Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development
Vol. 25, Issue 1, 2025
PRINT ISSN 2284-7995, E-ISSN 2285-3952

QUANTIFICATION OF DOMESTIC WATER USE FOR ESTIMATING IRRIGATION WATER AVAILABILITY OF SMALL RESERVOIRS IN NORTHERN GHANA

Naoko OKA[1], Abdul-Ganiyu SHAIBU[2]

[1]Japan International Research Center for Agricultural Sciences (JIRCAS), Rural Development Division, 1-1 Ohwashi, Tsukuba, Ibaraki 305-8686, Japan, Phone/Fax:+81 29 838 6690; E-mail: okan0307@jircas.go.jp
[2] University for Development Studies, School of Engineering, P. O. Box TL1350, Tamale, Ghana, Phone/Fax: +233 37 209 3697; E-mail: sganiyu2000@gmail.com

Corresponding author: okan0307@jircas.go.jp

Abstract

In Sub-Saharan Africa, small reservoirs that collect unused surface water have a high potential to improve agricultural productivity if developed. However, since water from small reservoirs is used for multiple purposes, allocating water for domestic use is crucial and needs to be prioritized over irrigation water in irrigation planning from small reservoirs. Thus, this study quantifies the water used at home in some rural communities in northern Ghana to develop an estimation method of water availability for irrigation development in small reservoirs. The applied methods are questionnaire-based interviews and measuring containers installed with a sensor logger to obtain long-term data. The measurement period was two years and nine months, from June 2017 to March 2020. The results clarified the general water use situation and seasonal differences in household water use. Further, an equation to estimate the domestic water demand is proposed with a value of 30 L per person per day as a guideline for the amount to be secured as household water in irrigation planning from small reservoirs.

Key words: *household water, dugout, livestock, irrigation plan, productive water use*

INTRODUCTION

Among the various irrigation facilities, reservoirs that can store water throughout the year in climate zones with irregular rainfall patterns are gaining attention. Along with ongoing climate change, reservoirs are crucial for maintaining production resilience. It is estimated that the construction of small reservoirs can almost double the production of cereals in Africa, even if the reservoir capacity ratio is as small as one [19]. Considerable potential for profitable smallholder irrigation expansion in Sub-Saharan Africa has been revealed, and the potential for area expansion by small reservoirs has been estimated at 22 million ha [21], [22]. Water resources are sufficient to farm all potential cultivable areas in some countries, including Ghana, even when rain-fed and irrigated systems are fully operational [1]. However, water resources in Sub-Saharan Africa have not yet been developed to meet their potential [22]. In Sub-Saharan Africa, small reservoirs that collect unused surface water have a high potential to improve agricultural productivity if developed.

In Ghana, small reservoir development in rural areas is essential to rural development. Many studies have been conducted to evaluate the potential of small reservoirs and assess their effectiveness. Kawachi et al. [8] described a prototype reservoir's design and construction practices in Ghana. A manual was developed to install a pair-pond system for supplementary irrigation in the Northern Region of Ghana [10]. An assessment of small reservoirs found that despite economic incentives, the perceived patronage of irrigation in most dams was low, and the organized management and operations of small reservoirs were poor [2]. Water users require a more substantial educational support for water management [13]. In these circumstances, the government of Ghana promotes the development of small reservoirs through various projects such as the "One Village, One Dam initiative," which aims to provide all-year water availability for smallholder farmers, focusing on northern Ghana. However, criticism has arisen as reservoirs are underutilized for irrigation, and some do not meet the expectations of the beneficiaries [3].

A critical shortcoming of the small reservoir for irrigation development in northern Ghana is the lack of a concept for water allocation among various uses [14]. Reservoir water is used for multiple purposes [11], [5], [9], and domestic water should be prioritized over irrigation water [4]. Domestic water should be secured separately from irrigation water to avoid conflict between water use, and it must be estimated before small reservoir irrigation development is designed.

Domestic water estimation is difficult because limited data are available. The World Health Organization (WHO) [20] stated that a minimum volume of 7.5 L per capita per day will provide sufficient water for hydration and incorporation into food for most people under most conditions. However, this figure excludes activities such as bathing and laundry. Thomson et al. [18] determined the mean daily domestic water per capita used by piped and un-piped households in rural and urban areas, focusing on all domestic water-related activities, which varied from approximately 20 to 70 L, through interviews and direct measurements in East Africa. It has also been reported that domestic water volume primarily depends on access, which is determined by distance or collection time. The likely quantity of water collected per capita is often less than 5 L per day if the distance is more than 1,000 m or the total collection time is over 30 min, and unlikely to exceed 20 L per day if the distance is between 100–1,000 m or the collection time is 5–30 min [20], [7]. Another study reported that the average per capita daily use is approximately 10 L, with considerable variation, according to a literature review [16]. However, updated information on household consumption in Ghana is far more limited. Furthermore, most studies relied on interviews, observation, or measurement by unspecified methods [15] [17] due to the difficulty of accurately measuring for an extended period.

Thus, this study quantifies the water used at home in some rural communities in northern Ghana by using measuring containers installed with a sensor logger to obtain long-term data and develop an estimation method for the water availability of small reservoirs for irrigation development.

MATERIALS AND METHODS

Definition of domestic water

This study defines domestic water as water used for household activities that can be differentiated into four categories: i) consumption (drinking and cooking), ii) hygiene (bathing, washing, and cleaning), iii) amenity use (watering lawns, car-washing, and other non-essential tasks), and iv) productive use (watering livestock and kitchen gardens and beer-brewing) [18]. In rural Ghana, some domestic water is used at home, while others are used outside. In this paper, we refer to the water used at home "household water," which is mainly collected by women and is stored at home for their activities.

Site description

The study was conducted in three villages, Nwogu, Kpilo, and Mbanayili, in the Kumbungu District, Northern Region. They are located in the Savannah climate zone, which has one rainy season and a long dry season from November to March. Rain-fed cultivation and livestock raising are common in Kumbungu District. Each of the three villages has a small reservoir called a dugout. Dugout usually serves one to two villages and is said to be installed primarily for domestic use and livestock, with limited use for irrigation [12].

Access to public taps is limited in Kumbungu District, and residents depend on open water sources, including dugouts. The statistics [6] show that 19.9% of households drink water from public taps or standpipes. In comparison, 27.6% mainly drink from dugouts or dams. For other domestic use, 15.3% is from public taps or standpipes, and 32.3% is from dugouts or dams [6].

Women collect household water from these sources [21], by walking from a water source to their house carrying water on their heads. The collected water is stored in various containers at home.

Interview survey

Questionnaire-based interviews were conducted in 2014 to gather an overview of domestic water use by the residents of the three villages. The questionnaire consisted of i) household water use by women, ii) animal water use during the dry season, and iii) agricultural water use during the dry season. The questionnaire excluded uncommon practices such as household water use by men or amenity water use.

Eighteen households were selected based on recommendations from village contacts. Eighteen men who were the heads of households and 18 women who were the wives of the heads of households were interviewed separately.

Measurement of household water use

The volume of water use at home was measured using measuring containers installed in eight households in Nwogu and Kpilo. The duration was two years and nine months, from June 2017 to March 2020. The measuring containers had a radius of 0.3 m and a height of 1.0 m, and a water level logger (HOBO U20L) was installed at the bottom. The water level loggers recorded the hourly absolute pressure and temperature, which were converted to water depth using the temperature and independently measured air pressure. An increase in water depth greater than 0.02 m was considered as a water level rise because the water level sensors had a measurement accuracy of ±1 cm. The water level rise was converted into volume added to the containers.

In addition to the measurements, the number and size of other water containers at home were measured with measuring tape. Demographic information about the households was confirmed, and specific purposes of water use from the measuring containers were obtained through interviews conducted on women in each family.

In addition, daily rainfall data were obtained from the meteorological station in Tamale, the capital city of the Northern Region, during the measuring period.

Data analysis

The collected and measured data were analyzed using the Excel add-in software (Excel multivariate analysis ver.8 by ESUMI) to explore the factors that affect the amount of water used at home.

RESULTS AND DISCUSSIONS

Overview of domestic water use

The women's interview results on household water use revealed that the water stored at home was used for consumption, hygiene, and in the productive categories (Table 1). Dugout and tap water were used almost in the same manner, except for one woman who used tap water only for drinking. Tap water use was slightly less rated for bathing than dugout water use.

Table 1. Number of respondents who used water in each subcategory

Subcategory of domestic water use	Use water from a dugout	Using tap water
Drinking	18	18
Cooking	18	17
Laundry	18	17
Cleaning	18	17
Bathing	18	14
Rice parboiling	7	5
Shea butter making	15	14
Others	1 (brick making)	1 (brick making)

Source: Results of the survey.

It is noted that productive water use for shea butter and rice parboiling is common among women, as 15 out of 18 women (83%) performed shea butter making or rice parboiling.

Productive water use is recognized as the most water-consuming domestic water use by those who make shea butter or parboiled rice (Table 2).

The interview results for men and women revealed variations in animal watering. Most respondents took their animals to a nearby dugout or allowed them to go alone, while others gave water at home fetched from a dugout or tap (Table 3). It also shows that men are the primary users of livestock water.

Table 2. Productive water use by women

Respondent	Rice parboiling	Shea butter making	Most water-consuming activity
KF1	-	-	Bathing
KF2	-	*	Shea butter making
KF3	-	*	Shea butter making
KF4	-	*	Shea butter making
KF5	-	*	Shea butter making
KF6	*	*	Shea butter making
M1F	*	*	Shea butter making
MF2	-	*	Shea butter making
MF3	*	*	Shea butter making
MF4	-	-	Bathing
MF5	*	*	Rice parboiling
MF6	*	*	Shea butter making
NF1	-	*	Shea butter making
NF2	-	*	Shea butter making
NF3	*	*	Shea butter making
NF4	-	*	Shea butter making
NF5	*	*	Shea butter making
NF6	-	-	Laundry

* : yes, -: no
K, M, and N denote each studied site, and F denotes women in the respondents' column.
Source: Results of the survey.

All men interviewed used water for livestock drinking, while only five women used it to rear cattle, sheep, and goats.

Men are more likely to use water for agriculture than women. Seventy-eight percent (78%) of men use dugout water for agriculture during the dry season. The crops cultivated under irrigation include chili peppers, amaranthus, tomatoes, other vegetables, and nursery trees. In contrast, only one woman uses dugout water to grow okra, amaranthus, and nalta jute, while another fetches water from dugout to irrigate her husband's crops fields.

Quantity of household water use

The obtained data on the total volume of water added to the measuring container was multiplied by the equivalent number of water containers at home and then divided by the number of measuring days and number of household members at home to give the daily volume of household water per person (Table 4).

The calculated daily water uses per person varied from 3.8 L to 20.2 L among households. The average water consumptions of the two villages are 14.3 L for Nwogu households and 7.4 L for Kpilo households. The distance to the village dugout may cause discrepancies in the village averages because the distance to the village dugout is 800 m for Nwogu households and 1,400 m for Kpilo. This result is consistent with those of previous studies [20] [7], which reported the effect of water collection distance on the amount of water use.

The seasonal variation in water use was observed by the monthly average of the daily volume of water used per person and the monthly precipitation during the study period (Fig. 1). On average, 12.43 L per day per capita was consumed in the dry season and 5.75 L in the rainy season, taking months with more than 100 mm/month of precipitation as the rainy season and months with no rain as the dry season, with a significant difference ($t(7) = 3.93$, $p=0.0057$). Previous studies have reported conflicting results on seasonal differences in water use [16, 17]. The results of the present study support the idea that people consume more water during the dry season because of the vital necessity for hydration and their higher dependence on water stored at home.

The daily water use per person in the three households was less than or equal to 7.5 L, the minimum volume required to provide sufficient water for hydration and incorporation into food for most people under most conditions [12]. These small values may be caused by differences in the water use by the measuring container. For example, the calculation results could be underestimated if laundry was frequently performed at the dugout site. Given this uncertainty, the measurement results indicate households' water consumption capability.

Correlation between household water volume and various factors

A Spearman's rank correlation test was conducted to determine the relationship between the daily volume of household water use and the quantitative variables: the rate of children in a family, the number of housewives, and the amount of livestock watered from the measuring containers. As a result, no significant correlation was observed with the data obtained in this study (Table 5). Furthermore, the correlation ratio was calculated between the qualitative variables, the presence or absence of activities with water from the measuring containers, and the daily water volume used at home (Table 6).

Table 3. Livestock watering during the dry season

Respondent	Choice of dugout	Reason for the choice	Animal kinds
KM1	Kpilo dugout	The dugout is close	Sheep, goats
KM2	Kpilo dugout, tap water	The dugout is a community-owned and close	Sheep, goats
KM3	Kpilo dugout (fetching)	Fetch water to prevent loss of animals	Sheep, goats
KM4	Tap water (fetching)	Na	Cattle, Sheep
KM5	Kpilo dugout (fetching)	Have no child to lead animals to the dugout	Sheep, goats
KM6	Tap water and Kpilo dugout	Use dugout water when the tap is not functioning	Sheep, goats
MM1	Mbanayili dugout	The dugout is a community-owned	Cattle, sheep and goats
MM2	Any dugout accessible to animals	Animals choose	Sheep, goats
MM3	Mbanayili dugout and at home	Animals choose	Sheep, goats
MM4	Give water at home	Dugouts are far	Cattle, sheep and goats
MM5	Mbanayili dugout	The dugout is a community-owned	Sheep, goats
MM6	Nwogu and Mbanayili dugout	Animal chose	Sheep, goats
NM1	Nwogu dugout	The dugout is close	Cattle, Sheep
NM2	Nwogu dugout	The dugout is close	Sheep, goats
NM3	Nwogu dugout	The dugout is close	Sheep, goats
NM4	Nwogu dugout	The dugout is close	Cattle, sheep, and goats
NM5	Nwogu dugout	The dugout is a community-owned	Cattle, goats
NM6	Any dugout accessible to animals	Animal chose	Goats
KF4	Bira dugout (the place is unknown)	Na	Sheep
KF5	Na	Na	Sheep
KF6	Kpilo dugout	Na	Goats
MF1	Kpilo dugout	Na	Sheep
MF2	Mbanayili dugout	Animals or children who lead them choose	Sheep, goats

K, M, and N denote each studied site; M for men, and F for women, respectively, in the respondent's column.
Source: Results of the survey.

Table 4. Daily household water consumption per person

	N1	N2	N3	N4	K1	K2	K3	K4
Total volume of water added (m^3)	102.10	72.60	57.36	78.39	23.97	17.03	34.77	30.28
Total number of measurement days	1006.5	1006.5	1006.5	1006.5	828.6	1006.5	1006.5	1006.5
Number of water containers at home (equivalent to the measuring containers)	2.5	2.8	2.5	2.8	2.8	3.8	2	2.8
Number of household members	20	10	19	13	11	17	7	10
Number of children among household members	9	4	7	5	2	3	3	4
Daily water consumption per person (L per day)	12.7	20.2	7.5	16.8	7.4	3.8	9.9	8.4
Watered livestock from the measuring container	5	7	6	3	4	5	1	0
Water use from the container								
Drinking	*		*		*	*	*	*
Cooking	*	*	*	*	*	*	*	*
bathing		*	*	*	*		*	*
cleaning		*			*	*	*	*
laundry	*	*			*		*	*
shea butter		*	*					*
parboiling	*	*	*		*			*

The N-number indicates households in Nwogu, and the K-number indicates households in Kpilo.
Source: Results of the survey.

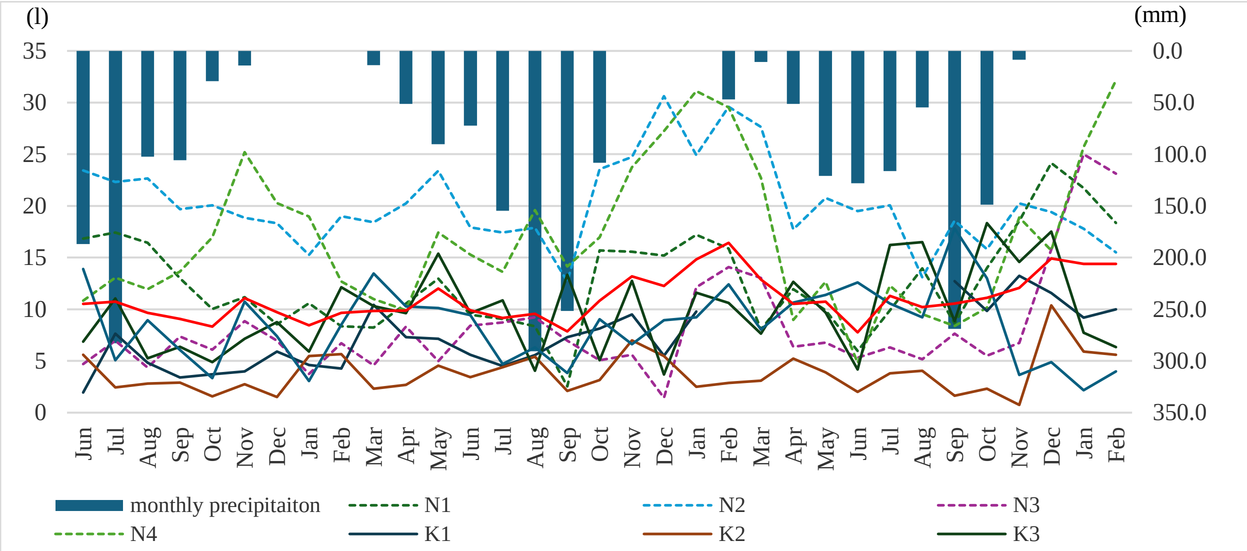

Fig. 1. Monthly average daily water volume per person and monthly precipitation from June 2017 to February 2020 in Tamale
Source: Results of the survey

Table 5. Correlation coefficients between the daily water volume per person and the quantitative variables

Variables	Correlation coefficient	*p*-value
Rate of children in the family	0.687	0.060
Number of housewives	-0.546	0.162
Amount of livestock water supplies at home	0.108	0.799

Source: Results of the survey.

Table 6. Correlation ratio between daily water volume per person and qualitative variables

Variables	Correlation ratio
Drinking	0.760**
Laundry	0.022
Cleaning	0.052
Bathing	0.019
Rice processing	0.082
Shea butter	0.123

***p* < .01
Source: Results of the survey.

The presence of productive activities was not correlated with water volume. This indicates the risk of depending on a recall survey because the interview showed that most women think productive water use is the most water-consuming activity. High water fetching load during productive activities may be linked to the perception that more water is being used than is the case.

The absence of drinking water from the container and the daily water volume were strongly correlated, with a correlation ratio = 0.760 and p-value = 0.005. In this case, less water is used when drinking water is taken from a measuring container. One possible explanation is that women who use more water tend to keep drinking water separately for hygiene. In future studies, measuring all water containers at home is recommended to avoid the risk of uneven water use.

Estimation of water availability in small reservoirs for irrigation development

The quantity of water available for irrigation development from a reservoir is given by equation (1) because domestic water should be prioritized over irrigation water [4].

$$V_{\text{irrigation}} = V_{\text{reservoir}} - V_{\text{domestic}}, \quad (1)$$

where: $V_{\text{irrigation}}$ is the irrigation volume, $V_{\text{reservoir}}$ is the reservoir water volume, and V_{domestic} is the domestic water demand.

According to the interview results, domestic water can be divided into household water use at home, livestock water use at reservoirs, existing agricultural water use, and other water uses such as brick-making [2, 16] and laundry at reservoirs, as equation (2):

$$V_{\text{domestic}} = U_{\text{house}} + U_{\text{livestock}} + U_{\text{agric}} + U_{\text{other}}, \quad (2)$$

where U_{house} is household water use at home, $U_{\text{livestock}}$ is livestock water use at reservoirs, U_{agric} is existing agricultural water use, and U_{other} is other water uses.

Equation (2) makes it easier to proceed with further quantification than dividing domestic water use according to categories in [18] because equation (2) 's item corresponds to the leading water user group with the gender specified.

This study explored the factors that determine water use volume, but no significant factors were identified. Thus, estimating household water use based on the presence or absence of activities is inappropriate based on currently available data. The small sample size and the survey design, which assumes that all water is used in the same way as the measuring containers, limit the analysis of the relationship between water use and the amount of water. Further investigations of water use by the whole household with additional samples may provide a clearer picture of water use in the study area.

However, because domestic water is essential to daily life, irrigation plans must secure it. Therefore, it is proposed to use 30 L per person per day as a guideline for the amount to be secured as household water U_{house} in irrigation planning from small reservoirs. The figure is the largest among the figures from the measurement (Fig. 1), indicating households' consumption capabilities. Together with $U_{\text{livestock}}$ and U_{agric}, applying existing studies on unit water requirements and the number of targeted animals or cultivated areas and other water use, if necessary, V_{domestic} and $V_{\text{irrigation}}$ can be estimated.

CONCLUSIONS

This study employed a questionnaire-based interview and a new method of estimating household water use in rural areas: the measuring containers with sensor loggers to record the hourly water level changes in the containers in rural households. The interview results clarified the study area's general water use situation: most women perform productive activities, which they recognize as the most water-intensive; animal water use is common among men and women, and agricultural water use is common among men. The analysis of measured household water use provided insight into domestic activities and their water use: household water shows seasonal differences, the presence of productive activities does not affect the total household water volume, and the number of animals given water at home does not, either. The limitation of using a single measuring container at home is discussed, and the measurement of all containers at home is proposed for future study. Further, an equation to estimate the domestic water demand is proposed with a value of 30 L per person per day as a guideline for the amount to be secured as household water in irrigation planning from small reservoirs. This equation and the value can be used to estimate the domestic water demand and the water volume for irrigation from a multi-purpose reservoir, together with data on water for livestock and agriculture.

ACKNOWLEDGEMENTS

This study was part of a collaborative research project implemented by the Ministry of Food and Agriculture of Ghana, Kwame Nkrumah University of Science and Technology, the University of Development Studies, and the Japan International Research Center for Agricultural Sciences. We acknowledge the financial support from the Ministry of Agriculture, Forestry, and Fishery of Japan, as well as from JSPS KAKENHI Grant Number 20K22601.

REFERENCES

[1]Abou Zaki, N., Haghighi, A.T., Rossi, P.M., Xenarios, S., Kløve, B., 2018, An Index-Based Approach to Assess the Water Availability for Irrigated Agriculture in Sub-Saharan Africa. Water, 10(7), 896. https://doi.org/10.3390/w10070896

[2]Acheampong, E.N., Ozor, N., Sekyi-Annan, E., 2014, Development of small dams and their impact on livelihoods: Cases from northern Ghana. African Journal of Agricultural Research, 9(24),1867-1877.

[3]Adogla-Bessa, D., 2019, One Village, One Dam not solving irrigation problems–Bongo residents complain. https://citinewsroom.com/2019/03/one-village-one-dam-not-solving-irrigation-problems-bongo-residents-complain/, Accessed on 27.08.2020.

[4]Bharati, L., Rodgers, C., Erdenberger, T., Plotnikova, M., Shumilov, S., Vlek, P., Martin, N., 2008, Integration of economic and hydrologic models:

Exploring conjunctive irrigation water use strategies in the Volta Basin. Agricultural Water Management, 95(8),925-936.
[5]de Fraiture, C., Kouali, G.N., Sally, H., Kabre, P., 2014, Pirates or pioneers? Unplanned irrigation around small reservoirs in Burkina Faso. Agricultural Water Management, 131, 212-220.
[6]Ghana Statistical Service, 2014, 2010 Population & Housing Census, District Analytical Report, Kumbungu District, Ghana Statistical Service, Ghana.
[7]Howard, G., Bartram, J., 2003, Domestic Water Quantity, Service Level and Health, WHO: Geneva.
[8]Kawachi, T., Aoyama, S., Yangyuoru, M., Unami, K., Matoh, T., Acquah, D., Quarshie, S., 2005, An irrigation tank for harvesting rainwater in semi-arid Savannah Areas: Design and Construction Practices in Ghana/West Africa. Journal of Rainwater Catchment Systems, 11(1),17-24.
[9]Koide, J., Yokoyama, S., Hirouchi, S., Hirose, C., Oka, N., Oda, M., Yanagihara, S., 2021, Exploring climate-resilient and risk-efficient cropping strategies using a new pond irrigation system: An experimental study in northern Ghana. Agricultural Systems 191:103149.
[10]Ministry of Food and Agriculture, Kwame Nkrumah University of Science and Technology, Japan International Research Center for Agricultural Sciences, 2017, Supplementary Irrigation Manual for Rice Production Using Small Reservoirs. https://www.jircas.go.jp/sites/default/files/publication/manual_guideline/manual_guideline-_-_61.pdf, Accessed on 29.06.2021.
[11]Namara, R.E., Horowitz, L., Kolavalli, S., Kranjac-Berisavljevic, G., Dawuni, B.N., Barry, B., Giordano, M., 2010, Typology of Irrigation Systems in Ghana (IWMI Working Paper 142), International Water Management Institute (IWMI), Colombo, Sri Lanka.
[12]Namara, R.E., Horowitz, L., Nyamadi, B., Barry, B., 2011, Irrigation Development in Ghana: Past experiences, emerging opportunities, and future directions, Ghana Strategy Support Program (GSSP), GSSP Working Paper No. 0027, International Food Policy Research Institute (IFPRI).
[13]Oka, N., Koide, J., Furihata, H., 2020, Feasibility and Issues of Collective Irrigation by Farmers Using Small Reservoirs in Northern Ghana: Evidence from a participatory on-farm trial near Tamale. [In Japanese], Irrigation, Drainage and Rural Engineering Journal, 311(88–2),95-102.
[14]Oka, N., Koide, J., Hirouchi, S., 2020, Leafy Vegetable Cultivation by Women's Group Using Village Pond Water for Irrigation. [In Japanese], Water, Land and Environ. Eng., 88(12),23–26.
[15]Osei-Asare, Y., 2005, Household water security and water demand in the Volta Basin of Ghana. Law, Economics & Management, European University Studies, 3152.
[16]Rosen, S., Vincent, J.R., 1999, Household Water Resources and Rural Productivity in Sub-Saharan Africa: A Review of the Evidence. Harvard Institute for International Development, Cambridge.
[17]Seidu, Y., Kyei-Baffour, N., Bawa, A., Mohammed, A.M., Issaka, Z., Ayuba, J., 2021, Assessment of Water Supply Sources in the three Districts of Northern Ghana in Terms of Availability, Use and Sufficiency. ADRRI Journal of Engineering and Technology, 5(3(4) October-December),17-34.
[18]Thompson, J., Porras, I.T., Tumwine, J.K., Mujwahuzi, M.R., Katui-Katua, M., Johnstone, N., Wood, L., 2001, Drawers of Water II. 30 years of change in domestic water use and environmental health in East Africa: summary, International Institute for Environment and Development, London.
[19]Wisser, D., Frolking, S., Douglas, E.M., Fekete, B.M., Schumann, A.H., Vörösmarty, C.J., 2010, The significance of local water resources captured in small reservoirs for crop production – A global-scale analysis. Journal of Hydrology, 384(3-4):264-275.
[20]World Health Organization, 2011, Guidelines for drinking-water quality. Fourth Edition, World Health Organization (WHO), Geneva.
[21]Xie, H., You, L., Wielgosz, B., Ringler, C., 2014, Estimating the potential for expanding smallholder irrigation in Sub-Saharan Africa. Agricultural Water Management, 131:183-193.
[22]You, L., Ringler, C., Wood-Sichra, U., Robertson, R., Wood, S., Zhu, T., Nelson, G., Guo, Z., Sun, Y., 2011, What is the irrigation potential for Africa? A combined biophysical and socioeconomic approach. Food Policy, 36(6):770-782.