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Chapter 12.

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GROUNDWATER SITUATION IN TANZANIA
Experiences from Mbarali District in Mbeya Region

ABSTRACT

This chapter examines groundwater situation in selected villages in rural areas of Mbarali District where drinking water infrastructures for domestic use are poor and or lacking. The study adopted sequential exploratory research design to collect quantitative and qualitative data. The sample size, randomly selected, was 90 groundwater users and 50% were women. Descriptive statistics, one way Analysis of Variance (ANOVA), correlation analysis and independent T-test were used to analyze quantitative data while qualitative data were subjected to content analysis. The results show that 66.7% of the respondents depend on the groundwater (deep wells) for domestic use. This was influenced by the perception that groundwater was clean or was the only source available. The mean distance from a household to a groundwater source was 249.50 metres. The variation, in terms of distance from households to the groundwater source between the villages, was significant at 5%. In addition, the relationship between socio-economic characteristics of the household heads and the amount of groundwater used was generally weak. The socio-economic characteristics involved were household heads' education level, household size, household annual income and distance from home to the groundwater source. The study concludes that groundwater was critical and dependable in supporting households' livelihoods. It is therefore pertinent, at a policy level, to enhance groundwater infrastructure

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development at the local level so long as surface water is dwindling. In addition, the question of groundwater governance in terms of groundwater quality, institutional structures and legal and policy issues worth an investigation to ensure sustainability of the groundwater resources.

Key words: Groundwater, accessibility, usage, challenges, Mbarali, Mbeya, Tanzania.

1. Introduction

In recent years, it has been acknowledged that a considerable proportion of the human population in the world is using groundwater resource for different purposes including domestic uses and irrigation. This trend is influenced by many factors. For instance, in developing countries like Tanzania, the increasing trend is influenced by, among other factors, diminishing of surface water because of changes in rainfall amount and its patterns, population growth and increasing economic development. Nevertheless, the interactions between groundwater resource and the society especially in rural Tanzania where infrastructures for domestic use including drinking water are poor and or lacking is not explored sufficiently. The importance of groundwater resource is acknowledged in many countries in the world. For instance, Garduño[1] reports that 97% of the accessible freshwater in the world is groundwater resource. About 2 billion people in the world depend on groundwater resource for domestic use, industrial development and irrigation. This indicates that groundwater is one of the critical natural resources for peoples' livelihoods and for development in general.

[1] H. Garduño, S. Romani, B. Sengupta, A. Tuinhof, R. Davis, *India groundwater governance case study*, Washington DC 2011, http://documents.worldbank.org/curated/en/758081468169178804/India-Groundwater-governance-case-study, visited 23 March 2017.

Groundwater is defined as freshwater from rain or melting ice and snow that soaks into the soil and is stored in the tiny spaces between rocks and particles of the soil. As such groundwater is not isolated with surface hydrological system, but interacts with each other across a variety of physiographic andclimatic landscapes[2]. Normally, people use deep wells, drilled shallow wells or dug wells to access groundwater resource. A deep well refers to the constructed well by either cable tool or rotary-drilling machines. It can be drilled even more than 300 metres deep. The space around the casing must be sealed with grouting material of neat cement to prevent contamination by water draining from the surface downward around the outside of the casing. On the other hand, drilled shallow well is constructed by drilling a pipe into soft ground, such as gravel or thick sand. A perforated pipe or screen is attached at the end of the pipe to allow water to flow into the well as well as to filter out sediment[3].

According to Wijnen [at el.][4], 70% of the population in the Southern African Development Community (SADC) depends on groundwater resource for various uses including agriculture, urban development, rural livelihood, livestock and safe drinking water supply systems. One of the factors that necessitate groundwater use

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[2] Z. Yang, Y. Zhou, S. Uhlenbrook, *Multi-method approach to quantify groundwater/surface water-interactions in the semi-arid Hailiutu River basin, northwest China*, „Hydrogeology Journal", 22(2014), pp. 527–554; D. Bhatt, R.K. Mall, *Surface Water Resources, Climate Change and Simulation Modelling*, „Aquatic Procedia", 4(2015), pp. 730–738.

[3] S. Collins, *Hand-dug Shallow Well, SKAT, Swiss Centre for Development Cooperation in Technology and Management*, St Gallen 2000; A. van der Wal, *Understanding Groundwater and Wells in Manual Drilling: Instruction Handbook for Manual Drilling Teams on Hydro-Geology for Well Drilling, Well Installation and Well Development*, „PRACTICA Foundation", 3(2010), pp. 1–4.

[4] M. Wijnen, A. Benedicte, H. Bradley, C. Ward, P. Huntjens, *Managing the Invisible- Understanding and Improving Groundwater Governance*, Thematic Paper No. 11. Groundwater Governance, A Global Framework for Action. GEF, World Bank, UNESCO-IHP, FAO and IAH, 2012.

is the dwindling of surface water particularly in semi-arid and arid areas. Literature reveals that the diminishing of surface water is accelerated by a number of factors including decreasing and changes in rainfall patterns, increasing multi-sectors demands, degradation of water catchments due to increase population, over abstraction, poor land use practices, urbanization and industrial development[5].

In Tanzania, groundwater use accounts for over 25% of the water supply for domestic use, livestock, agriculture and sustaining ecosystems[6]. Despite the fact that Tanzania is not mentioned as one of the water stressed countries, it has high rainfall variability suggesting decreasing amount of surface water in some areas. In some regions, semi-arid areas are affected by frequent drought. For instance, in the Southern Highlands the average annual rainfall is over 1 200 mm while in semi-arid areas including Mbarali District the mean annual rainfall is less than 600 mm[7]. Climate variability and change are mentioned to be the main causes of the rain shortage in arid and semi-arid areas[8]. The aridity situation

[5] J.J. Kashaigili, *Assessment of groundwater availability and its current and potential use and impacts in Tanzania. Report Prepared for the International Water Management Institute*, 2010; URT, Water Sector Status Report. Ministry of Water, Dar es Salaam 2012, [http://www.Water_ Sector_ Status_ Report-_Submitted_17-092012.pdf], site visited on16th February 2017.

[6] Water Resource Group, *Tanzania: Hydro-economic overview initial – analysis*, 2014, http://www.2030WRG_TANZANIA (USED).pdf, site visited on 12 April 2017.

[7] M. Van Camp, I.C. Mjemah, N. Al Farrah, K. Walraevens, *Modeling approaches and strategies for data-scarce aquifers: example of the Dar es Salaam aquifer in Tanzania*, „Hydrogeology Journal", 21(2013), no. 2, pp. 341–356; Water Resource Group, *Tanzania: Hydro-economic overview initial...*, op. cit.; W.C. Kayombo, *Assessing Meteorological Data for Reference Evapotranspiration – in Kyela and Mbarali District*, „Journal of Environment and Earth Science", 6(2016), no. 4, pp. 1–7.

[8] J.J. Kashaigili, *Assessment of groundwater availability...*, op. cit.; URT, *Water Sector Status Report...*, op. cit.; M.Y. Mkonda, *Assessment of Water Shortage and its Implications to Gender Role in Semi-arid Areas in Mvumi Ward, Dodoma in Tanzania*, „Arts Social Science Journal", 6(2015), pp. 142, doi: 10.4172/2151-6200.1000142.

in Mbarali District accelerates people to depend on groundwater source to support their livelihoods[9].

Although literatures acknowledge the importance of groundwater in supporting peoples' livelihoods, little is known about groundwater situation in terms of types of groundwater sources, availability of groundwater, and challenges related with groundwater resource. Understanding the situation of groundwater in Mbarali District remains vital since it informs various groundwater stakeholders on the existing interaction between the resource and the local community. It also reflects the magnitude of the local community dependency on groundwater resource in enhancing their livelihoods. This chapter is guided by the following research questions: What types of groundwater source exist in the study area and what are the challenges associated with groundwater sources? How far are the households from the groundwater source? What influences access to and or use of groundwater apart from using other water sources? The answers to these questions provide comprehensive knowledge about the interaction between the groundwater resource and community in the study area. This chapter is organized into four sections. Section one introduces the chapter and uncovers the research puzzle. Section two presents the methodology used while section three is devoted to results and discussion. Conclusions and recommendations are presented in section four.

2. Study area

This study was conducted in Mbarali District, Mbeya Region. The central part of Mbarali District is located at latitude 8° 51'

[9] J.J. Kashaigili, *Assessment of groundwater availability...*, op. cit.; K.G. Villholth, C. Tottrup, M. Stendel, A. Maherry, *Integrated mapping of groundwater drought risk in the Southern African Development Community (SADC) Region*, „Hydrogeology Journal", 21(2013), no. 4, pp. 863–885.

South, longitude: 33° 51' East. The altitude ranges from 1 000 to 1 800 meters above sea level[10]. The minimum temperature is 19°C (June–July) while the maximum is 35°C (August to December)[11]. The district covers an area of 16 632 square kilometres and has a population of 300 517. Administratively, the district is divided into 20 wards with a total of 99 villages[12]. The main soil characteristics in Mbarali District are dark grey and prismatic cracking clays. The water sources including groundwater laid in the Great Ruaha River Catchment, which is one of the four sub-basins of the Rufiji River Basin. The mean annual rainfall is 600 mm which falls between December and April and hence the District is vulnerable to water scarcity[13].

3. Methodology

The study employed sequential exploratory research design with two phases. The first phase involved collection and analysis of qualitative data, and the results of this phase were used to refine questionnaire for the second phase. The second phase involved collection of quantitative data through household survey using a structured questionnaire. Focus Group Discussions (FGDs) and key informant interviews guided by checklist of items were used to collect qualitative data.

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[10] R. Kangalawe, S. Mwakalila, P. Masolwa, *Climate Change Impacts, Local Knowledge and Coping Strategies in the Great Ruaha River Catchment Area, Tanzania*, „Natural Resources Journal", 2(2011), pp. 212–223.

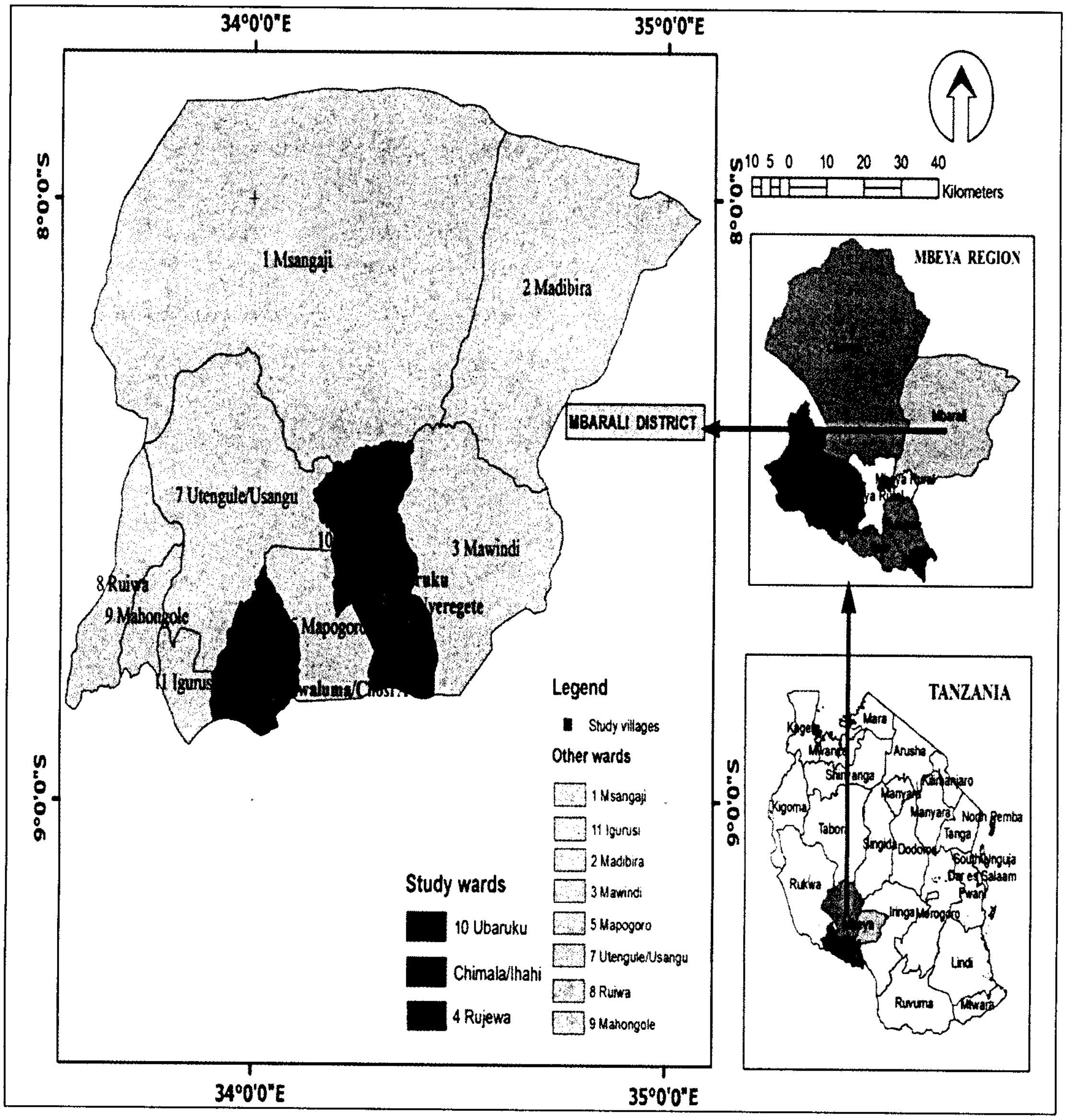
[11] Ibidem.

[12] URT-National Bureau of Statistics, *Basic Demographic and Socio-Economic Profile Report Tanzania Mainland*, 2014, http://www.TANZANIA_ MAINLAND_SOCIO_ECONOMIC_PROFIL_sw.pdf, site visited on 11 March 2017.

[13] W.C. Kayombo, *Assessing Meteorological Data...*, op. cit.; A. Sirima, *Social and Economic Impacts of Ruaha National Park Expansion*, „Open Journal of Social Sciences", 4(2016), pp. 1–11.

The study population encompassed groundwater users in the study sites. The sampling procedures involved purposive selection of three villages based on various criteria including accessibility and use of groundwater by household, groundwater degree of dependence, public use, degree of collective action arrangements in managing and use of groundwater. The villages were Nyeregete, Ubaruku and Mwaluma from Rujewa, Ubaruku and Ihahi wards respectively (Figure 1).

Figure 1. Location map of Mbarali district



The selected villages constitute an area for the Groundwater Futures in Sub-Saharan Africa (Grofutures) Project whereas this study is a part of the project. The Grofutures Project is a four years research project (2015–2018) funded by the United Kingdom (UK) government. The overall aim of the Grofutures is to develop scientific basis and participatory management processes by which groundwater resources can be used sustainably for poverty alleviation in Sub-Saharan Africa. This study contributes knowledge to the specific objective of constructing a set of plausible and stakeholder-informed groundwater development pathways. In each village 30 respondents were randomly selected making a sample size of 90 respondents. This sample size is appropriate because it allows statistical analysis leading to the reasonable conclusions[14].

One Focus Group Discussion was conducted in each village making a total of three FGDs. In order to get different experiences and perceptions on groundwater, sex and age were the criteria used to select FGDs participants. Each FGD comprised 8–12 participants. The proportion of women FGDs participants ranged from 5 to 7 in each group. Women were involved in FGDs because they are responsible to collect water for domestic uses. The information gathered during FGDs captured groundwater usage, type of groundwater sources, groundwater availability, factors that influence the household to access groundwater source, other water sources accessed by the households, socio economic activities and challenges of using groundwater sources. The Village Executive Officers (VEOs) from each village and the chairperson and secretary of Ubaruku Mpakani (UBAMPA) were involved as the key informants. UBAMPA is a Community Water Supply Organization (COWSO) that serves at Ubaruku and Mpakani villages.

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[14] K.D. Bailey, *Methods of Social Research*, 4th Edn., New York 1994.

The key informant interviews were conducted to obtain information about the number of groundwater sources in the villages and the intervention supporters of the constructed groundwater sources. The key informants were selected based on the fact that they were well informed and responsible for keeping all information related to groundwater facilities in a village. In addition, household survey guided by a questionnaire was used to collect quantitative data on demographic characteristics and the situation of groundwater in the selected villages. The situation of groundwater included groundwater usage, types of groundwater source, factors that influenced the households to access groundwater source, other sources of water accessed by the households, distance from a household to the groundwater source and estimated amount of water used at the household per day per capita.

4. Data analysis

Content analysis was used to analyze qualitative data by summarizing field data based on objectives of the study. The quantitative data were analyzed by using Statistical Package for Social Sciences (SPSS) by computing descriptive statistics to obtain means and percentage distribution of the responses. To determine the normality of data, the Sharpiro-Wilk test was used and it showed no significant ($P > 0.05$) difference between the normal curve and the curve of the amount of water used at the household per day and distance of a household to the groundwater source. This implies that the population from which the data were collected was normally distributed.

Therefore, one way Analysis of Variance (ANOVA) was used to test differences of the amount of water used at a household level per day and distance from the groundwater source to a household between the villages. The Post hoc particularly Tukey's Honestly Significant Difference (HSD) was used for multiple comparisons. The test is designed to make all pair wise comparisons while maintaining the experiment wise error rate at the pre-established level. In addition, the Independent T-test was used to compare the amount of water used at a household level reported by men and women respondents. This test is useful tocompare mean difference on continuous variables for two different groups if the data are normally distributed[15].

The analysis also involved running correlation analysis whereby Pearson correlation coefficient was computed to determine whether there was any relationship between the estimated amount of groundwater in litres used at a household per day and respondents characteristics including years of schooling, household size, annual income, number of years a household resided in the village, and distance from home to the groundwater source in metres. The Pearson correlation coefficient (r) is a measure of the strength of a relationship between two continuous variables. The value of r normally ranges between -1 and 1[16]. The strength of the relationship can be categorized into three groups. If r ranges from 0.10 to 0.29 the relationship is said to be weak whereas if r ranges from 0.30 to 0.49 the relationship is said to be moderate. In addition, a strong relationship exists when r ranges from 0.50 to 1.0 whereas a perfect relationship exists if r is either -1 or 1[17].

5. Results and discussion

5.1. Respondents' characteristics

Table 1 presents respondents' characteristics. The results showed that half (50%) of the respondents were females. The results also

[15] J.F. Pallant, *SPSS survival manual: Step-by-step guide to data analysis using SPSS for windows*, third edition, England 2007.

[16] N. Fenton, M. Neil, *Risk Assessment and Decision Analysis with Bayesian Networks*, 2012.

[17] J.F. Pallant, *SPSS survival manual...*, op. cit.

show that 58.9% and 33.3% of the respondents were household heads and spouses respectively. The rest were the grown-up other household members. The analysis also shows that 62.2% of the respondents depended on farming activities as their main source of income followed by 18.9% who depended on small scale businesses. This implies that majority of the respondents were smallholder farmers. Most of the United Republic of Tanzania reports indicate that more than 70% of the Tanzania work force depends on agricultural sector for the livelihoods[18].

Table 1. Respondents' characteristics (n=90)

Sex	**Nyeregete**	**Ubaruku**	**Mwaluma**	**Total**
Male	15(50)	15(50)	15(50)	45(50)
Female	15(50)	15(50)	15(50)	45(50)
Relationship to the Household head				
Head of Household	22(73.3)	16(53.3)	15(50)	53(58.9)
Spouse	7(23.3)	8(26.7)	15(50)	30(33.3)
Another Male Household member	0(0.0)	3(10)	0(0.0)	3(3.3)
Another Female Household member	1(3.3)	3(10.0)	0(0.0)	4(4.4)
Main source of income				
Farming	20(66.7)	20(66.7)	16(53.3)	56(62.2)
Livestock keeping	1(3.3)	2(6.7)	1(3.3)	4(4.4)
Small scale business	6(20.0)	7(23.3)	4(13.3)	17(18.9)
Casual labour	0(0.0)	0(0.0)	2(6.7)	2(2.2)
Salary	3(10.0)	1(3.3)	7(23.3)	11(12.2)

Note: Numbers in brackets are percentages

Table 2 presents respondents' response on other sources of income apart from what is considered as a main source. The results

[18] E.T. Lwoga, C. Stilwell, P. Ngulube, *Access and Use of Agricultural Information and Knowledge in Tanzania*, „Library Review", 60(2011), no 5, pp. 383–395.

show that 37.8% of the respondents reported livestock keeping. The rest reported farming, casual labour, remittance and small scale business as their households' supplementary sources of income. Livestock keeping and crop production as sub sectors are the leading households' other sources of income. This implies that majority depended on farming and or livestock keeping in supporting their livelihoods. These results are in line with literature which indicates that about 35% of the households in Tanzania are engaged both in crop production and livestock keeping[19].

Table 2. Other sources of income (n=90)

Source of income of the household	Nyeregete	Ubaruku	Mwaluma	Total
Farming	5(16.7)	5(16.7)	9(30)	19(21.1)
Livestock keeping	10(33.3)	13(43.3)	11(36.6)	34(37.7)
Casual labour wages	9(30)	3(10)	5(16.7)	17(18.9)
Remittances	3(10)	1(3.3)	2(6.7)	6(6.7)
Small scale business	3(10)	5(10)	0(0)	8(8.9)
None	0(0)	3(10)	3(10)	6(6.7)
Total	**30(100.0)**	**30(100.0)**	**30(100.0)**	**90(100.0)**

Note: Numbers in brackets are percentages

Table 3 shows the respondents' marital status and education levels. The findings show that 72.2% of respondents were married. Out of married couples, 55.4% were male. This indicates that the married males outnumbered the married females. With regard to the respondents' education level, 53.3% of the respondents held primary education. This implies the majority had acquired basic

[19] E. Engida, P. Guthiga and J. Karugia, *The Role of Livestock in the Tanzanian Economy: Policy Analysis Using a Dynamic Computable General Equilibrium Model for Tanzania*, in: 2015 Conference, August 9–14, Milan, Italy (No. 212039). International Association of Agricultural Economists, 2015.

education. Education is a major means of providing individuals with opportunity to achieve their full potential. This involves the ability of acquiring knowledge, skills, values and attitudes needed for various social and economic roles, as well as for their all-around personal development[20]. Thus, low education level may constrain development at the household level.

Table 3. Respondents' marital status and education level (n=90)

Marital status	**Male**	**Female**	**Total**
Married	36(80.0)	29(64.4)	65(72.2)
Single	4(8.9)	2(4.4)	6(6.7)
Divorced	1(2.2)	5(11.1)	6(6.7)
Widowed/widower	4(8.9)	9(20.0)	13(14.4)
Education level			
Non-formal education	10(22.2)	8(17.8)	18(20.0)
Primary education	26(57.7)	22(48.9)	48(53.3)
Secondary	3(6.7)	12(26.7)	15(16.7)
Tertiary education	3(6.7)	2(4.4)	5(5.6)
Higher Learning education	3(6.7)	1(2.2)	4(4.4)

Note: Numbers in brackets are percentages

Table 4 shows respondents' age, household size, total number of years a household resided in the village and household annual income. The results show that the mean age of the respondents was 43 years. This implies that majority of the respondents were young adults who are potential workforce on households' socio-economic development. Furthermore, the findings show that the mean number of persons per household was 5.9. This number is

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[20] URT, *Education in a Global Era: Challenges to Equity, Opportunity for Diversity. Paper presented at the Fourteenth Conference of Commonwealth Education Ministers (14 CCEM) Halifax, Nova Scotia, Canada, 27–30 November*, 2000.

above 4.9 persons reported at the national level[21]. With regard to the total number of years in which respondents resided in the village; the results show that the mean number was 18.4 years. This implies that respondents had enough experience with regard to water resource in the villages. The results also show that the mean annual income of household was Tanzania Shillings (TZS) 3 074 500, equivalent to TZS 256 208 per month per household. This amount is higher than the mean income at a national level. Literature shows that the mean household income is TZS 146,000 per month per household in Tanzania[22]. The higher household income in the study area can be associated with potential socio-economic activities including paddy production that are undertaken in the Usangu plain including Mbarali District.

Table 4. Descriptive statistics on respondents' characteristics (n=90)

Category	Minimum	Maximum	Mean	Std. Deviation
Age of the respondent	22	72	43.2	12.1
Number of people in the household	2	11	5.9	1.8
Number of years the household heads resided in a village	3	50	18.4	10.9
Annual household income	350 000	15 000 000	3 074 500	3 177 319

5.2. Groundwater sources and its challenges

Table 5 presents types of groundwater sources reported by the respondents. The results indicate that 66.7% of the respondents used deep groundwater wells. The rest used drilled shallow wells.

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[21] United Nations World Food Programme and World Bank, *Comprehensive Food Security and Vulnerability Analysis (CFSVA), Tanzania, 2012*, 2013, [http://www.UN-WorldFood-ProgrammeandWorldBank2013.pdf], site visited on 28/04/2017.

[22] URT, *National Baseline Survey Report for Micro, Small, and Medium Enterprises in Tanzania*, 2012, [MSME-National-Baseline-Survey-Report.pdf], site visited on 16/3/2017.

Table 5. Groundwater sources used (n=90)

Type of groundwater source	Nyeregete	Ubaruku	Mwaluma	Total
Deep well	0(0.0)	30(100)	30(100)	60(66.7)
Drilled Shallow well	30(100)	0(0.0)	0(0.0)	30(33.3)
Total	**30(100)**	**30(100)**	**30(100)**	**90(100)**

Note: Numbers in brackets are percentages

These results deviate from the 2012 Population and Housing Census (PHC) report, which show that dug wells are the main source of water in rural areas in Tanzania. About 25% of households in rural areas depend on unprotected water dug wells[23]. Possibly, this difference can be related with lack of groundwater intervention support in most rural areas. The key informants reported that all groundwater sources in the study area were financed by the international donors via the Tanzania government as an initiative to support local governments as well as the entire community to improve water services for domestic uses. For instance, the constructed deep and drilled wells at Ubaruku, Mwaluma and Nyeregete villages were constructed by local government at the district level with financial support from World Bank (WB), United Nations Children's Fund (UNICEF) and Danish International Development Agency (DANIDA) water programme. This connotes that there was no direct internal initiative established by community to enhance groundwater interventions. Dependence on external support jeopardizes sustainability of the groundwater sources. Apart from deep and drilled wells, direct observation and Focus Group Discussion (FGDs) revealed several dug wells owned by individual

[23] URT, *Mbarali District Council Strategic Plan 2013/14–2017/18*; Prime Minister's Office Regional Administration and Local Government, 2014, [http://www.mbaralidc.go.tz/storage/app/uploads/public/58d/10/58d101fccce7f653574057.pdf] site visited on 27/6/2017.

households. Even though, they were used communally. In addition, FGDs at Nyeregete and Ubaruku villages reported that: "People tend to construct wells around their houses for various purposes such as livestock use, brick making, domestic use and small scale irrigation". This indicates that apart from deep and drilled wells, dug shallow wells were commonly used by the respondents for various socio-economic activities.

By definition, hand dug wells are wells excavated and lined by human labour, usually by entering the well with a variety of hand tools. They may be as small as 80 cm diameter, and can range in depth from about five metres deep, to deep wells over 20 metres deep[24]. The key informants reported that the average depth of deep wells and drilled shallow wells were 85 and 8 metres respectively. FGDs, also reported that both deep and drilled shallow wells provided enough water throughout a year. „---all the time our well provides a lot of water. Therefore people can access water at any time except when they are in maintenance need" (FGD at Nyeregete village).

The use of groundwater has various advantages such as accessibility to water source in terms of distance, cleanness and adequacy of groundwater resource. However, during the Focus Group Discussions it was reported that groundwater use had a number of challenges. One of them is lack of knowledge on how and where to construct dug wells at a household level. „We use our own indigenous knowledge to dig wells around our homes to satisfy our household water needs but most of us know nothing about location. For instance, most of dug well users in this village are not well informed about the proper distance from pit latrines to the groundwater sources" (FGD at Nyeregete). Literature recommends that the bottom of pit latrines should be at least 2 m

[24] S. Collins, *Hand-dug Shallow Well...*, op. cit.

above groundwater level, and a minimum horizontal distance of 30 m between a pit latrines and dug well. This recommendation aims to limit exposure to microbial contamination[25].

Another challenge is poor wells protection. Through direct observation in all villages, the study found most of the dug wells were not and/or were poorly protected. Although this challenge is well known by the village authorities there was no seriousness in managing it. „Those dug wells are constructed by the households themselves for their own uses. Thus it is their responsibility to ensure that wells are well protected. I sometimes remind them to do it but most of them are not protecting those wells properly" (Source: key informant at Nyeregete). Although Water Resource Management Act (WRMA) no 11and 12 of 2009 directs that all groundwater sources have to be protected[26] the reality is the reverse. As such, groundwater sources can endanger household members.

In addition, uncertainty on groundwater safety for human consumption was also mentioned as a challenge. Even if the resource is perceived by the groundwater users as cleaner than surface water, FGDs reported groundwater from dug and drilled shallow wells were not treated. „We thank God that we have a lot of water from our groundwater sources. But to what extent the resource is safe for our health remains a mystery. We do not treat our drilled shallow wells or dug wells" (said by key informant in Nyeregete). According to the Secretary of COWSO it was reported that groundwater sample from the deep well is taken by UBAMPA once per year to the regional laboratory to test whether the resource is still healthy for human consumption. However, the UBAMPA had no say about

[25] R.A. Fenner, P.M. Guthrie, E. Piano, *Process selection for sanitation systems and wastewater treatment in refugee camps during disaster-relief situations*, „Water and Environment Journal", 21(2007), no. 4, pp. 252–264.

[26] URT, *Water Resource Management Act no 11*, Dar es Salaam 2009.

status of dug wells owned by individual households. "Water from this source is treated every month to ensure safety to all groundwater users. We know that if the source is not protected as well as if the resource is not treated it can lead to health problems. But we have no access to enforce water sources protection and water resource treatment to dug wells that are normally constructed and controlled by individuals' households" (Key informant at Ubaruku village). Generally, the findings related on dug wells indicate that the situation of dug wells in terms of protection and hygiene was not well known by the villages' authorities. Thus, there is a possibility of the groundwater users using these sources to get diseases such as typhoid and cholera.

Other water sources reported by the respondents apart from groundwater wells are presented in Table 6. The results show that 34.4% did not report other water sources apart from groundwater source while 30% and nearly 29% of the respondents reported water from springs and canals respectively. Literature defines springs as a land to which water rises naturally from below the ground flows by gravity. Normally, it occurs where the water table is very near or meets land surface[27]. Canal is defined as the main ditch which is used to convey water from an intake built from a river. The conveyed water from the canal is led to paddy fields through field(s) ditches or furrow(s). Therefore, village dwellers around the canal tend to use it as other source of water for domestic uses.

Focus Group Discussions reported that most of people do not prefer using canals and springs sources because of pollution. Water

[27] S.M. Awadh, K.K. Ali, A.T. Alazzawi, *Geochemical exploration using surveys of spring water, hydrocarbon and gas seepage, and geobotany for-determining the surface extension of Abu-Jir Fault Zone in Iraq: A new way for determining geometrical shapes of computational simulation models*, „Journal of Geochemical Exploration", 124(2013), pp. 218–229.

pollution is mainly caused by socio-economic activities such as irrigation whereby mortars to pump water from springs or canals are used. Hence, water becomes contaminated since some fuel drops remain in the water. In addition, human behaviour such as bathing or dumping sold wastes also discourages the use of water from springs and canals for domestic uses particularly for drinking. „---sometimes when we fetch water we see a lot of things such as plastic materials, tarnished clothes, faeces just few metres in or around water sources. I think such a situation also accelerates the use of groundwater at the households." (Source: FGDs in Mwaluma village). However, it should be noted that groundwater like surface water is also prone to pollutants. Thus, to deviate from using surface water to groundwater because of pollution created by the resource users themselves, it is likely to shift the problem from the visible to the invisible resource.

Table 6. Other water sources reported by the respondents in percentages (n=90)

Source of water	Nyeregete	Ubaruku	Mwaluma	Total
Canal	0(0.0)	26(86.7)	0(0.0)	26(28.9)
Water spring	0(0.0)	0(0.0)	27(90.0)	27(30)
Rainwater collection	0(0.0)	3(10.0)	3(10.0)	6(6.7)
None	30(100.0)	1(3.3)	0(0.0)	31(34.4)
Total	**30(100)**	**30(100)**	**30(100)**	**90(100)**

Note: Numbers in brackets are percentages

5.3. Distance to the groundwater source

Table 7 presents approximate distance from home to the groundwater sources in metres. The results show that the overall mean distance from a household to a groundwater source was 249.50 metres with a standard deviation of 174.4 metres. This indicates that groundwater resource in the study area was accessible. The National Water Policy (NAWAPO) of 2002 defines water as accessible when one water point serves 250 persons within a distance of 400 meters and users spend no more than 30 minutes for a round trip[28].

Although the national policy suggests a walkable distance to a water source, the reality is not the case. Literature shows that about 50% of households in arid areas obtain water service at the distance of more than 3 000 metres from their home[29]. This implies that groundwater resource has an advantage of being nearly accessed from home. Using ANOVA, the results of this study show that the distance from home to a water source between the villages was significant at 0.1%.

Table 7. Approximate distance from home to water source in meters (n=90)

Village Names	N	Mean	Std. Deviation	F	P-value
Ubaruku	30	174.83	120.32		
Nyeregete	30	227.00	156.14	9.036	0.00
Mwaluma	30	346.46	196.08		
Total	**90**	**249.50**	**174.42**		

Table 8 shows that there was a significant difference in terms of distance in metres from household to the groundwater source between Ubaruku and Mwaluma villages at 1% level of significance. This means that households in Ubaruku village were closer to groundwater source than the households in Mwaluma village. There was also a significant difference between Mwaluma and

[28] URT, Ministry of Water, *National Water Policy*, Dar es Salaam 2002; C.G.v Mandara, R. Lammeren, A. Niehof, *Assessing Water Service Coverage by Placeholders: Social Media Simulation, 7th RWSN Forum „Water for Everyone" 29 Nov – 02 Dec 2016*, Abidjan, Côte d'Ivoire.

[29] M.Y. Mkonda, *Assessment of Water Shortage...*, op. cit.

Nyeregete villages at 5% level of significance. These differences are largely associated by the total number of groundwater points within the villages. For instance, during key informant interviews, it was reported that there were 23 groundwater points in Ubaruku while Nyeregete and Mwaluma had 3 and 1 respectively. This is justified by a mean of distance from home to groundwater source at Mwaluma, Nyeregete and Ubaruku villages (Table 7) in relation to a total number of groundwater points. Thus, proper water points' distribution in a given population is important for improving water accessibility. By definition, water point is a place whereby people get access of water service[30]. In this study, water point refers to a place whereby the households in the villages obtained groundwater from either deep or drill shallow well.

Table 8. Compared mean difference on the approximate distance from home to the groundwater sources (n=90)

Compared village		Mean Difference	Std. Error	P-value	95% Confidence Interval	
					Lower Bound	Upper Bound
Ubaruku	Nyeregete	–52.167	41.448	0.422	–151.00	46.67
	Mwaluma	–171.833*	41.448	0.000	–270.67	–73.00
Nyeregete	Ubaruku	52.167	41.448	0.422	–46.67	151.00
	Mwaluma	–119.667**	41.448	0.013	–218.50	–20.83
Mwaluma	Ubaruku	171.833*	41.448	0.000	73.00	270.67
	Nyeregete	119.667**	41.448	0.013	20.83	218.50

*. Significant at 0.1%; **Significant at 5%.

5.4. Reasons for accessing and using groundwater

Table 9 shows the reasons that influenced access to groundwater resource apart from other sources. The results show that 40% of

[30] URT, Ministry of Water, *National Water Policy...*, op. cit.

the respondents used groundwater because they perceived it to be clean. Other reasons include: it is the only source of water available and near walking distance to groundwater source. This is in line with the qualitative results. For instance, FGDs reported that majority of the people in Ubaruku village used groundwater source than canal water source because groundwater was considered clean while people from Nyeregete village reported that groundwater was the only source available. With regard to the situation of water availability in Nyeregete, one of the key informants reported that „----I thank God for groundwater availability at Nyeregete village. I sometimes ask myself, what would happen in our village if we should have no groundwater resource? Perhaps many people could migrate to other villages to sustain their livelihoods". This implies that the availability of groundwater contributes in supporting peoples' livelihoods.

Table 9. Factors influencing access to and use of groundwater source (n=90)

Reasons	Male	Female	Total
Near walking distance to groundwater source	8(17.8)	6(13.3)	14(15.5)
Adequate groundwater source	2(4.4)	4(8.9)	6(6.7)
Affordability to groundwater charges	2(4.4)	6(13.3)	8(8.9)
Is the only source available	14(31.1)	12(26.7)	26(28.9)
Groundwater is clean and safe	19(42.2)	17(37.8)	36(40.0)
Total	45(100)	45(100)	90(100)

Note: Numbers in brackets are percentages

5.5. Groundwater use at a household level

Table 10 shows the overall amount of groundwater used per day at the household level. The results showed that the overall mean of the amount of water used at the household per day was 221 litres. This is equivalent to 41 litres per person per day in the study villages. This is relatively high compared to the minimum amount of 20 litres per person per day as suggested at the national level (URT, 2015). The difference can be associated by the accessibility in terms of distance from the household to the water source and its adequacy in the study villages. However, this amount of water is low compared to the United Nations (UN) recommendations on the water poverty line suggesting that a sufficient amount of water is at least 50 to 100 litres per person per day obtained from a safe source[31]. Reflecting that the amount of water used at the households' level in the study villages did not meet the requirement of the UN. Nevertheless, the results also show that the amount of groundwater used per person per day at Nyeregete village met the UN recommendations. Likely, the types of socio economic activities that used groundwater in Nyeregete led to high amount of groundwater used per day per person than other villages.

Table 10. Amount of groundwater used per household per day in litres (n= 90)

Village	**N**	**Mean**	**Std. Deviation**	**F**	**P. Value**
Nyeregete	30	261.00	105.02		
Ubaruku	30	236.00	96.22	8.966	0.00
Mwaluma	30	166.00	63.65		
Total	**90**	**221.00**	**97.80**		
Amount of water used per person per day					
Nyeregete	30	49.97	37.39	1.249	0.292
Ubaruku	30	40.09	19.99		
Mwaluma	30	39.95	24.02		
Total	**90**	**43.34**	**28.22**		

[31] United Nations World Food Programme and World Bank, *Comprehensive Food Security...*, op. cit.; I.S. Akoteyon, *Pattern of household access to water supply in Sub-urban settlement in parts of Logos state, Nigeria*, „Malaysian Journal of Society and Space", 12(2016), pp. 93–106.

The results also show that there was a significant difference in terms of the amount of water used at a household per day in Nyeregete and Ubaruku villages at 0.1% level of confidence. Furthermore, findings indicate that there was a significant difference between Mwaluma and Ubaruku villages at the 1% level of significance.

The difference can be attributed to a number of factors including availability of other water sources. For instance, in this study, 100% of the households in Nyeregete village used groundwater because it was the only water source available. The amount of water reported at a household in Nyeregete village was higher than the amount reported at a household level in Ubaruku and Mwaluma villages respectively (Table 11). Possibly, this variation is caused by differences in economic activities that were using groundwater resource. Through FGDs in Nyeregete village, it was reported that smallholder farmers were watering gardens using groundwater. However, in Mwaluma and Ubaruku, smallholder farmers were not using groundwater to water their gardens because of the belief that groundwater is hard water, which is unsuitable for plants growth including fruits. This perception has to be technically verified.

The results also show that there was a significant difference in terms of the amount of water used per person per day at Nyeregete and Mwaluma villages at 0.1% level of confidence. Similarly, there was a significant difference on the amount of water used per person per day at Ubaruku and Mwaluma villages at 0.1%. Since these significant differences are in line with the significant differences on the amount of water used at the household per day between villages, it implies that the factors that influence the amount of water used at the household per day are likely to influence the amount of water used per person per day too.

Table 11. Multiple comparisons on the amount of groundwater used per household per day in liters (n=90)

Compared villages		Mean Difference	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Nyeregete	Ubaruku	95.000*	23.258	0.000	39.54	150.46
	Mwaluma	25.000	23.258	0.532	-30.46	80.46
Ubaruku	Nyeregete	-95.000*	23.258	0.000	-150.46	-39.54
	Mwaluma	-70.000**	23.258	0.009	-125.46	-14.54
Mwaluma	Nyeregete	-25.000	23.258	0.532	-80.46	30.46
	Ubaruku	70.000**	23.258	0.009	14.54	125.46
Different amount of groundwater used per person per day in litres						
Nyeregete	Ubaruku	13.48987	6.30429	0.088	10.0127	40.0776
	Mwaluma	25.04517*	6.30429	0.000*	-1.5426	28.5223
Ubaruku	Nyeregete	-11.55529	6.30429	0.165	-40.0776	-10.0127
	Mwaluma	-25.04517*	6.30429	0.000*	-26.5877	3.4772
Mwaluma	Nyeregete	11.55529	6.30429	0.165	-28.5223	1.5426
	Ubaruku	-13.48987	6.30429	0.088	-3.4772	26.5877

* Significant at the 0.1% ; ** Significant at 1%

Table 12 shows responses of male and female on the amount of water in litres used per day at a household. The results indicate that there was no significant difference between male and female responses in reporting the amount of water used at the household level per day ($P > 0.05$).This can be associated by various factors including the nature of activities. For instance, the experience from the study area shows that at the household both male and female engage in brick making, watering garden and animals. These activities consume a lot more water than the amount used for cooking, bathing and washing. Even though, female respondents can be more familiar than male on the amount of water used for cooking and washing. This is because; these activities are mainly undertaken by female at a household level.

Table 12. Male and female responses on the amount of water in litres used at a household per day (n=90)

Groups compared	N	Mean	Std. Deviation	P-Value
Male	45	223.11	103.415	0.426
Female	45	218.89	92.986	

Table 13 presents directions and strengths of the relationship between the amount of water used in litres per day per household and respondents education level, household size, number of years the household resided in the village, household annual income and the distance from home to groundwater sources. The results show a positive relationship between the estimated amount of water used in litres/day per household and the household size, household annual income and the number of years the household resided in the village. This implies that as the household size, the number of years the household residing in the village and the household annual income increase, the amount of groundwater used in the household per day also increases.

Table 13. Relationship between amount of water used at a household per day and households' characteristics

	Education level	HH Size	Years the HH resided in the village	HH annual income	Distance from home to a water source
Pearson Correlation	-.334	.010	.104	.064	-.034
Sig. (2-tailed)	.001*	.923	.330	.547	.748
N	90	90	90	90	90

*Significant at 0.1%

The positive relationship between the amount of water used at the household per day and the household annual income connotes that the amount of water used at the household per day increases with mean annual income. This was associated with two things:

affordability of paying water charges, which was TZS 25 per bucket and engagement on various socio economic activities that used water resource. This implies that households with low income use the available water carefully so as to serve their money for other expenditures. On the other hand, households with high income will maximize the use of water and are likely to be involved in various socio-economic activities like animal keeping, home gardening, brick making among others as they can afford to pay for the water charges.

The results also show negative relationship between the estimated amount of water used per day at a household and education level and the distance from home to the groundwater source in metres. This indicates that as the education level of the household head and the distance from the household to the groundwater sources increase, the amount of groundwater used per day decreases. In relation to the education level this can be explained with the level of awareness on the value of water and the knowledge on proper amount of water to be extracted from groundwater source. Formal education can guide water users on where, when, why and how to use water resource. The decreasing amount of water used at the household per day in relation to the distance from home to groundwater sources is obvious, explained by different reasons including serving the time that should be spent by households to collect water. Literature shows that in some parts of arid and semi-arid areas in Tanzania people spend about 3 to 6 hours to collect water for domestic use[32]. This reduces time for other socio-economic activities at a household level and therefore can negatively affect development.

The results also show that there was a significant relationship between the amount of water used in litres/household per day and the respondents' education level 5%. The strength of the relationship between the estimated amount of water and number of years

[32] M.Y. Mkonda, *Assessment of Water Shortage...*, op. cit.

the household resided in the village and the household annual income was weak. This can be associated by various reasons including the nature of socio economic activities that households are doing. Although 62.2% of the respondents depended on farming activities as their main source of income, yet the results indicate that groundwater resource is less utilized compared to the number of years the household resided in the village. The weak relationship between the amount of groundwater used per household per day and the household annual income can be associated by the established water regulations. For instance, in Ubaruku village there was a regulation of water fee that consequently involved the household income while in Nyeregete and Mwaluma there was no water fee regulation. Thus, all groundwater users' households from Nyeregete and Mwaluma regardless of their income statuses were not limited by their income to use groundwater resource. In addition, there was a moderate relationship between estimated amount of water used per day at a household and years of schooling of the respondents. The results are in line with the respondents' education level whereas the majority acquired basic education.

5. Conclusions and recommendations

The main objective of this study was to examine groundwater situation in selected villages in rural areas of Mbarali District where there is increasing groundwater use for domestic purpose. Based on the results and discussion the study concludes that both deep wells and shallow wells are potential groundwater sources in supporting household livelihoods. However, its potentiality is threatened by lack of awareness of groundwater users particularly on dug wells proper construction, protection and groundwater treatment for human consumption. Furthermore, the study found that groundwater in the study area is accessible in terms of distance from the households to the water sources. Lastly, the study concludes that the majority depends on groundwater sources because they do not have an alternative.

Based on the conclusions the study recommends that different water stakeholders including local government should put more effort in addressing the challenges that exist in the interaction process between groundwater and the groundwater users. Based on the captured groundwater related challenges, the study recommends further studies on groundwater governance to determine whether the resource is effectively managed via its current water structures and institutions. Knowing the status of groundwater governance will help to determine the sustainability of the invisible groundwater resource. Lastly, the study recommends that groundwater users should continue protecting its sources in order to make them sustainable.

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