International Journal of Agriculture, Environment and Biotechnology
Citation: *IJAEB*: **17**(04): 727-730, December 2024
DOI: 10.30954/0974-1712.04.2024.11

ASSOCIATION FOR AGRICULTURE ENVIRONMENT AND BIOTECHNOLOGY

REVIEW PAPER

A Review on Invention of Automatic Closed Canopy Chamber for Evapotranspiration Measurement

Deepak Kumar[1*], Vikash Singh[2] and H.D. Rank[3]

[1]Department of Agricultural Engineering, School of Agriculture, GIET University, Gunupur, Odisha, India
[2]Department of Agricultural Engineering, Narayan Institute of Agricultural Sciences, Gopal Narayan Singh University, Sasaram, Bihar, India
[3]Department of Soil and Water Conservation Engineering, CAET, JAU, Junagadh, Gujarat, India

*Corresponding author: dk720244@gmail.com (**ORCID ID:** 0000-0002-9360-7658)

Paper No. 1191 **Received:** 13-09-2024 **Revised:** 08-11-2024 **Accepted:** 27-11-2024

ABSTRACT

The irrigation planning and Management either at field, water course, sub-canal or main canal level requires the information of crop evapotranspiration. The estimation of the crop water requirement or crop evapotranspirations requires the information of reference evapotranspiration (ET_0) and crop coefficient (K_C) for different stages of crops. The sizable research has been done to determine the crop evapotranspiration (ET_C) and crop coefficient (K_C) using the Lysimeter instrument. However, a few attempts have been done in world on the ET_C and K_C measurement using the Canopy Chamber. An attempt was done to collect the past work relevant to ET_0, ET_C, Lysimeter and K_C. From these reviews, it can be said that the Penman- Monteith (PM) equation reveales the most accurate one. Therefore,in this research work the well proved Penman-Monteith equation has been used as standard method to compare the different empirical methods. The Weighing type Lysimeters has been developed for measurement of crop evapotranspiration. However, there are some limitations in using the Lysimeter. The higher initial cost, regular maintenance and complex construction of the instrument restricts its use on field-scale. It can be used for only single crop in one season. For avoiding such problems, canopy chamber method has been developed for measuring crop evapotranspiration. However, very few studies have been conducted on development of automatic closed canopy chamber for evapotranspiration measurements. Crop coefficient of some important crops is not given in FAO-56 guideline; therefore, it is very necessary to develop region specific stage-wise crop coefficient of field crops. The main objective of the paper is to provide an overview of recent research in development of closed canopy chamber for evapotranspiration measurement. The study done in the areas during the last few years has been reviewed from the national and international research works. The application of artificial intelligence in development of automatic closed canopy chamber has been also taken into account.

HIGHLIGHTS

- Accurate estimation of crop evapotranspiration (ET_C) is essential for effective irrigation planning and management at various levels (field, water course, sub-canal, or main canal). This requires data on reference evapotranspiration (ET_0) and crop coefficients (K_C).
- The Penman-Monteith (PM) equation has been identified as the most accurate method for estimating crop evapotranspiration and crop coefficients, and it is used as a standard for comparing empirical methods.
- While the Lysimeter is a reliable tool for measuring ET_C, its high cost, maintenance demands, and limited use for single crops per season limit its application. The canopy chamber method offers an alternative, with fewer limitations and the potential for broader field use.
- Many crop coefficients for important crops are not included in FAO-56 guidelines, necessitating

How to cite this article: Kumar, D., Singh, V. and Rank, H.D. (2024). A Review on Invention of Automatic Closed Canopy Chamber for Evapotranspiration Measurement. *Int. J. Ag. Env. Biotech.*, **17**(04): 727-730.

Source of Support: None; **Conflict of Interest:** None

the development of region-specific, stage-wise crop coefficients to improve irrigation practices and crop water requirement estimations.

- The study highlights the emerging role of artificial intelligence (AI) in automating the closed canopy chamber system for evapotranspiration measurement, enhancing accuracy, efficiency, and scalability in data collection.

Keywords: Reference Evapotranspiration, Crop Coefficient, Lysimeter, Artificial Intelligence, Automatic Closed Canopy chamber, Temperature and Relative Humidity Sensor

Evapotranspiration (ET) plays a crucial role in the inter-connected system of soil, plants and the atmosphere, serving as a key component of energy exchange processes (Chao *et al.* 2021; Mercedeh *et al.* 2022). The research findings indicate that approximately 60% of the world's terrestrial precipitation is reabsorbed into the atmosphere through evapotranspiration (Zhang *et al. 2018*; Qiao *et al.* 2021). The amount of irrigation water is estimated based on crop evapotranspiration (ETc) for applying irrigation through sub-membrane drip irrigation system (Skaggs *et al.* 2010; Feng *et al.* 2018). Therefore, determining ETc, very accurately is essential for minimizing water usage during the crop's reproductive stage, enhancing water use efficiency (WUE) and promoting the advancement of water-efficient agricultural practices. (Liu *et al.* 2002; He *et al.* 2013). A study has shown that variation in plant leaf area has a substantially greater effect on evapotranspiration than that of variation in the climate and the climatic factors have a stronger influence on evapotranspiration indirectly through plant cover (Yang *et al.* 2022).

Evapotranspiration is the process by which water is transferred from the land to the atmosphere through evaporation from the soil and transpiration by plants. It is a critical component of the water cycle and an important factor in agricultural water management, hydrology, and climate studies. Measuring ET accurately is challenging due to the need to account for both soil evaporation and plant transpiration, which vary with environmental conditions and crop types.

Irrigation scheduling is often considered as the primary method to enhance water utilization efficiency, boost crop yields, improve water resource availability and positively impact soil and groundwater quality. Alaamer *et al.* (2023) concluded that the measuring crop evapotranspiration (ETc) directly is challenging and costly due to the expenses associated with instrument development and upkeep. As a substitute, the idea of reference crop evapotranspiration (ETo) was introduced to quantify the atmospheric demand for evaporation. (Allen *et al.* 1998; Pereira *et al*. 2015).

The Penman-Monteith equation (PM) is widely advocated as the standard method for estimating reference crop evapotranspiration (ETo) due to its robust scientific foundation and global applicability without requiring local adjustments (Goyal *et al.* 2023). However, the widespread adoption of the Penman-Monteith equation (PM) has been constrained, mainly by its reliance on numerous meteorological parameters as its inputs.

To take into account this issue, more straightforward empirical methods have been devised, utilizing readily available meteorological data such as radiation (Rn), humidity (RH) and temperature-based (T) approaches to provide reliable estimates of ETo. (Su *et al.* 2022). Nevertheless, there is considerable variability in accuracy among the empirical methods for ETo determination, influenced by varying data prerequisites and underlying theoretical assumptions (Chia *et al.* 2020; Su *et al.* 2022). Additionally, numerous researchers have noted that empirical methods exhibit considerable variations in accuracy, even when applied with identical input variables, due to differences in underlying structures and assumptions (Lu *et al.* 2023).Several studies have also discovered that ETo methods are greatly influenced by empirical parameters, which are linked to specific local climatic conditions and topographical features. (Bashir *et al.* 2023).

The energy balancing method, Lysimeters, and eddy covariance devices are all capable of directly measuring reference evapotranspiration. (Li *et al.* 2018; Nabavi-Pelesaraei *et al.* 2021). While lysimeters are highly accurate for directly calculating ETo, their suitability is hindered by their higher cost, the complexity and time required for measurements and their limited availability at many locations.

(Chia *et al*. 2020a, 2020b). Using closed canopy chambers can help circumvent these issues because they are straightforward to construct and easy to transport.

By employing canopy chambers, it becomes possible to estimate crop evapotranspiration directly, without relying on crop coefficients and this method can be applied across multiple types of crops simultaneously. Transient type chambers are noted for their ability to be easily moved within the field, facilitated by mounting them on various carriers such as farm tractors (Reicosky, 1985), forklifts (Dugas *et al.* 1997), gantries (Meyer *et al.* 1987) or by manual transport (Musgrave and Moss, 1961). Nevertheless, in all instances, the requirement for human involvement, especially during nighttime, imposes significant constraints on monitoring efforts.

To address these challenges, the development of an automated closed-system chamber is essential. Such a system would enable high-frequency measurements of both water vapor (H_2O) and carbon dioxide (CO_2) gas exchanges throughout day and night. While automated and unattended gas exchange monitoring offers distinct advantages, it may necessitate reducing the number of replicates or sampled locations (Kumar and Rank, 2021). Reicosky and Peters (1977) concluded that the chamber's accuracy, speed of measurement, portability, and cost-effectiveness make it a valuable tool for agricultural research. Reicosky *et al.* (1983) indicated a close agreement between CET and LET measurements, suggesting that portable chambers provide reliable estimates of ET under field conditions.

RESULTS AND DISCUSSION

The automatic closed canopy chamber is designed to measure ET by enclosing a section of the crop canopy in a sealed environment and monitoring the change in humidity or other parameters over time. The chamber is usually a transparent, closed structure placed over a crop canopy. It can automatically open and close to measure the ET at different times of the day. Sensors inside the chamber track changes in humidity, temperature, and other factors to calculate ET. Modern chambers are equipped with automated systems for opening and closing, data logging, and sometimes even remote monitoring. This reduces labour and increases the accuracy of measurements by allowing continuous monitoring. By enclosing a part of the canopy, this method isolates the area being measured, reducing the impact of external environmental factors and providing a more accurate ET measurement. The Automation reduces the need for manual intervention, increases the frequency of measurements, and allows for more comprehensive data collection. These chambers are often portable and can be used in various field conditions, making them versatile tools for different crop types and environments. Farmers can use ET data from these chambers to optimize irrigation schedules, improving water use efficiency and crop yields. Understanding how ET rates change with environmental conditions can help researchers predict how crops will respond to climate change. The data can inform soil and water conservation strategies, ensuring sustainable use of resources.

CONCLUSION

The invention of automatic closed canopy chambers represents a significant advancement in the field of evapotranspiration measurement. These tools offer a balance of accuracy, automation, and practicality, making them valuable for both research and practical applications in agriculture. Future developments will likely focus on improving accessibility and integrating advanced technologies to further enhance their capabilities. While automated systems reduce labour, the initial cost of these chambers can be high. The Operating and maintaining the system requires technical expertise, which may be a barrier in some regions. By improving the ability to measure ET accurately, the automatic closed canopy chamber plays a crucial role in ensuring the efficient use of water resources, which is essential for sustainable development in agriculture.

REFERENCES

Alaamer, S., Alsharifi, S.K. and Al-Sultani, A.T. 2023. Effect of subsurface drip irrigation system and two levels nitrogen fertilizer on corn growth and yield. *IOP Conf Series: Earth and Environmental Science*, **1158**(1): 062010.

Allen, R.G., Pereira, L.S., Raes, D. and Smith, M. 1998. Crop Evapotranspiration guidelines for Computing Crop Water requirements-FAO Irrigation and Drainage Paper 56. FAO. Food and Agricultural Organization of the United Nations (FAO), Rome, Italy, pp. 326.

Bashir, R.N., Khan, F.A., Khan, A.A., Tausif, M., Abbas, M.Z., Shahid, M.M.A., Khan, N., 2023. Intelligent optimization of reference evapotranspiration (ETo) for precision irrigation. *J. Inf. Comput. Sci.* **69**: 102025.

Chao, L.J., Zhang, K., Wang, J.F., Feng, J. and Zhang, M.J. 2021. A comprehensive evaluation of five evapotranspiration datasets based on ground and GRACE satellite observations: Implications for improvement of evapotranspiration retrieval algorithm. *Remote Sensing*, **13**(12): 2414.

Chia, M.Y., Huang, M.F., Koo, C.H. and Fung, K.F. 2020b. Recent Advances in Evapotranspiration Estimation Using Artificial Intelligence Approaches with a Focus on Hybridization Techniques—A Review. *Agronomy*, **10**(1): 101.

Chia, M.Y., Huang, Y.F. and Koo, C.H. 2020a. Reference evapotranspiration estimation using adaptive neuro-fuzzy inference system with limited meteorological data. *IOP Conf. Ser.: Earth Environ. Sci.*, **612**: 012017.

Chia, M.Y., Huang, Y.F. and Koo, C.H. 2020. Support vector machine enhanced empirical reference evapotranspiration estimation with limited meteorological parameters. *Comput. Electron. Agric.*, **175**: 105577.

Dugas, W.A., Reicosky, D.C. and Kiniry, J.R. 1997. Chamber and micrometeorological measurements of CO_2 and H_2O fluxes for three C_4 grasses. *Agricultural and Forest Meteorology*, **83**: 113-133.

Feng, H., Chen, J., Zheng, X., Xue, J., Miao, C., Du, Q. *et al.* 2018. Effect of sand mulches of different particle sizes on soil evaporation during the freeze–thaw period. *Water*, **10**: 536.

Goyal, P., Kumar, S. and Sharda, R. 2023. A review of the Artificial Intelligence (AI) based techniques for estimating reference evapotranspiration: current trends and future perspectives. *Comput. Electron. Agric.*, **209**: 107836.

He, J., Cai, H. and Bai, J. 2013. Irrigation scheduling based on CERES-wheat model for spring wheat production in the minqin oasis in Northwest China. *Agric. Water Manage.*, **128**: 19–31.

Kumar, D. and Rank, H.D. 2021. Comparison of Fenugreek Crop Evapotranspiration Measured by a Micro-lysimeter,Field Water Balance Method and Automatic Closed CanopyChamber. *Intern. J. Agric. Environ. Biotech.*, **14**(1): 29-49.

Li, M., Chu, R., Shen, S., Reza, A. Md. and Islam, T. 2018. Dynamic analysis of pan evaporation variations in the Huai River Basin, a climate transition zone in eastern China. *Science of The Total Environment*, **625**: 496-509.

Liu, C., Zhang, X. and Zhang, Y. 2002. Determination of daily evaporation and evapotranspiration of winter wheat and maize by large-scale weighing lysimeter and micro-lysimeter. *Agric. For. Meteorol.*, **111**: 109–120.

Lu, Y., Li, T., Hu, H. and Zeng, X. 2023. Short-term prediction of reference crop evapotranspiration based on machine learning with different decomposition methods in arid areas of China. *Agric. Water Manag.*, **279**: 108175.

Mercedeh, T., Abdolmajid, M., Fatemeh, G., Mostafa, B. and Mohsen, N. 2022 Energy-based approaches in estimating actual evapotranspiration focusing on land surface temperature: A review of methods, concepts, and challenges. *Energies*, **15**(4): 1264.

Meyer, W.S., Reicosky, D.C., Barrs, H.D. and Shell, G.S.G. 1987. A portable chamber for measuring canopy gas exchange of crops subject to different root zone conditions. *Agronomy Journal*, **79**: 181-184.

Musgrave, R.B. and Moss, D.N. 1961. Photosynthesis under field conditions. I. A portable, closed system for determining net assimilation and respiration of corn. *Crop Science*, **1**: 37-41.

Nabavi-Pelesaraei, A., Bayat, R., Hosseinzadeh-Bandbafha, H., Rashidi, R. and Shamshirband, S. 2021. Evaluation of reference evapotranspiration estimation using lysimeter and eddy covariance methods under different climatic conditions. *Journal of Hydrology*, **597**: 126.

Pereira, L.S., Allen, R.G., Smith, M. and Raes, D. 2015. Crop evapotranspiration estimation with FAO56: past and future. *Agric. Water Manag.*, **147**: 4–20.

Qiao, C., Du, L., Pan, H., Ma, L., Tian, J., Yuan, H. and Wu, H. 2021 Evaluating the effects of revegetated shrub on land surface ET in arid and semiarid areas using SEBAL model. *Transactions of the Chinese Society of Agricultural Engineering*, **37**(10): 110–117.

Reicosky, D.C. and Peters, D.B. 1977. A portable chamber for rapid evapotranspiration measurements on field plots. *Agronomy Journal*. **69**: 729-732.

Reicosky, D.C., Sharratt, B.S., Ljungkull, J.E. and Baker, D.G. 1983. Comparision of alfalfa evapotranspiration measured by a weighing lysimeter and a portable chamber. *Agricultural Meteorology*, **28**: 205-211.

Reicosky, D. C. 1985. Advances in evapotranspiration measured using portable field chambers. In: Proceeding of the national conference on Advances in Evapotranspiration, Chicago, IL, 16-17 December; American society of Agricultural Engineering, Publication no. 14-18. St. Joseph. MI., pp. 79-86.

Skaggs, T.H., Trout, T.J. and Rothfuss, Y. (2010). Drip irrigation water distribution patterns: effects of emitter rate, pulsing, and antecedent water. *Soil Sci. Soc Am. J.*, **74**: 1886–1896.

Su, Q., Singh, V.P. and Karthikeyan, R. 2022. Improved reference evapotranspiration methods for regional irrigation water demand estimation. *Agric. Water Manag.*, **274**: 107979.

Yang, W., Zhao, J., Zhao, Y. and Wang, Q. 2022. Factors affecting evapotranspiration analyzed based on a structural equation model. *J. Tsinghua Univ. (Science Technology)*, **62**: 581–588.

Zhang, M., Zeng, Y. and Qi, Y. 2018 Analyzing spatio-temporal variations of evapotranspiration in Dongting Lake Basin during 2000–2014 based on MOD16. *Transactions of the Chinese Society of Agricultural Engineering*, **34**(20): 160–168.