ECONOMIC ANALYSIS OF ROOFTOP RAINWATER HARVESTING IN KABUL NEW CITY: CASE STUDY OF FAMILY HOUSES

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1. INTRODUCTION

Kabul is the capital city of Afghanistan, and the city is growing at 5th speed in the world. Regarding this growth, the government has planned the project of Kabul New City (KNC). There are no permanent water resources near KNC[1]. KNC has to depend upon external water resources far from the city, and also have to save the water consumption by the use of rainwater.

The previous study was to evaluate the amount of water saved by applying the rooftop rainwater harvesting system in residential area of KNC. In addition to this, the economical analysis for this rainwater harvesting system is important to install the system in KNC. Especially, initial cost and a payback period are the important information for residents. Therefore, this study focuses on followings objectives;

1- The economic feasibility of rooftop rainwater harvesting system for four type of houses, based on the saving money by the system and items cost.
2- The evaluation of tank capacity to determine the project payback period

ANALYSIS METHOD

The volume of the harvested rainwater is determined by the following equation[2].

$$VR = (R \times A \times C/1000) \quad (1)$$

where VR (m^3) is the volume of the harvested rainwater, R (mm) is a rainfall intensity, A (m^2) is a rooftop area, and C is a runoff coefficient. This study employs the coefficient as 0.9, which has been used in the design of drainage system in KNC project[1].

The efficiency of the rainwater harvesting system is evaluated with using the following equation[2].

$$SWR(\%) = 100\ VR / PWD \quad (2)$$

where SWR means a saved water rate, and PWD means the volume of non-potable water demand.

The benefit cost ratio and payback period of the system are determined by the following equations[3].

Benefit cost ratio (BCR) = Total benefit/ Total cost (3)

Payback period (PBP) = Total cost/ Annual benefit (4)

2. RESULT AND DISCUSSION

a) Evaluation of rooftop rainwater harvesting system for residential houses

Table 1 Efficiency of rainwater harvesting system

House type	A (m^2)	VR (m^3/year)	Saved money (US$/year)	SWR (%)
Type-A (750m^2)	417	122.9	113.1	95.4
Type-B (500m^2)	245.8	72.4	66.6	56.2
Type-C (300m^2)	154	45.44	41.7	35.29
Type-D (200m^2)	149.6	44.1	40.5	34.28

The applicability of the rooftop rainwater harvesting system in Afghanistan is firstly investigated in this study based on 11 years daily rainfall data, from 2006 to 2016. The potential of the system is examined at houses based on the averaged total rainfall, 327.5mm. In the evaluation of the rooftop rainwater harvesting system, this study supposes a household with 6 members. The water consumption is assumed as 120 LCD that includes the non-potable water uses, 58.8 LCD. The price of water in KNC is set as 0.92 US$/$m^3$. In the analysis for Type-A with using the averaged total rainfall data, SWR is calculated as 95.4%, and the system saves 113.1 US$/year. Similarly in Type-B,C and Type-D. These estimations show the efficiency of the rooftop rainwater harvesting system for residential houses, as shown in table.1.

b) Estimation of required size of storage tank for residential houses

Table 2 Calculation of storage capacity for Type A

month	*Rain fall* (mm)	*PWD* (m^3)	*VR* (m^3)	*C.PWD* (m^3)	*C.VR* (m^3)	*CVR-CPWD* (m^3)
Jan.	35	10.7	13	10.7	13.1	2.4
Feb	73	10.7	27.4	21.5	40.5	19.1
Mar	56	10.7	21.0	32.2	61.5	29.3
Apr	60	10.7	22.5	43.0	84.1	41.1
May	30	10.7	11.3	53.7	95.3	41.6
Jun	7	10.7	2.6	64.4	98.0	33.5
Jul	5	10.7	1.9	75.2	99.8	24.6
Aug	8	10.7	3.0	85.9	102.8	16.9
Sep	4	10.7	1.5	96.7	104.3	7.7
Oct.	8	10.7	3.0	107.4	107.3	-0.1
Nov	18	10.7	6.8	118.1	114.1	-4.0
Dec	18	10.7	6.8	128.9	120.8	-8.0

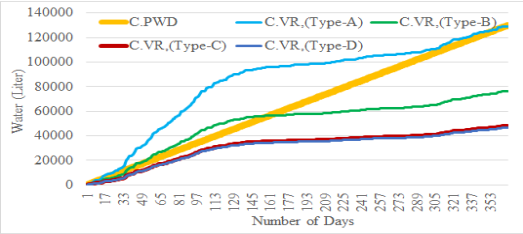

Fig.1 Daily changes of *C.VR* and *C.PWD*

Table 2 shows the monthly change of *VR* and *PDW* in the case of Type-A house. This table includes *C.PDW* and *C.VR*, where *C.PDW* and *C.VR* mean the cumulative of *VR* and *PWD*, respectively. The monthly non-potable water demand is 10.7 m^3 and *VR* is calculated with using the averaged monthly rainfall. The column of *C.VR-C.PWD* means a surplus of water that could be used as the non-potable water. From this table, 41.6 m^3 is the maximum number in the column of *C.VR-C.PWD*, and this volume could be considered as the required size of the rainwater harvesting tank for this Type-A house.

In addition to this analysis, the size of the rainwater harvesting tank for residential houses were estimated with using the averaged daily rainfall data. Fig.1 shows the daily changes of *C.VR* and *C.PWD* for Type-A, B, C and Type-D houses. In the case of Type-A house, the maximum number of *C.VR - C.PWD* is 44.2m^3, and the size of the rainwater harvesting tank will be estimated as this volume. Similarly, in Type-B house, the size of the tank is estimated 9.2m^3, while in Type-C and D are 4 m^3 *and 3.9* m^3 respectively.

c) Economic analysis and payback period

In Table.1, the saved money as the total financial gain to be paid as the bill of water supply without being the investment cost taking into account. The payback period is the total period of time required to return the investment. The capital cost of rooftop rainwater harvesting systems is dependent on the components of system. Besides the cost of the components, there is the cost of the system installation and this study considering 40US$ as the labor cost. While, the motor pump and the distribution pipes cost is 85.26US$.

Table 3 indicates the system total cost, the total benefits, the BCR and the PBP calculated from Eq. (3) and Eq. (4), and, the price of tanks comes from the local market. In the total cost calculation, this study considers the system components and labor costs. The total profit as the saved money by the system for 20 years. From the analysis of Type-A house PBP is calculated as 26 years and the BCR 0.76. On the other hand, the Type-B, C and Type-D houses PBP is much smaller compared to Type-A house because of the high initial cost for the bigger size tank.

Table 3 Calculation of economic analysis

Houses	Tank Price US$)	Total Cost (US$)	Total Benefit (US$)	BCR	PBP (year)
Type A	2846	2971	2262	0.76	26
Type B	680	805	1332	1.65	12
Type C	300	425	834	1.95	10
Type D	295	420	810	1.92	10.1

3. CONCLUSIONS

This study estimated the appropriate size of the rainwater harvesting tanks for the residential houses. In the economic analysis, this study confirmed that the Payback Period in the case of Type-A house is wider compared to the other types of houses because of the high initial cost for the bigger size tanks.

REFERENCES

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