

MAGNITUDE, DRIVERS AND SOCIO-ECONOMIC CONSEQUENCES OF GROUNDWATER DEPLETION IN KISASI SUB-COUNTY, KITUI COUNTY, KENYA**Charles Mwei Mwikya^{1*}, Vincent Kathumo² and Paul Mwanja³**¹Department of Geography, School of Education and Social Sciences, Lukenya University, Kenya.²Department of Agriculture, School of Agriculture Technical Studies and Natural Sciences, Lukenya University, Kenya.³Lukenya University, Kenya.<https://doi.org/10.35410/IJAEB.2026.1078>*Received: 10 Sept 2026/Published: 20 Oct 2026***ABSTRACT**

Groundwater depletion is an increasing livelihood concern in Kisasi Sub-County, Kitui County, Kenya, where households depend on boreholes and shallow groundwater for domestic use, farming, and livestock. This study evaluated the perceived magnitude of groundwater depletion, the key environmental and human factors contributing to it, and its socio-economic consequences for households. A descriptive survey design using a structured household questionnaire was used. Data were collected from 368 adult household respondents in Mosa, Masimbini and Maliku. Quantitative data were analysed using frequencies and percentages, while Pearson correlation and multiple regression examined the association between selected environmental and human factors and a household-reported depletion index. The reported magnitude of depletion was substantial: 79.3% of respondents reported declining groundwater availability over the preceding five to ten years, 74.5% reported drying shallow wells or seasonal springs, and 71.2% reported reduced borehole yields. Climate change and poor rainfall was the most widely reported driver (81.5%) and showed the strongest correlation with depletion ($r = 0.802$, $p < 0.001$), followed by excessive borehole drilling ($r = 0.793$, $p < 0.001$) and deforestation ($r = 0.762$, $p < 0.001$). A multiple regression model with five reported drivers explained 78.3% of the variance in the depletion index ($R = 0.885$, $R^2 = 0.783$, $F(5, 362) = 261.45$, $p < 0.001$). Livelihood effects included reduced crop production (73.4%), increased water costs (69.8%), livestock losses (65.2%), health problems (61.4%), community conflict (58.7%), school absenteeism (54.3%), and worsened poverty (71.2%). The study concludes that groundwater depletion in Kisasi is a combined climatic, governance, and land-management problem with wide-ranging livelihood consequences, and recommends coordinated borehole regulation and monitoring, land and recharge protection, and livelihood-support interventions.

Keywords: Groundwater depletion, Livelihoods, Socio-economic consequences, Environmental and human drivers, Semi-arid Kenya, Kitui County.

1. INTRODUCTION

Groundwater is an essential source of freshwater for households, agriculture, livestock production, and economic activity, and its importance is greatest in dry regions because aquifers can provide water between rainfall seasons and during drought (UNESCO, 2022). Satellite-based assessments have identified sustained losses of groundwater storage in several heavily used aquifer systems worldwide, while well observations show that intensive abstraction can outpace natural recharge over long periods (Rodell et al., 2018; Wada and Bierkens, 2019). Sub-Saharan

Africa presents a distinctive groundwater context because large reserves coexist with weak monitoring, uneven infrastructure, and high dependence on shallow sources in many rural areas (MacDonald et al., 2021; WaterAid and British Geological Survey [BGS], 2022).

Kenya reflects many of these regional conditions, particularly in its arid and semi-arid lands, where households commonly depend on groundwater and seasonal water sources for domestic use, livestock, and small-scale farming (Kenya National Bureau of Statistics [KNBS], 2019). Kitui County's semi-arid climate, irregular rainfall, and high evaporation make dependable water access a continuing development concern (Kitui County Government, 2022, 2023). Kisasi Sub-County provides a focused setting for examining these relationships because residents rely on boreholes, shallow wells, seasonal sources, and small-scale water-harvesting measures, yet existing local evidence does not bring the magnitude, drivers, and livelihood effects of depletion together in one analysis (Mutua and Wambua, 2021).

Households in Kisasi Sub-County increasingly report declining groundwater availability and reliability, evidenced by frequent borehole breakdowns, deepening wells, and seasonally drying rivers (Kitui County Integrated Development Plan, 2023). Unstable rainfall, over-abstraction linked to population and agricultural growth, and inadequate recharge have been cited as drivers of rising pressure on groundwater at the county level (Ndungu et al., 2021), but empirical evidence at the sub-county scale is missing. Communities in Kisasi have also reported negative effects associated with the decline, including reduced crop yields and longer distances travelled to water points, but no study has systematically measured the magnitude of depletion, its environmental and human drivers, or its association with household socio-economic wellbeing in this sub-county. This article addresses that gap by presenting locally grounded, evidence-based findings on the reported magnitude, drivers, and socio-economic consequences of groundwater depletion in Kisasi Sub-County.

Groundwater depletion is commonly assessed through changes in storage, water-table depth, borehole yield, spring flow, and the reliability of household water sources. Satellite-based studies have shown sustained groundwater losses in several intensively used aquifer systems (Panda and Wahr, 2020; Rodell et al., 2018; Zhou et al., 2019), while global modelling shows that human demand can exceed natural replenishment even where rainfall occurs regularly (Wada and Bierkens, 2019). A falling water table may first appear as longer pumping times, lower borehole yields, and unreliable shallow wells before complete source failure occurs (Wada et al., 2017), which supports the use of several household indicators rather than a single measure of depletion.

In Sub-Saharan Africa, groundwater conditions vary considerably, and observation networks remain uneven (MacDonald et al., 2021; WaterAid and BGS, 2022). At the local level, Mutua and Wambua (2021) found that many Kitui residents reported reduced reliability of groundwater, including drying hand-dug wells and slower recovery of borehole supplies, but did not combine these magnitude indicators with a structured assessment of drivers and socio-economic consequences in Kisasi, which is the gap addressed here.

Groundwater depletion results from the interaction between natural recharge conditions and human abstraction. Climate variability affects recharge through changes in rainfall amount, timing, and evapotranspiration (Taylor et al., 2019). Agricultural intensification can convert groundwater from a supplementary source into a continuous production input (Dalin et al., 2019; Shah and Singh, 2021), while rapid borehole drilling without effective licensing and monitoring

can intensify pressure on shared aquifers (Villholth et al., 2020; Water Resources Authority [WRA], 2022). Land-cover change can also reduce infiltration and recharge (Wambua et al., 2021), and sand harvesting in seasonal riverbeds is locally relevant because sandy channels can store water and support infiltration.

A key gap in the local literature concerns the relative influence of these factors rather than their simple identification; prior studies do not provide a Kisasi-specific ranking of drivers based on a common set of household observations (Muema et al., 2020). This study addresses that gap using correlation and multiple regression to examine the strength and joint contribution of the selected drivers.

Groundwater depletion affects livelihoods because water is an input into consumption, agriculture, livestock production, health, education, and enterprise (Adegoke et al., 2020). Climate-related water stress can weaken agricultural production and food security (Waswa and Mwanzia, 2021), while unreliable supply increases household expenditure, weakens livestock as a productive asset, and can shift time from schooling and paid work toward water collection, a burden often carried disproportionately by women and children (WaterAid and BGS, 2022). Competition over increasingly scarce sources can also generate community conflict (Hardin, 1968), and these effects can accumulate into worsening poverty (Adegoke et al., 2020). The specific gap addressed here concerns the pattern and relative prevalence of these consequences among Kisasi households.

The study drew on the Tragedy of the Commons (Hardin, 1968; Ostrom, 1990) to explain how groundwater, as a common-pool resource, can be degraded when many dispersed users pump independently without effective collective rules, and on Integrated Water Resources Management (Global Water Partnership, 2000; Rogers and Hall, 2003) to frame depletion as a problem requiring coordinated climate adaptation, land management, abstraction control, and livelihood support rather than a single-sector response. Together, these perspectives guided the expectation that environmental and human pressures increase reported depletion, and that greater depletion is associated with adverse household livelihood outcomes.

This article combines three of the four objectives of a wider study and addresses the following: (i) to assess the perceived magnitude and indicators of groundwater depletion in Kisasi Sub-County; (ii) to evaluate the key environmental and human factors contributing to groundwater depletion in Kisasi Sub-County; and (iii) to assess the socio-economic consequences of groundwater depletion in Kisasi Sub-County. The corresponding research questions ask what the perceived magnitude and indicators of depletion are, what environmental and human factors contribute to it, and what socio-economic consequences it has produced for households.

2. METHODOLOGY

Study area and design

The study was conducted in Kisasi Sub-County, Kitui County, in Kenya's arid and semi-arid lands, where residents depend on boreholes, shallow wells, and seasonal sources under low, erratic rainfall and high evaporation (National Drought Management Authority, 2022). A descriptive cross-sectional survey design was used because the objectives required measurable evidence from a relatively large number of affected residents, without manipulating the study environment (Kothari, 2004; Mugenda and Mugenda, 2003).

Population and sampling

The target population consisted of adult residents (18 years and above) of Mosa, Masimbini, and Maliku who relied on groundwater for domestic, agricultural, livestock, or small-scale livelihood needs, with an accessible population of approximately 30,000 (KNBS, 2019). The sample size of 395 was determined using the Yamane formula at a 5% margin of error, and a combination of purposive, stratified, and simple random sampling was used to select the sub-county, the three villages as strata, and households within each village. A total of 368 completed and usable questionnaires were obtained (a 93.2% response rate), distributed as 130 in Mosa, 125 in Masimbini, and 113 in Maliku.

Instrumentation, validity and reliability

Data were collected using a structured household questionnaire with mainly closed-ended, five-point Likert-scale items, organised into sections on demographic characteristics, magnitude of depletion, environmental and human factors, and socio-economic consequences. Content validity was addressed by aligning items with the study objectives, and the instrument was piloted with about 20 respondents in a neighbouring ward outside the main sample. Reliability, assessed using Cronbach's alpha during piloting, was 0.86 for the environmental and human factors scale, 0.82 for the groundwater-depletion scale, and 0.70 for the socio-economic consequences scale, all at or above the conventional 0.70 threshold.

Data collection and analysis

Questionnaires were administered by trained research assistants between February and March 2026, with informed consent obtained from all participants and translation into Kiswahili or Kikamba provided where necessary. Quantitative data were analysed in IBM SPSS Statistics Version 26. Descriptive statistics (frequencies and percentages) summarised responses on the magnitude of depletion, environmental and human factors, and socio-economic consequences. Pearson product-moment correlation examined the association between five selected environmental and human factors (excessive borehole drilling, deforestation, climate change and poor rainfall, excessive agricultural water use, and sand harvesting) and a composite household-reported depletion index, and multiple linear regression examined their joint and relative contribution to that index. Because the design is cross-sectional and based on self-reports, all statistical associations are interpreted as survey-based associations rather than as evidence of physical or hydrogeological causation.

3. RESULTS AND DISCUSSION**Socio-demographic characteristics of respondents**

Of 368 respondents, 52.7% were male and 47.3% female; 48.6% were aged 18–30 years; 73.4% had no formal education or only primary education; and 76.4% relied on farming as their main source of income, an activity directly sensitive to rainfall and water availability.

Magnitude of groundwater depletion in Kisasi Sub-County**Table 1. Magnitude of groundwater depletion in Kisasi Sub-County (n = 368).**

Statement	SA (%)	A (%)	N (%)	D (%)	SD (%)
Decline in groundwater availability compared with 5-10 years ago	43.2	36.1	12.5	6.0	2.2

Statement	SA (%)	A (%)	N (%)	D (%)	SD (%)
Shallow wells/seasonal springs drying up	39.7	34.8	15.2	7.6	2.7
Boreholes yielding less water	37.5	33.7	17.4	8.7	2.7
Longer distances to fetch water	35.9	32.8	19.6	9.2	2.5
Frequent household water shortages	34.2	32.1	20.7	10.1	3.0
Groundwater use is sustainable	3.3	9.2	25.8	39.7	22.0

SA = strongly agree; A = agree; N = neutral; D = disagree; SD = strongly disagree. Source: Field survey data (2026).

A total of 79.3% of respondents agreed or strongly agreed that groundwater availability had declined compared with five to ten years earlier. Drying of shallow wells and seasonal springs was reported by 74.5%, reduced borehole yield by 71.2%, longer distances to fetch water by 68.7%, and frequent household shortages by 66.3%. Only 12.5% agreed that current groundwater use was sustainable (Table 1).

The finding that 79.3% of respondents perceived declining groundwater availability over five to ten years is consistent with Mutua and Wambua's (2021) Kitui survey, which reported reduced reliability of local wells and boreholes, and extends that evidence by showing that perceived decline is accompanied by drying shallow sources, reduced borehole yield, longer collection distances, and recurrent shortages within the same sample. Reduced borehole yield, reported by 71.2%, is especially important because boreholes are often treated as the more dependable alternative when shallow sources fail; global evidence shows that groundwater storage can decline even where wells continue to produce water, with users first experiencing lower yields before complete failure (Rodell et al., 2018; Wada and Bierkens, 2019). Only 12.5% of respondents considered current use sustainable, consistent with WRA (2022) concerns about unregulated abstraction. Because these are household-reported indicators rather than direct aquifer measurements, a geohydrological monitoring programme is needed to quantify the physical scale of depletion and test how closely perceptions correspond to measured groundwater levels.

Environmental and human factors contributing to groundwater depletion

Table 2. Environmental and human factors contributing to groundwater depletion (n = 368).

Statement	SA (%)	A (%)	N (%)	D (%)	SD (%)
Climate change and poor rainfall	45.7	35.8	10.3	6.0	2.2
Deforestation as a major cause	39.7	32.6	15.8	8.7	3.2
Excessive borehole drilling	32.1	36.4	18.5	9.8	3.2

Statement	SA (%)	A (%)	N (%)	D (%)	SD (%)
Sand harvesting contributes to groundwater loss	30.4	33.7	20.1	11.4	4.3
Excessive agricultural water use	25.5	34.3	22.8	13.6	3.8
Community awareness of conservation is high	5.7	17.9	28.3	34.5	13.6
Groundwater use is effectively regulated	4.3	14.2	25.5	38.6	17.4

SA = strongly agree; A = agree; N = neutral; D = disagree; SD = strongly disagree. Source: Field survey data (2026).

Table 3. Pearson correlation between environmental/human factors and reported groundwater depletion (N = 368).

Variable	r (with depletion)	p-value
Climate change and poor rainfall	0.802	< 0.001
Excessive borehole drilling	0.793	< 0.001
Deforestation	0.762	< 0.001
Excessive agricultural water use	0.614	< 0.001
Sand harvesting	0.583	< 0.001

Source: Correlation analysis using SPSS Version 26.

Table 4. Multiple regression coefficients for predictors of reported groundwater depletion (N = 368).

Variable	B	SE	Beta	t	p	95% CI
Constant	0.924	0.088	—	10.55	< 0.001	0.752–1.096
Excessive borehole drilling	0.192	0.029	0.272	6.55	< 0.001	0.135–0.250
Deforestation	0.152	0.027	0.218	5.57	< 0.001	0.098–0.206
Climate change and poor rainfall	0.210	0.034	0.269	6.19	< 0.001	0.143–0.276
Excessive agricultural water use	0.106	0.021	0.155	5.10	< 0.001	0.065–0.147
Sand harvesting	0.105	0.020	0.155	5.34	< 0.001	0.066–0.143

Source: Regression analysis using SPSS Version 26.

Climate change and poor rainfall received the highest agreement (81.5% agreeing or strongly agreeing), followed by deforestation (72.3%), excessive borehole drilling (68.5%), sand harvesting (64.1%), and excessive agricultural water use (59.8%). Only 23.6% considered community conservation awareness high, and only 18.5% considered groundwater use effectively regulated (Table 2).

Pearson correlation showed that all five factors were positively and significantly associated with the household-reported depletion index ($p < 0.001$), with climate change and poor rainfall showing the strongest association ($r = 0.802$), followed by excessive borehole drilling ($r = 0.793$) and deforestation ($r = 0.762$); sand harvesting and excessive agricultural water use recorded the smallest, though still significant, coefficients (Table 3).

Multiple regression of the five predictors on the depletion index was statistically significant, $F(5, 362) = 261.45$, $p < 0.001$, with $R = 0.885$, $R^2 = 0.783$, adjusted $R^2 = 0.780$, and a standard error of estimate of 0.359 — that is, the five reported drivers jointly accounted for about 78.3% of the variation in the reported depletion index. All five predictors were positive and significant at the 1% level; by standardised weight, excessive borehole drilling ($\beta = 0.272$) and climate change and poor rainfall ($\beta = 0.269$) contributed most, followed by deforestation ($\beta = 0.218$), with excessive agricultural water use and sand harvesting contributing least ($\beta = 0.155$ each) (Table 4). The fitted equation was: Depletion index = $0.924 + 0.192(\text{borehole drilling}) + 0.210(\text{climate and poor rainfall}) + 0.152(\text{deforestation}) + 0.106(\text{agricultural water use}) + 0.105(\text{sand harvesting})$.

Climate change and poor rainfall emerged as the most widely reported driver and the strongest factor in both correlation and regression, consistent with Taylor et al. (2019), who show that groundwater recharge in Africa is sensitive to rainfall intensity and timing. Excessive borehole drilling was the second strongest factor, consistent with WRA (2022) and Villholth et al. (2020) concerns about the governance difficulty created by many dispersed groundwater users; because borehole development is more directly controllable at local level than rainfall variability, this offers a practical entry point for management. Deforestation was also strongly associated with depletion, consistent with Wambua et al. (2021), who link land-cover change in Kitui County with reduced recharge. Sand harvesting and excessive agricultural water use, while contributing least by standardised weight, remained statistically significant, consistent with Dalin et al. (2019) and Shah and Singh (2021) on the link between agricultural water use and depletion. The low perceived regulation (18.5%) and conservation awareness (23.6%) reflect the Tragedy of the Commons logic (Hardin, 1968), because users may continue individual extraction where collective limits are weak, while the pattern of drivers overall supports an Integrated Water Resources Management response combining climate adaptation, extraction control, land restoration, and efficient water use rather than a single-cause intervention (Global Water Partnership, 2000).

Socio-economic consequences of groundwater depletion

Table 5. Socio-economic consequences of groundwater depletion (n = 368).

Statement	SA (%)	A (%)	N (%)	D (%)	SD (%)
Reduced crop production	40.2	33.2	15.8	8.2	2.7
Increased water costs	37.5	32.3	18.5	9.2	2.5

Statement	SA (%)	A (%)	N (%)	D (%)	SD (%)
Livestock loss due to water scarcity	34.8	30.4	20.1	11.4	3.3
Water scarcity causes community conflict	29.3	29.4	22.8	13.6	4.9
Children miss school to fetch water	27.7	26.6	25.5	15.2	5.0
Unsafe water sources cause health problems	32.6	28.8	21.7	12.5	4.3
Groundwater depletion has worsened poverty	38.6	32.6	16.8	9.0	3.0

SA = strongly agree; A = agree; N = neutral; D = disagree; SD = strongly disagree. Source: Field survey data (2026).

Reduced crop production was reported by 73.4% of respondents, increased water costs by 69.8%, and livestock losses related to water scarcity by 65.2%. Health problems associated with unsafe water sources were reported by 61.4%, community conflict related to water scarcity by 58.7%, and children missing school to fetch water by 54.3%. A further 71.2% agreed that groundwater depletion had worsened poverty in the area (Table 5).

Reduced crop production, the most frequently reported consequence (73.4%), is consistent with Waswa and Mwanzia (2021), who link climate-related water stress with food-security challenges in Kitui and Makueni; because farming is the main income source for more than three-quarters of the sample, reduced water availability affects both food production and cash income simultaneously. Increased water cost (69.8%) shows that scarcity creates an economic burden even before a household loses access entirely, helping explain why 71.2% also reported worsened poverty. Livestock losses (65.2%) represent a further pathway because water scarcity can weaken this productive and drought-buffering asset base. Health problems (61.4%) and school absenteeism (54.3%) show that consequences extend beyond income into wellbeing and human capital, consistent with WaterAid and BGS (2022) on the wider social importance of reliable groundwater access. Community conflict (58.7%) connects the livelihood findings with the Tragedy of the Commons, because weak collective rules can generate both physical depletion and disputes over access (Hardin, 1968). Taken together, these findings show that groundwater depletion in Kisasi is not confined to a single sector but accumulates across production, expenditure, health, education, and social relations, consistent with the characterisation of groundwater and livelihood challenges in Sub-Saharan Africa as an emerging cross-sectoral development concern (Adegoke et al., 2020).

4. CONCLUSION AND RECOMMENDATION

Groundwater depletion in Kisasi Sub-County is a widespread and worsening livelihood concern rather than a short seasonal inconvenience. Most respondents reported declining availability, drying shallow sources, reduced borehole yields, longer collection distances, and recurrent shortages, and residents experience the problem through both source performance and daily access.

Depletion is driven by a combination of climatic and human pressures, with climate change and poor rainfall the strongest factor, followed by excessive borehole drilling and deforestation,

while agricultural water use and sand harvesting make smaller but significant contributions. The problem should therefore be managed through coordinated climate adaptation, extraction control, land conservation, and efficient water use rather than a single-cause response.

Groundwater depletion also has broad socio-economic effects, with reduced crop production, higher water costs, livestock losses, health concerns, school absence, community conflict, and worsening poverty all reported by substantial proportions of the sample; these consequences are mutually reinforcing, so groundwater security in Kisasi should be treated as a development priority linked to food security, education, health, and poverty reduction.

The Water Resources Authority and county institutions should maintain an up-to-date borehole register, verify licensing status, and prioritise monitoring where households report declining yields and high drilling pressure, introducing abstraction records or metering where feasible. A small network of consistently monitored groundwater points linked to rainfall records should be established to distinguish seasonal fluctuation from long-term depletion. County environment and water programmes should prioritise native and drought-tolerant tree planting, protection of riverbanks, and control of sand harvesting in sensitive watercourses. Agricultural extension services should promote water-efficient irrigation practices, drought-tolerant crops, and livelihood diversification so that groundwater conservation remains compatible with household food security and income. Future research should combine this household evidence with direct hydrogeological monitoring, comparative studies across other Kitui sub-counties, and gender-disaggregated time-use research to quantify the distribution of water-collection burdens.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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