

Addressing the impacts of climate change on the water resources of a small island: Case study – Mauritius

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ABSTRACT

Since the beginnings of concern over the possible consequences of global warming, it has been widely recognised that changes in the cycling of water between land, sea, and air could have very significant impacts across many sectors of the economy, society, and the environment. The characteristics of many terrestrial ecosystems, for example, are heavily influenced by water availability and, in the case of instream ecosystems and wetlands, by the quantity and quality of water in rivers and aquifers. Water is fundamental to human life and many activities, most obviously agriculture but also industry, power generation, transportation, and waste management, and the availability of clean water often is a constraint on economic development. Consequently, there have been a great many studies into the potential effects of climate change on hydrology (focusing on cycling of water) and water resources (focusing on human and environmental use of water). The possible changes in the water balance, for example, the changes in streamflow through the year; and the impacts of these changes for water resources, such as the reliability of a water supply reservoir or the risk of flooding and possible adaptation strategies are also very important. This study assesses our understanding of the implications of climate change for the hydrological cycle, water resources, and their management in a small isolated island.

Mauritius is an isolated island located in the Indian Ocean. Similar to other small islands, its contribution to green house gases is very small on the international level, but the impacts of climate change are likely to be very significant. Mauritius is already experiencing some of the impacts, such as; extreme events such as droughts, flood rainfalls, stronger cyclones, coastal erosion and more acute vector borne diseases. The present study illustrates the changes noted in climatic parameters over a period of 36 years and the impacts of these change on water resources capacity of the island. The island being isolated, has to find solutions to such problems, since it cannot rely on neighbours for help. For islands like Mauritius, adaptation to climate change is a must. Reuse of treated wastewater, leakage

detection, sensitization campaigns, water demand management techniques are likely to be beneficial for sustainable development of the limited water resources capacity. At this stage the island also needs to come up with its climate variability maps. This study has shown that a decrease in the climatic parameters, and consequently a decrease in annual recorded rainfall and this has a directly impact on the water resources capacity of the island.

INTRODUCTION

The Earth has experienced many changes during its 4.5 billion year life. There have been ice ages as well as periods of heat and low rainfall. The Earth is accustomed to experiencing widespread severe environmental change and it has always adapted to these changes. Since human beings have lived on this planet, they have coped with earthquakes, volcanic eruptions, tsunamis, droughts, floods, heat waves and mini-ice ages as well as numerous other forms of environmental hazards. Yet human beings have not had to cope with a warming of the planet at the speed and scale that is currently occurring and that is expected to increase over the coming decades and centuries. This warming is mainly due to an enhancement of the natural greenhouse effect causing Global Warming.

The natural greenhouse effect helps to regulate the temperature of our planet. It is essential for life on Earth and is one of Earth's natural processes. It is the result of heat absorption by certain gases, also known as greenhouse gases, in the atmosphere and re-radiation downward of some of that heat. Water vapor is the most abundant greenhouse gas, followed by carbon dioxide and other trace gases. Without a natural greenhouse effect, the temperature of the Earth would be about -180°C instead of its present 14°C . So, the concern is not with the fact that we have a greenhouse effect, but whether human activities are leading to Global Warming and Climate Change. Almost every person on the planet contributes to the climate change problem by driving cars, using air-conditioning or heating, because of the way our global society has developed. Fossil fuels are our main sources of energy but unfortunately when we burn fossil fuels we create the greenhouse gases that are significantly changing the climate.

The warming that we are experiencing is likely to bring about two main changes: a change in the average climate around the world, and a change in the incidence of extreme events. Warmer weather and seas will bring with them a range of impacts including: rising sea levels (from thermal expansion of the oceans), changing distribution of carriers of disease (such as

mosquitoes), an increased incidence of hot days, changes in rainfall patterns (making it harder to plan for dry seasons), and a more acidic ocean. Extreme events such as storm surges, flash floods and tropical cyclones could all potentially be exacerbated by the other changes in the climate. While there are regional differences in how climate change will manifest itself, in general it is likely that climate change will lead to both worse flooding in the rainy seasons, and worse droughts in the dry seasons. It is also likely to lead to more hot days, which could affect the elderly, the poor and the sick. Sea-level rise is already affecting coastal infrastructure, coastal populations and increasing the pressure on scarce land resources.

Climate change is expected to worsen existing vulnerabilities and create new vulnerabilities. Unfortunately, while small islands contribute only less than 1% of the global greenhouse gas emissions, they are likely to be the first to experience the worst effects of climate change, particularly through sea-level rise on low lying islands or through water shortages on porous and low lying islands. Clearly small islands, which are already vulnerable economically and physically, will be placed under increasing pressure by some of the impacts of climate change. If there is no immediate reduction in the global level of greenhouse gases, then small islands need to start preparing for the environmental risks associated with climate change for the next few centuries. Adaptation preparations to cope with the forthcoming risks are critical now.

ASSESSING VULNERABILITY TO CLIMATE CHANGE

Assessing the health and other effects of climate variability and climate change is critical for effective planning in small-island states. Because climate change, including extreme climate events, affects not only human health, but also agriculture, water supply, tourism, the coastal zone, and other aspects of island life, policymakers need to address climate variability and change within an integrated framework that includes assessing vulnerability, mitigating potential disasters, and building resilient communities.

Sustainable development, the “development that meets the needs of the present without compromising the ability of future generations to meet their own needs” is a very important concept for small islands. Small-island developing states are defined by their remoteness, their small size, their geographic dispersion, the fragility of their ecosystems, their heavy dependence on imports, and their lack of natural resources and skilled endogenous human

resources. In the year 1999, Mauritius faced the most severe drought of the past century. The dry spell started in November 1998, which should have been the beginning of the wet season, creating the serious drought conditions in Mauritius.

During the whole period of the dry spell lasting from November 1998 to December 1999, a rainfall deficiency of 50% as compared to the Long-Term Mean over the island was recorded (Table 1). Frequency analysis of annual rainfall data of Savinia, which is a station that has a long record of 120 years, was carried out in order to compute return periods of events. One conclusion, which is striking, is that rainfall in the hydrological year of 1998/1999 (starting November 1998) was the lowest among the data recorded during the past 120 years. Therefore, the severe dry spell can be qualified as the drought of the 20th Century in Mauritius.

Table 1 shows the cumulative rainfall for the period (November 1998-December 1999) for the 5 regions of Mauritius and their Long Term Mean.

Region	L.T.M Rainfall (mm)	1999 Rainfall (mm)	% of L.T.M
North	1508	588	39
South	2645	1358	51
East	2167	1492	69
West	1051	465	44
Central	2862	1343	47
Whole Island	2110	1059	50

The persistent deficiency in rainfall during the first three months of the hydrological year (November 1998-January 1999) affected river flows to a great extent. Water levels continued to drop from November 1998 to January 1999 and attained low levels records in January 1999, the lowest observed since 1972.

The below normal summer rains of February and March recharged the rivers only slightly. The rivers in the Northern part of the island were severely affected by the deficiency in rainfall. The winter rains that followed, however scarce, were beneficial to some rivers especially to those located on the windward slopes on the eastern and southern part of the island. The annual river flows during the 1998/99 hydrological year were very much below normal and generally varied between 15-45% of the normal.

The groundwater production for domestic purposes, from the boreholes located in the aquifers over the island stayed at normal level of 225, 000 m³/day till November 1998. The prolonged deficiency in rainfall during the November 1998-December 1999 period caused the groundwater production to decrease. Due to the depletion of storage in the aquifers the operation of six boreholes located in the north and south was interrupted. To compensate for the drop in groundwater, eighteen additional boreholes were put into operation as from January 1999 providing an additional volume of about 64, 000 m³/day. The total production including the yield from the additional boreholes was about 174, 000 m³/day corresponding to 77% of the normal.

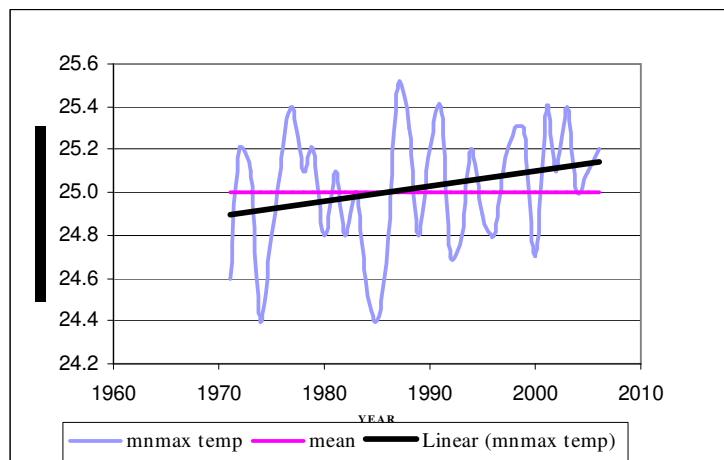
The levels in the surface reservoirs fell sharply due to lack of inflow. The rate of depletion of the storage levels was dramatic (Table 2). The storage level of the Mare-aux-Vacoas reservoir decreased by as much as 10Mm³ for the period 01 Nov 1998 to 31 Jan 1999 against 2Mm³ with normal inflow. La Nicoliere reservoir dropped by 1.8Mm³ during the same period attaining a storage of only 0.79Mm³ for that period. La Ferme and Mare Longue reservoirs were almost dry by the end of January 1999. The storage capacity in the five major reservoirs namely Mare-aux-Vacoas, La Nicoliere, Piton du Milieu, La Ferme and Mare Longue at the end of January 1999 was 14.5Mm³ representing only 28% of the total capacity at full reservoir level against a normal level of about 52% for the same period.

Table 2: Storage Variation of Reservoirs during 1999 Drought

		01.11.98		01.12.98		01.01.99		01.02.99	
Name of Reservoir	Capacity (Mm ³)	Mm ³	%	Mm ³	%	Mm ³	%	Mm ³	%
Mare-aux-Vacoas	25.89	22.58	87	19.05	74	15.44	60	12.31	48
La Nicoliere	5.26	2.55	48	1.64	31	1.06	20	0.79	15
Piton du Milieu	2.99	2.81	94	2.34	78	1.77	59	1.18	39
La Ferme	11.52	2.80	24	1.10	10	0.29	3	0.21	2
Mare Longue	6.28	3.13	50	1.70	27	0.00	0	0.00	0
Total	51.94	33.77	65	25.83	50	18.56	36	14.49	28

ANALYSIS AND DISCUSSION

Temperature, evaporation analysed for Climate river flow catchment W Feeder



rainfall and data were Vacoas Station and data for (La Ferme Canal). The

results of the analyses are discussed below:

MEAN MAXIMUM TEMPERATURE

The graph in Figure 1 shows the variation of the mean maximum temperature over 36 years. The mean is 25⁰C and the standard deviation is 0.29. This indicates that the values are well distributed about the mean. The trend line produced shows that there is a general increase in the mean maximum temperature. As discussed before, this increase is mainly due to Global Warming. This trend, in a way, confirms that our climate is changing.

Figure 1 – Long term variation of mean maximum temperature

To better assess the variation of the long term mean maximum temperature over time, the data for the 36-year period was broken into three groups of 12 years and their means were tested using ANOVA Analysis. If the P-value is greater than 0.05 then the means of the three groups of years are not equal. The P-value for the analysis of the mean maximum temperature is 0.44 and this confirms the change in temperature over the years.

MEAN MINIMUM TEMPERATURE

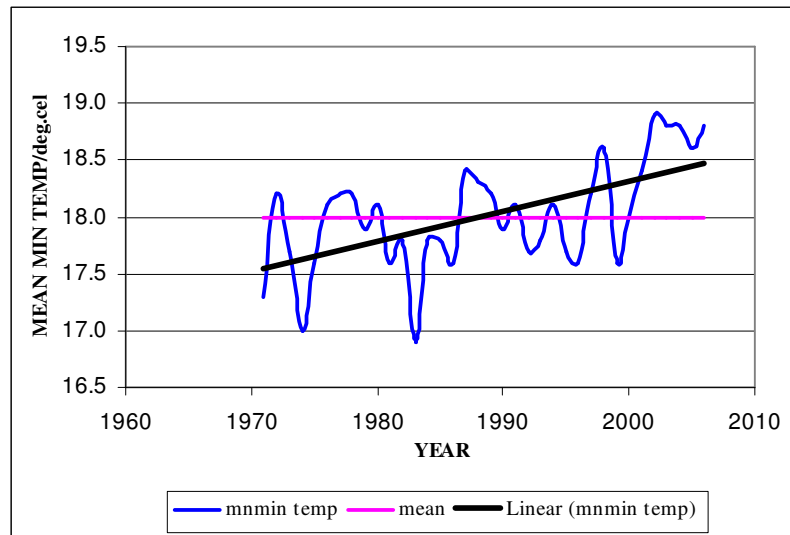


Figure 2 – Long term variation of mean minimum temperature

The above graph (Figure 2) shows the variation of the mean mini temperature over 36 years. The mean is 18⁰C and the standard deviation is 0.48. This indicates that the values are well distributed about the mean. The trend line produced shows that there is a general increase in the mean minimum temperature. This trend was expected as the mean maximum temperature is also increasing over the years.

Here also, the data for the 36-year period was broken into three groups of 12 years and their means were tested. The P-value is 0.01 (<0.05). This result indicates that the means of the three groups are equal. This, in turn, does not support that the mean minimum temperature has been increasing over time.

ANNUAL

RAINFALL

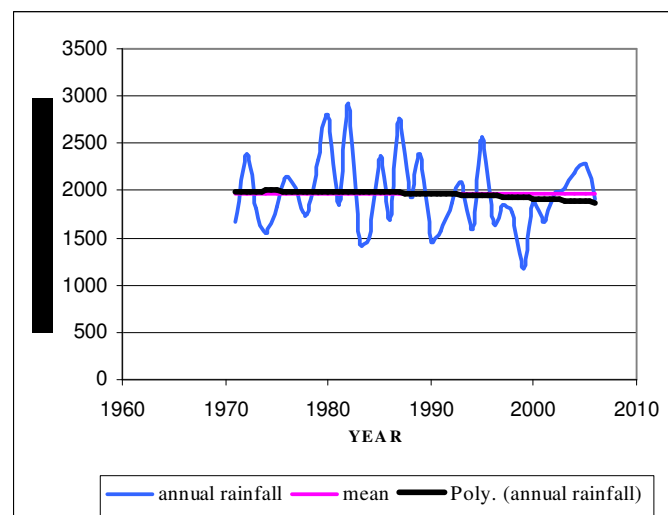


Figure 3 – Long term variation of mean annual temperature

The graph (Figure 3) shows the variation of the annual rainfall over 36 years. The mean is 1961.4 mm and the standard deviation is 409. The large value of standard deviation is due to large difference between the annual rainfall values. The trend shows that there is a decrease in the annual rainfall regime over the years.

The data for the 36-year period was broken into three groups of 12 years and their means were tested. The P-value is 0.45 (>0.05) and indicates that the means for the different groups are not the same. This confirms the decrease in the annual rainfall regime over time.

ANNUAL EVAPORATION

Figure 4 illustrates the variation of the evaporation over 36 years. The mean is 1537.8L and the standard deviation is 243.8. The large value of standard deviation is due to large difference between the evaporation values. The trend shows a decrease from year 1971 to 1990 but it can be seen that there is a slight increase from year 2000 to 2006. This is mainly due to the increase in temperature.

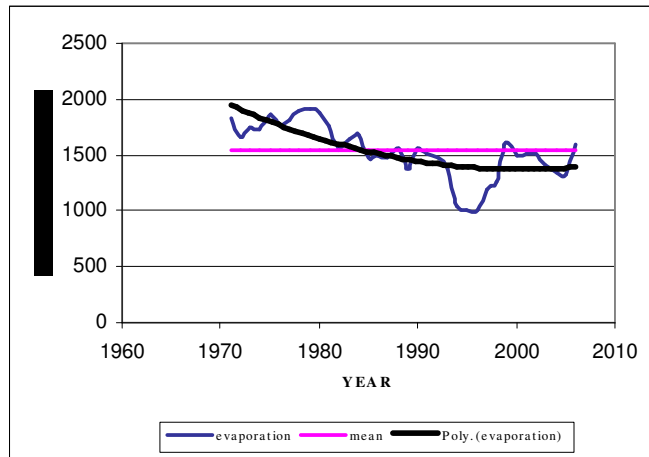


Figure 4– Long term variation of mean annual evaporation

The data for the 36-year period was broken into three groups of 12 years and their means were tested. The P-value is 0.07 (>0.05) and indicates that the means for the different groups are not the same. This confirms the change shown by the above graph.

SUMMARY OF THE ANOVA ANALYSIS

To get a better feel of the changes of the climate parameters over time, a seasonal analysis (summer and winter) was also carried out, and the results have been summarised in table 3.

Table 3: Summary Of The ANOVA Analysis

CLIMATE PARAMETERS	P-value
Mean Maximum Temperature (yearly)	0.44
<i>Mean Minimum Temperature (yearly)</i>	<i>0.01</i>
Mean Maximum Temperature (summer)	0.05
<i>Mean Minimum Temperature (summer)</i>	<i>0.01</i>
Mean Maximum Temperature (winter)	0.79
<i>Mean Minimum Temperature (winter)</i>	<i>0.02</i>
Annual Rainfall	0.45
Annual Evaporation	0.07

It can thus be concluded (table 3) that there is a change in the mean maximum temperatures over the years but not in the mean minimum. The P-values for annual rainfall and annual evaporation show that a change is occurring over the years.

FLOW OF LA FERME FEEDER CANAL

Having analysed the impacts of climate change on the climatic parameters, the next stage in this study was to analyse the impacts of climate change on the water resources, both surface water resources and groundwater resources.

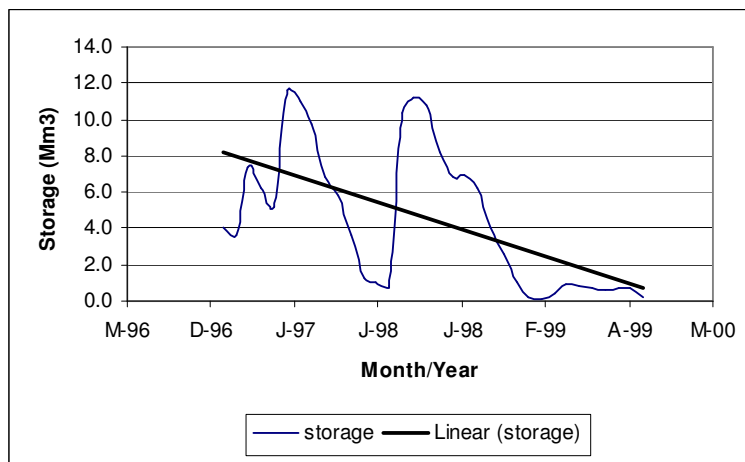


Figure5 – Annual flow at a surface water body

The monthly regulated flow of La Ferme Feeder Canal for the years 1997, 1998 and 1999 were plotted. A decrease in the regulated flow is observed. La Ferme Feeder Canal is fed by River Plaines Wilhems. Since there is human intervention on the flow of La Ferme Feeder Canal, the variation in its flow is not solely dependent on climate change but also on the policy of the flow regulating body.

STORAGE IN LA FERME RESERVOIR

The storage in La Ferme reservoir (Figure 6) was analysed for the same period as the analysis for the flow of La Ferme Feeder Canal. Again the trend shows that there is a drastic decrease in storage.

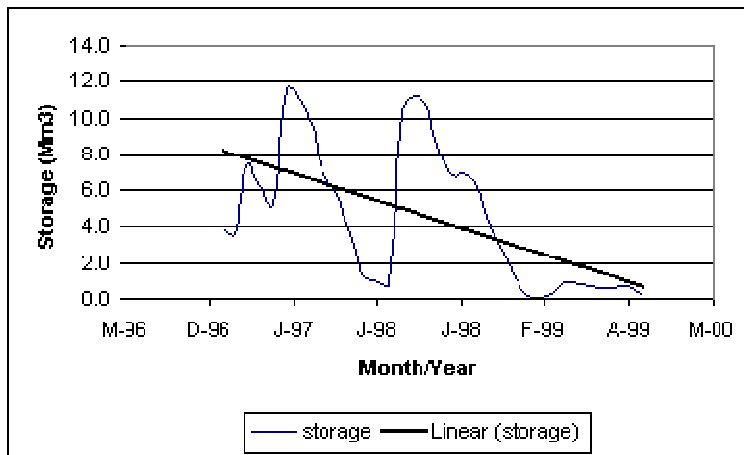


Figure 6 – Change in storage capacity of a natural reservoir

FLOW AND STORAGE ANALYSIS FOR THE WETTEST AND DRIEST MONTHS

Values of the wettest month (February) and the driest month (October) are quoted in the table below for the flow at La Ferme Feeder Canal and at La Ferme Reservoir were compared. It can be seen from Table 4 that for the wettest month, from year 97 to year 99, regulated flow has decreased considerably due to the 1999 drought and observed values shows that storage also has decreased. The same trend is observed for the driest month.

Table 4: Flow and Storage for Wettest and Driest Months

February	Flow (m³/s Days)	Storage (Mm³)
Year-97	17.817	3.6
Year-98	35.988	0.8
Year-99	4.568	0.1
October		
Year-97	0.723	5.8
Year-98	2.957	4.0
Year-99	0.100	0.2

CONCLUSION

The fact that the global mean temperature has increased since the 19th century and that other trends have been observed does not necessarily mean that an anthropogenic or human-induced effect on the climate system has been identified. Climate has always varied on all time-scales, so the observed change may be natural. The Secondary Assessment Report of the IPCC concluded nevertheless, on the basis of careful analyses, that “the observed change in global mean, annually averaged temperature over the last century is unlikely to be due entirely to natural fluctuations of the climate system. Can one attribute the detected change in climate to human activities, or could it also be due to natural causes? But that question is not of main consideration nowadays. Climate change has been detected and its impacts are affecting a large portion of the world’s population especially the Small Island States.

However, the uncertainty associated with climate change encourages skeptics to argue that policymakers cannot take action in anticipation of future trends or events. Small Island states do not have the luxury of non-action. They are currently coping with climate variability, and some are already coping with the effects of global warming. Mauritius is already facing the

consequences and impacts of climate change. For example, coastal erosion is already affecting a major part of the island and this is a major threat to the tourism industry. The water resources of the island are also severely affected by the change in climate. The availability of water for domestic and irrigation purposes is in danger of decreasing considerably as more frequent drought events are expected in the future.

The main area of concern nowadays is to find appropriate adaptation measures that will help reduce the impacts of climate change, be it short-term or long-term. For this to be successful, vulnerable areas must be identified and the severity of the impacts must be assessed. More frequent sensitization programs on the subject of climate change and its impacts on the water resources of the island must be made. It should be made clear in the mind of people that water is becoming a scarce commodity and that wastage must be prevented at all cost. Moreover groundwater production from boreholes located in the aquifers over the island must be used efficiently as groundwater is very important especially during drought periods.

The use of “gray water” for secondary household uses must be encouraged through a massive public education campaign. This has been done successfully in many countries and is fairly easy to implement. Mass Construction of household back-up rain-catchment tanks can prove to be very useful during drought conditions. However, water quality needs to be tested periodically. Efficient Water Resources Management Techniques need to be implemented to meet management objectives. The broad spectrum of techniques such as building a dam or managing demand is well known, but there is a need for research into opportunities for seasonal flow forecasting and innovative water supply and treatment technologies such as desalination.

Scenarios can be developed that are simplified, but plausible, descriptions of what might happen in the future, based on a coherent and internally consistent set of assumptions about driving forces and relationships. Climate forecasts can be used to prepare for climate variability and extreme events, and they can help policymakers build resilient communities and attain the goal of sustainable development.

Learning how to incorporate climate-forecast information (as part of decision information systems) into local planning is a challenge, but one well worth addressing. Forecast information coupled with a good vulnerability assessment will surely lead to appropriate

adaptation measures and this will help protect the health of island people and further the goal of sustainable development in small island states.

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