LAND IQ

A DATA DRIVEN APPROACH

OVERVIEW

What is Land IQ ET?

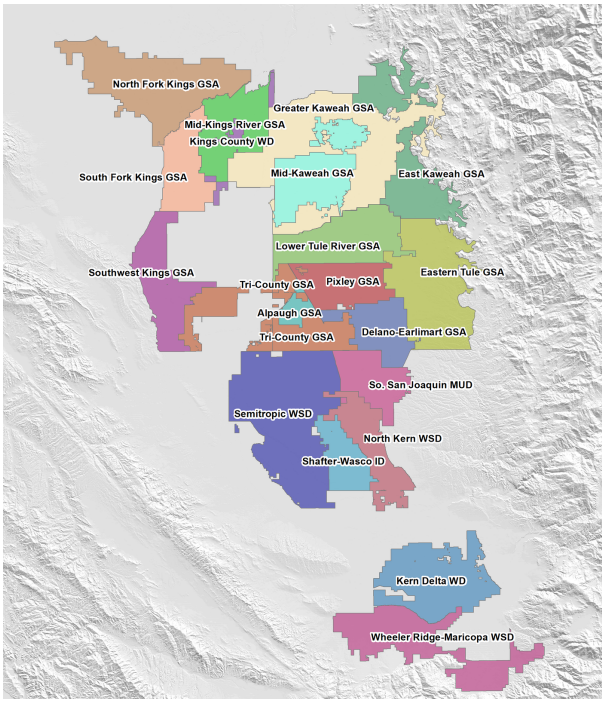
Land IQ ET is a data driven model that was developed for detailed, field-scale water use estimation. Water use estimation is calculated as evapotranspiration (ET), or the amount of water consumed by the plant through evaporation and transpiration.

How does Land IQ ET determine field-level ET?

A rich set of ground measurements from approximately 90 Land IQ and other monitoring field stations is used to generate hourly ET data, which are then used as dependent variables in the modeling process. The field data are used to calibrate remote sensing models for actual ET and to extrapolate those actual ET measurements across all fields to generate a complete estimate of monthly ET and ET by crop type by field. The Land IQ ET model is unique because it models at the field scale and incorporates and considers real time climatic and environmental station data, high-accuracy land use data, permanent crop age, and agronomic practices of modern cropping systems.

What is the difference between consumed water and applied water?

The amount of water applied to the field can be measured by gauges or meters, however the amount consumed is what is used by the crop. The remaining is usually returned to the groundwater system and is a function of the efficiency of the irrigation management.



How does Land IQ ET compare to other remote sensing models?

The Land IQ ET model was developed for detailed, field-scale water use tracking. It uses robust ground station data and direct image analysis to interpret image data. The Land IQ ET model is differentiated from other models by the following:

- **Data-driven** - The data driven approach makes the model completely objective. There is no need to hand-pick calibration pixels, as required in other models, which can introduce uncertainty, depending on an analyst's knowledge and experience.
- **Ground truth distribution/validation data** – The Land IQ model integrates data from repeated and rigorous ground truth climatic and environmental stations (currently approximately 90). Field stations are distributed to correspond with the range and dominant crop types in the service area and are continuously monitored via telemetered systems to detect inconsistencies in collection or outages. Field station data is key for model calibration and to validate model accuracy.
- **Scale** – Modeling is performed at the field level; thus, results can be aggregated to any larger unit of analysis desired.
- **Remote sensing imagery** - Land IQ ET uses available remote sensing images (Landsat, Sentinel, other purchased imagery, if needed). Typically, the model uses up to three times the imagery rather than relying on Landsat alone.
- **Integration of agronomic features of modern cropping systems** - Unlike other methods, the Land IQ land use data is derived from and guided by our understanding of agricultural systems, landscape processes, production systems, and crop phenology. In addition to basic land use data, the Land IQ ET model also considers and incorporates permanent crop age, permanent crop density, and unique field conditions including irrigation method and management.

Who is using Land IQ ET?

Land IQ ET was initially developed for use in the Semitropic Water Storage District (SWSD). Since 2016, in addition to SWSD, the organizations utilizing Land IQ ET has grown to cover over 1.7 million acres including:

- 20 Groundwater Sustainability Agencies (GSAs) or Irrigation Districts
- Covering approximately 40 crop types
- Utilizing multiple water sources

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GEOGRAPHIC & TEMPORAL SCALE

At what scale is the analysis conducted?
The primary unit of analysis by Land IQ ET is the field. With such a granular approach, the results can be "rolled up" to any unit desired such as parcel level, County, Irrigation District, GSA or groundwater basin.

What is the data source for field boundaries?
Land IQ ET utilizes the same land use data the Department of Water Resources (DWR) provides for the implementation of the Sustainable Groundwater Management Act (SGMA). These data are provided with the consumed water from the same field as a complete deliverable to the client. Thus, we can ensure that consistency of acreage is maintained between public mapping used by SGMA and internal mapping.

Utilizing remote sensing technologies and statistical and temporal analysis methods, Land IQ's spatial database of crop types exceeds 97% accuracy on the classification of crops. Baseline statewide crop mapping was conducted in 2014 and 2016 for the DWR, and continues with multi-cropping in 2018, 2019, 2020 and 2021. Thus, the land use that drives consumed water by the crops, is highly accurate, approved by DWR and the State of California, and forms one of the foundations of the accurate ET results.

At what interval is the data delivered?
Results are delivered within 25 days of the end of the previous month, allowing the GSAs to provide growers with critical decision-making tools, on a monthly basis, for managing water use through the growing season.

SATELLITE DATA

What satellite data is used for the Land IQ ET remote sensing models?
Land IQ ET uses multiple remote sensing images including:

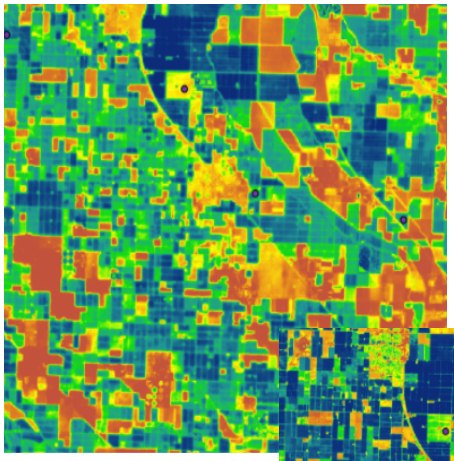
- Landsat (30 m, every 16 days)
- Sentinel (10 m, every 5 days)
- High Resolution (1-2 m, every 30 days)

Satellite data are screened for cloud cover and corrected for the effects of terrain or different topographic positions on reflectance.

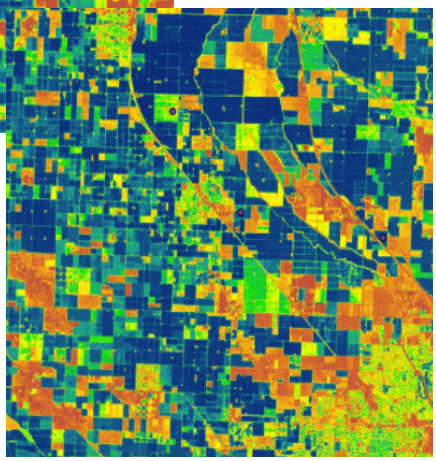
How does Land IQ address cloud or smoke cover?
Because 7 to 8 images are used (in comparison to 1 or2 images if only Landsat were used), there is more opportunity to capture cloud/smoke free days. In the case of cloud/smoke cover, data is screened for the cloud/smoke cover and the terrain is corrected.

When cloud/smoke cover does restrict image analysis, Land IQ can rely on actual ET measurements from the network of field stations. Therefore, continuous field-by-field actual ET is consistently produced.

How is satellite imagery used in the Land IQ ET model?
Remotely sensed satellite imagery of the service area is collected on all available cloud free overpass dates within each month. For each station, spectral features such as single band information, vegetation indices, or surface temperature are extracted and combined for the models. For daily and monthly models, the features are related to measured actual ET to build models that are applied to the entire area for daily and monthly actual ET image calculation. Generally, up to two cloud-free Landsat 8 imagery and up to six Sentinel 2 images can be used for monthly actual ET estimation. Applying more daily satellite imagery captures more of each field's variation, which provides more accurate monthly actual ET. The remote sensing analysis is conducted every 5-16 days during each month to characterize ET and calibrate daily, time-resolved analysis for the year.



Coarser ET Results Using Landsat Only



Refined ET Results Using Multiple Imagery Sources

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GROUND TRUTH DATA

How is the ground truthing data used for calculating ET?

Land IQ uses meteorological stations to determine the amount of energy exchanged between the land surface and the atmosphere. All Land IQ stations follow the same surface energy balance approach, defined by the following equation:

$$Rnet - G - H - \lambda E = 0$$

Where:

- **Rnet** is the net radiation that accounts for both incoming and outgoing solar and terrestrial radiation.
- **G** is the surface soil heat flux and is derived from changes in soil temperature and moisture.
- **H** is the sensible heat flux measured as the exchange of heat between the plant canopy and surrounding atmosphere.
- **λE** is the latent heat flux, where λ is the latent heat of vaporization and E is the evapotranspiration term in plant systems or evaporation in open water or bare soil surfaces.

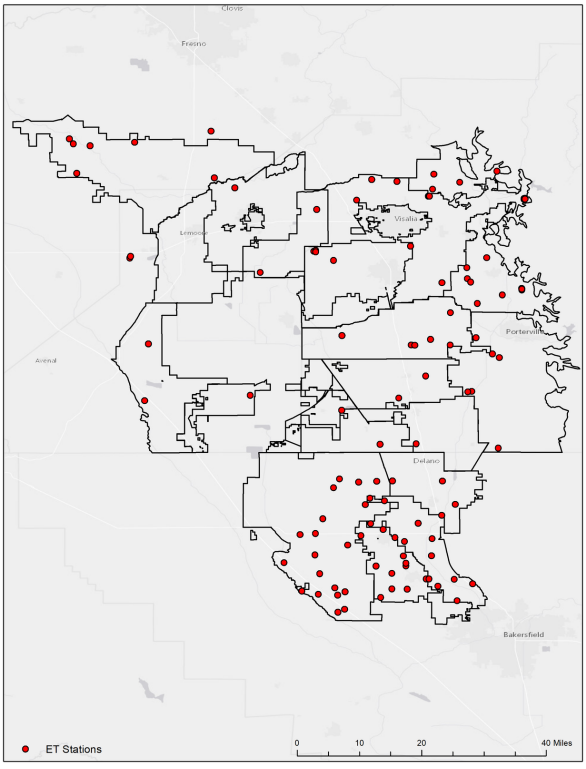
How does Land IQ obtain ground truthing data?

Land IQ ET uses a combination of instrument types to capture the range of data needed for ground calibration. Land IQ ET stations include full residual energy balance stations (Full), Water IQ (WIQ) stations (improved surface renewal), and Tule Tech stations (using surface renewal). All stations are placed appropriately to collect representative results and to avoid disruption in wind movement that introduces error in data collection.

- **Full Station**: The full station approach uses independent instruments to directly measure the Rnet, G, and H.
- **Water IQ (WIQ) Stations**: Land IQ's WIQ stations directly measure Rnet and H with a calibration factor from a full station and assumes that G is zero over a 24-hour period. On most occasions, the amount of energy received by the soil during the day will escape back to the atmosphere at night.
- **Tule Technology stations**: The Tule Tech stations model the daily Rnet, directly measures H, and assumes G term to be zero over a 24-hour period.

Where are the stations currently located?

The Land IQ network currently consists of approximately 90 stations. The stations are distributed across Fresno, Kern, Kings and Tulare Counties.



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GROUND TRUTH DATA

How are the locations for stations determined?

The quantity and location of stations are driven by crop distribution. Crops that dominate the landscape are instrumented in such a way so that differences in age, canopy and geography are adequately characterized. Individual fields are selected based on their size (large acreage blocks (>40ac) are preferred) and representation of the common surface conditions in the area, such as crop type, age, and canopy characteristics. Site selection criteria include:

- Crop type
- Field uniformity
- Topography
- Representative production practices (e.g. irrigation and crop management)
- Predominant wind directions
- Soil types
- Spatial distribution within a particular AOI

How does Land IQ take into account different field management techniques?

In our initial assessment of a new AOI, the Land IQ land use data, which is derived from and guided by our understanding of agricultural systems, landscape processes, production systems, and crop phenology, is used to determine the most expansive crop types for placement of the stations. In addition to basic land use data, the Land IQ ET model also considers and incorporates permanent crop age, permanent crop density, and unique field conditions including irrigation method and management. Additionally, we have an ongoing working relationship with the University of California system to determine effects of variables like row orientation, the amount of applied irrigated water, as well as irrigation and pruning techniques.

How are the data transmitted?

Data stations are fully telemetered by cellular communication systems to Land IQ servers. Data is transmitted every six hours and incorporates data flagging protocols to identify any inconsistencies in collection or outages. A thorough QA/QC effort is conducted on all field collected data prior to remotely sensed analysis.

How are the stations maintained?

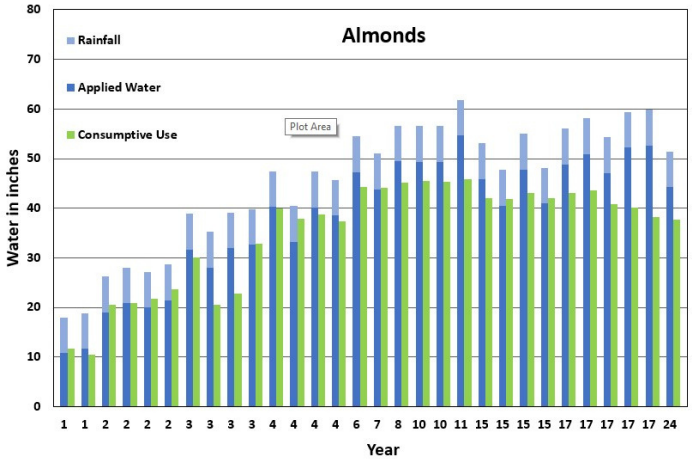
Station maintenance is the responsibility of Land IQ and is performed at least monthly, if not more frequently.

ACCURACY

How accurate is the Land IQ ET model?

Robust accuracy assessments require two sets of model input data. During early model development, Land IQ used all field station data to calibrate the ET model because this data proved to be critical to model development. Using as much field station data as possible results in more accurate model predicted values. Fully independent data were not initially set aside, however moving forward in 2021, data will be set aside for complete blind independent validation. That said, several other indicators of accuracy and precision have been conducted:

- A comparison of predicted versus measured values at the field level.
- A comparison of diurnal and seasonal fluctuations in alfalfa.
- A comparison of two models for specific crops and time periods. Model 1 used all station field data and model 2 excluded data from two field stations.
- An independent comparison of model 2 results and independent field station data from the excluded stations.
- Precision was assessed by comparing the results between stations located in similar conditions, including crop type and canopy cover.
- Comparison of predicted ETa to known values of applied water.
- Multiple comparisons of applied to consumed water as shown below.



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DATA USAGE

How can the Land IQ ET data be used?

The data can be used for the development and implementation of Groundwater Sustainability Plans and to track progress towards reaching sustainability, complying with groundwater allocations, improving overall groundwater management and water management modeling, improving irrigation district water management, billing growers on water consumed, instead of water delivered, and to view historic results for future water management.

Can the data be used for billing purposes?

Yes, Land IQ ET results are increasingly used for billing water users for the water consumed instead of water delivered.

Can the data be used for irrigation scheduling?

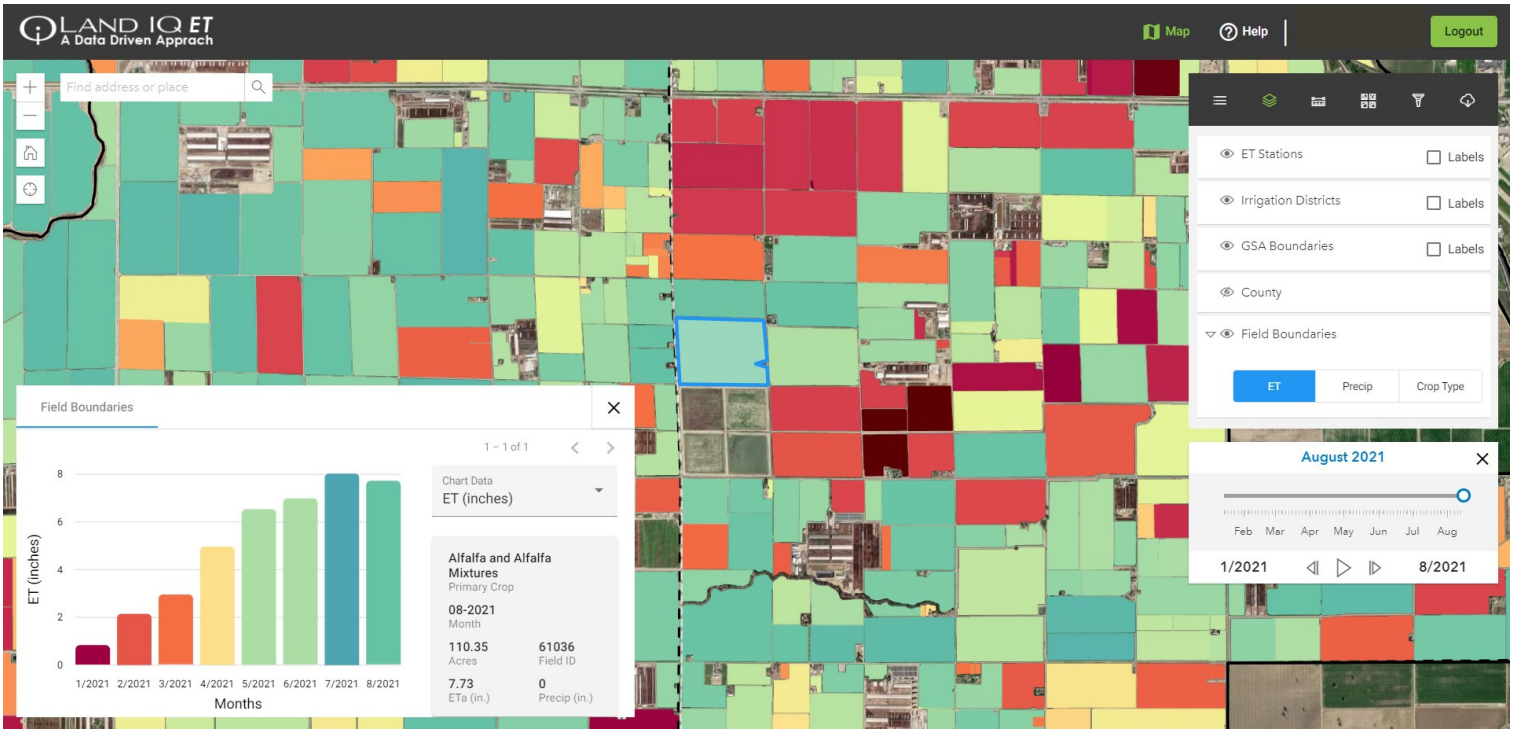
The Land IQ ET data is not intended for day-to-day irrigation scheduling, however it can be used for overall field-by-field water management.

Can the data be used for tracking water allocations?

Yes, because of the granularity and accuracy of the analysis, water managers can track and reconcile monthly consumed water use by grower. The analysis is delivered within 25 days of the end of the previous month, allowing the managers to provide growers with critical decision-making tools, on a monthly basis, for managing water use through the main growing season and across the entire year.

Does Land IQ have a platform for viewing data?

Yes, Land IQ has a data visualization platform (see below). Depending on the needs of the water manager, a platform can be customized to range from single user to multiple users with unique log-in and viewing capabilities.



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Land IQ is a specialized Agricultural Science and Remote Sensing firm that pairs scientific knowledge of agronomic, native plant and land systems with advanced remote sensing technologies, custom modeling, and analytical methods to develop powerful and cost-effective client solutions. We focus on large scale land systems and management applications.

Land IQ understands the need for sound scientific support as well as practical experience. Many of our staff have roots in agriculture and bring first hand and irreplaceable understanding of agricultural production systems to projects.

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