2100	cnrm_cm3_a2_run1_2046_2065	mri_cgcm2_3_2a_b1_run5_2081_2100	mri_cgcm2_3_2a_b1_run5_2046_2065
2	Baseline	2319	699	1020	2003	2566	2577
2	BAU			1089	2245	2831	
2	BMP			1036	2093	2654	
2	CONS			783	1415	1781	
2	DEV			1068	2075	2650	
2	MIX			1033	2158	2713	
Sub-basin		Historical	cccma_cgcm3_a2_run2_2081_2100	ipsl_cm4_a2_run1_2081_2100	cnrm_cm3_a2_run1_2046_2065	mri_cgcm2_3_2a_b1_run5_2081_2100	mri_cgcm2_3_2a_b1_run5_2046_2065
3	Baseline	2454	538	871	1977	2678	2734
3	BAU			1003	2361	3088	
3	BMP			918	2126	2815	
3	CONS			707	1448	1864	
3	DEV			971	2112	2818	
3	MIX			940	2187	2854	

7.3 Nizao Basin

7.3.1 Water Yield

For a given land use land cover scenario the water yield increases with the increase in precipitation. As the Haina basin, for a given climate change projection the best management practice scenarios produces the lower water yield while the combination scenario produces the largest water yield. However, the results do not differ significantly across the different land use land cover scenarios (***Table 7-5***, ***Table 7-6***, and ***Table 7-7***).

The baseline water yield is greater than the water yield from the simulations with the dry and hot climate change projection across all LULC scenarios. Conversely, the baseline water yield is less than the water yield from the simulations with the wet and warm climate change projection across all LULC scenarios.

7.3.2 Peak Flow

For a given land use land cover scenario the peak flow is lower for the dry and hot climate change projection than for the median and wet and warm projection. The median climate change projection (cnrm_cm3_a2_run1_2046_2065) tends to yield the largest peaks. However, the peak flows for the median climate zone do not differ significantly from the peak flows in the wet and warm climate zone. For a given climate change projection, the variation in peak flows is not significant across all LULC scenarios. The combination scenario produces the lowest peak for most of the sub-basins.

The baseline peaks are very similar to the peak flows from the combination scenario and the median climate change projection (cnrm_cm3_a2_run1_2046_2065). The baseline peaks are also larger than the peaks predicted with the dry and hot climate change projection (see ***Table 7-8***, ***Table 7-9***, ***Table 7-10***).

7.3.3 Sediment

In general, for a given land use land cover scenario the sediment load is lower for the dry and hot climate change projection than for the median and wet and warm projections for most sub-basins. For the combination scenario, this trend does not hold at the outlet of the basin (sub-basin 15). The dry and hot projection (ipsl_cm4_a2_run1_2081_2100) produces more sediment even when the peak flow and the surface runoff decrease with respect to the baseline. This might be due to the timing of the peaks in relation to the stage of the crop canopy.

For a given climate change projection, the conservation scenario produces the lower sediment yield followed by the best management practice scenario. The combination scenario produces the largest sediment load even though this scenario also produces the lowest peaks. This result is due to the surface runoff component of the hydrograph. The sediment yield depends not only on the magnitude of the peaks but also on the amount of surface runoff. A comparison of the surface runoff generated by the wet and warm and the median climate change projections with the baseline results for the combination scenario indicates an increase in surface runoff (***Figure 7-5***).

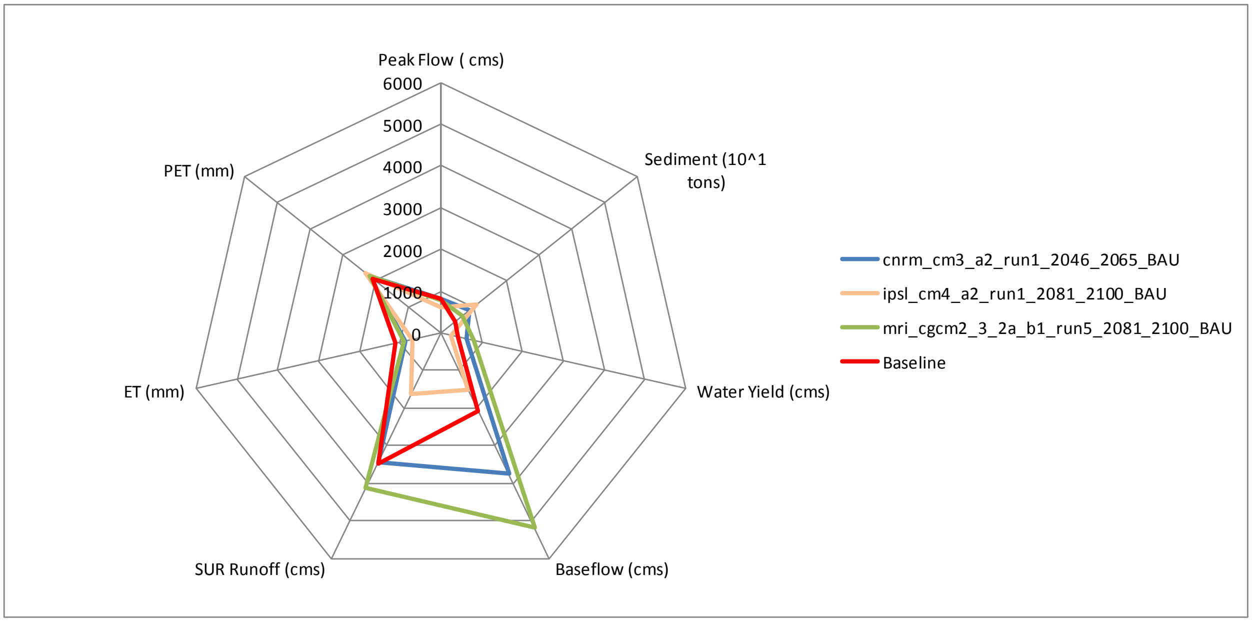

Figure 7-5. Comparison between the baseline results and the combination scenario and all climate change projections results for sub-basin 15.

The baseline sediment load is larger than the results from the dry and hot and median climate change projections for all but the combination scenarios. ***Table 7-11***, ***Table 7-12***, and ***Table 7-13*** summarize the sediment results in the Nizao basin.

7.3.4 Baseflow

For a given land use land cover scenario the baseflow increases with the increase in precipitation. For a given climate change projection, the largest baseflow is produced by the combination scenario. In general, the wet and warm scenario produces larger baseflows than the baseline simulation while the median and dry and hot climate change projections tend to produce less baseflow than the baseline simulation (see ***Table 7-14***, ***Table 7-15***, and ***Table 7-16***). The minimum amount of baseflow is produced by the best management practice scenario.

The results for the Nizao basin are highly variable. The combination scenario produces more water yield, baseflow, sediment load, and lower peaks. The conservation scenario produces the minimum sediment load. An intermediate land use land cover scenario between the conservation and the combination scenarios might produce more water yield and less sediment.

Table 7-5. Mean annual water yield for sub-basins 5, 7, and 8 in the Nizao basin for all LULC and climate change projections modeled. Units are cms.

			Dry and Hot Climate Zone		Median	Wet and Warm Climate Zone	
Sub-basin		Historical	cccma_cgcm3_a2_run2_2081_2100	ipsl_cm4_a2_run1_2081_2100	cnrm_cm3_a2_run1_2046_2065	mri_cgcm2_3_2a_b1_run5_2081_2100	mri_cgcm2_3_2a_b1_run5_2046_2065
5	2003	745	246	304	674	852	858
5	BAU			315	700	882	
5	BMP			310	693	874	
5	CONS			328	701	875	
5	DEV			316	705	888	
5	MIX			435	951	1184	
Sub-basin		Historical	cccma_cgcm3_a2_run2_2081_2100	ipsl_cm4_a2_run1_2081_2100	cnrm_cm3_a2_run1_2046_2065	mri_cgcm2_3_2a_b1_run5_2081_2100	mri_cgcm2_3_2a_b1_run5_2046_2065
7	2003	3720	1355	1611	3374	4236	4245
7	BAU			1654	3470	4356	
7	BMP			1595	3390	4271	
7	CONS			1572	3189	3983	
7	DEV			1656	3497	4395	
7	MIX			2425	5035	6225	
Sub-basin		Historical	cccma_cgcm3_a2_run2_2081_2100	ipsl_cm4_a2_run1_2081_2100	cnrm_cm3_a2_run1_2046_2065	mri_cgcm2_3_2a_b1_run5_2081_2100	mri_cgcm2_3_2a_b1_run5_2046_2065
8	2003	703	248	299	641	804	810
8	BAU			304	659	826	
8	BMP			303	659	825	
8	CONS			322	667	829	
8	DEV			331	728	929	
8	MIX			378	827	1033	

Table 7-6. Mean annual water yield for sub-basins 10, 12, and 14 in the Nizao basin for all LULC and climate change projections modeled. Units are cms.

			Dry and Hot Climate Zone		Median	Wet and Warm Climate Zone	
Sub-basin		Historical	cccma_cgcm3_a2_run2_2081_2100	ipsl_cm4_a2_run1_2081_2100	cnrm_cm3_a2_run1_2046_2065	mri_cgcm2_3_2a_b1_run5_2081_2100	mri_cgcm2_3_2a_b1_run5_2046_2065
10	2003	1227	468	550	1126	1400	1406
10	BAU			554	1145	1427	
10	BMP			547	1136	1415	
10	CONS			578	1151	1414	
10	DEV			588	1251	1591	
10	MIX			710	1532	1908	
Sub-basin		Historical	cccma_cgcm3_a2_run2_2081_2100	ipsl_cm4_a2_run1_2081_2100	cnrm_cm3_a2_run1_2046_2065	mri_cgcm2_3_2a_b1_run5_2081_2100	mri_cgcm2_3_2a_b1_run5_2046_2065
12	2003	754	301	351	691	852	850
12	BAU			362	708	871	
12	BMP			354	694	857	
12	CONS			319	596	734	
12	DEV			354	738	935	
12	MIX			493	995	1221	
Sub-basin		Historical	cccma_cgcm3_a2_run2_2081_2100	ipsl_cm4_a2_run1_2081_2100	cnrm_cm3_a2_run1_2046_2065	mri_cgcm2_3_2a_b1_run5_2081_2100	mri_cgcm2_3_2a_b1_run5_2046_2065
14	2003	106	41	48	98	123	123
14	BAU			48	100	126	
14	BMP			47	96	122	
14	CONS			49	98	122	
14	DEV			49	106	138	
14	MIX			72	160	203	

Table 7-7. Mean annual water yield for sub-basin 15 in the Nizao basin for all LULC and climate change projections modeled. Units are cms.

			Dry and Hot Climate Zone		Median	Wet and Warm Climate Zone	
Sub-basin		Historical	cccma_cgcm3_a2_run2_2081_2100	ipsl_cm4_a2_run1_2081_2100	cnrm_cm3_a2_run1_2046_2065	mri_cgcm2_3_2a_b1_run5_2081_2100	mri_cgcm2_3_2a_b1_run5_2046_2065
15	2003	436	85	127	380	527	526
15	BAU			168	461	627	
15	BMP			135	412	574	
15	CONS			149	412	565	
15	DEV			180	499	678	
15	MIX			239	619	818	

Table 7-8. Annual peak flow in sub-basins 5, 7, and 8 in the Nizao basin for all LULC and climate change projections modeled. Units are cms.

			Dry and Hot Climate Zone		Median	Wet and Warm Climate Zone	
Sub-basin		Historical	cccma_cgcm3_a2_run2_2081_2100	ipsl_cm4_a2_run1_2081_2100	cnrm_cm3_a2_run1_2046_2065	mri_cgcm2_3_2a_b1_run5_2081_2100	mri_cgcm2_3_2a_b1_run5_2046_2065
5	2003	100	58	94	128	123	109
5	BAU			98	129	121	
5	BMP			98	129	122	
5	CONS			96	110	108	
5	DEV			98	129	121	
5	MIX			86	107	97	
Sub-basin		Historical	cccma_cgcm3_a2_run2_2081_2100	ipsl_cm4_a2_run1_2081_2100	cnrm_cm3_a2_run1_2046_2065	mri_cgcm2_3_2a_b1_run5_2081_2100	mri_cgcm2_3_2a_b1_run5_2046_2065
7	2003	466	247	414	595	588	525
7	BAU			425	597	584	
7	BMP			434	607	588	
7	CONS			406	506	499	
7	DEV			424	598	585	
7	MIX			354	465	441	
Sub-basin		Historical	cccma_cgcm3_a2_run2_2081_2100	ipsl_cm4_a2_run1_2081_2100	cnrm_cm3_a2_run1_2046_2065	mri_cgcm2_3_2a_b1_run5_2081_2100	mri_cgcm2_3_2a_b1_run5_2046_2065
8	2003	94	52	86	120	116	104
8	BAU			89	121	116	
8	BMP			90	122	116	
8	CONS			90	105	103	
8	DEV			62	102	115	
8	MIX			84	108	99	

Table 7-9. Annual peak flow in sub-basins 10, 12, and 14 in the Nizao basin for all LULC and climate change projections modeled. Units are cms.

			Dry and Hot Climate Zone		Median	Wet and Warm Climate Zone	
Sub-basin		Historical	cccma_cgcm3_a2_run2_2081_2100	ipsl_cm4_a2_run1_2081_2100	cnrm_cm3_a2_run1_2046_2065	mri_cgcm2_3_2a_b1_run5_2081_2100	mri_cgcm2_3_2a_b1_run5_2046_2065
10	2003	622	326	548	790	790	701
10	BAU			561	793	784	
10	BMP			570	805	790	
10	CONS			551	680	673	
10	DEV			523	760	772	
10	MIX			482	635	602	
Sub-basin		Historical	cccma_cgcm3_a2_run2_2081_2100	ipsl_cm4_a2_run1_2081_2100	cnrm_cm3_a2_run1_2046_2065	mri_cgcm2_3_2a_b1_run5_2081_2100	mri_cgcm2_3_2a_b1_run5_2046_2065
12	2003	711	373	626	902	901	799
12	BAU			641	905	894	
12	BMP			649	917	901	
12	CONS			618	768	764	
12	DEV			586	858	878	
12	MIX			540	711	678	
Sub-basin		Historical	cccma_cgcm3_a2_run2_2081_2100	ipsl_cm4_a2_run1_2081_2100	cnrm_cm3_a2_run1_2046_2065	mri_cgcm2_3_2a_b1_run5_2081_2100	mri_cgcm2_3_2a_b1_run5_2046_2065
14	2003	725	378	635	919	920	815
14	BAU			651	922	914	
14	BMP			659	934	921	
14	CONS			630	784	780	
14	DEV			593	871	895	
14	MIX			548	723	691	

Table 7-10. Annual peak flow in sub-basin 15 in the Nizao basin for all LULC and climate change projections modeled. Units are cms.

			Dry and Hot Climate Zone		Median	Wet and Warm Climate Zone	
Sub-basin		Historical	cccma_cgcm3_a2_run2_2081_2100	ipsl_cm4_a2_run1_2081_2100	cnrm_cm3_a2_run1_2046_2065	mri_cgcm2_3_2a_b1_run5_2081_2100	mri_cgcm2_3_2a_b1_run5_2046_2065
15	2003	805	408	695	1021	871	897
15	BAU			714	1026	1012	
15	BMP			719	1038	882	
15	CONS			706	867	869	
15	DEV			646	965	842	
15	MIX			608	817	770	

Table 7-11. Mean annual sediment volume in sub-basins 5, 7, and 8 in the Nizao basin for all LULC and climate change projections modeled. Units are tons

			Dry and Hot Climate Zone		Median	Wet and Warm Climate Zone	
Sub-basin		Historical	cccma_cgcm3_a2_run2_2081_2100	ipsl_cm4_a2_run1_2081_2100	cnrm_cm3_a2_run1_2046_2065	mri_cgcm2_3_2a_b1_run5_2081_2100	mri_cgcm2_3_2a_b1_run5_2046_2065
5	2003	5077	927	1623	4673	6321	6256
5	BAU			1673	4800	6532	
5	BMP			1132	3241	4378	
5	CONS			935	1835	2394	
5	DEV			1566	4461	6047	
5	MIX			27991	68895	93279	
Sub-basin		Historical	cccma_cgcm3_a2_run2_2081_2100	ipsl_cm4_a2_run1_2081_2100	cnrm_cm3_a2_run1_2046_2065	mri_cgcm2_3_2a_b1_run5_2081_2100	mri_cgcm2_3_2a_b1_run5_2046_2065
7	2003	13009	2000	3645	12048	17021	16144
7	BAU			5143	14633	20024	
7	BMP			2573	8203	11571	
7	CONS			2793	6223	8538	
7	DEV			5198	17435	22421	
7	MIX			169080	477078	658976	
Sub-basin		Historical	cccma_cgcm3_a2_run2_2081_2100	ipsl_cm4_a2_run1_2081_2100	cnrm_cm3_a2_run1_2046_2065	mri_cgcm2_3_2a_b1_run5_2081_2100	mri_cgcm2_3_2a_b1_run5_2046_2065
8	2003	14741	2346	4231	13671	19820	18143
8	BAU			3484	11142	16132	
8	BMP			3258	10415	15083	
8	CONS			2943	5840	8083	
8	DEV			5628	12524	15266	
8	MIX			43577	121367	170728	

Table 7-12. Mean annual sediment volume in sub-basins 10, 12, and 14 in the Nizao basin for all LULC and climate change projections modeled. Units are tons.

			Dry and Hot Climate Zone		Median	Wet and Warm Climate Zone	
Sub-basin		Historical	cccma_cgcm3_a2_run2_2081_2100	ipsl_cm4_a2_run1_2081_2100	cnrm_cm3_a2_run1_2046_2065	mri_cgcm2_3_2a_b1_run5_2081_2100	mri_cgcm2_3_2a_b1_run5_2046_2065
10	2003	0	0	0	0	0	0
10	BAU			0	0	0	
10	BMP			0	0	0	
10	CONS			0	0	0	
10	DEV			0	0	0	
10	MIX			0	6748	24237	
Sub-basin		Historical	cccma_cgcm3_a2_run2_2081_2100	ipsl_cm4_a2_run1_2081_2100	cnrm_cm3_a2_run1_2046_2065	mri_cgcm2_3_2a_b1_run5_2081_2100	mri_cgcm2_3_2a_b1_run5_2046_2065
12	2003	39141	4007	8933	36431	55904	49863
12	BAU			5390	22611	35108	
12	BMP			4813	19720	30651	
12	CONS			0	0	0	
12	DEV			8412	13878	22277	
12	MIX			42100	145811	214766	
Sub-basin		Historical	cccma_cgcm3_a2_run2_2081_2100	ipsl_cm4_a2_run1_2081_2100	cnrm_cm3_a2_run1_2046_2065	mri_cgcm2_3_2a_b1_run5_2081_2100	mri_cgcm2_3_2a_b1_run5_2046_2065
14	2003	81	7	18	74	117	104
14	BAU			39	90	120	
14	BMP			13	51	80	
14	CONS			0	0	0	
14	DEV			0	188	169	
14	MIX			162	0	782	

Table 7-13. Mean annual sediment volume in sub-basin 15 in the Nizao basin for all LULC and climate change projections modeled. Units are tons

			Dry and Hot Climate Zone		Median	Wet and Warm Climate Zone	
Sub-basin		Historical	cccma_cgcm3_a2_run2_2081_2100	ipsl_cm4_a2_run1_2081_2100	cnrm_cm3_a2_run1_2046_2065	mri_cgcm2_3_2a_b1_run5_2081_2100	mri_cgcm2_3_2a_b1_run5_2046_2065
15	2003	4461	512	1047	4392	6142	5836
15	BAU			1682	1819	1596	
15	BMP			233	579	806	
15	CONS			0	0	0	
15	DEV			4158	6313	4861	
15	MIX			10918	8865	6425	

Table 7-14. Mean annual baseflow for sub-basins 5, 7, and 8 in the Nizao basin for all LULC and climate change projections modeled. Units are cms.

			Dry and Hot Climate Zone		Median	Wet and Warm Climate Zone	
Sub-basin		Historical	cccma_cgcm3_a2_run2_2081_2100	ipsl_cm4_a2_run1_2081_2100	cnrm_cm3_a2_run1_2046_2065	mri_cgcm2_3_2a_b1_run5_2081_2100	mri_cgcm2_3_2a_b1_run5_2046_2065
5	2003	301	105	130	267	330	350
5	BAU			135	291	357	
5	BMP			133	286	351	
5	CONS			135	309	394	
5	DEV			136	296	363	
5	MIX			256	596	750	
Sub-basin		Historical	cccma_cgcm3_a2_run2_2081_2100	ipsl_cm4_a2_run1_2081_2100	cnrm_cm3_a2_run1_2046_2065	mri_cgcm2_3_2a_b1_run5_2081_2100	mri_cgcm2_3_2a_b1_run5_2046_2065
7	2003	1629	605	732	1436	1786	1839
7	BAU			750	1500	1871	
7	BMP			719	1446	1812	
7	CONS			693	1475	1898	
7	DEV			759	1549	1939	
7	MIX			1484	3286	4128	
Sub-basin		Historical	cccma_cgcm3_a2_run2_2081_2100	ipsl_cm4_a2_run1_2081_2100	cnrm_cm3_a2_run1_2046_2065	mri_cgcm2_3_2a_b1_run5_2081_2100	mri_cgcm2_3_2a_b1_run5_2046_2065
8	2003	299	115	137	268	328	344
8	BAU			140	284	349	
8	BMP			139	283	346	
8	CONS			139	294	373	
8	DEV			187	439	562	
8	MIX			209	475	601	

Table 7-15. Mean annual baseflow for sub-basins 10, 12, and 14 in the Nizao basin for all LULC and climate change projections modeled. Units are cms.

			Dry and Hot Climate Zone		Median	Wet and Warm Climate Zone	
Sub-basin		Historical	cccma_cgcm3_a2_run2_2081_2100	ipsl_cm4_a2_run1_2081_2100	cnrm_cm3_a2_run1_2046_2065	mri_cgcm2_3_2a_b1_run5_2081_2100	mri_cgcm2_3_2a_b1_run5_2046_2065
10	2003	2163	806	971	1912	2369	2441
10	BAU			991	1994	2483	
10	BMP			957	1935	2414	
10	CONS			937	1980	2536	
10	DEV			1056	2265	2875	
10	MIX			1861	4189	5277	
Sub-basin		Historical	cccma_cgcm3_a2_run2_2081_2100	ipsl_cm4_a2_run1_2081_2100	cnrm_cm3_a2_run1_2046_2065	mri_cgcm2_3_2a_b1_run5_2081_2100	mri_cgcm2_3_2a_b1_run5_2046_2065
12	2003	2471	909	1102	2176	2703	2780
12	BAU			1130	2276	2837	
12	BMP			1091	2207	2755	
12	CONS			1056	2229	2861	
12	DEV			1197	2634	3374	
12	MIX			2118	4796	6047	
Sub-basin		Historical	cccma_cgcm3_a2_run2_2081_2100	ipsl_cm4_a2_run1_2081_2100	cnrm_cm3_a2_run1_2046_2065	mri_cgcm2_3_2a_b1_run5_2081_2100	mri_cgcm2_3_2a_b1_run5_2046_2065
14	2003	2513	916	1114	2211	2750	2828
14	BAU			1142	2312	2886	
14	BMP			1103	2240	2802	
14	CONS			1069	2262	2908	
14	DEV			1210	2683	3445	
14	MIX			2149	4893	6177	

Table 7-16. Mean annual baseflow for sub-basin 15 in the Nizao basin for all LULC and climate change projections modeled. Units are cms.

			Dry and Hot Climate Zone		Median	Wet and Warm Climate Zone	
Sub-basin		Historical	cccma_cgcm3_a2_run2_2081_2100	ipsl_cm4_a2_run1_2081_2100	cnrm_cm3_a2_run1_2046_2065	mri_cgcm2_3_2a_b1_run5_2081_2100	mri_cgcm2_3_2a_b1_run5_2046_2065
15	2003	2076	562	761	1701	2323	2381
15	BAU			841	1845	2503	
15	BMP			817	1788	2453	
15	CONS			876	1926	2627	
15	DEV			1003	2378	3216	
15	MIX			1496	3755	5158	

7.4 Ozama Basin

7.4.1 Water Yield

For a given land use land cover scenario, the water yield increases with increases in precipitation. For a given climate change projection and across all land use land cover scenarios, the conservation scenario produces the largest amount of water yield. The 2003 land use land cover produces the lowest water yield for all the climate change projections.

The results from the dry and hot climate change projection (ipsl_cm4_a2_run1_2081_2100) for all land use land cover scenarios are always lower than the water yield from the baseline. Conversely, the wet and warm climate change projection (mri_cgcm2_3_2a_b1_run5_2081_2100) for all land use land cover scenarios produce more water yield than the baseline. The median climate change projection (cnrm_cm3_a2_run1_2046_2065) produces mix results, some of them above and some below the baseline water yield. The results for all the runs are included in ***Table 7-17***, ***Table 7-18***, ***Table 7-19***, and ***Table 7-20***.

7.4.2 Peak Flow

For a given land use land cover scenario, the peak flow increases with an increase in precipitation. However, the difference in peak magnitude is not significant across all climate change projections. For a given climate change projection both the conservation and the best management practice scenarios produce the lowest peaks for most of the basins.

The results from the dry and hot climate change projection (ipsl_cm4_a2_run1_2081_2100) for all land use land cover scenarios are always lower than the peak flow from the baseline, except at sub-basin 12. Sub-basin 12 is at the outlet of the Ozama basin and contains the city of Santo Domingo. The urban land type produces larger peaks due to the impervious area in the basin.

The wet and warm (mri_cgcm2_3_2a_b1_run5_2081_2100) and the median (cnrm_cm3_a2_run1_2046_2065) climate change projections produce similar results to the baseline for all sub-basins, except for sub-basin 12. The results for all the runs are included in ***Table 7-21***, ***Table 7-22***, ***Table 7-23***, and ***Table 7-24***.

7.4.3 Sediment

For a given land use land cover scenario, the sediment load increases from the dry and hot to the wet and warm climate change projections for all land use land cover and all sub-basins, except for sub-basins 11 and 12. Under the median and wet and warm climate change projections, the sediment transport capacity in sub-basins 11 and 12 is not large enough to transport the total amount of sediment from the upstream basins. The output sediment from these two basins is less than the upstream contribution.

For a given climate change projection, the sediment load from all land use land cover scenarios is larger than that from the 2003 land use land cover scenario. The conservation and the best management practice scenarios produce the least amount of sediment for most of the sub-basins.

The land use land cover scenario that produces the most erosion varies per sub-basin. However, the combination and development scenarios appear to produce the largest sediment load most of the time.

Except for a few cases, the sediment load for the baseline scenario tends to be lower than the load produced under all climate change projections and all land use land cover scenarios. The results are included in ***Table 7-25***, ***Table 7-26***, ***Table 7-27***, and ***Table 7-28***.

7.4.4 Baseflow

For a given land use land cover scenario the baseflow increases with increases in precipitation. For a given climate change projection, the conservation scenario produces the largest baseflow. The baseflow for the baseline scenario tends to be larger than the baseflow estimated with the dry and hot climate change projection and all land use land cover scenarios, except for the conservation scenario. The minimum baseflow is produced by the development and the 2003 LULC scenarios under all climate change projections. The baseflow results are summarized in ***Table 7-29***, ***Table 7-30***, ***Table 7-31***, and ***Table 7-32***.

The conservation land use land cover scenario is more favorable with respect to reductions in sediment, peak flows and increases in water yield and baseflow under future climates. Sediment is predicted to increase with respect to the baseline simulation for all climate futures and land use land cover scenarios for most of the sub-basins.

Table 7-17. Mean annual water yield for sub-basins 1, 2, and 3 in the Ozama basin for all climate change projections and land use land cover scenarios.

			Dry and Hot Climate Zone		Median	Wet and Warm Climate Zone	
Sub-basin		Historical	cccma_cgcm3_a2_run2_2081_2100	ipsl_cm4_a2_run1_2081_2100	cnrm_cm3_a2_run1_2046_2065	mri_cgcm2_3_2a_b1_run5_2081_2100	mri_cgcm2_3_2a_b1_run5_2046_2065
1	2003	2632	654	865	2274	3000	2969
1	BAU			1223	2968	3806	
1	BMP			1229	3018	3860	
1	CONS			1561	3685	4611	
1	DEV			1172	2887	3702	
1	MIX			1202	2957	3790	
Sub-basin		Historical	cccma_cgcm3_a2_run2_2081_2100	ipsl_cm4_a2_run1_2081_2100	cnrm_cm3_a2_run1_2046_2065	mri_cgcm2_3_2a_b1_run5_2081_2100	mri_cgcm2_3_2a_b1_run5_2046_2065
2	2003	772	176	238	666	887	879
2	BAU			366	923	1186	
2	BMP			362	931	1195	
2	CONS			381	935	1199	
2	DEV			348	895	1151	
2	MIX			351	903	1162	
Sub-basin		Historical	cccma_cgcm3_a2_run2_2081_2100	ipsl_cm4_a2_run1_2081_2100	cnrm_cm3_a2_run1_2046_2065	mri_cgcm2_3_2a_b1_run5_2081_2100	mri_cgcm2_3_2a_b1_run5_2046_2065
3	2003	1669	405	541	1444	1909	1890
3	BAU			781	1886	2410	
3	BMP			739	1856	2382	
3	CONS			772	1910	2445	
3	DEV			712	1793	2303	
3	MIX			733	1842	2367	

Table 7-18. Mean annual water yield for sub-basins 4, 5, and 6 in the Ozama basin for all climate change projections and land use land cover scenarios.

			Dry and Hot Climate Zone		Median	Wet and Warm Climate Zone	
Sub-basin		Historical	cccma_cgcm3_a2_run2_2081_2100	ipsl_cm4_a2_run1_2081_2100	cnrm_cm3_a2_run1_2046_2065	mri_cgcm2_3_2a_b1_run5_2081_2100	mri_cgcm2_3_2a_b1_run5_2046_2065
4	2003	1079	285	373	933	1214	1203
4	BAU			472	1130	1435	
4	BMP			474	1144	1447	
4	CONS			545	1282	1608	
4	DEV			459	1105	1405	
4	MIX			464	1116	1419	
Sub-basin		Historical	cccma_cgcm3_a2_run2_2081_2100	ipsl_cm4_a2_run1_2081_2100	cnrm_cm3_a2_run1_2046_2065	mri_cgcm2_3_2a_b1_run5_2081_2100	mri_cgcm2_3_2a_b1_run5_2046_2065
5	2003	876	231	304	762	986	978
5	BAU			323	797	1023	
5	BMP			329	814	1042	
5	CONS			357	879	1121	
5	DEV			317	787	1010	
5	MIX			320	793	1020	
Sub-basin		Historical	cccma_cgcm3_a2_run2_2081_2100	ipsl_cm4_a2_run1_2081_2100	cnrm_cm3_a2_run1_2046_2065	mri_cgcm2_3_2a_b1_run5_2081_2100	mri_cgcm2_3_2a_b1_run5_2046_2065
6	2003	2510	661	869	2164	2812	2786
6	BAU			1205	2794	3515	
6	BMP			1212	2836	3560	
6	CONS			1410	3209	3974	
6	DEV			1171	2730	3432	
6	MIX			1209	2818	3539	

Table 7-19. Mean annual water yield for sub-basins 7, 8, and 9 in the Ozama basin for all climate change projections and land use land cover scenarios.

			Dry and Hot Climate Zone		Median	Wet and Warm Climate Zone	
Sub-basin		Historical	cccma_cgcm3_a2_run2_2081_2100	ipsl_cm4_a2_run1_2081_2100	cnrm_cm3_a2_run1_2046_2065	mri_cgcm2_3_2a_b1_run5_2081_2100	mri_cgcm2_3_2a_b1_run5_2046_2065
7	2003	1992	513	677	1726	2249	2229
7	BAU			768	1892	2439	
7	BMP			763	1912	2461	
7	CONS			780	1959	2514	
7	DEV			744	1856	2396	
7	MIX			754	1874	2420	
Sub-basin		Historical	cccma_cgcm3_a2_run2_2081_2100	ipsl_cm4_a2_run1_2081_2100	cnrm_cm3_a2_run1_2046_2065	mri_cgcm2_3_2a_b1_run5_2081_2100	mri_cgcm2_3_2a_b1_run5_2046_2065
8	2003	6699	1541	2096	5779	7680	7605
8	BAU			2890	7227	9310	
8	BMP			2785	7245	9379	
8	CONS			2844	7433	9604	
8	DEV			2644	6879	8928	
8	MIX			2723	7072	9169	
Sub-basin		Historical	cccma_cgcm3_a2_run2_2081_2100	ipsl_cm4_a2_run1_2081_2100	cnrm_cm3_a2_run1_2046_2065	mri_cgcm2_3_2a_b1_run5_2081_2100	mri_cgcm2_3_2a_b1_run5_2046_2065
9	2003	929	246	320	803	1048	1039
9	BAU			415	964	1228	
9	BMP			404	967	1236	
9	CONS			575	1309	1619	
9	DEV			419	968	1228	
9	MIX			444	1032	1303	

Table 7-20. Mean annual water yield for sub-basins 10, 11, and 12 in the Ozama basin for all climate change projections and land use land cover scenarios.

			Dry and Hot Climate Zone		Median	Wet and Warm Climate Zone	
Sub-basin		Historical	cccma_cgcm3_a2_run2_2081_2100	ipsl_cm4_a2_run1_2081_2100	cnrm_cm3_a2_run1_2046_2065	mri_cgcm2_3_2a_b1_run5_2081_2100	mri_cgcm2_3_2a_b1_run5_2046_2065
10	2003	1673	422	552	1445	1905	1889
10	BAU			811	1908	2427	
10	BMP			757	1883	2413	
10	CONS			1011	2397	2997	
10	DEV			809	1901	2412	
10	MIX			836	1975	2502	
Sub-basin		Historical	cccma_cgcm3_a2_run2_2081_2100	ipsl_cm4_a2_run1_2081_2100	cnrm_cm3_a2_run1_2046_2065	mri_cgcm2_3_2a_b1_run5_2081_2100	mri_cgcm2_3_2a_b1_run5_2046_2065
11	2003	1129	379	439	999	1263	1252
11	BAU			540	1147	1392	
11	BMP			479	1091	1370	
11	CONS			628	1398	1735	
11	DEV			560	1176	1411	
11	MIX			565	1187	1425	
Sub-basin		Historical	cccma_cgcm3_a2_run2_2081_2100	ipsl_cm4_a2_run1_2081_2100	cnrm_cm3_a2_run1_2046_2065	mri_cgcm2_3_2a_b1_run5_2081_2100	mri_cgcm2_3_2a_b1_run5_2046_2065
12	2003	5113	1425	1775	4451	5726	5652
12	BAU			2167	4890	5943	
12	BMP			1953	4845	6177	
12	CONS			2539	6005	7563	
12	DEV			2184	4905	5967	
12	MIX			2204	4961	6047	

Table 7-21. Annual peak flow for sub-basins 1, 2, and 3 in the Ozama basin for all climate change projections and land use land cover scenarios.

			Dry and Hot Climate Zone		Median	Wet and Warm Climate Zone	
Sub-basin		Historical	cccma_cgcm3_a2_run2_2081_2100	ipsl_cm4_a2_run1_2081_2100	cnrm_cm3_a2_run1_2046_2065	mri_cgcm2_3_2a_b1_run5_2081_2100	mri_cgcm2_3_2a_b1_run5_2046_2065
1	2003	334	235	312	350	376	359
1	BAU			265	321	333	
1	BMP			263	319	331	
1	CONS			231	291	294	
1	DEV			267	321	335	
1	MIX			265	322	335	
Sub-basin		Historical	cccma_cgcm3_a2_run2_2081_2100	ipsl_cm4_a2_run1_2081_2100	cnrm_cm3_a2_run1_2046_2065	mri_cgcm2_3_2a_b1_run5_2081_2100	mri_cgcm2_3_2a_b1_run5_2046_2065
2	2003	108	76	100	115	122	109
2	BAU			84	103	106	
2	BMP			83	102	106	
2	CONS			87	105	108	
2	DEV			85	103	106	
2	MIX			87	104	108	
Sub-basin		Historical	cccma_cgcm3_a2_run2_2081_2100	ipsl_cm4_a2_run1_2081_2100	cnrm_cm3_a2_run1_2046_2065	mri_cgcm2_3_2a_b1_run5_2081_2100	mri_cgcm2_3_2a_b1_run5_2046_2065
3	2003	216	143	201	228	243	230
3	BAU			179	213	218	
3	BMP			180	214	221	
3	CONS			178	217	219	
3	DEV			183	214	222	
3	MIX			182	213	221	

Table 7-22. Annual peak flow for sub-basins 4, 5, and 6 in the Ozama basin for all climate change projections and land use land cover scenarios.

			Dry and Hot Climate Zone		Median	Wet and Warm Climate Zone	
Sub-basin		Historical	cccma_cgcm3_a2_run2_2081_2100	ipsl_cm4_a2_run1_2081_2100	cnrm_cm3_a2_run1_2046_2065	mri_cgcm2_3_2a_b1_run5_2081_2100	mri_cgcm2_3_2a_b1_run5_2046_2065
4	2003	127	91	123	130	140	144
4	BAU			112	124	129	
4	BMP			112	123	128	
4	CONS			102	119	120	
4	DEV			112	124	130	
4	MIX			113	124	130	
Sub-basin		Historical	cccma_cgcm3_a2_run2_2081_2100	ipsl_cm4_a2_run1_2081_2100	cnrm_cm3_a2_run1_2046_2065	mri_cgcm2_3_2a_b1_run5_2081_2100	mri_cgcm2_3_2a_b1_run5_2046_2065
5	2003	541	367	500	567	607	587
5	BAU			431	517	540	
5	BMP			429	516	538	
5	CONS			405	502	503	
5	DEV			434	519	542	
5	MIX			433	520	542	
Sub-basin		Historical	cccma_cgcm3_a2_run2_2081_2100	ipsl_cm4_a2_run1_2081_2100	cnrm_cm3_a2_run1_2046_2065	mri_cgcm2_3_2a_b1_run5_2081_2100	mri_cgcm2_3_2a_b1_run5_2046_2065
6	2003	286	205	278	294	318	326
6	BAU			234	273	279	
6	BMP			231	272	278	
6	CONS			218	261	263	
6	DEV			235	273	280	
6	MIX			233	272	279	

Table 7-23. Annual peak flow for sub-basins 7, 8, and 9 in the Ozama basin for all climate change projections and land use land cover scenarios.

			Dry and Hot Climate Zone		Median	Wet and Warm Climate Zone	
Sub-basin		Historical	cccma_cgcm3_a2_run2_2081_2100	ipsl_cm4_a2_run1_2081_2100	cnrm_cm3_a2_run1_2046_2065	mri_cgcm2_3_2a_b1_run5_2081_2100	mri_cgcm2_3_2a_b1_run5_2046_2065
7	2003	541	362	492	572	608	578
7	BAU			448	534	554	
7	BMP			447	535	555	
7	CONS			476	556	571	
7	DEV			451	537	557	
7	MIX			450	534	556	
Sub-basin		Historical	cccma_cgcm3_a2_run2_2081_2100	ipsl_cm4_a2_run1_2081_2100	cnrm_cm3_a2_run1_2046_2065	mri_cgcm2_3_2a_b1_run5_2081_2100	mri_cgcm2_3_2a_b1_run5_2046_2065
8	2003	788	491	661	852	896	804
8	BAU			588	779	794	
8	BMP			565	781	803	
8	CONS			656	827	853	
8	DEV			584	791	815	
8	MIX			579	789	811	
Sub-basin		Historical	cccma_cgcm3_a2_run2_2081_2100	ipsl_cm4_a2_run1_2081_2100	cnrm_cm3_a2_run1_2046_2065	mri_cgcm2_3_2a_b1_run5_2081_2100	mri_cgcm2_3_2a_b1_run5_2046_2065
9	2003	112	82	110	116	126	126
9	BAU			101	110	116	
9	BMP			99	109	115	
9	CONS			75	93	95	
9	DEV			102	110	116	
9	MIX			96	108	112	

Table 7-24. Annual peak flow for sub-basins 10, 11, 12 in the Ozama basin for all climate change projections and land use land cover scenarios.

			Dry and Hot Climate Zone		Median	Wet and Warm Climate Zone	
Sub-basin		Historical	cccma_cgcm3_a2_run2_2081_2100	ipsl_cm4_a2_run1_2081_2100	cnrm_cm3_a2_run1_2046_2065	mri_cgcm2_3_2a_b1_run5_2081_2100	mri_cgcm2_3_2a_b1_run5_2046_2065
10	2003	328	224	315	342	368	358
10	BAU			295	324	341	
10	BMP			281	317	333	
10	CONS			213	272	276	
10	DEV			295	323	340	
10	MIX			286	319	332	
Sub-basin		Historical	cccma_cgcm3_a2_run2_2081_2100	ipsl_cm4_a2_run1_2081_2100	cnrm_cm3_a2_run1_2046_2065	mri_cgcm2_3_2a_b1_run5_2081_2100	mri_cgcm2_3_2a_b1_run5_2046_2065
11	2003	447	299	420	470	499	486
11	BAU			392	440	455	
11	BMP			377	436	452	
11	CONS			287	369	378	
11	DEV			390	437	453	
11	MIX			381	431	445	
Sub-basin		Historical	cccma_cgcm3_a2_run2_2081_2100	ipsl_cm4_a2_run1_2081_2100	cnrm_cm3_a2_run1_2046_2065	mri_cgcm2_3_2a_b1_run5_2081_2100	mri_cgcm2_3_2a_b1_run5_2046_2065
12	2003	1248	2044	1065	3231	3459	3254
12	BAU			2411	2961	3036	
12	BMP			902	2975	3091	
12	CONS			2423	3002	3057	
12	DEV			2412	2980	3030	
12	MIX			2389	2964	3013	

Table 7-25. Mean annual sediment load for sub-basins 1, 2, and 3 in the Ozama basin for climate change projections and all land use land cover scenarios.

			Dry and Hot Climate Zone		Median	Wet and Warm Climate Zone	
Sub-basin		Historical	cccma_cgcm3_a2_run2_2081_2100	ipsl_cm4_a2_run1_2081_2100	cnrm_cm3_a2_run1_2046_2065	mri_cgcm2_3_2a_b1_run5_2081_2100	mri_cgcm2_3_2a_b1_run5_2046_2065
1	2003	182504	45926	63649	158481	220316	205667
1	BAU			233550	608357	833260	
1	BMP			120858	313891	428528	
1	CONS			18940	51819	69898	
1	DEV			255658	658805	902432	
1	MIX			137111	357632	487691	
Sub-basin		Historical	cccma_cgcm3_a2_run2_2081_2100	ipsl_cm4_a2_run1_2081_2100	cnrm_cm3_a2_run1_2046_2065	mri_cgcm2_3_2a_b1_run5_2081_2100	mri_cgcm2_3_2a_b1_run5_2046_2065
2	2003	1917	411	707	1677	2434	2221
2	BAU			14856	33657	47458	
2	BMP			8850	20276	28382	
2	CONS			20691	54655	74947	
2	DEV			17535	39558	55683	
2	MIX			24997	60760	83914	
Sub-basin		Historical	cccma_cgcm3_a2_run2_2081_2100	ipsl_cm4_a2_run1_2081_2100	cnrm_cm3_a2_run1_2046_2065	mri_cgcm2_3_2a_b1_run5_2081_2100	mri_cgcm2_3_2a_b1_run5_2046_2065
3	2003	1665	370	847	1441	2203	1896
3	BAU			27834	58721	84001	
3	BMP			15651	33348	47323	
3	CONS			14887	31596	44855	
3	DEV			31638	66765	94728	
3	MIX			35277	80377	109593	

Table 7-26. Mean annual sediment load for sub-basins 4,5 and 6 in the Ozama basin for climate change projections and all land use land cover scenarios.

			Dry and Hot Climate Zone		Median	Wet and Warm Climate Zone	
Sub-basin		Historical	cccma_cgcm3_a2_run2_2081_2100	ipsl_cm4_a2_run1_2081_2100	cnrm_cm3_a2_run1_2046_2065	mri_cgcm2_3_2a_b1_run5_2081_2100	mri_cgcm2_3_2a_b1_run5_2046_2065
4	2003	19537	5383	7551	17083	23357	21772
4	BAU			42610	80128	109815	
4	BMP			24925	46950	63840	
4	CONS			10799	16456	21899	
4	DEV			49189	95146	129941	
4	MIX			55436	118593	157876	
Sub-basin		Historical	cccma_cgcm3_a2_run2_2081_2100	ipsl_cm4_a2_run1_2081_2100	cnrm_cm3_a2_run1_2046_2065	mri_cgcm2_3_2a_b1_run5_2081_2100	mri_cgcm2_3_2a_b1_run5_2046_2065
5	2003	314	0	438	253	620	369
5	BAU			12332	23473	33443	
5	BMP			6182	12020	17087	
5	CONS			5991	11111	15707	
5	DEV			12744	24436	34790	
5	MIX			12680	27557	37889	
Sub-basin		Historical	cccma_cgcm3_a2_run2_2081_2100	ipsl_cm4_a2_run1_2081_2100	cnrm_cm3_a2_run1_2046_2065	mri_cgcm2_3_2a_b1_run5_2081_2100	mri_cgcm2_3_2a_b1_run5_2046_2065
6	2003	37307	10497	13797	32151	43784	41747
6	BAU			161028	358465	489575	
6	BMP			88502	198738	271511	
6	CONS			27871	61493	83722	
6	DEV			181932	405797	553750	
6	MIX			104354	231987	313881	

Table 7-27. Mean annual sediment load for sub-basins 7, 8, and 9 in the Ozama basin for climate change projections and all land use land cover scenarios.

			Dry and Hot Climate Zone		Median	Wet and Warm Climate Zone	
Sub-basin		Historical	cccma_cgcm3_a2_run2_2081_2100	ipsl_cm4_a2_run1_2081_2100	cnrm_cm3_a2_run1_2046_2065	mri_cgcm2_3_2a_b1_run5_2081_2100	mri_cgcm2_3_2a_b1_run5_2046_2065
7	2003	2258	701	2724	2124	3644.28	2630
7	BAU			55937	93056	128126	
7	BMP			28699	49381	64307	
7	CONS			28940	51837	71487	
7	DEV			54027	91896	127830	
7	MIX			60012	126735	171836	
Sub-basin		Historical	cccma_cgcm3_a2_run2_2081_2100	ipsl_cm4_a2_run1_2081_2100	cnrm_cm3_a2_run1_2046_2065	mri_cgcm2_3_2a_b1_run5_2081_2100	mri_cgcm2_3_2a_b1_run5_2046_2065
8	2003	17436	4313	9762	15798	23618	20309
8	BAU			142439	254309	340012	
8	BMP			61757	117118	160167	
8	CONS			54051	108118	148896	
8	DEV			130736	245220	335621	
8	MIX			117121	251453	342376	
Sub-basin		Historical	cccma_cgcm3_a2_run2_2081_2100	ipsl_cm4_a2_run1_2081_2100	cnrm_cm3_a2_run1_2046_2065	mri_cgcm2_3_2a_b1_run5_2081_2100	mri_cgcm2_3_2a_b1_run5_2046_2065
9	2003	43143	11639	15907	37563	51392	48104
9	BAU			192204	454821	611770	
9	BMP			90773	215915	290727	
9	CONS			6491	15013	20118	
9	DEV			201796	472639	633984	
9	MIX			69844	153702	202105	

Table 7-28. Mean annual sediment load for sub-basins 10, 11 and 12 in the Ozama basin for climate change projections and all land use land cover scenarios.

			Dry and Hot Climate Zone		Median	Wet and Warm Climate Zone	
Sub-basin		Historical	cccma_cgcm3_a2_run2_2081_2100	ipsl_cm4_a2_run1_2081_2100	cnrm_cm3_a2_run1_2046_2065	mri_cgcm2_3_2a_b1_run5_2081_2100	mri_cgcm2_3_2a_b1_run5_2046_2065
10	2003	53271	17734	24007	51326	66914	62606
10	BAU			303403	641137	845644	
10	BMP			153643	318845	418168	
10	CONS			42581	54339	58249	
10	DEV			324249	676427	888371	
10	MIX			162775	290549	362002	
Sub-basin		Historical	cccma_cgcm3_a2_run2_2081_2100	ipsl_cm4_a2_run1_2081_2100	cnrm_cm3_a2_run1_2046_2065	mri_cgcm2_3_2a_b1_run5_2081_2100	mri_cgcm2_3_2a_b1_run5_2046_2065
11	2003	0	15019	17371	11740	0	0
11	BAU			0	0	0	
11	BMP			3154	0	0	
11	CONS			104665	111351	92581	
11	DEV			0	0	0	
11	MIX			46967	0	0	
Sub-basin		Historical	cccma_cgcm3_a2_run2_2081_2100	ipsl_cm4_a2_run1_2081_2100	cnrm_cm3_a2_run1_2046_2065	mri_cgcm2_3_2a_b1_run5_2081_2100	mri_cgcm2_3_2a_b1_run5_2046_2065
12	2003	6670	24144	34600	58991	45716	37130
12	BAU			79696	0	0	
12	BMP			94606	67512	18814	
12	CONS			99617	155196	168069	
12	DEV			84716	0	0	
12	MIX			151744	240322	223903	

Table 7-29. Mean annual baseflow for sub-basins 1, 2, and 3 in the Ozama basin for all climate change projections and all the land use land cover scenarios.

			Dry and Hot Climate Zone		Median	Wet and Warm Climate Zone	
Sub-basin		Historical	cccma_cgcm3_a2_run2_2081_2100	ipsl_cm4_a2_run1_2081_2100	cnrm_cm3_a2_run1_2046_2065	mri_cgcm2_3_2a_b1_run5_2081_2100	mri_cgcm2_3_2a_b1_run5_2046_2065
1	2003	879	202	270	735	974	959
1	BAU			761	1839	2359	
1	BMP			782	1927	2465	
1	CONS			1307	3117	3909	
1	DEV			700	1733	2221	
1	MIX			735	1811	2322	
Sub-basin		Historical	cccma_cgcm3_a2_run2_2081_2100	ipsl_cm4_a2_run1_2081_2100	cnrm_cm3_a2_run1_2046_2065	mri_cgcm2_3_2a_b1_run5_2081_2100	mri_cgcm2_3_2a_b1_run5_2046_2065
2	2003	266	54	76	221	293	288
2	BAU			235	594	762	
2	BMP			235	612	783	
2	CONS			255	606	772	
2	DEV			214	559	716	
2	MIX			212	556	711	
Sub-basin		Historical	cccma_cgcm3_a2_run2_2081_2100	ipsl_cm4_a2_run1_2081_2100	cnrm_cm3_a2_run1_2046_2065	mri_cgcm2_3_2a_b1_run5_2081_2100	mri_cgcm2_3_2a_b1_run5_2046_2065
3	2003	659	177	231	559	726	725
3	BAU			529	1209	1519	
3	BMP			485	1175	1486	
3	CONS			530	1254	1587	
3	DEV			447	1082	1369	
3	MIX			470	1140	1446	

Table 7-30. Mean annual baseflow for sub-basins 4, 5, and 6 in the Ozama basin for all climate change projections and all the land use land cover scenarios.

			Dry and Hot Climate Zone		Median	Wet and Warm Climate Zone	
Sub-basin		Historical	cccma_cgcm3_a2_run2_2081_2100	ipsl_cm4_a2_run1_2081_2100	cnrm_cm3_a2_run1_2046_2065	mri_cgcm2_3_2a_b1_run5_2081_2100	mri_cgcm2_3_2a_b1_run5_2046_2065
4	2003	332	81	109	279	364	367
4	BAU			243	587	739	
4	BMP			253	620	773	
4	CONS			378	885	1107	
4	DEV			227	553	698	
4	MIX			231	562	708	
Sub-basin		Historical	cccma_cgcm3_a2_run2_2081_2100	ipsl_cm4_a2_run1_2081_2100	cnrm_cm3_a2_run1_2046_2065	mri_cgcm2_3_2a_b1_run5_2081_2100	mri_cgcm2_3_2a_b1_run5_2046_2065
5	2003	1581	354	487	1311	1747	1731
5	BAU			1147	2829	3642	
5	BMP			1191	2980	3814	
5	CONS			1853	4458	5611	
5	DEV			1067	2679	3449	
5	MIX			1110	2776	3576	
Sub-basin		Historical	cccma_cgcm3_a2_run2_2081_2100	ipsl_cm4_a2_run1_2081_2100	cnrm_cm3_a2_run1_2046_2065	mri_cgcm2_3_2a_b1_run5_2081_2100	mri_cgcm2_3_2a_b1_run5_2046_2065
6	2003	749	178	242	631	826	827
6	BAU			711	1659	2085	
6	BMP			750	1767	2210	
6	CONS			1088	2485	3070	
6	DEV			668	1574	1976	
6	MIX			723	1703	2134	

Table 7-31. Mean annual baseflow for sub-basins 7, 8, and 9 in the Ozama basin for all climate change projections and all the land use land cover scenarios.

			Dry and Hot Climate Zone		Median	Wet and Warm Climate Zone	
Sub-basin		Historical	cccma_cgcm3_a2_run2_2081_2100	ipsl_cm4_a2_run1_2081_2100	cnrm_cm3_a2_run1_2046_2065	mri_cgcm2_3_2a_b1_run5_2081_2100	mri_cgcm2_3_2a_b1_run5_2046_2065
7	2003	1611	369	503	1336	1774	1767
7	BAU			1051	2578	3314	
7	BMP			1032	2646	3400	
7	CONS			1103	2735	3490	
7	DEV			938	2399	3096	
7	MIX			975	2484	3209	
Sub-basin		Historical	cccma_cgcm3_a2_run2_2081_2100	ipsl_cm4_a2_run1_2081_2100	cnrm_cm3_a2_run1_2046_2065	mri_cgcm2_3_2a_b1_run5_2081_2100	mri_cgcm2_3_2a_b1_run5_2046_2065
8	2003	2944	600	854	2424	3312	3244
8	BAU			1571	4062	5315	
8	BMP			1672	4466	5851	
8	CONS			1697	4579	5980	
8	DEV			1423	3845	5066	
8	MIX			1532	4115	5411	
Sub-basin		Historical	cccma_cgcm3_a2_run2_2081_2100	ipsl_cm4_a2_run1_2081_2100	cnrm_cm3_a2_run1_2046_2065	mri_cgcm2_3_2a_b1_run5_2081_2100	mri_cgcm2_3_2a_b1_run5_2046_2065
9	2003	274	66	88	233	304	305
9	BAU			184	432	551	
9	BMP			204	494	628	
9	CONS			491	1138	1412	
9	DEV			178	422	536	
9	MIX			228	550	694	

Table 7-32. Mean annual baseflow for sub-basins 10, 11 and 12 in the Ozama basin for all climate change projections and all the land use land cover scenarios.

			Dry and Hot Climate Zone		Median	Wet and Warm Climate Zone	
Sub-basin		Historical	cccma_cgcm3_a2_run2_2081_2100	ipsl_cm4_a2_run1_2081_2100	cnrm_cm3_a2_run1_2046_2065	mri_cgcm2_3_2a_b1_run5_2081_2100	mri_cgcm2_3_2a_b1_run5_2046_2065
10	2003	818	200	263	688	909	911
10	BAU			575	1383	1769	
10	BMP			645	1602	2049	
10	CONS			1351	3204	4005	
10	DEV			555	1351	1722	
10	MIX			650	1603	2038	
Sub-basin		Historical	cccma_cgcm3_a2_run2_2081_2100	ipsl_cm4_a2_run1_2081_2100	cnrm_cm3_a2_run1_2046_2065	mri_cgcm2_3_2a_b1_run5_2081_2100	mri_cgcm2_3_2a_b1_run5_2046_2065
11	2003	1166	287	371	975	1295	1300
11	BAU			740	1773	2269	
11	BMP			809	2036	2622	
11	CONS			1703	4093	5143	
11	DEV			732	1762	2243	
11	MIX			833	2031	2580	
Sub-basin		Historical	cccma_cgcm3_a2_run2_2081_2100	ipsl_cm4_a2_run1_2081_2100	cnrm_cm3_a2_run1_2046_2065	mri_cgcm2_3_2a_b1_run5_2081_2100	mri_cgcm2_3_2a_b1_run5_2046_2065
12	2003	8877	1803	2472	7059	9855	9982
12	BAU			3950	10511	14469	
12	BMP			3892	10769	15425	
12	CONS			4914	14959	20567	
12	DEV			3826	10284	14236	
12	MIX			4028	10927	15082	

7.5 Yaque del Norte Basin

7.5.1 Water Yield

For a given land use land cover the water yield increases with increases of precipitation. For a given climate change scenario, the best management practice scenario produces the largest water yield except for few cases (e.g. Sub-basin 5 in wet and warm climate zone, sub-basin 8 and all climate zones). Sometimes the combination scenario and the 2003 land use land cover produce more water yield for the median and wet and warm climate change projections. The minimum water yield is produced by the business-as-usual scenario for most of the sub-basins.

The dry and hot climate change projection (ipsl_cm4_a2_run1_2081_2100) produces less water yield across all land use land cover scenarios than the baseline. The water yield results are included in ***Table 7-33***, ***Table 7-34***, ***Table 7-35***, and ***Table 7-36***.

7.5.2 Sediment

The sediment production results are highly variable in this basin. In general, the sediment load increases with increases in precipitation. However, there are some sub-basins where this trend does not hold for some of the land use land cover scenarios (e.g. sub-basins 4, 12).

For a given climate change scenario, the best management practice scenario produces the least amount of sediment.

There is not a single trend between the sediment load from the baseline scenario and all climate change projections. The baseline sediment load might be larger or lower than the other results depending on the sub-basin, the climate change projection, and the land use land cover scenario. The sediment results are included in ***Table 7-37***, ***Table 7-38***, ***Table 7-39***, and ***Table 7-40***.

7.5.3 Peak Flow

For a given land use land cover scenario, the peak flows are larger for the wet and warm climate change projection (mri_cgcm2_3_2a_b1_run5) than for the dry and hot climate change projection (ipsl_cm4_a2_run1_2081_2100). For all land use land cover scenarios the peak flows for the median climate change projection (cnrm_cm3_a2_run1_2046_2065) tend to be larger than for the wet and warm climate change projection.

The baseline peak flows are lower than those for the median and wet and warm climate change projections for all land use land cover scenarios. In addition, the baseline peak flows are similar in magnitude to the peak flows from the dry and hot climate change projection (ipsl_cm4_a2_run1_2081_2100).

The largest peaks are produced under the business-as-usual and development scenarios for all climate change projections. The lowest peaks are not consistently produced by one land use land cover scenario. The peak flow results are included in ***Table 7-41***, ***Table 7-42***, ***Table 7-43***, and ***Table 7-44***.

7.5.4 Baseflow

For a given land use land cover scenario, the baseflow increases with increases in precipitation. For a given climate change model the combination and the best management practice scenarios tend to produce the largest baseflows. The baseline baseflow is larger than the baseflow simulated with the dry and hot climate change projection (ipsl_cm4_a2_run1_2081_2100) for all land use land cover scenarios. The baseline baseflow is similar in magnitude to the baseflow simulated with the median and wet and warm scenarios. The baseflow results are in ***Table 7-45***, ***Table 7-46***, ***Table 7-47***, and ***Table 7-48***.

Overall, the best management practice scenario produces the largest water yield and baseflow and lowest sediment load. The lowest peaks are not consistently produced by a single land use land cover scenario.

Table 7-33. Mean annual water yield for sub-basins 1, 4, and 5 in the Yaque del Norte basin for all climate change projections and land use land cover scenarios.

			Dry and Hot Climate Zone		Median	Wet and Warm Climate Zone	
Sub-basin		Historical	cccma_cgcm3_a2_run2_2081_2100	ipsl_cm4_a2_run1_2081_2100	cnrm_cm3_a2_run1_2046_2065	mri_cgcm2_3_2a_b1_run5_2081_2100	mri_cgcm2_3_2a_b1_run5_2046_2065
1	2003	5708	1682	2455	5791	6224	6546
1	BAU			1922	4852	5083	
1	BMP			2510	6002	6428	
1	CONS			1955	4967	5234	
1	DEV			2093	5046	5290	
1	MIX			2345	5520	5831	
Sub-basin		Historical	cccma_cgcm3_a2_run2_2081_2100	ipsl_cm4_a2_run1_2081_2100	cnrm_cm3_a2_run1_2046_2065	mri_cgcm2_3_2a_b1_run5_2081_2100	mri_cgcm2_3_2a_b1_run5_2046_2065
4	2003	6139	2360	3097	5849	6359	6321
4	BAU			3057	5403	5905	
4	BMP			3280	5797	6329	
4	CONS			3077	5455	5959	
4	DEV			3113	5486	5996	
4	MIX			3264	5768	6297	
Sub-basin		Historical	cccma_cgcm3_a2_run2_2081_2100	ipsl_cm4_a2_run1_2081_2100	cnrm_cm3_a2_run1_2046_2065	mri_cgcm2_3_2a_b1_run5_2081_2100	mri_cgcm2_3_2a_b1_run5_2046_2065
5	2003	798	278	382	758	831	827
5	BAU			359	664	730	
5	BMP			392	723	794	
5	CONS			385	707	776	
5	DEV			385	701	769	
5	MIX			391	726	796	

Table 7-34. Mean annual water yield for sub-basins 8, 12, and 13 in the Yaque del Norte basin for all climate change projections and land use land cover scenarios.

			Dry and Hot Climate Zone		Median	Wet and Warm Climate Zone	
Sub-basin		Historical	cccma_cgcm3_a2_run2_2081_2100	ipsl_cm4_a2_run1_2081_2100	cnrm_cm3_a2_run1_2046_2065	mri_cgcm2_3_2a_b1_run5_2081_2100	mri_cgcm2_3_2a_b1_run5_2046_2065
8	2003	1000	361	493	977	1073	1083
8	BAU			350	754	815	
8	BMP			475	963	1054	
8	CONS			377	799	865	
8	DEV			350	755	817	
8	MIX			412	860	936	
Sub-basin		Historical	cccma_cgcm3_a2_run2_2081_2100	ipsl_cm4_a2_run1_2081_2100	cnrm_cm3_a2_run1_2046_2065	mri_cgcm2_3_2a_b1_run5_2081_2100	mri_cgcm2_3_2a_b1_run5_2046_2065
12	2003	3217	1136	1553	3174	3487	3487
12	BAU			1699	3298	3528	
12	BMP			2019	3899	4230	
12	CONS			1729	3353	3591	
12	DEV			1811	3431	3671	
12	MIX			1966	3777	4078	
Sub-basin		Historical	cccma_cgcm3_a2_run2_2081_2100	ipsl_cm4_a2_run1_2081_2100	cnrm_cm3_a2_run1_2046_2065	mri_cgcm2_3_2a_b1_run5_2081_2100	mri_cgcm2_3_2a_b1_run5_2046_2065
13	2003	232	46	72	227	256	260
13	BAU			89	219	229	
13	BMP			131	295	320	
13	CONS			102	241	254	
13	DEV			90	222	231	
13	MIX			115	267	285	

Table 7-35. Mean annual water yield for sub-basins 14, 21, and 23 in the Yaque del Norte basin for all climate change projections and land use land cover scenarios.

			Dry and Hot Climate Zone		Median	Wet and Warm Climate Zone	
Sub-basin		Historical	cccma_cgcm3_a2_run2_2081_2100	ipsl_cm4_a2_run1_2081_2100	cnrm_cm3_a2_run1_2046_2065	mri_cgcm2_3_2a_b1_run5_2081_2100	mri_cgcm2_3_2a_b1_run5_2046_2065
14	2003	214	66	91	220	243	249
14	BAU			108	247	252	
14	BMP			144	319	348	
14	CONS			112	256	262	
14	DEV			108	249	254	
14	MIX			144	315	339	
Sub-basin		Historical	cccma_cgcm3_a2_run2_2081_2100	ipsl_cm4_a2_run1_2081_2100	cnrm_cm3_a2_run1_2046_2065	mri_cgcm2_3_2a_b1_run5_2081_2100	mri_cgcm2_3_2a_b1_run5_2046_2065
21	2003	8824	4049	4929	8424	9008	8873
21	BAU			5848	9663	10382	
21	BMP			5944	9814	10543	
21	CONS			5858	9680	10399	
21	DEV			5849	9664	10383	
21	MIX			5999	9897	10634	
Sub-basin		Historical	cccma_cgcm3_a2_run2_2081_2100	ipsl_cm4_a2_run1_2081_2100	cnrm_cm3_a2_run1_2046_2065	mri_cgcm2_3_2a_b1_run5_2081_2100	mri_cgcm2_3_2a_b1_run5_2046_2065
23	2003	35	10	16	38	41	43
23	BAU			16	36	33	
23	BMP			25	55	59	
23	CONS			16	37	34	
23	DEV			16	36	33	
23	MIX			18	40	38	

Table 7-36. Mean annual water yield for sub-basins 27 and 29 in the Yaque del Norte basin for all climate change projections and land use land cover scenarios.

			Dry and Hot Climate Zone		Median	Wet and Warm Climate Zone	
Sub-basin		Historical	cccma_cgcm3_a2_run2_2081_2100	ipsl_cm4_a2_run1_2081_2100	cnrm_cm3_a2_run1_2046_2065	mri_cgcm2_3_2a_b1_run5_2081_2100	mri_cgcm2_3_2a_b1_run5_2046_2065
27	2003	10015	4515	5665	9660	10412	10264
27	BAU			6272	10528	11302	
27	BMP			6524	11060	11892	
27	CONS			6293	10568	11345	
27	DEV			6349	10612	11387	
27	MIX			6519	10980	11804	
Sub-basin		Historical	cccma_cgcm3_a2_run2_2081_2100	ipsl_cm4_a2_run1_2081_2100	cnrm_cm3_a2_run1_2046_2065	mri_cgcm2_3_2a_b1_run5_2081_2100	mri_cgcm2_3_2a_b1_run5_2046_2065
29	2003	9603	4132	5337	9189	9919	9794
29	BAU			5438	9110	9767	
29	BMP			6219	10575	11377	
29	CONS			5553	9322	10000	
29	DEV			5798	9324	9924	
29	MIX			6394	10862	11683	

Table 7-37. Mean annual sediment load in sub-basins 1, 4, 5 in the Yaque del Norte basin for all climate change projections and land use land cover scenarios.

			Dry and Hot Climate Zone		Median	Wet and Warm Climate Zone	
Sub-basin		Historical	cccma_cgcm3_a2_run2_2081_2100	ipsl_cm4_a2_run1_2081_2100	cnrm_cm3_a2_run1_2046_2065	mri_cgcm2_3_2a_b1_run5_2081_2100	mri_cgcm2_3_2a_b1_run5_2046_2065
1	2003	163456	79090	101239	243862	249643	252681
1	BAU			118088	0	0	
1	BMP			154317	100198	88776	
1	CONS			92163	9641	21969	
1	DEV			0	98093	159354	
1	MIX			316427	222822	200953	
Sub-basin		Historical	cccma_cgcm3_a2_run2_2081_2100	ipsl_cm4_a2_run1_2081_2100	cnrm_cm3_a2_run1_2046_2065	mri_cgcm2_3_2a_b1_run5_2081_2100	mri_cgcm2_3_2a_b1_run5_2046_2065
4	2003	220031	85094	192906	342081	362582	261626
4	BAU			236088	939893	803451	
4	BMP			83027	329019	279792	
4	CONS			112077	450351	382878	
4	DEV			215749	860494	735776	
4	MIX			91925	333200	284082	
Sub-basin		Historical	cccma_cgcm3_a2_run2_2081_2100	ipsl_cm4_a2_run1_2081_2100	cnrm_cm3_a2_run1_2046_2065	mri_cgcm2_3_2a_b1_run5_2081_2100	mri_cgcm2_3_2a_b1_run5_2046_2065
5	2003	17007	5668	13065	28102	27909	20734
5	BAU			15142	71889	60409	
5	BMP			6253	28866	24056	
5	CONS			7018	32974	27775	
5	DEV			11951	56540	47851	
5	MIX			6068	28423	24007	

Table 7-38. Mean annual sediment load in sub-basins 8, 12, and 13 in the Yaque del Norte basin for all climate change projections and land use land cover scenarios.

			Dry and Hot Climate Zone		Median	Wet and Warm Climate Zone	
Sub-basin		Historical	cccma_cgcm3_a2_run2_2081_2100	ipsl_cm4_a2_run1_2081_2100	cnrm_cm3_a2_run1_2046_2065	mri_cgcm2_3_2a_b1_run5_2081_2100	mri_cgcm2_3_2a_b1_run5_2046_2065
8	2003	15858	1324	2171	18319	18821	17747
8	BAU			6861	49928	52069	
8	BMP			1488	11680	11738	
8	CONS			3215	23734	24542	
8	DEV			6851	50218	51896	
8	MIX			2286	18037	18088	
Sub-basin		Historical	cccma_cgcm3_a2_run2_2081_2100	ipsl_cm4_a2_run1_2081_2100	cnrm_cm3_a2_run1_2046_2065	mri_cgcm2_3_2a_b1_run5_2081_2100	mri_cgcm2_3_2a_b1_run5_2046_2065
12	2003	7699	3495	32879	19236	35624	19049
12	BAU			42035	219230	220006	
12	BMP			4431	17698	17436	
12	CONS			19758	104773	105229	
12	DEV			187435	173950	196745	
12	MIX			13839	59948	59293	
Sub-basin		Historical	cccma_cgcm3_a2_run2_2081_2100	ipsl_cm4_a2_run1_2081_2100	cnrm_cm3_a2_run1_2046_2065	mri_cgcm2_3_2a_b1_run5_2081_2100	mri_cgcm2_3_2a_b1_run5_2046_2065
13	2003	464	87	1062	1393	1555	554
13	BAU			1442	12452	12655	
13	BMP			303	1916	1990	
13	CONS			701	5664	5651	
13	DEV			1386	11875	12082	
13	MIX			507	3740	3779	

Table 7-39. Mean annual sediment load in sub-basins 14, 21, and 23 in the Yaque del Norte basin for all climate change projections and land use land cover scenarios.

			Dry and Hot Climate Zone		Median	Wet and Warm Climate Zone	
Sub-basin		Historical	cccma_cgcm3_a2_run2_2081_2100	ipsl_cm4_a2_run1_2081_2100	cnrm_cm3_a2_run1_2046_2065	mri_cgcm2_3_2a_b1_run5_2081_2100	mri_cgcm2_3_2a_b1_run5_2046_2065
14	2003	419	108	0	881	0	498
14	BAU			2680	19758	24760	
14	BMP			285	1185	1462	
14	CONS			1317	9208	11392	
14	DEV			2679	19725	24780	
14	MIX			616	3773	4727	
Sub-basin		Historical	cccma_cgcm3_a2_run2_2081_2100	ipsl_cm4_a2_run1_2081_2100	cnrm_cm3_a2_run1_2046_2065	mri_cgcm2_3_2a_b1_run5_2081_2100	mri_cgcm2_3_2a_b1_run5_2046_2065
21	2003	24091	16190	215279	52533	187272	51980
21	BAU			19743	67263	66147	
21	BMP			4740	11197	11489	
21	CONS			10170	32356	31971	
21	DEV			19484	66362	65159	
21	MIX			5035	13154	13356	
Sub-basin		Historical	cccma_cgcm3_a2_run2_2081_2100	ipsl_cm4_a2_run1_2081_2100	cnrm_cm3_a2_run1_2046_2065	mri_cgcm2_3_2a_b1_run5_2081_2100	mri_cgcm2_3_2a_b1_run5_2046_2065
23	2003	134	0	0	0	0	73
23	BAU			1159	4516	6073	
23	BMP			160	455	531	
23	CONS			333	2034	2702	
23	DEV			1015	4465	6032	
23	MIX			1053	2705	3041	

Table 7-40. Mean annual sediment load in sub-basins 27 and 29 in the Yaque del Norte basin for all climate change projections and land use land cover scenarios.

			Dry and Hot Climate Zone		Median	Wet and Warm Climate Zone	
Sub-basin		Historical	cccma_cgcm3_a2_run2_2081_2100	ipsl_cm4_a2_run1_2081_2100	cnrm_cm3_a2_run1_2046_2065	mri_cgcm2_3_2a_b1_run5_2081_2100	mri_cgcm2_3_2a_b1_run5_2046_2065
27	2003	78373	45033	246958	171078	286163	144030
27	BAU			180443	667843	668831	
27	BMP			9559	27407	27583	
27	CONS			85747	316874	316669	
27	DEV			314266	611116	627583	
27	MIX			44592	162822	163416	
Sub-basin		Historical	cccma_cgcm3_a2_run2_2081_2100	ipsl_cm4_a2_run1_2081_2100	cnrm_cm3_a2_run1_2046_2065	mri_cgcm2_3_2a_b1_run5_2081_2100	mri_cgcm2_3_2a_b1_run5_2046_2065
29	2003	381598	180050	408551	436746	595408	421922
29	BAU			749777	2411033	2455913	
29	BMP			143658	451080	461898	
29	CONS			341539	1102013	1121143	
29	DEV			2536989	644114	908364	
29	MIX			104346	335659	342796	

Table 7-41. Annual peak flow for sub-basins 1, 4, and 5 in the Yaque del Norte basin for all climate change projections and land use land cover scenarios.

			Dry and Hot Climate Zone		Median	Wet and Warm Climate Zone	
Sub-basin		Historical	cccma_cgcm3_a2_run2_2081_2100	ipsl_cm4_a2_run1_2081_2100	cnrm_cm3_a2_run1_2046_2065	mri_cgcm2_3_2a_b1_run5_2081_2100	mri_cgcm2_3_2a_b1_run5_2046_2065
1	2003	2750	1057	1758	864	848	2625
1	BAU			831	4538	4058	
1	BMP			2059	3438	3232	
1	CONS			2456	4370	3928	
1	DEV			2826	4751	4304	
1	MIX			2135	3719	3438	
Sub-basin		Historical	cccma_cgcm3_a2_run2_2081_2100	ipsl_cm4_a2_run1_2081_2100	cnrm_cm3_a2_run1_2046_2065	mri_cgcm2_3_2a_b1_run5_2081_2100	mri_cgcm2_3_2a_b1_run5_2046_2065
4	2003	378	179	258	546	474	261
4	BAU			386	755	623	
4	BMP			330	648	547	
4	CONS			381	743	615	
4	DEV			394	754	624	
4	MIX			336	669	560	
Sub-basin		Historical	cccma_cgcm3_a2_run2_2081_2100	ipsl_cm4_a2_run1_2081_2100	cnrm_cm3_a2_run1_2046_2065	mri_cgcm2_3_2a_b1_run5_2081_2100	mri_cgcm2_3_2a_b1_run5_2046_2065
5	2003	47	20	30	74	59	31
5	BAU			51	112	88	
5	BMP			44	96	77	
5	CONS			49	103	82	
5	DEV			57	116	91	
5	MIX			43	97	77	

Table 7-42. Annual peak flow for sub-basins 1, 4, and 5 in the Yaque del Norte basin for all climate change projections and land use land cover scenarios.

			Dry and Hot Climate Zone		Median	Wet and Warm Climate Zone	
Sub-basin		Historical	cccma_cgcm3_a2_run2_2081_2100	ipsl_cm4_a2_run1_2081_2100	cnrm_cm3_a2_run1_2046_2065	mri_cgcm2_3_2a_b1_run5_2081_2100	mri_cgcm2_3_2a_b1_run5_2046_2065
8	2003	44	15	10	69	64	37
8	BAU			43	151	118	
8	BMP			28	81	71	
8	CONS			40	141	112	
8	DEV			43	151	118	
8	MIX			36	119	99	
Sub-basin		Historical	cccma_cgcm3_a2_run2_2081_2100	ipsl_cm4_a2_run1_2081_2100	cnrm_cm3_a2_run1_2046_2065	mri_cgcm2_3_2a_b1_run5_2081_2100	mri_cgcm2_3_2a_b1_run5_2046_2065
12	2003	116	45	47	181	166	86
12	BAU			170	402	361	
12	BMP			114	215	215	
12	CONS			164	390	351	
12	DEV			200	401	369	
12	MIX			137	294	275	
Sub-basin		Historical	cccma_cgcm3_a2_run2_2081_2100	ipsl_cm4_a2_run1_2081_2100	cnrm_cm3_a2_run1_2046_2065	mri_cgcm2_3_2a_b1_run5_2081_2100	mri_cgcm2_3_2a_b1_run5_2046_2065
13	2003	2	1	2	3	5	2
13	BAU			9	33	32	
13	BMP			6	14	15	
13	CONS			8	29	28	
13	DEV			8	32	31	
13	MIX			7	22	21	

Table 7-43. Annual peak flow for sub-basins 1, 4, and 5 in the Yaque del Norte basin for all climate change projections and land use land cover scenarios.

			Dry and Hot Climate Zone		Median	Wet and Warm Climate Zone	
Sub-basin		Historical	cccma_cgcm3_a2_run2_2081_2100	ipsl_cm4_a2_run1_2081_2100	cnrm_cm3_a2_run1_2046_2065	mri_cgcm2_3_2a_b1_run5_2081_2100	mri_cgcm2_3_2a_b1_run5_2046_2065
14	2003	294	158	232	428	734	207
14	BAU			296	447	433	
14	BMP			277	400	396	
14	CONS			294	443	429	
14	DEV			296	447	433	
14	MIX			266	390	386	
Sub-basin		Historical	cccma_cgcm3_a2_run2_2081_2100	ipsl_cm4_a2_run1_2081_2100	cnrm_cm3_a2_run1_2046_2065	mri_cgcm2_3_2a_b1_run5_2081_2100	mri_cgcm2_3_2a_b1_run5_2046_2065
21	2003	288	156	227	418	727	202
21	BAU			284	418	406	
21	BMP			269	388	383	
21	CONS			283	415	403	
21	DEV			284	418	406	
21	MIX			257	372	369	
Sub-basin		Historical	cccma_cgcm3_a2_run2_2081_2100	ipsl_cm4_a2_run1_2081_2100	cnrm_cm3_a2_run1_2046_2065	mri_cgcm2_3_2a_b1_run5_2081_2100	mri_cgcm2_3_2a_b1_run5_2046_2065
23	2003	462	229	311	651	558	330
23	BAU			501	788	730	
23	BMP			424	639	608	
23	CONS			496	780	723	
23	DEV			521	799	741	
23	MIX			440	690	647	

Table 7-44. Annual peak flow for sub-basins 1, 4, and 5 in the Yaque del Norte basin for all climate change projections and land use land cover scenarios.

			Dry and Hot Climate Zone		Median	Wet and Warm Climate Zone	
Sub-basin		Historical	cccma_cgcm3_a2_run2_2081_2100	ipsl_cm4_a2_run1_2081_2100	cnrm_cm3_a2_run1_2046_2065	mri_cgcm2_3_2a_b1_run5_2081_2100	mri_cgcm2_3_2a_b1_run5_2046_2065
27	2003	460	229	310	650	555	328
27	BAU			497	779	721	
27	BMP			422	636	605	
27	CONS			493	771	715	
27	DEV			517	790	732	
27	MIX			437	682	640	
Sub-basin		Historical	cccma_cgcm3_a2_run2_2081_2100	ipsl_cm4_a2_run1_2081_2100	cnrm_cm3_a2_run1_2046_2065	mri_cgcm2_3_2a_b1_run5_2081_2100	mri_cgcm2_3_2a_b1_run5_2046_2065
29	2003	521	276	365	726	640	353
29	BAU			664	988	723	
29	BMP			455	686	661	
29	CONS			630	942	860	
29	DEV			840	1152	1071	
29	MIX			410	629	611	

Table 7-45. Mean annual baseflow for sub-basins 1, 4, and 5 in the Yaque del Norte basin for all climate change projections and land use land cover scenarios.

			Dry and Hot Climate Zone		Median	Wet and Warm Climate Zone	
Sub-basin		Historical	cccma_cgcm3_a2_run2_2081_2100	ipsl_cm4_a2_run1_2081_2100	cnrm_cm3_a2_run1_2046_2065	mri_cgcm2_3_2a_b1_run5_2081_2100	mri_cgcm2_3_2a_b1_run5_2046_2065
1	2003	25872	6409	9757	21604	25209	25922
1	BAU			8886	17832	21278	
1	BMP			10430	22820	26664	
1	CONS			9066	18549	22181	
1	DEV			9265	18511	22196	
1	MIX			10608	22618	27097	
Sub-basin		Historical	cccma_cgcm3_a2_run2_2081_2100	ipsl_cm4_a2_run1_2081_2100	cnrm_cm3_a2_run1_2046_2065	mri_cgcm2_3_2a_b1_run5_2081_2100	mri_cgcm2_3_2a_b1_run5_2046_2065
4	2003	5312	1921	2602	4909	5477	5452
4	BAU			2423	3847	4513	
4	BMP			2698	4448	5112	
4	CONS			2472	3956	4624	
4	DEV			2473	3945	4614	
4	MIX			2656	4365	5030	
Sub-basin		Historical	cccma_cgcm3_a2_run2_2081_2100	ipsl_cm4_a2_run1_2081_2100	cnrm_cm3_a2_run1_2046_2065	mri_cgcm2_3_2a_b1_run5_2081_2100	mri_cgcm2_3_2a_b1_run5_2046_2065
5	2003	688	230	323	635	713	712
5	BAU			288	463	555	
5	BMP			323	542	634	
5	CONS			314	516	608	
5	DEV			307	499	591	
5	MIX			323	545	637	

Table 7-46. Mean annual baseflow for sub-basins 8, 12, and 13 in the Yaque del Norte basin for all climate change projections and land use land cover scenarios.

			Dry and Hot Climate Zone		Median	Wet and Warm Climate Zone	
Sub-basin		Historical	cccma_cgcm3_a2_run2_2081_2100	ipsl_cm4_a2_run1_2081_2100	cnrm_cm3_a2_run1_2046_2065	mri_cgcm2_3_2a_b1_run5_2081_2100	mri_cgcm2_3_2a_b1_run5_2046_2065
8	2003	880	292	415	844	947	957
8	BAU			271	571	657	
8	BMP			396	823	924	
8	CONS			298	621	711	
8	DEV			272	572	658	
8	MIX			333	697	790	
Sub-basin		Historical	cccma_cgcm3_a2_run2_2081_2100	ipsl_cm4_a2_run1_2081_2100	cnrm_cm3_a2_run1_2046_2065	mri_cgcm2_3_2a_b1_run5_2081_2100	mri_cgcm2_3_2a_b1_run5_2046_2065
12	2003	2547	701	1075	2474	2764	2787
12	BAU			1159	2305	2546	
12	BMP			1499	3107	3416	
12	CONS			1196	2382	2628	
12	DEV			1136	2251	2485	
12	MIX			1427	2877	3171	
Sub-basin		Historical	cccma_cgcm3_a2_run2_2081_2100	ipsl_cm4_a2_run1_2081_2100	cnrm_cm3_a2_run1_2046_2065	mri_cgcm2_3_2a_b1_run5_2081_2100	mri_cgcm2_3_2a_b1_run5_2046_2065
13	2003	212	32	56	204	233	238
13	BAU			71	182	192	
13	BMP			112	268	291	
13	CONS			85	206	220	
13	DEV			72	185	196	
13	MIX			97	235	253	

Table 7-47. Mean annual baseflow for sub-basins 14, 21, and 23 in the Yaque del Norte basin for all climate change projections and land use land cover scenarios.

			Dry and Hot Climate Zone		Median	Wet and Warm Climate Zone	
Sub-basin		Historical	cccma_cgcm3_a2_run2_2081_2100	ipsl_cm4_a2_run1_2081_2100	cnrm_cm3_a2_run1_2046_2065	mri_cgcm2_3_2a_b1_run5_2081_2100	mri_cgcm2_3_2a_b1_run5_2046_2065
14	2003	7026	2864	3658	6595	7125	7049
14	BAU			4461	7636	8268	
14	BMP			4601	7915	8573	
14	CONS			4476	7665	8300	
14	DEV			4462	7639	8271	
14	MIX			4664	8015	8670	
Sub-basin		Historical	cccma_cgcm3_a2_run2_2081_2100	ipsl_cm4_a2_run1_2081_2100	cnrm_cm3_a2_run1_2046_2065	mri_cgcm2_3_2a_b1_run5_2081_2100	mri_cgcm2_3_2a_b1_run5_2046_2065
21	2003	6869	2843	3614	6435	6944	6860
21	BAU			4403	7467	8095	
21	BMP			4506	7661	8292	
21	CONS			4414	7488	8117	
21	DEV			4403	7469	8098	
21	MIX			4570	7770	8404	
Sub-basin		Historical	cccma_cgcm3_a2_run2_2081_2100	ipsl_cm4_a2_run1_2081_2100	cnrm_cm3_a2_run1_2046_2065	mri_cgcm2_3_2a_b1_run5_2081_2100	mri_cgcm2_3_2a_b1_run5_2046_2065
23	2003	7459	2948	3964	7053	7737	7640
23	BAU			4340	7316	8015	
23	BMP			4662	8195	8946	
23	CONS			4365	7378	8079	
23	DEV			4311	7267	7953	
23	MIX			4625	7970	8705	

Table 7-48. Mean annual baseflow for sub-basins 27 and 29 in the Yaque del Norte basin for all climate change projections and land use land cover scenarios.

			Dry and Hot Climate Zone		Median	Wet and Warm Climate Zone	
Sub-basin		Historical	cccma_cgcm3_a2_run2_2081_2100	ipsl_cm4_a2_run1_2081_2100	cnrm_cm3_a2_run1_2046_2065	mri_cgcm2_3_2a_b1_run5_2081_2100	mri_cgcm2_3_2a_b1_run5_2046_2065
27	2003	7439	2952	3963	7030	7711	7613
27	BAU			4341	7307	8008	
27	BMP			4651	8157	8903	
27	CONS			4365	7364	8067	
27	DEV			4312	7258	7946	
27	MIX			4624	7956	8692	
Sub-basin		Historical	cccma_cgcm3_a2_run2_2081_2100	ipsl_cm4_a2_run1_2081_2100	cnrm_cm3_a2_run1_2046_2065	mri_cgcm2_3_2a_b1_run5_2081_2100	mri_cgcm2_3_2a_b1_run5_2046_2065
29	2003	7408	2853	3940	6926	7631	7554
29	BAU			3634	5541	6135	
29	BMP			4626	7865	8599	
29	CONS			3805	5903	6520	
29	DEV			2626	4168	4586	
29	MIX			4832	8262	9006	

7.6 Seasonal Results

The analysis of the historical climate data shows two precipitation seasons in the Haina, Nizao, Ozama and Yaque del Norte basins (***Figure 3-4***). The wet season is from about April through November with high precipitation in May and September-October and the dry season from about December through March. The daily water yield and sediment load time series output from the SWAT models were accumulated for these two seasons for each land use land cover scenario and climate change projection run.

Riverside developed four spreadsheets with the seasonal results. These spreadsheets create dynamic plots of sediment load and water yield. The users can select the following information to create the plots: reach number, land use land cover scenario and climate change projection. ***Figure 7-6*** shows an example of the sediment load in reach 3 of the Haina basin for all land use land cover scenarios, three climate change projections and both seasons, the dry season in blue and the wet season in red. This plot shows that more sediment is produced during the dry season than during the wet season in this sub-basin. The opposite results are obtained in sub-basin 1 (***Figure 7-7***) for most of the climate change models and land use land cover scenarios.

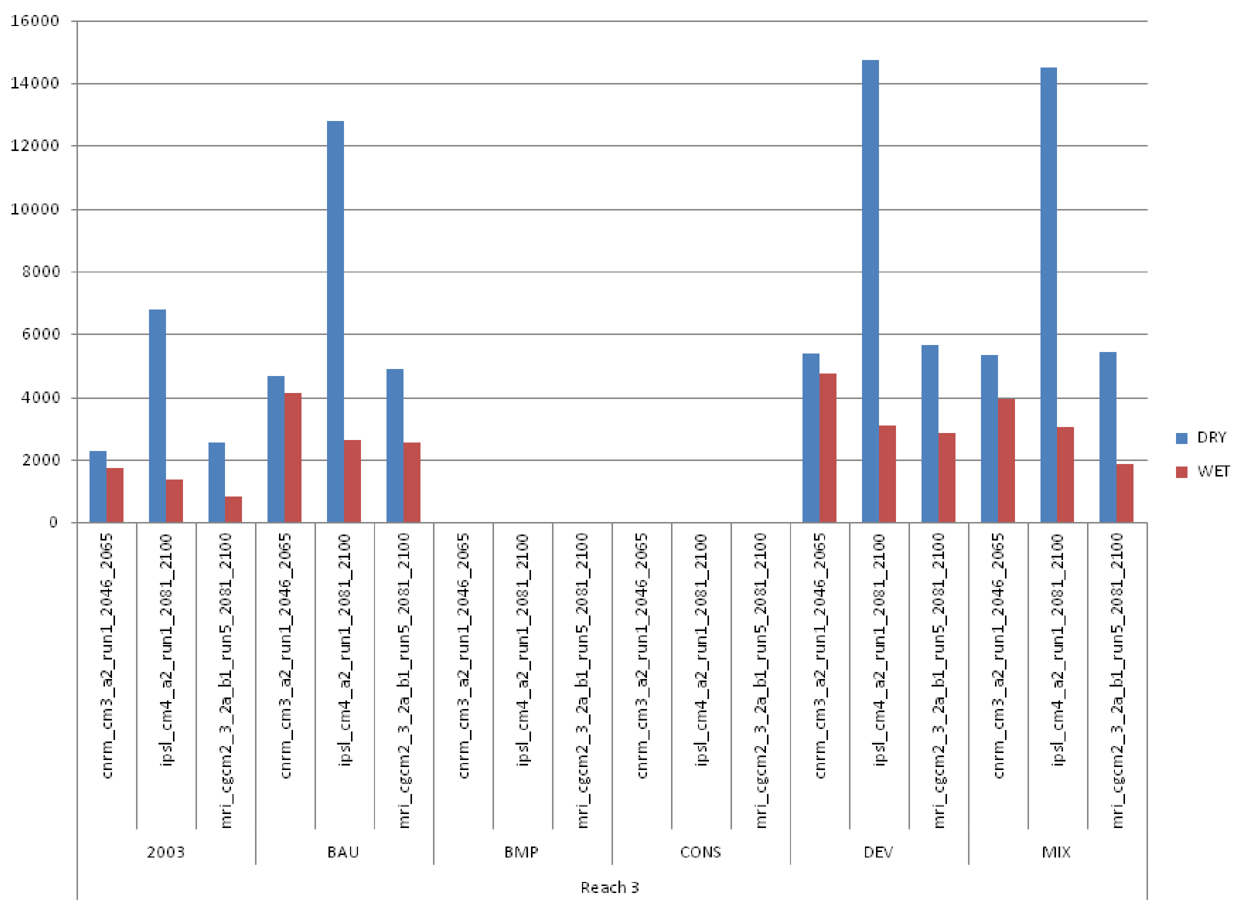

Figure 7-6. Seasonal variation of sediment load in reach 3 of the Haina basin for the dry and wet seasons.

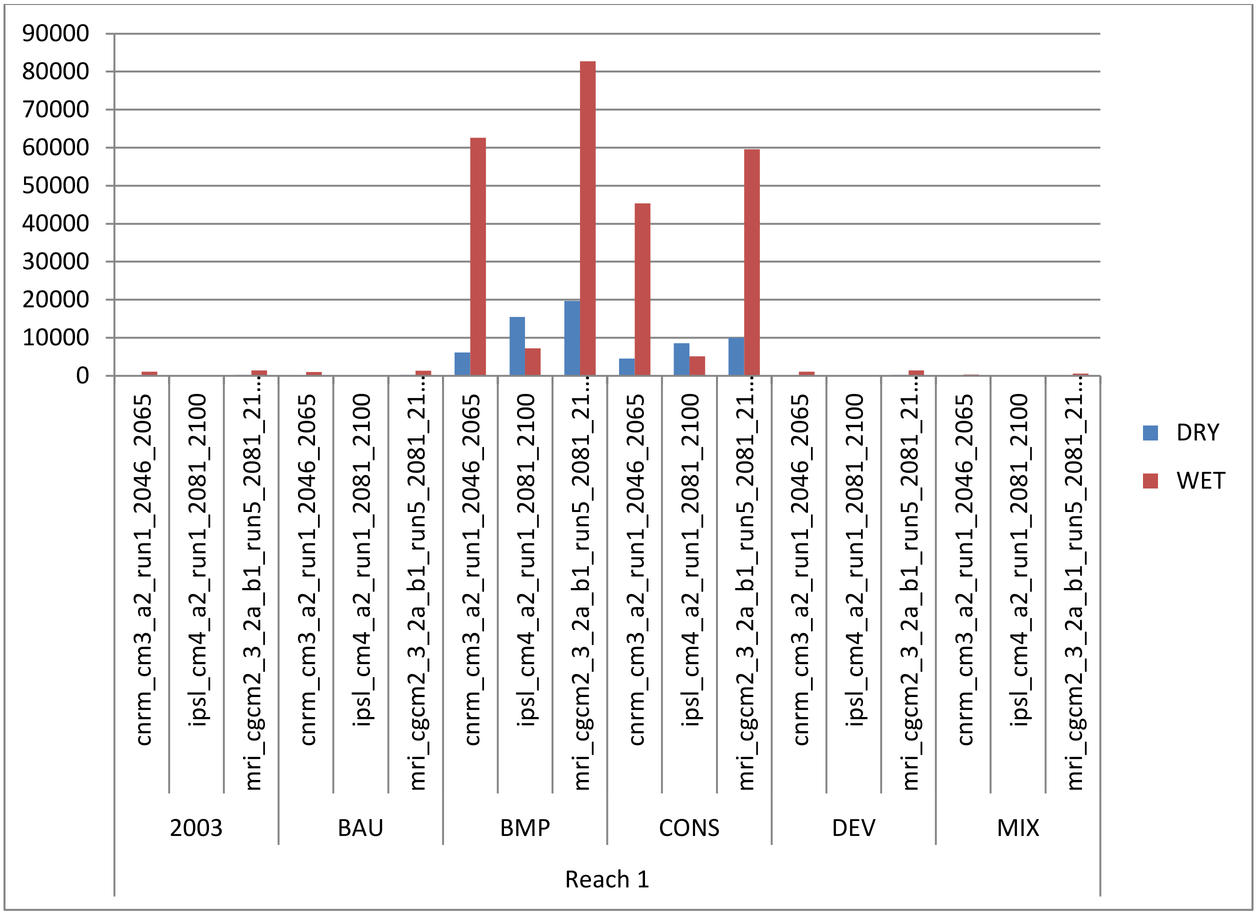

Figure 7-7. Seasonal variation of sediment load in reach 1 of the Haina basin for the dry and wet seasons.

The seasonal analysis of the climate change projections shows that all projections do not follow the same seasonal pattern. Some of them have increased precipitation amounts from November through March while others predict increased precipitation almost year round. A very interesting result is that the climate change projection for the dry and hot climate zone (ipsl_cm4_a2_run1_2081_2100) always produces more sediment for the dry season while the other two projections produce similar results.

The relationship between the occurrence of the events, the moisture condition of the basins and the stage of the crops will affect the hydrologic and sediment respond of the basins. Sub-basins 1 and 3 have different predominant land uses. Sub-basin 1 has more crops and less forest than sub-basin 3. Therefore, more sediment can be generated from the crop lands in sub-basin 1 when the occurrence of the largest flow peaks coincides with the end of the crop seasons.

The following worksheets are included in the spreadsheets with the seasonal results:

Sediment_Chart: contains the dynamic graph with the seasonal sediment load data
Water_Yield_Chart: contains the dynamic graph with the seasonal water yield data
Sediment_Pivot_Table: contains the data filtered in the sediment graph.
Water_Yield_Pivot_Table: contains the data filtered in the water yield graph.
Sediment_Data: contains all sediment data. This worksheet is protected and cannot be edited.
Water_Yield_Data: contains all water yield data. This worksheet is protected and cannot be edited.

To change the plots, select the plot, go to the Analyze tab and bring up the PivotChart Filter (***Figure 7-8***). This filter contains three drop down menus. Select under these menus the results for which the user

wants to generate a plot. LULC contains a list of all land use land cover scenarios modeled. The Reach menu contains a list of the reaches and the Climate Model menu contains the list of the climate change projections.

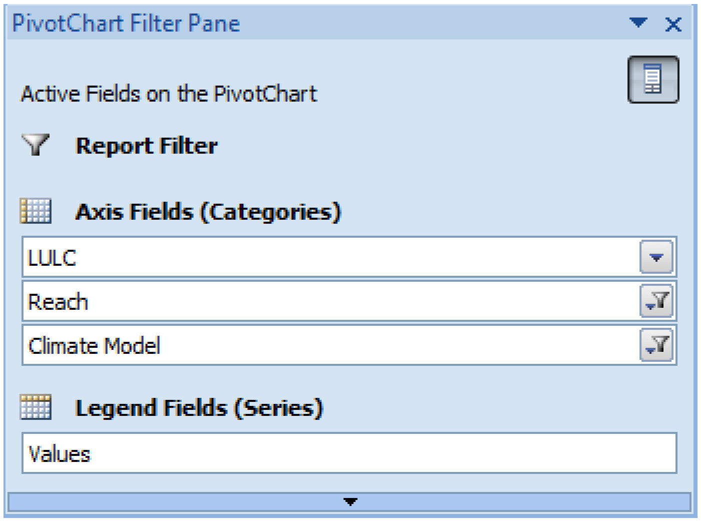

Figure 7-8. PivotChart Filter use to select the seasonal water yield and sediment data

8.0 Conclusions and Recommendations

The modeling exercise carried out in this project demonstrates the complex processes involved in the hydrologic response of basins to changes in climate and land use land cover types. How much water and sediment is produced in a given basin is not a linear function of inputs. Each basin has particular storage characteristics that will depend on the soil drainage properties and the land cover type. The sequence and frequency of rainfall events as well as the seasonal variation also impact the hydrologic response.

The climate change projections do not all display a consistent seasonal pattern as the historical baseline. The timing of the occurrence of the precipitation events in relation to the moisture conditions of the basins and the stage of the crop growth determines the amount of sediment and water produced by the basins.

The land use land cover scenarios that produce more water and less sediment are considered the best scenarios to adapt to future climates. For the Haina basin, the conservation scenario produces the lowest water yield and baseflow. Both, the conservation and the best management practice scenarios tend to produce the least amount of sediment.

For the Nizao basin, the combination scenario produces more water yield and peak flows. The conservation scenario produces less sediment.

For the Ozama basin, the conservation scenario is more favorable with respect to reduction in sediment load, peak flows, and increases in water yield and baseflow under future climates.

For the Yaque del Norte basin, the best management scenario tends to produce more water yield and baseflow and less sediment for most of the sub-basins.

The results of this study provide guidance to plan for future climate and land use changes. Decision makers could interpret the results on a sub-basin level to assess local problems in each basin.

The results of this study were somewhat limited by the availability of some data. In particular,

- The precipitation data do not correlate well with the streamflow data. The precipitation station network in the basins is sparse and does not capture well the spatial variability of rainfall over the basins.
- There is a lack of irrigation and regulation data within the basins. This study could be extended by including models for irrigation diversions, return flows, and reservoir regulation. Regulation modeling will allow water users to assess the impact of land use and climate change on water availability at a specific time and point in the watershed.
- There is a lack of soil data. It is recommended that additional the soil data be collected in these basins to improve the estimation of parameters required by SWAT.

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Appendix A – List of Precipitation Stations and Results from the Quality Control Task

List of Precipitation Stations

NOMBRE	SIGLAS	CODIGO	AGENCY	LON	LAT	ELEV (M)	START_POR	END_POR
Aerop. Las Américas	ALA	78485	ONAMET	-69.67	18.45	10	1/1/1960	7/31/2012
Altamira	ALT	24546	ONAMET	-70.86	19.66	422	6/1/1950	7/31/2012
Aerop. La Unión	ALU	78457	ONAMET	-70.50	19.76	89	5/1/1977	12/31/2011
Azua	AZU	21595	ONAMET	-70.72	18.42	34	1/1/1931	7/31/2012
Baní	BAN	21436	ONAMET	-70.36	18.31	118	1/1/1936	7/31/2012
Bayaguana	BAY	78473	ONAMET	-69.60	18.73	52	8/1/1938	7/31/2012
Bonao	BON	23499	ONAMET	-70.44	18.97	199	1/1/1939	7/31/2012
Cevicos	CEV	23309	ONAMET	-69.97	19.02	108	9/1/1938	4/30/2002
Constanza	CON	22584	ONAMET	-70.75	18.86	1723	1/1/1931	7/31/2012
Cotuí	COT	23423	ONAMET	-70.14	19.04	76	1/1/1938	7/31/2012
Dajabon	DAJ	24714	ONAMET	-71.72	19.59	28	1/1/1945	12/31/2003
El Seibo	ESE	22251	ONAMET	-69.05	18.78	99	4/1/1945	7/31/2012
Aerop. de Herrera	HER	78484	ONAMET	-69.99	18.47	46	8/8/1983	2/21/2006
Hato Mayor	HMA	22255	ONAMET	-69.24	18.74	87	7/1/1934	7/31/2012
Imbert	IMB	24557	ONAMET	-70.86	19.73	188	1/1/1939	12/31/2003
Jarabacoa	JAR	23523	ONAMET	-70.67	19.12	581	1/1/1931	7/31/2012
La Vega	LAV	23551	ONAMET	-70.55	19.26	133	9/1/1924	7/31/2012
Los Llanos	LLL	22239	ONAMET	-69.51	18.63	40	4/1/1940	7/31/2012
Las Matas de Farfán	LMF	22759	ONAMET	-71.53	18.82	522	1/1/1948	7/31/2012
Luper≤n	LUP	24589	ONAMET	-70.96	19.88	16	5/1/1950	7/31/2012
La Victoria	LVI	22346	ONAMET	-69.90	18.64	23	7/1/1938	7/31/2012
Mao	MAO	24622	ONAMET	-71.07	19.50	125	5/1/1939	7/31/2012
Monte Cristi	MCR	78451	ONAMET	-71.66	19.85	17	4/1/1933	7/31/2012
Moca	MOC	23591	ONAMET	-70.54	19.41	189	1/1/1931	7/31/2012
Monci≤n	MON	23693	ONAMET	-71.16	19.40	350	1/1/1931	7/31/2012
Monte Plata	MPL	22365	ONAMET	-69.79	18.80	47	7/1/1938	7/31/2012
Peralta	PER		ONAMET	-70.79	18.59	699	1/1/1939	12/31/2008
Padre las Casas	PLC	22559	ONAMET	-70.97	18.75	529	10/1/1938	7/31/2012
Pepillo Salcedo	PPS	24745	ONAMET	-71.74	19.69	8	8/1/1958	3/31/1992
Rancho Arriba	RAN	22449	ONAMET	-70.49	18.74	1009	3/1/1939	7/31/2012
Restauraci≤n	RES	23773	ONAMET	-71.67	19.29	630	1/1/1939	9/30/1998
Salcedo	SAL	23489	ONAMET	-70.41	19.39	204	1/1/1931	7/31/2012
San Cristobal	SCR		ONAMET	-70.13	18.40	91	8/1/1934	7/31/2012
Sabana de la Mar	SDM	78467	ONAMET	-69.39	19.05	7	1/1/1939	7/31/2012
San José de las Matas	SJM	23579	ONAMET	-71.02	19.32	599	1/1/1931	12/31/1997
San José de Ocoa	SJO	22510	ONAMET	-70.52	18.53	457	1/1/1931	7/31/2012
San Juan	SJU	78470	ONAMET	-71.21	18.80	411	1/1/1931	7/31/2012
Santiago	SNT	78460	ONAMET	-70.78	19.47	159	1/1/1931	7/31/2012
Santiago Rodriguez	SRO	24608	ONAMET	-71.36	19.47	128	3/1/1938	7/31/2012
Santo Domingo (Central)	STD	78486	ONAMET	-69.84	18.48	29	1/1/1931	7/31/2012
Villa Altagracia	VIA	22443	ONAMET	-70.26	18.69	425	8/1/1938	7/31/2012
Villa Vasquez	VIV	24659	ONAMET	-71.41	19.77	102	1/1/1939	7/31/2012
Yamasá	YAM	22460	ONAMET	-70.01	18.76	97	7/1/1938	7/31/2012

NOMBRE	SIGLAS	CODIGO	AGENCY	LON	LAT	ELEV (M)	START_POR	END_POR
Yásica	YAS	24533	ONAMET	-70.66	19.64	397	11/1/1948	7/31/2012
Don Miguel	010001	010001	INDRHI	-71.68	19.50	84	10/1/1965	12/31/1988
Manabao	040001	040001	INDRHI	-70.79	19.08	943	11/16/1983	6/30/2006
Puente San Rafael	040008	040008	INDRHI	-71.06	19.59	59	10/1/1968	6/30/1974
Boma	040017	040017	INDRHI	-70.67	19.17	521	6/1/1974	7/31/1979
Los Quemados	180001	180001	INDRHI	-70.46	18.89	282	6/1/1960	6/30/2006
Tireo	183102	183102	INDRHI	-70.57	18.88	928	4/1/1981	8/31/2006
Maimon	184001	184001	INDRHI	-70.29	18.90	130	3/1/1960	8/31/1970
Abadesa II	187002	187002	INDRHI	-69.93	19.02	100	3/1/1960	8/31/1998
Excavacion	311001	311001	INDRHI	-69.41	18.63	38	8/1/1972	11/30/2002
El Cerro	331101	331101	INDRHI	-69.77	18.78	39	3/18/1960	6/30/1988
Palmarejo	333001	333001	INDRHI	-69.99	18.55	19	10/1/1972	6/30/1982
Higuero	333101	333101	INDRHI	-69.99	18.57	22	4/1/1960	8/31/2006
El Tablazo	360001	360001	INDRHI	-70.17	18.48	175	8/1/1960	10/9/1970
La Estrechura	380001	380001	INDRHI	-70.48	18.73	891	3/1/1968	2/28/1973
Palo de Caja	380002	380002	INDRHI	-70.38	18.55	557	5/1/1974	11/30/1999
Paso Del Ermita±o	380003	380003	INDRHI	-70.27	18.43	351	4/1/1968	11/11/1975
El Recodo	400001	400001	INDRHI	-70.34	18.37	331	11/16/1979	8/31/2006
El Chorro	491301	491301	INDRHI	-70.76	18.90	1157	11/16/1983	6/30/2006
Guazumal	493002	493002	INDRHI	-71.26	18.91	494	7/1/1970	8/31/1982
Jaquime	493904	493904	INDRHI	-71.30	19.04	870	8/16/1982	2/28/1998
Pozo Hondo	543101	543101	INDRHI	-71.49	18.99	635	4/1/1972	3/31/2006

Flagged Precipitation Values and Actions Taken

Group	Flags	Date Start	Date End	MM	Notes
1	RES	9/28/1961		175	RES is at a higher elevation than all other stations in the group. Precipitation amounts above 160 mm and 200 mm have been reported in other stations at other times. Do not set to missing
1	RES	11/29/1961		235	RES is at a higher elevation than all other stations in the group. Precipitation amounts above 160 mm and 200 mm have been reported in other stations at other times. Do not set to missing
1	MCR	11/15/1963		194	Set to missing
2	LUP	5/16/1982		320	Set to missing.
3	SJM	4/12/1993		250	This is the largest precipitation amount in the group for all years. However, this station is at a high elevation (600 m). 250 mm is not unreasonable in DR. Do not set to missing
4	SAL	8/25/1988		225	Set to missing.
5	JAR	6/18/1987		105	Do not set to missing. Even though the rain was much lower at other stations the JAR is at a higher elevation.
5	JAR	6/20/1987		100	Do not set to missing. Even though the rain was much lower at other stations the JAR is at a higher elevation.
6,7	SJU	4/11/1958		210	Set to missing
6,7	SJU	7/12/2011		180	Only rainfall at SJU and PLC. It rained at PLC (a lower amount than in SJU). However, similar values have been reported in SJU at other times. Do not set to missing.
6	493904	5/9/1987		240	Only compared to SJU. However, it is the largest amount for the entire por for all stations. Set to missing
7	CON	2/5/1956		200	CON is at a very high elevation and at 15 and 30 miles from the other stations. Do not set to missing
7	PLC	6/18/1980		90	Set to missing
9	SDM	3/27/1956	3/28/1956	290	Set to missing
9	SDM	5/3/1965		275	Set to missing
9	CEV	1/17/2000		130	Set to missing
11	MPL	3/18/1983		315	Set to missing
11	331101	3/22/1987		375	Set to missing
14	VIA	1/25/1950		255	Set to missing
14	VIA	3/14/1983		220	Set to missing
14	VIA	11/12/1994	11/15/1994	240	Set to missing
14	RAN	10/28/2007	10/31/2007	170	tropical storm Noel. Do not set to missing
15	DAJ	6/16/1991		287.5	Compared with surrounding stations PPS, RES, MCR, VIV and SRO which showed no significant precip. Set to missing
8	BON	1997	1998		Recorded 0's for monthly values set to missing
9	COT	Dec All years		0	Every month of December recorded as 0 precipitation set to missing
1,3	SRO	Sept and Oct 1980		0	Recorded 0's that do not correspond with surrounding stations...setting to missing
1,3	SRO	March, April, August 1981		0	Recorded 0's that do not correspond with surrounding stations...setting to missing
3	MON	Jun-82		0	Recorded 0's that do not correspond with surrounding stations...setting to missing
4	SAL	Jan-81		0	Recorded 0's that do not correspond with surrounding stations after missing period...setting to missing
5	040001	Nov, Dec 1989		0	Recorded 0's set to missing
6	543101	Aug-91	Sep-94		Values significantly lower than surrounding stations...set to missing

Precipitation stations removed from the MAP analysis

NOMBRE	SIGLAS	CODIGO	AGENCY	LON	LAT	ELEV (M)	START_POR	END_POR	Reason to be removed from analysys
Hato Viejo	041001	041001	INDRHI	-70.63	19.13	535	1/10/2001	7/31/2006	POR not during MAP development
Pinalito	042101	042101	INDRHI	-70.78	19.30	344	6/1/1967	3/31/2003	High biases, Poor Monthly averages
Ranchito	185002	185002	INDRHI	-70.41	19.19	58	7/1/1970	7/31/2006	Ranchito (Macasia), Poor correlation and Monthly averages
Don Juan	330001	330001	INDRHI	-69.95	18.82	48	3/22/1960	8/31/1970	Poor Monthly Charcts
Cacique	331001	331001	INDRHI	-69.86	18.81	48	3/1/1960	8/31/2006	Poor Monthly Charcts
Sabaneta	493001	493001	INDRHI	-71.29	18.98	596	5/1/1967	5/31/1976	Poor Monthly Charcts
Pinar Quemado		040002	INDRHI	-70.67	19.09		11/1/1968	9/30/1972	Less than 5 years of data
Las Charcas		040004	INDRHI	-70.71	19.41		9/1/1967	8/31/1970	Less than 5 years of data
Palo Verde		040010	INDRHI	-71.56	19.76		11/1/1968	7/31/1970	Less than 5 years of data
Sabana Iglesia		042002	INDRHI	-70.75	19.31		8/1/1967	9/30/1970	Less than 5 years of data
Guanajuma		042201	INDRHI	-70.75	19.29		5/1/1967	8/31/1970	Less than 5 years of data
Inoa		043001	INDRHI	-70.98	19.35		8/1/1967	8/31/1970	Less than 5 years of data
Bulla		044001	INDRHI	-71.08	19.42		8/1/1967	8/31/1970	Less than 5 years of data
Yasica		100003	INDRHI	-70.60	19.64		5/1/1985	3/31/1986	Less than 5 years of data
El Limon		180004	INDRHI	-69.82	19.15		1/1/1986	12/31/1988	Less than 5 years of data
Los Cacaos		383001	INDRHI	-70.30	18.53		8/1/1967	7/31/1970	Less than 5 years of data
Carrizal		462001	INDRHI	-70.82	18.54		7/1/1967	12/31/1971	Less than 5 years of data
Arroyo Limon		440001	INDRHI	-70.51	18.49				No data available
Bayacanes		185001	INDRHI	-70.59	19.23				No data available
Blanco		183001	INDRHI	-70.52	18.88				No data available
Bocaina		380011	INDRHI	-70.46	18.69				No data available
Caobal		340002	INDRHI	-70.15	18.59				No data available
El Aguaca		490011	INDRHI	-71.02	18.86				No data available
El Corte		540001	INDRHI	-71.63	19.14				No data available
La Cruz		200001	INDRHI	-69.40	19.00				No data available
La Espenza		020001	INDRHI	-71.55	19.58				No data available
Los Brazos		100002	INDRHI	-70.43	19.66				No data available
Los Corozos		340004	INDRHI	-70.12	18.52				No data available
Los Platanos		180007	INDRHI	-70.23	18.99				No data available
Los Valencios		493008	INDRHI	-71.29	19.08				No data available
Los Velasquitos		040018	INDRHI	-70.68	19.21				No data available
Paso de Lima		493006	INDRHI	-71.30	19.03				No data available
Piedra los Veganos		180011	INDRHI	-70.47	18.82				No data available
Rancho Arriba		380004	INDRHi	-70.47	18.72				No data available
Rincon		045001	INDRHI	-71.39	19.53				No data available
Rincon1		185201	INDRHI	-70.41	19.11				No data available
Alto Bandera	ALB	22572	ONAMET	-70.59	18.84				No data available
Bßnica	BCA	23714	ONAMET	-71.70	19.07				No data available
Cimpa	CIM		ONAMET	-70.84	19.57				No data available
La Castilla	LAC		ONAMET	-70.65	18.94				No data available
La Cumbre de Santiago	LCS		ONAMET	-70.60	19.52				No data available
Loma de Cabrera	LDC		ONAMET	-71.62	19.42				No data available
Manzanillo	MAN		ONAMET	-71.67	19.72				No data available
Valle Nuevo	VNU		ONAMET	-70.66	18.81				No data available

Correction factors applied during PXPP/IDMA consistency analysis.

Station	Month	Year	Corr.	Month	Year	Corr.	Month	Year	Corr.	Month	Year	Corr.	Month	Year	Corr.
COT	1	1950	1.08	3	1969	0.71	9	1977	1						
IMB	1	1950	0.87	10	1985	1									
RAN	1	1950	1.09	9	1962	0.53	6	1966	1.12	6	1974	1.73	4	1981	1
SCR	1	1950	0.87	9	1975	1									
SJO	1	1950	0.8	12	1960	1.49	4	1979	1						
SRO	1	1950	0.69	8	1955	0.92	4	1970	1						
VIA	1	1950	1.18	8	1955	0.85	9	1966	1.24	10	1980	1			
YAM	1	1950	1.29	9	1958	0.73	11	1968	1						
180001	5	1960	1.23	10	1975	1									
183102	4	1981	1.59	5	1987	1									
187002	2	1960	0.73	4	1995	1									
331001	3	1960	0.43	11	1992	1									
333101	3	1960	0.96	8	1964	1.46	6	1969	1						

Appendix B – List of Temperature Stations and Results from the Quality Control Task

List of climate stations with temperature data

Name	ID	Number	Agency	LON	LAT	ELEV (m)	TMAX	TMIN
Aerop. Las Américas	ALA	78485	ONAMET	-69.67	18.45	10	x	
Altamira	ALT	24546	ONAMET	-70.86	19.66	422	x	x
Aerop. La Unión	ALU	78457	ONAMET	-70.50	19.76	89	x	
Azua	AZU	21595	ONAMET	-70.72	18.42	34	x	
Baní	BAN	21436	ONAMET	-70.36	18.31	118	X	
Bayaguana	BAY	78473	ONAMET	-69.60	18.73	52	x	
Aerop. de Herrera	HER	78484	ONAMET	-69.99	18.47	46	x	x
Jarabacoa	JAR	23523	ONAMET	-70.67	19.12	581	x	x
Luperón	LUP	24589	ONAMET	-70.96	19.88	16	x	x
La Victoria	LVI	22346	ONAMET	-69.90	18.64	23	x	x
Monte Cristi	MCR	78451	ONAMET	-71.66	19.85	17	x	x
Monte Plata	MPL	22365	ONAMET	-69.79	18.80	47	x	x
Pepillo Salcedo	PPS	24745	ONAMET	-71.74	19.69	8	x	x
Rancho Arriba	RAN	22449	ONAMET	-70.49	18.74	1009	x	x
Restauraci≤n	RES	23773	ONAMET	-71.67	19.29	630	x	x
San Cristobal	SCR		ONAMET	-70.13	18.40	91	x	x
San José de las Matas	SJM	23579	ONAMET	-71.02	19.32	599	x	x
San José de Ocoa	SJO	22510	ONAMET	-70.52	18.53	457	x	X
San Juan	SJU	78470	ONAMET	-71.21	18.80	411	x	x
Santiago Rodriguez	SRO	24608	ONAMET	-71.36	19.47	128	x	x
Santo Domingo (Central)	STD	78486	ONAMET	-69.84	18.48	29	x	
Villa Altagracia	VIA	22443	ONAMET	-70.26	18.69	425	x	x
Villa Vasquez	VIV	24659	ONAMET	-71.41	19.77	102	x	x
Yamasá	YAM	22460	ONAMET	-70.01	18.76	97	x	x
Yásica	YAS	24533	ONAMET	-70.66	19.64	397	x	x
Dajabon	DAJ		ONAMET	-71.7	19.55	36	x	
Engombe	ENG_I	3401	INDRHI	-70.002	18.45023	27	x	x
Jarabacoa	JAR_I	401	INDRHI	-70.639	19.13079	535	x	x
La Antona	LAN_I	408	INDRHI	-71.4029	19.63358	56	x	x
Mata Grande	MGR_I	411	INDRHI	-70.9876	19.20107	887	x	x
Medina	MED_I	3402	INDRHI	-70.1445	18.53523	157	x	x
Nizao	NIZ_I	3801	INDRHI	-70.452	18.61495	594	x	x
Quinigua	QUI_I	405	INDRHI	-70.7737	19.52663	136	x	x
Santiago Rodriguez	SRO_I	407	INDRHI	-71.3362	19.47802	122	x	x
Tavera	TAV_I	402	INDRHI	-70.7181	19.28357	323	x	x
Valdesia	VAL_I	3802	INDRHI	-70.2806	18.40856	156	x	x

Flagged temperature data

Station ID	Time Period with Problem		Note
PPS	6/1/1960	6/29/1960	0's set to missing
MCR	8/10/2009		99 set to missing
VIV	pre 1957		Questionable data when compared with MCR which matches better for later record (check in IDMA)
VIV	Jun-77	May-78	Drops below MCR which it is consistently above for all other periods (flattens out)
DAJ	Aug-04	Jan-05	Erratic flat lining, high values in Oct
PPS	pre Aug 1960		Questionable data when compared with MCR and VIV which matches better for later record (check in IDMA)
SRO	Feb-63	Oct-63	Flattens out, does not match pattern of other stations or previous years.
SRO	Jan-48		Too high
RES	pre 1964		Flattens out, does not match pattern of other stations or later years.
ALU	Oct-10	Nov-10	low, set to missing
YAS	Pre 1965		Looks Questionable (check in IDMA)
SJO	pre 1960		Looks Bad (check in IDMA)
VIA	pre 1963		Looks Bad (check in IDMA)
STD	11/16/1992		.31.8 set to 31.8
STD	11/25/1999		.31.5 set to 31.5
STD	9/1/2010		32..3 set to 32.3
ALA	11/12/2004		99.9 set to missing
BAY	12/20/1993		30..3 set to 30.3
BAY	8/4/2009		3 set to missing
BAY	9/1/1959	Nov-60	Bad data, set to missing
MPL	pre 1958		Low, set to missing
YAM	pre 7-1963		Does not drop below 30 post 1958, un-natural pattern
MCR	1/1/2007		TMAX lower than TMIN
PPS	4/26/1959		TMAX lower than TMIN
*PPS	pre 1976		Unusual
SCR	12/24/1946		TMAX lower than TMIN
SJM	7/18/1993		TMAX lower than TMIN
SJO	Jul-59	Oct-59	Set to missing
SJO	Nov-64	Feb-65	Set to missing
SJO	3/1/1981	3/4/1981	Set to missing
SJU	Oct-72	Apr-73	Set to missing

Station ID	Time Period with Problem		Note
Jarabacoa	1/20/2007		98.2 set to missing
Tavera	7/3/2007		52 set to missing
Mata_Grande	Jan-91	Apr-92	low, set to missing
Jarabacoa	post 2006		Questionable or bad but outside POR
Tavera	post 2006		Questionable or bad but outside POR
Mata_Grande	post 2006		Questionable or bad but outside POR
Quinigua	Jan-09		Outside of POR
Medina	Apr-92	May-94	low, set to missing
Medina	post 2009		Bad but outside POR
Valdesia	Nov-79	Feb-80	low, set to missing

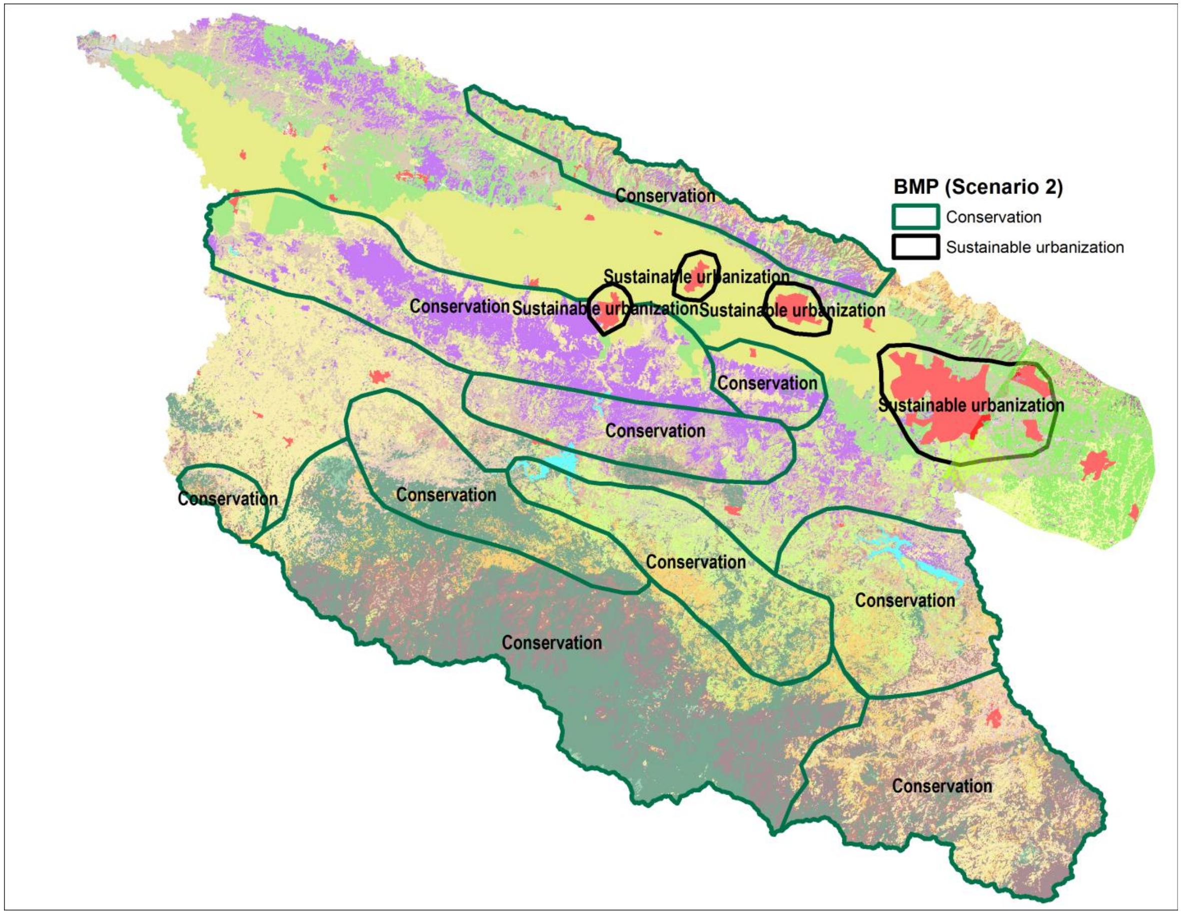
Temperature correction factors

Station	Dates		TMAX CF	TMIN CF
MCR	1 1955	3 1965	-1.12	-1.12
PPS	6 1960	3 1981	0.54	0.54
VIV	1 1955	12 1970	-0.63	-0.63
VIV	12 1970	3 1976	-1.4	-1.4
LAN_I	10 1967	1 1985	1.05	1.05
LUP	1 1955	7 1976	0.49	0.49
LUP	7 1976	8 1990	0.96	0.96
RES	9 1959	4 1964	-2.44	-2.44
SJM	1 1955	10 1963	1.76	1.76
JAR	10 1979	12 1982	-2.17	-2.17
SJU	1 1955	4 1973	-1.91	-1.91
SJO	1 1955	12 1966	2.52	2.52
SCR	1 1955	6 1985	-0.67	-0.67
MPL	1 1955	2 1979	-0.52	-0.52
ALT	1 1955	11 1964	-1.22	-1.22
YAS	12 1967	11 1978	1.07	1.07
QUI	7 1971	3 1987	0.73	0.73
TAV	10 1976	11 1984	0.65	0.65

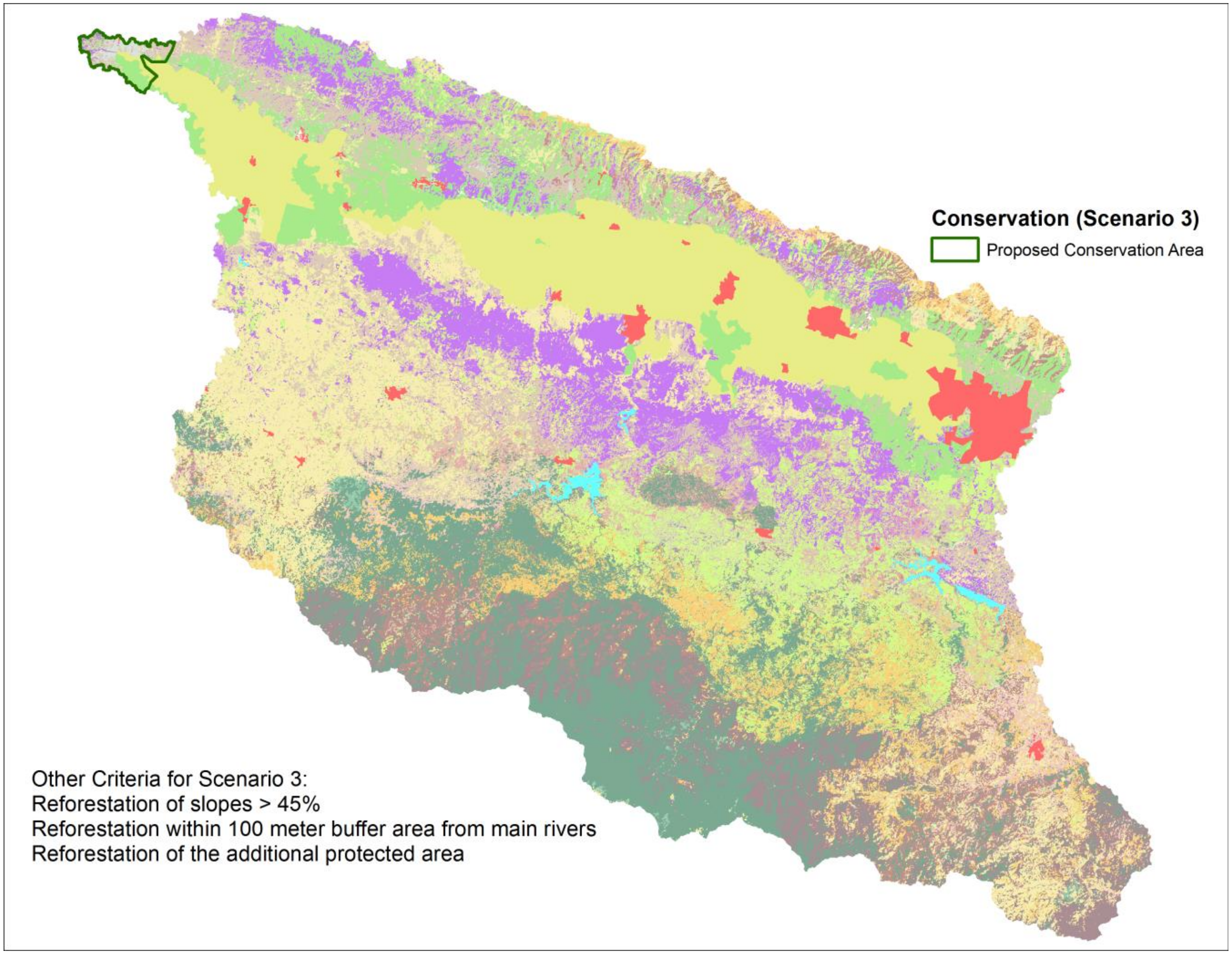
Appendix C – Stakeholder Meeting Digitized Map

Yaque del Norte Basin:

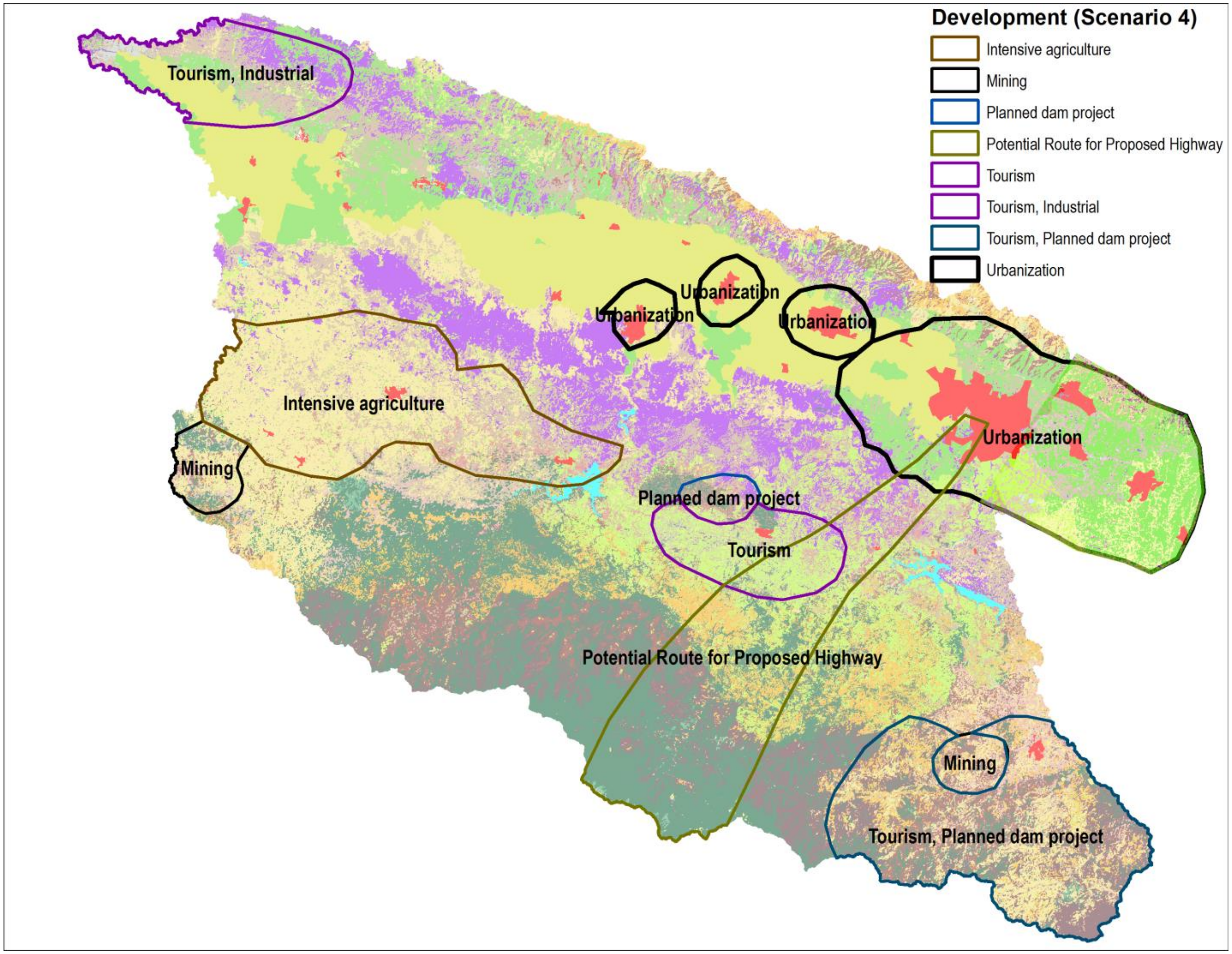
Best Management Practice (BMP):



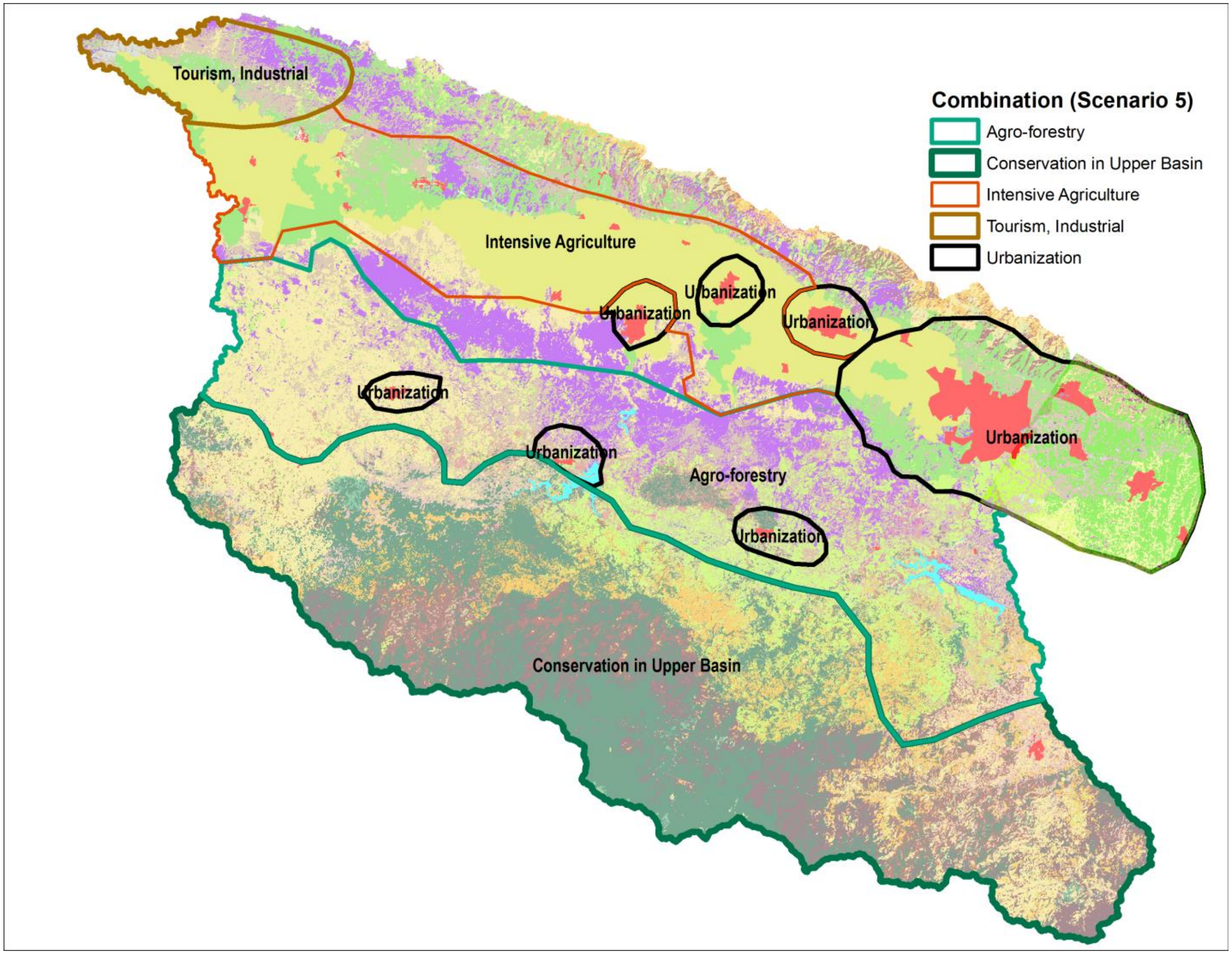
Conservation (CONS):



Development (DEV):

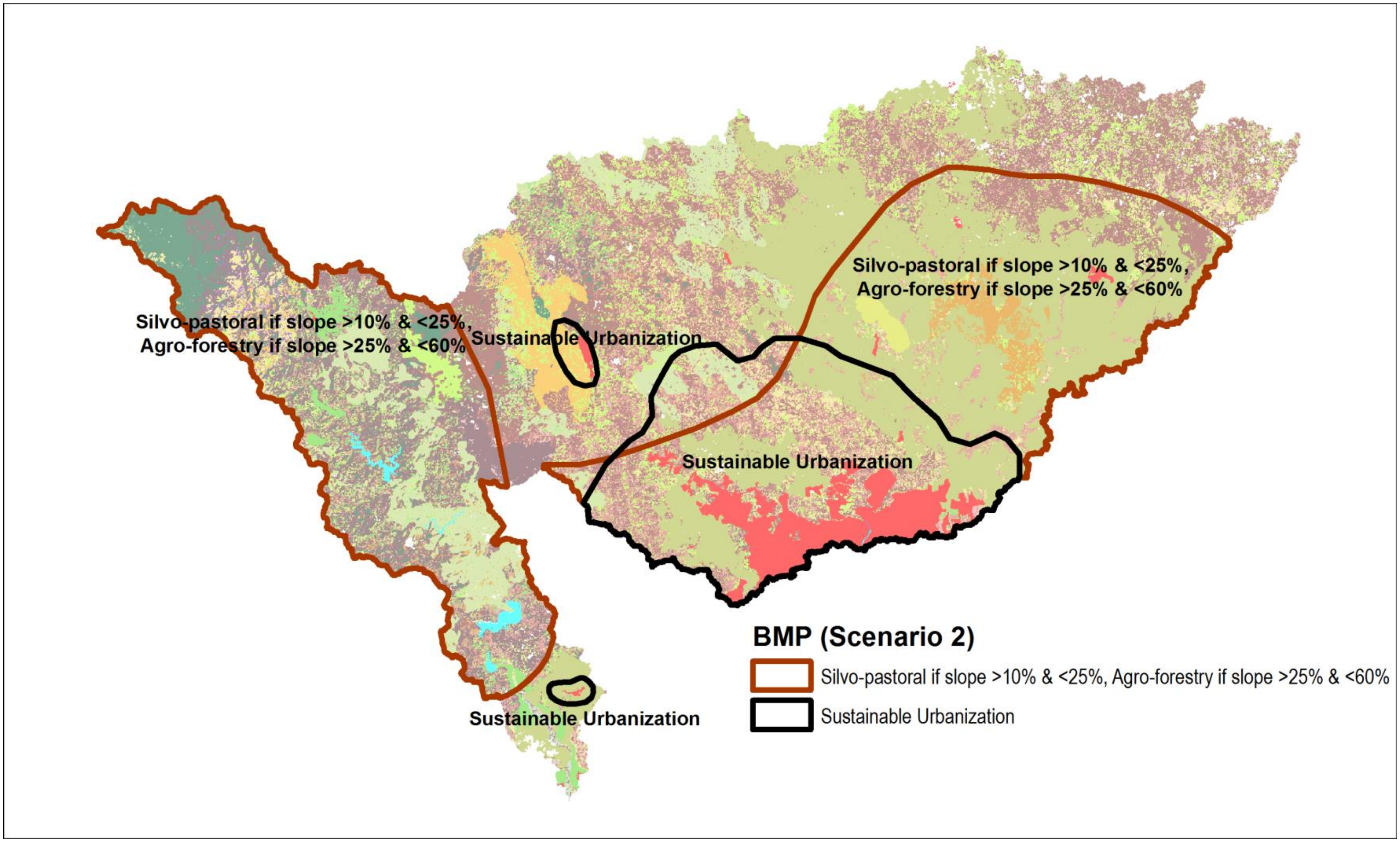


Combination (MIX):

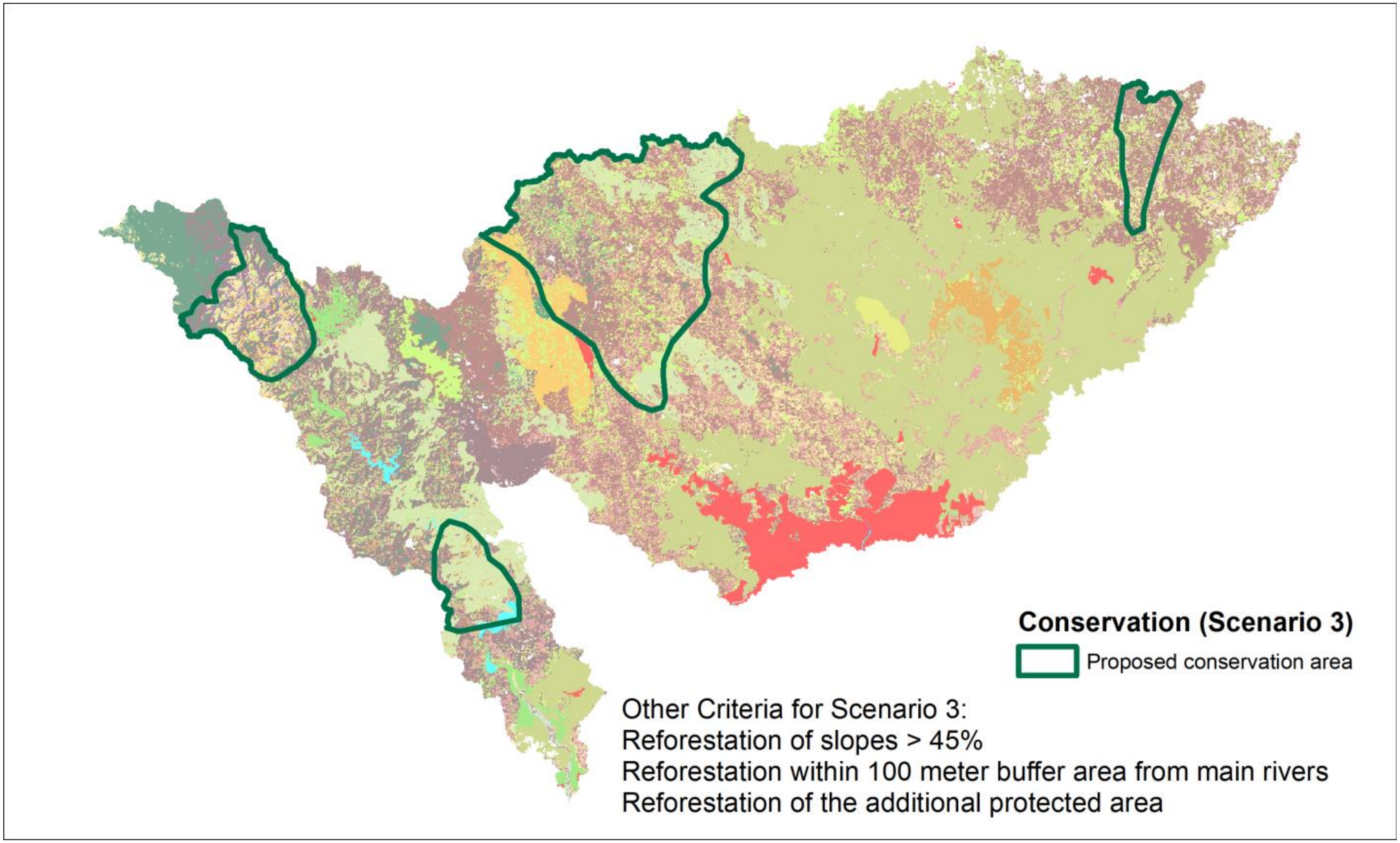


Nizao-Haina-Ozama:

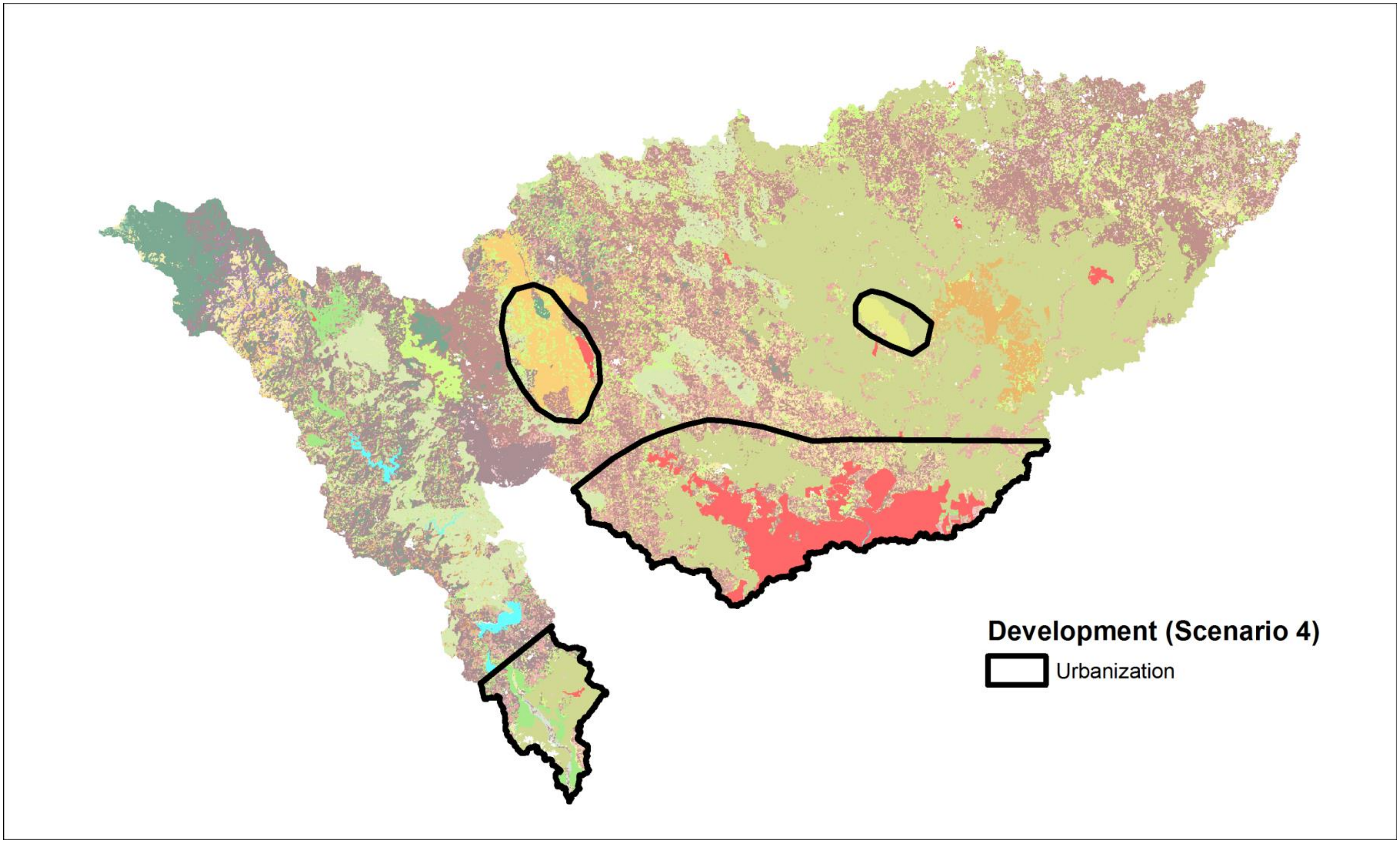
BMP (BMP):



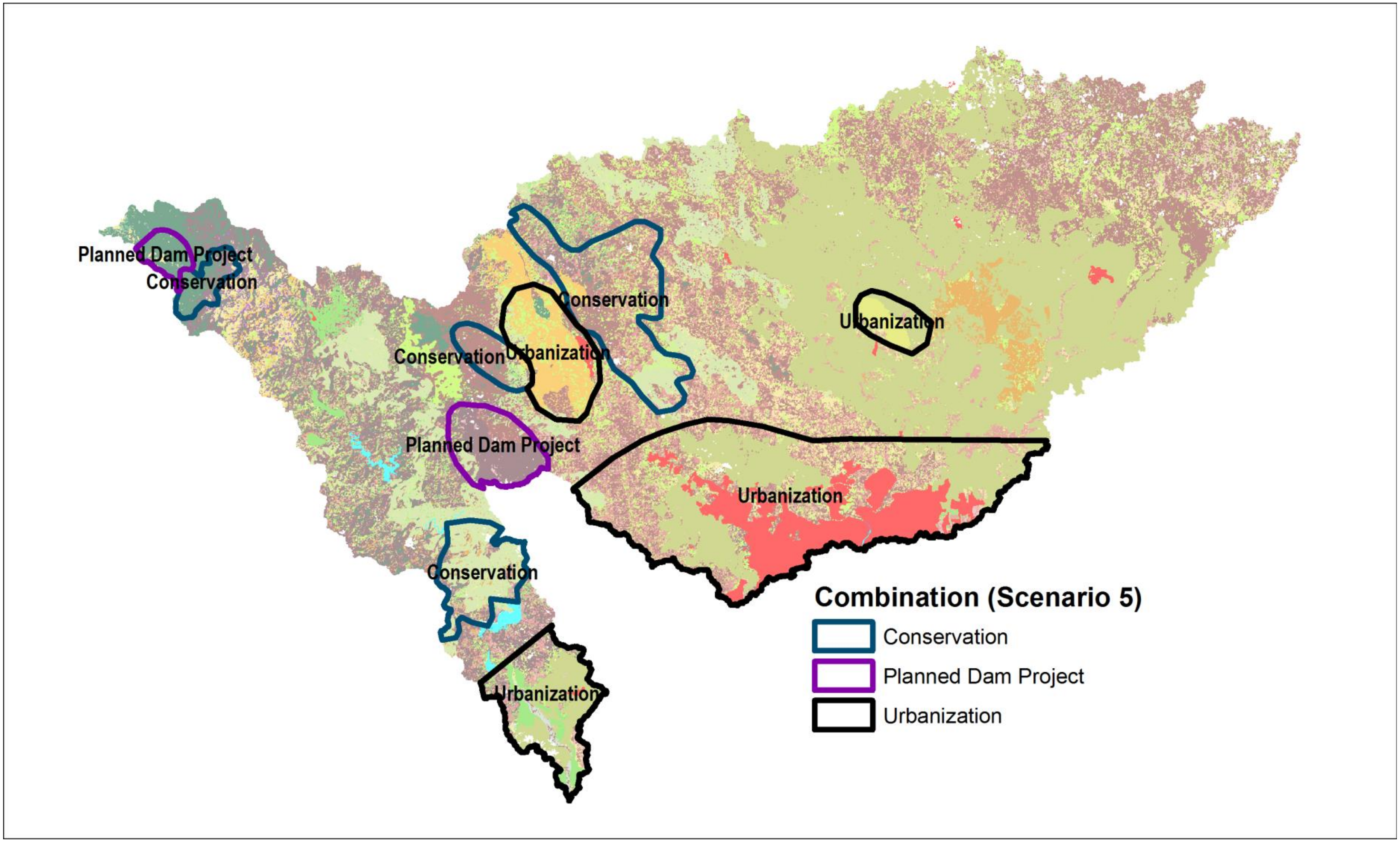
Conservation (CONS):



Development (DEV):



Combination (MIX):



Appendix D – GEOMOD Methodology

Simulating Land Change with GEOMOD

In the implementation of these steps, the only difference from one scenario to another is the masks used to determine the study area to be simulated. Idrisi Help is also a good source to consult on GEOMOD.

Steps for Simulating Urban land and Cropland Change to 2055 with GEOMOD:

1. Estimate urban land in 2055 based on projections of urban pop growth and of GDP
2. Simulate urban expansion with GEOMOD in four steps (for the years 2016, 2029, 2042 and 2055) using the following neighborhood constraints (for HNO 5,5,5,11 and for YdN 5,9,17,55).The differences in the neighborhood constraints allow to simulate a more realistic urban expansion, closer to the city in the first time steps and farther as the time goes on.
3. Estimate cropland for rice, export crops, and other crops in 2055 based on change in respective cropland across the country between 2002 and 2011.
4. Start simulating change in each of the three types of cropland starting from rice (because it is the most constrained in its spatial distribution also important as a staple crop and for smallholders) then land for other crops and finally export crops (because other crops are more profitable and more likely to displace export crops).
    a. Determine cropland for rice that is lost to the simulated urban growth
    b. Add that to total projected cropland for rice in 2055 in Step 3
    c. To simulate change in cropland for rice in GEOMOD, open the parameter file hno_bau-crop:

       Beginning landuse image: HNO_rice. This file corresponds to the 2003 rice layer.
       Mask image HNO_bau This file corresponds to all water bodies, protected areas and new conservation areas where changes in crops will not be simulated.
       Neighborhood constraint to 23 (equal to about 2km)
       Time step 52 (from 2003 to 2055)
       Driver images: HNO_2055urban, HNO_wdtr, and HNO_slope with weights 0.8, 0.1, and 0.1, respectively. We give more weight to the first map to force GEOMOD allocate change to areas not already simulated to become urban.
       HNO_2055urban corresponds to the 2055 urban expansion.
       HNO_wdtr corresponds to the proximity to roads map.
       HNO_slope corresponds to the slope map.
    d. The amount shown under 'Ending Time Quantities' tab for State 1 BGN is different than (more specifically, it is less than) the actual amount of cropland for rice in 2003. This is because some cropland for rice is located within the masked-out area (i.e., protected areas). Determine the difference and subtract that from the amount you calculated in Step 4b (meaning that you assume the cropland for rice within the masked-out area will not change).
    e. Name the output file HNO_2055Rice and click OK. GEOMOD will run and generate the output file with the given name plus "_1".
    f. Create a map (HNO2055_urbrice) with cell values of 0 for outside the watershed area, 1 for simulated urban and cropland for rice in 2055 and 2 the rest of the watershed area.

Create another map (HNO2055_urbrice1) with cell values of 1 for simulated urban and cropland rice in 2055 and 0 the rest (including outside the watershed area). Using this map (HNO2055_urbrice1), determine the cropland for other crops that is lost to the simulated urban growth plus simulated growth in cropland for rice.

g. Add the amount you calculated in Step 4f to the projected amount calculated in Step 3.
h. Simulate change in cropland for other crops in GEOMOD: Use mask image HNO_bau, set neighborhood constraint to 23 (equal to about 2km), time step 52, drivers images are HNO2055_urbrice, HNO_wdtr, HNO_slope with weights 0.8, 0.1, and 0.1, respectively. We give more weight to the first map to force GEOMOD allocate change to areas not already simulated to become urban or rice.
i. Repeat Step 4d and Step 4e for other cropland.
j. As in Step 4f for rice, create two maps (HNO2055_urbriceothcr and HNO2055_urbriceothc1). Using the later map (HNO2055_urbriceothcr1), determine the cropland for export crops that is lost to the simulated urban growth plus simulated growth in cropland for rice and for other crops.
k. Repeat Step 4g.
l. Simulate change in cropland for export crops in GEOMOD: Use mask image HNO_bau, set neighborhood constraint to 23 (equal to about 2km), time step 52, drivers images are HNO2055_urbriceothc, HNO_wdtr, HNO_slope with weights 0.8, 0.1, and 0.1, respectively. We give more weight to the first map to force GEOMOD allocate change to areas not already simulated to become urban, rice, or other crops.

5. Create the final simulated map of land cover in 2055:
    a. In creating the final map, the priority in decreasing order is: urban, rice, other crops, export crops. Recall that some of the existing cropland in 2003 will have changed to urban or a different type of cropland during the simulation process above.
    b. The cells that remained unchanged in Step 4 are assumed to stay in their original land cover.
    c. Merge the masked out sections of the watershed area with the section used in the land change simulations. Name the resulting map HNO2055_BAU

Appendix E – Land Use Type Distribution per Sub-basin.

Haina Basin

Subbasin 1	2003	BAU	BMP	CON	DEV	MIX
AGRC	3.8%	0.0%	0.0%	0.0%	0.0%	0.0%
OTHER using AGRC	0.0%	12.2%	12.0%	9.9%	12.6%	14.0%
AGRL	14.0%	0.0%	0.0%	0.0%	0.0%	0.0%
EXPORT using AGRL	0.0%	13.2%	12.6%	9.3%	13.6%	11.9%
FRSE	0.1%	0.1%	0.5%	10.1%	0.1%	1.9%
FRST	68.8%	65.6%	63.1%	63.7%	64.6%	63.7%
OILP	1.1%	0.0%	0.0%	0.0%	0.0%	0.0%
ORAN	2.3%	0.0%	0.0%	0.0%	0.0%	0.0%
PAST	4.0%	3.2%	3.2%	2.0%	3.0%	2.5%
RNGB	4.5%	4.1%	4.0%	3.6%	4.0%	3.8%
SUGC	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
URBN	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%
WATR	1.3%	1.5%	1.4%	1.4%	2.1%	2.1%
WETL	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
AGRE	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
AGRT	0.0%	0.0%	2.9%	0.0%	0.0%	0.0%
SILE	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
SILT	0.0%	0.0%	0.2%	0.0%	0.0%	0.0%

Subbasin 2	2003	BAU	BMP	CON	DEV	MIX
AGRC	1.0%	0.0%	0.0%	0.0%	0.0%	0.0%
AGRL	5.3%	0.0%	0.0%	0.0%	0.0%	0.0%
EXPORT using AGRL	0.0%	8.9%	5.5%	2.3%	8.8%	7.0%
FRSE	2.1%	2.0%	3.6%	41.4%	2.0%	2.7%
FRST	44.9%	39.7%	37.5%	41.3%	39.1%	40.4%
OILP	0.2%	0.0%	0.0%	0.0%	0.0%	0.0%
ORAN	27.1%	0.0%	0.0%	0.0%	0.0%	0.0%
OTHER using ORAN	0.0%	31.0%	33.7%	8.3%	33.0%	32.2%
PAST	15.7%	11.7%	12.0%	4.2%	10.7%	11.3%
RNGB	2.1%	1.8%	1.9%	1.1%	1.8%	1.8%
SUGC	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
URBN	1.2%	4.4%	1.2%	1.2%	4.2%	4.2%
WATR	0.3%	0.3%	0.4%	0.2%	0.3%	0.3%
WETL	0.1%	0.1%	0.1%	0.0%	0.1%	0.1%

Subbasin 2	2003	BAU	BMP	CON	DEV	MIX
AGRE	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%
AGRT	0.0%	0.0%	1.5%	0.0%	0.0%	0.0%
SILE	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%
SILT	0.0%	0.0%	2.6%	0.0%	0.0%	0.0%

Subbasin 3	2003	BAU	BMP	CON	DEV	MIX
AGRC	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
AGRL	2.2%	0.0%	0.0%	0.0%	0.0%	0.0%
OTHER using AGRL	0.0%	0.0%	0.0%	0.0%	8.2%	5.6%
FRSE	0.0%	0.0%	2.3%	55.3%	0.0%	0.0%
FRST	28.0%	13.6%	18.1%	23.4%	14.3%	18.4%
OILP	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
ORAN	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
PAST	9.3%	3.9%	7.7%	0.0%	4.0%	5.3%
RNGB	2.4%	1.4%	2.0%	0.0%	1.4%	1.6%
SUGC	36.9%	0.0%	0.0%	0.0%	0.0%	0.0%
EXPORT using SUGC	0.0%	45.0%	42.2%	0.1%	33.3%	30.3%
URBN	21.0%	35.8%	20.6%	21.1%	38.7%	38.7%
WATR	0.2%	0.4%	0.4%	0.0%	0.1%	0.1%
WETL	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
AGRE	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
AGRT	0.0%	0.0%	0.4%	0.0%	0.0%	0.0%
SILE	0.0%	0.0%	0.3%	0.0%	0.0%	0.0%
SILT	0.0%	0.0%	6.0%	0.0%	0.0%	0.0%

Nizao Basin

Mahoma River Basin = Subbasin 5	2003	BAU	BMP	CON	DEV	MIX
AGRC	6.1%	0.0%	0.0%	0.0%	0.0%	0.0%
OTHER using AGRC	0.0%	16.3%	15.8%	32.9%	17.5%	41.9%
AGRL	24.8%	0.0%	0.0%	0.0%	0.0%	0.0%
EXPORT using AGRL	0.0%	25.0%	21.2%	12.6%	24.3%	10.1%
COFF	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
FRSE	11.6%	11.0%	10.0%	14.8%	10.9%	10.3%
FRST	42.1%	33.3%	21.1%	27.0%	33.1%	24.1%
FRSD	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
OILP	0.3%	0.0%	0.0%	0.0%	0.0%	0.0%
PAST	13.3%	12.7%	12.4%	11.2%	12.5%	11.9%
RICE	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
RNGB	0.4%	0.3%	0.2%	0.2%	0.3%	0.3%
SUGC	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
URBN	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
WATR	1.3%	1.3%	1.3%	1.4%	1.3%	1.3%
WETL	0.1%	0.0%	0.0%	0.0%	0.1%	0.0%
AGRE	0.0%	0.0%	2.0%	0.0%	0.0%	0.0%
AGRT	0.0%	0.0%	5.6%	0.0%	0.0%	0.0%
AGRD	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
SILE	0.0%	0.0%	0.8%	0.0%	0.0%	0.0%
SILT	0.0%	0.0%	9.6%	0.0%	0.0%	0.0%
SILD	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

Upstream from Jiguey Reservoir = Subbasin 7	2003	BAU	BMP	CON	DEV	MIX
AGRC	8.7%	0.0%	0.0%	0.0%	0.0%	0.0%
OTHER using AGRC	0.0%	15.9%	16.7%	19.1%	17.9%	24.8%
AGRL	16.3%	0.0%	0.0%	0.0%	0.0%	0.0%
EXPORT using AGRL	0.0%	16.3%	12.0%	5.8%	17.3%	18.0%
COFF	3.0%	1.9%	1.5%	0.1%	2.2%	1.4%
FRSE	22.9%	22.3%	17.4%	38.1%	22.3%	21.4%
FRST	39.3%	34.2%	15.5%	32.1%	32.8%	28.1%
FRSD	2.0%	1.7%	0.7%	2.0%	1.5%	1.2%
OILP	0.6%	0.0%	0.0%	0.0%	0.0%	0.0%
PAST	3.8%	3.2%	2.3%	1.2%	0.0%	2.2%

Upstream from Jiguey Reservoir = Subbasin 7	2003	BAU	BMP	CON	DEV	MIX
RICE	0.1%	0.6%	0.5%	0.3%	0.6%	0.6%
RNGB	2.2%	1.7%	0.9%	0.3%	1.5%	1.1%
SUGC	0.0%	0.0%	0.0%	0.0%	2.9%	0.0%
URBN	0.1%	1.0%	0.1%	0.1%	0.1%	0.1%
WATR	0.9%	1.2%	1.0%	1.0%	1.1%	1.1%
WETL	0.1%	0.1%	0.1%	0.0%	0.1%	0.0%
AGRE	0.0%	0.0%	10.0%	0.0%	0.0%	0.0%
AGRT	0.0%	0.0%	8.9%	0.0%	0.0%	0.0%
AGRD	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%
SILE	0.0%	0.0%	1.9%	0.0%	0.0%	0.0%
SILT	0.0%	0.0%	10.0%	0.0%	0.0%	0.0%
SILD	0.0%	0.0%	0.4%	0.0%	0.0%	0.0%

Mahomita River basin = Subbasin 8	2003	BAU	BMP	CON	DEV	MIX
AGRC	6.8%	0.0%	0.0%	0.0%	0.0%	0.0%
OTHER using AGRC	0.0%	19.2%	19.2%	37.7%	20.7%	39.6%
AGRL	31.0%	0.0%	0.0%	0.0%	0.0%	0.0%
EXPORT using AGRL	0.0%	28.5%	27.7%	19.1%	28.8%	21.0%
COFF	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
FRSE	1.4%	1.3%	1.4%	5.2%	1.3%	0.9%
FRST	43.1%	35.8%	19.0%	25.4%	34.3%	24.7%
FRSD	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
OILP	1.7%	0.0%	0.0%	0.0%	0.0%	0.0%
PAST	14.0%	13.4%	12.9%	11.3%	13.1%	12.4%
RICE	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
RNGB	0.8%	0.7%	0.7%	0.6%	0.7%	0.6%
SUGC	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
URBN	0.1%	0.1%	0.0%	0.1%	0.1%	0.1%
WATR	0.9%	0.9%	0.8%	0.6%	0.8%	0.8%
WETL	0.1%	0.1%	0.1%	0.0%	0.1%	0.0%
AGRE	0.0%	0.0%	0.3%	0.0%	0.0%	0.0%
AGRT	0.0%	0.0%	5.0%	0.0%	0.0%	0.0%
AGRD	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
SILE	0.0%	0.0%	0.6%	0.0%	0.0%	0.0%
SILT	0.0%	0.0%	12.2%	0.0%	0.0%	0.0%
SILD	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

Upstream from Aguacate Reservoir and downstream from Jiguey Reservoir = Subbasin 10	2003	BAU	BMP	CON	DEV	MIX
AGRC	7.1%	0.0%	0.0%	0.0%	0.0%	0.0%
OTHER using AGRC	0.0%	13.4%	12.7%	14.8%	13.5%	16.7%
AGRL	31.5%	0.0%	0.0%	0.0%	0.0%	0.0%
EXPORT using AGRL	0.0%	28.6%	23.6%	20.4%	28.5%	24.9%
COFF	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
FRSE	5.4%	5.2%	3.8%	12.4%	5.3%	5.9%
FRST	45.9%	45.2%	27.2%	45.4%	45.4%	44.9%
FRSD	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
OILP	2.4%	0.0%	0.0%	0.0%	0.0%	0.0%
PAST	4.7%	4.3%	4.1%	3.8%	4.2%	4.3%
RICE	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
RNGB	0.9%	0.9%	0.9%	0.8%	0.9%	0.9%
SUGC	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
URBN	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
WATR	2.1%	2.4%	2.2%	2.3%	2.2%	2.2%
WETL	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%
AGRE	0.0%	0.0%	6.1%	0.0%	0.0%	0.0%
AGRT	0.0%	0.0%	17.3%	0.0%	0.0%	0.0%
AGRD	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
SILE	0.0%	0.0%	0.8%	0.0%	0.0%	0.0%
SILT	0.0%	0.0%	1.2%	0.0%	0.0%	0.0%
SILD	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

Upstream from Valdesia Reservoir and downsteram from Jiguey Reservoir = Subbasin 12	2003	BAU	BMP	CON	DEV	MIX
AGRC	3.7%	0.0%	0.0%	0.0%	0.0%	0.0%
OTHER using AGRC	0.0%	9.2%	8.8%	6.3%	10.2%	5.0%
AGRL	47.6%	0.0%	0.0%	0.0%	0.0%	0.0%
EXPORT using AGRL	0.0%	41.0%	38.6%	5.8%	41.4%	27.4%
COFF	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
FRSE	1.5%	1.5%	3.3%	49.1%	1.5%	25.7%
FRST	29.2%	26.0%	9.7%	27.2%	25.2%	28.2%
FRSD	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
OILP	4.8%	9.5%	8.2%	3.0%	9.7%	2.9%
PAST	2.2%	1.9%	1.2%	0.5%	1.6%	1.4%
RICE	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

Upstream from Valdesia Reservoir and downsteram from Jiguey Reservoir = Subbasin 12	2003	BAU	BMP	CON	DEV	MIX
RNGB	3.0%	2.8%	2.2%	1.0%	2.6%	1.8%
SUGC	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
URBN	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
WATR	7.7%	7.9%	7.2%	7.1%	7.5%	7.5%
WETL	0.3%	0.2%	0.1%	0.1%	0.2%	0.2%
AGRE	0.0%	0.0%	3.3%	0.0%	0.0%	0.0%
AGRT	0.0%	0.0%	8.0%	0.0%	0.0%	0.0%
AGRD	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
SILE	0.0%	0.0%	1.3%	0.0%	0.0%	0.0%
SILT	0.0%	0.0%	8.1%	0.0%	0.0%	0.0%
SILD	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

Upstream from Las Barias Reservoir and downstream from Valdesia Reservoir = Subbasin 14	2003	BAU	BMP	CON	DEV	MIX
AGRC	7.3%	0.0%	0.0%	0.0%	0.0%	0.0%
OTHER using AGRC	0.0%	15.8%	14.7%	17.8%	17.7%	18.2%
AGRL	19.9%	0.0%	0.0%	0.0%	0.0%	0.0%
EXPORT using AGRL	0.0%	18.1%	16.7%	13.8%	18.8%	10.3%
COFF	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
FRSE	0.0%	0.1%	4.7%	5.8%	0.1%	7.7%
FRST	53.6%	50.5%	26.6%	49.2%	49.3%	49.5%
FRSD	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
OILP	4.1%	0.0%	0.0%	0.0%	0.0%	0.0%
PAST	3.5%	3.2%	2.7%	2.5%	3.0%	3.1%
RICE	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
RNGB	5.1%	4.6%	4.4%	4.3%	4.6%	4.7%
SUGC	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
URBN	0.0%	0.9%	0.0%	0.0%	0.0%	0.0%
WATR	6.2%	6.6%	6.2%	6.5%	6.4%	6.4%
WETL	0.2%	0.2%	0.1%	0.1%	0.2%	0.2%
AGRE	0.0%	0.0%	0.4%	0.0%	0.0%	0.0%
AGRT	0.0%	0.0%	10.5%	0.0%	0.0%	0.0%
AGRD	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
SILE	0.0%	0.0%	0.3%	0.0%	0.0%	0.0%
SILT	0.0%	0.0%	12.9%	0.0%	0.0%	0.0%

Upstream from Las Barias Reservoir and downstream from Valdesia Reservoir = Subbasin 14	2003	BAU	BMP	CON	DEV	MIX
SILD	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

Downstream from Las Barias Reservoir to the outlet of the basin = Subbasin 15	2003	BAU	BMP	CON	DEV	MIX
AGRC	16.6%	0.0%	0.0%	0.0%	0.0%	0.0%
OTHER using AGRC	0.0%	29.1%	32.2%	29.6%	29.7%	26.8%
AGRL	4.0%	0.0%	0.0%	0.0%	0.0%	0.0%
COFF	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
FRSE	0.0%	0.0%	2.0%	6.2%	0.0%	0.0%
FRST	31.3%	23.9%	18.6%	23.9%	23.1%	23.5%
FRSD	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
OILP	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
PAST	3.4%	2.6%	2.5%	2.3%	2.3%	2.4%
RICE	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
RNGB	3.5%	2.9%	3.0%	2.8%	2.8%	2.9%
SUGC	37.5%	0.0%	0.0%	0.0%	0.0%	0.0%
EXPORT using SUGC	0.0%	31.2%	31.9%	32.6%	29.4%	31.5%
URBN	0.8%	8.8%	0.8%	0.8%	11.6%	11.6%
WATR	2.7%	1.3%	1.8%	1.7%	1.0%	1.2%
WETL	0.2%	0.1%	0.2%	0.1%	0.1%	0.1%
AGRE	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
AGRT	0.0%	0.0%	0.6%	0.0%	0.0%	0.0%
AGRD	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
SILE	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%
SILT	0.0%	0.0%	6.3%	0.0%	0.0%	0.0%
SILD	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

Ozama Basin

Don Juan Headwater = Subbasin 1	2003	BAU	BMP	CON	DEV	MIX
AGRC	4.8%	0.0%	0.0%	0.0%	0.0%	0.0%
OTHER using AGRC	0.0%	13.2%	14.8%	1.6%	15.4%	16.4%
AGRL	24.8%	0.0%	0.0%	0.0%	0.0%	0.0%
COFF	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
FRSE	0.2%	0.2%	2.2%	42.3%	0.2%	0.3%
FRST	45.0%	39.7%	40.3%	44.2%	37.7%	38.8%
OILP	0.6%	0.0%	0.0%	0.0%	0.0%	0.0%
ORAN	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
PAST	15.4%	12.8%	12.6%	2.8%	11.9%	12.4%
RICE	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
RNGB	0.8%	0.7%	0.7%	0.2%	0.7%	0.7%
SUGC	8.0%	0.0%	0.0%	0.0%	0.0%	0.0%
URBN	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
WATR	0.3%	0.4%	0.5%	0.0%	0.2%	0.2%
WETL	0.1%	0.1%	0.1%	0.0%	0.1%	0.1%
EXPORT using AGRL	0.0%	32.8%	28.8%	8.9%	33.8%	31.0%
AGRE	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
AGRT	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
SILE	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
SILT	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

Cacique Headwater = Subbasin 2	2003	BAU	BMP	CON	DEV	MIX
AGRC	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
AGRL	5.0%	0.0%	0.0%	0.0%	0.0%	0.0%
OTHER using AGRL	0.0%	9.4%	10.0%	17.3%	10.3%	13.6%
COFF	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
FRSE	0.0%	0.0%	1.3%	4.1%	0.0%	0.0%
FRST	46.7%	42.1%	43.2%	36.4%	41.1%	38.3%
OILP	0.0%	0.0%	0.0%	0.1%	0.0%	0.1%
ORAN	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
PAST	20.4%	17.6%	17.9%	15.6%	16.9%	16.7%
RICE	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
RNGB	0.5%	0.5%	0.5%	0.4%	0.5%	0.4%
SUGC	24.6%	0.0%	0.0%	0.0%	0.0%	0.0%

EXPORT using SUGC	0.0%	28.9%	25.0%	24.5%	29.9%	29.4%
URBN	0.1%	0.1%	0.1%	0.2%	0.1%	0.1%
WATR	2.4%	1.1%	1.9%	1.3%	1.0%	1.2%
WETL	0.2%	0.2%	0.2%	0.1%	0.2%	0.2%
AGRE	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
AGRT	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
SILE	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
SILT	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

El Cerro Headwater = Subbasin 3	2003	BAU	BMP	CON	DEV	MIX
AGRC	0.4%	0.0%	0.0%	0.0%	0.0%	0.0%
AGRL	3.1%	0.0%	0.0%	0.0%	0.0%	0.0%
OTHER using AGRL	0.0%	12.1%	12.4%	10.5%	12.6%	9.7%
COFF	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
FRSE	0.0%	0.0%	0.0%	0.2%	0.0%	0.0%
FRST	36.0%	30.7%	29.0%	32.4%	30.2%	31.4%
OILP	0.2%	0.0%	0.0%	0.0%	0.0%	0.0%
ORAN	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
PAST	12.1%	8.9%	9.9%	9.8%	8.6%	9.2%
RICE	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
RNGB	5.0%	4.4%	4.7%	4.7%	4.4%	4.6%
SUGC	37.7%	0.0%	0.0%	0.0%	0.0%	0.0%
EXPORT using SUGC	0.0%	41.0%	36.6%	38.4%	41.5%	41.7%
URBN	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
WATR	5.3%	2.8%	4.0%	3.8%	2.7%	3.2%
WETL	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%
AGRE	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
AGRT	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%
SILE	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
SILT	0.0%	0.0%	3.2%	0.0%	0.0%	0.0%

Rio Yamasa = Subbasin 4	2003	BAU	BMP	CON	DEV	MIX
AGRC	1.4%	0.0%	0.0%	0.0%	0.0%	0.0%
AGRL	21.0%	0.0%	0.0%	0.0%	0.0%	0.0%
OTHER using AGRL	0.0%	11.0%	11.7%	5.2%	12.2%	14.5%
COFF	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
FRSE	0.0%	0.0%	1.3%	22.0%	0.0%	0.2%
FRST	33.8%	27.7%	29.0%	30.5%	26.3%	25.7%

Rio Yamasa = Subbasin 4	2003	BAU	BMP	CON	DEV	MIX
OILP	0.3%	0.0%	0.0%	0.0%	0.0%	0.0%
ORAN	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
PAST	11.6%	7.7%	8.5%	3.9%	7.2%	7.6%
RICE	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
RNGB	0.4%	0.3%	0.3%	0.1%	0.2%	0.2%
SUGC	30.6%	0.0%	0.0%	0.0%	0.0%	0.0%
EXPORT using SUGC	0.0%	52.4%	48.3%	37.6%	53.1%	50.7%
URBN	0.6%	0.5%	0.5%	0.6%	0.5%	0.6%
WATR	0.3%	0.3%	0.3%	0.0%	0.3%	0.3%
WETL	0.1%	0.1%	0.1%	0.0%	0.1%	0.1%
AGRE	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
AGRT	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
SILE	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
SILT	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

Confluence of Ozama River with Guanuma River = Subbasin 5	2003	BAU	BMP	CON	DEV	MIX
AGRC	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
AGRL	1.9%	0.0%	0.0%	0.0%	0.0%	0.0%
OTHER using AGRL	0.0%	6.7%	6.5%	5.0%	6.8%	5.0%
COFF	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
FRSE	0.0%	0.0%	4.1%	13.0%	0.0%	0.0%
FRST	7.5%	4.8%	5.4%	5.5%	4.6%	5.0%
OILP	0.2%	0.0%	0.0%	0.0%	0.0%	0.0%
ORAN	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
PAST	5.8%	4.3%	4.6%	4.6%	4.0%	4.4%
RICE	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
RNGB	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%
SUGC	84.2%	0.0%	0.0%	0.0%	0.0%	0.0%
EXPORT using SUGC	0.0%	84.0%	78.9%	71.6%	84.4%	85.3%
URBN	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
WATR	0.1%	0.0%	0.1%	0.0%	0.0%	0.0%
WETL	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
EXAG	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
AGRE	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
AGRT	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
SILE	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

SILT	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%

Rio Guanuma = Subbasin 6	2003	BAU	BMP	CON	DEV	MIX
AGRC	0.5%	0.0%	0.0%	0.0%	0.0%	0.0%
AGRL	21.7%	0.0%	0.0%	0.0%	0.0%	0.0%
OTHER using AGRL	0.0%	20.9%	22.8%	9.9%	22.8%	21.3%
COFF	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
FRSE	1.2%	1.1%	1.9%	26.5%	1.1%	1.3%
FRST	51.1%	38.2%	41.9%	45.3%	36.8%	39.9%
OILP	0.5%	0.0%	0.0%	0.0%	0.0%	0.0%
ORAN	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
PAST	13.9%	11.4%	11.4%	3.5%	10.6%	10.9%
RICE	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
RNGB	0.2%	0.1%	0.2%	0.1%	0.1%	0.2%
SUGC	10.7%	0.0%	0.0%	0.0%	0.0%	0.0%
EXPORT using SUGC	0.0%	27.3%	21.6%	14.8%	27.6%	25.5%
URBN	0.0%	0.8%	0.0%	0.0%	0.8%	0.8%
WATR	0.1%	0.1%	0.1%	0.0%	0.1%	0.1%
WETL	0.1%	0.1%	0.1%	0.0%	0.1%	0.1%
AGRE	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
AGRT	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
SILE	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
SILT	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

Rio La Savita = Subbasin 7	2003	BAU	BMP	CON	DEV	MIX
AGRC	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
AGRL	2.6%	0.0%	0.0%	0.0%	0.0%	0.0%
COFF	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
FRSE	0.1%	0.0%	0.7%	3.0%	0.0%	0.0%
FRST	17.7%	10.8%	11.5%	12.3%	10.4%	11.0%
OILP	6.8%	0.0%	0.0%	0.0%	0.0%	0.0%
OTHER using OILP	0.0%	24.7%	24.3%	20.9%	25.0%	20.3%
ORAN	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
PAST	7.1%	3.1%	4.4%	4.2%	3.1%	3.7%
RICE	1.5%	4.7%	4.4%	4.4%	4.5%	4.5%
RNGB	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%
SUGC	63.1%	0.0%	0.0%	0.0%	0.0%	0.0%
EXPORT using SUGC	0.0%	54.5%	52.1%	54.4%	56.2%	59.7%

Rio La Savita = Subbasin 7	2003	BAU	BMP	CON	DEV	MIX
URBN	0.4%	1.8%	0.3%	0.4%	0.4%	0.4%
WATR	0.4%	0.2%	0.3%	0.3%	0.2%	0.2%
WETL	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%
AGRE	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
AGRT	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%
SILE	0.0%	0.0%	0.2%	0.0%	0.0%	0.0%
SILT	0.0%	0.0%	1.5%	0.0%	0.0%	0.0%

Rio Yabacao = Subbasin 8	2003	BAU	BMP	CON	DEV	MIX
AGRC	0.3%	0.0%	0.0%	0.0%	0.0%	0.0%
AGRL	4.7%	0.0%	0.0%	0.0%	0.0%	0.0%
COFF	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
FRSE	0.0%	0.0%	5.6%	6.4%	0.0%	0.0%
FRST	30.6%	22.5%	23.9%	26.8%	22.7%	24.6%
OILP	4.9%	0.0%	0.0%	0.0%	0.0%	0.0%
OTHER using OILP	0.0%	18.9%	18.9%	15.3%	19.5%	16.2%
ORAN	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
PAST	10.1%	6.9%	6.1%	6.9%	6.7%	7.4%
RICE	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
RNGB	5.7%	4.5%	3.0%	4.3%	4.5%	4.8%
SUGC	41.4%	0.0%	0.0%	0.0%	0.0%	0.0%
EXPORT using SUGC	0.0%	41.2%	38.6%	38.5%	43.8%	44.2%
URBN	0.4%	4.5%	0.4%	0.4%	1.3%	1.3%
WATR	1.8%	1.6%	1.1%	1.4%	1.4%	1.5%
WETL	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
EXAG	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
AGRE	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
AGRT	0.0%	0.0%	1.0%	0.0%	0.0%	0.0%
SILE	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
SILT	0.0%	0.0%	1.4%	0.0%	0.0%	0.0%

Rio Higuero = Subbasin 9	2003	BAU	BMP	CON	DEV	MIX
AGRC	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%
AGRL	33.2%	0.0%	0.0%	0.0%	0.0%	0.0%

Rio Higuero = Subbasin 9	2003	BAU	BMP	CON	DEV	MIX
OTHER using AGRL	0.0%	27.5%	25.8%	0.6%	27.8%	12.1%
COFF	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
FRSE	0.2%	0.1%	0.1%	58.9%	0.1%	0.2%
FRST	43.8%	20.6%	27.5%	36.5%	20.0%	33.1%
OILP	0.5%	0.0%	0.0%	0.0%	0.0%	0.0%
ORAN	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
PAST	16.2%	10.8%	11.6%	0.8%	10.0%	13.9%
RICE	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
RNGB	0.3%	0.1%	0.2%	0.0%	0.1%	0.2%
SUGC	5.7%	0.1%	0.1%	0.0%	0.0%	0.0%
URBN	0.0%	5.3%	0.0%	0.0%	8.1%	8.0%
WATR	0.2%	0.2%	0.2%	0.0%	0.2%	0.2%
WETL	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
EXPORT using AGRL	0.0%	35.3%	34.3%	3.1%	33.7%	32.3%
AGRE	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
AGRT	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
SILE	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
SILT	0.0%	0.0%	0.3%	0.0%	0.0%	0.0%

Rio Isabela - Palmarejo Station = Subbasin 10	2003	BAU	BMP	CON	DEV	MIX
AGRC	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
AGRL	12.3%	0.0%	0.0%	0.0%	0.0%	0.0%
OTHER using AGRL	0.0%	16.7%	17.7%	0.9%	17.3%	12.5%
COFF	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
FRSE	0.1%	0.2%	0.9%	52.5%	0.1%	0.2%
FRST	44.4%	28.1%	34.9%	37.4%	28.2%	33.5%
OILP	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
ORAN	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%
PAST	12.5%	8.1%	10.0%	1.8%	7.9%	9.2%
RICE	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
RNGB	2.0%	1.3%	1.6%	0.4%	1.3%	1.5%
SUGC	20.5%	0.0%	0.0%	0.0%	0.0%	0.0%
EXPORT using SUGC	0.0%	29.3%	25.4%	0.2%	27.1%	24.9%
URBN	6.7%	15.6%	6.5%	6.8%	17.4%	17.4%
WATR	1.3%	0.7%	1.1%	0.0%	0.6%	0.8%
WETL	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
EXAG	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

Rio Isabela - Palmarejo Station = Subbasin 10	2003	BAU	BMP	CON	DEV	MIX
AGRE	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
AGRT	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%
SILE	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%
SILT	0.0%	0.0%	1.7%	0.0%	0.0%	0.0%

Rio Isabela, downstream from Palmarejo Station = Subbasin 11	2003	BAU	BMP	CON	DEV	MIX
AGRC	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
AGRL	9.2%	0.0%	0.0%	0.0%	0.0%	0.0%
OTHER using AGRL	0.0%	19.8%	22.2%	0.0%	18.9%	15.2%
COFF	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
FRSE	0.0%	0.0%	0.4%	51.4%	0.0%	0.0%
FRST	21.2%	0.6%	12.1%	7.7%	0.7%	2.2%
OILP	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
ORAN	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
PAST	6.2%	0.2%	3.4%	0.0%	0.2%	0.6%
RICE	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
RNGB	0.6%	0.0%	0.4%	0.0%	0.1%	0.1%
SUGC	21.8%	0.0%	0.0%	0.0%	0.0%	0.0%
EXPORT using SUGC	0.0%	20.8%	20.7%	0.0%	16.1%	17.7%
URBN	40.7%	58.6%	40.1%	40.9%	64.0%	64.1%
WATR	0.2%	0.1%	0.2%	0.0%	0.0%	0.1%
WETL	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
EXAG	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
AGRE	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
AGRT	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
SILE	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
SILT	0.0%	0.0%	0.4%	0.0%	0.0%	0.0%

Rio Ozama = Subbasin 12	2003	BAU	BMP	CON	DEV	MIX
AGRC	0.2%	0.0%	0.0%	0.0%	0.0%	0.0%
AGRL	6.9%	0.0%	0.0%	0.0%	0.0%	0.0%
OTHER using AGRL	0.0%	15.1%	17.0%	4.8%	14.5%	11.4%
COFF	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
FRSE	0.1%	0.1%	1.5%	42.5%	0.1%	0.1%

Rio Ozama = Subbasin 12	2003	BAU	BMP	CON	DEV	MIX
FRST	16.2%	4.0%	9.4%	7.5%	3.9%	4.7%
OILP	1.3%	0.0%	0.0%	0.0%	0.0%	0.0%
ORAN	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
PAST	4.8%	1.3%	3.0%	1.0%	1.3%	1.6%
RICE	2.4%	4.3%	4.2%	3.9%	4.3%	4.3%
RNGB	0.8%	0.2%	0.6%	0.0%	0.2%	0.2%
SUGC	54.1%	0.0%	0.0%	0.0%	0.0%	0.0%
EXPORT using SUGC	0.0%	42.7%	50.7%	26.9%	40.0%	42.1%
URBN	13.1%	32.2%	13.0%	13.2%	35.6%	35.5%
WATR	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%
WETL	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
EXAG	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
AGRE	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
AGRT	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
SILE	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%
SILT	0.0%	0.0%	0.3%	0.0%	0.0%	0.0%

Yaque del Norte Basin

Lower Yaque = Subbasin 1	2003	BAU	BMP	CON	DEV	MIX
AGRC	17.3%	0.0%	0.0%	0.0%	0.0%	0.0%
OTHER using AGRC	0.0%	23.6%	25.7%	24.0%	20.2%	21.7%
AGRL	7.3%	4.2%	2.2%	3.9%	4.2%	3.1%
COFF	1.6%	0.0%	0.0%	0.0%	0.0%	0.0%
EXPORT using COFF	0.0%	1.4%	1.4%	1.4%	1.4%	1.5%
FRSE	0.1%	0.0%	1.5%	4.4%	0.0%	0.0%
FRST	4.2%	1.1%	1.8%	1.2%	1.1%	1.7%
FRSD	14.0%	5.9%	7.8%	6.1%	5.8%	5.8%
ORAN	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
PAST	4.5%	0.7%	3.0%	0.7%	0.6%	1.3%
RICE	29.9%	52.6%	34.6%	51.1%	46.8%	39.9%
RNGB	16.4%	2.4%	10.0%	2.5%	2.2%	4.1%
URBN	4.6%	7.7%	6.5%	4.6%	7.7%	7.8%
WATR	0.2%	0.3%	0.5%	0.3%	0.3%	0.3%
WETL	0.2%	0.0%	0.1%	0.0%	0.0%	0.0%
AGRE	0.0%	0.0%	0.0%	0.0%	0.0%	1.0%
AGRT	0.0%	0.0%	0.0%	0.0%	0.0%	0.3%
AGRD	0.0%	0.0%	0.0%	0.0%	0.0%	2.1%
SILE	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%
SILT	0.0%	0.0%	1.4%	0.0%	0.0%	0.0%
SILD	0.0%	0.0%	3.4%	0.0%	0.0%	0.0%
MINE	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
TRIN	0.0%	0.0%	0.0%	0.0%	9.4%	9.4%
TOUR	0.0%	0.0%	0.0%	0.0%	0.2%	0.0%

Rio Guyubin = Subbasin 4	2003	BAU	BMP	CON	DEV	MIX
AGRC	1.6%	0.0%	0.0%	0.0%	0.0%	0.0%
AGRL	50.7%	0.0%	0.0%	0.0%	0.0%	0.0%
OTHER using AGRL	0.0%	70.5%	58.3%	70.1%	66.6%	60.7%
COFF	3.6%	0.0%	0.0%	0.0%	0.0%	0.0%
EXPORT using COFF	0.0%	3.3%	2.7%	3.3%	3.1%	3.1%
FRSE	12.7%	11.3%	13.4%	12.8%	10.8%	15.7%
FRST	3.8%	1.4%	1.9%	1.4%	1.2%	3.1%
FRSD	4.6%	2.7%	3.5%	2.7%	2.7%	2.1%
ORAN	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

PAST	5.1%	1.2%	3.4%	1.2%	1.1%	2.8%
RICE	0.0%	1.5%	0.1%	1.2%	1.5%	1.1%
RNGB	17.4%	6.8%	13.5%	6.8%	6.6%	9.0%
URBN	0.4%	1.3%	0.4%	0.4%	1.3%	1.3%
WATR	0.0%	0.0%	0.2%	0.0%	0.0%	0.0%
WETL	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
AGRE	0.0%	0.0%	0.0%	0.0%	0.0%	0.3%
AGRT	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%
AGRD	0.0%	0.0%	0.0%	0.0%	0.0%	0.7%
SILE	0.0%	0.0%	1.3%	0.0%	0.0%	0.0%
SILT	0.0%	0.0%	0.9%	0.0%	0.0%	0.0%
SILD	0.0%	0.0%	0.3%	0.0%	0.0%	0.0%
MINE	0.0%	0.0%	0.0%	0.0%	5.1%	0.0%
TRIN	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
TOUR	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

Upstream Preas Maguaca = Subbasin 5	2003	BAU	BMP	CON	DEV	MIX
AGRC	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
AGRL	54.2%	0.0%	0.0%	0.0%	0.0%	0.0%
OTHER using AGRL	0.0%	79.1%	64.1%	74.6%	62.9%	67.1%
COFF	0.5%	0.0%	0.0%	0.0%	0.0%	0.0%
EXPORT using COFF	0.0%	0.0%	0.0%	0.0%	0.0%	0.5%
FRSE	9.2%	7.1%	9.9%	13.5%	3.1%	9.5%
FRST	3.8%	1.1%	1.9%	1.1%	0.5%	3.6%
FRSD	6.0%	2.0%	3.8%	2.0%	2.0%	0.0%
ORAN	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
PAST	11.7%	4.0%	8.5%	3.6%	3.5%	6.7%
RICE	0.0%	2.5%	0.0%	1.2%	2.4%	0.2%
RNGB	14.1%	3.5%	9.6%	3.3%	2.2%	7.7%
URBN	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%
WATR	0.3%	0.5%	1.0%	0.6%	0.5%	0.5%
WETL	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
AGRE	0.0%	0.0%	0.0%	0.0%	0.0%	1.4%
AGRT	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
AGRD	0.0%	0.0%	0.0%	0.0%	0.0%	2.5%
SILE	0.0%	0.0%	0.2%	0.0%	0.0%	0.0%
SILT	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%

Upstream Preas Maguaca = Subbasin 5	2003	BAU	BMP	CON	DEV	MIX
SILD	0.0%	0.0%	0.8%	0.0%	0.0%	0.0%
MINE	0.0%	0.0%	0.0%	0.0%	22.8%	0.0%
TRIN	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
TOUR	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

Cana Basin = Subbasin 8	2003	BAU	BMP	CON	DEV	MIX
AGRC	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
AGRL	26.1%	0.0%	0.0%	0.0%	0.0%	0.0%
OTHER using AGRL	0.0%	54.2%	34.3%	52.9%	54.2%	51.6%
COFF	0.3%	0.0%	0.0%	0.0%	0.0%	0.0%
EXPORT using COFF	0.0%	0.1%	0.1%	0.1%	0.1%	0.2%
FRSE	6.0%	3.3%	4.7%	7.7%	3.3%	5.8%
FRST	4.6%	0.1%	2.3%	0.1%	0.1%	1.1%
FRSD	17.4%	14.2%	16.2%	14.2%	14.2%	12.1%
ORAN	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
PAST	6.5%	2.4%	5.4%	2.2%	2.4%	3.3%
RICE	3.2%	18.9%	4.5%	16.2%	18.9%	6.8%
RNGB	35.8%	6.7%	28.8%	6.6%	6.8%	15.5%
URBN	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
WATR	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%
WETL	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
AGRE	0.0%	0.0%	0.0%	0.0%	0.0%	0.9%
AGRT	0.0%	0.0%	0.0%	0.0%	0.0%	0.4%
AGRD	0.0%	0.0%	0.0%	0.0%	0.0%	2.3%
SILE	0.0%	0.0%	2.3%	0.0%	0.0%	0.0%
SILT	0.0%	0.0%	1.0%	0.0%	0.0%	0.0%
SILD	0.0%	0.0%	0.3%	0.0%	0.0%	0.0%
MINE	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
TRIN	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
TOUR	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

Amina Basin = Subbasin 12	2003	BAU	BMP	CON	DEV	MIX
AGRC	1.7%	0.0%	0.0%	0.0%	0.0%	0.0%
AGRL	4.3%	0.0%	0.0%	0.0%	0.0%	0.0%
OTHER using AGRL	0.0%	34.9%	9.1%	34.6%	21.1%	21.7%
COFF	7.1%	0.0%	0.0%	0.0%	0.0%	0.0%
EXPORT using COFF	0.0%	7.4%	6.6%	7.2%	6.9%	5.1%

Amina Basin = Subbasin 12	2003	BAU	BMP	CON	DEV	MIX
FRSE	17.8%	13.6%	16.7%	15.5%	13.1%	16.7%
FRST	12.5%	8.4%	10.5%	8.4%	8.1%	7.9%
FRSD	14.3%	8.0%	11.4%	8.3%	8.1%	1.3%
ORAN	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
PAST	19.7%	8.4%	18.4%	8.4%	6.5%	10.0%
RICE	1.6%	9.6%	1.6%	8.6%	9.6%	6.9%
RNGB	20.7%	8.9%	20.0%	8.7%	7.6%	10.0%
URBN	0.2%	0.7%	0.2%	0.2%	0.8%	0.7%
WATR	0.0%	0.0%	0.0%	0.0%	0.4%	0.0%
WETL	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
AGRE	0.0%	0.0%	0.0%	0.0%	0.0%	9.1%
AGRT	0.0%	0.0%	0.0%	0.0%	0.0%	1.4%
AGRD	0.0%	0.0%	0.0%	0.0%	0.0%	9.1%
SILE	0.0%	0.0%	1.2%	0.0%	0.0%	0.0%
SILT	0.0%	0.0%	1.3%	0.0%	0.0%	0.0%
SILD	0.0%	0.0%	2.8%	0.0%	0.0%	0.0%
MINE	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
TRIN	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
TOUR	0.0%	0.0%	0.0%	0.0%	17.9%	0.0%

Gurabo Basin = Subbasin 13	2003	BAU	BMP	CON	DEV	MIX
AGRC	0.0%	0.1%	0.1%	0.1%	0.1%	0.1%
AGRL	16.7%	0.0%	0.0%	0.0%	0.0%	0.0%
OTHER using AGRL	0.0%	56.8%	24.3%	53.1%	56.4%	42.1%
COFF	0.4%	0.0%	0.0%	0.0%	0.0%	0.0%
EXPORT using COFF	0.0%	0.2%	0.2%	0.2%	0.2%	0.2%
FRSE	3.1%	0.1%	2.6%	6.9%	0.1%	2.6%
FRST	3.7%	0.1%	1.9%	0.1%	0.1%	0.8%
FRSD	27.8%	20.4%	23.1%	20.7%	20.7%	14.9%
ORAN	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
PAST	6.8%	1.5%	6.0%	1.4%	1.5%	3.3%
RICE	3.1%	10.5%	3.2%	7.9%	10.3%	3.7%
RNGB	38.0%	9.8%	32.5%	9.2%	10.2%	20.8%
URBN	0.4%	0.5%	0.4%	0.4%	0.4%	0.5%
WATR	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
WETL	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
AGRE	0.0%	0.0%	0.0%	0.0%	0.0%	2.3%
AGRT	0.0%	0.0%	0.0%	0.0%	0.0%	0.2%

Gurabo Basin = Subbasin 13	2003	BAU	BMP	CON	DEV	MIX
AGRD	0.0%	0.0%	0.0%	0.0%	0.0%	8.6%
SILE	0.0%	0.0%	0.5%	0.0%	0.0%	0.0%
SILT	0.0%	0.0%	0.8%	0.0%	0.0%	0.0%
SILD	0.0%	0.0%	4.5%	0.0%	0.0%	0.0%
MINE	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
TRIN	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
TOUR	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

Downstream from Presa Moncion and Upstream from Contraembalse Presa Moncion = Subbasin 14	2003	BAU	BMP	CON	DEV	MIX
AGRC	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
AGRL	5.2%	0.0%	0.0%	0.0%	0.0%	0.0%
OTHER using AGRL	0.0%	55.6%	7.0%	52.7%	55.6%	25.3%
COFF	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%
EXPORT using COFF	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%
FRSE	0.1%	0.0%	2.3%	2.3%	0.0%	0.0%
FRST	4.7%	1.5%	2.2%	1.6%	1.5%	0.8%
FRSD	32.8%	22.2%	27.3%	22.3%	22.2%	1.2%
ORAN	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
PAST	18.6%	4.8%	16.7%	5.0%	4.7%	9.1%
RICE	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
RNGB	36.5%	13.9%	34.9%	14.0%	14.1%	17.7%
URBN	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%
WATR	1.8%	1.8%	1.8%	1.9%	1.8%	1.8%
WETL	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
AGRE	0.0%	0.0%	0.0%	0.0%	0.0%	18.4%
AGRT	0.0%	0.0%	0.0%	0.0%	0.0%	2.2%
AGRD	0.0%	0.0%	0.0%	0.0%	0.0%	23.3%
SILE	0.0%	0.0%	0.3%	0.0%	0.0%	0.0%
SILT	0.0%	0.0%	2.2%	0.0%	0.0%	0.0%
SILD	0.0%	0.0%	5.0%	0.0%	0.0%	0.0%
MINE	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
TRIN	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
TOUR	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

Upstream from Moncion Reservoir = Subbasin 21	2003	BAU	BMP	CON	DEV	MIX
AGRC	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
AGRL	0.7%	0.0%	0.0%	0.0%	0.0%	0.0%
OTHER using AGRL	0.0%	4.5%	1.0%	4.3%	4.4%	1.5%
COFF	8.7%	0.0%	0.0%	0.0%	0.0%	0.0%
EXPORT using COFF	0.0%	8.8%	7.7%	8.5%	8.8%	5.3%
FRSE	45.9%	45.3%	47.5%	45.7%	45.3%	50.6%
FRST	31.6%	31.1%	30.9%	31.1%	31.1%	31.3%
FRSD	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%
ORAN	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
PAST	6.2%	4.7%	5.4%	4.7%	4.8%	5.4%
RICE	0.0%	0.2%	0.0%	0.2%	0.2%	0.0%
RNGB	4.6%	3.3%	3.5%	3.1%	3.3%	3.6%
URBN	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%
WATR	1.9%	2.0%	2.1%	2.1%	2.0%	2.0%
WETL	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
AGRE	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
AGRT	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%
AGRD	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
SILE	0.0%	0.0%	1.0%	0.0%	0.0%	0.0%
SILT	0.0%	0.0%	0.6%	0.0%	0.0%	0.0%
SILD	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
MINE	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
TRIN	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
TOUR	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

Downstream from Bao reservoir and Upstream from Angostura reservoir = Subbasin 23	2003	BAU	BMP	CON	DEV	MIX
AGRC	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
AGRL	11.1%	0.0%	0.0%	0.0%	0.0%	0.0%
OTHER using AGRL	0.0%	88.3%	18.5%	87.2%	88.1%	78.0%
COFF	0.3%	0.0%	0.0%	0.0%	0.0%	0.0%
EXPORT using COFF	0.0%	0.0%	0.2%	0.0%	0.0%	0.1%
FRSE	3.8%	0.1%	6.7%	7.4%	0.0%	0.0%
FRST	8.2%	0.0%	3.8%	0.0%	0.0%	0.0%
FRSD	11.6%	0.1%	5.7%	0.1%	0.1%	0.0%
ORAN	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
PAST	21.2%	0.1%	14.5%	0.1%	0.1%	0.8%

Downstream from Bao reservoir and Upstream from Angostura reservoir = Subbasin 23	2003	BAU	BMP	CON	DEV	MIX
RICE	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
RNGB	39.9%	1.1%	33.2%	1.2%	1.1%	4.6%
URBN	1.2%	7.5%	1.1%	1.1%	7.8%	8.0%
WATR	2.8%	2.9%	2.9%	3.0%	2.9%	2.9%
WETL	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
AGRE	0.0%	0.0%	0.0%	0.0%	0.0%	2.9%
AGRT	0.0%	0.0%	0.0%	0.0%	0.0%	1.1%
AGRD	0.0%	0.0%	0.0%	0.0%	0.0%	1.6%
SILE	0.0%	0.0%	4.3%	0.0%	0.0%	0.0%
SILT	0.0%	0.0%	3.7%	0.0%	0.0%	0.0%
SILD	0.0%	0.0%	5.5%	0.0%	0.0%	0.0%
MINE	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
TRIN	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
TOUR	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

Upstream from Bao Reservoir - Rio Bao = Subbasin 27	2003	BAU	BMP	CON	DEV	MIX
AGRC	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
AGRL	1.7%	0.0%	0.0%	0.0%	0.0%	0.0%
OTHER using AGRL	0.0%	23.2%	1.4%	22.3%	17.9%	14.3%
COFF	14.7%	0.0%	0.0%	0.0%	0.0%	0.0%
EXPORT using COFF	0.0%	14.3%	14.1%	14.4%	12.9%	10.8%
FRSE	39.0%	36.9%	37.8%	37.6%	36.5%	40.3%
FRST	16.8%	12.8%	14.9%	12.8%	12.2%	12.5%
FRSD	0.5%	0.1%	0.3%	0.1%	0.0%	0.0%
ORAN	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
PAST	19.9%	9.9%	19.3%	9.8%	9.3%	13.0%
RICE	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
RNGB	6.6%	2.1%	6.3%	2.1%	2.0%	3.3%
URBN	0.0%	0.1%	0.0%	0.0%	0.4%	0.1%
WATR	0.7%	0.8%	0.8%	0.8%	0.8%	0.8%
WETL	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
AGRE	0.0%	0.0%	0.0%	0.0%	0.0%	2.3%
AGRT	0.0%	0.0%	0.0%	0.0%	0.0%	2.3%
AGRD	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%
SILE	0.0%	0.0%	2.3%	0.0%	0.0%	0.0%

Upstream from Bao Reservoir - Rio Bao = Subbasin 27	2003	BAU	BMP	CON	DEV	MIX
SILT	0.0%	0.0%	2.6%	0.0%	0.0%	0.0%
SILD	0.0%	0.0%	0.2%	0.0%	0.0%	0.0%
MINE	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
TRIN	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
TOUR	0.0%	0.0%	0.0%	0.0%	7.9%	0.0%

Upstream from Tavera Reservoir - Rio Yaque del Norte = Subbasin 29	2003	BAU	BMP	CON	DEV	MIX
AGRC	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
AGRL	18.5%	0.0%	0.0%	0.0%	0.0%	0.0%
OTHER using AGRL	0.0%	51.2%	17.7%	47.9%	10.6%	17.4%
COFF	10.8%	0.0%	0.0%	0.0%	0.0%	0.0%
EXPORT using COFF	0.0%	11.3%	10.3%	11.0%	2.3%	7.8%
FRSE	14.6%	9.3%	10.7%	13.5%	4.4%	23.9%
FRST	38.5%	21.0%	22.4%	21.3%	6.0%	36.5%
FRSD	0.3%	0.0%	0.2%	0.0%	0.0%	0.0%
ORAN	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
PAST	3.0%	1.2%	2.8%	1.2%	1.0%	2.1%
RICE	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
RNGB	13.4%	4.1%	12.6%	4.0%	1.0%	9.0%
URBN	0.4%	1.1%	0.4%	0.4%	1.1%	0.4%
WATR	0.6%	0.8%	0.8%	0.8%	1.3%	0.8%
WETL	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
AGRE	0.0%	0.0%	0.1%	0.0%	0.0%	0.5%
AGRT	0.0%	0.0%	0.4%	0.0%	0.0%	1.5%
AGRD	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%
SILE	0.0%	0.0%	6.0%	0.0%	0.0%	0.0%
SILT	0.0%	0.0%	15.6%	0.0%	0.0%	0.0%
SILD	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%
MINE	0.0%	0.0%	0.0%	0.0%	5.9%	0.0%
TRIN	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
TOUR	0.0%	0.0%	0.0%	0.0%	66.5%	0.0%