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Can OpenET Transform Irrigation Management in the Southwestern U.S.?

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Introduction

Arizona's agricultural systems face increasing challenges due to drought, groundwater depletion, and growing competition for water from industrial and urban sectors. Water districts across the state must navigate strict compliance with reduced water allocations, adding to the pressure on growers to maintain crop productivity under increasingly limited water supplies. These challenges are further intensified by the impacts of climate change (Elsadek, 2023), which heightens the risks of water scarcity in already arid regions.

For Arizona's growers, especially those producing high water-use crops like alfalfa, adopting effective irrigation management techniques is vital for sustaining yields while optimizing water use. Accurate water-use data is key to this process, helping farmers make informed decisions about when and how much to irrigate.

This publication provides growers with a guide to improving water efficiency in alfalfa production, using data from a field study conducted in Buckeye, Arizona. The study assessed the performance of various OpenET models in simulating alfalfa evapotranspiration (ETc). By evaluating which models provide the most accurate and reliable estimates of crop water needs, this guide aims to help growers in Arizona and other arid and semi-arid states implement smarter irrigation practices, conserve water, and adapt to the ongoing challenges posed by climate change.

Alfalfa, a perennial forage crop

Alfalfa (*Medicago sativa L.*) is an important perennial forage crop for livestock production systems due to its high nutritional value and desirable agricultural traits (McDonald et al., 2021). In the US, alfalfa is ranked as the fourth largest crop in terms of area harvested and production (USDA-NASS, 2022), with an estimated economic value of $11.7 billion (USD). Most of the alfalfa production is focused in the irrigated arid and semi-arid regions of the country (Eltarabily et al., 2024). In such environments, irrigation water is the main limiting factor for crop growth (Gu et al., 2018), where evapotranspiration often exceeds the received precipitation (Djaman et al., 2020). Although alfalfa is more drought-tolerant than most forage legumes (Yu et al., 2018), its growth, dry biomass, and forage quality are greatly influenced by water deficiency (Li et al., 2018). In contrast, boosting forage yields through intensive irrigation and fertilizers may be compromised by a loss in nutritive values (Hakl et al., 2021). Moreover, excessive irrigation may damage alfalfa stands due to salinization in arid and semi-arid regions (Li et al., 2018).

OpenET Dataset Acquisition

The satellite-based OpenET database, available at https://explore.etdata.org/#5/39.665/-110.396, allows you to easily access data on crop water use (crop evapotranspiration - ETc), reference evapotranspiration (ETo), precipitation, and plant health (measured by NDVI, which indicates how green and healthy plants are). You can download daily, monthly, or yearly data in two ways: by using the "Explore Data" tool to draw areas of interest on a map and then running the "Run Time Series" application to get the data, or by using the "Explore API," which is more suited for researchers and advanced users who want to analyze the data.

The “Explore Data” process involves the following steps: (a) Open the link https://etdata.org/ to create a free user account or log in to an existing one, (b) After signing in, navigate to “Explore Data," select the desired time period and measurement units, then click on the “Draw custom area” icon, (c) Use the polygon drawing tools to define the area for data retrieval, (d) Choose the models (Single model, Ensemble, or All) and parameters (ETc, ETo, P, NDVI), and download the data in your preferred format (image, CSV, or PDF) (Figure 1).

To access the OpenET API, users must create an account through https://account.etdata.or. After logging in, users can complete their profile and generate an API key by clicking the “API keys” icon. This API key will be linked to the account and used to authorize data requests. These requests can be made through the OpenET Graphical User Interface (GUI) at https://openet-api.org/#/, which offers pre-filled endpoints and allows users to modify parameters of interest or programmatically, for example, using Python (Figure 2).

You can select specific areas, such as single points, polygons, multi-polygons, or entire field (Figure 3), using the parameters and variables listed in the “API reference” section at https://openet.gitbook.io/docs/reference/api-reference. The data can be downloaded in either “JSON” or “CSV” format.

The "Explore Data" and "Explore API" methods offer the same parameters. However, the "Explore Data" interface allows manually downloading only 5 to 6 years of archived data. In contrast, the API can automatically access and retrieve data spanning 30 years or more, benefiting from greater precision and accuracy due to its use of scripts and geospatial coordinates. For growers, the "Explore Data" method may be more user-friendly.

Evaluation of OpenET models

A study was conducted to evaluate six satellite-based ET models (ALEXI/DisALEXI, eeMETRIC, geeSEBAL, PT-JPL, SIMS, and SSEBop) and their Ensemble, derived from the OpenET platform, in estimating the ETc of alfalfa. Four statistical metrics, normalized root-mean-squared error (NRMSE), coefficient of determination (R^2), mean bias simulation error (MBE), and prediction/simulation error (Pe), were used to evaluate the seven alternative estimates in comparison with measured ET (ETmea) at a field scale with four replicates during the 2023 alfalfa growing season in Buckeye, Arizona (Figure 3).

Our results demonstrated that specific models, such as ALEXI/DisALEXI, geeSEBAL, and PT-JPL, generally underestimated the actual ETc of alfalfa. However, while these models provided useful insights, their ability to simulate actual crop water use ranged from fair to poor. On the other hand, eeMETRIC, SIMS, and SSEBop models tended to overestimate the ETmea, with fair to poor prediction errors. The Ensemble approach, which combined all OpenET models, underestimated the alfalfa ET by about 3.37 mm (0.13”) on average, indicating a fair agreement with the ETmea during the growing period in 2023 (Table 1 and Figure 4). Our findings highlight the importance of improving the OpenET estimates to provide farmers and decision-makers with the best satellite-based approach for efficient irrigation management and water use in arid regions.

Conclusions

Our findings showed that eeMETRIC, SIMS, and SSEBop overestimated ETmea with fair to poor with fair to poor simulation of ETc. In contrast, ALEXI/DisALEXI, geeSEBAL, and PT-JPL generally underestimated actual ETc with fair to poor simulation of ETc. Similarly, The Ensemble approach, which combined all OpenET models, underestimated the actual ETc, with a fair agreement with the ETmea of alfalfa during the growing period in 2023.

One challenge of using OpenET for in-season irrigation scheduling is the delay in ETc data, which can take 8-16 days depending on satellite passes and weather conditions. OpenET handles this by using weather data to estimate ETo calculated with the Penman-Monteith equation. The actual ETc on satellite overpass dates is divided by the ETo to determine the fraction of ETo, which is then linearly interpolated on a daily timestep for the days between overpasses. This daily fraction of ETo is multiplied by the daily ETo to estimate the actual ETc for each pixel. Although this method reduces latency, the interpolated data may be less precise than direct satellite measurements, limiting its effectiveness for real-time management. Therefore, addressing the uncertainties and limitations of individual OpenET models will provide more precise estimates of crop water use. This will lead to better decision-making and enhance water productivity.

References

Brisson, N., Ruget, F., Gate, P., Lorgeou, J., Nicoullaud, B., Tayot, X., Plenet, D., Jeuffroy, M.-H., Bouthier, A., Ripoche, D., Mary, B., Justes, E., 2002. STICS: A generic model for simulating crops and their water and nitrogen balances. II. Model validation for wheat and maize. Agronomie 22, 69–92. https://doi.org/10.1051/agro:2001005

Djaman, K., Smeal, D., Koudahe, K., Allen, S., 2020. Hay Yield and Water Use Efficiency of Alfalfa under Different Irrigation and Fungicide Regimes in a Semiarid Climate. Water 12, 1721. https://doi.org/10.3390/w12061721

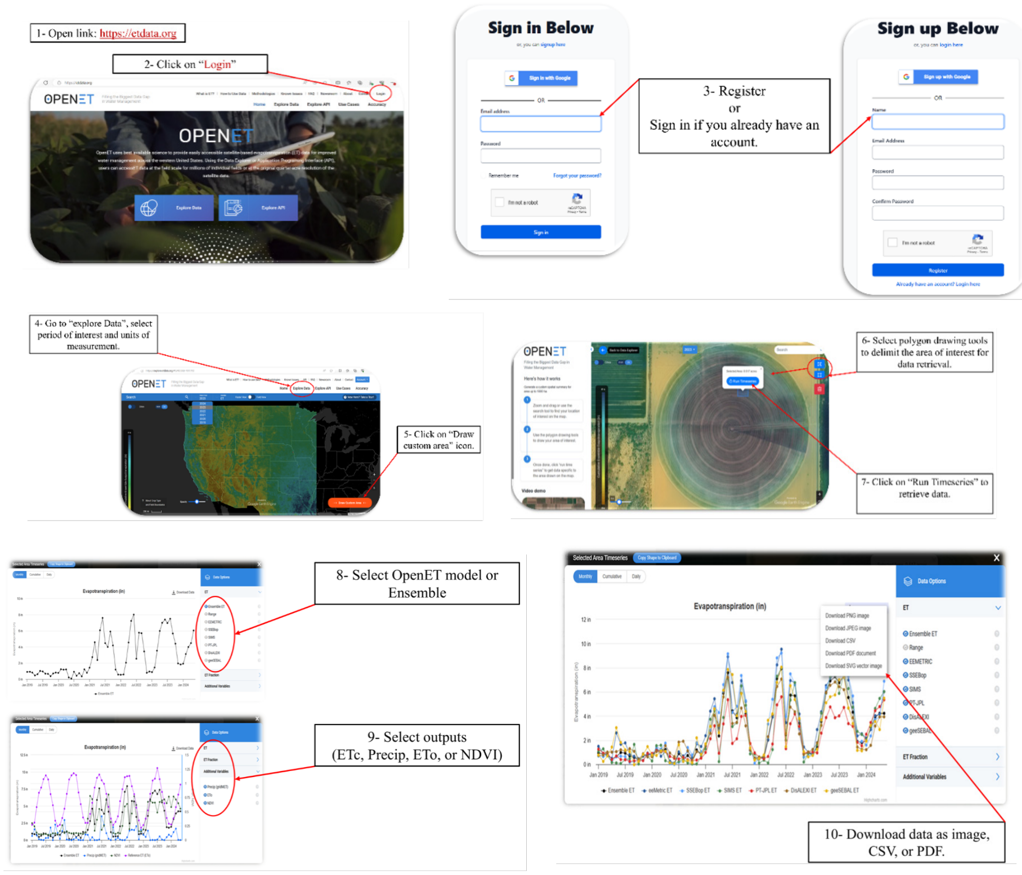

Figure 1. Step-by-step OpenET dataset acquisition using the "Explore Data" method.

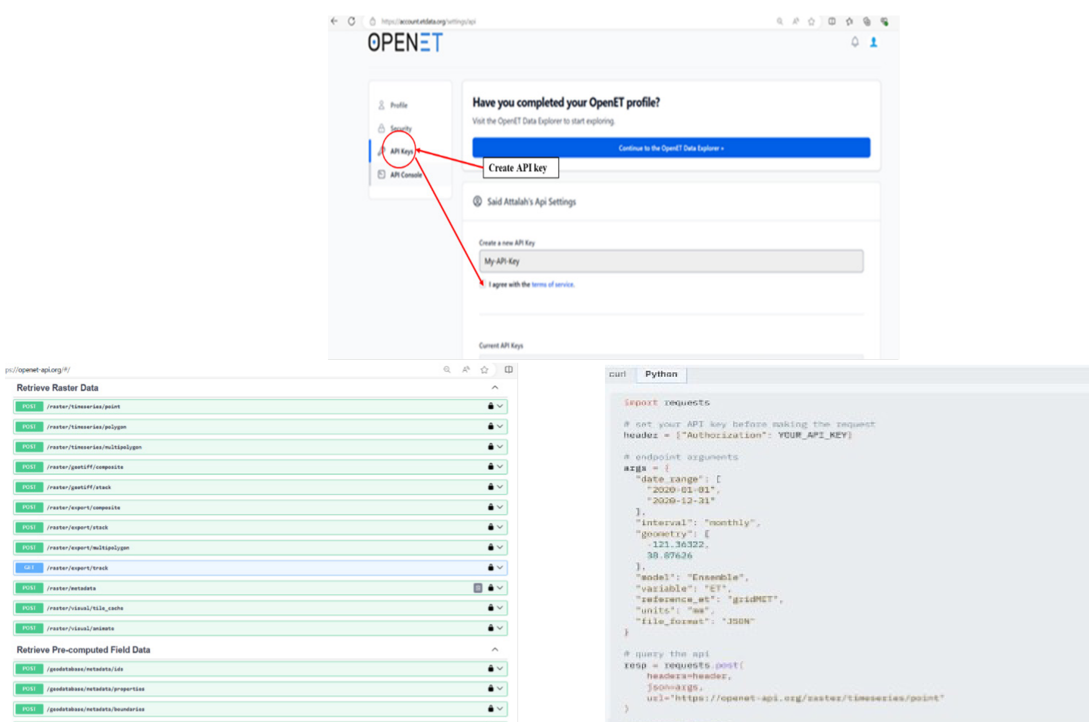

Figure 2. Accessing OpenET data via the "Explore API": (a) the procedure for creating a user account and generating an API key; (b) available options for retrieving raster data and pre-computed field data through different endpoints; (c) a sample Python script demonstrating monthly ET data retrieval using the OpenET Ensemble model.

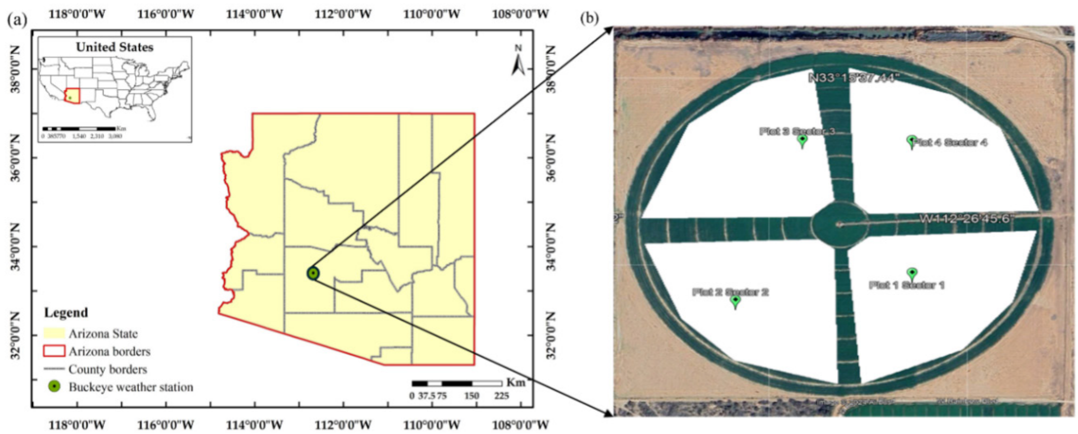

Figure 3. (a) Geographic location and (b) experimental layout of the alfalfa field under the center pivot irrigation system with four quarter-section plots (1-4) at Buckeye, Arizona.

Table 1. Summary of statistical metrics comparing the OpenET models with measured evapotranspiration for alfalfa, on average, at Buckeye, Arizona, in 2023.

	Statistical metric			
Model	**NRMSE**	**R2**	**MBE, mm**	**Pe, %**
ALEXI/DisALEXI	25.06	0.89	-4.89	-13.37
eeMETRIC	23.77	0.88	3.29	8.99
geeSEBAL	22.13	0.88	-0.59	-1.62
PT-JPL	32.19	0.77	-3.08	-8.43
SIMS	25.81	0.86	0.75	2.05
SSEBop	33.44	0.91	9.40	25.71
Ensemble	25.40	0.87	-3.37	-9.21

Notes: NRMSE, R2, MBE, and Pe refer to normalized root-mean-squared error, coefficient of determination, mean bias simulation error, and prediction/simulation error, respectively. The simulation results were considered excellent at NRMSE < 10%, good at 10% ≤ NRMSE ≤ 20%, fair at 20% ≤ NRMSE ≤ 30%, and poor at NRMSE > 30% (Jamieson et al., 1991). R^2 close to one shows a good fit between the simulated and measured datasets. The MBE value > 0 indicates overestimation, whereas the value < 0 indicates underestimation of the measured dataset. A zero value for MBE represents no bias. Pe between ±15 is acceptable (Brisson et al., 2002)

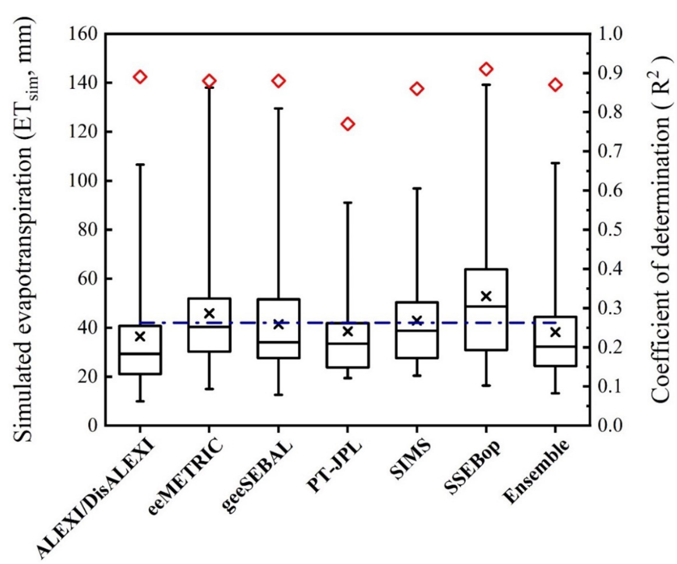

Figure 4. Average biases in simulated evapotranspiration (ETsim) by six OpenET models and their Ensemble for all plots/replicates during 2023. The dashed line represents the average measured ET. The X and line within the box mark the average and median ETsim, respectively, and whiskers above and below the box indicate the maximum and minimum ETsim values. The X above the dashed line represents overestimation, while the X below the line indicates underestimation. The red diamonds indicate the coefficient of determination.

Elsadek, E.A., 2023. Study on the In-Field Water Balance and the Projected Impacts of Climate Change on Rice Yields in the Nile River Delta. Hohai University, China.

Eltarabily, M.G., Mohamed, A.Z., Begna, S., Wang, D., Putnam, D.H., Scudiero, E., Bali, K.M., 2024. Simulated soil water distribution patterns and water use of Alfalfa under different subsurface drip irrigation depths. Agric. Water Manag. 293, 108693. https://doi.org/https://doi.org/10.1016/j.agwat.2024.108693

Gu, Y.-J., Han, C.-L., Fan, J.-W., Shi, X.-P., Kong, M., Shi, X.-Y., Siddique, K.H.M., Zhao, Y.-Y., Li, F.-M., 2018. Alfalfa forage yield, soil water and P availability in response to plastic film mulch and P fertilization in a semiarid environment. F. Crop. Res. 215, 94–103. https://doi.org/https://doi.org/10.1016/j.fcr.2017.10.010

Hakl, J., Kunzová, E., Tocauerová, Š., Menšík, L., Mrázková, M., Pozdíšek, J., 2021. Impact of long-term manure and mineral fertilization on yield and nutritive value of lucerne (Medicago sativa) in relation to changes in canopy structure. Eur. J. Agron. 123, 126219. https://doi.org/https://doi.org/10.1016/j.eja.2020.126219

Jamieson, P.D., Porter, J.R., Wilson, D.R., 1991. A test of the computer simulation model ARCWHEAT1 on wheat crops grown in New Zealand. F. Crop. Res. 27, 337–350. https://doi.org/10.1016/0378-4290(91)90040-3

Li, M., Wang, Y., Adeli, A., Yan, H., 2018. Effects of application methods and urea rates on ammonia volatilization, yields and fine root biomass of alfalfa. F. Crop. Res. 218, 115–125. https://doi.org/https://doi.org/10.1016/j.fcr.2018.01.011

McDonald, I., Baral, R., Min, D., 2021. Effects of alfalfa and alfalfa-grass mixtures with nitrogen fertilization on dry matter yield and forage nutritive value. J. Anim. Sci. Technol. 63, 305–318. https://doi.org/10.5187/jast.2021.e33

USDA-NASS, 2022. Data and statistics. United States Department of Agriculture, National Agricultural Statistics Service. Available [WWW Document]. URL https://www.nass.usda.gov/Data_and_Statistics/index.php (accessed 3.10.22).

Yu, M., Tian, Y., Gao, Q., Xu, X., Wen, S., Fan, Z., Li, X., Gong, J., Liu, Y., 2018. Nonlinear response of lucerne (Medicago sativa) biomass and biological nitrogen fixation to different irrigations and sowing modes. Appl. Soil Ecol. 125, 257–263. https://doi.org/https://doi.org/10.1016/j.apsoil.2018.02.003

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