Journal of Environmental Science International
25(3); 447~456; March 2016
pISSN: 1225-4517 eISSN: 2287-3503
http://dx.doi.org/10.5322/JESI.2016.25.3.447

TECHNICAL NOTE

Rainwater Harvesting Potential in a New Residential Area in North Bujumbura, Burundi

Mfuranzima Kheria, Daeseok Kang, Kijune Sung*

Department of Ecological Engineering, Pukyong National University, Busan 48513, Korea

Abstract

Access to clean and affordable water is one of the fundamental human rights because water is essential to life and a foundation for socioeconomic development of any country in the world. Despite the efforts to secure water supply in Burundi, the amount of water supplied by public utilities does not meet the demand of the population because population keeps increasing with fluctuation of weather conditions. This study selected north Bujumbura that is a sprawling new residential area in the western part of Burundi as a case to investigate the potential of rainwater harvesting in meeting water demand of the country. Based on a long-term average monthly precipitation in the region, the rainwater harvesting potential was assessed as a function of roof sizes, number of households, and runoff coefficients of roof materials. For the entire region of north Bujumbura, the current water supply capacity of the local water company combined with the rainwater harvesting potential resulted in the water surplus of 468,604.1 m^3/yr. Although three communes among them still showed water deficit in dry season, they still got help from rainwater to relieve their water shortage. This suggests that at the regional scale, proper storages and water quality control for harvestable rainwater could contribute to relieving the regional water shortage and allow the population growth.

Key words : Rainwater harvesting potential, Water deficit, Residential area, Africa

1. Introduction

Access to clean and affordable water is one of the fundamental human rights because water is essential to life and a foundation for socioeconomic development of any country in the world. Food production is essentially a function of water availability at farm and industrial levels(FAO, 2008). By extension, it is a necessity for realizing other basic human rights (WHO, 2000). Despite the fact that water is crucial to all human beings, most countries, especially the sub Saharan countries in Africa, experience water scarcity and droughts and the ratio of water-scarce countries is expected to grow to two thirds by 2025(Koppen, 2003). Water scarcity in those countries is due to population increase and climate change(UNDP, 2012) and most of them are among the poorest countries in the world of which Burundi has been identified to be a part. Despite its critical role as a resource, projections by the United Nations(UN) indicated that, as a result of declining global water supply, an estimated two billion people will lack access to safe water by the middle of the 21st century(Ohlsson, 2000). Sub-Saharan Africa is also confronted with similar problems as indicated in a study by the New Partnership for Africa’s Development(NEPAD, 2009)

Received 16 October, 2015; **Revised** 11 January, 2016;
Accepted 15 February, 2016
***Corresponding author** : Kijune Sung, Department of Ecological Engineering, Pukyong National University, Busan 48513, Korea
phone: +82-51-629-6544
E-mail: ksung@pkun.ac.kr

which revealed that about 50% of Africa's population will be affected by water scarcity by 2025(WHO, 2000; Malley et al., 2008).

According to a government survey done in 2006, the water supply in Burundi has decreased from 200 million m^3 to 150 million m^3 since 1993 due to war and other crises that have troubled the country, especially in urban areas that were most affected by the 1993 war(REGW, 2006). Public statistics show that the demand for water in towns and cities has tripled in the last 20 years and that in rural areas has increased from 170 million m^3 in 1990 to over 400 million m^3 in 2010(REGW, 2010). Despite the efforts to secure water supply in Burundi, the amount of water supplied by public utilities does not meet the demand of the population because population keeps increasing. Sometimes women and children have to walk miles to fetch water because they cannot afford to get water from the public water supply system operated by private companies and have no other options than taking water from rivers and lakes without any treatment.

Rainwater harvesting is a technology used for collecting and storing rainwater for human uses from rooftops, land surfaces or rock catchments using simple as well as engineered techniques(Helmreich, 2009). Rainwater harvesting has been practiced for more than 4,000 years. It is an option that has been adopted in many parts of the world where conventional water supply systems have failed to meet the needs of the people(Handia et al., 2003). The application of appropriate rainwater harvesting systems is important for the utilization of rainwater as a water resource. Many countries in the world, especially in Africa where water shortage is a very important issue, have adopted a new system of rainwater harvesting in order to mitigate water scarcity and rainwater has gained much attention in many countries(Mwenge et al., 2007). Considering the current problems in water supply, low-cost rainwater harvesting could also provide a viable alternative to meet the water demand in Burundi.

Burundi receives a long-term average precipitation of 1,274 mm/yr(FAO, 2015). There is, however, much seasonal variation that makes it difficult to get enough water during the dry season (typically from June to August) with the precipitation less than 50 mm. People normally can have access to rainwater for 6 to 8 months in a year on average. Rainwater can be a good supplementary water resource for domestic uses since it is a free water that does not need further treatment unless it is for drinking purposes(IGEBU, 2009).

This study selected north Bujumbura that is a sprawling new residential area in the western part of Burundi as a case to investigate the potential of rainwater harvesting in meeting water demand of the country. Tanganyika Lake is the only source of water for the north Bujumbura area and a private water company is providing treated water to households in the area. However, as the urban residential area is expanding, water demand in some communities has exceeded the water supply of the company because the coverage for urban water supply has not kept pace with the water demand created by new residential development(REGW, 2015). This study aimed to estimate possible contribution of rooftop rainwater harvesting system to reduce water stress in six communities in north Bujumbura and derive implications for regional water supply.

2. Materials and Methods

2.1. Study area

This study selected a residential area of 6 communes in north Bujumbura in Burundi as a site to assess the rainwater harvesting potential. It is a strictly residential area with no agricultural and industrial activities (Fig. 1). Total area of the north Bujumbura is 1,323.6 km^2. Total population of the communes in the

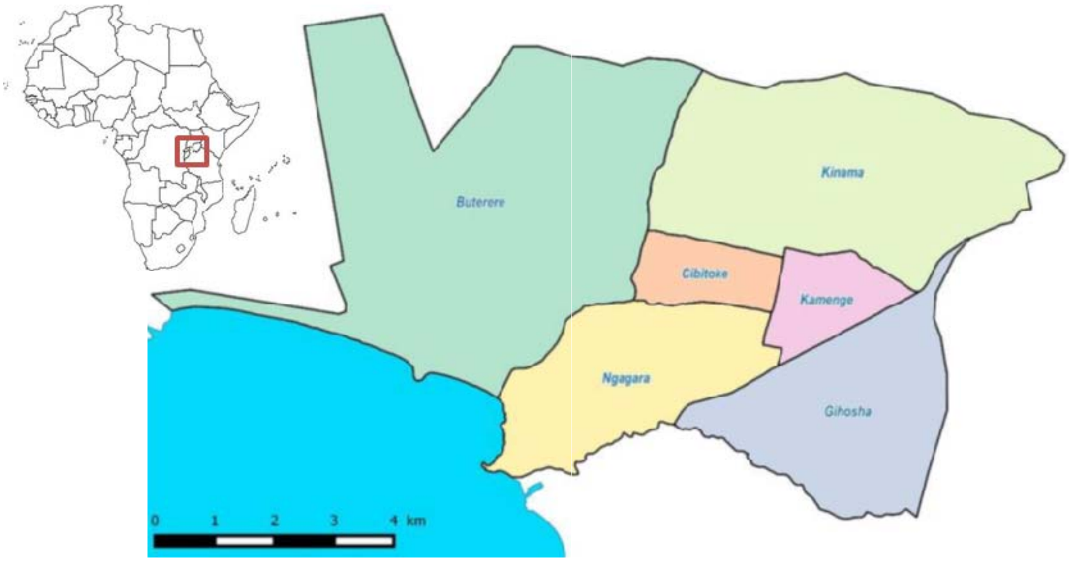

Fig. 1. Map showing the six communes in north Bujumbura, Burundi.

study area is 369,224 persons in 83,106 households as of 2008 (Table 1) and the population density is 200 persons/km^2 (MPHF, 2013).

Table 1. Demographic data of each commune in the study area (MPHF, 2013)

Commune	Population	Households
Kamenge	49,861	11,397
Ngagara	59,557	13,954
Gihosha	62,881	12,526
Buterere	71,459	18,436
Kinama	97,537	21,435
Cibitoke	27,929	5,358
Total	369,224	83,106

2.2. Water demand, supply, and rainwater harvesting potential

Water demand was estimated by multiplying the total population of a commune by per capita water use, as in the equation 1.

$$\text{Water demand (Dw)} = NP \cdot WU \quad (1)$$

Where NP is the total population of each commune (number of people) and WU is the per capita water use (m^3/person).

Because there were not enough data to calculate per capita water use in the study area, the average domestic water use (20 liters per capita) suggested by FAO(FAO, 2007) was used to estimate the water demand in this study.

Even though rainwater harvesting can rely on surface or rooftop runoff, this study focused only on the rooftop runoff for rainwater harvesting because it is a cleaner alternative for water supply compared to the surface runoff. Therefore, the rainwater harvesting potential is a function of roof area, rainfall intensity, and runoff coefficient that depends on roof material and system design. The rainwater harvesting potential of the study area was calculated using the equation 2.

$$\text{Rainwater Harvesting Potential (RHP)} = A \cdot P \cdot C \cdot NH \cdot E \quad (2)$$

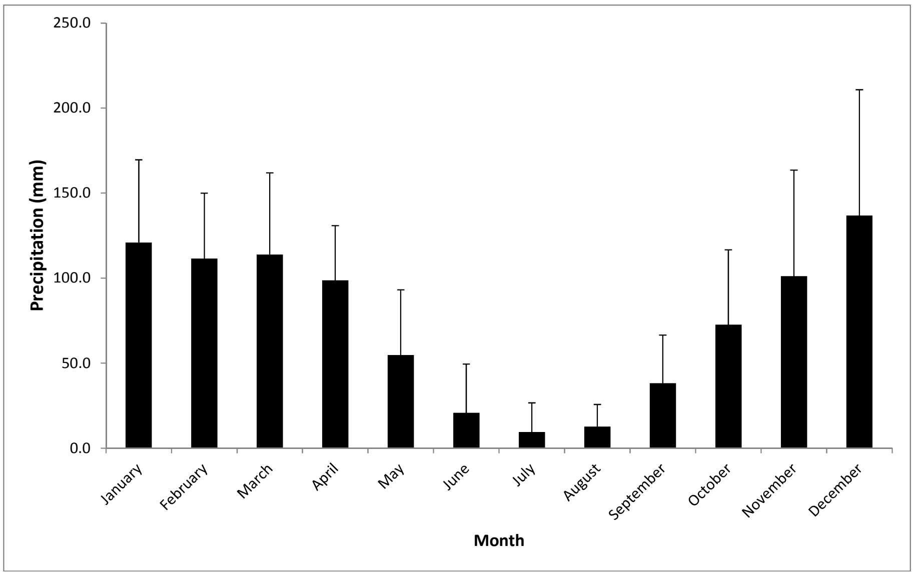

Fig. 2. Average monthly precipitation during the period of 2005~2014 in the north Bujumbura area in Burundi (IGEBU, 2015).

where A is the average roof area of a household that can be used for rainwater harvesting (m^2/household), P is the monthly precipitation (m/month), C is the runoff coefficient, NH is the number of households, and E is the storage efficiency. The standard size of roofs in the study area was 40 m^2 per household (MIB, 2008). The runoff coefficient of 0.85 and the storage efficiency of 0.4 were adopted because houses in this area have mostly hard roofs in the humid tropics where rain is often intense with high precipitation variation(Thomas and Martinson, 2007). Average monthly precipitation during a ten-year period of 2005~2014(IGEBU, 2015) was used to estimate the potential rainwater that could be harvested in the area (Fig. 2). The average monthly precipitations were assumed the same in all the communes.

There is a large monthly variation of precipitation in a year in the study area. It is a dry season from June through August with precipitation less than 20.8±28.7 mm/month. The average monthly precipitation increases since September, reaching more than 100 mm/month during a wet season from December to April.

A total of 2,119,293.5 m^3/yr of water was supplied by a local water company to the six communes of the north Bujumbura area(REGW, 2015; Fig. 3). The amount of water supplied to the communes was highest for the Buterere commune at 489,007.2 m^3/yr, while Cibitoke was the commune with the least water supply of 213,008.8 m^3/yr.

Water deficit before the implementation of rainwater harvesting was calculated as the difference between the current water supply to the communes and their water demand.

$$\text{Water Deficit (WDb)} = Sw - Dw \quad (3)$$

Where Sw is the current water supply (m^3/yr or month) and Dw is the water demand of the communes (m^3/yr or month).

If WDb is greater than 0, it means that there is a surplus of water for a commune. Negative WDb

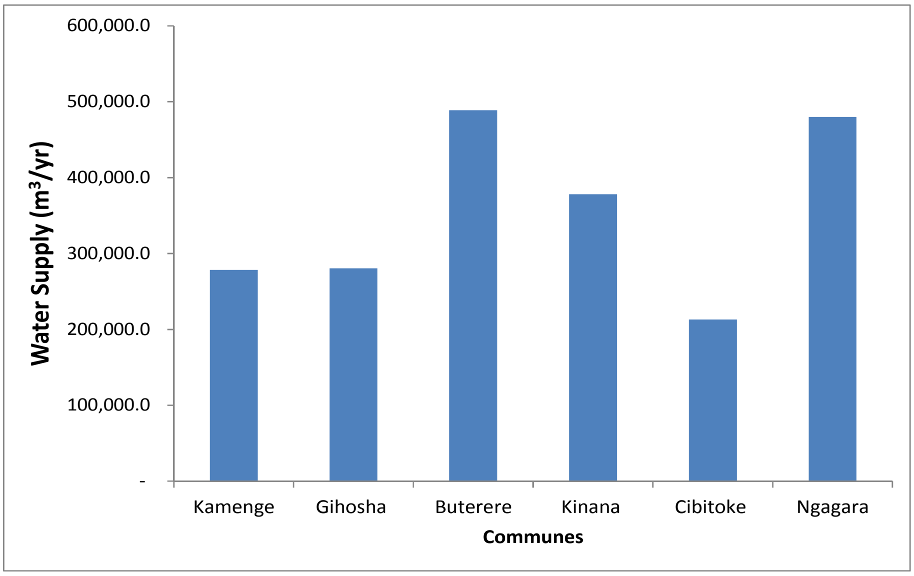

Fig. 3. The amount of water supply to the six communes in north Bujumbura, Burundi, by a local water company(REGW, 2015).

indicates that a commune cannot meet its water demand with the current supply of water by the local water company.

The water deficit (WDb) and the rainwater harvesting potential (RHP) were then combined to calculate the final water deficit, as in the equation 4.

$$\text{Final Water Deficit (WDf)} = \text{WDb} + \text{RHP} \quad (4)$$

Where RHP is the rainwater harvesting potential (m^3/yr or month) and WDb is the current water deficit (m^3/yr or month) in the communes. If WDf of a commune is less than 0, it still will not have enough water to meet its demand. Communes with WDf greater than 0 will have excess water over their demand that could be utilized to optimize water supply at the regional scale by the local water company, resulting in the reduction of water bills for the inhabitants at the household scale in those communes. The fraction of the water demand of a commune that could be met by rainwater harvesting was calculated using the equation 5.

Fraction of water demand met by RHP (Frw, %)

$$= \frac{RHP}{WDb} \cdot 100 \quad (5)$$

Frw can be used to assess the contribution of rainwater for reducing water deficit in the study area.

3. Results and Discussions

3.1. Current water demand and supply in the Bujumbura area

The current water demand of six communes ranges from 201,088.8 m^3/yr for Cibitoke to 702,266.4 m^3/yr for Kinama, depending on the number of population of different communes. Monthly water demands were 29,916.6, 37,728.6, 42,875.4, 58,522.2, 16757.4, and 35,734.2 m^3/yr for Kamenge, Gihosha, Buterere, Kinama, Cibitoke, and Ngagara, respectively. The water deficit for each commune in north Bujumbura was calculated using these water demand data (Fig.

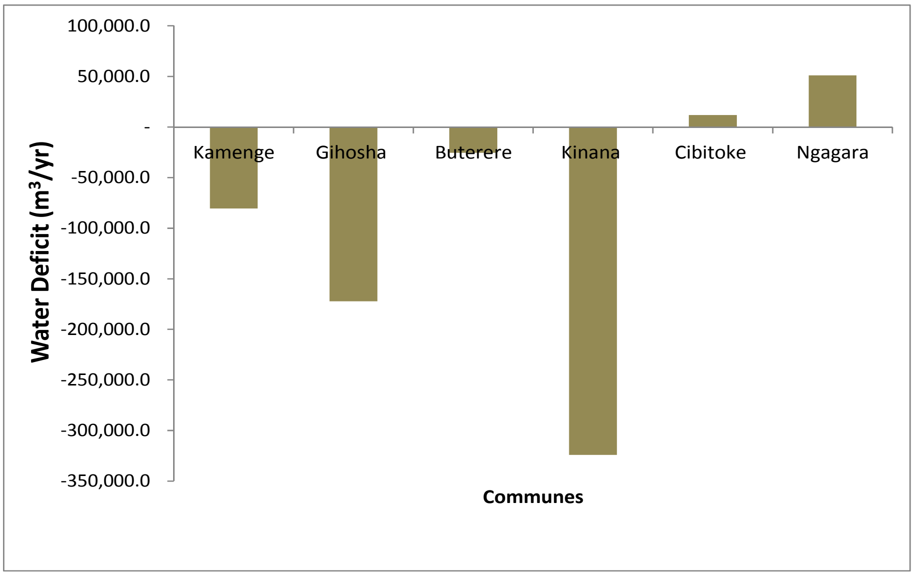

Fig. 4. Water deficit before the rainwater harvesting was considered in north Bujumbura, Burundi.

4). Only two communes, Cibitoke and Ngagara, are meeting their water demand with water supplied by the local water company. They are water surplus communes and received 5.9% and 11.9%, respectively, more than their water demands. However, other four communes of Buterere, Kinama, Gihosha, and Kamenge did not have enough water supply to meet their demand with the water deficit in the range of 5.0~46.1% of their demands. The Kinama commune showed the largest water deficit of -324,047.3 m^3/yr which amounted to 46.1% of its water demand.

The results in Fig. 4 suggest that the rainwater harvesting could play a role in relieving water shortage as a supplementary source of usable water for the communes of Buterere, Kamenge, Kanyosha, and Kinama, considering that the water supply coverage by the local water company may not be expanded in the near future. For Cibitoke and Ngagara with enough water supply from the local water company, the rainwater harvesting can also contribute to the communities because rainwater could be used for non-drinking purposes to reduce the use of water supplied by the water company and thereby cut the spending on water. This will free the capacity of water supply of the company for the communes without enough safe water supply.

3.2. Rainwater harvesting potential

Fig. 5 shows the monthly variation of the rainwater harvesting potentials in six communes in Bujumbura. For all six communes, the months of January and December with the highest precipitation had the greatest rainwater harvesting potential with an average of 24,271 m^3/month for each commune. During the wet season from January to May and from September to December, an average of 18,825.3 and 16,428.5 m^3/month of rainwater could be harvested, varying depending on the available catchment area.

The rainwater harvesting potential was low during the dry season from June through August with an average of 2,704.4 m^3/month, with the lowest potential in July during which monthly precipitation was lowest for all the communes. Cibitoke was the

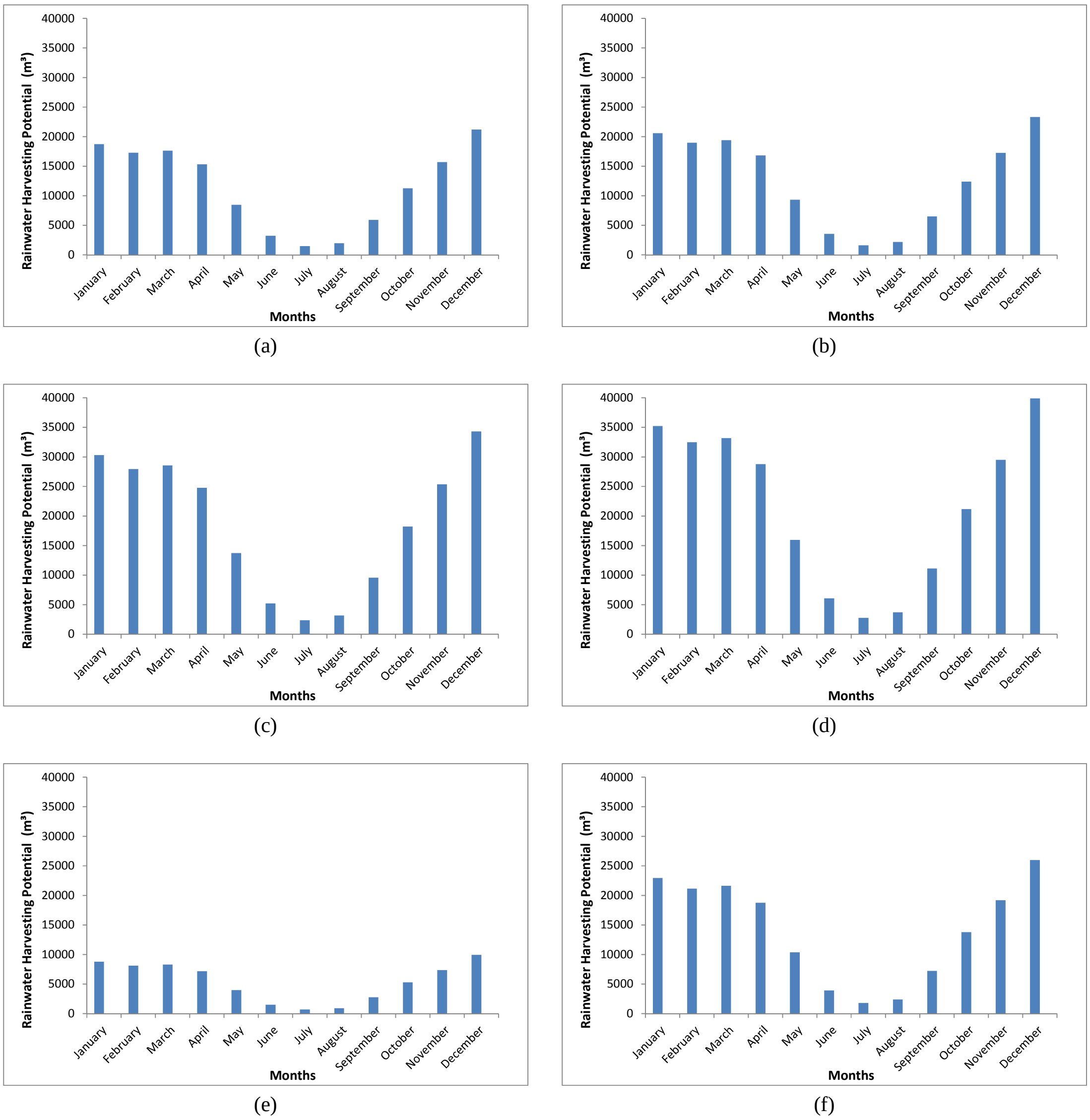

Fig. 5. Rainwater harvesting potential in six communes in north Bujumbura, Burundi. (a) Kamenge, (b) Gihosha, (c) Buterere, (d) Kinama, (e) Cibitoke, and (f) Ngagara.

commune with the lowest rainwater harvesting potential of 696.6 m^3/month in July and Kinama showed the highest July potential of 2,786.9 m^3/month.

The annual rainwater harvesting potentials of the communes were in the range of 64,969.8~259,915.7 m^3/yr, with Kinama having the largest potential of 259,915.7 m^3/yr followed by Buterere at 223,550.5 m^3/yr. Cibitoke was the commune with the lowest rainwater harvesting potential of 64,969.8 m^3/yr, due to its small number of households (5,358) compared to other communes.

Table 2. Potential contribution of rainwater harvesting to the water balance of six communes in the north Bujumbura area in Burundi

Months	Communes	Kamenge	Gihosha	Buterere	Kinama	Cibitoke	Ngagara	Total
January	WDf	12,030.7	6,232.6	28,175.9	8,225.8	9,799.5	27,198.8	91,663.1
	Frw (%)	279.5	143.4	1,426.0	130.5	NA	NA	304.0
February	WDf	10,568.9	4,626.2	25,811.5	5,476.8	9,112.3	25,409.2	81,004.9
	Frw (%)	257.7	132.2	1,314.8	120.3	NA	NA	280.3
March	WDf	10,951.8	5,047.0	26,430.8	6,196.8	9,292.3	25,877.9	83,796.6
	Frw (%)	263.4	135.2	1,343.9	122.9	NA	NA	286.5
April	WDf	8,605.1	2,467.8	22,634.7	1,783.3	8,189.1	23,004.8	66,684.7
	Frw (%)	228.4	117.2	1,165.3	106.6	NA	NA	248.4
May	WDf	1,788.2	-5,024.3	11,607.7	-11,037.6	4,984.3	14,658.5	16,976.7
	Frw (%)	126.7	65.0	646.3	59.1	NA	NA	137.8
June	WDf	-3,475.6	-10,809.5	3,092.9	-20,937.5	2,509.7	8,213.7	-21,406.3
	Frw (%)	48.1	24.7	245.6	22.5	NA	NA	52.4
July	WDf	-52,193.3	-12,726.0	272.2	-24,217.0	1,689.9	6,078.8	-34,121.5
	Frw (%)	22.1	11.3	112.8	10.3	NA	NA	24.1
August	WDf	-4,732.6	-1,219.1	1,059.5	-23,301.7	1,918.7	6,674.7	-30,570.5
	Frw (%)	29.4	15.1	149.9	13.7	NA	NA	32.0
September	WDf	-7,83.2	-7,850.5	7,448.1	-15,873.9	3,775.4	11,510.1	-1,774.0
	Frw (%)	88.3	45.3	450.5	41.2	NA	NA	96.1
October	WDf	4,559.6	-1,978.4	16,090.7	-5,825.3	6,287.2	18,051.6	37,185.4
	Frw (%)	168.0	86.2	857.3	78.4	NA	NA	182.8
November	WDf	8,981.7	2,881.8	23,244.0	2,491.6	8,366.2	23,465.9	69,431.2
	Frw (%)	234.0	120.1	1,193.9	109.2	NA	NA	254.5
December	WDf	14,509.0	8,956.6	32,185.0	12,887.1	10,964.7	30,233.3	109,735.7
	Frw (%)	316.5	162.4	1,614.7	147.7	NA	NA	344.3
Total	WDb	-80,413.2	-172,255.2	-25,497.6	-324,047.3	11,919.6	51,174.4	-539,119.3
	WDf	57,784.1	-20,367.9	198,052.9	-64,131.6	76,889.4	220,377.2	468,304.1
	Frw (%)	171.9	88.2	876.8	80.2	NA	NA	186.9

* WDb: Water Deficit without rainwater harvesting potential (RHP) considered (m^3/month or yr), WDf: Final Water Deficit with RHP (m^3/month or yr) included, and Frw: Fraction of water demand met by RHP (%), and NA: Not applicable.

3.3. Potential contribution of rainwater harvesting in the north Bujumbura area

Table 2 shows the water balance after the rainwater harvesting, as a supplementary water source in the study area, was taken into account. Monthly total for all the communes and annual total for each commune were calculated with an assumption that all surplus water could be used for uses during next months or in other communes.

Ngagara and Cibitoke showed the annual water surpluses of 220,377.2 m^3/yr and 76,889.4 m^3/yr, respectively, because the current water supply fully meets their demands and the harvestable rainwater increased their surpluses. These communes could replace water supplied by the local water company with rainwater for the portion of their water demands that are used for non-drinking purposes such as gardening. This will reduce water bills for inhabitants at the household scale and free the water supply capacity of the company to be used to supply safe drinking water for other communes at the regional scale.

For the communes such as Kamenge, Gihosha and Kinama, rainwater harvesting could provide an excellent supplementary source of water to solve their water shortage except during the dry season with low monthly precipitation. To better assess the contribution of rainwater harvesting, however, it is important to estimate the fraction of water supplied by the local water company that is used for non-drinking purposes in those communes. Even the addition of rainwater harvesting was not enough to meet the water demands from May to October for Gihosha and Kinama and June to September for Kamenge. They still got help from rainwater to relieve their water shortage in the range of 10.3~86.2 % of the amount of monthly water deficit before RHP was considered. Buterere could avoid any water shortage for the entire year if rainwater harvesting were employed to supplement the current water supply, even resulting in a surplus of 198,052.9 m^3/yr.

For the entire region of north Bujumbura, the current water supply capacity of the local company combined with the rainwater harvesting potential resulted in the water surplus of 468,604.1 m^3/yr. This suggests that at the regional scale, proper storages and water quality control for harvestable rainwater could contribute to relieving the regional water shortage and allow the population growth.

4. Conclusion

The current water supply and demand in six communes in north Bujumbura, Burundi, were estimated and compared to understand water balance in those communes. Based on a long-term average monthly precipitation in the region, the rainwater harvesting potential was assessed as a function of roof sizes, number of households, and runoff coefficients of roof materials. Cibitoke and Ngagara were the communes that fully satisfy their water demands throughout the year with water supplied by the local water company. When harvestable rainwater was added to their current water supply, their annual water surpluses increased to 76,889.4 m^3/yr and 220,377.2 m^3/yr, respectively.

The remaining communes suffered water shortage for the entire year with water supply from the local company as their sole source of water. This study showed that Buterere could avoid any water shortage for the entire year if rainwater harvesting were employed to supplement the current water supply, even resulting in a surplus of 198,052.9 m^3/yr. Kamenge could have water surplus of 57,784 m^3/yr with rainwater supply but still experience water shortage during dry season (June to August). Water shortage problem is at its worst in Gihosha and Kinama. They had longer water shortage period (May to October) than Kamenge and still lack 11.8% and 19.8% of water for the entire year, respectively, even if harvestable rainwater were added as a supplementary source of water.

When rainwater harvesting was considered, most of the communes in the north Bujumbura area could relieve their water shortage except during the dry season for some communes. Because the rainwater harvesting has a potential to provide about 1.9 times the water deficit of the entire study area, seasonal as well as regional strategy for water allocation could contribute to dealing with the water shortage issue in the north Bujumbura area. Optimum allocation of water supply capacity of the local water company that takes into account harvestable rainwater could provide a partial solution to the water problem at the regional scale of the area. Expansion of water supply capacity of the local water company is needed to solve the water shortage in the area in the long run. This study has demonstrated that rainwater harvesting could provide a good supplementary water source in Burundi to meet its water demand for non-drinking purposes, allowing the population growth.

ACKNOWLEDGEMENT

This work was supported by a Research Grant of Pukyong National University (2015).

REFERENCES

FAO (food and agriculture organization), 2007, AQUASTAT, Country profile Burundi, Rome, Italy.

FAO, 2008, Climate change, water and food security, Rome, Italy.

FAO, 2015, AQUASTAT, Country Fact Sheet: Burundi. Food and Agriculture Organization of the United Nations, Accessed on 10/13/2015.

Handia, L., Tembo, M., Mwiindwa, C., 2003, Potential of rainwater harvesting in urban Zambia, Phys. Chem. Earth., 28, 893-896.

Helmeich, B., Horn, H., 2009, Opportunities in rainwater harvesting, Desalination 248, 118-124.

IGEBU (institute of geography of burundi), 2009, Burundi's rainfall and precipitation, Bujumbura, Burundi.

IGEBU, 2015, Burundi's rainfall and precipitation, Bujumbura, Burundi.

Ishaku, H., Rafee, M., Majid, F., 2011, Rainwater Harvesting: An alternative to safe water Supply in Nigerian rural communities, Water Resour. Manage., 26, 295-305.

Koppen, B., 2003, Water reform in sub-saharan africa: what is the difference? Phys. Chem. Earth., 28, 1047-1053.

Malley, Z., Mzimbiri, M., Mwakasendo, J., 2009, Integrating local knowledge with science and technology in management of soil, water and nutrients: implications for management of natural capital for sustainable rural livelihoods, Int. Sustain. Develop. & World Ecol., 16(3), 151-163.

MIB (minister of interior of burundi), 2008, General census of population and household in Burundi characteristics of household and habitat, 3, 32-33.

MPHF (minister of public health and fight against HIV), 2013, Document of plan extension of the territory of national population of du Burundi, 20-25.

Mwenge, K., Akpfure, E., Boroto, J., 2007, Domestic rainwater harvesting to improve water supply in rural South Africa, Phys. Chem. Earth., 32, 1050-1057.

NEPAD (new partnership for africa's development), 2009, Water resources and river basin management joint training course.

Ohlsoon, L., 2000, Water conflicts and social resource scarcity, Phys. Chem. Earth., 25, 213-220.

REGDW (regie of distribution of water), 2006, Burundi's water status in urban areas, Bujumbura, Burundi.

REGDW (regie of distribution of water), 2010, Burundi's water supply and sanitation (WSS), Bujumbura, Burundi.

REGDW (regie of distribution of water), 2015, Burundi's water status in urban areas, Bujumbura, Burundi.

Thomas, T. T., Martin, D. B., 2007, Roof water harvesting, International Water and Sanitation Centre, Delft, The Netherlands.

UN (united nations) water, 2010, Water for life: the human rights to water and sanitation, USA.

UNDP (united nations development programme), 2012, Millennium development goals: Climate change, USA.

WHO (world health organization), 2000, Water and sanitation in the world.