*Asian Journal of Geographical Research*

***Volume 7, Issue 1, Page 58-68, 2024; Article no.AJGR.112034***
***ISSN: 2582-2985***

# The Impact of Water Abstraction on River Mutonga Discharge Over the Last 30 Years

**Padiel Mwirigi [a*], Kagendo Jane [a] and David Karienye [b]**

*[a] Mount Kenya University, Kenya.*
*[b] Garissa University, Kenya.*

***Authors' contributions***

*This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.*

***Article Information***

DOI: 10.9734/AJGR/2024/v7i1214

**Open Peer Review History:**
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/112034

***Original Research Article***

***Received: 23/11/2023***
***Accepted: 28/01/2024***
***Published: 01/02/2024***

## ABSTRACT

The declining water levels among rivers flowing through Tharaka Nithi County have been a major concern in the region for the last 30 years. The decline has adversely affected environmental sustainability, water resources, agriculture and the ecosystem. Understanding the relationship between rivers, change of climate and human activities are essential challenging areas. The research aimed to assess the impact of changed rainfall pattern and amount to the declining water levels in Mutonga River over years from 1990 to 2020 and it contribution to the changing water levels in river Mutonga. An exploratory survey and a correlational study were used to compile the data for this analysis. Three regional NEMA officials and three regional water resources authority officials were also surveyed, along with 270 residents in the River Mutonga area. The samples were based on 30% as per Mugenda Mugenda samples analysis. The rainfall and temperature data was acquired from the regional meteorological department based in Embu town. Data on river discharge was acquired from regional water resource authority (WRA) based in Meru town. The result may also recommend suitable practices for management of water resources and come up

**Corresponding author: E-mail: padielmwirigi@gmail.com;*

with disaster control measures in water sector. The local community may also benefit from the study by getting the right information on better methods of conserving water resources, the findings and recommendations from the study may be used as basis for future research related to this study. From the findings, results show that river Mutonga flows has been decreasing over the last 30 years, water abstraction trend has been rising over the entire period in three decades causing a tremendous decline in river discharge. climatic changes have been noted in the region with rainfall amount dropping significantly and temperatures increasing, this has led to decline of the river discharge due reduced rainwater adding to the rivers and increased evaporation rates which leads to loss of water from rivers to the atmosphere. The result from the research may be used to enlighten the County Government of Tharaka Nithi, in making decision, especially in development projects implementation and in the strategic plans of the County Government.

*Keywords: Water abstraction; irrigation; river flow; river discharge.*

## 1. INTRODUCTION

A growing global population and shifting weather patterns have put a damper on the availability of the world's many water sources, which has a profound impact on economic and social growth (Odhiambo, 2017). The world's population has increased at a high rate, resulting to an increased use of non-renewable resources by a factor of 30 (Mohsin et al*.,* 2019)*.*

Several natural and human made factors have been hypothesized as the key contributor of the big variations, and changes in water levels, particularly precipitation (natural) and activities associated with man such as water abstraction and water reservoirs constructions have significantly decreased and increased respectively. (Fenta et al*.,* 2017). Change in rainfall patterns and amount together with temperature variations over the years has led to frequent drought and enhanced evaporation resulting in reduced water levels in streams, natural springs, and lakes, and in turn has caused an increased decline in water levels in rivers globally [1,2].

In Tharaka Nithi majority of the rivers have been affected by uncontrolled water abstraction from rivers and drilling uncontrolled boreholes. These human activities lead to underground water depletion, which have significant effects on natural springs that feed rivers hence causing a majority of rivers to dry up (Esilaba, 2021).

Water is said to be the most abundant natural resource as it covers 70% of the earth, however the freshwater covers only 3%. It is a scarce natural resource that will need to support an anticipated population of 9.7 billion in the next three decades. Therefore, the challenge of declining water levels needs to be addressed earliest possible [3,4]. The rapidly declining water levels of rivers running through Tharaka Nithi county threaten the livelihood of approximately 393,177 of Tharaka Nithi residents that depend on these rivers for domestic and industrial use. Therefore, there is need to investigate the cause and the impact leading to decline of water levels among key rivers flowing through Tharaka Nithi County. Other rivers under threat include river Maara, and river Nithi, which have shown a significant decline in water levels in the last 30 years, Mutonga river being the most affected. Much of the water reduction in this river has been attributed to; change in rainfall pattern and amount and increased temperatures over the years [5-8]. However, the aspect of over abstraction of water either for agriculture, domestic or industrial use has not been given adequate attention in previous studies. This river stands a threat of drying up permanently if appropriate measures to combat the situation won't be put forward. The research is aimed to assess the impact of water abstraction on River Mutonga discharge over the last 30 years.

## 2. LITERATURE REVIEW

### 2.1 Water Abstraction

People have been abstracting water for thousands of years, some of the great civilizations like Egyptians [9]. China and the Inca culture of South America were based on a large-scale irrigation system involving water from rivers to farm fields [10]. In Mesopotamia, river emirates was among the rivers that were majorly involved in irrigation activities.

According to research by Kuriqi et al. (2021), man has greatly influenced several rivers globally Both reservoirs and water withdrawals result in decreased annual river flow values, affecting the seasonality of a river flow. For example, research done by Masaki et al. [11] showed, the construction of dams to provide water for irrigation resulted to a decline in season flows for the Krishna River in India. From the Krishna River, RAO has taken enough water to irrigate over 14.5 million acres of land in the districts of Prakasam, Krishna, Guntur, and West Godavari in Andhra (Pradesh (2018).

In South America, the Parana river average discharge is 17000 m^3/s however that has gone down to an average of 6200 cubic meters per second slightly above the recorded flow of 5800 recorded in 1994, That has be reduced by half due to dams constructed to generate electricity by the hydroelectric plants of Yacyreta that spans river Parana between Paraguay and Argentina. It supplies14 % of electricity used in Argentina. Olazar, et al., (2021). According to Olazar, et al., (2021), revealed that the reduction of water levels in the region has interfered with the fish reproduction process affecting the fish population in the region. In Africa due to river water abstraction by human, there has been a significant decline in annual discharge downstream (Veldkamp, et al., 2017). Water abstraction for agriculture in Zambezi River Basin (ZRB) has been the main economic activity in the region, irrigation farming is the main practice in the economies which is agricultural based of the basin countries where activities related to agriculture dominate countries such as Mozambique, Malawi, Tanzania, Zambia and Zimbabwe. The amount of water taken out of the river basin is proportional to the amount of arable land. for example, Malawi which has the largest land under crop cultivation abstract largest volumes of water from Zambezi River Basin (Dirwai, 2019).

In Mali there are several irrigation schemes using water withdrawn from river Niger. Some parts of the Office-Riz-Mopti (ORM) irrigation system are partly classic irrigation schemes (free flooding and recession flooding), as noted by Afouda et al. The "Office du Niger (ON)" irrigation plan was developed primarily for domestic use, particularly in flooded rice agriculture. Gravity transports water from the Markala dam on the River Niger to the main, secondary, and tertiary canals that make up ON's irrigation network (Mariko et al., 2017). He also noted that from 2001 to 2011, the two primary irrigation schemes received the vast majority of the monthly water withdrawals. Mopti was the site of the first irrigation project, which watered 3600 acres using water diverted from the river Bani (responsible Office –Riz Mopti (ORM). The second irrigation system uses water from the Markala dam, which is supplied by the river Niger, to irrigate an area of cropland (particularly rice) that is believed to be about 1,000,000 hectares in size (responsible "office du Niger (ON). There has also been a notable increase in regions with minimal water use or downstream of few controlled lakes where control results to reduced river flows, e.g., Lake katwe and Lake Victoria. Therefore, the decline of seasonal water volumes due to reservoirs is consistent (Dumka, et al., 2017).

In Kenya, Tana River Basin (TRB) is an example of a basin in which water conflict, reduced riverine habitat diversity and interference of agricultural production system associated with the construction of hydroelectric dams in 1980s is assumed to be the only variable to have modified the normal flow of the discharge of river Tana. The Tana River forms five dams from the upper part of the stream to the downstream, these large reservoirs have significantly altered the Tana River hydrological regime (Kibet, et al., 2019).

In Burguret river, the community water projects abstracted water from the river amounting to the approximately 21000m^3 per day or up to 97 percent of the normal dry season river flows, this was attributed to the land use system whereby the lower part of Burguret are smallholders parcels of cultivated land (Thomas, et al., 2018). Thomas also observed that seven out of 113 abstractors of water accounted for 83 percent of the total volume abstracted with the remaining percentage being abstracted by 106 small abstractors made up primarily of portable irrigation pumps. Due to these massive water project Environmentalist, claim that this water transfer upset natural balances of streams, lakes, estuaries and terrestrial ecosystem (William & woodland, 2016).

## 2.2 Study Area

The Mutonga River supplies a large portion of the water used in Tharaka, and by extension, the northern half of Meru County. The catchment has an area of nearly 72,000 $km^2$ (MRDA, 2016). The lower Catchment of Mutonga river has an approximate area of about 7,000 $km^2$ and altitude ranges from 400 m to 4800 m on Mt. Kenya. Rainfall, land use and soils varies with the changes in altitude. (MRDA, 2011).

Mutonga river has it origin in Ntua hill which is found within mount Kenya forest, the upper part of Mutonga river constituent's tributaries of north Maara, south Maara and Maara Manyi streams which later join river Thuci before finally its joins Tana river which end up draining into Indian ocean. Other minor tributaries of Mutonga river includes river Kithinu and river Iraru which joins the river upstream. The river flows in u shaped valleys at the youthful stage of its profile before it later connects to v shaped valleys with interlocking spurs. According to ESIA Project report (2019) The youthful and middle profile of Mutonga river is chaacteised by steep slopes with gradient falling From the highest point of Mount Kenya (5,200 masl) to the mouth of the Tana River is less than 100 kilometers (km), making the longitudinal slope 0.25 percent.

## 2.3 Description of Study Area

### 2.3.1 Land use

The water yields of a certain catchment are greatly influenced by the type of land use through dynamics of evapotranspiration, evaporation and interference of the canopy (Wang et al*.,* 2010; Cadol et al*.,* 2012; Rwigi, 2014). Crop farming is the major land use within the study area, maize. Peas millet, sorghum, green grams and vegetable farming along Mutonga river and the surroundings areas being the main crops under irrigation. The most cultivated crops are millet and green grams with a total acreage of 315 acres and 286 acres respectively during OND and 239 acres and 228 acres respectively during MAM. Beans and pigeons' peas are the least cultivated in both seasons (Mukopi, et al., 2017). Other land uses include built up areas, natural vegetation, barren sandy grounds and grazing lands.

### 2.3.2 Climate

The climate of Tharaka region, like the whole of East Africa region, is determined by interaction between the Monsoonal Winds, intertropical convergence zone (ITCZ), el nino/southern oscillation (ENSO), extra-tropical systems (St. Helena, Mascarene, Arabian and Azores), the Indian Ocean Dipole (IOD), the Quasi-Biennial Oscillation (QBO), and meso-scale circulations Omeny et al. 2006; [12]. The movements of the ITCZ control the direction of the seasonal monsoon winds Nicholson & Yin, 2002; [12]. Westward monsoons sweep humid maritime air inland during the wet seasons. These are interchanged by easterly dry-season winds, which bring arid continental air masses to the East African region (Okoola, 2016). Extended droughts or excessive rains are often caused by irregularities in the monsoon pattern. The study area has two rainfall seasons, whereby long rains occurs from the month of April to May (MAM) and the brief ones from October to December. (OND). Which are the two rainy seasons that are experienced in most parts of Kenya. However, on average the region experiences low and unreliable rainfall which may be unfavorable for agriculture this is in accordance to Otieno et al 2016 who observed that regions around Mt Kenya. Below 1,000m elevation level, the regions experiences rainfall less than 700 mm/year which mainly favors livestock grazing rather than intensive agriculture.

### 2.3.3 Hydrological characteristics

There are seasonal variations in river discharge in several streams and rivers in the region as well as underground water found in boreholes and waterholes, this is not only common in the lowlands of the affected region but even at relatively higher altitude. according to a hydrological assessment study report by John N Kinyanjui (2020), the total flow on annual basis was estimated at 370.2mm^3 of the upper Mutonga river. The Supply of water during the dry periods is not adquate to meet the high demand of water for urban needs, irrigation and domestic consumptions in rural areas. An ESIA project report was completed in 2019 for the planned Thombo dam on the North Maara River (upper Mutonga) in the Maara Sub-County of Tharaka Nithi County as required by the Environmental Management and Coordination Act (EMCA). Environmental Impact Assessment and Audit Regulations, 2019 (as modified) (Cap 387). For both countries, the planned Thambo Dam Project is a huge win. It will include places like Magutuni, Kaare, Kithino, and the rest of the Tharaka north and Tharaka south sub counties in Tharaka Nithi County, where the majority of the population consists of small-scale farmers who live on small demarcated plots and farms and engage in small-scale irrigation practices in their farms, resulting from an ESIA Study (2019)

## 3. METHODOLOGY

The study used a correlational research methodology. It was used to assess how variations in temperature and precipitation could explain the long-term decline in river Mutonga water levels and to determine whether or not there is a correlation between water abstraction and river discharge. The central concentration of the study was the Area around Tharaka south, the water Catchments in the region that comprises of Kathwana, Chiakariga and Tunyai.

The area lies south of Mt Kenya, neighboring Tharaka North, Meru south and Maara, coordinates $0^0$ 18`S 380, 0`E.

### 3.1 Sources of Data and Research Instruments

Both primary and secondary sources were used to compile the information included in the study. Questionnaires, interview schedules, and images were used to gather primary data. The secondary data sources were obtained from the data record books at Water Resources Authority (WRA) regional offices located in Meru town and metrological data base at regional offices situated in Embu town. Primary Data was obtained from face-to- face interviews with the key informant from the NEMA and WRA regional officials, which was carried out through a pre-organized interview schedule. Questionnaires were administered to Tharaka south residents benefiting from river Mutonga, NEMA and WRA regional officials.

Secondary Data were acquired from bodies such as water resources management authority (WRA), and meteorological department.

### 3.2 Sample Size and Sampling Procedure

Tharaka south has a population of Nine hundred households that have a vast experience of river Mutonga for years, Ten regional water resource Authority officials and Ten NEMA officials in Embu town.

The respondents for the study were drawn from Tharaka south residents, NEMA officials and WRA regional officials. Each taking a sample of 30% (Mugenda & Mugenda, 2003).

Tharaka south is subdivided into three zones, that is Chiakariga, Tunyai and Kathwana. Therefore, to make sure the three zones are given equal chances to take part in the study, stratified sampling technique was employed whereby 90 individuals were drawn from each of the three zones to come up with a sample of 270. The sampling frame was necessary because it is cheaper and engage few intellectuals and less time was required in collecting the data which was much precise as compared to the study of the whole population.

Residents: $900\times 30/100=270$

## 4. RESULTS

The current study sampled 270 households consisting of 170 female and 100 male households in Tharaka area. All the participants effectively completed the assessment giving it a 100% response rate.

The administered questionnaires assembled all the participants' demographic information, including sex, age, and highest education levels. Table 1 shows that the greatest percentage (29.63%) was between 40 to 49 years and the least 4.07% for ages above 80. Data on the gender showed that (63%) were female while (37%) were male participants. Data on the highest education level attained indicated majority accounting for 34.4% of the respondents, had attained High school education, and the least accounting for 6.3% had attained an Advanced Degree.

### 4.1 Impact of Water Abstraction on River Discharge

Over abstraction of water from river Mutonga has led to the general decline of water levels to a big extent.

The Table 2 shows majority agrees that water abstraction has been a key factor in the declining of Mutonga river discharge over the last 30 years, this is indicated by a mean score of 1.20. This observation concurs with Phillip, et al., (2019) who observed that increase in water abstraction rates by human population results to reduced water levels in rivers. Human induced activities have led to declined water levels in River Mutonga.

From Table 3, There is settlement along River Mutonga and most households, at times, take advantage of their proximity to the river to maintain their agricultural farms through irrigation and abstracting river water for home and industrial use, this is indicated by a mean score of (1.3). This is in agreement with Sabater at al (2019) who on his study on the effect of water stress caused by human beings on river ecosystem: a meta-analysis observed that human utilization of fresh water resources may lead to water stress in riverine water systems, by causing changes in quantity and quality of water beyond their natural variability.

**Table 1. Respondents' demographic information**

| **Gender** | **Count** | **%** |
|---|---|---|
| Female | 170 | 63.0 |
| Male | 100 | 37.0 |
| **Age group** | **Count** | **%** |
| 18-29 | 15 | 5.6 |
| 30-39 | 20 | 7.4 |
| 40-49 | 80 | 29.6 |
| 50-59 | 76 | 28.1 |
| 60-69 | 44 | 16.3 |
| 70-79 | 24 | 8.89 |
| 80 + | 11 | 4.1 |
| **Highest education level attained** | **Count** | **%** |
| Elementary School | 55 | 20.4 |
| High School | 93 | 34.4 |
| Bachelor's Degree | 31 | 11.5 |
| Tertiary college | 74 | 27.4 |
| Advanced Degree | 17 | 6.3 |

*Source: Field Data (2022)*

**Table 2. To what extent do you believe over abstraction of water from river Mutonga has led to the general decline of water levels?**

| **Mean** | **1.2** |
|---|---|
| Standard Error | 0.02 |
| Median | 1 |
| Mode | 1 |
| Standard Deviation | 0.4 |
| Sample Variance | 0.2 |
| Kurtosis | 3.1 |
| Skewness | 1.9 |
| Range | 2 |
| Minimum | 1 |
| Maximum | 3 |
| Sum | 321 |
| Count | 270 |

**Table 3. Human induced activities has resulted to decline of water levels in river Mutonga**

| **Do you live within Tharaka area and along river Mutonga, do you use the river for any domestic or industrial purposes?** | |
|---|---|
| Mean | 1.3 |
| Standard Error | 0.03 |
| Median | 1 |
| Mode | 1 |
| Standard Deviation | 0.5 |
| Sample Variance | 0.2 |
| Kurtosis | -1.6 |
| Skewness | 0.6 |
| Range | 1 |
| Minimum | 1 |
| Maximum | 2 |
| Sum | 363 |
| Count | 269 |

### 4.2 Trend Relationship between Water Intakes Project and River Discharge

The graph above shows a sharp rise in the number of intakes for water abstraction over the last three decades. There was a slight increase in river discharge between1990-2000, which was followed by a decrease from 2001 to 2020. The graph indicates that there is increasing number of water intakes over the entire period which in turn leads to a decline in river water discharge. This finding agrees with studies by Nilson, et al., (2005), Steffen, et al., (2011) and Genz, (2012) which observed that human activities such as construction of dam along river course, diversion of water flows through canals and uncontrolled abstraction of water for agricultural and domestic use have negatively affected the natural behavior of rivers.

### 4.3 Relationship between River Water Abstraction and the River Discharge

The above regression model shows a linear relationship between river discharge and water intakes. Number of intakes built for water abstraction correlates positively with river flow (R squared = 0.8597). As more and more water intakes are built to extract water from the river Mutonga, the river's discharge has decreased. This is in consensus with a study carried out by (Nilson et al 2005) who observed a prevalent abstraction of water from rivers by growing population which in turn alters hydrological regime of streams and rivers.

### 4.4 Trend Relationship between Rainfall, Temperatures and the River Discharge in the Study Area

The graph shows, the average river discharge increased between year 1990 to 2000, since then it has decreased significantly up to year 2020. There was a sharp rise in mean annual rainfall between 1990 to 2000. However, there was notable decrease of annual rainfall totals from 2001 up to 2021. There were insignificant changes in average annual temperatures throughout the period, though generally the temperatures have been seen to be on an increasing trend for the three decades. Therefore, the graph shows changes in rainfall and temperatures has a significant effect on the river discharge, this is in agreement with Mueni (2016) who observed the effect of changes in climate on river water yields is simulated based on the rainfall (minimum &maximum) and temperatures on monthly basis.

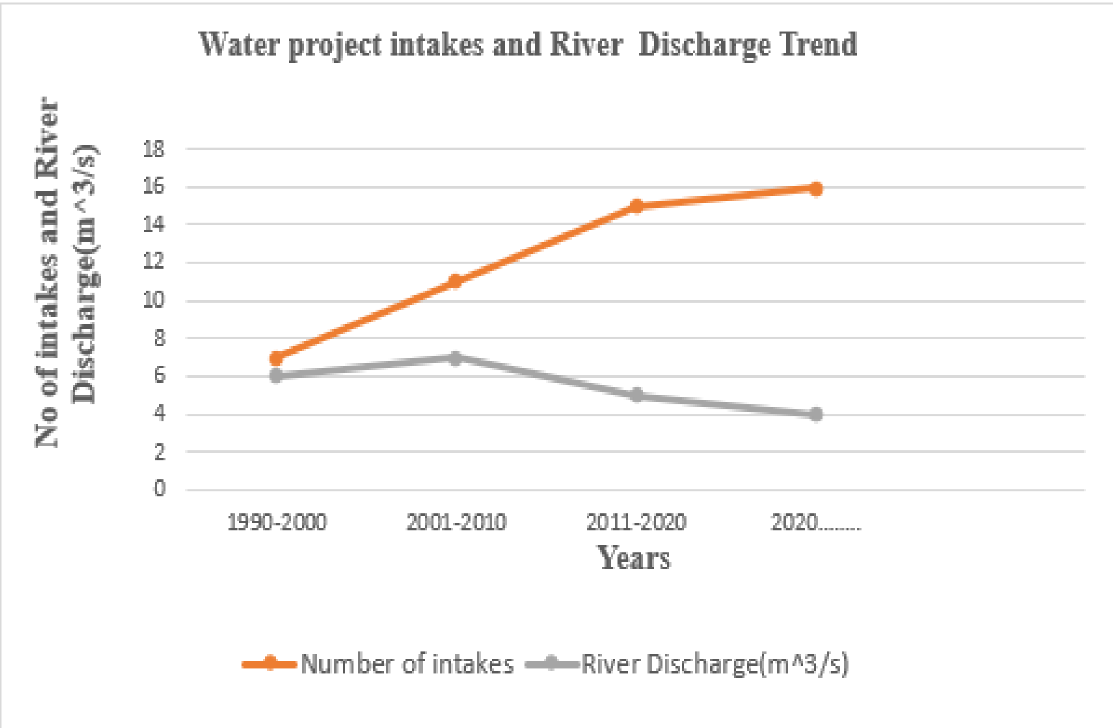


**Fig. 1. Relationship between water intakes and river discharge**

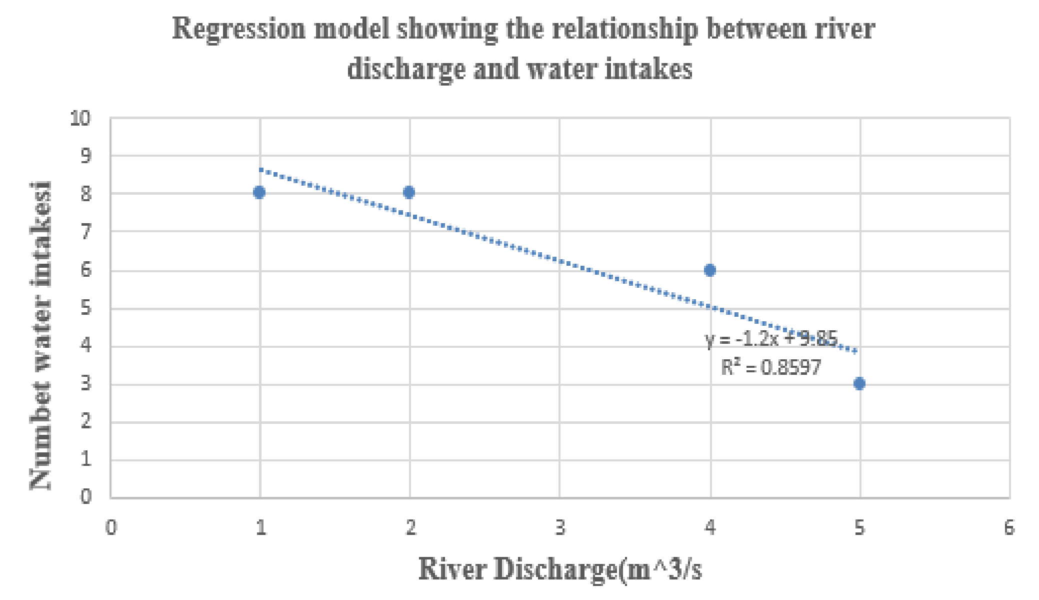


**Fig. 2. Regression linear model on relationship between the number of water intakes and river discharge**

### 4.5 There is a Significant Relationship between Increased Temperatures and River Discharge Amount

From the Table 4, the results indicates that there is a significant relationship between increased temperatures and river discharge amount (0.639816>0.05) since the correlation coefficient is significantly above zero. This was also observed by center for climate and energy solution(C2ES), (2023) on drought and climate change who noted that increased temperatures enhanced evaporation rates which in turn reduced surface water and caused drying of soils and vegetation.

## 5. DISCUSSION

The previous study has given controversial reasons behind the causes of water-level decline in rivers. The current study outcome reveals that most households are located near River Mutonga. Thus, they take advantage of the closer proximity to the rivers to abstract water excessively for agricultural purposes. Our overall findings on the reasons behind water decline in the river show that varying climatic conditions and water abstraction have been the primary drivers. This finding is consistent with Zeinalzadeh & Rezaei (2017). The increased water abstraction results from more extended drought periods that increased water demand and therefore establish a direct relationship between the snowballing agricultural water demand and climatic variations (Jaffee & Case, 2018; Espinosa, 2019). Other literature claims that climate change results from declined precipitation amounts and increased temperatures, which are primarily accountable for lowering the water level in rivers (Xiao & Lettenmaier, 2018; de Jong, P et al., 2018; Rajsekhar & Gorelick, 2017). Devlin, A. et al. (2017) study partially agrees with the current. It established a weak correlation between climatological variables and water levels and settled that mostly anthropogenic changes triggered the decline in water levels. Fathian et al. (2018) exhibited a decrease in the amount of discharge in the headwater catchment zones, showing that climate-induced variations and reservoirs do not substantially impact water levels. This was primarily caused by an unrestrained growth of the irrigated area and extensive reservoirs construction. An significant correlation between rising temperatures and river flow was found in the research. This shows that Water levels decrease is associated with increasing temperatures.

Increasing temperatures reduces water levels in rivers and other water sources due to increased evaporation rates. water abstraction from the river for domestic and industrial use is also associated with decreased water levels in rivers.

**Table 4. increased temperatures and river discharge amount**

| **Regression Statistics** | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Multiple R | 0.217257 | | | | | | | |
| R Square | 0.047201 | | | | | | | |
| Adjusted R Square | -0.14336 | | | | | | | |
| Standard Error | 0.933432 | | | | | | | |
| Observations | 7 | | | | | | | |
| **ANOVA** | | | | | | | | |
| | **df** | **SS** | **MS** | **F** | **Significance F** | | | |
| Regression | 1 | 0.215814 | 0.215814 | 0.247694 | 0.639816 | | | |
| Residual | 5 | 4.356474 | 0.871295 | | | | | |
| Total | 6 | 4.572288 | | | | | | |
| | **Coefficients** | **Standard Error** | **t Stat** | **P-value** | **Lower 95%** | **Upper 95%** | **Lower 95.0%** | **Upper 95.0%** |
| Intercept | 6.341313 | 10.12515 | 0.626293 | 0.5586 | 19.6862 | 32.36884 | 19.6862 | 32.36884 |
| Temperatures | 0.21024 | 0.422429 | 0.49769 | 0.639816 | 1.29613 | 0.87565 | 1.29613 | 0.87565 |

*Source: SPSS Generated (2022)*

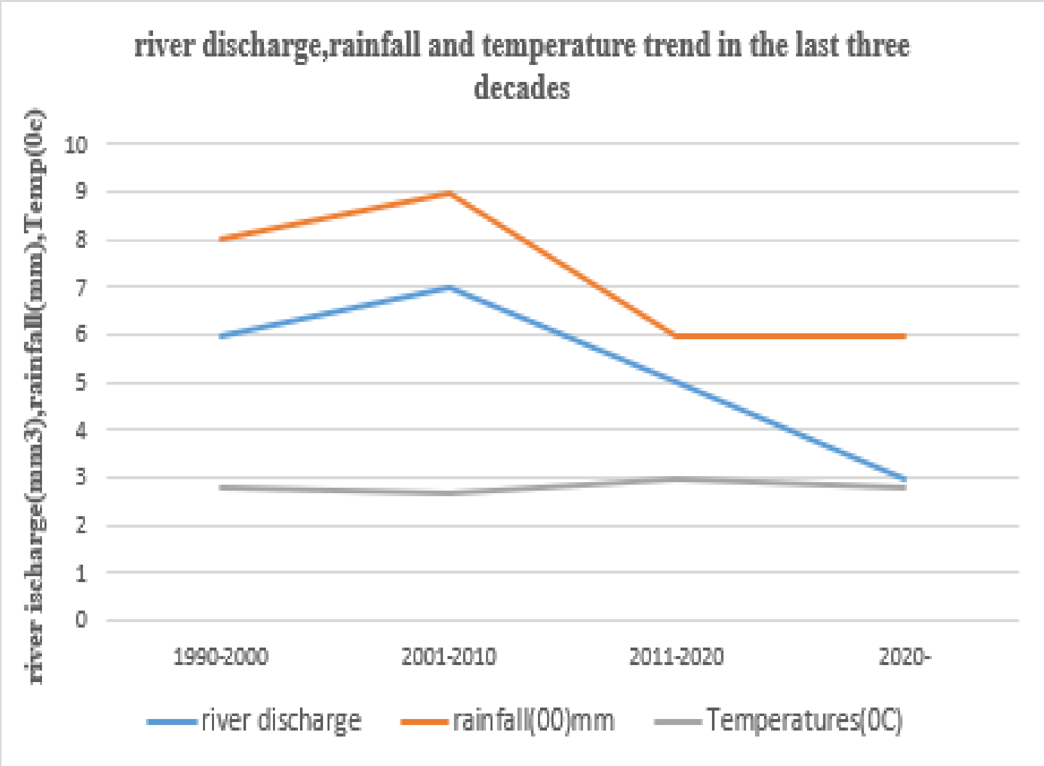


**Fig. 3. Relationship between rainfall, temperatures and river discharge in Tharaka region**

## 6. CONCLUSION

From this study there has been changing rainfall patterns and amount and temperatures variations over the years as shown in Fig. 3, River discharge volumes slightly depend on the Precipitation, temperature fluctuations and water abstraction. The decrease in rainfall amount over a lengthy period leads to decline of average river flows, increase in the temperatures causes increase in the evapotranspiration rates hence reduced discharge in rivers. The current status shows that the rainfall trends have been gradually decreasing over the catchment and the temperatures have been on a significant increasing trend. A major factor in the decrease in discharge is the growing number of water intakes that are used to extract water from rivers. Since the number of water intakes along the river has been rising between 1990 and 2020, this has had an adverse effect on the river's discharge.

## COMPETING INTERESTS

Authors have declared that no competing interests exist.

## REFERENCES

1. Arnold JG, Srinivasan R, Muttiah RS, Williams JR. Large area hydrologic modeling and assessment part I: Model development1. Journal of the American Water Resources Association. 1998;34(1), 73- 89.
2. Mundia CW, Secchi S, Akamani K, Wang G. A regional comparison of factors affecting global sorghum production: The case of North America, Asia and Africa's Sahel. Sustainability. 2019;11(7):2135.
3. Neitsch SL, Arnold JG, Kiniry JR, Williams JR. Soil and water assessment tool theoretical documentation version. Texas Water Resources Institute; 2011.
4. Roth N, Jaramillo F, Wang-Erlandsson L, Zamora D, Palomino-Ángel S, Cousins SA. A call for consistency with the terms 'wetter'and 'drier'in climate change studies. Environmental Evidence. 2021;10 (1):1-7.
5. Ngaina JN, Mutua FM, Muthama NJ, Kirui JW, Sabiiti G, Mukhala E, Maingi NW, Mutai BK. Drought monitoring in Kenya: A case of Tana River County; 2014.

6. Okoola RE. Space-Time Characteristics of the ITCZ over Equatorial Eastern Africa during Anomalous Years. Phd Thesis, Department of Meteorology, University of Nairobi; 1996.
7. Omondi PAO, Awange JL, Forootan E, Ogallo LA, Barakiza R, Girmaw GB, Komutunga E. Changes in temperature and precipitation extremes over the Greater Horn of Africa region from 1961 to 2010. International Journal of Climatology. 2014;34(4):1262-1277.
8. Otieno FAO, Maingi SM, Gichuki FN, Mungai DN, Gachene CKK, Thomas DB. Sedimentation problems of Masinga reservoir. In Land and water management in Kenya: towards sustainable land use. Proceedings of the Fourth National Workshop, Kikuyu, Kenya. Soil and Water Conservation Branch, Ministry of Agriculture and Rural Development. 2000; 43-46.
9. Ahmed AT, El Gohary F, Tzanakakis VA, Angelakis AN. Egyptian and greek water cultures and hydro-technologies in ancient times. Sustainability. 2020;12(22):97-60.
10. Uphoff N. Improving international irrigation management with farmer participation: Getting the process right. Routledge; 2019.
11. Masaki Y, Hanasaki N, Biemans H, Schmied HM, Tang Q, Wada Y, Hijioka Y. Intercomparison of global river discharge simulations focusing on dam operation-multiple models analysis in two case-study river basins, Missouri–Mississippi and Green–Colorado. Environmental Research Letters. 2017;12(5):055-002.
12. Ngaina J, Mutai B. Observational evidence of climate change on extreme events over East Africa. Global Meteorology. 2013;2 (e2):6–12.



*Peer-review history:*
*The peer review history for this paper can be accessed here:*
*https://www.sdiarticle5.com/review-history/112034*