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Sustainable household water-saving and demand management options for Kabul City

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Sustainable household water-saving and demand management options for Kabul City

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Abstract. Increasing water demand has led to water scarcity in many urban areas in the arid and semi-arid regions. Indeed, population growth and the expansion of urban and industrialized areas have put great pressure on water resources. Currently, Kabul city is facing groundwater shortage, which is the main source of potable water. Due to rapid urbanization and population growth, and climate impacts, the groundwater level is lowered (~ 1m/year), which has led to many wells drying out in recent years since 1998. Therefore, this study focuses on alternative options to sustain water resources and achieve water sustainability through implementing water-saving practices, including tapping new water resources (rainwater harvesting), and some of the options (faucet aerators, low-flow showerheads, and dual flush toilets), others as gray-water reuse. To analyze the potential of rainwater in Kabul city, long-term precipitation data from 1960-1980 and 2006-2013 from several stations around the city are used. The rooftops of the dwellings assumed to account for 30% of the total land area, according to the State of Afghanistan City 2015 report. Moreover, existing household water efficiency is compared to the most efficient available technologies. The result indicated 346 mm annual average precipitation, and 38.0 million m^3/Year the potential precipitation volume that could be harvest from dwellings rooftops in Kabul city. Moreover, the rainwater harvesting could produce an average of 29 L/capita/day (LCD) of water for domestic usage, with a maximum of 75 LCD in February, a minimum of 5 LCD in September, and an annual 9593 L/capita/year (LCY). If we manage the maximum months, then it could produce the full domestic usage (38.1 LCD) until July. Furthermore, in terms of demand management, we have performed a case study on Macrorayon's (1^{st}, 2^{nd}, 3^{rd}, 4^{th}) apartments that if low flow fixtures were utilized, how much water could be saved? The Macrorayon Department estimates the service population of its system at 100,000 people, the volume of consumption calculated to be 12,500 m^3/day (125 LCD). Results show that after application of low flow fixtures, per capita consumption can be reduced to 57 LCD, 2.08 MCM/Year would be saved; and an additional population of 119,298 people would be covered by water supply. The result of this study is essential for policymakers to adopt current and future water challenges in Kabul city.

1. Introduction

Kabul city is the largest and the capital city of Afghanistan and is the fifth fastest growing city in the world [1]. According to (2017-18) CSO [2] estimated the population of the city around 3,961,487 in 22 districts.

Currently, Kabul city is not equipped with an appropriate water distribution system, that is why almost 85 % of households and inhabitants individually connected to water resources through wells or canals [3]. Groundwater is the main source of potable water, and supply services are inadequate compared to

the number of households [4]. By rapid urbanization, population growth, and climate change impacts, the groundwater level is lowered, as dried many wells in recent years since 1982 [5]. Kabul population is continuously growing up, and there is increasing pressure to further exploitation of groundwater for various purposes. This trend will cause further negative consequences on groundwater quality and quantity [5]. The inhabitants of Kabul are under scarcity of water and would face severe shortages for drinking water. There are high chances to increase water demand in the future due to lifestyle changes [6].
To illustrate the point, the Millennium Development Goals (MDG) clarifies that necessary and safe drinking water is a key element in sustainable development [7]. The capital city of Afghanistan has a huge and growing population due to massive and continuous rural-urban migrants who flow into the city seeking a 'better' life [8].

1.1. Main challenges

- Kabul city quaternary layer groundwater potential estimated 44.5 MCM/Year (MCM: million cubic meter million cubic meter) by KFW in 2005, while 28 MCM/Year is usable that is not sustainable for present water demand [9].
- Estimated that 5 million population with 125 Liter/day/capita requires 228,125,000 m3/year, which is incomparable with 28,000,000 m3/year.
- The groundwater table around the city area shown a decreasing trend at a mean rate of 3.8m/year, and it indicates a 23m groundwater depletion from 2006 to 2018 [10].
- The population of Kabul city is projected to be increased by 2030 to 7 million [11].
- High chances of land collapse around Kabul city due to high groundwater extractions [12].
- Lack of proper and applicable groundwater policy yet [12].

To overcome the mentioned and future problems of Kabul city water scarcity, we concluded two main solutions;

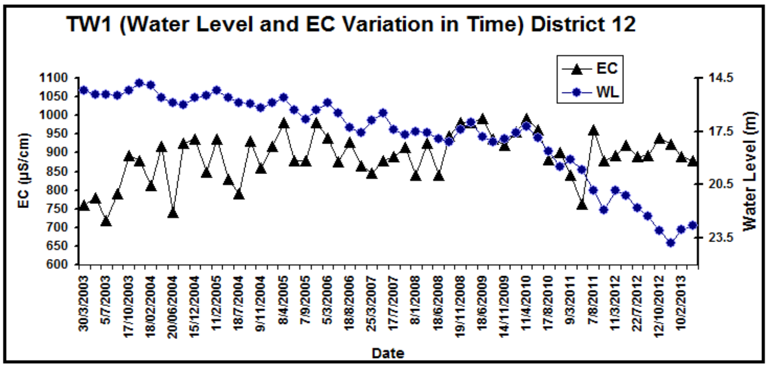
- To increase water availability in Kabul city by constructing new dams, which planned by the government (e.g, Shahtoot dam, Gulbahar Dam, Shah wa Aros Dam, Salang Dam), however, they are time consumed [13].
- To decrease pressure on available water resources through short-term water-saving technics

This study aims to evaluate the short-term solutions, focuses on domestic water management options to achieve water sufficiency in Kabul city. Moreover, the results benifites the policy makers with implication of the outcomes to reach the targets for Sustainable Development Goals - 6 (Ensure availability and sustainable management of water and sanitation for all). Where Afghanistan is commited to achieve universal and equitable access to safe and aforadable drinking water for all (SDG 6.1), increase water-use efficientcy across all sectos by 2030 (SDG 6.4), which is not remarkably achieved yet [14].

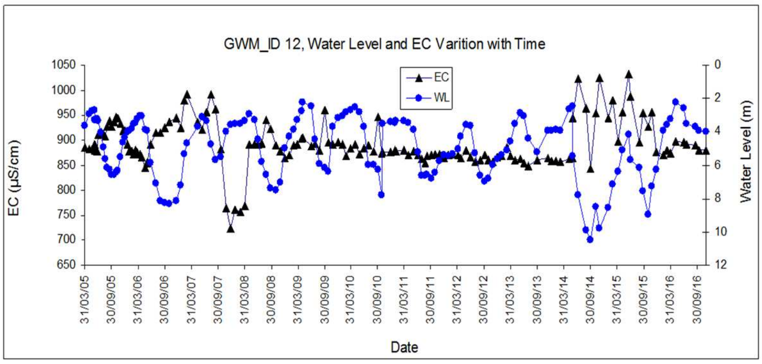
2. Kabul city water resources

The water availability in Kabul will be the most critical constraint to the development of the capital city. The current water supply in Kabul depends exclusively on local groundwater resources [10]. Four major well fields provide water supply to 30% of households in Kabul city are Logar, Allaudin, Macroryan, and Afshar, which respectively recharged by Logar, Kabul, and Paghman rivers [15]. The estimated potential of Kabul city groundwater is approximately 44.5 million m^3 (MCM) per year, according to the KfW water study [9]. In comparison to the minimum per capita demand of water 40 LCD (litter per capita per day) for the 3.96 million population of the city [2]; it requires 57.8 MCM per year to fulfill the demand, while it shows a 23% deficit exists. Though if the standard demand of 125 LCD (as per AUWSS Supply to Macrorayon, [13]), the Kabul city residents need 173.5 MCM; a (-183.6) MCM of deficits.
In terms of groundwater level fluctuations, there is a drastic decline observed between 1960 and 2000 as a result of low-normal precipitation and increasing population in the urban areas of the Kabul [16].

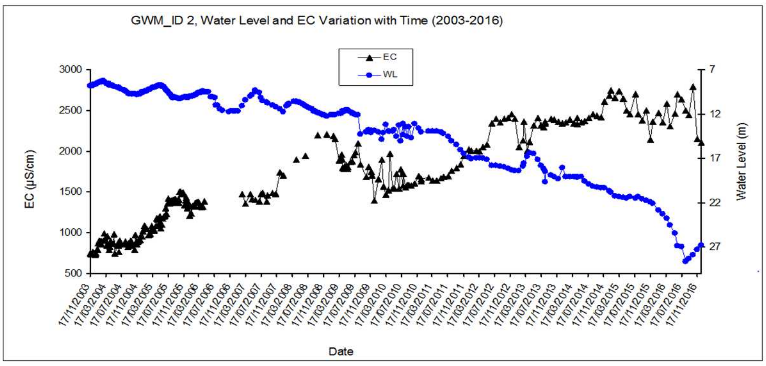
However, with the increasing rate of population in the city, up to 25% of these water supply wells are reported to be inoperative or dried [16]. To this point, the population is seeking water at the lower level of ground while DACAAR's study in 2011 affirms that very deep aquifers contain so much salty and low-quality water or other pollutants as are located in a lower level in the ground as fuel water at Neogene layer [5]. Figure 1 shows a rapid decline of groundwater around Kabul city, and with decline of groundwater, the salinity is increasing.



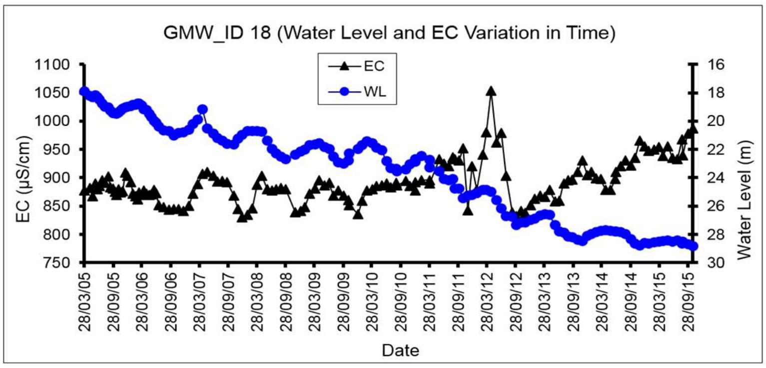
A) District 12



B) Bagrami



C) Ahmad Shah Baba Meena



D) Near to AUWSS

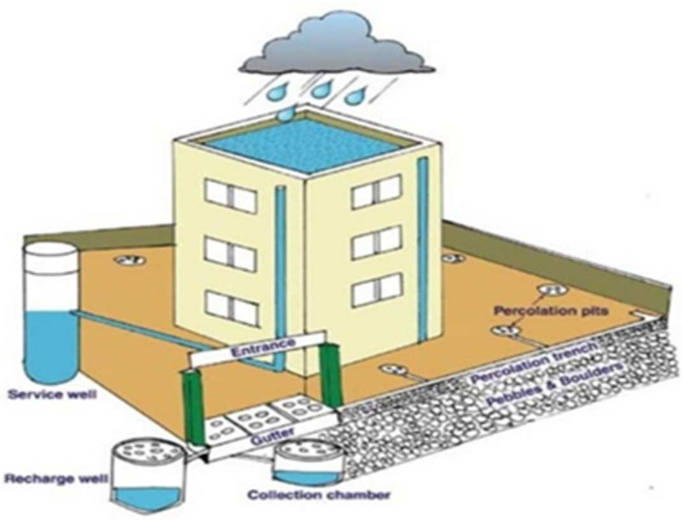
Figure 1. Groundwater table and salinity trend at different parts of Kabul city [5].

3. Water-saving practices as a proposed short-term solutions

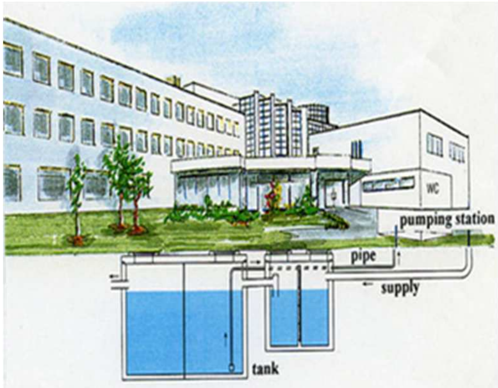
follow Water sustainability could be achieved by implementing water-saving practices and using newly developed water management approaches, including tapping new water resources (rainwater harvesting) [17]. An overview has made of potential domestic water management options; (1) rainwater harvesting system (RWHS) (2) greywater reuse system (GWRS) (3) indoor water savings; i.e. the dual flush toilet (DFT), low flow showerhead (LFSH), and the faucet aerators (FA). These options were chosen to reduce water consumption at the bathroom sink, the kitchen, bath, and shower.

3.1. Rooftop rainwater harvesting

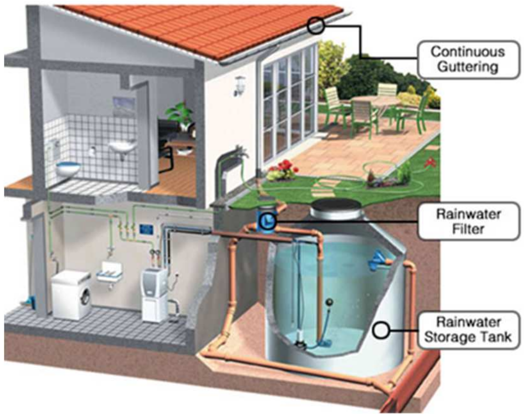
Water harvesting is “the collection of runoff for productive purposes. Instead of runoff being left to cause erosion, it is harvested and utilized” [18] (Figure 2). Rainwater harvesting (RWH) reduces pressure on aquifers and surface water sources and economic advantages for consumers that reduce the amount of water purchased from public systems. Therefore, the integration of RWH systems into buildings is an effective way to minimize the use of treated water for non-potable tasks and supply drinking water in places where water is scarce [19].



A) Rainwater harvesting from apartment.



B) Rainwater harvesting from an institutional area.



C) Rainwater harvesting from a building.

Figure 2. Different rainwater harvesting systems at A) Apartments [20], B) institutional area [21], C) Building [22].

Harvesting the rain is practiced as a traditional system in such countries as Australia, China, New Zealand, and Thailand, as well as throughout Africa, South Asia, and Southeast Asia [23]. RWH is an independent system that helps to foster a value for water as an essential and precious resource. Furthermore, a roof collection system can address both water quality and water quantity issues [24].

3.2. Application of rooftop rainwater harvesting in Kabul city

Kabul city has a good potential of precipitation that varies at different months of the year. Data from 1960 to 2013 shows average annual precipitation of 346 mm (Figure 3) that contributes the snowfall and rainfall as the major water resource in the city.

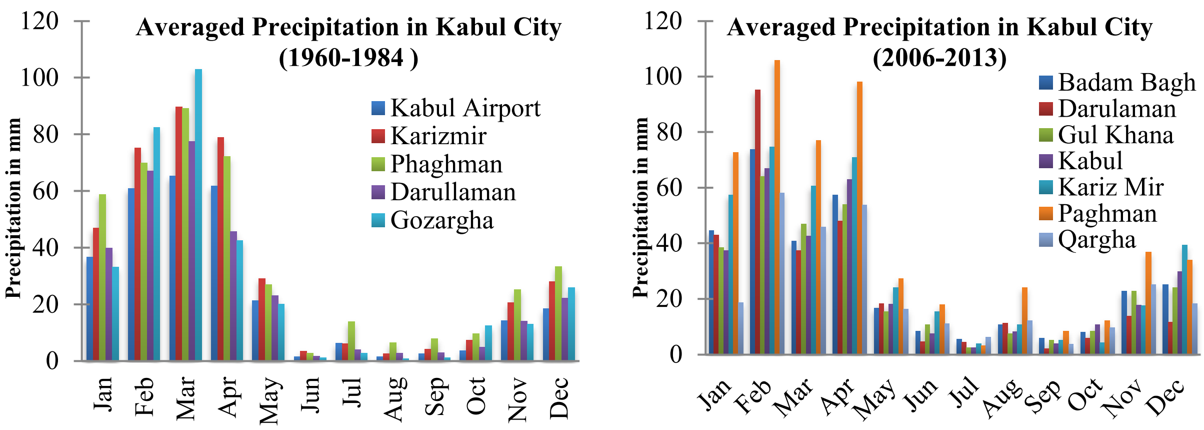


Figure 3. Precipitation data in mm from seven stations around Kabul city in two period of time.

Some evidences indicate changes in precipitation pattern from snow to rain, which no longer last and store at higher altitude. Though there is still a good potential of precipitation (snow and rain), but water scarcity challenges Kabul city. Therefore, rooftop rainwater harvesting is an appropriate solution as alternative water resources to respond to the scarcity.

Currently, Kabul city is equipped with a 39% built-up area (Figure 4), which impermeable layers have reduced water infiltration [25].

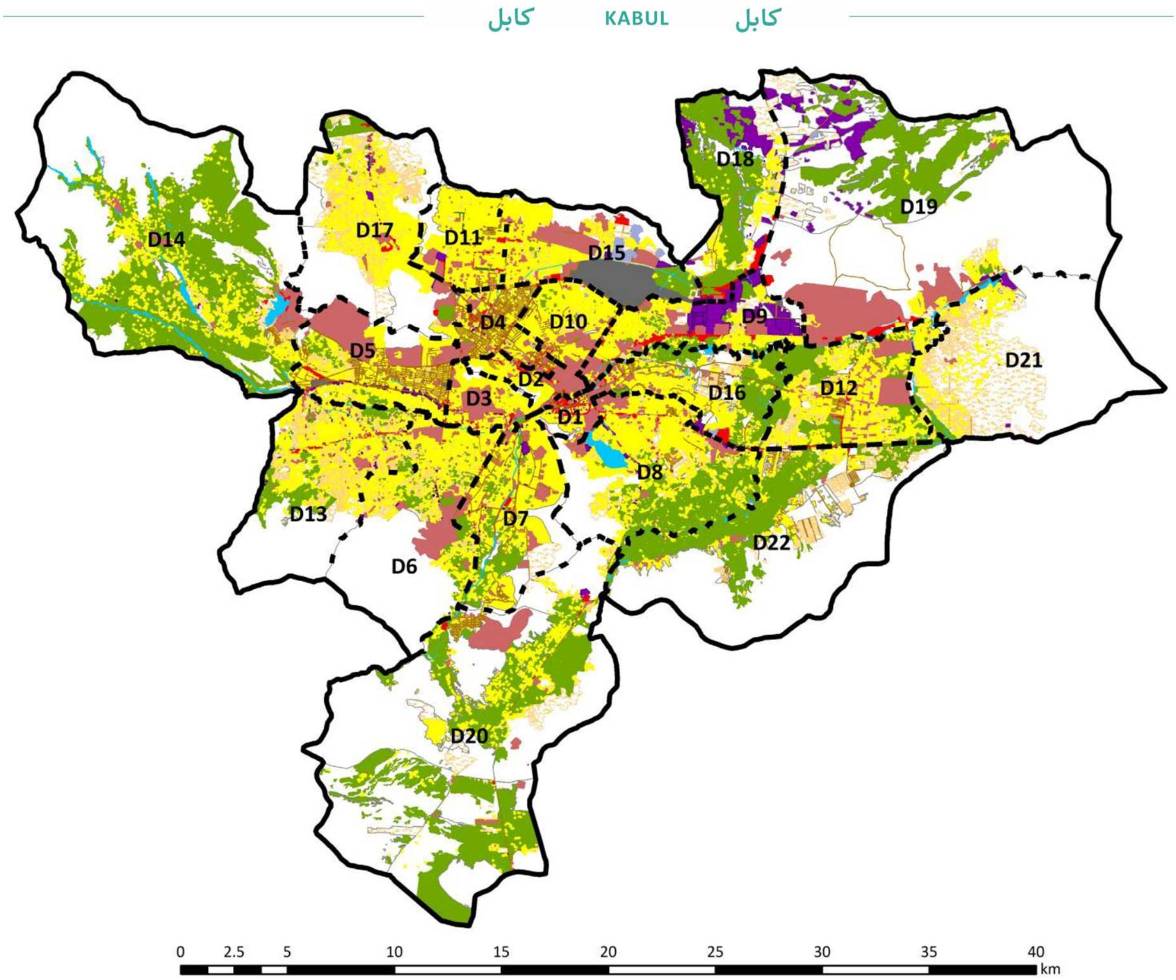


Figure 4. Kabul city administrative and physical map, D indicate number of districts.

Table 1 indicates total area of dwellings which could harvest precipitation, in which 30% is considered a rooftop area. Furthermore, this study has used formula (1) to calculated total precipitation from dwelling's rooftops as; assuming constant rainfall within each time step t, the rainwater volume can be calculated from a rooftop of a building as follows:

$$Q_t = \varphi \cdot A_{TOT} \cdot R_t = A \cdot R_t \quad (1)$$

Where, Qt is the inflow volume supplied from rooftop at time step t (m^3), φ is the runoff coefficient depending on water loss (dimensionless), Rt is the rainfall at time t (m), ATOT is the total catchment surface area (m^2), and A is the effective impervious surface area (m^2). Evaporation losses are neglected. In this study, φ is set equal to 0.9 [26].

The result shows that Kabul city has the potential of 38 million m^3 per year. This amount can be utilized for different domestic usages like; cooking, shower, Laundry, Dish Washing and Floors, Toilet, Cooling, and Ventilation, Miscellaneous, and even for drinking after some purification process. The potential of Rainwater harvesting is higher at regular houses, irregular houses, and Institutional areas. So far, the most consumption of water is in institutional areas; therefore, the application of rainwater harvesting is recommended to be implemented into these dwellings as the first priority.

Table 1. Built-up land area in (m^2) and total precipitation accumulation in m^3 from different rooftops of dwellings in Kabul city

		Dwelling	Total land Area (m^2)	Rooftop Area (m^2) Assumption as 30% of the total Area	Precipitation accumulation on the Roof-top (m^3)
Built-Up Area	Residential	Houses Regular	45,795,000	13,738,500	4,759,016
		Houses Irregular	90,881,000	27,264,300	9,444,354
		Houses Hillside	31,380,000	9,414,000	3,261,010
		Apartments	2,759,000	827,700	286,715
		Apart. Mixed-use	797,000	239,100	82,824
		IDP camps/Kuchi/Other	1,738,000	521,400	180,613
		Total from residential	173,350,000	52,005,000	18,014,532
		Commercial	10,058,000	3,017,400	1,045,227
		Institutional	64,796,000	19,438,800	6,733,600
		Industrial	18,933,000	5,679,900	1,967,517
		Roads/Streets	29,568,000	29,568,000 (100%)	10,242,355
	Total Built-up		123,355,000	57,704,100	19,988,700
	Total Built-up and Residential Areas		296,705,000	109,709,100	38,003,232

Also, this study has calculated estimation of water supply from rainwater harvest, by dividing the total amount of 27,760,877 m^3 (exempt roads/streets) rainwater harvest to the total population of the city (3,961,487) at each month, it allocates 233.6 LCD/Year to individual population. The result in comparison to JICA 2009 and MRRD report showed in Figure 5, the three-level of different water consumptions;

1. Low-class peoples 15-25 LCD
2. Medium class 30-40 LCD
3. High class 100-125 LCD

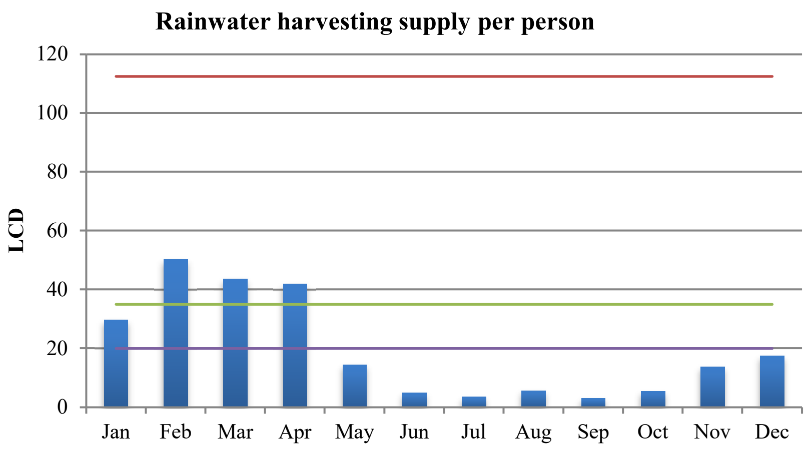


Figure 5. Shows rainwater that provides water per capita to Kabul city in the absence of other sources of water.

3.3. Household water saving alternatives

Low flow water fixtures are sink faucets, showerheads, and toilets that use less water per minute than older, traditional models. Low-flow water fixtures conserve water by using a high-pressure technique to produce a strong or equal flow of water with less water than other less-efficient fixtures [27]. According to the WHO, a minimum of 25 liters per day is required to meet basic needs [28].

3.3.1. Faucet aerators (FA) and low-flow shower head (LFSH)

These devices limit the amount of water going through the faucet or showerheads but mix air, so the flow of water appears the same [29]. Faucet aerators reduce water usage, lower utility bills, and preserve the environment with very little investment. Standard or old fashion water flow for aerators is 2.2 GPM or even higher, while with water-saving, the flow is considered 1.0-1.5 GPM, saving up to 30-50% more water (Figure 6) [30]. Though in Afghanistan, people are using the old fashion aerators and even destroying the faucet aerators filters to get more water due to lack of awareness.

Figure 6. Samples of fauscet aerators [31], and low-flow shower head [32].

3.3.2. Dual flush toilets (DFT)

Dual flush toilets (DFT): "these are toilets that use less water than conventional toilets and have two volumes of flushes" [29,33]. The Dual Flush Toilet has a significant resource with the option of two flush volumes. The users can choose between two flush volume buttons, 1.6 gallons per flush for solid waste, and 0.8 gallons per flush for liquid waste. In contrast, the standard or ordinary Toilets use 7 gallons per flush. According to the EPA, the average person flushes five times a day, and 4 out of 5 flushes require only less water because they are for flushing liquid waste. 8 out of 10 times you flush your toilet, you could be wasting as much as 70% of the water being flushed, which adds up to hundreds of dollars in wasted water every year [34]. Moreover, DFT reduces the energy consumption used by water utilities' to pump, treat, and dispose of water; it can save more than 20,000 gallons of water per year for a four-member family [27].

Figure 7. Picture of a dual flush toilets [35].

3.3.3. Gray-water reuse systems (GWRS)

Gray-water is "defined as untreated, used household water from showers, bathrooms, washbasins, and washing machines" [29,36]. Grey-water considered safe and beneficial water for irrigation, though it contains traces of dirt, food, grease, hair, and certain household cleaning products [37]. Grey-water could be used directly with pipe system to irrigate ornamental plants or fruit trees, vegetable plants as long as it does not contact edible parts of the plants. It is recommended to use "plant friendly" products, those without salts, boron, or chlorine bleach [37].

3.3.4. Application of household water saving alternatives in Macrorayon apartment

Macrorayon apartments are the collection of buildings located at district 9th of Kabul city (Figure 8). The Macrorayon Department estimates the service population of its system at 100,000 beneficiaries with 16,000 m^3/day volume of water supply in a fixed-rate [38]. Moreover, 25% of the water supply is assumed as losses to the end-users (12,500 m^3/day). Based on the available data presented here, the water consumption is estimated at 125 LCD (Total water supply divided to total population). To analyze the per capita sub-consumption of water at the household level, we divided the per capita consumption (125 LCD) into sub-part of consumption (Figure 9).

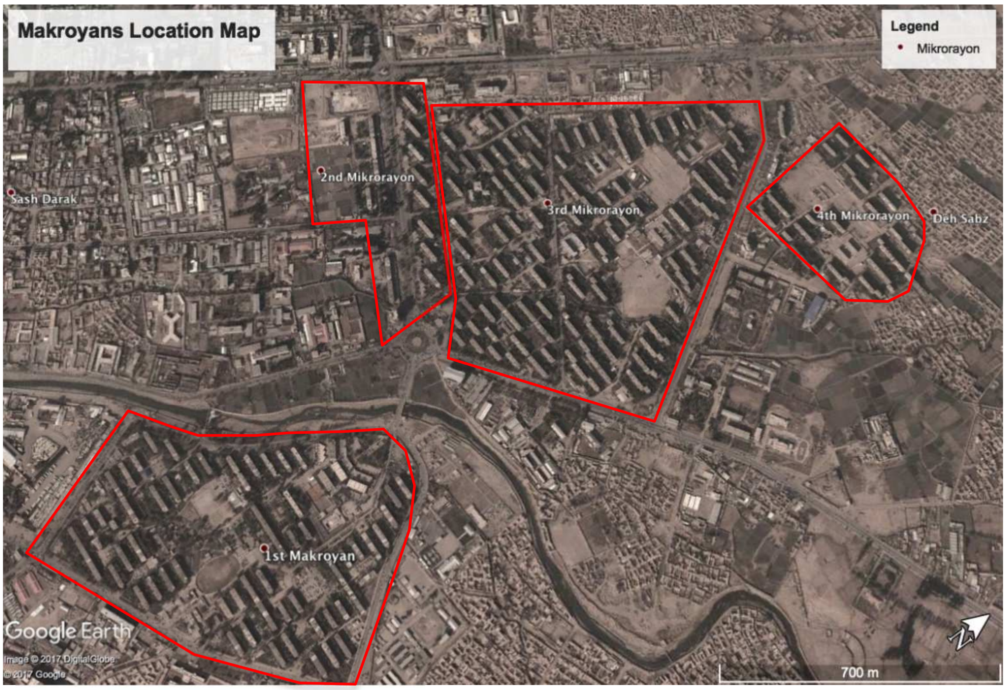


Figure 8. Map of Macrorayon buildings.

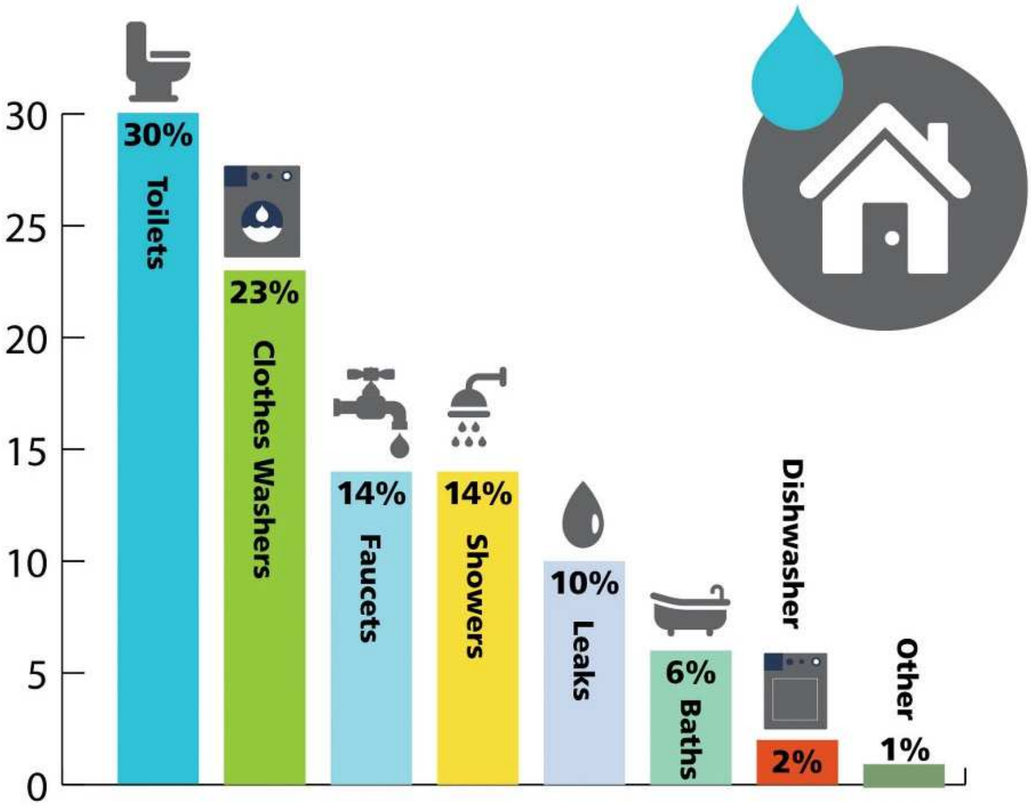


Figure 9. Typical consumption of water [39].

Table.2: Current and future water consumption for Macrorayon residence before and after application of interventions.

Subpart of per capita water consumption	Water consumption in %	Water consumption in a liter (based on 125 Liter/capita/day)	Water-Saving through low flow fixtures (LCD) - (30%)	Gray-water (80%) (LCD)	Gray-water (80%) reused (LCD)	Reduces in water supply per capita (LCD)
Toilet	30%	37.5	18		18	0
Clothes Washers	32%	28.75	29	23		28.75
Faucets	14%	17.5	11	8.4		10.5
Showers	14%	17.5	11	8.4		10.5
Leaks	1%	12.5	0			0
Dishwashing	8%	10	6	4.8		6
Other	1%	1.25	1			1.25
Total	**100%**	**125**	**75.17**	**44.6**	**18.17**	**57**

An extra gray-water of 964,695 m^3/year can be utilization for greenery and washing (cars and floors).

Result described in Table. 2 and Table.3, that with the application of low flow fixtures, we could decrease the demand from 125 LCD to 75 LCD, and with the utilization of gray-water for toilets, demand will more decreases into 57 LCD. An extra gray-water of about 26 LCD or 964,695 M^3/Year could be utilizing for greenery around and washing floors and cars. The current water supply to Macrorayon is 4.5 Million Cubic Meters (MCM) per year, which could be decreased into 2.08 MCM/Year after application of low flow fixtures interventions. With the saved amount of water, an extra 119,298 population could be cover by the water supply system.

Table.3 Amount of water supply at current and after application of interventions per year.

Current Supply (M^3/Year)	Supply after application of water-saving interventions (M^3/Year)	Saved Amount of water (M^3/Year)	Extra population underwater supply system (57 LCD)
4,562,500	2,080,500	2,482,000	119,298

4. Conclusions

Kabul city is extremely in state of water scarcity

- Groundwater is the only sources of domestic usage, estimated 44.5 MCM/Year which is not renewable at every year
- Groundwater declined by 3m to 20 meters from 2003 to 2013 with many wells dried out around Kabul city
- Kabul city is in a deficit of 30% water; if the minimum per capita demand of water considered 40 LCD for the total population (22 districts) 3,961,487 (CSO 2017-18).

Findings of this study propose alternative options for domestic water consumption of Kabul city as a short-term action to reduce pressures on groundwater and provide alternative resources

- Rooftop rainwater harvesting
  All dewlings except roads in Kabul city can conserve 27.8 MCM/Year of water, which can be utilize for several purposes (Toilet, Clothes washing, Dishwashing, Yard greenery and more)
- Application of low flow fixtures, dual flush toilets, and gray-water reuse
  If mentioned interventions applied to Macrorayon apartments (100,000 population, 125 LCD, and 4.6 MCM/year water consumption), the per capita consumption will reduce to 57 LCD, 2.08 MCM/Year will save; additional 119,298 populations will be cover by water supply.

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