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CLIMATE CHANGE IMPACT OVER THE HYDRAULIC RESOURCES OF THE PAPAGAYO RIVER BASIN IN MEXICO

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Summary Climate changes occurring at the planetary level are characterized by destructive environmental phenomenon such as droughts, floods, and changes in precipitation. However, this global problem has local solutions. Development and implementation of appropriate policies are required to counteract this global phenomenon. 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. The purpose of this study was to analyze the effects of global climate changes at the Papagayo river basin area, a region pertaining 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 using an analysis of Thiessen polygons in the Papagayo river basin. These values were used to adjust the average annual precipitation values using unit triangular hydrogram method, as well as the percentage decrease in precipitation in respect to the percentage of decline in flow via a regression analysis. 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. These models predict that the 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.

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.

2 DESCRIPTION OF THE STUDY AREA

2.1 Papagayo river basin

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 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.

2.2 Guerrero State, Mexico

The State of Guerrero is located south of Mexico facing the Pacific Ocean, between the 16o18' 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.

2.3 Papagayo river basin characteristics

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

2.4 Precipitation, floods and droughts

The volume of fluvial precipitations in this region is characterized by large contrasts across the year. The volumetric flow rate of the rivers in this basin drastically increases during the summer season, developing strong fluid flows that drag huge amounts of sediment, which, among other problems, produces the rapid sedimentation of dams. Moreover, precipitation gradients are not uniform during the summer. In particular, heavy rains occur especially when cyclones reach the region, resulting in river’s overflows and extensive land floods.

On the other hand, during the winter, river’s flow is greatly lowered, lots of streams dries out, exposing their gravel and sand. In cities like Chilpancingo, the restriction in water consumption became evident in recent years. The cycle repeats year after year, resulting in a huge water deficit in the winter that is mitigated when the rain season arrives. These rains are sufficient to sustain the consumption of fluid for several months and to partially recharge aquifers. However, they are not enough to remediate the winter drought, so the construction of more and better dams permitting an optimal management of after resources is critical to the region.

Figure 2 Papagayo river basin

3 HYDROLOGIC ANALYSIS

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, Gama 2 parameters, Gumbel, Gumbel two populations, log-normal, Nash, normal and Pearson III. These results were then used to calculate the maximum precipitation in 24 hr weighted mean in respect of each chosen area per climatologic station using an analysis of Thiessen polygons in the Papagayo river basin.

4 APPLICATION OF THE VARIATION IN CLIMATE CHANGE MODEL

4.1 Changes in average annual rainfall

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 using unit triangular hydrogram method, as well as the percentage decrease in precipitation in respect to the percentage of decline in flow via a regression analysis.

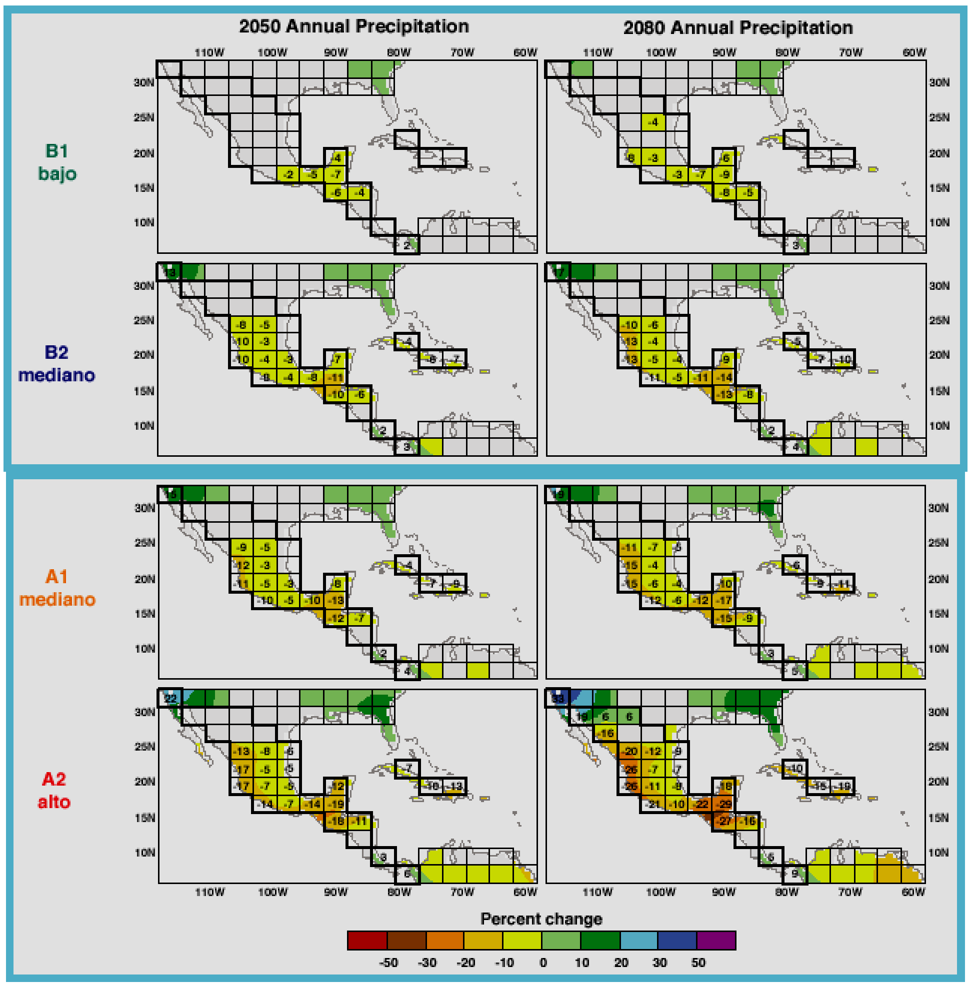

Figure 3: Changes in average annual rainfall (percent change for the average climate 1961-90) for periods of 30 years focusing on the decades of 2050 and 2080, for each of the four scenarios. Source: Hulme, M. and Sheard, N. (1999), scenarios of climate change to Mesoamerica, research climate unit, Norwich, UK.

4.2 Determination of the reduction in the percentage of flows of the basin

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.

In the table 1 summarizes rates decrease flows and runoffs to decreased precipitation for each period of return rates.

Flow variation percentage	Tr=2	5	10	20	50	100	500
No variation	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Diminution of precipitation 4%	26,00	13,54	10,44	9,25	8,34	7,87	7,16
Diminution of precipitation 5%	31,93	16,80	12,99	11,52	10,39	9,81	8,93
Diminution of precipitation 7%	43,08	23,16	18,00	15,99	14,46	13,66	12,44
Diminution of precipitation 8%	48,31	26,26	20,46	18,20	16,46	15,57	14,19
Diminution of precipitation 12%	66,79	38,12	30,04	26,83	24,36	23,07	21,08

Runoff variation percentage	Tr=2	5	10	20	50	100	500
No variation	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Diminution of precipitation 4%	26,00	13,54	10,44	9,25	8,34	7,87	7,16
Diminution of precipitation 5%	31,93	16,80	12,99	11,52	10,39	9,81	8,93
Diminution of precipitation 7%	43,08	23,16	18,00	15,99	14,46	13,66	12,44
Diminution of precipitation 8%	48,31	26,26	20,46	18,20	16,46	15,57	14,19
Diminution of precipitation 12%	66,79	38,12	30,04	26,83	24,36	23,07	21,08

Table 1 : Rates decrease flows and runoffs to decreased precipitation.

The runoff precipitation unchanged and for each reduction of precipitation that is -4%, -5%, -7%, -8%, and -12% for different periods of return is calculated in table 2.

As it is possible to be appreciated in the results, the effects that the diminution of the precipitation produces magnify in relation to the flow.

Based on the results of the implementation models there are indications that in areas of very limited availability of water possibly it could increase in future, although the overall trend is raising droughts.

	No variation		Diminution of the precipitation 4%	
	Tp = 10.74 h	Tb = 28.67 h	Tp = 10.74 h	Tb = 28.67 h
Tr	Flow	Runoff	Flow	Runoff
(years)	(m^3/s)	(Mm^3)	(m^3/s)	(Mm^3)
2	55,05	2,84	40,73	2,10
5	394,72	20,37	341,27	17,61
10	1009,18	52,08	903,79	46,64
20	1632,79	84,26	1481,74	76,47
50	2519,47	130,02	2309,32	119,17
100	3237,88	167,09	2982,93	153,94
500	4981,17	257,06	4624,71	238,66

	Diminution of the precipitation 5%		Diminution of the precipitation 7%	
	Tp = 10.74 h	Tb = 28.67 h	Tp = 10.74 h	Tb = 28.67 h
Tr	Flow	Runoff	Flow	Runoff
(years)	(m^3/s)	(Mm^3)	(m^3/s)	(Mm^3)
2	37,47	1,93	31,33	1,62
5	328,40	16,95	303,30	15,65
10	878,10	45,32	827,54	42,71
20	1444,73	74,56	1371,66	70,79
50	2257,62	116,51	2155,28	111,23
100	2920,08	150,69	2795,50	144,26
500	4536,55	234,11	4361,43	225,08

	Diminution of the precipitation 8%		Diminution of the precipitation 12%	
	Tp = 10.74 h	Tb = 28.67 h	Tp = 10.74 h	Tb = 28.67 h
Tr	Flow	Runoff	Flow	Runoff
(years)	(m^3/s)	(Mm^3)	(m^3/s)	(Mm^3)
2	28,46	1,47	18,28	0,94
5	291,06	15,02	244,25	12,60
10	802,67	41,42	706,07	36,44
20	1335,60	68,92	1194,66	61,65
50	2104,65	108,61	1905,82	98,35
100	2733,78	141,08	2490,83	128,54
500	4274,48	220,59	3930,96	202,86

Table 2: Runoff-precipitation unchanged and for each reduction of precipitation for different periods of return

5 EQUATIONS DEVELOPED

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:

$$\begin{gathered}\%VQ = (5.567)(\%VP) + 2.6171 \quad \text{(Linear)} \\ \%VQ = (-0.1175)(\%VP)^2 + (6.9771)(\%VP) - 0.0073 \text{ (Second degree polynomial)}\end{gathered} \tag{1}$$

For a return period of 5 years:

$$\begin{gathered}\%VQ = (3.1772)(\%VP) + 0.5849 \\ \%VQ = (-0.0263)(\%VP)^2 + (3.4926)(\%VP) - 0.0022\end{gathered} \tag{2}$$

For a return period of 10 years:

$$\begin{gathered}\%VQ = (2.5032)(\%VP) + 0.5849 \\ \%VQ = (-0.0136)(\%VP)^2 + (2.6666)(\%VP) - 0.0014\end{gathered} \tag{3}$$

For a return period of 20 years:

$$\begin{gathered}\%VQ = (2.2363)(\%VP) + 0.2150 \\ \%VQ = (-0.0097)(\%VP)^2 + (2.3524)(\%VP) - 0.0011\end{gathered} \tag{4}$$

For a return period of 50 years:

$$\begin{gathered}\%VQ = (2.0299)(\%VP) + 0.1560 \\ \%VQ = (-0.0070)(\%VP)^2 + (2.1142)(\%VP) - 0.0009\end{gathered} \tag{5}$$

For a return period of 100 years:

$$\begin{gathered}\%VQ = (1.9228)(\%VP) + 0.1285 \\ \%VQ = (-0.0058)(\%VP)^2 + (1.9923)(\%VP) - 0.0008\end{gathered} \tag{6}$$

For a return period of 500 years:

$$\begin{gathered}\%VQ = (1.7571)(\%VP) + 0.0900 \\ \%VQ = (-0.0041)(\%VP)^2 + (1.8058)(\%VP) - 0.0006\end{gathered} \tag{7}$$

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.

6 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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