Heliyon 9 (2023) e16398

Contents lists available at ScienceDirect

Heliyon

journal homepage: www.cell.com/heliyon

Research article

Economic evaluation of groundwater resource in the Effutu Municipality: An application of the Gisser-Sanchez effect

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ARTICLE INFO

Keywords:
Economic valuation
Groundwater
Benefit
Statistical analysis
Gisser-Sanchez effect
Willingness to pay

ABSTRACT

This study presents an economic valuation of the groundwater resource in the Effutu Municipality. It tests the validity of the Gisser-Sanchez's position that the benefits derived from implementing a groundwater management intervention are insignificantly small compared to when no intervention is made. Hundred groundwater-user households were sampled by quota, convenience, and simple random sampling techniques. Assuming a quantitative approach, a contingent valuation-based willingness to pay questionnaire was used for data collection. Respondents were asked to value groundwater under two regimes based on quality: (1) unmanaged quality and (2) hypothetically-managed quality regimes. Using the Lancaster demand theory, the values assigned under either regime were assumed as the benefits users would derive from using groundwater. The statistical difference between the benefits of the two regimes was established by the Wilcoxon Signed Rank Test. The findings revealed that groundwater users are willing to pay 20 Pesewas (GH₵ 0.2) and 30 Pesewas (GH₵ 0.3), respectively, for a 10 L bucket of groundwater from the unmanaged quality regime and groundwater from the hypothetically-managed quality regime. The study established a statistically significant difference between the economic values of groundwater under either regime, indicating that the Gisser-Sanchez effect does not hold for groundwater used for drinking and domestic purposes in the Effutu Municipality. It has been expressed that improving groundwater quality will significantly increase the economic value of the resource. It has therefore been recommended that efforts should be made to treat groundwater to assume the quality of the Ghana Water Company's pipe-borne water after drilling projects in the Municipality.

1. Introduction

Groundwater is part of the hydrologic system and is essential for supplying water for human consumption. Ninety-nine percent of potable water accessible to humans worldwide comes from groundwater [1]. Increasing development of groundwater resources is required in some countries where groundwater is a major water source. Groundwater has become an active alternative to surface water during periods of increasing storage and distribution costs of surface water [2,3]. The global population is increasing, and various economic pursuits have detrimental effects on groundwater quality [4]. [5] contends that groundwater resources are regularly used but are ineffectively managed in several economies, making it challenging to create efficient management systems for these resources. The effectiveness of water management interventions is different across geographical, political, economic, and social spaces. [6] argue

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https://doi.org/10.1016/j.heliyon.2023.e16398
Received 8 September 2022; Received in revised form 28 April 2023; Accepted 16 May 2023
Available online 25 May 2023
2405-8440/

that the management of groundwater resources needs proper integration of fundamental hydrogeochemical and socioeconomic variables. The social objective of groundwater resource development must be to maximise societal benefits rather than individuals' [5]. [7] therefore advocate that the economic analysis of groundwater should consider beyond the efficient use and management of the resource to include the derived advancements in their resilience to accompanying risks to the environment, property, and life.

Economic analysis of groundwater can provide a framework for identifying potential benefits, outlining trade-offs, and facilitating debate of options for developing and managing the resource. [8] avers that precise knowledge regarding the resource is essential for successful planning and management of groundwater. Economic concepts of efficiency and equality are fundamental to developing the conception of water as an economic commodity because it is a scarce and productive resource [5]. The market or shadow price of water for various uses can be evaluated using willingness to pay, ability to pay, and valuation techniques. Combined with hydrological data, this analysis can give policymakers the crucial information they need to balance efficiency and equity principles. Economic analysis, when is incomplete for lack of data, could be detrimental to the overall development goals of the economy. Water resource management choices must include potential trade-offs between uses to optimize economic advantages as competition for water among users increases [5].

[9] have it that the benefit derived from implementing a groundwater management intervention is insignificantly small when compared to when no intervention is made. The authors developed a mathematical economic model (Gisser-Sanchez model) based on groundwater abstraction for irrigation under managed and non-managed groundwater regimes. [10] reviewed the model and positions by concluding that "regulation of groundwater would not enhance the welfare of farmers compared with a strategy of free markets" (p. 2064). This effect of regulating groundwater is termed the Gisser-Sanchez effect.

The Gisser-Sanchez model, however, is criticized for having failed to acknowledge the cost of environmental externalities created by the pumping of groundwater for irrigation, but only based on the cost of pumping groundwater by farmers. Relevant studies posit that economic costs like opportunity cost [11] and externalities [12] as well as financial costs related to the management and development of groundwater resources must be considered in economic analyses of the development of the resource, its allocation, and use.

Despite the failure to factor in variables such as environmental externalities of using groundwater for irrigation, the following literature: [13,14,15,16,17,18,19], and [20] have confirmed the robustness of the model. However, [21,22,23,24] expressed a need for the model to have considered groundwater quality; following advancements in this discourse, there appears to be a paucity of knowledge on the marginal benefits of groundwater use due to improvement in its quality. The contribution of the current study to the discourse is to review the Gisser-Sanchez model with consideration for a case where management implies improvement in groundwater quality.

The current study aimed to investigate the robustness of the Gisser-Sanchez effect with a water quality caveat. This addresses the novel question of how valid is the position according to the Gisser-Sanchez effect under a domestic water use setting with a water quality caveat. In essence, the study tests the validity or applicability of [9]'s position that the benefits derived from implementing a groundwater management intervention are insignificantly small when compared to when no intervention is made. The current study establishes the values residents are willing to pay for groundwater for domestic purposes under two groundwater quality regimes. The first regime considers groundwater as not managed, and hence its quality is crude, just as in the state it is being used. The second regime considers a hypothetical case where groundwater is assumed to be managed, with management focused on improving groundwater quality. Under this hypothetical regime, groundwater quality is assumed to be the same quality as treated pipe-borne water. Based on these, the following hypothesis was tested:

H_o = There is no significant difference between the values of groundwater based on its quality under unmanaged and hypothetically-managed quality regimes.

H_1 = There is a significant difference between the values of groundwater based on its quality under unmanaged and hypothetically-managed quality regimes.

1.1. Valuation of non-market goods (groundwater)

Changes in prices of goods and services which are exchanged in the normal market can be associated with consumer behaviour. [25] asks that in cases with no observable markets, how do you express utility such as the benefits of higher education, or protection of the environment, healthcare, or standard of living? According to Ref. [26], a solution approach that involves defining the benefits in terms of monetary value has been suggested. This development stems from a belief that non-market resources such as natural resources will be continued to assign a zero value unless their values are expressed in monetary units. [27] have expressed that money may not be ideal. This is because they argued that economic valuation is a means of systemizing and rationalizing behaviour. The Lancaster Demand Theory [28] counters by confirming that consumers are assumed to derive utility not as directly from consuming goods or services but rather from some characteristics of the goods or services being consumed [29]. Solution approaches for valuation include direct and indirect methods such as the contingent valuation method, travel cost method, conjoint analysis, hedonic pricing method, choice experiments, advertising behaviour, choice ranking, and contingent rating [30].

Contingent valuation (CV) is one of the valuation techniques among preferences in measuring the values of environmental goods [27]. Contingent valuation methods ask people to express their priorities for the good to measure its value directly. This means that the economic worth is determined by utilizing questionnaires and a fictitious market. Contrary to revealed preference approaches, contingent valuation is primarily used to identify environmental non-use values such as existence value, altruistic value, and bequest value because these values do not appear in any associated market. By asking respondents how much they would be prepared to pay for a hypothetical product, or if they would be willing to pay a specific price premium, contingent valuation quantifies the value consumers attribute to goods [31].

2. Materials and methods

2.1. Study area

The Effutu Municipality is perched between longitudes 0°33′11.87″W and 0°40′21.78″W, and latitudes 5°19′38.17″N, 5°26′30.45″N (Google Earth readings), as shown in Fig. 1. The area, approximately 85 km^2, is primarily low-lying, with scattered hills and granite outcrops around Winneba [32]. The Municipality is drained by the Ayensu and Gyahadze rivers, which have their mouths at Woarabeba and Opram. The Effutu Municipal is in the dry-equatorial climatic zone, and it is characterized by annual rainfall ranges of 400 mm–500 mm, and mean temperatures ranging from 22^{O}C to 28^{O}C. The coastal savannah grassland, which is supported by saline clayey soil, dominates the vegetation of the area [33].

The [33] reiterates that 86.6% of households have access to pipe-borne water, and so use pipe-borne water for drinking and or domestic purposes. The district's analytical report [33] also shows that sachet water accounts for 10.0% of solutions to drinking water needs, and protected wells and rainwater account for only 0.1%.

2.2. Study design, population, and sampling

The study assumed a quantitative approach with a cross-sectional survey design to value the groundwater resource in the Effutu Municipality. The survey method has been adopted following [34], who expressed that by examining a sample of that group, the survey design provides a quantitative description of the population's trends and attitudes. The study administered a self-constructed questionnaire of closed-ended items reflecting the willingness to pay questionnaire to obtain the values that respondents would be willing to pay for groundwater under two different regimes, using face-to-face questionnaire administration. All respondents gave informed verbal consent before their engagement in the study. Ethical approval for human subjects' engagement in the study was obtained from the Ethical Review Board of the University of Education, Winneba.

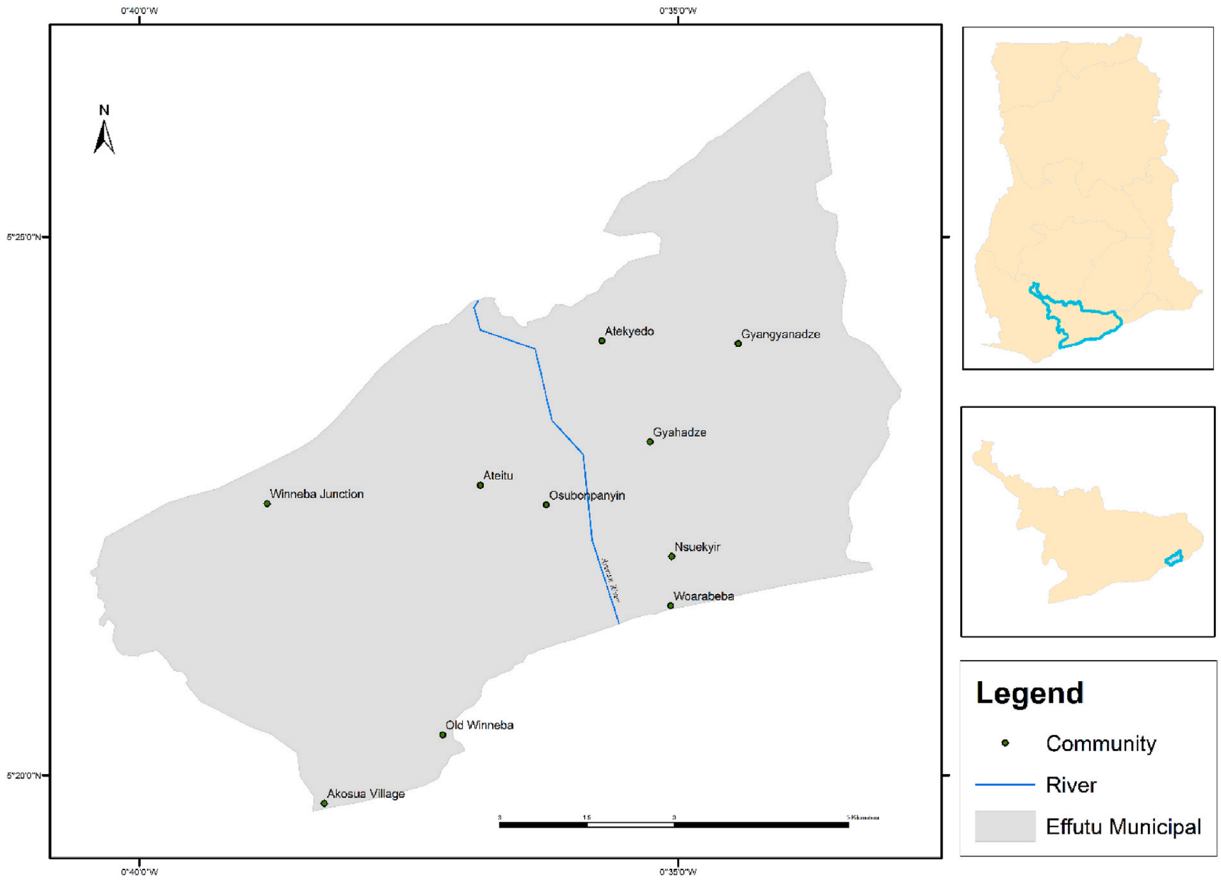

Fig. 1. Map of Effutu Municipal
Source: Fieldwork (2022).

The population for the study constituted all groundwater-user households in the Effutu Municipality. Groundwater users were considered because they have experienced the nature of the groundwater resource since they use it for some domestic activities. As such, they could value the resource better than the ordinary resident of the Municipality who does not know of the nature of the groundwater resource. According to Ref. [33], 136 out of 17121 households in the Effutu Municipal suss their domestic freshwater needs with groundwater sources. [35]'s table for estimating sample size [24] offers that, for a population of 130 households, a sample of 100 households is appropriate. The study considered one hundred (100) groundwater-use households in the Municipality.

Based on the nature of the population, the study used quota, convenience and simple random sampling techniques to sample households to respond to the survey. In line with [24], quota sampling ensures that each significant aspect of the population is considered and reflected in the sample. All wells in the Municipality were identified using local knowledge. A total of twenty-seven (27) wells were identified. The study grouped groundwater users based on the individual wells they use. As such, all households that collect water from the same well were considered as a single group. This grouping was used as the quota category, so twenty-seven (27) categories were observed. Given the sample size of one hundred (100) groundwater user households, a quota of four (4) households was determined to be sampled per well. Owing to the communality of dependence of groundwater users on wells, this grouping is also justified as it ensured the representation of all identified wells in the study. In sampling the users for individual wells, the study employed convenience sampling to sample households, where the availability of households and willingness to respond to the study were considered. For all the identified twenty-seven (27) active wells in the Municipality for which the quota of four (4) households sampled, a sample of one hundred and eight (108) groundwater user households was established. All sampled households were engaged to respond to the study. All responses were collated and assigned number identities. Using the simple random sampling technique, a sub-sample of one hundred (100) responses was drawn from the one hundred and eight (108).

2.3. Data analysis and contingent valuation workflow

The study used the contingent valuation method to value groundwater in the Effutu Municipality. The amount (in Ghanain Cedis) groundwater users are willing to pay (WTP) for a unit of groundwater was used to assess the value of the available groundwater resource. The study used Statistical Product and Service Solutions (SPSS) version 24 to analyze the data collected with the willingness to pay questionnaire. The data analysis was done according to the workflow in Fig. 2. This diagram is a construct of the authors which is based on the United States Environmental Protection Agency's [36] framework for assessing the economic value of groundwater (EPA 230-B-95-003). The framework depicts the data analysis workflow for the study. The essence of the adaptation of this framework [36] is to offer the study the grounds to value groundwater as a non-market good and test the applicability of the Gisser-Sanchez's effect to the groundwater resource of the Effutu Municipality.

The framework features a three-horizontal level workflow. At the first level (x and y), the prices respondents are willing to pay per unit of groundwater they collect from respective wells were sought concurrently. As such, x is dedicated to the prices users would be willing to pay for unmanaged groundwater with crude quality, which has not been treated by any water treatment process (in essence, this groundwater has common/crude/raw quality). In the case of y, a hypothetical groundwater management case is assumed. Here, the quality of groundwater in respective wells is considered or assumed to be the same as the quality of treated pipe-borne water. The price that users would be willing to pay for the same unit of the hypothetically-managed groundwater is also sought. The values that individual respondents are willing to pay for groundwater under either regime were entered into SPSS as variables x and y.

The second level presents the economic values of the groundwater (Bx and By) under the two groundwater regimes, where Bx is the economic value or benefit of using unmanaged groundwater with crude quality. By is the economic value or benefit of using a hypothetically-managed groundwater with enhanced quality. The economic values of groundwater are considered as the equivalence of the benefits users would derive from using the resource. The Lancaster demand theory [28] justifies this assumption that the benefits users derive from using a unit of a resource are the expressions of the prices they are willing to pay for a unit of the resource [28]. Bx and By are established as the averages of the prices that respondents would be willing to pay per unit of groundwater under x and y regimes respectively. Descriptive statistics employing mean and median with standard deviation were the unit of analysis at this level of the workflow. Considering the economic value of groundwater as the benefit of using the resource is to establish an avenue to

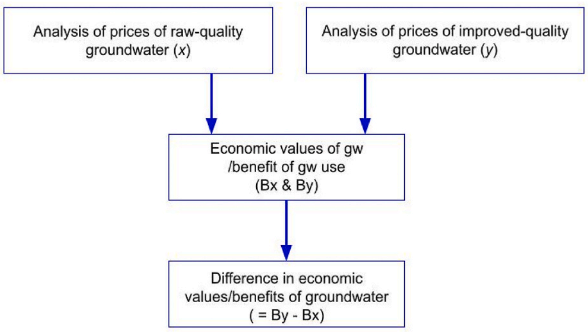

Fig. 2. Contingent valuation workflow
Source: Adapted from USEPA (1995).

analyse the difference in the benefits of using groundwater under either regime for the test of the applicability of Gisser-Sanchez's [9] effect.

The last level focused on the differences in the economic values of groundwater (= *By* - *Bx*). As shown in the workflow, the values of groundwater as a result of the change in quality are calculated by simple difference (*Bx* subtracted from *By*), following [37]. This difference in the economic values of groundwater *Bx* and *By* is an expression of the marginal benefits that users will derive from using groundwater following a hypothetic improvement in its quality. This connotes the value added to groundwater when its quality is improved from its raw state to the state considered in the hypothetical quality, in essence, the quality of treated pipe-borne water. A positive difference between the economic values of groundwater (*By* – *Bx* = Positive) suggests positive economic returns (profit) from the improvement of groundwater quality. A negative difference in the economic values (*By* – *Bx* = Negative) suggests negative returns (loss) from improving groundwater quality, and a zero (0) or no difference means neither economic gains nor losses.

Inferential statistics employing the Wilcoxon Signed Rank Test was also used to establish significant differences between the x and y. The Wilcoxon Signed Rank Test was used because the valuation data violated the assumption of normality as significant Kolmogorov-Smirnov and Shapiro-Wilk statistics were found for x and y (Table 3). As it has been expressed according to the Lancaster demand theory [28], the statistical difference between the values x and y of groundwater is a test of the applicability of Gisser-Sanchez's effect [9] in this study's context. A significant increase in the value of groundwater ($y > x$) refutes the Gisser-Sanchez effect, as this expresses a considerable increase in the benefit gains from groundwater usage when its quality is improved. No significant difference, therefore, suggests the validity of Gisser-Sanchez's effect in the context of drinking and domestic groundwater utilization.

3. Results and discussion

3.1. Background characteristics of groundwater-user households

The socio-demographic attributes of respondents were assessed to get readers to appreciate the results of the survey. This is presented in Table 1. The study revealed that out of the 100 respondent households sampled, 85% of them were represented by females, and males represented the remaining 15%. This is not to say that the representation in the study was strictly by household heads. Impliedly, as the study investigated water use which characterizes females more than males, women, therefore, offered to respond to the survey more than men. In the case of some households, men directed the researchers to their feminine counterparts to respond to the study since they viewed that the females could respond better than they would.

The study found that the mean age of respondents was 42.75 (SD = 19.39) years old. The respondents are aged 20 years old to 85 years old. Recording a minimum of 3.00 and a maximum of 15.00 for the household size, the study found a mean household size of 7.42 (SD = 3.76) persons per groundwater user household. Also, the study found that 41% of the respondents from groundwater user households in the Municipality had no formal education, 32% had primary school education, and 15% had up to junior high school education. Sounding insignificant, only 4% of the respondent households expressed that they have attained tertiary education, with 8% falling in the senior high school category. The study revealed that the majority of respondents earn less than or up to 500 Ghanaian Cedis as their average monthly income. Groundwater usage by respondents is all for domestic purposes. No respondent in the study uses groundwater in a commercial venture within the Municipality. However, the study concedes the likelihood of future commercial usage of the groundwater resource in the Effutu Municipality. We have put this across based on the sight of an ongoing groundwater drilling project which is intended for sachet water production.

Table 1
Demographic characteristics of respondents.

Variable	Response	Frequency	Percent
Gender of respondent	Male	15	15
	Female	85	85
Age of respondent	20–30 years	32	32
	31–40 years	31	31
	41–50 years	12	12
	51–60 years	4	4
	61–70 years	9	9
	70–80 years	4	4
	Over 80 years	8	8
Respondent's household size	≤5 persons	43	43
	6 to 10 persons	37	37
	>10 persons	20	20
Average monthly income	Up to 500 Cedis	44	44
	501–1000	37	37
	Over 1000 Cedis	19	19
Respondent's level of education	No formal education	41	41
	Primary school education	32	32
	Junior high school education	15	15
	Senior high school education	8	8
	Tertiary education	4	4

Source: Fieldwork (2022)

3.2. Willingness to pay for groundwater

The study investigated the amount of money that groundwater users are or would be willing to pay for a 10L capacity bucket of groundwater. The study considered two groundwater regimes (*x and y*) and asked groundwater-user households how much they would be willing to pay for the stated unit of the groundwater resource under either regime. Ten-litre (10L) capacity was adopted because that is the average size of buckets households use to collect water. This helped during the survey because respondents could readily appreciate how much water they were being asked to value.

3.3. Analysis of benefits from unmanaged groundwater quality regime (x)

In the first regime, the groundwater is unmanaged, and its quality is as crude as it is. That is, groundwater quality is considered raw or unrefined just as it is, and this is the regular state in which users collect groundwater. Its quality is not improved by any water treatment technique. The study inquired how much user households would be willing to pay for every 10L of groundwater they collect from their respective wells, should they be made to pay for it.

The study established that groundwater-user households are willing to pay amounts ranging from 10 Pesewas (GH₵ 0.1) to 50 Pesewas (GH₵ 0.5) for every 10L of groundwater they collect from wells. For this, the study found a mean amount of 22 Pesewas (GH₵ 0.22) as the average amount of money in Ghanaian Cedis (GH₵) terms that users are willing to pay for 10L of unmanaged groundwater. However, as shown in Tables 2 and 3, the study found that the valuation data obtained from the willingness to pay survey violates the assumption of normality. The medium price groundwater-user households are willing to pay for every 10L of raw groundwater they collect from wells has been established as the value of unmanaged groundwater with crude quality. Therefore, the study concludes that groundwater users in the Effutu Municipality are willing to pay 20 Pesewas (GH₵ 0.2) for every 10L of groundwater they collect from wells.

Based on the data from the willingness to pay survey, the study has found Fig. 3 to be the demand curve for unmanaged groundwater with raw quality for domestic use in the Effutu Municipality. The demand for unmanaged groundwater in the Effutu Municipality agrees with the known inverse relationship between a commodity's price and the quantity demanded of it. That is to express that several respondent households are willing to afford more of raw groundwater at lower prices than higher prices. In the Effutu Municipality, should groundwater under no management intervention be offered for sale, we posit that revenue from the sale of raw groundwater will be zero (0) when it is sold at 50 Pesewas (GH₵ 0.5) per 10L, as shown in Fig. 3.

3.4. Analysis of benefits from hypothetically-managed groundwater regime (y)

Under the second regime, where a hypothetical management intervention of groundwater assumed as improvement in quality is considered, groundwater-user households in the Effutu Municipality are willing to pay amounts ranging from 20 Pesewas (GH₵ 0.2) to 60 Pesewas (GH₵ 0.6) for every 10L of groundwater they would collect. Based on the observed values that respondents have priced the resource as what they would be willing to pay for it, the study has found an average amount of 35 Pesewas (GH₵ 0.35) as the value of groundwater resource under improved groundwater quality conditions, according to Table 2. As an address to the violation of normality, the study has found that groundwater-user households would generally be willing to pay 30 Pesewas (GH₵ 0.3) per 10L of hypothetically improved-quality groundwater for domestic purposes in the Effutu Municipality.

It is recommended that groundwater management for domestic use in the Effutu Municipality should set the price of improved-quality groundwater resource at 30 Pesewas (GH₵ 0.3) per 10L. The study, however, proposes that as the demand for groundwater respects the law of demand, the price for the enhanced-quality groundwater should not be set above 30 Pesewas (GH₵ 0.3) per 10L to achieve better cost efficiency for the groundwater resource, and hence sustainable development. Also, this conclusion has been drawn on considering the elastic nature of the demand curve for the groundwater with hypothetical quality at points equal to or below the price of 30 Pesewas (GH₵ 0.3), as shown in Fig. 4. This expresses that an attempt by a manager of groundwater to slightly reduce the price of the resource with an improved quality will yield revenues which are proportionately more than the decrease in the medium price of the improved-quality groundwater.

3.5. Economic values of groundwater under x and y (Bx & By)

Considering the establishments so far, we postulate that the value of groundwater in the Effutu Municipality is 20 Pesewas per 10L (2 Pesewas/L). However, the value of the groundwater resource in the Municipality is subject to increase up to 30 Pesewas per 10L in the form of value-added when the quality of the groundwater is improved. This finding presupposes that groundwater has a better economic efficiency than surface water in consideration for public supply and use. The Ghana Water Company, with the Public Utilities

Table 2
Descriptive statistics of x and y.

	N	Min	Max	Mean	Median	Std. D.	Skewness	Std. E.	Kurtosis	Std. E.
x	100	0.10	0.50	0.22	0.20	0.08	1.77	0.24	4.85	0.48
y	100	0.20	0.60	0.35	0.30	0.10	1.03	0.24	−0.36	0.48

Source: Fieldwork (2022)

Table 3
Test of normality.

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	Df	Sig.	Statistic	Df	Sig.
x	0.377	100	0.000	0.711	100	0.000
y	0.432	100	0.000	0.677	100	0.000

[a] Lilliefors Significance Correction.
Source: Fieldwork (2022)

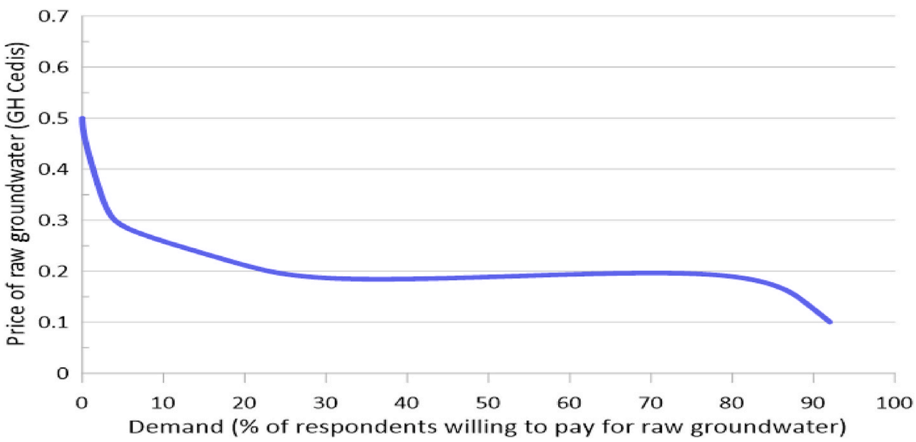

Fig. 3. Demand for raw groundwater
Source: Fieldwork (2022).

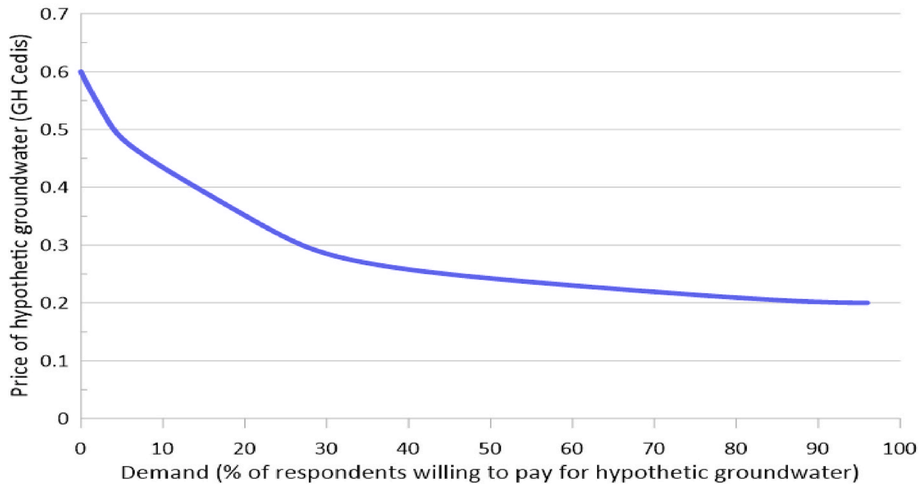

Fig. 4. Demand for hypothetic groundwater
Source: Fieldwork (2022).

Regulatory Commission, has pegged the water tariff for domestic consumers at GH₵ 433.3840/m^3 [38,39]. This expresses an equivalence of GH₵ 0.43/L (43 Pesewas per litre), connoting that comparatively, groundwater would be a cheaper resource, other things being equal. Looking at the rate of the tariff, it is evident that respondents consider water offered for sale by the Ghana Water Company as expensive because they would be willing to pay less for an alternative that is presented as having the same characteristics as this water.

[40] viewed that hypothetical bias, the differences between how much people say they would be willing to pay in a hypothetical situation and the actual figure or how much they offer in real-life events characterizes contingent valuation. We concede this bias could play a role in this valuation. [41] hold those hypothetical bias problems are due to poorly designed or inadequate surveys. Conscious

efforts were taken to develop the willingness to pay questionnaire, where a relevant real-life commodity that is known to respondents was linked to the hypothetical situation. Given this, we believe that the values of groundwater under the unmanaged and hypothetically-managed regimes, and hence the benefits that accrue to users from using 10L of groundwater in the Municipality is equivalent to 20 Pesewas (*Bx*) and 30 Pesewas (*By*) respectively. This position is supported by Refs. [27,28], and [29].

3.6. Change in the economic values/benefits of groundwater under x and y (Bx & By)

The study from the preceding reveals that the benefits groundwater users in the Effutu Municipality derive from using groundwater are equivalent to the price they are willing to pay for a unit of groundwater they use. As established, the benefits are equivalent to 20 Pesewas and 30 Pesewas per 10 L of groundwater.

Thus:

Bx = 20 Pesewas/10L;

By = 30 Pesewas/10L;

Therefore, By – Bx = (30–20) Pesewas/10L;

= 10 Pesewas/10L;

= 0.1 Pesewas/L.

Given this, the study concludes with a marginal value of 10 Pesewas (GH₵ 0.10) as the value added to a 10L of groundwater when the state of its quality is improved to that for treated pipe-borne water. The positive value added suggests that managing groundwater resources for use by way of improving its quality will be a worth-investing enterprise subject to the condition that the marginal value of 10 Pesewas can fund the cost of treating the groundwater resource.

As such, the study put across that managing the quality of groundwater will yield positive returns when the management which is taking the form of improvement in quality is successfully enacted. It is worth noting that the fact that there will be positive returns does not imply the returns will be able to cater for the cost of improving the quality of groundwater. The researchers, therefore, assert that until the cost of treating groundwater is set, the study is limited on the overall economic viability of improving the quality of groundwater resource. Therefore, we call forth advanced research into assessing the treatment cost per unit volume of groundwater, especially in coastal areas such as the Effutu Municipality.

3.7. Statistical difference in benefits of groundwater use under unmanaged and hypothetically-managed quality regimes

Due to the nature of the data, the study used a Wilcoxon Signed Ranks Test to establish the paired sample's difference in the value of the groundwater under the two groundwater regimes. Despite the data meeting all other assumptions of parametric tests, the data violates the assumption of normality as have been presented in Table 3, where a significant Kolmogorov-Smirnov test statistic was found for either regime: $x = 0.377$, $p = 0.00$; $y = 0.432$, $p = 0.00$. This is the justification for the decision to reject the use of the parametric paired samples *t*-test.

The study has established a statistically significant increase in the benefits gained [42] from using groundwater following value addition to the groundwater resource, which takes the form of improved use conditions, emphasizing improvement in the quality of groundwater ($Z = -9.071$, $p = 0.000$). This is shown in Table 4. A large effect size ($r = 0.6414$) is found for this difference, which presupposes a practically and realistically significant difference between the economic values of unmanaged groundwater with crude quality and hypothetically-managed groundwater with improved quality [43]. This thus implies a substantial difference between the benefits of groundwater under either regime.

According to Ref. [9], in the case of the Pecos Basin (New Mexico), the results found that the benefits or welfare gains by farmers who are users of the resource under optimal control (conceptualized as the hypothetically-managed regime, '*y*' in this study) and no control (conceptualized as the unmanaged regime, '*x*' in this study) groundwater management regimes, were almost identical. According to them, the temporal optimal control of groundwater, which implies resource management, would not improve farmers' welfare compared with a free market strategy, where there is no groundwater management. This is to say that according to Ref. [9], the value added to groundwater under the optimal control management regime is not significant to induce significant welfare gains by farmers when compared to gains accrued under no control regime. This brings to light the assumption that the benefit derived from implementing a groundwater management intervention is insignificantly small when compared to when no intervention is made [9].

Based on the finding in this study on the statistical difference between the benefits derived from groundwater use in the Effutu Municipality, the study rejects the null hypothesis stated. The study has found a significant difference between the benefits of using a

Table 4
Wilcoxon signed ranks test to explore the statistical difference between the values of groundwater in the Effutu Municipality.

	$x - y$
Z	-9.071[b]
Asymp. Sig. (2-tailed)	0.000

[b] Based on negative ranks.
Source: Fieldwork (2022)

unit of unmanaged groundwater (*Bx*) and the benefits of using same unit of hypothetically-managed groundwater (*By*). The case found here addresses the position of [22,23,44], and [21] that the Gisser-Sanchez model ought to have considered the quality of groundwater. This significant difference refutes the [9]'s claim that the benefits derived from implementing a groundwater management intervention are insignificantly small when compared to when no intervention is made [9]. This suggests that the Gisser-Sanchez effect holds under groundwater use for agricultural irrigation but not under drinking and domestic groundwater use in the Effutu Municipality.

The study projects that this finding is established due to the dissimilarity in groundwater quality for the two regimes and hence, the indices and parameters for determining drinking and irrigation water quality. Drinking water quality indices vary considerably with irrigation water quality indices. The difference is not only with the thresholds of parameters but also in the number of individual parameters considered in respective index. This expresses that there are parameters included in drinking water quality indices that are not featured in irrigation water quality indices, and vice-versa. This brings to light differences in the suitability of groundwater for drinking and irrigation purposes. Domestic and drinking water use involves direct contact with users, whilst it is not necessarily the case in the use of water for irrigational purposes. According to the [45], water quality is significant for health and development, irrespective of the purpose the water serves: drinking, irrigation, and or recreation. High thresholds are, however set for drinking water quality parameters than irrigation water quality parameters, which justifies why a change in quality was significantly valued by the groundwater users studied. This presupposes that water sources polluted slightly beyond permissible limits for drinking purposes may still be within acceptable limits for irrigation purposes. This finding conforms with [46], who underscore that amidst water scarcity, groundwater with somewhat poorer quality indices still represents a potential solution to water shortage, especially for irrigational purposes.

Therefore, we stand with the conviction that the variances in water quality indices for different water uses is the main difference between drinking water quality and irrigation water quality. In this case, there is a significant difference between the values of unmanaged and hypothetically-managed groundwater. As such, the benefits they render, which contradict the Gisser-Sanchez effect is due to variances in their measures of quality. This is because that is the main attribute distinguishing drinking water quality from irrigation water quality.

4. Conclusion and recommendations

The study concludes by establishing the results that the monetary values of unmanaged and hypothetically-managed groundwater in the Effutu Municipality are 20 and 30 Ghanaian Pesewas respectively, or their equivalence in other currencies. The study arrived at this finding through the contingent valuation method, emphasizing the amount of money that respondent groundwater users are willing to pay for 10L of groundwater.

The study has also established that there would be a significant increase in the value of groundwater when management targets improving groundwater quality. Based on these findings, the study has concluded that the benefit derived from using groundwater that is managed by improving its quality for drinking is significantly higher than when the resource is unmanaged and hence no improvement in groundwater quality is observed. Theoretically, the current study holds that the benefits derived from domestic and drinking usage of groundwater with a managed quality intervention are significantly higher than the benefit that is derived from domestic and drinking usage without a managed quality intervention. This is against and refutes the Gisser-Sanchez effect [9].

Given the significant increase in the value and hence benefits derived from using groundwater following management of quality, the study recommends that the Water Resources Commission should implement groundwater treatment interventions. This can be achieved by integrating water treatment into groundwater drilling projects. Also, the Ghana Water Company Limited should prioritize the integration of groundwater into the public water supply following the better resilience of groundwater resources amidst the fictile nature of surface water bodies to environmental and anthropogenic stressors. Adopting the pump and treat method for implementing this recommendation would be sustainable, where groundwater is pumped into a reservoir and treated before distribution to the end-users, as recommended by Ref. [47] that treated groundwater is suitable for drinking.

The study faced a limitation in respondents' appreciation of the hypothetical groundwater quality regime. This was delimited by likening the case to the quality of treated pipe-borne water which respondents are familiar with. The study could also not establish the economic viability of groundwater quality treatment. Despite an increment in value being 'observed' following groundwater quality improvement, actual economic viability would be when the value added would exceed the cost of treatment. Therefore, we implore that research in the area should investigate the cost of groundwater treatment.

Author contribution statement

Sender Kyeremeh, and Kofi Adu-Boahen: Conceived and designed the experiments.
Sender Kyeremeh: Analyzed and interpreted the data.
Sender Kyeremeh, Kofi Adu-Boahen and Millicent Obeng Addai: Contributed materials, and data.
Sender Kyeremeh: wrote the paper.

Data availability statement

Data will be made available on request.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.heliyon.2023.e16398.

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