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SUSTAINABILITY OF THE WATER RESOURCES OF A RIVER BASIN

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ABSTRACT

It was analyzed the effect of global climate changes at the *Papagayo river basin* area, a region located close to the cost of the state of *Guerrero* in the country of *Mexico*. Therefore, a general diagnosis of the basin was performed, including the assessment of its main physiographic features such as: hydrology, geology, geomorphology, climatology, soil, vegetation and fauna. The prediction of precipitations at 2, 5, 10, 20, 50, 100 and 500 years was performed based on mean annual rainfall records and using a statistical analysis of 8 probability distribution functions. These results were then used to calculate the maximum precipitation in 24 hr weighted mean in respect of each chosen area per climatologic station. The analysis of the 4 different proposed scenarios in climate change demonstrate that changes in precipitation expected by the year 2050 and 2080 will significantly affect the hydrologic cycle, and area drained by the *Papagayo river*. Based on the percentage of variation in precipitation obtained by these simulations, we obtained a series of polynomial models describing the percentage of variation in flow as a function of the precipitation rate in the region.

1. INTRODUCTION

Climate changes occurring at the planetary level are characterized by devastating environmental consequences such as droughts, floods, and changes in precipitation. Development and implementation of appropriate policies are required to counteract this global phenomenon. However, this global problem has local solutions. Each region of the world must promote measures against climate change in their countries. These, in turn, must promote the development of optimal policies, programs and local actions to reduce the effects of climate changes on their social and economic activities. These policies should also help populations to best adapt themselves to the new global climatic conditions.

In this study, the effects of global climate changes were analyzed in the *Papagayo river basin* area, a region pertaining to the 20th hydrological region located close to the cost of the state of *Guerrero* in the country of *Mexico*. Unfortunately, stresses on water resources in this area have been exacerbated due to the combination of factors including its scarcity and growing demand by local populations. Importantly, the *Papagayo river* basin includes in its territory the capital of the State of

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Guerrero, Chilpancingo, and therefore, possible changes in the future use of water, (i.e. irrigation, storage, supply populations, industrial and ecological use) are of major political relevance to this region. Indeed, the impact on the hydrological cycle by current climate changes will only aggravate social conflicts between populations disputing for water both locally and regionally.

Due to the already critical scarcity of water in most of the basins of the country, and the expectation that this situation will worsen in the coming years, it is necessary to analyze the availability of this resource at the current time, as well as to develop novel strategies aimed to lessen or eliminate conflicts arising by the dispute for water. In the South of *Mexico*, this problem will be magnified by the effects of climate change in the near future.

2. STUDY ZONE

The State of *Guerrero* is located at the south of *Mexico* facing the Pacific Ocean, between the 16°18' and 18°48' north latitude and the 98°03' and 102°12' west longitude. Although the whole of its territory is in the intertropical area, its complex geography makes possible the existence of multiple climate types.

Figure 1 Map of the geographical region of study located at the State of Guerrero in the country of Mexico.

The *Papagayo river basin* is the most important of the south-west region in *Mexico* and brings together the waters of the *Omitlán, Azul or Petaquillas and Papagayo* rivers. The later, flows into the waters of the Pacific Ocean, and in this basin is located *La Venta* hydroelectric dam.

Figure 2 Papagayo river basin

3. METHODS

ERIC 2 (fast weather information extractor) database was used to collect weather records prepared by the Mexican Institute of water technology. In this database, each station is assigned a name and its geographical coordinates for their location. The prediction of precipitations at 2, 5, 10, 20, 50, 100 and 500 years was performed based on mean annual rainfall records and using a statistical analysis of 8 probability distribution functions such as: exponential, 2 parameter gamma, Gumbel, Gumbel two populations, log-normal, Nash, normal and Pearson III in a computer program. These results were then used to calculate the maximum precipitation in 24 hr weighted mean in respect of each chosen area per climatologic station.

The resulting map of variation on precipitation for Mexico was obtained from the mean value of 10 recent simulations for global climate models response. These simulations were performed by seven climatic laboratories located in 6 different countries. Among the many existing models, the 7 most important are the Canadian Climate Center Model (CCCM), United Kingdom Meteorological Office Model (UKMO), United Kingdom Office Model run 1989 (UK89), Goddard Institute for Space Studies (GISS), Geophysical Fluid Dynamics Laboratory (GFDL), Hadley Centre Models (HADCMGHG and HADCMGHS), and include some derivatives of them such as CC-J1 (Boer et al., 1992; McFarlane et al., 1992), GFDL-A3 (Wetherland and Manabe, 1989), GFDL-X 2 (Manabe et al., 1991, 1992), UKMO-H3 (Mitchell et al., 1989)(GIECC, 2001).

Figure 3 presents the changes in average annual rainfall (percent change for the average climate 1961-90) for a period of 30 years between the decades of 2050 and 2080, for each of the four scenarios. Numbers on the grid display the change estimated in average annual rainfall for each model. Changes are only displayed in cases that are significantly different in respect to the variability of the annual precipitation in a 30 years period of time (Hulme et al., 1999).

Percentage values corresponding to the four different scenarios of climate change were selected accordingly to the location of the Papagayo river basin, as proposed in figure 3. These values were used to adjust the average annual precipitation values, as well as the percentage decrease in precipitation in respect to the percentage of decline in flow via a regression analysis.

The maximum flow was determined as a function of the return period, with variations predicted for different scenarios of reduced average percentage of annual precipitation. These maxima were obtained using the mean weighted by the maximum precipitation using Thiessen polygons in a 24 hours period of time.

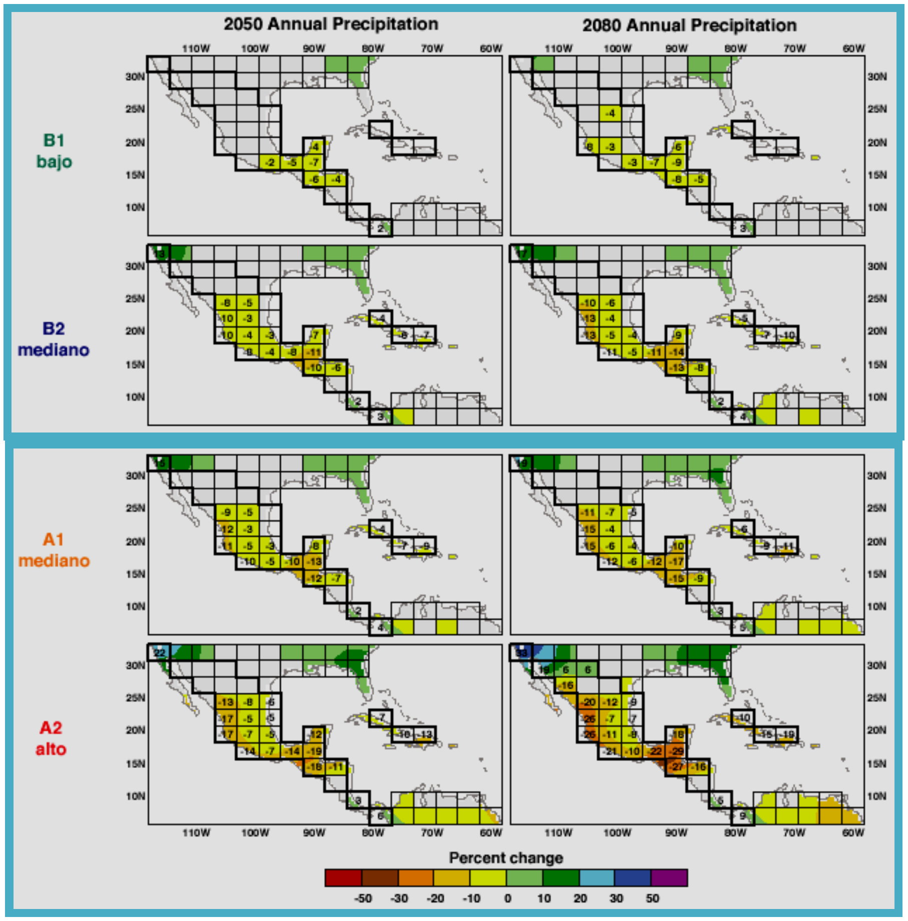

Figure 3 Changes in average annual rainfall (percent change for the average climate 1961-90) for periods of 30 years focusing on the decades of 2050 and 2080, for each of the four scenarios.

4. RESULTS

The analysis of the 4 different proposed scenarios in climate change demonstrate that changes in precipitation expected by the year 2050 and 2080 will significantly affect the hydrologic cycle, and area drained by the *Papagayo* river. Water availability at the *Papagayo* river basin will be importantly reduced due to the influence of the use by the City. Therefore, there is urgent need to take local measures to reduce the consequences of this prediction. Such policies should include the ecological conservation of the local ecosystem and a more rational use of the vital fluid.

The percentage of variation of rainfall rates used in this analysis was generated from the mean of 10 recent simulation models for global climate changes. These simulations were performed by 7 independent climate laboratories located across 6 different countries.

Based on the percentage of variation in precipitation obtained by these simulations, the following equations were obtained, which describe the percentage of variation in flow as a function of the precipitation rate in the region. The equations on variation in flow are shown for return periods of 2, 5, 10, 20, 50, 100 and 500 years.

For a return period of 2 years:

$$\%VQ = (5.567)(\%VP) + 2.6171 \tag{1}$$

$$\%VQ = (-0.1175)(\%VP)^2 + (6.9771)(\%VP) - 0.0073 \tag{2}$$

For a return period of 5 years:

$$\%VQ = (3.1772)(\%VP) + 0.5849 \tag{3}$$

$$\%VQ = (-0.0263)(\%VP)^2 + (3.4926)(\%VP) - 0.0022 \tag{4}$$

For a return period of 10 years:

$$\%VQ = (2.5032)(\%VP) + 0.5849 \tag{5}$$

$$\%VQ = (-0.0136)(\%VP)^2 + (2.6666)(\%VP) - 0.0014 \tag{6}$$

For a return period of 20 years:

$$\%VQ = (2.2363)(\%VP) + 0.2150 \tag{7}$$

$$\%VQ = (-0.0097)(\%VP)^2 + (2.3524)(\%VP) - 0.0011 \tag{8}$$

For a return period of 50 years:

$$\%VQ = (2.0299)(\%VP) + 0.1560 \tag{9}$$

$$\%VQ = (-0.0070)(\%VP)^2 + (2.1142)(\%VP) - 0.0009 \tag{10}$$

For a return period of 100 years:

$$\%VQ = (1.9228)(\%VP) + 0.1285 \tag{11}$$

$$\%VQ = (-0.0058)(\%VP)^2 + (1.9923)(\%VP) - 0.0008 \tag{12}$$

For a return period of 500 years:

$$\%VQ = (1.7571)(\%VP) + 0.0900 \tag{13}$$

$$\%VQ = (-0.0041)(\%VP)^2 + (1.8058)(\%VP) - 0.0006 \tag{14}$$

Where: VQ % = percentage decrease in flow, VP % = percentage decrease in precipitation.

Results from the regression analysis indicate that the model with the lesser error is the second order polynomial. Nevertheless, a linear regression has also shown acceptable results. It can also be noticed that the variation in flow increases as a function of the precipitation, indicating that the effects of the decrease in precipitation is magnified in respect to the flow. The analysis of the results of the implementation models suggest that the general trend in water flow predicts increasing droughts, especially in areas of very limited availability of water.

Table 1 Flow variation and runoff variation.

Flow variation	TR=	5	1	2	5	10	50
No	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Diminution of 4	26,0	13,5	10,4	9,2	8,3	7,8	7,1
Diminution of precipitation 5	31,9	16,8	12,9	11,5	10,3	9,8	8,9
Diminution of precipitation 7	43,0	23,1	18,0	15,9	14,4	13,6	12,4
Diminution of precipitation 8	48,3	26,2	20,4	18,2	16,4	15,5	14,1
Diminution of precipitation 12	66,7	38,1	30,0	26,8	24,3	23,0	21,0

Runoff variation	TR=	5	1	2	5	10	50
No	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Diminution of variation precipitation 4	26,0	13,5	10,4	9,2	8,3	7,8	7,1
Diminution of precipitation 5	31,9	16,8	12,9	11,5	10,3	9,8	8,9
Diminution of precipitation 7	43,0	23,1	18,0	15,9	14,4	13,6	12,4
Diminution of precipitation 8	48,3	26,2	20,4	18,2	16,4	15,5	14,1
Diminution of precipitation 12	66,7	38,1	30,0	26,8	24,3	23,0	21,0

5. CONCLUSIONS

The processes of deforestation and erosion of the *Sierra Madre del Sur* in the Papagayo river basin are a consequence of the reduction of water from rivers, lakes and dams, and the increase in the mudslides and sedimentation. Such changes in the ecosystem may stop the use of important energy sources for the country, such as the *La Parota* hydroelectric dam.

Provisions should be taken to ensure that sufficient water resources will be available in the future. Because of the local geography, water production in the area depends on the regional woods, forming the main superficial and underground hydrologic sources for the *Papagayo* River. It is thus critical to protect the natural hydrologic cycle, via the preservation of the forest at the *Sierra Madre del Sur*, re-foresting the woods, controlling fires, deforestation by nomad stockbreeding, extensive agricultural practices, etc. Ecological education should be promoted in the populations living in this region, through the financial funding of programs supporting environmental practices, appropriate management of water resources and natural resources.

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