Some Problems Occurring in Development and Utilization of Rainwater Resources for Sustainable Water Resources Use

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The great leader Comrade **Kim Jong Il** said as follows.

"**At present, water has become a serious problem throughout the world. I am told that the earth is drying up, probably because of crustal movements. From now on we should economize on water and protect water resources.**"

Rainwater is one of the main water resources, the use of which has now become important because of precipitation decrease due to climatic change and water pollution resulting from sewage and waste water for development and utilization of rainwater resources.

Use of rainwater resources has been studied for a long time. [1-6]

Proceeded works [3-5] gave definitions of rainwater resources and proposed some ways in which development and use of rainwater resources were to be in farming regions. Other work [6] introduced estimation method of arresting rainwater and tank sizes for collecting and storing it in agricultural areas.

These studies discussed only some partial aspects of rainwater resources use and they are lack of taking into account a comprehensive way by systematically considering rainwater utilization through its seasonal distribution. It can be seen in the fact that they used average daily or yearly precipitation in estimating rainwater storing amount and tank sizes.

In this paper, some problems are proposed in development and utilization of rainwater resources and estimation method for designing tank size for rainwater collection in consideration of water balance between rainwater resources and water demand.

1. Uses of rain water through resources oriented and some problems to solve

1.1. Uses of rain water through resources oriented

Rainwater resources can be seen as less polluted water different from sewage or waste water. Thus the processes of its development and utilization are relatively simple

and it has a variety of uses.

In general, water resources can be used as water for life, industrial water and agricultural water, but in case of rainwater, used as living water, water for city management, industrial water and agricultural water. And living water is divided as water for toilet, washing, heating, cooling and washing. And water for city management is divided as water for street cleaning, greenbelt irrigation and scenery. And industrial water is divided as water for cooling, boiler, material washing, and agricultural water is divided as water for irrigation and stockbreeding.

1.2. Some problems raised in rainwater resources uses

① Rainwater resources should be used as much as possible.

Although storm water or heavy rain cannot be directly used for peoples' life and production, we should divert it into rainwater resources. This is an effective way in which we can reduce flood damage and increase benefit by rainwater utilization.

② In a way in which we use rainwater before it falls down on the earth surface, we should divert rainwater as resources. For this purpose, we should establish rainwater collecting systems at houses, public establishments and production buildings.

③ We should realize rainwater use to avoid damages from the drought in agricultural areas. By collecting and storing rainwater, we should regulate excess use within seasons or a year and solve time-inconsistency between rainwater supply and growth period of crops.

④ We should strengthen water control between soil and crops, storing and use capacity and make soil store water as much as possible in development and utilization of rainwater resources.

2. Estimation method of tank size for rainwater collection by water balance

2.1. Estimation of amounts of rainwater demand and collection

① Estimation of amounts of rainwater demand

A yearly total amounts of rainwater demand can be calculated as a total monthly amount of rainwater demand by use according to branch of rainwater use.

$$W_d = \sum_{i=1}^{12} \sum_{j=1}^{n} D_{ij} \quad (\text{㎥}) \qquad (1)$$

where W_d is a yearly total amount of rainwater demand, D_{ij} are monthly

amounts of rainwater demand by use and *n* is the number of branch of rainwater uses.

② Estimation of amounts of rainwater collection

Amounts of rainwater collection can be calculated in consideration of runoff factor of a surface with different characters.

$$W_c = 10^{-3} \cdot \sum_{i=1}^{12} \sum_{j=1}^{n} R_i \cdot S_j \cdot \varphi_j \quad (\text{㎥}) \qquad (2)$$

where S_j is an area of rainwater collection territory *j*, R_i is an average precipitation in i^{th} month and φ_j is runoff factor of rainwater collection territory *j*.

Table1. The runoff factor according to surface characters (in town)

Surface character	Water	greenbelt	Paved road and square	Building roof
φ_j	1	0.15	0.9	0.9

The runoff factors in farming regions can be values observed according to soil characters and cover kinds.

2.2. Estimation of tank volume designed for rainwater collection

Tank volume designed for rainwater collection can be calculated by water balance equation between amounts of rainwater collection and demand.

$$\frac{dV}{dt} = C - D \qquad (3)$$

where V is storing amount of rainwater collection tank(㎥), C is amount of rainwater collection and D is amount of rainwater demand(㎥/s).

It is necessary to make the above equation linear and discrete per month using the equation (3) as following.

$$\pm \Delta V = C_i - D_i \qquad (4)$$

where C_i is amount of rainwater collection in i^{th} month and D_i is amount of rainwater demand in i^{th} month.

The tank volume designed for rainwater collection is calculated with two methods, provided that rain water supplies and demands are given per month, and they remain unchanged every year.

It can be said that when yearly demands are less than yearly collections, yearly total collections of rain water become greater than the demand. At that case, the estimation can

be made by adding rain water to the months of collections less than the demand per month: the tank volume designed for rain water collection can be calculated by taking monthly shortage into account.

3. Case Study of estimation of tank size for rainwater collection

We applied aforementioned method in the 'ㄷ' tea farm located in the 'ㄱ' green model area.

In case of yearly demand smaller than the collection, the resulting tank volumes to be designed for rainwater collection can be seen in Table2.

Table2. the calculation results of tank volumes for rainwater collection($\times 10^3 m^3$)

Month	Demand	Collection	difference	Available accumulation		Supplementary volume
				A year	Two year	
1	75	51	-24	0	2852	-24
2	75	63	-12	0	2840	-12
3	150	123	-27	0	2813	-27
4	150	260	110	110	2923	0
5	301	420	119	229	3152	0
6	301	486	185	414	3566	0
7	301	1394	1093	1507	5073	0
8	301	1117	816	2323	7396	0
9	150	618	468	2791	10187	0
10	150	156	6	2797	12984	0
11	75	167	92	2889	15873	0
12	75	62	-13	2876	18749	0
Total	2104	4917	2813			63

As shown in Table 2, the difference between collection and demand is 2 813$\times 10^3 m^3$ and tank size necessary for rainwater collection is 63$\times 10^3 m^3$.

In case of yearly demand higher than the collection, the tank size necessary for rainwater collection was calculated and recorded in Table3.

Table3. tank size for rainwater collection($\times 10^3 m^3$) in case of yearly demand higher than the collection

month	demand	Collection	difference	Available accumulation	
				A year	Two year
1	75	17	-58	0	62
2	75	21	-54	0	8
3	150	41	-109	0	0
4	150	87	-63	0	0
5	301	140	-161	0	0
6	301	162	-139	0	0
7	301	465	164	164	164
8	301	372	71	235	235
9	150	206	56	291	291
10	150	52	-98	193	193
11	75	56	-19	174	174
12	75	21	-54	120	120
Total	2104	1640	-464		

As shown in Table 3, the difference between collection and demand is -464×10^3㎥, tank size necessary for rainwater collection is 291×10^3㎥. Then insufficient amounts could be supplied by underground water or water from neighboring areas.

Conclusion

In order to sustainably use water resources, rainwater collection system should be established and rainwater resources should be effectively used. The tank size for rainwater collection should be rationally decided by considering natural and socio-economic conditions of any particular region.

References

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