Journal of Environmental Sciences and Technology

[ISSN 2958-1176]
Volume: 01 Issue: 01 | December-2022

JEST

DETERMINATION OF THE INFLUENCE OF SOCIO-ECONOMIC ACTIVITIES ON STREAMFLOW IN SOUTH WEST UPPER TANA BASIN, KENYA

Author
Philip K. Mwendwa
Email: philkimms@gmail.com

Kabarak University, Kenya.

Cite this article in APA
Mwendwa, P. K. (2022). Determination of the influence of socio-economic activities on streamflow in South West upper Tana basin, Kenya. *Journal of environmental sciences and technology, 1*(1), 58-72. https://doi.org/10.51317/jest.v1i1.321

OPEN ACCESS A publication of Editon Consortium Publishing (online)

Article history
Received: 18.10.2022
Accepted: 12.12.2022
Published: 15.12.2022

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Abstract
The study aimed to determine the influence of socio-economic activities on streamflow undertaken in South West Upper Tana Basin, Kenya (SWUT), one of the larger Upper Tana Basin basins. In this study, primary data was obtained by administering questionnaires, while secondary data was obtained from Water Resources Authority (WRA). The administration of questionnaires was in the period between April 2019 and June 2020. Logit regression was run to determine the influence of the different socio-economic activities on streamflow. The results showed that agriculture was the main socio-economic activity influencing water abstraction in the study area. Agricultural practices such as farm size, income from crop sales and fertiliser use significantly influenced water abstraction with P values (0.04, 0.01 and 0.02) < 0.05. The study also established household characteristics such as the income of the household head, income level of household head, marital status, age, residence period, level of education, the technology used, and gender of the household head positively influenced water abstraction. However, these factors did not significantly influence water abstraction with P values of 0.23, 0.78, 0.50, 0.60, 0.74, and 0.52 for the income level of household head, marital status, age, residence period and level of education, respectively, being > 0.05. The study recommends the formulation of policies to ensure efficient water abstraction in the basin. Water Resources Authority should also ensure that all water abstractors are licensed to minimise over-abstraction.

Key terms: Agricultural practices, household characteristics, socio-economic activities, south west upper tana basin, streamflow.

1.0 INTRODUCTION

Historically, rivers have determined many socio-economic aspects of human beings, from agricultural development to settlements, territorial expansion, location of trading posts, building systems and transportation (Peixoto, 2013). This places rivers at the pinnacle of socio-economic development (Zhong et al., 2020). Thus, the influence of human activities on streamflow should be a major research area for the attainment of sustainable water resources management (Xue et al., 2017). However, in the recent past, the impact of climate change on streamflow has captured the attention of many scientific studies. The influence of socio-economic scenarios has been given very little attention (Stefanova et al., 2019).

Rivers, as freshwater resources, offer unprecedented support to the socio-economic systems of the earth (Mwendwa et al., 2019a). Thus, man has tried to exploit these resources for various purposes, such as irrigation, rural-urban water supplies, hydroelectric power generation and flood control (Jim & Truls, 2005). In addition, river basins in the world are experiencing multiple stressors, including infrastructure development, water abstraction, pollution and eutrophication (MEA, 2005). The root causes of water abstraction could basically be those economic activities that significantly impact or alter the flow of a river (Voulivoulis & Giakoumis, 2017). These include; fisheries, agriculture, industry, aquaculture, forestry, energy, both non-hydropower and hydropower, urban development, transport, tourism and recreation. Moreover, Pletterbauer et al. (2017) observed that the causes also include different adaptive social processes such as population change, flood control, technology advances and drought management.

The amount of water abstracted in many river basins has exceeded the renewable amounts (IWMI, 2007). Anthropogenically driven water abstraction leads to abrupt changes in streamflow. This results in changes in water temperature and light penetration, eventually affecting aquatic life (Acuna et al., 2005; Von Schiller et al., 2017). This abstraction could also lead to habitat degradation, which affects biofilm biomass (Allan & Castillo, 2007). In South West Upper Tana Basin, low streamflows have been recorded, especially in the dry season. The root causes of these changes in streamflow have not been well understood. Most of the studies conducted in the basin and the larger Upper Tana Basin have been speculative due to the unlimited data. This study sought to unravel the influence of socio-economic activities on streamflow in the SWUT Basin. This will guide the authorities and other relevant stakeholders in establishing a framework that will strike a balance between socio-economic activities and streamflow in the basin.

2.0 LITERATURE REVIEW

Location

SWUT Basin is located in the central region of Kenya in the counties of Murang'a and Kiambu (Figure 1). The area extent of the basin is 2558.8 km^2. In terms of latitude and longitudinal extent, the area lies between 0^o 34' S and 1^o 7' S and 36^o E and 37^o 27' E, respectively. The lowest point in the study area is 1340 m above sea level in the east, while the highest point is 2190 m above sea level (Mwendwa et al., 2019b).

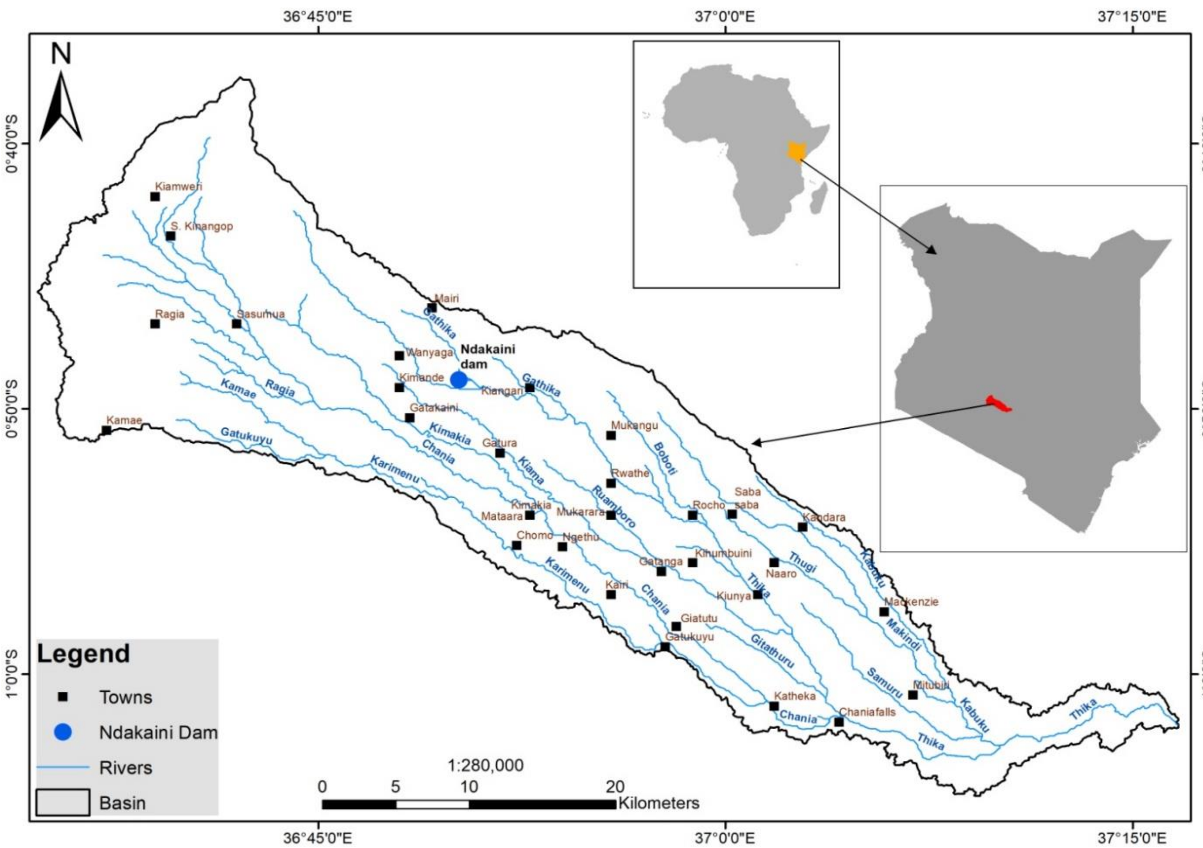

Figure 1: Location of the SWUT Basin in Kenya

Climate

The climatic conditions in the study area are highly influenced by the monsoon winds and the relief factors of the Aberdare Mountain ranges (Muranga County Integrated Development Plan, 2018). The winds blow through the area twice a year, leading to two rainy seasons, October to December (short rains) and March to May (Long rains). The highest annual rainfall experienced in the higher elevations of the Aberdare Mountain ranges is 1800 mm (Otieno et al., 2000). The highest temperature in the area ranges between 18^{o} C and 26^{o} C in the high-elevation areas of the Aberdare ranges and the lower-elevation areas on the eastern side, respectively (Kitheka et al., 2019). The lowest temperature is experienced in the period between March and October, while the highest temperature is in the month of September and January. The lower altitudes have the highest mean annual potential evaporation of 2300 mm per year, while in the higher altitudes, the mean annual potential evaporation is 1200 mm per year. The mean annual relative humidity in the study area is estimated to be 65 per cent in the lower elevations, but it rises to 80 per cent in elevations above 2000 meters above sea level (Leisher et al., 2016).

Hydrology and Drainage

The main rivers in the study area are River Thika, River Kiama, River Chania and River Kimakia. The rivers originate from the higher elevation areas in the west and flow south-eastwards. They deeply dissect the topography in the area and intersect at Ndururumo to form the main Thika River that flows to River Tana (figure 2).

Soils

The main soils in the study area are nitosols, cambisols and andosols (Mwendwa et al., 2019a). On the higher altitude areas (above 1800 m), dark surface horizon soils, implying an abundance of organic matter, are found. These soils mainly have low bulk density since they originated from pyroclastic rocks (Kimenju, 2018). In the lower slopes (below 1800 m), soil formation was mainly influenced by the amount of rainfall. For example, areas under forest, an indicator of high rainfall, have red soils.

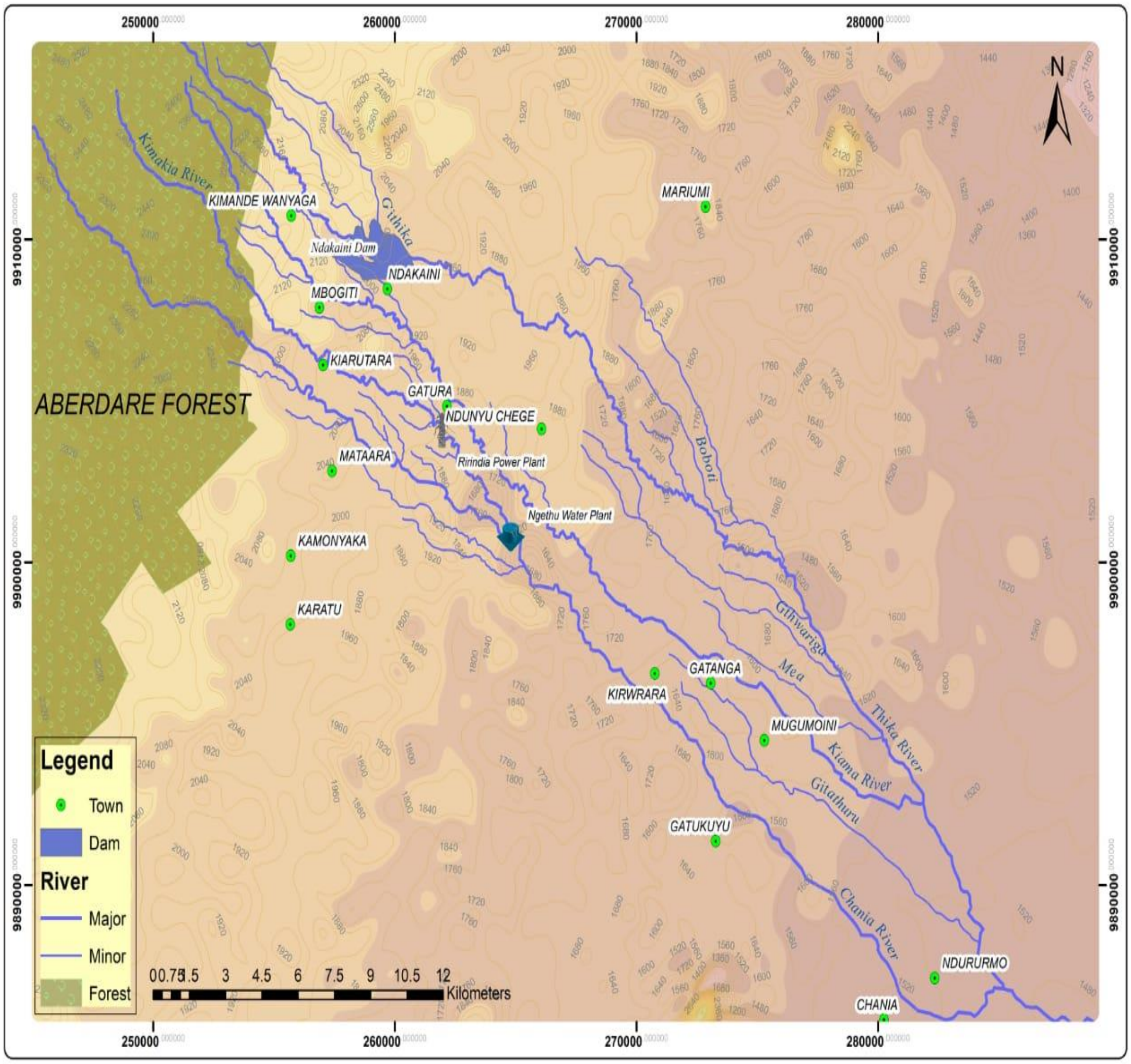

Figure 2: Location of Main Rivers in the Study Area

Land Uses

The most dominant land use activity in the study area is crop farming. Approximately 98 per cent of the farmers grow cash crops dominated by tea and coffee. Horticultural and subsistence farming is also common in the area, with crops such as bananas, potatoes, cabbages, kales and flowers grown in various parts (TNC, 2015). Livestock farming is also practised in the study area for milk, mutton and beef, while pig farming is widely spread (Agwata, 2006). Other land use activities include forestry on the upper slopes of Aberdares and wildlife conservation in Aberdares National Park (Agwata, 2006). There are also urban centres where most of the agricultural produce is sold. In the recent past, some of the coffee estates near major towns like Thika have been converted into real estate (Kitheka et al., 2019).

Socio-Economic Activities

The study area is rich in agricultural production, with towns such as Thika and Nairobi city relying on it for the supply of horticultural produce. It is also a key cash crop-producing area with numerous tea and coffee plantations (Githinji et al., 2015). Tea and coffee are grown in the high-altitude areas, while in the lower elevations, cereals and fruits such as pineapples are grown. About 80 per cent of the people in the study area depend on agriculture (Kimenju, 2018). This area supplies 84 per cent of Nairobi city's water demand. It is also a major source of water for hydroelectric power projects since the rivers are major tributaries of River Tana (Leisher, 2013).

3.0 METHODOLOGY

Determination of the Influence of Household Characteristics and Water Abstraction

To determine the extent to which household characteristics influence water abstraction, a questionnaire survey was done (Mwadini, 2018).

Questionnaire Survey

Questionnaires were administered to those households that abstract water from the rivers in the study area. Household data collected through the questionnaires included age, occupation, income, marital status, gender, education, the technology used to abstract water and the length of stay in the study area/settlement period. Hundred and twenty (120) questionnaires were administered. Four transects which were mainly the four main rivers in the study area were identified, and then thirty questionnaires (30) were randomly administered along each transect (Kothari, 2004).

Determination of Sample Size

To determine the sample size, the Cochran formula was used (Pallant, 2011)

$$n = \frac{z^2 pq}{e^2}$$ .... **equation 1**

Where; n was the size of the sample, p was an estimated proportion of a particular attribute found in the population (0.5), q was 1-p while z^2 was the abscissa of the normal curve, which cuts off an area α at the tails (the z value was obtained from the statistical table). The formula generated a sample size of 116.04 (at a 10% significant level) which was equivalent to 120 households.

Determination of the Influence of Agricultural Practices on Water Abstraction

To determine the extent to which agricultural practices influence water abstraction, primary data from questionnaire surveys, field-based observations and secondary data from relevant institutions were analysed. Agricultural data on the size of farms, type of crops grown, amount of water abstracted for irrigation, fertiliser use, the best period for sale of crops and the income obtained from crop sales was collected. Secondary data was obtained from the County agricultural office and the Murang'a County Integrated Development Plan (MCIDP) 2018.

Statistical Data Analysis

The data analysis methods used in this study were descriptive statistics and logit regression analysis.

Descriptive Statistics

In this study, descriptive statistics were mean, percentages and cross-tabulation. This data analysis method was important in the analysis and presentation of household characteristics data, socio-economic data and agricultural characteristics data (Mwadini 2018; Mwendwa et al., 2019b).

Logit Regression Analysis

This data analysis method was used to discover the relationship between the dependent variable (water abstraction) and the independent variables. Logit regression analysis was chosen because there were several socio-economic variables that influence water abstraction in SWUT Basin. For instance, the agricultural practices that influence water abstraction could include the crops grown, the size of the farm, income from crop sales and fertiliser use on the farm. Further, household characteristics that influence water abstraction in SWUT could include the size of the household, gender of the household head, age of the household head, marital status, income and settlement period.

Logit regression analysis was based on the following equation;

$y=\beta o+\beta_1 X_1+\beta_2 X_2+\cdots+\beta_k X_k+\varepsilon$ .... **equation 2**

Where; Y was the dependent variable (water abstraction), βo was Y-intercept, β_1- β_2... were the estimated coefficients, X_1, X_2...X_k were the explanatory variables whereas ε, was the random error which was taken to be a random variable with variance (σ^2) and mean 0. The description of the explanatory variables is shown in table 1 and table 2 below.

Table 1: A Description of the Explanatory Variables for Predicting the Influence of Household Characteristics on Water Abstraction

Variable	Description	Expected sign
*Y	Abstraction of water from the rivers in litres (Yes=1, Otherwise=0)	
X_1	Size of household (number of members in the family)	+/-
X_2	Household head's age (number of years)	+/-
X_3	Household head's marital status (1=married, 0=not married)	+/-
X_4	Settlement period (Length of stay in the present home)	+
X_5	Income level of the household head (Ksh)	+/-
X_6	Level of education of the household head (years of schooling)	

X_7	Use of technology in water abstraction (1=Yes, 0=No)	+
X_8	Gender of household head (1=male, 0=female)	+

***Dependent variable**

Table 2: A Description of the Explanatory Variables for Predicting the Influence of Agricultural Practices on Water Abstraction

Variable	Description	Expected sign
*Y	Abstraction of water from the rivers in litres (Yes=1, otherwise 0)	
X_1	Income from sale of crops in irrigated farms (Kshs)	+
X_2	Size of farm for each household (Acres)	+
X_3	Use of fertiliser in the farms (Kgs)	+

***Dependent Variable**

4.0 RESULTS AND DISCUSSION

Influence of Household Characteristics on Water Abstraction

The determination of the influence of household characteristics on water abstraction was achieved through the administration of 120 questionnaires to the households in the study area. The household characteristics analysed are summarised in table 3 below.

The study's results showed that 76 per cent of the household heads in the study area were married, while 20 per cent of the household heads were single, with most of them being women (table 3). Only 4 per cent were divorcees. It was established that 90 per cent of the water abstractors have been living in the study area since they were born, while 10 per cent migrated to the study area because of the proximity to rivers to abstract water for irrigation. Some of the immigrants migrated to the area to work in the tea farms. With regard to household size, it was noted that 40 per cent of the households consisted of 5 members. Households with 4 members accounted for 25 per cent, while those with 3 members were 20 per cent of the sample. Most of the households in the area of study abstract <10,000 litres per day. It was established that some of the small households were abstracting more water than the larger households. This could be attributed to the financial ability of such households to acquire technologies such as water pumps that could abstract more water from the rivers.

Table 3: Household Characteristics in SWUT Basin

Characteristic	Description	Number (%)
Marital status of household head	Married Single Divorced	76 20 4
Residence period	Since birth Immigrant	90 10

Household size	3 members 4 members 5 members More than 5 members	20 25 40 15
Gender of abstractor	Male Female	44 56
Age of the abstractor	Active age (25-50 years) Retirement age (above 50 years)	90 10
Income level of abstractor	Kshs. 5000-25,000 Above Kshs. 25,000	67 33
Education level of abstractor	Primary school Secondary school Tertiary	15 54 31
Abstraction technology	Buckets Diversion canals Water pumps Pipes	41.25 26.25 24.75 7.75

***Dependent variable**

This study determined that 56 per cent of the water abstractors in the SWUT Basin were women, while 44 per cent were men. The higher percentage of women in water abstraction could be caused by the fact that many of the single-parent families are headed by women. In addition, most men in the study area have migrated to the nearby urban centres to search for employment, leaving women in charge of the households for the most part of the year. Household heads between 25 and 50 years abstracted more water than those above 50 years. Those in the active age (25-50) years could be abstracting more water for irrigation to ensure their farms produce enough to feed their young families. For those above 50 years, water abstraction is not a priority since most of them are their retirement age; hence, they do not have enough energy to engage in water abstraction for irrigation farming.

It was established that 67 per cent of the respondents earn a relatively low monthly income of between Kshs 5,000 and 25,000. This low-income level had pushed many of the residents in the study area to water abstraction for irrigation to ensure they produce more from the farms to supplement the low income. The education level of the household head could also be a major driver of water abstraction in the study area. The study found that 69 per cent of the water abstractors had only acquired primary and secondary school education. This means that they could not qualify for formal employment, leaving water abstraction for farming as the only option. The low level of education could also be the reason why most farmers did not have knowledge of efficient ways of water abstraction. Buckets were the preferred water abstraction technology. This was attributed to the fact that acquiring a bucket is relatively cheap as compared to other water abstraction technologies like water pumps. Large irrigation farms and the water supply companies such as Nairobi City Water and Sewerage Company (NCWSC) mainly used diversion canals.

The logit regression results in table 4 show that household size negatively influenced water abstraction (coefficient = -0.01; odds ratio = 1.26; P = 0.95). The P value of 0.95 was greater than the alpha value of 0.05. Thus, household size was deemed to have an insignificant influence on water abstraction in SWUT Basin. The age of water abstractor positively influenced water abstraction (Coefficient = 0.05; odds ratio = 1.36; p = 0.50). The results indicate that a unit increase in the age of water abstractor led to a 0.05 unit increase in the probability of water abstraction. The influence was, however, insignificant since 0.50 >0.05. Further, the marital status of the water abstractor had a positive influence on water abstraction (Coefficient = 0.01; odds ratio = 1.36; p = 0.78). The results indicate that married abstractors were 1.36 times more likely to abstract water than unmarried abstractors. The P value of 0.78 was, however, greater than the alpha value of 0.05; hence, the influence was not significant.

Table 4: Influence of Household Characteristics on Water Abstraction

Explanatory variable	Estimated coefficient	Odds ratio	P value
Household size	-0.01	1.26	0.95
Age of the abstractor	0.05	1.36	0.50
Marital status of household head	0.01	0.29	0.78
Residence period	0.23	2.17	0.60
Education level of abstractor	0.16	0.40	0.74
Income of abstractor	0.09	1.24	0.23
Abstraction technology	1.12	3.97	0.52
(Constant)	0.00	1.88	0.97

The residence period of water abstractor in the study area had a positive relation with water abstraction. The water abstractors who have resided in the study area for a long time were 2.17 times more likely to abstract more water as compared to those who migrated there recently. The logit regression results also indicate that the educational level of the water abstractor positively influenced water abstraction. A unit increase in the education level increased the probability of water abstraction by a factor of 0.40. Moreover, the income of the water abstractor and the abstraction technology positively influenced water abstraction. The results indicate that the water abstractors with higher income levels were 1.24 times more likely to abstract water as compared to those with low incomes. With regard to the abstraction technology used, the results indicate that a unit improvement in the technology used led to a 3.97 unit increase in the probability of water abstraction. However, the influence of income level and abstraction technology on water abstraction was insignificant since the P values >0.05.

Influence of Agricultural Practices on Water Abstraction

This study established that most of the farms in the study area were 1 acre (table 5). Only 0.5 per cent of the irrigated farms in the study area were 10 acres in size. The small size of the farm in the study area could be attributed to the high population in the area that has increased land subdivision (Onduru & Muchena, 2011; MCIDP, 2014). It was also established that the main crop grown under irrigation in the study area was cabbage (table 6). The other major crops grown under irrigation in the study area were maize, kales, pineapples, tomatoes, potatoes and carrots, with 27.21, 17.79, 13, 17.01, 7.65 and 5.39 acres, respectively (AWSB, 2014). Irrigated agriculture has increased in the recent past due to the unreliability of rainfall in the study area. Most of the farmers have turned to irrigation farming to improve crop production and increase income from crop sales. The irrigated crops also take a shorter period to mature, thus guaranteeing the farmers short-term returns from their farms.

Table 5: The Size of Irrigated Farms in SWUT Basin (%)

	Farm Size (acre)					
Sub basin	**0.5 acre**	**1 acre**	**2 acres**	**3 acres**	**5 acres**	**10 acres**
Kiama	2	11	6	4	1	2
Thika	2	11	5	7	0	0
Kimakia	3	11	3	6	2	0
Chania	5	8	7	3	2	0
Mean	3	10.25	5.25	5	1.25	0.5

Table 6: Irrigated crops in SWUT Basin (%)

Sub basin	**Cabbage**	**Kales**	**Maize**	**Beans**	**Carrots**	**Potatoes**	**Tomatoes**	**Pineapples**	**Tea**
Kiama	23.75	3.39	5.65	1.13		3.39	6.78		8
Thika	24.86	11	10.17		2.26		2.3		11
Kimakia	16.95	2.3	8	5	1.13	2	1.13		10
Chania	15.82	1.1	3.39	2	2	2.26	6.78	13	10.17

Total	81.38	17.79	27.21	8.13	5.39	7.65	17.057	13	39.17

It was established that crop yields increase with an increase in water abstraction. For instance, farmers who abstracted above 4,000 litres per day realised crop sales amounting to Kshs. 400,000 per season. Such farmers are able to sell their products to different counties in the country, including the major cities of Nairobi and Mombasa. Further, farmers who abstracted 500 litres per day realised crop sales of Kshs. 15,000 per season. Farmers in this category only sell their produce locally in the nearby market centres and urban areas like Thika. This indicates that the trading patterns are a key socio-economic driver of water abstraction in the study area. The study also established that the use of fertilisers has increased over the years. However, the amount applied to the farm depends on the farmers' income level as well as the farm size. Farmers who are able to put more land under irrigation apply more fertilisers and abstract more water for their farms as well. The main fertilisers used were DAP (Diammonium Phosphate) (570 kgs) per season, CAN (Calcium Ammonium Nitrate) (360 kgs) and TSP (Triple Super Phosphate) (57 kgs).

The logit regression results indicated that income from crop sales, size of the farm and use of fertiliser positively influence water abstraction. A unit increase in the income from sale of crops increased the probability of abstracting water 22.35 times. Further, the size of the farm increased the probability of water abstraction by a factor of 11.19. A unit increase in the use of fertiliser in the irrigated farms increased the probability of abstracting water by 3.08 units. The results indicated that all the explanatory variables significantly influenced water abstraction with P values < 0.05.

Table 7: Influence of Agricultural Practices on Water Abstraction

Explanatory variable	Estimated coefficient	Odds ratio	P value
Income from sale of crops	0.78	22.35	.01*
Size of farm	0.85	11.19	.04*
Use of fertiliser	0.65	3.08	.02*
(Constant)	0.03	.02	.04*

Note: *indicates significance at 5%

Influence of Household Characteristics on Water Abstraction

This study's results indicated that the household size in the study area negatively influenced water abstraction (coefficient = -0.05; odds ratio = 1.26; P = 0.95). This means that some of the smaller households abstract more water than the larger households. This could be accredited to the ability of such households to procure technologies such as water pumps that abstract more water from the river. These results contradict those of Mokaya (2014), who noted that household size was a major determinant of water abstraction (Keshavarzi et al., 2006; Froukh, 2001). The age of the water abstractor was established as having a positive influence on water abstraction (Coefficient = 0.05; odds ratio = 1.36; p = 0.50). It was also determined that residents aged between 30 and 50 years were abstracting more water. This could be accredited to the fact that they have young families that they need to provide for. The results concur with Speelman (2009), who established that age was an important factor influencing water abstraction in South Africa.

The study established that women (56%) were more involved in water abstraction as compared to men (44%). This was attributed to the fact that most men in the study area had migrated to the nearby towns in search of employment opportunities (Kimani & Kombo, 2010; Belay & Bayene, 2013; MCIDP, 2014). The results agree with Nhemachena and Hassan (2007), who found that the decline in men's participation in farm activities was attributable to their emigration to urban areas in Central Kenya (Kossa et al., 2014). The educational level of the household head (coefficient 0.16; odds ratio 0.40) positively influences water abstraction. Further, most of the household heads had only acquired secondary education. This makes them unable to secure formal employment; hence, they have to rely on farming for their livelihood. The results of the income level of the household head showed that high-income earners were 1.24 times more likely to abstract more water as compared to low-income earners. The results are in agreement with those of Chebil et al. (2012), who determined that income and education level influenced water demand in Tunisia. It was also established that water abstraction technology used positively influenced water abstraction in SWUT Basin. Buckets were the main water abstraction technology used in the study since they are cheap to acquire. Most of the farmers prefer using buckets since they have small farm sizes that do not require a lot of water for irrigation. Diversion canals and water pumps are basically used by high-income earners and those with large farms (Mwadini, 2018).

Influence of Agricultural Practices on Water Abstraction

The results of this study indicate that agriculture is one of the main socio-economic activity that influences water abstraction in the SWUT Basin. There was a positive influence of income from crop sales, the size of farms and fertiliser use on water abstraction. This influence was also deemed significant since all the P values (0.01, 0.04 and 0.02) were <0.05. Farmers with larger farms under irrigation were more likely to obtain more yields, which translates to higher income. The larger farms also require more water for irrigation, hence, increased water abstraction. The results are in agreement with Hussain et al. (2011), who established that irrigated agriculture improved crop production and the income of the farmer. The findings also concur with Michailidis et al. (2010), who found that irrigated agriculture was a major driver of water abstraction in many developing countries (Speelman, 2009; Shah et al., 2013).

5.0 CONCLUSIONS AND RECOMMENDATION

Conclusions: This study concluded that household characteristics such as the size of the household, the income of the household head, the education level of the household head, the technology used to abstract water, residence period, age and marital status do not significantly influence water abstraction in the study area. However, they could still be considered as some of the socio-economic factors influencing water abstraction in SWUT Basin since, apart from the household size, all the other factors positively influence water abstraction. Further, the study concluded that agricultural practices in the study area are the main socio-economic factors influencing water abstraction. Farm size, income from crop sales and fertiliser use not only influenced water abstraction positively but also had a significant influence on water abstraction. The study recommends that the ministry of water and irrigation formulate policies that will ensure efficient water abstraction in SWUT Basin. Water Resources Authority should be well funded to enable regular monitoring of the rivers to weed out illegal and unlicensed water abstractors. Farmers should be educated on efficient water uses and irrigation practices that conserve water, such as drip irrigation.

Recommendation: The study recommends the formulation of policies to ensure efficient water abstraction in the basin. Water Resources Authority should also ensure that all water abstractors are licensed to minimise over-abstraction.

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