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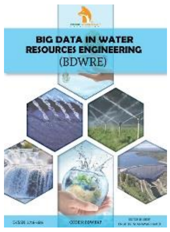


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*RESEARCH ARTICLE*

# ESTIMATION OF EVAPOTRANSPIRATION USING METRIC MODEL WITH HIGH RESOLUTION SATELLITE IMAGERY IN KOREA

**Muhammad Mazhar Iqbal[a*], Muhammad Abdullah[b], Tehmena Rashid[c]**

[a] *Water Management Training Institute, Agriculture Department (Water Management Wing), Government of Punjab, Lahore 54000, Pakistan.*
[b] *University of Agriculture Faisalabad, Punjab, Pakistan, 38000.*
[c] *Agriculture Mechanization Research Institute (AMRI) Multan, Agriculture Department, Government of Punjab, Multan 60000.*
***Corresponding author email: drofwm@gmail.com***



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**ABSTRACT**

One of the most significant elements of the hydrological cycle is evapotranspiration (ET) as it is a functional part of meteorological conditions. The Visualization of Evapotranspiration at high definition with integrated calibrated (METRIC) model is an example of an image-processing tool that involves the utilization of satellite data in order to compute evapotranspiration as a residual to surface energy equilibrium. Therefore, we used the METRIC model to enumerate ET using 30 m high spatial resolution from Landsat 9 scenes for a study period of 2024 over Cheongmicheon flux tower (CFK) site in Korean peninsula. The METRIC estimations were compared with flux tower measurements obtained from a warm continental climate CFK site for the accuracy assessment. The estimated and measured actual evapotranspiration (AET) at daily scale had good agreement with strong coefficient of determination 0.97. In addition, the trend of ET in comparison to the air temperature was also comparable. This evaluation seeks to enhance the understanding of the strength of the model for mapping the energy balance at the regional scale. Additionally, it is a step towards developing a methodology that can be applied to a wide variety of ecosystems that are heterogeneous.

**KEYWORDS**

Evapotranspiration, METRIC, Landsat 9, Cheongmicheon, CFK

## 1. INTRODUCTION

Global water resources have been severely pretentious by the global warming and climate change, altering the hydrological cycle, catering the needs for efficient monitoring of evapotranspiration. Utilization of satellite images for efficient monitoring of evapotranspiration gives valuable analysis for the estimation of water losses from the soil and vegetation surfaces, aiding the accurate estimation of crop water requirement. Crop water requirement estimation, satellite remote sensing, and hydrodynamic modeling of water quality are pivotal for investigating the effects of anthropogenetic events and climate change, such as water salinity, nutrient load and water quality imbalances (Aslam et al., 2021; Cheema et al., 2023; Hussain et al., 2020; Iqbal et al., 2022a; Iqbal et al., 2022b; Iqbal et al., 2019; Iqbal et al., 2018; Mazhar Iqba et al., 2020; Waqas et al., 2021; Waqas et al., 2018).

Through, the application of energy balance models, energy balance fluxes extents, and radiation data, scientists can well comprehend the changing aspects of evapotranspiration, under the varying global warming and climate change, these fluxes and short wave and long wave radiation estimation enable the sustainable monitoring of water utilization. Short-wave and long-wave radiations are the primary drivers of water movement, weather, and the environment of the earth system(Chen et al., 2025; Sun et al., 2024; Yang and Roderick, 2019; Zhang et al., 2024). Energy is constantly being transferred between the atmosphere and the earth surface through these radiations (Li et al., 2021; Li et al., 2023b; Xue et al., 2022). For the purpose of improving the numerical modelling of the atmosphere and refining the role of climate regimes on a scale ranging from regional to global, it is essential to enumerate the energy budget above vegetation (Alizadeh, 2022; Demuzere et al., 2022; Pongratz et al., 2021; Zhu et al., 2023).

This is also important for analysing the differences in hydrological cycles. It is possible for estimates of ET to be influenced by a variety of hydro-meteorological factors of varying degrees (Chandole et al., 2019; Shuttleworth, 2012). The characteristics of the land surface have changed over time and space, and there has been a significant trend in solar radiation. These factors include both of these things. Specifically, the estimation of accurate ET is made more difficult by the complex ecosystem and the large variations in the physical process of the interaction between the soil, plants, and atmosphere (Chandole et al., 2019; Feng et al., 2023; Li et al., 2023a). This is because of the fact that the ecosystem is complex. During the course of the last few decades, significant efforts have been made to update the remote sensing-based methodologies that provide indirect estimation of actual evapotranspiration (AET) by quantifying distributed surface energy balance parameters at various spatial and temporal scales (Cai et al., 2021; Derardja et al., 2024; Hadadi et al., 2022).

These methodologies have been subjected to these efforts in order to ensure that they are kept up to date. The actual evapotranspiration (AET) is determined by measuring the distributed surface energy balance parameters at various temporal and spatial scales (Awada et al., 2022; García-Santos et al., 2022; Hadadi et al., 2022). There has been a significant amount of effort put into regularly updating remote sensing-based methods during the last several years in order to gain more knowledge about the AET. The Surface Energy Balance Algorithm for Land is just one of many residual energy balance algorithms and its variant METRIC, are acknowledged as the most practical model for calculating additional

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energy transfer (AET) (Allen et al., 2007b; Chen et al., 2021; Liou and Kar, 2014; Song et al., 2022; Xu et al., 2022). METRIC provides significant advantages over conventional methods for estimating AET based on crop coefficient values.

This is due to the fact that it does not require the specific crop type or the growth stages of the crop to be known. METRIC does not require them, which is one of the advantages that they offer. The difficulty in optimizing the extreme hydrological context (dry/wet scaling) across the scene is one of the most significant limitations of the METRIC model when it comes to its application. This is one of the most significant limitations. Errors are frequently propagated in the final output's at large scales as a consequence of this complex difficulty (Allen et al., 2011a; Baeumler et al., 2019; Reyes-González et al., 2017; Rezaei et al., 2021; Senay et al., 2011; Trezza et al., 2013). To estimate the daily ET, we used the METRIC model in the current investigation. This was accomplished by combining the Landsat 9 land surface datasets that are currently available for operational purposes with the energy flux data sets. As a result, the daily ET was estimated. In order to simulate the complex landscape of the Korean peninsula, simulations were carried out for the year 2024-25.

## 2. Study Area and Datasets

This study was conducted at cropland (rice paddy) site CFK (Cheongmicheon; South Korea) belonging to the KoFlux network operated by the hydrological survey center in the Korean Peninsula (Figure 1).

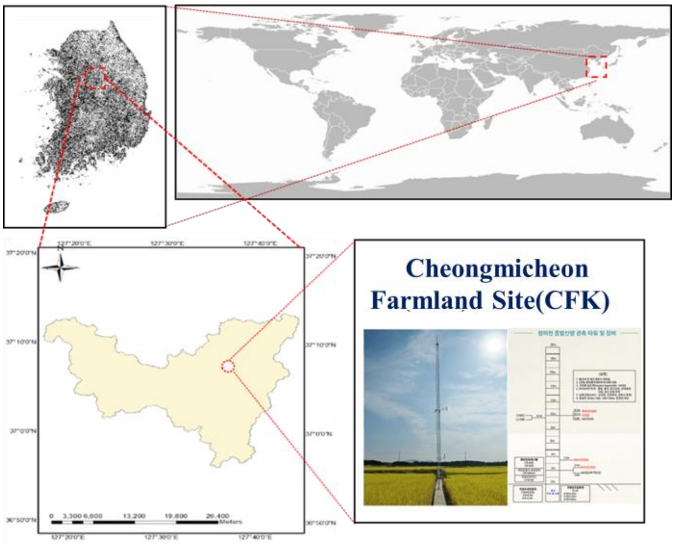


**Figure 1:** Geographical locations of the study site

### 2.1 Remotely sensed data

High resolution Landsat 9 thermal and visible cloud free, shortwave scenes were acquired from

the Global Visualization Viewer USGS (http://glovis.usgs.gov/) site. The number of cloudless images retrieved were 10 on different day of year (DOY) represented by DOY 75, DOY 83, DOY 91, DOY 131, DOY 163, DOY 195, DOY 227, DOY 243, DOY 323, DOY 339.

### 2.2 Flux tower data

The surface heat fluxes and other climatological half hourly data were acquired via hydrological survey center Korea for CFK site under the fair-use policy. A quality control technique was applied to check the reliability of the datasets (CFK) and diminish errors with reverence to coordinate rotation, Webb–Pearman–Leuning (WPL) density correction, and spike detection (Foken et al., 2012; Massman et al., 2003; Mauder et al., 2008; Novick et al., 2013; Rebmann et al., 2012; Runkle et al., 2012).

### 2.3 Model Descriptions

The model known as METRIC is one that is widely used and published (Allen et al., 2007a). Therefore, to access the surface energy fluxes by making use of remote sensing data, we provided a concise summary of the fundamentals of the model as well as the computational procedures that are involved in the model. Instantaneous computations are performed by the model for the vast majority of the energy balance components it contains. This is because satellite data typically provide information about the land surface during the time that the satellite is passing over. This is the reason why this is the case. For the purpose of METRIC operation and the overall preprocessing of Landsat data, we have provided a summary of the most important process (Figure 2). This is Figure 2. This is a flow chart that illustrates the different processes that are involved in (a) the processing of Landsat and flux tower datasets in order to prepare inputs for (b) the application of the METRIC model.

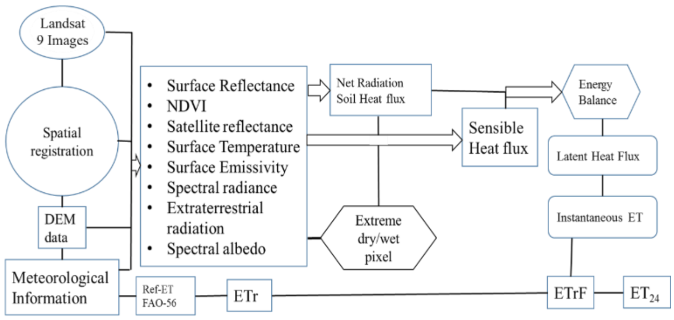


**Figure 2:** Flow chart showing key processing of METRIC model

METRIC (Allen et al., 2007a), a variant model of the SEBAL model (Bastiaanssen et al., 2005) , is a model developed by University of Idaho that uses Landsat satellite imageries in order to estimate ET. To obtain an accurate estimate of ET, a significant amount of information must be considered. The factors include heat transfer into the soil, heat transfer into the air above the surface, and total net radiation from both shortwave and longwave radiation that reaches the soil or vegetation's surface. When METRIC calculates evapotranspiration, the remaining amount is utilized to calculate the surface energy balance.

In order for the METRIC model to function, remote sensing data sets as well as meteorological data sets observed from the eddy covariance flux tower were settled as input data sets. As satellite data usually provide land surface information during the satellite's overpass time, the model primarily computes the energy balance component at instantaneous time scale. Instantaneous ET ($ET_{ins}$) was converted into daily ET ($ET_{24}$) by using the fraction of reference ET (ETrF) and cumulative 24-hour daily reference ET ($ET_{r\_24}$).

$$ET_{24} = ET_r F \times ET_{r\_24}$$

## 3. Results and Discussion

Figure 3 illustrates how well the model performs when it comes to deriving the instantaneous latent heat flux (LE) as a residual from the energy budget. This is in comparison to the flux tower observations, which are the measured LE. With coefficients of determination of 0.97, RMSE 16.29, MAE 15.30 and Bias 1.5, respectively, the modelled LE was found to have a strong correlation with the flux tower LE. It is possible that the derived LE could be biased due to the uncertainties that are associated with endpoint calibration in METRIC (Allen et al., 2011b; Allen et al., 2007a; Allen et al., 2007b; Dhungel and Barber, 2018; Foolad et al., 2018; Irmak et al., 2012; Kjaersgaard et al., 2011).

Furthermore, the modelled LE was significantly closer to the observed LE for DOY that had exactly zero percent cloudiness (DOY=155 and 236), which indicates that METRIC can be an appropriate model for indirect ET estimation. It was discovered that DOY 163 and DOY 195, both of which have high air temperatures, had the highest instantaneous ET, and this upward trend was almost identical for all DOYs (Figure 4). An illustration of the spatial patterns of net radiation (Rn), sensible heat flux (H), soil heat flux (G), and ET for the day of year 83 is presented in Figure 5. The spatial distribution of fluxes for the year 83 revealed that mountainous deep wellies have a lower net radiation than flat area land, which depicted a uniform distribution of fluxes.

Both H and G displayed a spatial distribution that was almost identical across the entirety of the site, with only a slight degree of inconsistency. On the other hand, H exhibited a greater topographic response than G. This could be because of the influence of local microclimates, which have a greater impact on H than they do on G (Allen et al., 2011b; Bales et al., 2006; Knowles et al., 2015; Marmy et al., 2016). As opposed to this, G, which is directly influenced by net radiation and the temperature of the land surface, exhibited a variable range of heterogeneity that was in agreement with the Rn distribution.

In general, the entire study site demonstrates heterogeneity in fluxes for all DOY 83 species. One possible explanation for this flux heterogeneity in a mountainous landscape is that the following factors are at play: (1) These include a variety of thermal properties of the substrate, such as thermal conductivity and admittance, among others. (2) Variations in the aerodynamic properties, such as the roughness length; (3) Variations in the quantities of moisture that are already available; and (4) Variations in the vegetative controls (Bales et al., 2006; Fugger et al., 2024; Knowles et al., 2015; Marmy et al., 2016).

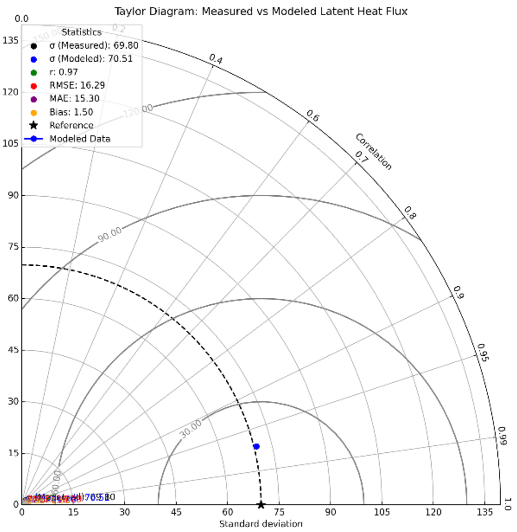


**Figure 3:** Statistical analysis of Measured and Modeled LE

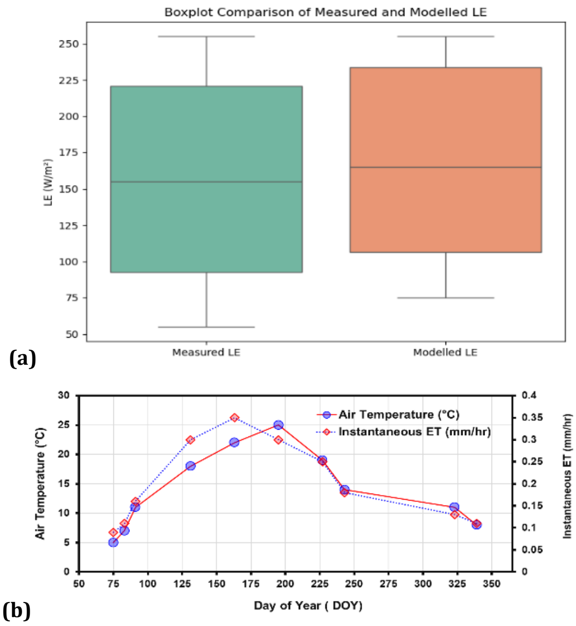


**Figure 4:** (a) Boxplot comparison of Measured and Modeled LE; **(b)** Pattern of Air T mperature and $ET_{ins}$ with Day of Year.

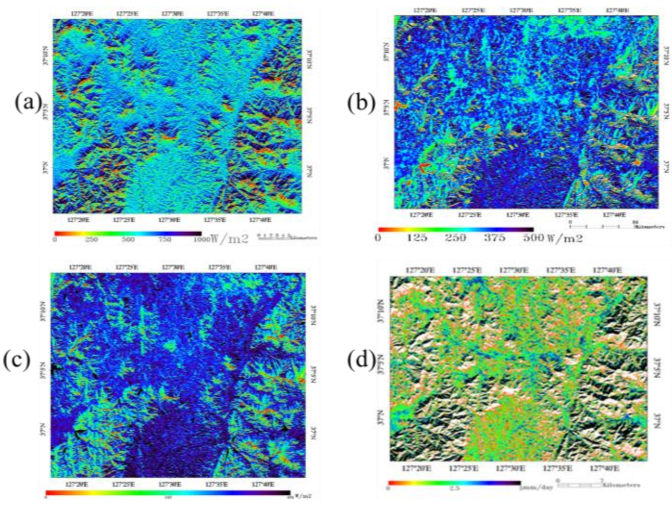


**Figure 5:** Spatial distribution map of (a) Rn (b) H (c) G and (d) ET for DOYs 83

## 4. Conclusion

A satellite-based model known as METRIC is utilized to compute extraterrestrial temperature (ET) as a residual of energy balance at the surface of the Earth. The energy balance model developed by METRIC was implemented on the cropland site in Korea known as CFK. For the purpose of AET estimation, Landsat 9 images were retrieved for each of the ten different DOYs. The meteorological data from CFK were utilized as input components, and the flux data were utilized for the approval of the AET. In-situ flux data were used in the statistical analysis, and the results showed that METRIC has the potential to be an appropriate model for indirect AET estimation on a regional scale. Due to the fact that this model was developed for dry and semi-arid climates, it appears that some adjustments are still required in order to extend the applicability of the model. This is because there are some limitations in the assumptions that underlie the hot and cold pixel (i.e., a hot pixel has little to no ET, and a cold pixel has little to no H) when applied in a humid climate. When taken as a whole, these findings would be extremely helpful in the construction of effective water management and irrigation systems. The optimization of the dry/wet scaling, which isolates the performance of the model, should be improved for the purpose of further research. This will allow for a more precise application of the model in environments that are complex and full of various types of topography.

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