WATER SHORTAGE MANAGEMENT AND ADOPTATION TO CLIMATE CHANGE IN MALDIVES

Your Name : Fathmath Shaushan Moosa **Supervisor: Prof. Kuniyoshi Takeuchi**
Your ID (MEE 15626) **Dr.Akira Hasegawa**

ABSTRACT

Every years from January to April, Maldives experiences a dry period. It is in this period, the country faces a shortage in drinking water. To assess the problem, the precipitation, roof area, water storage capacity and population data was used in the studies. From the results, we came to an understanding that for the present time, increasing of the storage tanks can solve the problem. As there is enough precipitation in the rainy season, we need more storage space to store rainwater for the dry season.

The Future climate studies were done by using MRI-AGCM3.2S with RCP 8.5 scenario (greenhouse gas emission scenario, which has a high impact in the climate change). Daily precipitation data for future data between the years 2075 - 2099 was used. It showed an increase in the future rainfall but at the same time an increase in water shortages by 24% was also predicted in the future.

The future climate data was again studied further by SPI and cSPI approach. It showed that there will be an increase in the extreme events in the future. The extreme wetness as well as extreme water shortage were increasing. Implicating that there will be severe floods and severe water shortages in the future. According to the findings and results of these studies, we came up with some recommendations, which can be implemented by the government of Maldives and practiced by the inhabitants. There counter measures can be used to eradicate water shortages and to reduce flood risk in the Study area *Noonu Atoll* as well as other atolls of the country.

Keywords: *Rainwater harvesting, Water shortage, Climate change, Extreme events, SPI & cSPI approach*

INTRODUCTION

Water scarcity is a major problem in the world. Around 1.2 billion people in the world lives in areas of physical scarcity of water. (UNDESA, 2005). Because of the geography and topography of the country, it can be said that the Maldives is a country of physical scarcity of water. As it is, a small island nation made up with 1192 small coral islands, which is only 1% dry land out of its 90,000 km^2 area of the country. The country experiences equatorial tropical climate with an evenly distributed rainfall of 1924 mm of average annual rainfall. Out of the two monsoons, southwest monsoon has a wet period from May to November and the northeast monsoon has a dry period from January to March. It is in this dry period, the shortage of water is experienced throughout the country every year.

The main freshwater resource in Maldives occurs as groundwater embedded in basal aquifers, generally unconfined in nature, and extending below sea level in the form of a thin freshwater lens. (Maldives Water and Sanitation Authority, n.d.). These aquifers are vulnerable to excessive abstraction as well as contamination due to human activities such as pollution, improper sewage disposal, and saltwater intrusion owing to the freshwater-seawater interaction (Ministry of Housing Transport and Environment Government of Maldives, 2009). Because of vulnerability and high chance of contamination, groundwater is no longer a reliable source of drinking water. Another source of freshwater in Maldives is desalinated water, which is an expensive source of water for the population. Many technical issues that can lead to a huge water shortage in the country face the source. (e.g. the 04th December 2014 Male' water crisis.)

For these reasons, rainwater harvesting, which is practiced in the country for a long time is the most convenient and economical method of fresh water source in Maldives. The Maldives practice a roof top rainwater harvesting technique. It a low cost technique to collect domestic rainwater. Yet, precipitation is characterized by extreme variability and extreme events that propagate natural disasters such as floods, droughts, and storm surges. It gives a challenge in managing the rainwater to make it available all year round even in the dry season. Hence, the need to develop a plan thorough understanding of the trends and frequencies of such disasters that may cause water scarcity is in high priority .Apparently, rainfall is threatened by the climate change phenomena, which is increasing temporal and spatial variability in the patterns, amount, and distribution.

THEORY AND METHODOLOGY

This research work is mainly focused on assessing the water shortage and frequency and find the countermeasures for water shortage in the *Noonu Atoll* of Maldives. In order to achieve this, the study is divided into different phases. The first phase is to study the existing rainwater harvesting system in order to find out the gaps in the system and to come up with improvements that needs to be introduced into the system. This will be followed by a study, the historical rainfall data for this, *Hanimaadhoo* station rainfall data for the period from 1994-2015 will be used. The analysis will involve use of Standardized Precipitation Indices (SPI) in order to assess the frequency of shortages in water over the years and also water shortage and floods. We developed a model "Water Shortage Assessment Model" to assess severity of water taking into consideration the precipitation, roof area, and storage tank capacity and water demand. By the results we get from this model, we can understand how much water is being utilized and how much water is being thrown away as waste. After calibration and validation of the module, and comparing the results we can identify the root cause of water shortages in *Noonu Atoll*. It was also used to find the optimum storage needed for the atoll as well as the capacity needed for the different households as per the resident population. GCM data (General Circulation Model or Global Climate Model) was used to for the study of climate change in the area and predicting the future rainfall and water shortages. The data was based on MRI-AGCM3.2S, an atmospheric global climate model covering the whole world with spatial resolution of 20-km grid cell developed by Metrological Research Institute (MRI) of Japan Metrological Agency (JMA) The set of data that are to be applied for this studies are the daily precipitation data from year 1979 to 2003 and the future precipitation data that is from year 2075 to 2099. We considered using RCP8.5 scenarion in this study. It corrusponds to the pathway with the highest green house gas emission. Which has a high impact on climate change. (Riahi et al, 2011). Historical water shortages and floods were quantified using standardized indices of SPI. Future water shortages and floods were quantified using standardized indices of comparative Standard Precipitation Index cSPI approach. The same data set was used on the "Water Shortage Assessing Model" estimate the future water shortages, its frequency and severeness. Recommendations was made, on ways that can eliminate water shortages in the *Noonu Atoll* according to the results that was obtained from the models used in the studies.

DATA

The study area for this research is *Noonu Atoll* also known as *Miladhunmadulu Dhekunuburi*, which is one of the 26 Atolls, the country corresponding to the southern section of *Miladhunmadulu Atoll* and the northern most atoll of Maldives. *Noonu Atoll* is a code letter assigned to this atoll in the present administrative division. There are 71 islands in this atoll while 13 are inhabited islands. The total population of this 13 island is 11,229 according to 2014 census. The estimated total land area of this 13 island is 403.711 km^2. Most of the other important data collected for these studies include, observed precipitation data from five main stations of the country, roof area, storage capacity, population, Islands area. Most of these data are collected directly from government departments, the published materials, or internet and are sought after extensively.

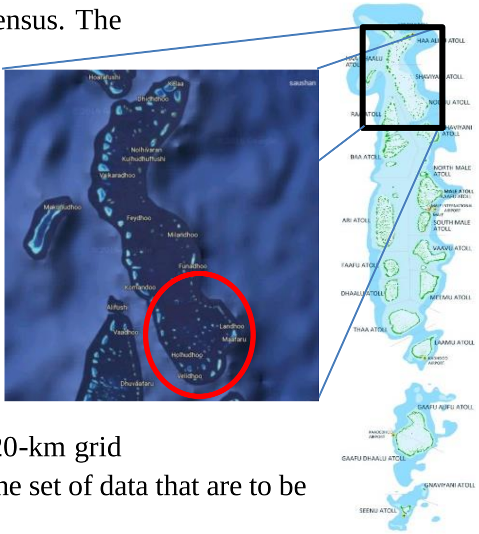
Figure 1: Study area (*Noonu Atoll*)

To understand the future impacts of climate change on precipitation was studies by using GCM data. The data is based on MRI-AGCM3.2S, an atmospheric global climate model covering the whole world with spatial resolution of 20-km grid cell developed by (MRI) of (JMA) (Ryo MIZUTA, 2012). The set of data that are to be applied for this studies are the daily precipitation data from year 1979 to 2003 and the future precipitation data that is from year 2075 to 2099. We considered using RCP8.5 scenarion in this study. It corrusponds to the pathway with the highest green house gas emission. Which has a high impact on climate change. (Riahi et al, 2011)

RESULTS AND DISCUSSION

Results of this study is based on the “Water Shortage Assessing Model” that was used to study the water shortages and frequencies. The observed precipitation data from *Hanimaadhoo* station for the study area *Noonu* Atoll was used. In the first section we concentrated on 2011 water shortage, since it was the year with the least average monthly rainfall for the first four months of the year and hence the year with the most severe water shortage in the recent days. Figure 2 shows the amount of water that was used from the water stored in the tank (orange bar) and the water in shortage (red line) and the amount of water that was spilled out (blue bar) due to less storage capacity. Although there is no / less rainfall in the first four months of the year, water shortage started to occur in the month of January. This is because of the rainwater that was collected and stored in last months of the year (2010).

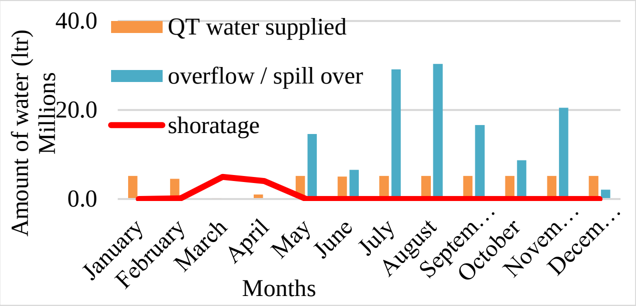

Figure 3: Water availability, overflow, and shortage graph for the year 2011

It showed that there was a water shortage of 14%. Only 27.8% of rainwater was harvested, the other 72.2% was spilled out because the storage tank was full at the time of rainfall.

The model was again used to determine the optimal storage capacity that was needed to avoid the water shortage for the year 2011. The same whether condition (precipitation data) was used and the storage volume was changed several times so that we can get a 0%

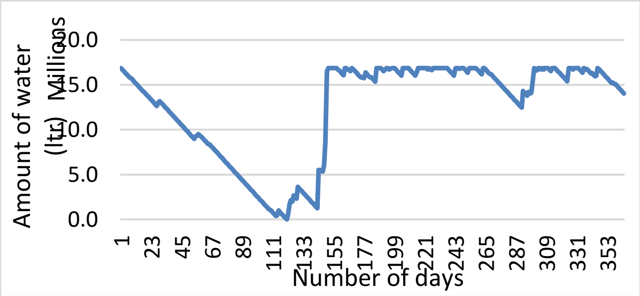

Figure 2: Daily water level in take after the tank capacity has been increased using the “Water Shortage Assessing Model” for the year 2011

water shortage for the year 2011. With a storage capacity of 16,859,000 liters, the water shortage was observed as “0%.” With the amount of increase in storage capacity 32.9% of rainwater was harvested, the other 67.1% of rainwater was spilled out. And with the increase in storage capacity the water shortages for the past years was also brought down to 0%.

Since rainwater, harvesting is an individual household effort, the optimal rainwater harvesting tank capacity and roof area needed for the individual households are also calculated. Assuming that the water demand is 15 L/d/p, and using the rainfall data from 1979 to 2015 (36 years). The calculations were made and the results are as in Table 1.

Table 1: Storage capacity and roof area need for the households depending on the size of the family

Household size (person)	**Roof Area (m2)**	**Storage tank size (Liters.)**	**Water demand (L/d/p)**	**Percentage stored in the tank**	**Percentage spill over**
4	30	5000	15	45%	55%
6	30	8000	15	68%	32%
7	35	8000	15	59%	41%
8	35	10000	15	77%	23%
10	40	20000	15	68%	32%

It shows a roof area between 30 m^2 and 40 m^2 and storage tank capacity from 5000 Ltrs to 20000 Ltrs that can be used to supply a household size of 4 to 10 people. The percentage of water that is collected in the tank and the percentage of water that is lost due to spillover due to the size of the catchment area and storage tank size can also be seen in the table. For example a household of 7 people, it would require a storage capacity of 8000 Ltrs capacity with a roof area of 35 m^2 to go through an year without running the storage tank dry. An amount of 59% of rainwater that is caught on the roof will be collected and stored in the storage tank.

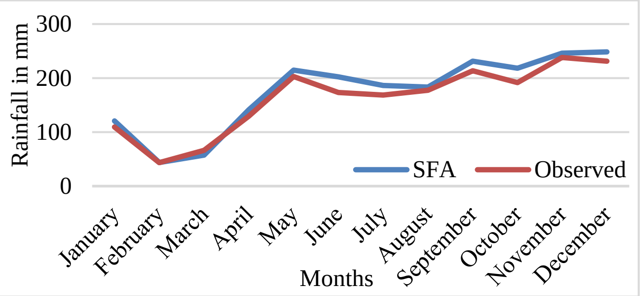

Figure 4: Monthly average rainfall – SFA future and observed

To understand the future impacts of climate change on precipitation was studies by using GCM data (Global Climatic Model). To do this the observed rainfall data for the *Hulhule* station was compared with the downscaled MRI-AGCM3.2S data under the current climatic condition. A simple bias correction was applied to the AGCM data to reduce the uncertainty of the data that may come from underestimation. The PGF data was used to bias correct the MIRI-AGCM3.2S data present data from 1979 to 2003 and future data from 2075-2099.

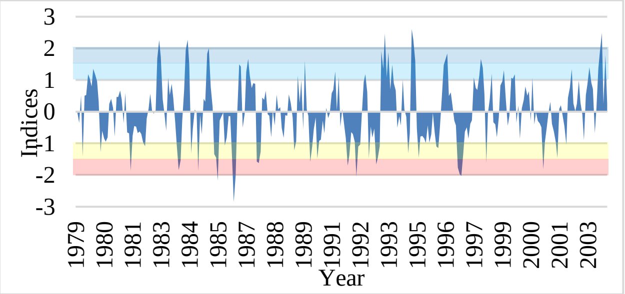

Figure 5: 3-month SPI of *Hulule* station

To analyze the future precipitation, the future (2075-2099) rainfall data for MRI-AGCM3.2S data was studied and compared with the current observed data from (1975-2003). Figure 4 shows an increase in the future rainfall from 1925 mm/y (present) to 2093 mm/y for the future yet the dry season from February to March remains as the driest months of the year.

SPI and cSPI approach was used to analyse the climate change assesment at 3-month timescale. It can be used to monitor the condition of drought (in this study will refer to as water shortage) or wetness in a variety of time scale. (World Meteorological Organization, 2012)

The SPI values indicated by the negative values mean a drier period and positive values means wetter periods based on climate conditions. In the graphs, the moderate dryness is shaded in light yellow while severe dryness is shaded in orange. Moderate wetness in shaded in blue and severe wetness is shaded in light blue.

The figure 5 shows the SPI of 3-month time scale for the observed precipitation data for *Hulule* station.

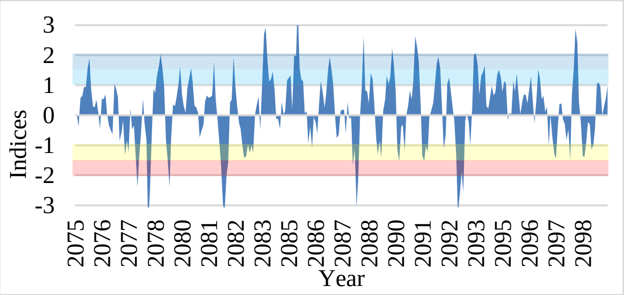

Figure 6: 3-month cSPI (2075 – 2099) of *Hulule*

For predicting the future water shortage and wetness, we used the cSPI approach for the climate change assessment. In estimating future climate and precipitation (Figure 6), we substitute the observed precipitation data with the future climate data for *Hulule* station, with MRI-AGCM3.2S in future 2075-2099. Referring to the SPI and cSPI data for the three months' time scale we calculated the probability of water shortages and wet conditions in the future with comparison to the present climate condition. By comparing the SPI and cSPI data, we can see that the future extreme events of both water shortage and wetness are increasing. Although the severe water shortages that we face every twenty years now will be less in the future, this is replaces by an extreme water shortage by once in every twenty seven years.

Table 2: Probability of water shortages and wetness in future with comparison to the present climate

SPI Values	Category	Present Condition	Future Condition
≥ 2.0	Extreme wetness	1/42 years	1/25 years
1.50 to 1.99	Severe wetness	1/21 years	1/12 years
0 to 1.49	Mild - Moderate wetness	1/7 years	1/6 years
0 to -1.49	Mild - Moderate water shortage	1/1 year	1/1 years
-1.50 to -1.99	Severe water shortage	1/20 years	1/42 years
≤ -2.0	Extreme water shortage	1/75 years	1/27 years

However, in case of wetness the severe and extreme events are increasing in the future. The probability of having a severe wetness or an extreme wetness in the future is more, compared to the present climate.

To estimate the future impacts of the water shortages, climate data of MRI-AGCM3.2S data for the present climate (1979-2003) and the future climate (2075-2096) was applied to the "Water shortage assessing model." Assuming the same population, storage capacity, and roof area. It shows (Figure 7) an increase of 24% of the future water shortage from year 2075-2096. Although there was an increase in the precipitation of the future climate data, we can see an increase in the water shortages as well. This maybe caused due to the extreme events, which was seen in the SPI and cSPI analysis.

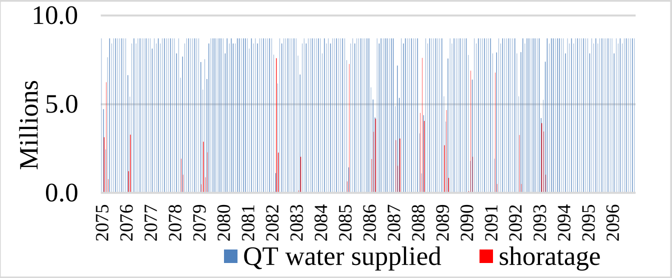

Figure 7: Monthly water supply and shortage with future data (2075-2096)

RECOMMENDATION

As the country has a high amount of precipitation in the rainy season, the best way to overcome the water shortage problem is to Increase the storage capacity of the islands. Therefore, that in the time of the dry season there will be enough water for consumption. One of the reason why people tend not to have a higher capacity of storage tanks is due to lack ground space. Since the storage tanks takes a lot of space from the less available space of ground. To address this issue, it is recommended to encourage people to have more of underground water tanks below the house. So that the land space can be used as well as the required amount of storage capacity can also be achieved.

Desalination plants can also be an alternative for the water shortage problem. Especially for the islands with a higher population density and where ground water is not an alternative for rainwater. However, it is recommended to encourage people to harvest rainwater. Since desalination of water is a costlier method. Therefore, we would suggest having at least one desalination plant per atoll so that the transport cost of water will be reduced than the present situation.

After a heavy rainfall, it is common to see stagnating water in the islands. At present, the water is pumped into the sea. It is recommended to have Infiltration pits, basins, and injection wells so that this water can be used to infiltrate recharge the aquifer.

ACKNOWLEDGEMENTS

I would like to express my gratitude to my supervisor Professor Kuniyoshi Takeuchi, advisor to International Centre for Water Hazard and Risk Management (ICHARM) for his unconditional guidance, support, suggestions, and patients through my individual studies and development of this master’s thesis. I am also thankful to Dr.Akira Hasegawa for sharing his time, knowledge, and advice and suggestions in the studies as a sub supervisor.

REFERENCES

A. Hasegawa, M. G. a. T. U. J. M. Y. I., 2015. *Drought assessment in the Pampanga River basin, the.* Gold Coast, Australia, 21st International Congress on Modelling and Simulation.

Akio Kitoh, H. E., March 2016. Changes in precipitation extremes projected by a 20-km mesh global atmospheric model. *Weather and Climate Extremes ,* Volume 11, p. 41–52.

Maldives meteorological service, 2016. *meteorology.gov.mv.*

Ministry of Housing and Environment water and senitation department, 2011. *An Assessment of Rainwater Catchment & Storage Capacity in the Maldives,* Male, Maldives: Ministry of Housing and Environment water and senitation department.

Moosa, F. S., 2015. *Maldives Country Report,* Kobe, Japan: Asian Disaster Reduction Centre.

UNDESA, U. N. D. o. E. a. S. A., 2005. *Internationa Decade for Action "Water for Life" 2005-2015.* [Online] Available at: http://www.un.org/waterforlifedecade/scarcity.shtml

K. T., 2012. A New Global Climate Model of the Meteorological Research Institute: MRI-CGCM3. *Journal of the Meteorological Society of Japan,* 90A (Meteorological Research Institute, Tsukuba, Japan), pp. 23-64

R. K. Parghane, S. P. K. A. D., 11-12 Nov. 2006. *Rain Water Harvesting and Recharging Ground Water.* Nagpur, National Seminar on Rainwater Harvesting and Water Management.

Riahi et al, K. R. S. K. V., 2011. RCP 8.5—A scenario of comparatively high greenhouse gas emissions. *Climate Change.*

Ryo MIZUTA, Hiromasa YOSHIMURA, 2012. Climate Simulations Using MRI-AGCM3.2 with 20-km Grid. *Journal of the Meteorological Society of Japan.,* Vol. 90A(Meteorological Research Institute, Tsukuba, Japan), pp. pp. 233--258.

Thomas B. McKee, N. J. D. a. J. K., 1993. *THE RELATIONSHIP OF DROUGHT FREQUENCY.* Anaheim, California, Department of Atmospheric Science.

World Meteorological Organization, 2012, *Standardized Precipitation Index User Guide.* Geneva, Switzerland: World Meteorological Organization (WMO).