

# Systematic Review of Non-Parametric Modelling Techniques on Effects of Climate Change on Availability of Water in Kenya

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**Abstract** The purpose of the study was to evaluate the effectiveness of adaptation measures taken by the Ministry of Water and Sanitation to combat the effects of climate change on availability of water in Kenya. Specifically the study sought to assess the effectiveness of water harvesting and storage measures in adapting to effects of climate change on water availability in Kenya, to assess the effectiveness of catchment protection in combating effects of climate change on water availability in Kenya, to explore the effectiveness of green technology in combating climate change effects on availability of water in Kenya, to suggest effective measures to combat the effects of climate change on water availability in Kenya. The study employed a case study research design where purposive sampling was used to determine the sample size of the respondents. Primary data was used which was collected using structured questionnaires. Descriptive such as frequencies and percentages were used to summarize data while inferential statistics such as correlation coefficient and regression were used to test non causal and causal relationships between variables respectively. It was established that there exists a statistically significant positive relationship between water harvesting measures, protection of water catchment areas, green technology and availability of water in Kenya. It was concluded that inadequacy of funds, gaps in policy, inadequate political goodwill, inadequate technical capacity and skills and inadequacy of technical capacity and skills were main barriers in protection of water catchment areas as adaptation measure of climate change. It was recommended that the National and County governments should ensure legislations are passed which would require residential and commercial constructions to be installed with water harvesting and storage facilities.

**Keywords** Climate change, Climate smart, Adaptation measures, Water harvesting, Non-parametric Techniques

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## 1. Introduction

### Background

Water-related ecosystems and the environment have always provided natural sites for human settlements and civilizations, bringing benefits such as transportation, natural purification, irrigation, flood protection and habitats for biodiversity. However, population growth, agricultural intensification, urbanization, industrial production and pollution, and climate change are beginning to overwhelm and undermine nature's ability to provide key functions and services [1]. More than 2 billion people live in countries experiencing high water stress. Climate change is severely impacting the hydrological cycle and consequently, water management. Global warming is likely to intensify,

accelerate or enhance the global hydrological cycle. According to [2] changes in precipitation, which higher average temperatures and temperature extremes are projected to cause, will affect water resources availability through changes in form, frequency, intensity and distribution of precipitation, soil moisture, glacier- and ice/snowmelt, river and groundwater flows, and lead to further deterioration of water quality. There is increasing evidence that this is already happening in many regions. The global picture, however, is complicated and uneven, with different regions, river basins and localities being affected in different degrees and in a variety of ways [3,4].

Policy response to climate change has been dominated by the need for mitigation. Although these measures can slow down climate change, they will not halt or reverse it [5]. Because the effects of climate change are inevitable in the short and medium term, adaptation needs to be addressed with the same urgency as mitigation [6]. Adaptation, as integrated into the Nairobi Work Programme of the United Nations Framework Convention on Climate Change (UNFCCC), relies on better understanding of the effects of

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climate change and on making informed decisions on how to cope with it. Water management, based on integrated and system wide approaches, is the key to climate change adaptation [5].

Effective adaptation not only requires that water is at the heart of national climate change adaptation strategies, but also that climate change adaptation is mainstreamed into existing national water policies, plans and funds. For effective adaptation, institutions should be strengthened and capacities built for holistic land and water management building on the principles of participation of civil society, equality and decentralization [2]. Accurate, consistent, timely and relevant information about water and climate needs should be widely available. Infrastructure must be designed to cope with climate uncertainty. Cost-benefit analysis of adaptation measures should consider all potential benefits, especially those related to health [7]. Technologies, appropriately adapted to local conditions, must be facilitated, and the capacity to implement and operate them supported [8].

According to [7] increased support is needed for adaptation actions through targeted financing and improved aid effectiveness. In the context of this study, therefore, effectiveness is the extent to which the climate change

adaptation measures being implemented are successful in increasing availability of water in Kenya, in the context of the outlined indicators.

This research aimed to evaluate the effectiveness of adaptive measures being undertaken to combat effects of climate change on availability of water in Kenya.

## 2. Material and Methods

### Conceptual Framework

The diagram below presents a conceptual framework for the effectiveness of climate change adaptation measures on availability of Water in Kenya [2,9]. The effectiveness of the measures was determined by looking at variables such as political goodwill, financing, time requirements, sustainability, policy, technical capacity, and public and stakeholder awareness among others.

In order to combat the effects of Climate Change and enhance availability of Water in Kenya, it is critical to apply adaptation measures such as water harvesting and storage, use of green technologies and protection of water catchment areas [3]. The research explored the effectiveness of these three adaptation measures.

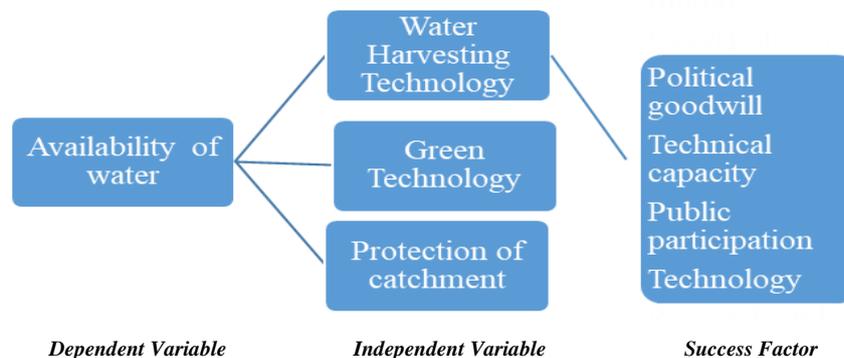


Figure 1. Conceptual Framework

The study's findings are likely to contribute towards realization of Sustainable Development Goal (SDG) 6 (six) that seeks to ensure availability and sustainable management of water and sanitation for all as well as SDG 13 which seeks to urgently combat climate change and its impacts. The findings may also provide valuable feedback to policy makers, practitioners and the general public [7].

### Assumptions

Assumption was made that the Ministry of Water and Sanitation is actively implementing certain adaptation measures in attempting to ensure water availability in Kenya [10]. The study also assumed that enough data exists to sufficiently assess the effectiveness of the measures against the indicators, and that efficient implementation of these measures will result in increased water availability. Finally, an assumption was made that there existed a gap in the effectiveness of the various measures, and that through the

study it was possible to pinpoint where these gaps are and recommended potential solutions.

### Theoretical Framework

#### Approaches for Assessing Climate Change Adaptation Measures

A number of approaches have been employed to assess the effectiveness and adequacy of adaptation measures to climate change. The catastrophe theory for assessing water security under different management strategies has been applied. The model involves scenarios of future climate change and population growth and economic development [11].

Theoretical framework for Place-Based Climate Change Engagement is based on principles from place attachment theory, place-based education, free-choice learning, and norm activation theory. The framework demonstrates the power of engaging citizens in action-based learning at

physical, material places, which are also symbolic sites for inspiring political action and learning about climate change impacts [12].

This study adopted the planned adaptation to climate change approach. Planned adaptation to climate change means the use of information about present and future climate change to review the suitability of current and planned practices, policies, and infrastructure. Adaptation planning involves addressing questions such as: How will future climatic and non-climatic conditions differ from those of the past? Do the expected changes matter to current decisions? What is a suitable balance between the risks of acting (too) early and those of acting (too) late? Eventually, adaptation planning is about making recommendations about who should do what more, less, or differently, and with what resources.

### Empirical Review

#### Effectiveness of water harvesting and storage in adapting to effects of climate change on availability of water in Kenya

While population growth increases water requirements by about 1,300 m<sup>3</sup> per capita per year for each additional person, climate change is projected to have regionally different effects on water availability. Increasing temperatures will increase agricultural water demand everywhere, whereas changes in precipitation vary strongly from region to region and also among climate models and emissions scenarios.

#### Effectiveness of catchment protection to combat effects of climate change on water availability in Kenya

According to [4,13] Land use and climate change may pose additional challenges to water management in the future. In order to assess the impacts of environmental change, the NRM3 Stream flow Model, a simple, semi-distributed, grid-based water balance model, was evaluated as a tool for discharge prediction in six meso-scale catchments on the western slopes of Mt. Kenya, and used to analyze the impact of land use and climate change scenarios on water resources. The results of the scenario analysis show that cultivation or degradation of natural land cover types in this area result in higher runoff, mainly in increased high flows. The reduction of low flows through reduced groundwater contributions under cropland is comparably small, but still worrying given the scarcity of water in dry periods already experienced under current conditions – and irrigation water demand would greatly increase if more land was turned to cropland. Modeling results also indicate that deforestation in the upper forest zone might have the greatest influence on low flows. Climate change, according to the GCM predictions applied here, has a much larger impact on the water resources in the area than land use change. This corresponds to the results of other combined land use/climate change impact assessments in Tropical Africa [14].

### Green technology as an adaptation measure of climate change in Kenya

Many agricultural practices and technologies such as minimum tillage, different methods of crop establishment, nutrient and irrigation management and residue incorporation can improve crop yields, water and nutrient use efficiency and reduce Greenhouse Gas (GHG) emissions from agricultural activities.

## 3. Results and Discussion

### Sample Size, Tools and Interpretation

Purposive sampling was employed to identify 105 policy and technical level personnel from the Ministry of Water and Sanitation and its Agencies. These were identified based on their functions in policy formulation and direction.

The study utilized both quantitative data in the form of ordinal scales acquired through use of structured questionnaires. Primary data was used which was collected using structured questionnaires that were closed-ended. Likert scale questions were employed to measure correlation/regression between the variables.

Descriptive statistics such as frequencies and percentages were used to summarize data while inferential statistics such as a correlation coefficient and regression analysis were used to test non-causal relationship (correlation) and causal relationship respectively between independent variables and the dependent variable. The following regression model was applied:

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \varepsilon$$

Where  $Y$  = Availability of water

$\beta_0$  = regression constant or  $Y$  intercept

$\beta_1, \beta_2, \beta_3$  = Beta coefficients for independent variables

$X_1$  = water harvesting and storage measures

$X_2$  = protection of water catchment areas

$X_3$  = green technology

$\varepsilon$  = Stochastic Error term assumed to be normally distributed

### Response Rate

Out of 105 questionnaires that were distributed to the respondents, 99 were returned and dully filled. This represented a response rate of 94.2%.

### Demographic representation

Table 1. Age

	Frequency	Percent	
	less than 30 years	22	22.2
	31-40 years	40	40.4
<b>Valid</b>	41-50 years	22	22.2
	above 51 years	15	15.2
	Total	99	100.0

## Gender Representation

**Table 2.** Gender

		Frequency	Percent
Valid	male	71	71.7
	female	28	28.3
	Total	99	100.0

## Highest Education Level Representation

**Table 3.** Highest Level of Education

		Frequency	Percent
Valid	certificate	3	3.0
	diploma	23	23.2
	bachelor degree	47	47.5
	masters	24	24.2
	PhD	2	2.0
	Total	99	100.0

## Institution Representation

**Table 4.** Name of your Institution

		Frequency	Percent
Valid	ministry of water	29	29.3
	water agency	18	18.2
	water services trust fund	19	19.2
	department of water county	22	22.2
	water resource authority	9	9.1
	Other	2	2.0
	Total	99	100.0

## DESCRIPTIVE STATISTICS AND DISCUSSIONS

### Testing the relation between measures taken to combat effects of climate change and availability of water

The study examined non-causal and causal relationship between measures taken to combat effects of climate change (independent variables) and availability of water (dependent variable).

### Correlation Analysis

The study examined non-causal relationship (correlation) between the independent variables and the dependent variable using Pearson Correlation. According to [15] correlation results are between -1 and 1. A result of -1 means that there is a perfect negative correlation between the two values, while a result of 1 means that there is a perfect positive correlation between the two variables. Result of 0 means that there is no correlation between the two variables.

As presented on table 5, there exists positive significant correlation between water harvesting and storage and availability of water in Kenya ( $r = 0.623$ ,  $p < 0.05$ ). The results also show that there exists positive significant non-causal relationship between protection of water catchment areas and availability of water in Kenya ( $r = 0.537$ ,  $p < 0.05$ ). Further, it was established that the correlation between green technology and availability of water in Kenya was positive and statistically significant ( $r = 0.661$ ,  $p < 0.05$ ). The statistically positive correlation results reported indicate that, when water harvesting and storage, protection of water catchment areas and green technology increases or are enhanced, availability of water in Kenya will increase though the direction or quantity of increases is not definite (non-causal relationship).

**Table 5.** Correlations

		Water harvesting and storage	Protection of water catchment areas	Green technology	Availability of water
Water harvesting and storage	Pearson Correlation	1			
	Sig. (2-tailed)				
	N	99			
Protection of water catchment areas	Pearson Correlation	.418	1		
	Sig. (2-tailed)	.159			
	N	99	99		
Green technology	Pearson Correlation	.662	.555	1	
	Sig. (2-tailed)	.040	.126		
	N	99	99	99	
Availability of water	Pearson Correlation	.623*	.537*	.661*	1
	Sig. (2-tailed)	.006	.000	.020	
	N	99	99	99	99

\*. Correlation is significant at the 0.05 level (2-tailed).

**Regression Analysis**

A multiple regression analysis was carried out to establish the joint causal relationship between measures taken to

combat effects of climate change (independent variables) and availability of water (dependent variable).

**Table 6.** Model Summary<sup>b</sup>

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	R Square Change	Change Statistics			Sig. F Change	Durbin-Watson
						F Change	df1	df2		
<b>1</b>	<b>.679<sup>a</sup></b>	<b>.678</b>	<b>.549</b>	<b>.54313</b>	<b>.678</b>	<b>33.139</b>	<b>3</b>	<b>95</b>	<b>.000</b>	<b>1.851</b>

a. Independent: (Constant), green technology, water harvesting and storage, protection of water catchment areas

b. Dependent Variable: availability of water

The table above present the goodness of fit for the regression between the independent variables and the outcome variable (Dependent variable). The overall R<sup>2</sup>= 0.58678 which indicates 67.8 percent of the variation in the dependent variable (availability of water in Kenya) is explained by the independent variables (measures taken to combat effects of climate change) that are included in the model. The remaining 32.2% variation in the dependent

variable is explained by other factors not included in the model denoted by (ε) in the model. Further, the Durbin-Watson statistic value of 1.851 indicates that there is no autocorrelation in the residuals from the statistical regression analysis. Durbin-Watson statistic ranges in value from 0 to 4 with an ideal value of 2 indicating that errors are not correlated.

**ANOVA**

**Table 7.** ANOVA<sup>a</sup>

Model		Sum of Squares	df	Mean Square	F	Sig.
<b>1</b>	Regression	58.085	3	19.362	65.633	.000 <sup>b</sup>
	Residual	28.097	95	0.295		
	Total	86.182	98			

a. Dependent Variable: availability of water

b. Independent Variable: (Constant), green technology, water harvesting and storage, protection of water catchment areas

The ANOVA results on Table 7 results show that the mean square of the residuals is small (0.295) compared the mean square of the regression (19.362). Further, the F-statistics of the regression (F<sub>(3, 95)</sub> = 65.633) whose probability value is 0.001 which is less than the conventional

probability value of 0.05, indicate that the model is good and significantly fitted to explain the relationship between variables the independent variables and the dependent variable in the study.

**CO-EFFICIENTS**

**Table 8.** Coefficients<sup>a</sup>

Model		Unstandardized Coefficients		Standardized Coefficients		t	Sig.
		B	Std. Error	Beta			
<b>1</b>	(Constant)	2.828	0.445			6.3551	.002
	Water harvesting and storage	.470	.198	.343		2.373	.000
	Protection of water catchment areas	.336	.119	.238		2.823	.016
	Green technology	.350	.127	.203		2.755	.006

a. Dependent Variable: availability of water

From the findings on table 8 the regression equation was obtained using the unstandardized beta coefficients in determining how the dependent variable varies as a result of a unit change in the independent variables. The following regression equation was obtained;

$$AVWT=2.828+0.470 WAHS +0.336 PWCA + 0.350 GTEC +\epsilon$$

Where:

AVWT- availability of water in Kenya

WAHS- Water harvesting and storage

PWCA- Protection of water catchment areas

GTEC- Green technology

ε- Other factors not included in the model that can explain change in availability of water in Kenya

## 4. Conclusions

### Effectiveness of Water Harvesting and Storage Measures

It was concluded that water harvesting and storage measures have a significant effect on adapting to effects of climate change on water availability in Kenya. It was concluded that water harvesting and storage as an adaptation measure of climate change is not successful in Kenya. The National and County governments should ensure legislations are passed which would require residential and commercial constructions to be installed with water harvesting and storage facilities.

### Effectiveness of Water Catchment areas Protection

It was concluded that protection of water catchment areas has a significant effect on combating effects of climate change on water availability. It was concluded that protection of water catchment areas as an adaptation measure of climate is not successful in Kenya. Protection of water catchment areas is a sustainable measure of combating effects of climate change on water availability. Availability of funds, good policies in place, political goodwill, adequate capacity and skills and adequate public participation and awareness the main success factors in protection of water catchment areas as adaptation measure of climate change. It is recommended that the National Government through the Ministry of Water and Sanitation, and Ministry of Environment and Forestry should ensure protection and rehabilitation of water towers, and catchment areas. They should also sensitize the public on the merits of planting trees. Adequate funds ought to be allocated for this exercise and there should be a consensus among leaders in all political divide so as to ensure political goodwill.

### Effectiveness of Green Technology

It was concluded that green technology has a significant effect on combating effects of climate change on water availability. It was concluded that green technology as an adaptation measure of climate change was not successful in Kenya. Green technology is a sustainable measure of combating effects of climate change on water availability. Further, conclusions can be made that availability of funds, good policies in place, political goodwill, adequate capacity and technical skills and adequate public participation are the main success factors to green technology as an adaptation measure of climate change in Kenya. It was concluded that the Ministry of Water and Sanitation in collaboration with relevant stakeholders should adopt latest green technology in a bid to mitigate climate change. Adoption of such technologies could only be realized through adequate resource allocation, adequate technical capacity building and public participation and awareness.

Further, the study recommends that further studies be conducted on more potential predictors, since in this study, 32.2% of variance in dependent variable remained unexplained by the three conceptualized predictors.

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