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Combined High-Resolution Remote Sensing for Measuring Evapotranspiration in Brazos County, TX

Xiangmin Sun

Department of Ecosystem science and management, TAMU

sunxm03@tamu.edu

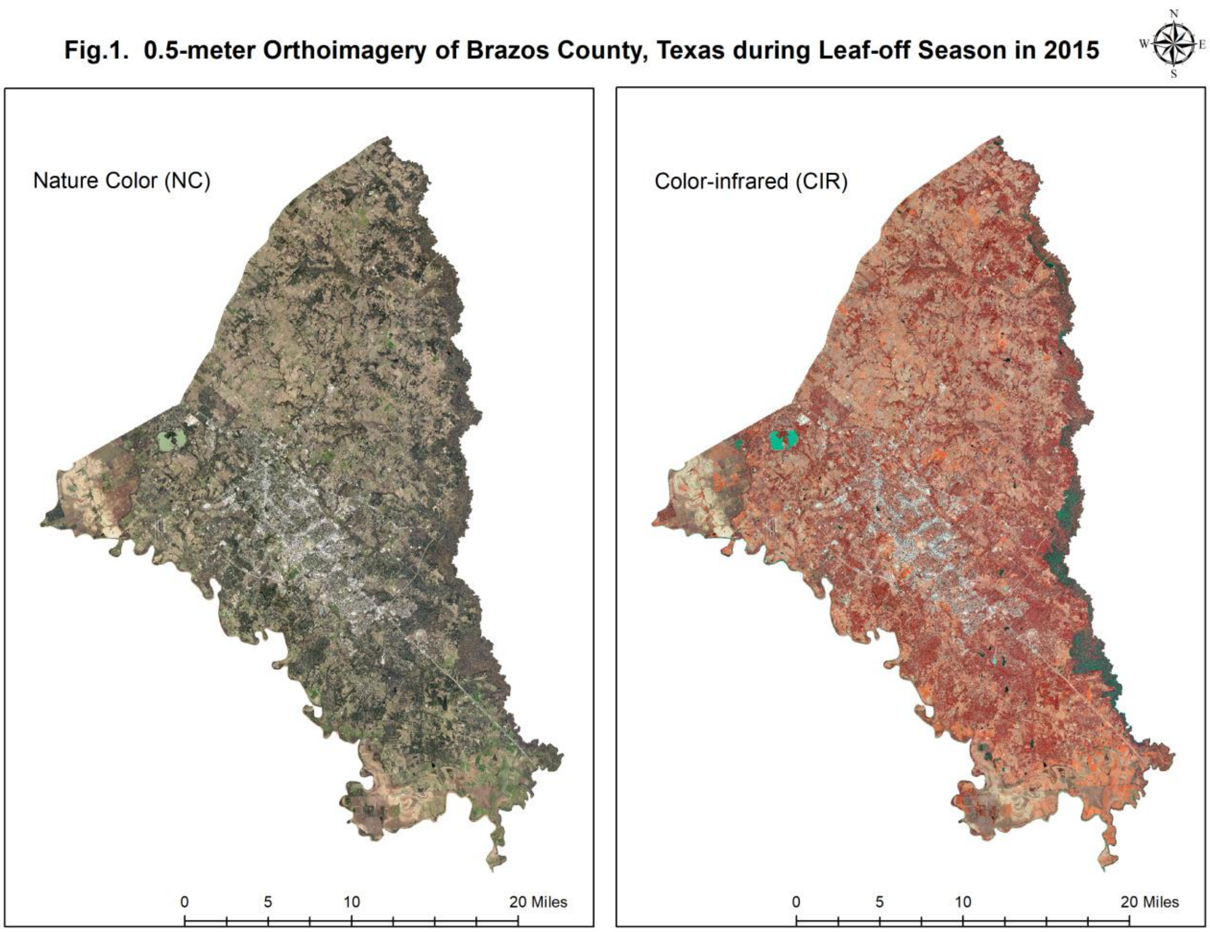
Abstract:

Land Surface Energy Balance (LSEB) provides an important method for physical-based remote sensing modeling on regional dynamics of evapotranspiration (ET). Mapping Evapotranspiration at high Resolution with Internalized Calibration (METRIC) model was applied to process individual Lansat 7 imagery by Earth Engine Evapotranspiration Flux (EEFlux) via the Google Earth Engine system. We selected EEFlux results with cloud coverage less than 15% for Brazos County in 2015. ET is expressed in terms of EToF which represents ET as a fraction of reference ETo. In EEFlux, ETo is calculated as grass reference ET as defined with the ASCE Standardized Penman-Monteith equation. EToF is similar to the traditionally used 'crop coefficient'. Our results showed that ETo varied seasonally from 2.02 ± 0.05 mm/day in December to 9.60 ± 0.29 mm/day in August, with varied spatial pattern through the year. Actual ET showed typical seasonal dynamics and spatial characteristics, with regional averages from 0.94 ± 0.63 mm/day in December to 8.65 mm/day in July, which well agreed with results with other methods in this region.

Introduction:

Terrestrial evapotranspiration (ET) is the amount of water exchanged between the atmosphere and the land surface, accounting for about 75% of continental precipitation globally (Brooks 2015). Because ET is a major hydrologic flux, estimation of ET quantity and partitioning is constantly an important topic in water resources planning, especially for changing landscapes such as those in Brazos County. Brazos County has witnessed dramatic land cover changes—especially urbanization and woody plant encroachment (Fig. 1). Thus the increasingly fragmented and heterogeneous landscape poses significant challenges for accurate ET estimation.

Fig.1. 0.5-meter Orthoimagery of Brazos County, Texas during Leaf-off Season in 2015



Source from Texas Orthoimagery Program (TOP) 2015 50cm NC\CIR Orthoimagery (https://tnris.org)

Methodology:

EEFlux uses NLDAS and GridMET gridded weather data to calibrate the surface energy balance for the image (Allen et al. 2015). EEFlux utilizes the thermal band of Landsat to drive the surface energy balance and short wave bands to estimate vegetation amounts, albedo, and surface roughness. Level 1 of EEFlux employs automated calibration of the image.

Mapping EvapoTranspiration at high Resolution with Internalized Calibration (METRIC) is one of the most popular satellite-based energy balance models to estimate land surface evapotranspiration. This model (Allen, Tasumi, and Trezza 2007) was developed based on the well-known SEBAL model (Bastiaanssen W.G.M. et al. 1998). It has been broadly applied around the world to estimate evapotranspiration (ET) at field scales and over large areas in different vegetation and crops types, including wheat, corn, soybean and alfalfa (3 - 20% of error); additionally in recent years it has also been applied over spare woody canopies such us vineyards and olive orchards, in both plain and mountainous terrain (Olmedo et al. 2016).

ET is estimated as a residual of the surface energy equation:

$$LE = Rn - G - H$$

where LE is latent energy consumed by ET ($W \cdot m^{-2}$); Rn is net radiation ($W \cdot m^{-2}$); G is sensible heat flux conducted into the ground ($W \cdot m^{-2}$); and H is sensible heat flux convected to the air ($W \cdot m^{-2}$).

Estimation on Rn, G and H for each pixel into a Landsat satellite scene is supported by data from weather stations. Then instantons LE fluxes during satellite scanning moment (ET_{inst}) were computed as:

$$ET_{inst}=3600 \cdot LE/\lambda\rho_w$$

where ET_{inst} is the instantaneous ET at the satellite flyby ($mm \cdot h^{-1}$); 3600 is the convert factor from seconds to hours; ρ_w is density of water = 1000 $kg \cdot m^{-3}$; and λ is the water latent heat of vaporization ($J \cdot kg^{-1}$).

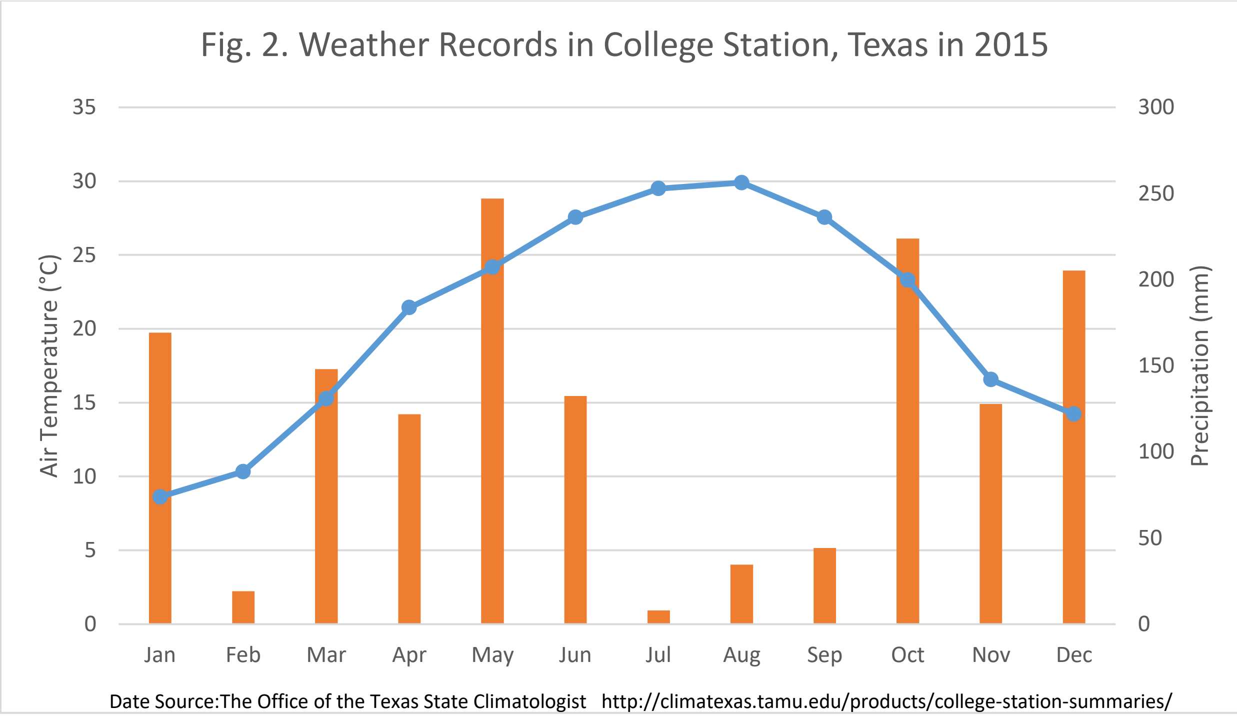
Finally, the daily ET is computed pixel by pixel (30 x 30 m) computed based on reference ET (ET_r) as:

$$ET_{24} = (ET_{inst} / ET_r)\ ET_{r\_24}$$

Results and conclusion:

1. Weather

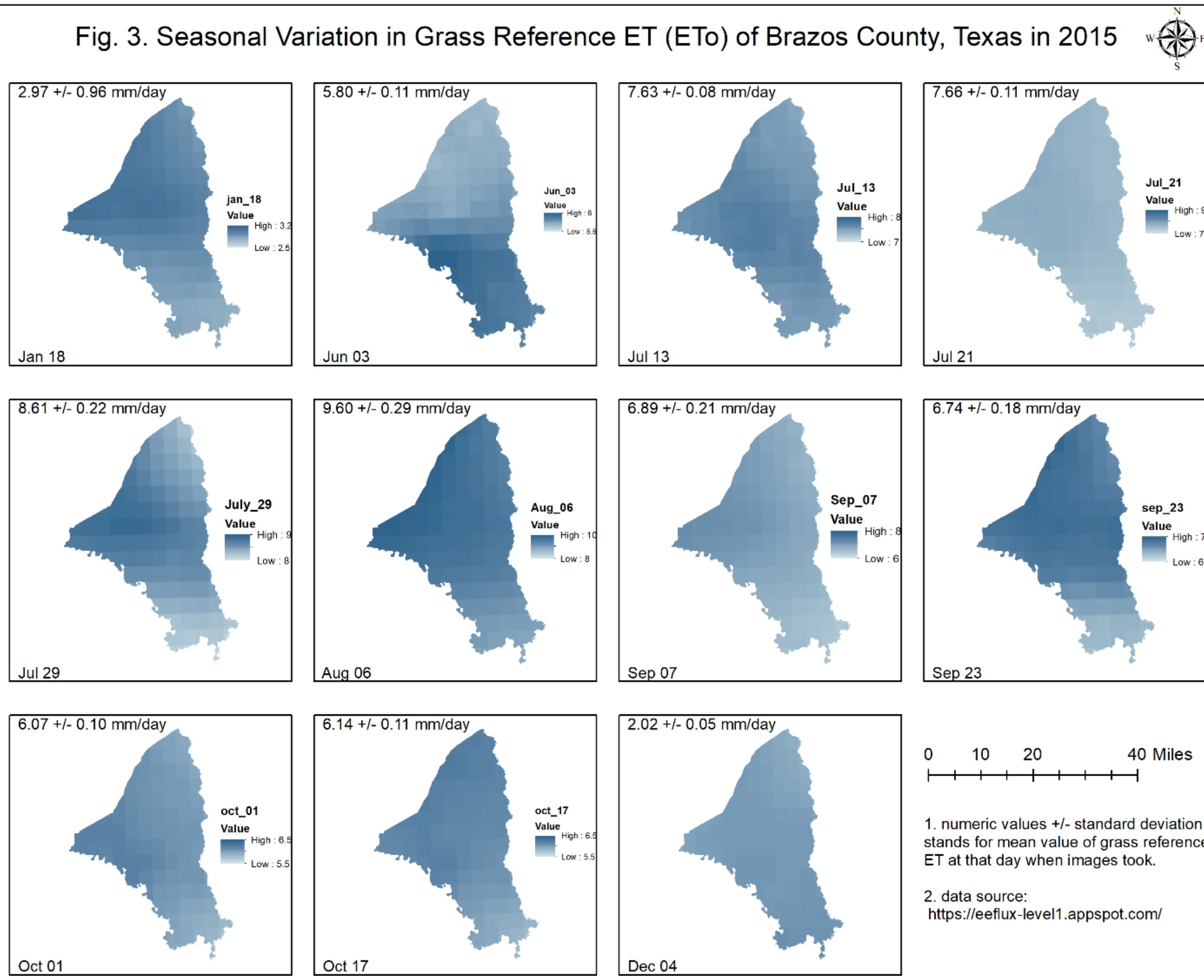
Annual air temperature is 20.7 ± 7.17 ºC and annual precipitation was 1481.07 mm in 2015. Monthly dynamics of air temperature and precipitation are shown in Fig.2. A very dry summer from June to September with summary of 218.95 mm in precipitation, only accounted for 14.8% of annual precipitation depth. Especially the July witnessed only 7.87 mm in rainfall as nearly the hottest month in 2015.



2. Reference ET

The 'tall' (alfalfa) reference ETr calculated from the Gridmet data for the day of the image using the ASCE Standardized Penman-Monteith equation. The alfalfa ETr is generally 1.2 to 1.4 times grass reference ETo depending on wind speed and humidity conditions. In this study, we selected grass reference ETo due to the land use characteristics in Brazos County. The spatial pattern and seasonal dynamics of ETo are shown in Fig. 3. We can see the typical seasonal pattern of ETo, with highest value of 9.60 ± 0.29 mm/day in Aug 06, which corresponded to hottest temperature in August. The spatial distribution patterns also varied without consistent configurations.

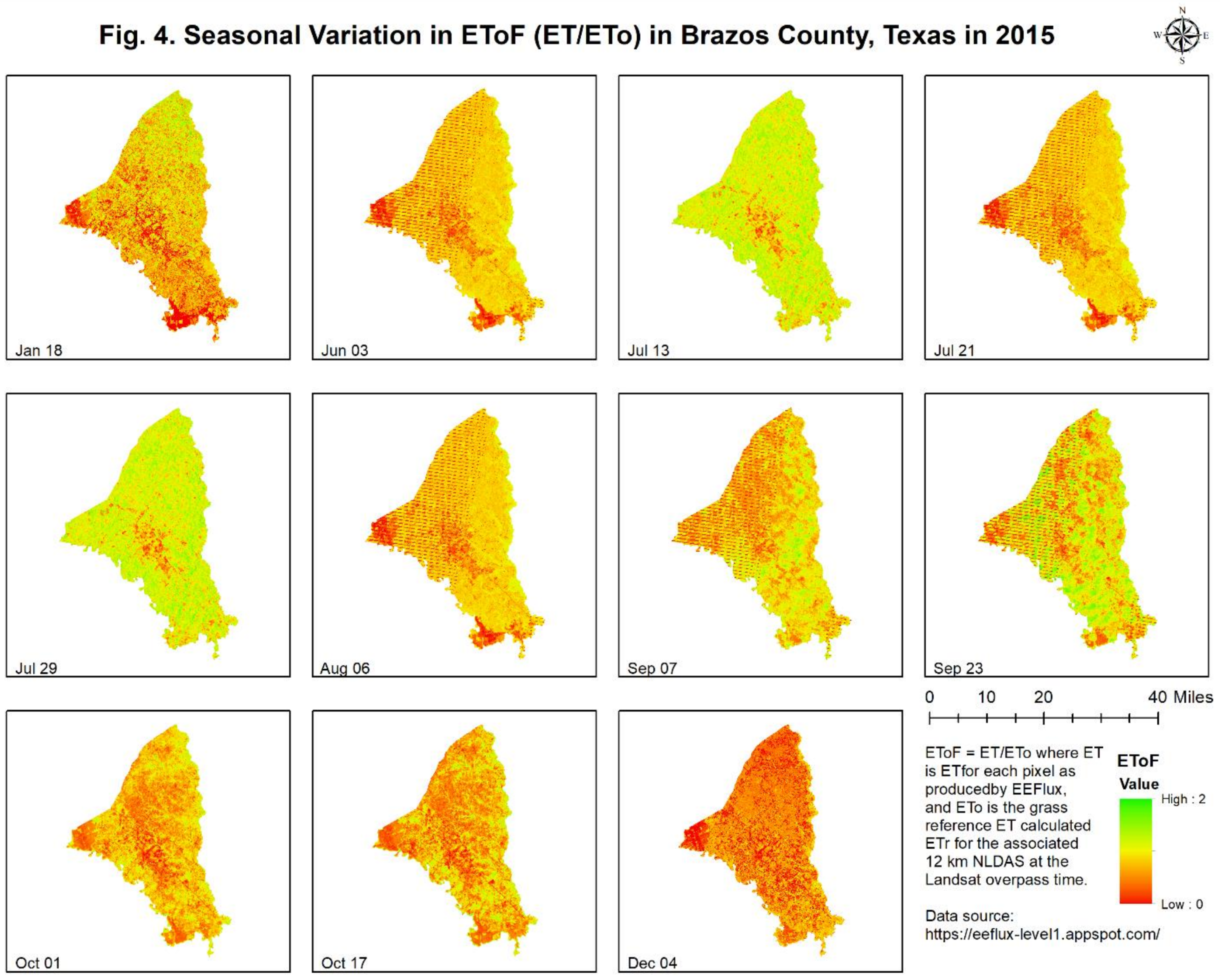
Fig. 3. Seasonal Variation in Grass Reference ET (ETo) of Brazos County, Texas in 2015



3. EToF—ET as a fraction of reference ETo, or EToF = ET/ETo.

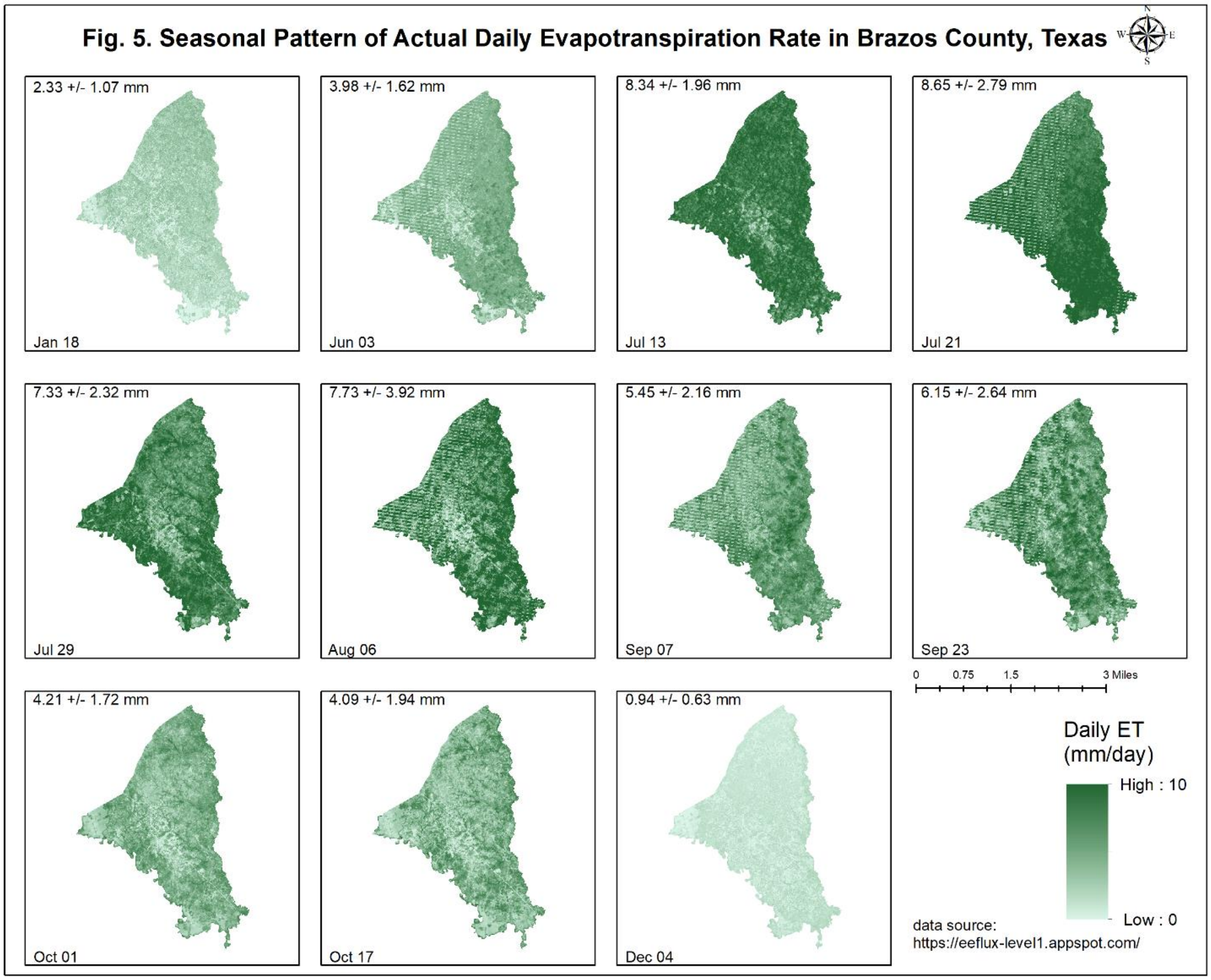
For each pixel, ET was produced by EEFlux and ETr is the calculated by the associated 12 km NLDAS at the Landsat overpass time. ETr is the tall reference, as shown in Fig. 4. ETrF can be converted to EToF by multiplying by the ratio of ETr to ETo where ETo is grass reference ET. Due to widely woody plant encroachment, actual ET (ET) could bigger than ETo in some situations. The ratio in urban areas always lower because of ground pavement and constructions with constrained evaporation and transpiration. The EToF changed dramatically according to the weather conditions of that scanning time, implication for the high variation in temporal scale for ET estimation. Even July was the driest month, but EToF was higher at the two ends of this month, probably due to coincidence with rain events or irrigation. But generally EToF was generally lower than 1, indicating relative deficit of soil moisture in growing season.

Fig. 4. Seasonal Variation in EToF (ET/ETo) in Brazos County, Texas in 2015



4. Actual ET—ET for the day of the Landsat overpass.

   Actual ET is calculated as ETo$F \times$ ETo_day where ETo_day is 24-hour reference ET computed from the GRIDMET, as shown in Fig. 5. Actual ET showed typical seasonal pattern with annual peaks similar with air temperature, but not strongly restricted by precipitation pattern. Thus we advocate that ET in Brazos was more controlled by transpiration by woody plants, for which surface soil moisture was not the controlling factor. The urban area in College Station and Bryan showed relatively lower values.



Suggestions:

Results from EEFlux showed highly variations in reference ET, EToF, and actual ET in 2015, both spatially and temporally. With reference ET and actual ET was more controlled by weather conditions and woody plants, future ET predicting should put emphasis on different future scenarios of urbanization and woody plant encroachment. Interpolation in ET for times series and higher temporal observation of ET based on remote sensing and field experiments are indispensable for accurate description of this main hydrologic flux.

Citations:

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