沙漠研究 **22**-1, 287 -290 (2012)
Journal of Arid Land Studies

"ICAL 1 / DT X"
－Refereed Paper－

The Prevention Methods of Leak and Evaporation for Consecutive Water Reservoir

Satoru TAKAHASHI*[1], Shinji SUZUKI[1], Fumio WATANABE[1], Akio GOTO[2] and Ayumi KUBO[2] [3]

Abstract: Authors have developed a practical use of the consecutive water reservoir system as a source of small scale irrigation for stable cropping in Semi-Arid Africa. Particularly in Semi-Arid Africa, it is important to prevent the losses of leak and evaporation at the water reservoirs. In this study, the prevention methods of those losses from the water reservoir were considered in semi-arid area of Central Ethiopia, where the irrigation system based on consecutive water reservoir is expected to be prevailed among small scale farmers. The consecutive water reservoir system consists of the primary, the secondary and the tertiary reservoirs. This study focuses on the tertiary reservoir since small scale farmers can afford to establish only small reservoirs sized as the tertiary reservoir. For the prevention of leak loss, it is important to analyze soil characteristics in the area and to compact soil at the optimum water content based on the Proctor's Principle of soil compaction. In this study it was revealed that it is the most effective to compact soil when water content is 33%. For the prevention of evaporation loss, foam polystyrene was proposed as a material to cover the water surface of reservoir and it was revealed that the coverage rate of 80% is the most effective covering rate in terms of both effectiveness and efficiency.

Key Words: Foam polystyrene, Reservoir, Semi-Arid Africa, Soil compaction, Water resource

1. Introduction

In the arid and semi-arid area where rain-fed agriculture is run, the shortage of water is the limiting factor of crop cultivation. The water harvesting method has been proposed as a solution against the above issue, however, there had been little study done to determine stable, minimum, and timely water supply in case of water shortage caused by rainfall fluctuation in the area. Therefore, the consecutive water reservoir system consists of the primary, the secondary and the tertiary reservoirs was proposed as the measure of stable water supply against rainfall fluctuation (**Fig. 1**).

However, there are issues associated with water leakage from the bottom or the side of reservoirs and evaporation from water surface. Those issues are notable particularly in semi-arid area of Africa.

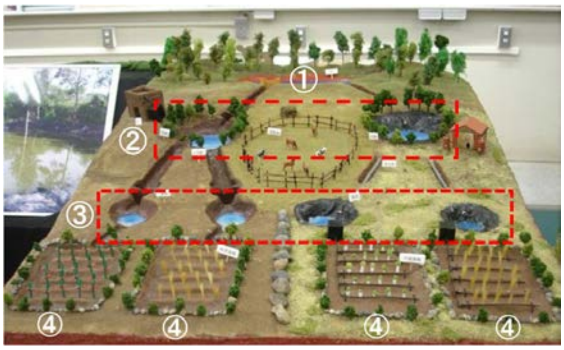

Fig. 1. Consecutive water reservoir system. ①the primary reservoir, ②the secondary reservoirs, ③the tertiary reservoirs, ④cropping field.

Therefore authors selected an arid area in Central Ethiopia where rainfall fluctuation is severe as it is represented with the trend of annual rainfall at Adami Tulu Agricultural Research Centre (N7°51'44", E38°42'44", alt 1,650m.a.s.l.) (**Fig. 2**), to study on the current situation of arid lands in Ethiopia where the irrigation system based on consecutive water reservoir is expected to be prevailed among small scale farmers. Following this, the counter measurements of above problems are discussed. This paper focused particularly upon the issues of leaking water and surface evaporation at tertiary reservoirs of small scale farmers.

2. The Actual Condition of Leak and Evaporation at Reservoirs

There are some individual reservoirs sized like secondary and tertiary reservoirs of consecutive water reservoir system in the semi-arid area of Ethiopia for human consumption (drinking), feeding animal and small scale irrigation. The reservoirs have the same chronic and mutual problems such as leaking water and surface evaporation. In result, none of them retains and supplies adequate amount of water for usage. Therefore, authors conducted surveys to reveal the actual

* Corresponding Author: satoru@nodai.ac.jp
1-1-1, Sakuragaoka Setagaya Tokyo, JAPAN
1) Faculty of Regional Environment Science, Tokyo university of Agriculture, Japan
2) Graduate School of Agriculture, Tokyo University of Agriculture, Japan
3) NTC INTERNATIONAL CO., LTD

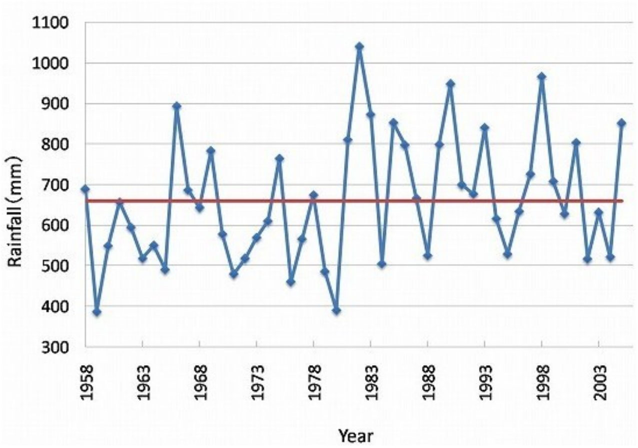

Fig. 2. The trend of annual rainfall between 1958 and 2006 observed at Adami Tulu Agricultural Research Centre (ATARC) located in the Central Ethiopia.

situation and the problem of leak and evaporation of existing water reservoirs.

2.1. The actual situation of leak loss in the reservoirs

Out of investigation into the actual situation of existing water reservoirs, it was revealed that the circumstances of reservoirs vary in wide range from empty reservoirs to well-filled reservoirs. The differences among those reservoirs were determined whether the intrusion of domesticated animals into the reservoirs occurred or not. Reservoirs with the intrusion of domesticated animals retain water. On the contrary, reservoirs without intrusion do not retain water.

In an interview survey, it was revealed that farmers believe functional reservoirs which hold water can be constructed only when materials such as polythene or cement are used, and the cost is not affordable to most farmers. Farmers are not aware of other methods to prevent leak loss for the construction of reservoirs besides using the above materials. It is a major reason why water harvesting technologies such as reservoirs are not prevailed among farmers.

Out of the above results, it can be pronounced that one of the major problems in the construction of reservoirs is the lack of soil compaction in most cases. Therefore authors suggest applying the Proctor's Principle of soil compaction as a counter measurement against the above problem particularly for challenging farmers in terms of finance.

2.2. The actual condition of evaporation loss

To reveal the actual situation of evaporation loss, the monthly average evaporation rates were calculated from the evaporation data of Adami Tulu Agricultural Research Centre (ATARC) for 24 years (**Fig. 3**). The data was measured using A-pan method.

Annual average cumulative evaporation rate is approximately 6.5 mm/day although the cumulative evaporation rate tends to be slightly lower in rainy season. The high evaporation rate represents a characteristic of semi-arid land. Furthermore, the evaporation rate is equivalent to the evapotranspiration rate of common crop in the area which is approximately 6 mm/day. In other words, the amount of evaporation loss is almost the same as the amount of water which is supplied by irrigation.

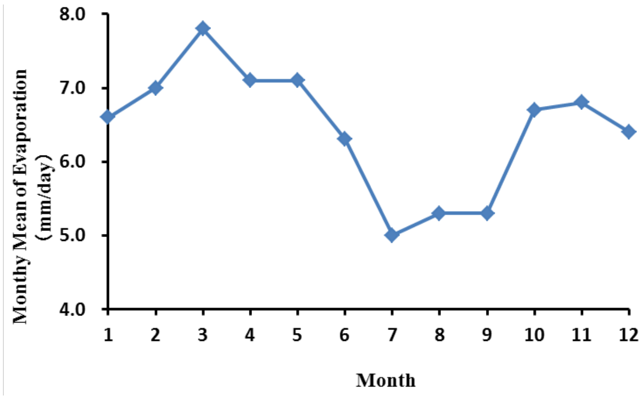

Fig. 3. Monthly mean evaporation rates at ATARC for 24 years.

In addition, it was reported that one fourth of flowed-in water was lost by the evaporation at experiment reservoirs in 2008. This indicates that the prevention of evaporation loss from the water surface of reservoirs in semi-arid area is a significant issue to overcome.

To prevent the evaporation loss, it is common to cover the water surface with materials. Authors proposed white-colored foam polystyrene as the covering material since the material should be floatable-waterproof, and flexible to the shape of reservoirs and the movement of water levels. It should also insulate and reflect sunshine which promotes evaporation. In addition to the above, foam polystyrene can be piled up each other while water level goes down, which promotes the effect of preventing evaporation. Therefore it is important to know how much foam polystyrene should be applied in reservoirs to develop a practical method of usage.

3. Verification of Counter-measurement against the Losses of Leak and Evaporation in the Reservoirs

3.1. Materials and Methodologies

Experiments on soil compaction and saturated hydraulic conductivity were conducted by using a soil shown in **Table 1** at ATARC which is located in the central part of Ethiopia.

The evaluation on the prevention of evaporation using foam polystyrene was examined at the experimental field of the Tokyo University of Agriculture in Japan (**Fig. 4**). The different covering ratios namely 40%, 60%, 80%, 100% and 200% were tested comparing with control.

3.2. Results and Discussions

3.2.1. The prevention of leak loss

The compaction curve and saturated hydraulic conductivity examined in ATARC are shown in **Figure 5**. When the water content was 33% and the bulk density was 1.26 g/cm^3 (at point S in Fig. 5), the saturated hydraulic conductivity decreased up to minimum level (100 × 10^{-6} cm/s) (**Fig. 5**). That is to say, it is effective to compact soil with 33 % of the water content for preventing leaking water. A traditional technology of compacting soil in Japan which can be applied for the situation is shown in **Figure 6**. These technologies can be adopted by financially challenging farmers in Ethiopia since the investment is quite affordable to small scale farmers. Besides, the several layers of lining with clay soil can add more value as a counter measurement on leak loss.

Table 1. Physical characteristics of experimented soil.

Soil Texture	Soil Particle Density (g / cm^3)	Bulk Density (g / cm^3)	Saturated Hydraulic Conductivity (cm / s)
Sandy loam	2.52	1.01	1.15 x 10^{-13}

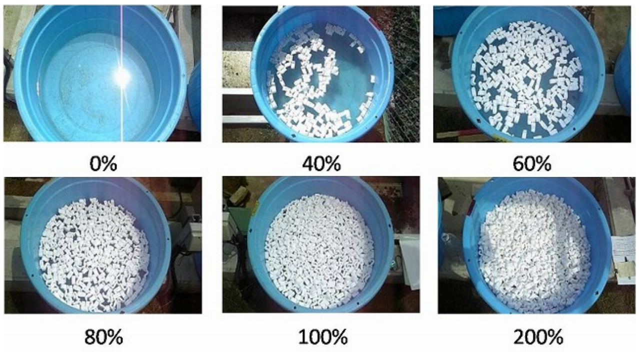

Fig. 4. A experiment on the prevention of evaporation loss using different covering ratio with foam polystyrene to water surface at Tokyo University of Agriculture in Tokyo, Japan.

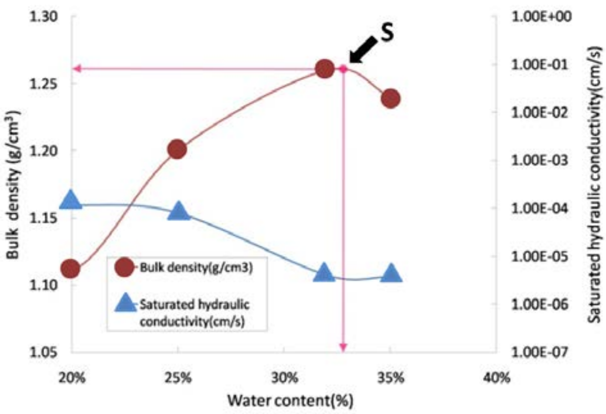

Fig. 5. Compaction curve and hydraulic conductivity.

Fig. 6. A traditional construction technique of compacting soil for reservoirs in Japan.

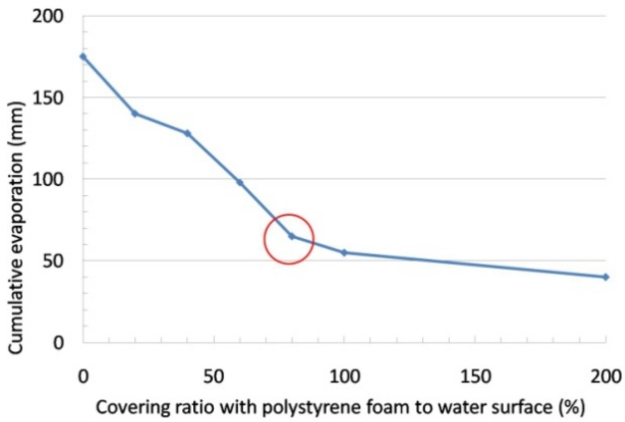

Fig. 7. The relation between the cumulative evaporation and covering ratio with foam polystyrene observed in the field of Tokyo University of Agriculture in Tokyo, Japan (5th August 2009 - 23rd October 2009).

3.2.2. Prevention of evaporation loss

The relationship between the cumulative evaporation from water surface and covering ratio with styrene foam floating on water surface is shown in **Figure 7**. When the covering ratio was 80%, the cumulative evaporation was approximately 65 mm (the 60% decrease comparing to the control). However, the increment of covering ratio above 80% did not give efficient effects in terms of the decrement of the cumulative evaporation from water surface. That is to say, 80% is the most effective cover rate in terms of both effectiveness and efficiency.

4. Conclusions

It is effective to compact soil with the adequate water contents based on the Proctor's Principle of soil compaction to reduce the leak loss from the bottom or side of water reservoirs. However one should study about the climates and soil characteristics in the experimental field. This is the basic principle for the development of technologies.

With respect to the prevention method of the evaporation from water surface, it is effective to cover water surface (with 80% covering ratio) with a material such as foam polystyrene which is floatable-waterproof, and flexible to the shape of reservoirs and the movement of water levels.

References

Takahashi S. *et al*. (2011): Consecutive Irrigation Reservoir System in Semi-Arid Area of East Africa. *Journal of The Japanese Society of Irrigation, Drainage and Rural Engineering*, **79**(2): 109-112

Takahashi S. *et al*. (2011): Improvement and Horizon of Rain-fed Agriculture in Africa from the Point of View of Water Usage. *Journal of Arid Land Studies*, **20**(4): 219-226

Takahashi S. *et al*. (2010): *Final report for useful technology in developing countries and Feasibility study with university*. Japan International Cooperation Agency: 148-149