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DESIGN REQUIREMENTS FOR INSTALLATION OF LYSIMETERS

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ABSTRACT

For accurate and reliable measurements of different components of crop hydrologic cycle the lysimeters should be constructed, installed and operated properly. The installation of lysimeters must meet several design requirements for the data to be representative of field conditions. Some design requirements on lysimeter depth, water control, drainage, area, wall, filling of soil, soil moisture, soil heat flux and comparability of plant cover are discussed which may be helpful in a proper installation of lysimeters.

INTRODUCTION

Water is one of the most important resources for the production of crops. For the planning, design and operation of irrigation projects it is necessary to determine the amount of water use by agricultural crops. Although various methodshave been used to determine the amount of water consumed by agricultural crops, the most reliable estimates can only be made by means of lysimeters. A lysimeter is a device in which a volume of soil, with or without crop is located in a container to isolate it hydrologically from the surrounding. Lysimeters have been known for a long time. For more than a century hydrologists, meteorologists, engineers and agricultural scientists have conducted many lysimeteric studies. The purpose of most lysimeter investigations has been to study the problems in hydrology or nutrient balance or both. Quantitative evaluation of different components of the hydrologic cycle and losses of nutrients in drainage water is possible with the lysimeters.

Harrold[1] made an excellent review of lysimetry for evapotranspiration studies. For accurate and reliable measurement of evapotranspiration the lysimeters should be constructed, installed and operated properly. Pelton[2] has discussed the requirements for proper use of lysimeters in evapotranspiration research. Tanner[3] also described the general features of different types of lysimeters for measurement of evapotranspiration.

Lysimeters contain either disturbed or undisturbed soil profile. Lysimeters which contain disturbed soil are called as filled in type and those which have undisturbed soil block are designated as 'monolith' type. The nature of evapotranspiration data to be obtained dictates the suitability of lysimeters. When lysimeters are employed to measure actual evapotranspiration it is desirable that they should contain an undisturbed representative soil profile. On the other hand when the objective is to

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measure potential evapotranspiration, the physical constitution of the soil is of less significance and lysimeter may contain disturbed soil profile. It may be pointed out that potential evapotranspiration occurs if there is an aboundant supply of water in the soil for use of vegetation, whereas, actual evapotranspiration takes place when moisture content in the soil is below the field capacity.

According to the system used for estimating the water loss, two general types of lysimeters are in use (i) non-weighing type and (ii) weighing type. Non-weighing lysimeters are well suited for measuring the long term evapotranspiration data. Non-weighing lysimeters can be classified as (a) constant water table type and (b) percolation type. Constant water table non-weighing lysimeters provide reliable data in areas of high water table conditions. Percolation type non-weighing lysimeters are often used in areas of high rain. Singh and Shukla[4] have discussed the procedure for measurement of evapotranspiration by different types of non-weighing lysimeters.

Weighing lysimeters furnish evapotranspiration data for short periods but their installation and operation cost is too high. Weighing lysimeters differ not only in the mode of weighing but also in features of construction. Three types of weighing systems have been developed; (i) mechanical (ii) hydraulic load cell and (iii) floating type. The most common type of weighing lysimeter employs mechanical balances to measure the weight loss. The balances usually are of special design. In the simplest arrangement the soil container is attached to a portable overhead balance and lifted free of its support when weighed. Mechanical weighing system with automatic readouts are also used for continuous recording of evapotranspiration data. Precision weighing lysimeters have been developed by Pruitt and Angus[5] Van Bavel and Mayers[6] and Ritchie and Burnett[7] Bhardwaj and Sastry[8] has also developed a simple weighing type lysimeter in which indigenous materials have been used. Hydraulic load cell type weighing system and floating type systems are used where economy and simplicity of the system are important. Temperature sensitivity of the liquid on which the soil mass rests limits the convenience and accuracy of such systems. With proper corrections for temperature sensitivity, however, these units can be made accurate enough for daily or possibly more frequent observations of evapotranspiration. Hydraulic load cell lysimeters have been developed by Hanks and Shawcroft[9], Black et al.[10] and Korven and Pelton[11]. King et al.[12] described a floating lysimeter for measuring evapotranspiration.

Lysimeters have been successfully installed in many countries and have been tested under a variety of soil and climatic conditions. Lysimeters can yield valuable information regarding rate of soil moisture movement, irrigation requirements and various other soil water plant relationships. The installation of lysimeters must meet several design requirements for the data to be representative of field conditions. In this paper some design requirements on lysimeter depth, water control, drainage area, filling of soil, soil moisture, soil heat flux and comparability of plant cover are discussed which may be helpful in a proper installation of lysimeters.

LYSIMETER DEPTH, WATER CONTROL AND DRAINAGE

It is very important to realize that condition of water availability and root development inside the lysimeter are identical to those of the surrounding soil. Van Bavel[13] discussed the effect of the lysimeter on the water regime. A lysimeter prevents the natural vertical flow and distribution of water due to the nature of its construction. This is illustrated in Figure 1 which represents the initial water condition following rainfall or irrigation. At that time a zero-pressure plane is present at the bottom and thereby the moisture tension as well as moisture content are different from those in the surrounding soil. This may have two effects (1) more water may be available for evapotranspiration during a prolonged dry spell, and (2) the development of the root system of crops grown in the lysimeter may differ from that in the surrounding area. In constant water table lysimeters, the same applies except that then the water table is the zero pressure plane. These lysimeters can duplicate surrounding conditions only in areas of permanent and high water tables.

The difficulty may be reduced by making the lysimeters deep, so that they extend well below the root zone. Obviously, it is more difficult to construct a deep lysimeter. A more basic solution is to maintain tension at the bottom of a lysimeter deep enough to allow normal root development. This requires a rigid porous support for which the bubbling pressure is higher than the highest tension one wishes to establish. Tension can then be maintained to equal or approximate the tension in the surrounding profile at the same depth. A net work of ceramic tubes connected to a vaccum system is suitable for maintaining required suction and drainage rates. When lysimeters are used to measure actual evapotranspiration it seems necessary that they are either quite deep or fitted with a tensioning device. For measurement of potential evapotranspiration rates, the moisture conditions in the lysimeters are not critical as long as the root growth is normal.

LYSIMETER AREA AND WALL

The evapotranspiration is determined by dividing the measured volume of water loss to the 'effective area' of the lysimeter. The effective area of a lysimeter is the ratio of lysimeter evapotranspiration per unit area to the average evapotranspiration per unit area of the surrounding field. A ratio other than unity is caused by inadequate sampling and depend largely on the relative size of the lysimeter to the scale of patchiness or crop inhomogeneity. The measured area of the lysimeter container equals the effective area only when the evapotranspiration from the lysimeter is representative of the average evapotranspiration from an equal area of surrounds. Generally area of the lysimeter is dictated by the structure of the vegetation. A properly exposed lysimeter should have a large area compared to the non-uniformity of the vegetation to represent a similar field area.

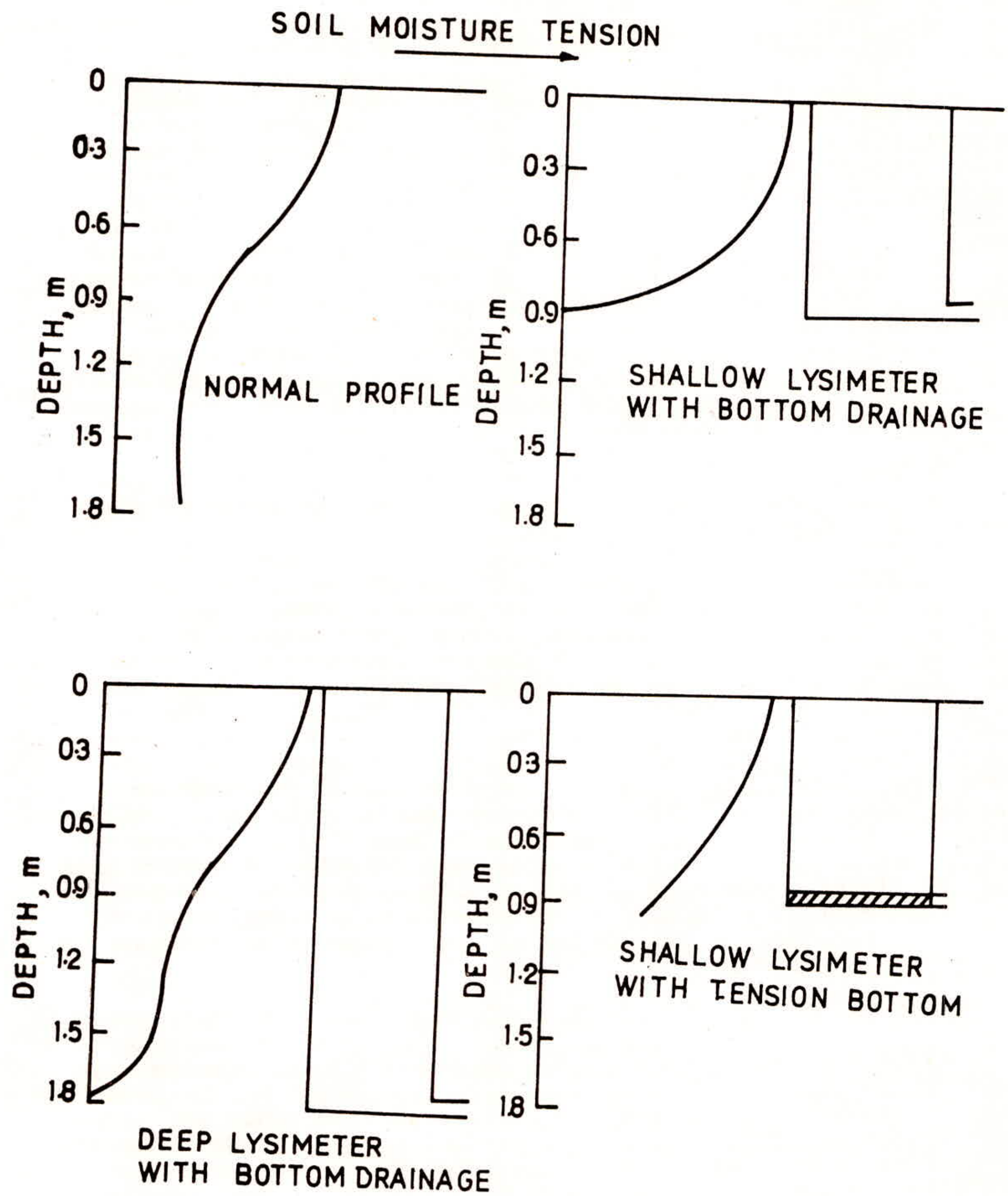

FIG. 1. Idealized relationship between soil moisture tension and depth lysimeters.

For row crop studies in which the ground cover is some what uniform but may not be complete, it is important that the amount of soil exposed per unit of plant row be similar to that in the surrounding field. Therefore, for such studies a lysimeter should be rectangular with width dimensions equal to a multiple of the field row width. A circular lysimeter provides little cover proportionality between evapotranspiration from the lysimeter and the field for row crops but it can beproved useful for forage crop studies. A circular design also offers an advantage since the walls of the lysimeter can be kept at a minimum thickness for a given strength of material.

The presence of lysimeter walls around the soil introduces some what unnatural conditions in the system. In addition to the large scale advection of heat on the field, there is small scale advection from the area of surface occupied by the lysimeter walls. This effect can be reduced by making the ratio of the perimeter to the area of the lysimeter small, and for this reason a circular design is considered best. It can also be reduced by making the total wall plus gap area, small compared to the enclosed area.

Wall effect also involves growth and transpiration differences of plants immediately adjacent to the inner and outer walls. This error can be minimized by designing a large size lysimeter so that the affected area becomes a relatively small portion of the total surface area. Temperature gradient from those in surrounding soil will affect movement of water, especially in vapour phase, but these are small where lysimeters are burried so that the soil surface is at the same level as outside.

FILLING OF SOIL

An ideal lysimeter should contain an undisturbed representative soil profile. Under field condition soil is never uniform and there are infinite variations due to distribution of cracks and structural changes and fine fissures of different depths left by rotting roots, and the presence of worm holes and passages caused by insects and rodents. It is thus very difficult to ensure that the soil in the lysimeter is a fair sample of that in the surrounding area.

The disturbed soil in a lysimeter will probably alter the plant growth. This will not be a serious problem in monolith lysimeter which contains an undisturbed soil block. But in case of monolith lysimeter, a large area of soil around the lysimeter is disturbed in order to lower the container down over the undisturbed soil block and make room for installation of measuring system.

Another problem of using disturbed soil may be the alterning of its physical and hydraulic properties especially the moisture retention characteristics, leadingto differences in soil moisture tension and soil heat flux component of the surface energy balance. This is not appreciable for light textured soils when lysimeter is filled in correct order and the soil is settled by saturating and draining of it. Figure 2 shows the properly filled concrete lysimeters which were installed at Pantnagar.

SOIL MOISTURE

If soil moisture conditions inside and outside a lysimeter are different, it may affect the rate of evapotranspiration. Therefore, the soil moisture conditions within the lysimeter should neither appreciably wetter nor drier than in the surrounding soil. In order to drain excess water from the lysimeter an adequate drainage system must be provided as close as possible to the natural drainage rate in the field.

The method of application of water is also responsible for soil moisture conditions within the lysimeter. There should be no difficulty in applying water to the surface in accurately measured amounts but methods of watering from overhead may leave the foliage wetted in an unnatural way. This can be avoided by applying water through a small pipe fitted with a series of nozzles, so that the foliage is not wetted.

SOIL HEAT FLUX

The thermal properties of the soil in the lysimeter and in the field should be similar after setting the soil. Any differences in the vertical temperature gradients will change the soil heat flux. A metal container readily conducts some heat in deeper soil layers. In order to maintain similar soil heat flux inside and outside of the lysimeter, the gap at the ground surface between the containing and retainingwalls should be sealed with a non-conducting material sheet such as polythene or polyvinyl. Fiber glass containing and retaining walls have also been used with success.

If the water distribution in the lysimeter differs from that outside, the heat transfer and storage will be affected. The surface layer (30 to 40 cm) is of greatest importance where hourly measurements are made, though the seasonal soil heat flux is affected by much deeper layers. If the lysimeter is shallow, discontinuities in thermal properties at the tank bottom can cause error in weekly or monthly measurements.

COMPARABILITY OF PLANT COVER

It is essential that the surface of the lysimeter should be representative of surrounding area. The lysimeter itself should be indistinguisable from the surrounding area as shown in Figure 3. The lysimeter is only then a true sample of prevailing field conditions if its physical environment is identical to that typical for the field. The lysimeter must be sited in identical surrounds and with representative fetch. Nearby obstructions or non-evaporating surfaces including balance access structures and recording instruments, paths leading to the lysimeter, roads, and exposed roots of under ground shelters should be avoided.

A considerable border or guard area must be maintained around the lysimeter and this area must receive the same treatment with regard to vegetal cover, water management and fertility as does the lysimeter itself. If representative evapotranspira-

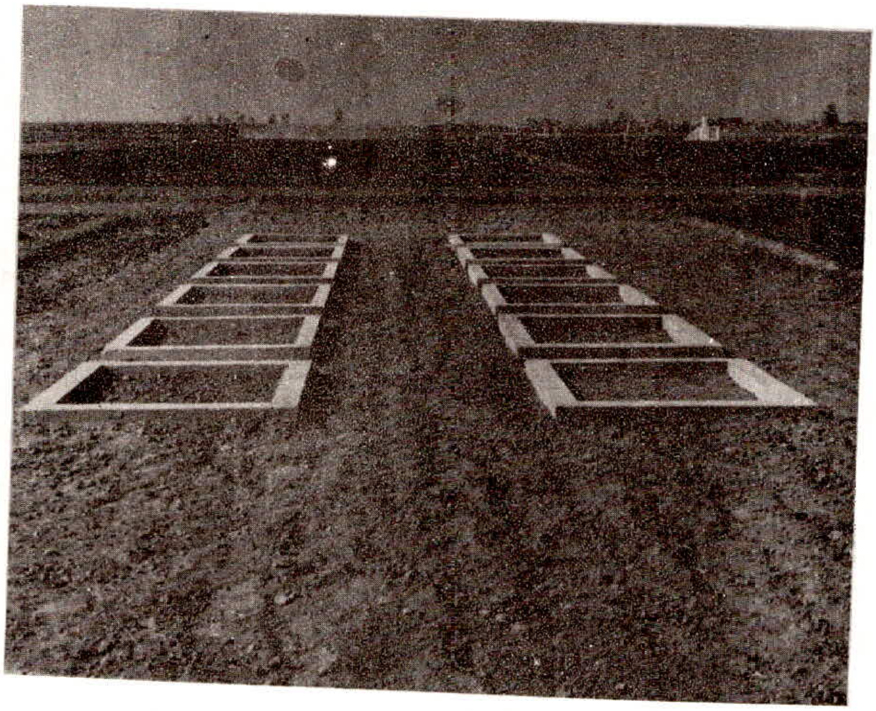

Fig. 2. Filled-in type concrete lysimeter.

Fig. 3. Wheat crop cover showing that the lysimeter crop was indistinguisable from the surroundings.

tion rates are to be obtained, a lysimeter must be located in the middle or a homogeneous area and must contain soil and vegetation typical of the area. It is extremely important that the height of the crop and its growth rate within the lysimeter should not deviate appreciably from the environment. Any discontinuity between the growth of the crop in the lysimeter in the surrounding field will by changing the turbulance of the air moving over it, cause unrepresentative evapotranspiration from the lysimeter. This error may decrease as the lysimeter area increases.. The small scale addvection from the area of surface occupied by the lysimeter walls can also be minimized by making the ratio of the perimeter to the area of the lysimeter small.

Great care must be exercised in using a lysimeter in arid regions. If it is placed in the middle of a dry field, the lysimeter will overestimate evapotranspiration from a large crop, because the air over the lysimeter is continuously replaced by dry air with a low vapour pressure. The lysimeter should have a buffer zone of atleast 400 meter in arid regions to give representative results.

REFERENCES

1. Harrold, L.L. 1966. Measuring evapotranspiration by lysimetry. Proce of conference on Evapotranspiration and its Rolein Water Resource Management. ASAE, Chicogo, pp. 28 - 33.

2. Pelton, W.L. 1961. The use of lysimetric methods to measure evapotranspiration. Proc. Second Canadian Hydrology Symposium Toronto, Vol. 2, pp. 106-139.

3. Tanner, C.B. 1967. Measurement of evapotranspiration. In Irrigation of Agricultural Lands. Hagan, R.M.; House, H.R. and Edminister, T.W. (Editions) Agronomy Monograph No. 11, American Society of Agronomy, Madison, Wisconsin, pp. 543-574.

4. Singh, R.V. and Shukla, K.N. 1978. Installation of non-weighing lysimeters for measurement of evapotranspiration. Journal of Agricultural Engineering. Vol.15(2): 74 - 85.

5. Pruitt, W.O., and Angus, D.E. 1960. Large weighing lysimeter for measuring evapotranspiration. Transc. Amer. Soc. Agr. Eng., 3(2) : 13-18.

6. Van Bavel, C.H.M. and Myers, L.E. 1962. An automatic weighing lysimeter, Agr. Eng. 43, 580-583 and 587-588.

7. Ritchie, J.T. and Burnett, E. 1968. A precision weighing lysimeter for row crop water use studies. Agron. J. 60 : 545-549.

8. Bhardwaj, S.P. and Sastry, G. 1979. Development and installation of a simple mechanical weighing type lysimeter. Trans. ASAE, Vol. 22(4) : 797-802.

9. Hanks, R.J. and Shawcroft, R.W. 1965. An economical lysimeter for evapotranspiration studies. Agron. J. 57: 634 - 636.

10. Black, T.A., Thurtell, G.W. and Tanner, C.B. 1968. Hydraulic load, Cell lysimeter, Construction calibration and tests·soil Sci. Soc. Amer. Proc. 32 : 623 - 629.

11. Korwen, H.C. and Pelton, W.D. 1972. Hydraulic load cell lysimeters. Can. Agr. Eng. 14 : 33 - 36.

12. King, K.M., Tanner, C.B. and V.E. Suomi, 1956. A floating lysimeter and its evaporation recorder. Transc. Amer. Geophys. Union, 37(6) : 738 - 742.

13. Van Bavel, C.H.M. 1961. Lysimetric measurements of evapotranspiration rates in the Eastern United States.Soil Sci. Soc. Amer. Proc. 25(2) : 138 - 141.