AgHive

Research for Impact

Hadi Jaafar
Associate Professor
Chair, Department of Agriculture
Faculty of Agricultural and Food Sciences
Remote Sensing Summer School – May 30- June 2, 2022

AUB DEPARTMENT OF AGRICULTURE

CORE OF
REMOTE SENSING & GEOSPATIAL ANALYSIS
AT FAFS

The Unit for the Remote Sensing
and Geospatial Lab and the Smart Irrigation Lab at the
American University of Beirut

01 ABOUT US

The unit

02 RESEARCH

Active Projects

03 OUTREACH

Workshops & Field Work

01 ABOUT US

Our philosophy, partners, and services

OUR PHILOSOPHY 01

The Middle East and other regions in the world are suffering from an expanding population, dwindling water resources, and an increase in the frequency of conflicts, thereby threatening food and global security. Monitoring water use and stress at the field scale is of great importance to the success of agriculture in such areas.

—**Dr. Hadi Jaafar**
Founder & Lab Lead, AgHive

OUR PILLARS 01

Remote Sensing

Smart Irrigation

Water Resources

Big Data

Software

OUR RESOURCES 01

GRADUATE STUDENTS/ RESEARCHERS









HIGHLY MOTIVATED TEAM

OUR RESOURCES 01

Boundary Layer Scintillometer

Experimental Field in Beqaa (AREC)

2 Laboratories

2 Eddy Covariance towers;
2 Surface Renewal Stations
5 Infrared Radiometers
3 Weather Stations

OUR SERVICES 01

Agricultural Studies

Conflicts, Food & Water Security Studies

GIS and Remote Sensing

Climate Change Impact Studies

Hydrology & Floodplain Studies

Irrigation System Design Rehabilitation & Development

02

RESEARCH

Current projects and applications

WHAT SETS US APART?

Research for Social Good

Applications of GIS and remote sensing in smart irrigation, food security, and water resources management

Informed Action

We combine remotely sensed data, satellite imagery, and local knowledge

Motive

We aim to utilize and manage water resources for sustainable crop production

Responsiveness

We work directly with farmers and stakeholders and generate tools to help the user community combat pressing challenges

RECENT RESEARCH (Global Impact)

nature › scientific data › data descriptors › article

Data Descriptor | Open Access | Published: 12 August 2019

GCN250, new global gridded curve numbers for hydrologic modeling and design

Hadi H. Jaafar, Farah A. Ahmad & Naji El Beyrouthy

https://jaafarhadi.users.earthengine.app/view/hydrologic-curve-number#GEE

Earth Engine Apps Experimental

Search places

GCN250m: Global Hydrologic Curve Number Explorer

This interface allows users to visualize the gridded hydrologic curve number dataset at ~250m resolution globally. Use the mouse-wheel to zoom in and out and click the map to query a wet, dry, or average antcedent runoff conditions.You can also zoom to a specific country of interest.

Version 1.0

Please cite: Jaafar, H. H., Ahmad, F. A., & El Beyrouthy, N. (2019). GCN250, new global gridded curve numbers for hydrologic modeling and design. Scientific data, 6(1), 1-9. https://www.nature.com/articles/s41597-019-0155-x

Select layer:

Choose a runoff condition...

Hint: Layer transparency can be changed at the top-right of the screen (layers box)!

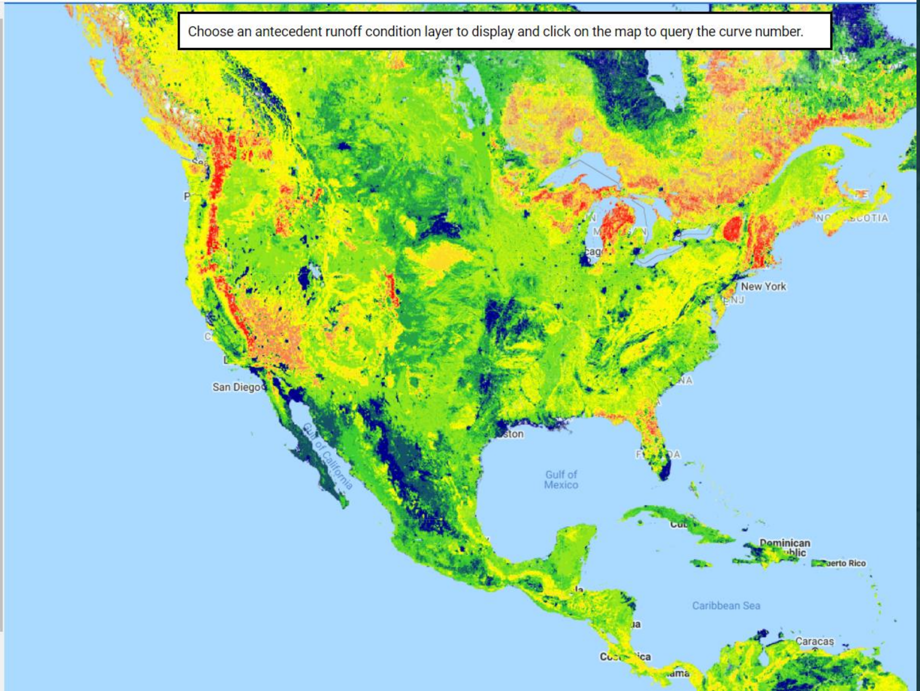
Zoom to Country:

Choose a country ...

For more information:

Curve numbers for Hydrologic Runoff based on GLCC

Manuscript



RECENT RESEARCH (Global Im

remote sensing

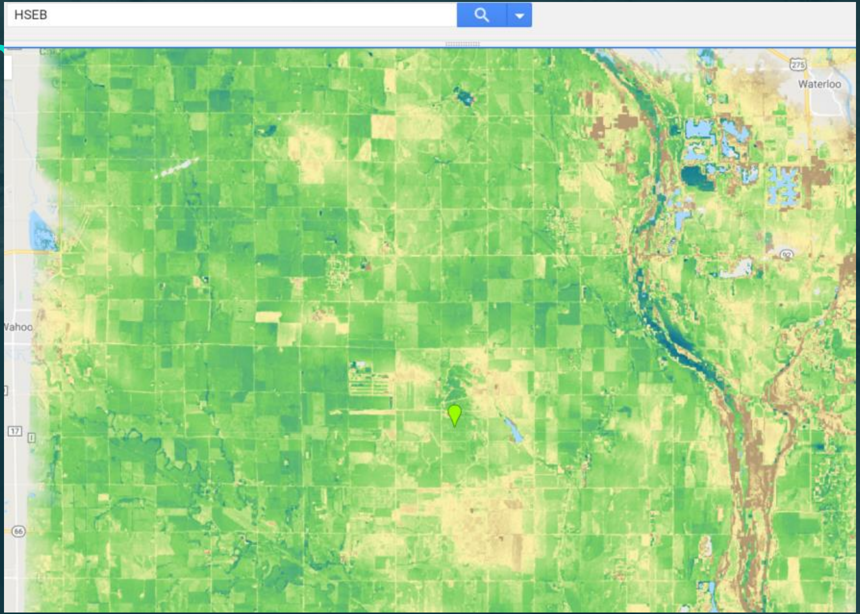
MDPI

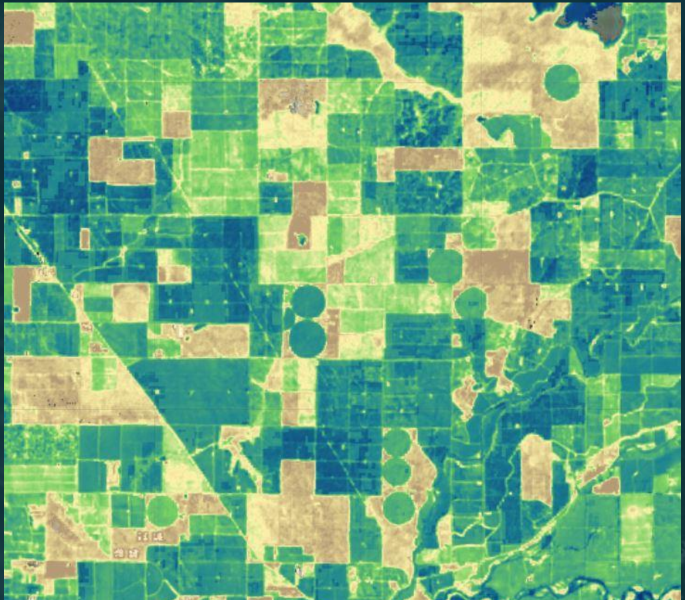
Article

GYMEE: A global field-scale crop yield and ET mapper in Google Earth Engine based on Landsat, weather and soils data

Hadi Jaafar [1,*], Roya Mourad[1]

[1] Department of Agriculture, Faculty of Agricultural and Food Sciences, American University of Beirut, Bliss St., Beirut, 2020-1100, Lebanon, hj01@aub.edu.lb, Corresponding Author
[*] Correspondence: hj01@aub.edu.lb; Tel.: +961-1-350-000





ACTIVE PROJECTS 02

MuSLI

NASA

USDA

Characterizing Field-Scale Water Use, Phenology and Productivity in Agricultural Landscapes using Multi-Sensor Data Fusion

ITSET

Ministry of Foreign Affairs Netherlands

UNESCO – United Nations Educational, Scientific and Cultural Organization · IHE DELFT Institute for Water Education in partnership with UNESCO

Integrating Time Series ET Mapping into Operational Irrigation Management Framework

TALANOA WATER

PRIMA – Partnership for Research and Innovation in the Mediterranean Area

Talanoa Water Dialogue for Transformational Adaptation to Water Scarcity Under Climate Change

Seeds for Recovery

ISDC – International Security and Development Center

Department for International Development

The Long-Term Impacts of a Complex Agricultural Intervention on Welfare, Behavior and Stability in Syria

SPIRM

TIDES – A Force for Social Good

Google.org

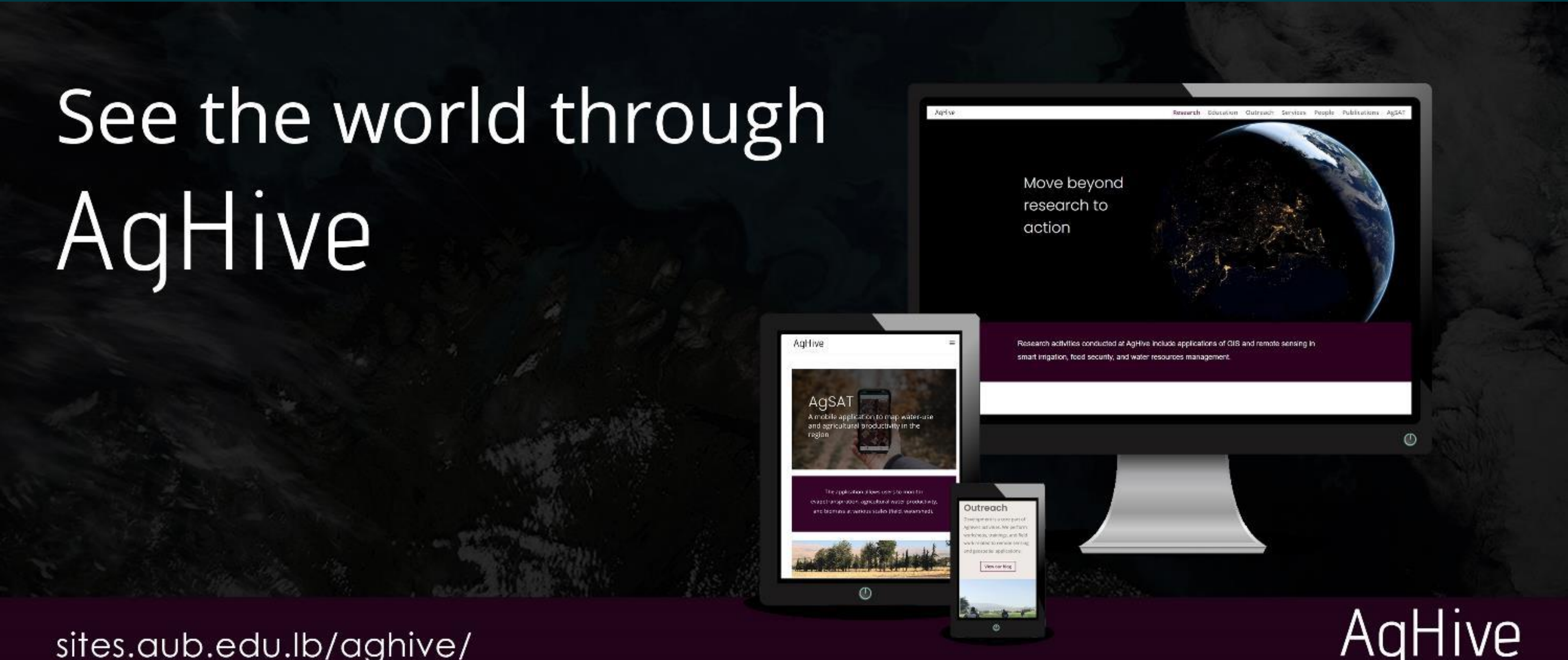
Smart and Precision Irrigation with Remote Sensing & Machine Learning

WORKSHOPS 03

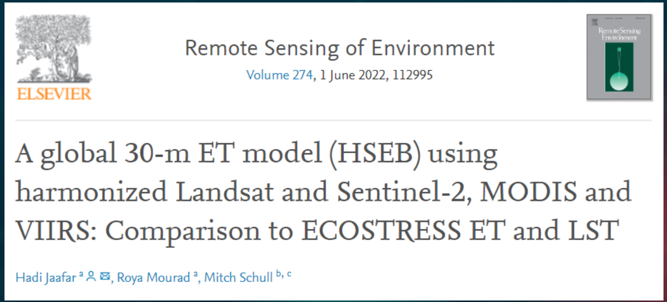
FIELD WORK 03

Micasense multispectral and thermal sesnor

Access the full list of projects and publications on our website



HSEB: A global 30-m ET model using harmonized Landsat and Sentinel-2, MODIS and VIIRS


Remote Sensing of Environment
Volume 274, 1 June 2022, 112995

A global 30-m ET model (HSEB) using harmonized Landsat and Sentinel-2, MODIS and VIIRS: Comparison to ECOSTRESS ET and LST

Hadi Jaafar[a], Roya Mourad[a], Mitch Schull[b,c]

AUB AgHive

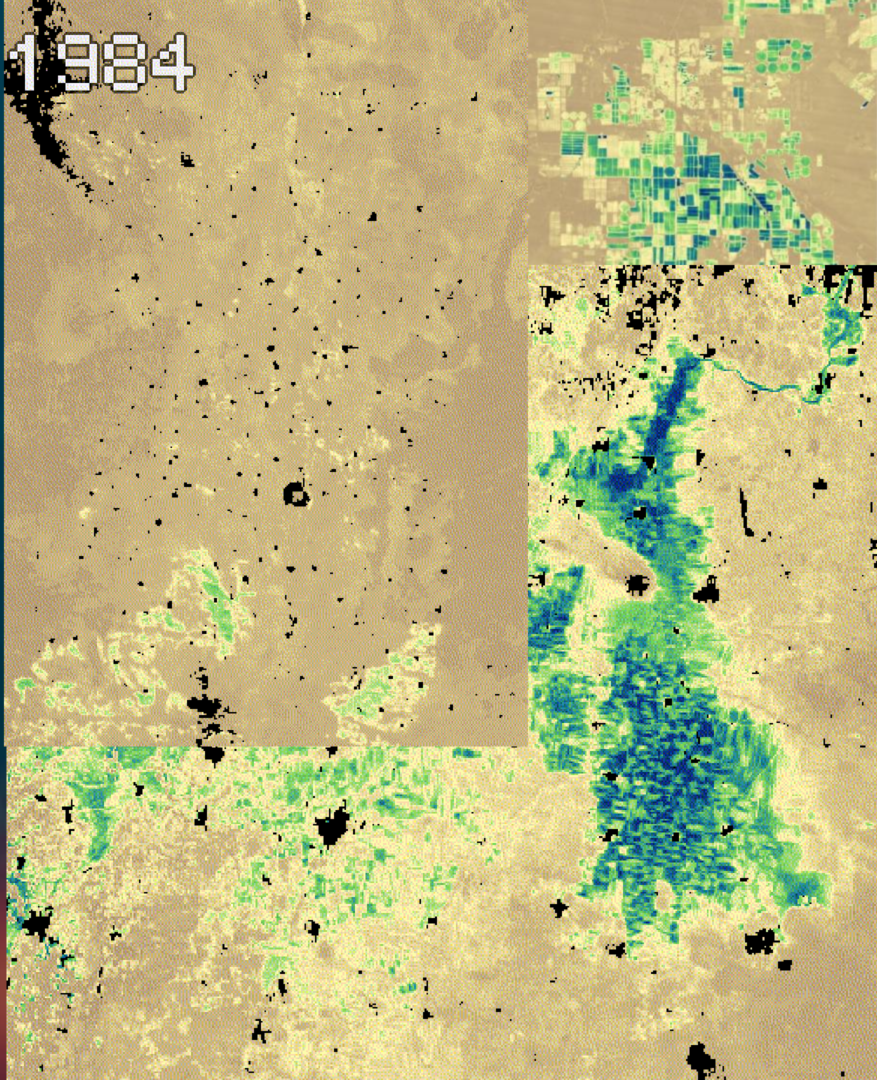
Outline

- Introduction
  - Why measure ET?
  - How to measure/estimate ET?
- Methodology
  - HSEB Model Description
  - Input Data
  - Thermal Sharpening
  - HSEB ET validation
- Results
  - HSEB ET performance
  - HSEB ET benchmarked with ECOSTRESS ET
  - Assessment of sharpened LSTs
  - Impact of LST on HSEB ET results
- Applications and Conclusions

INTRODUCTION

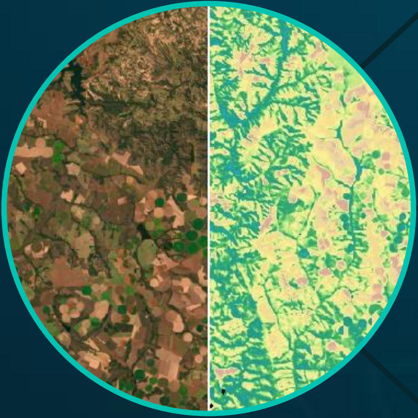
Why Measure Evapotranspiration (ET) in Agricultural Applications?

- Irrigation management
- Monitoring drought and crop stress
- Yield prediction
- Water use accounting (crop per drop)
- Water rights regulations and planning

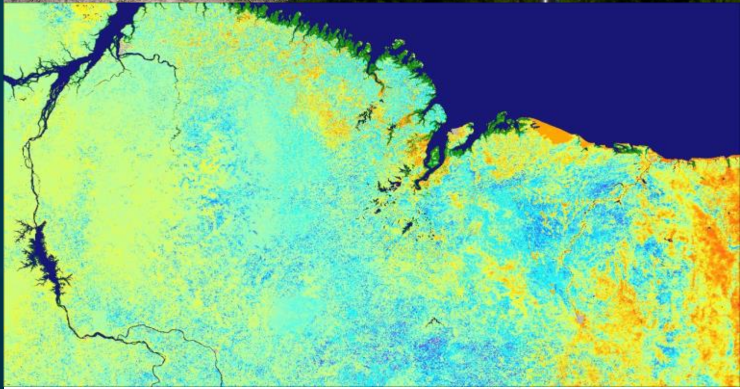


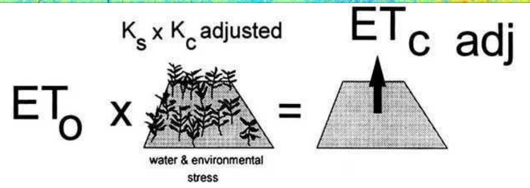
INTRODUCTION

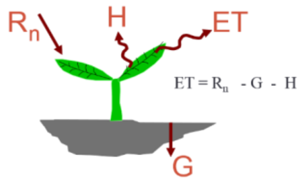
How to measure/estimate ET?



- ET Observational Systems
  - Eddy Covariance
  - Lysimeter
- Models
  - Land Surface Models
- Satellite
  - Crop Coefficient/ETo Methods
  - Energy Balance Methods





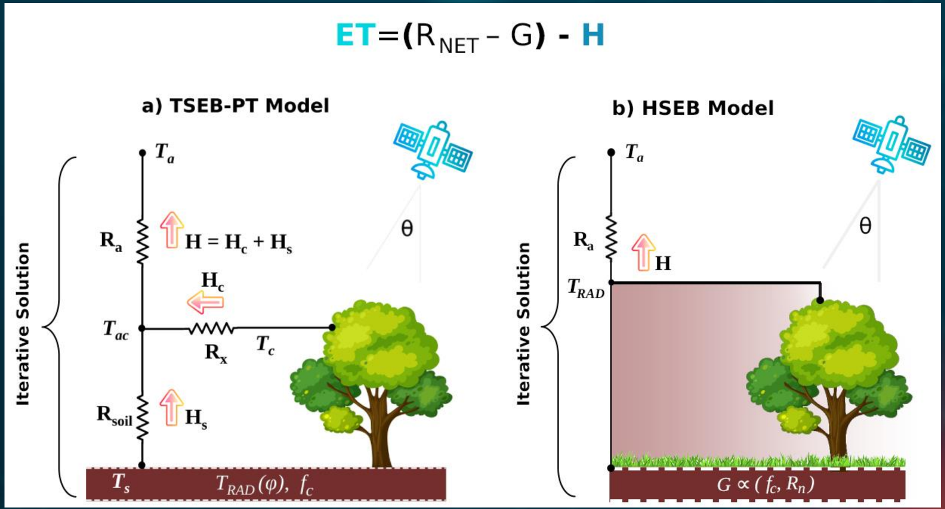


METHODOLOGY

Hybrid single-source energy balance (HSEB)

- Single-source energy balance models, where vegetation & soil are analyzed in a combined energy budget

- ET is calculated as a "residual" of the energy balance.
- Thermal imagery is key + solar irradiance



METHODOLOGY

HSEB Model Description

$$R_n - G = H + LE$$

- Components of the radiation balance are used to determine the net radiation (Rn) – SW ↓ , α, ε, Ts, LW ↓

$$R_n = (1- \alpha)\ SW\downarrow + \varepsilon\ LW\downarrow - LW\uparrow$$

- The ground heat flux (G) is parameterized as a function of fractional cover – LAI/NDVI relationships

METHODOLOGY

HSEB Model Description

- HSEB calculates H using similarity theory

$$L = \frac{-u_*^3}{k\left(\frac{g}{\rho c_p T_a}\right) H + 0.608\, c_p\, E\, T_a)}$$

$$u_* = \frac{\bar{u}k}{\ln\left(\frac{z_u - d_0}{z_{OM}}\right) - \psi_M\left(\frac{z_u - d_0}{L}\right) + \psi_M\left(\frac{z_{OM}}{L}\right)}$$

$$H = \frac{(T_s - T_a) k\, u_* \rho\, c_p}{[\ln((z - d_0)/z_{0h}) - \psi_h((z - d_0)/L) + \psi_h\,(z_{0h}/L)]}$$

Wind, air temperature, humidity
(aerodynamic resistance ,
)

Various sub-modules for calculating needed components…

METHODOLOGY

Input Data

- HSEB model leverage globally available state-of-the-art thermal, surface reflectance, reanalysis, & land cover datasets in Google Earth Engine (GEE).

Google Earth Engine

Data layers	Source	Resolution
Land Surface Temp	Landsat-7 & 8 / VIIRS-VNP02/VIIRS-VNP21/ /MODIS-Terra (MOD11A1.006)	60-100 m/ 375 m/ 750 m/1000m
Surface reflectance	Landsat-4,5,7 & 8/9/Sentinel-2	30,20, 10 m
Meteorological forcing	ECMWF	0.2º/0.1º
Elevation	SRTM	30 m
Landcover	CGLS-LC100	100 m

METHODOLOGY

FIELD-SCALE DAILY EVAPOTRANSPIRATION

SW/TIR

- ERA-5
- VIIRS-MOIDS-S2
- Landsat

→

- HSEB
- DMS
- GLC100

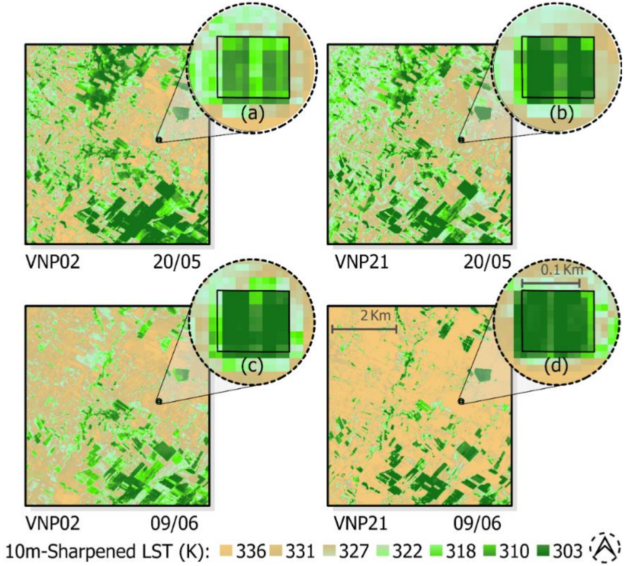
→

Sub-Weekly 10- 30 m ET

METHODOLOGY

Thermal Sharpening

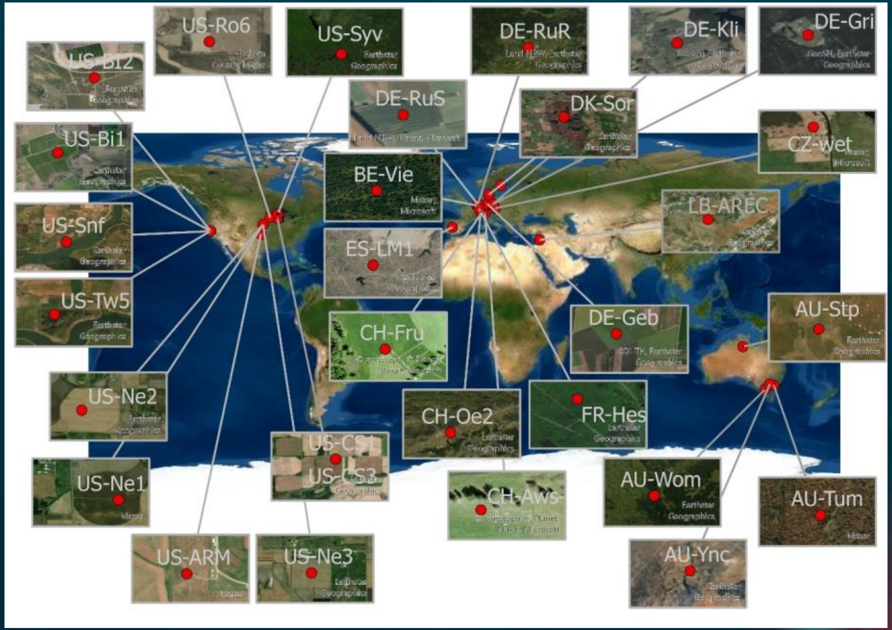
- HSEB runs TIR data sharpened with harmonized SR data from Landsat, S-2, & DEM.
- Random forest sharpener or TsHarp algorithm.
- Over fields in Lebanon, sharpened LST data were compared to LST observations



METHODOLOGY

HSEB comparison with ground observations

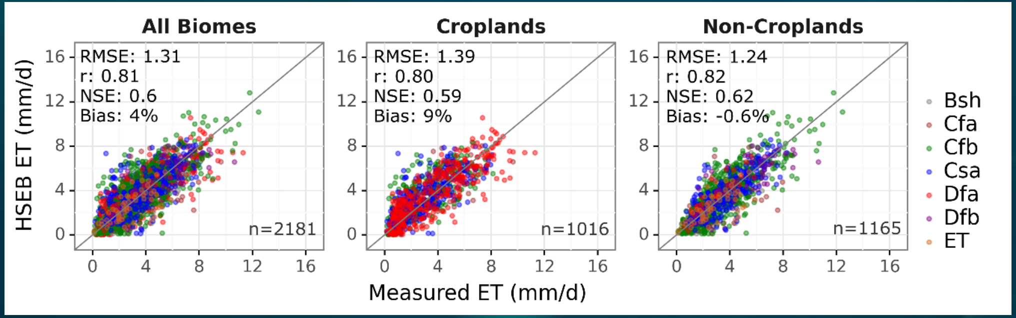
- HSEB is validated over 2018–2020 with 2181 observations from 29 flux towers
- HSEB was constructed over target investigated sites (US, EU, and Australia)

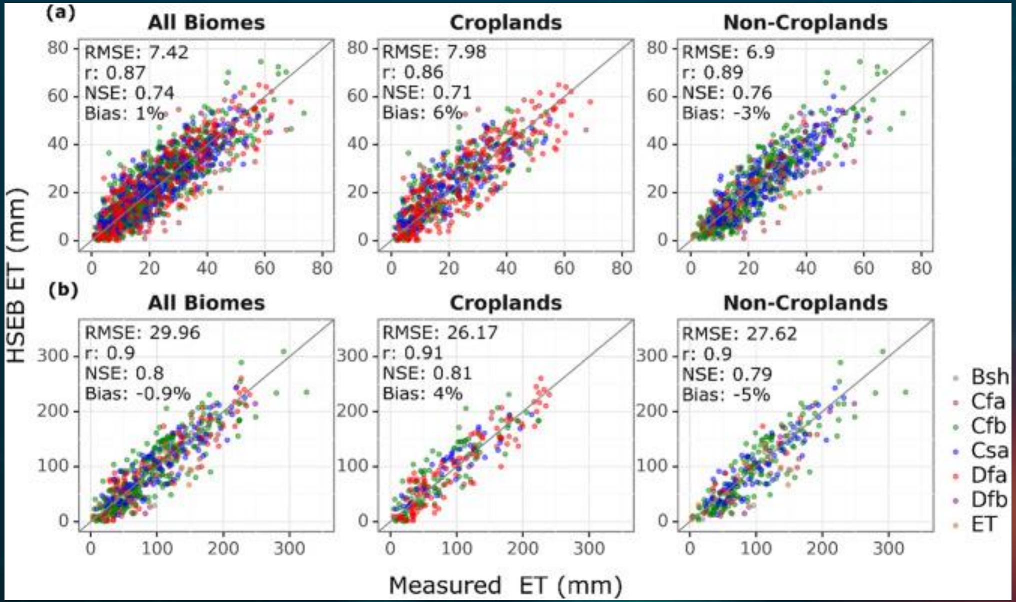


RESULTS

HSEB ET performance

- HSEB performed well in all considered biome types and climatic conditions (r = 0.81, 0.87, and 0.8, NSE of 0.6, 0.74, 0.8, and a bias of 4%, 1%, and –0.9% at the daily, weekly, and monthly scales, respectively).
- RMSE averaged at 1.31 mm/day

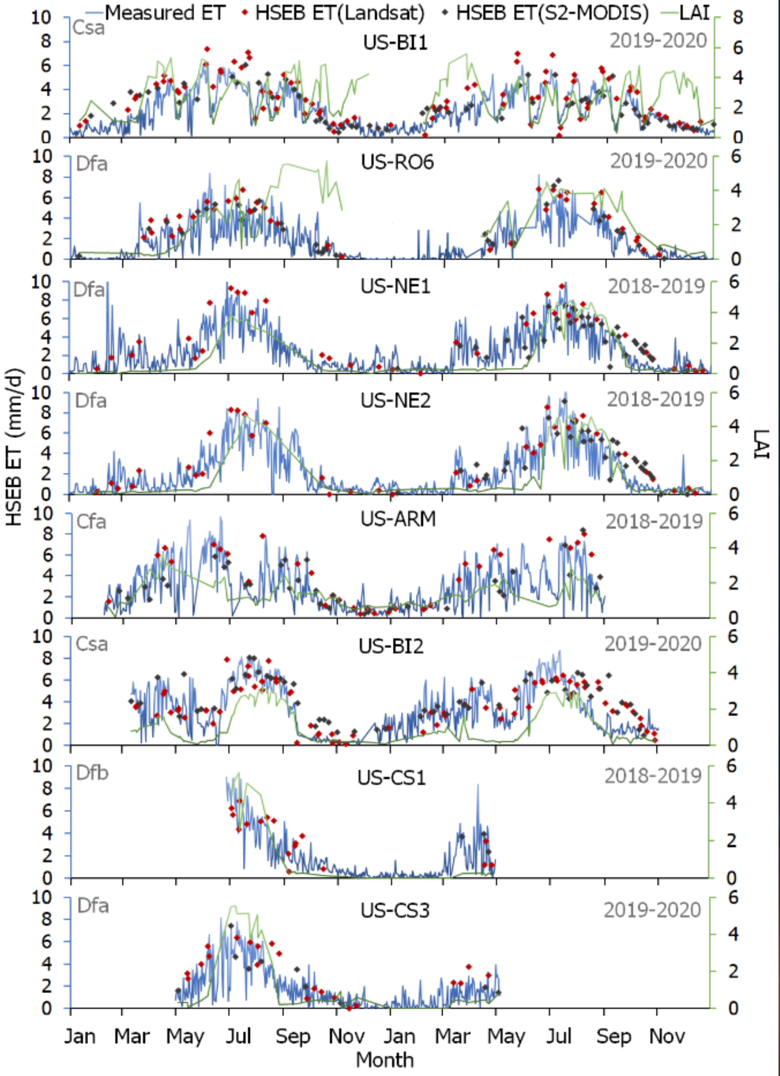




RESULTS

HSEB ET performance

- The time series over US cropland sites, demonstrate good agreement between HSEB with the observed ET over the growing cycle.
- ET at these cropland sites generally correlates well with LAI

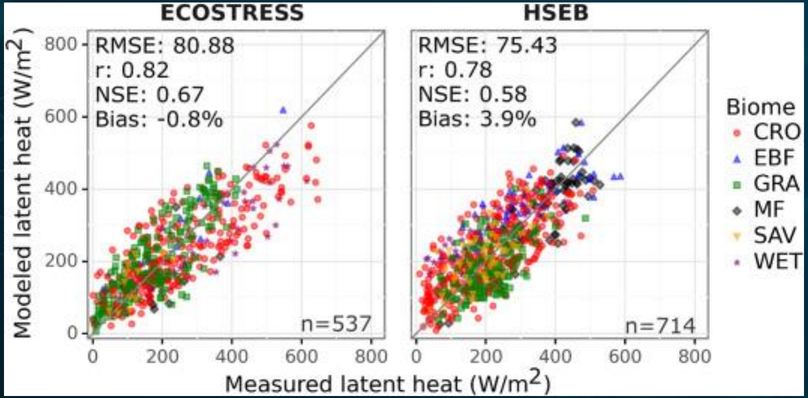


ECOSTRESS

HSEB ET Benchmarked with ECOSTRESS ET

RESULTS

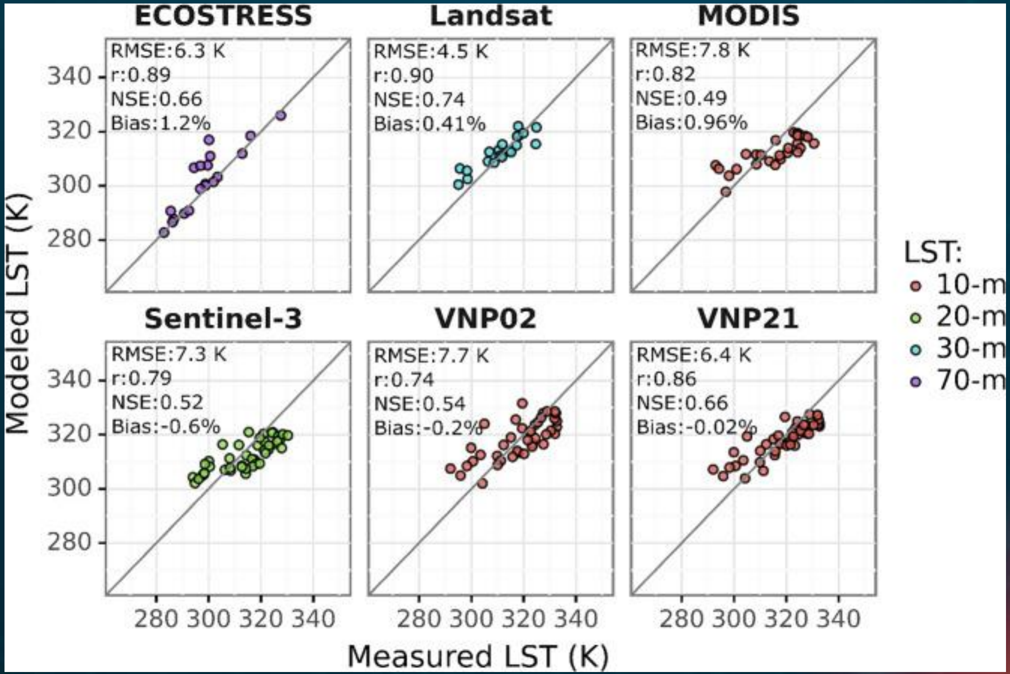
- HSEB produces acceptable results, although ECOSTRESS had a slightly lower bias (3.8% for HSEB vs. -0.8% for ECOSTRESS)
- HSEB performed better over croplands



Assessment of Sharpened LSTs

RESULTS

- Both ECOSTRESS and Landsat showed better performance at different LST ranges and time of day when compared to LST observation collected over a small potato field in Lebanon.

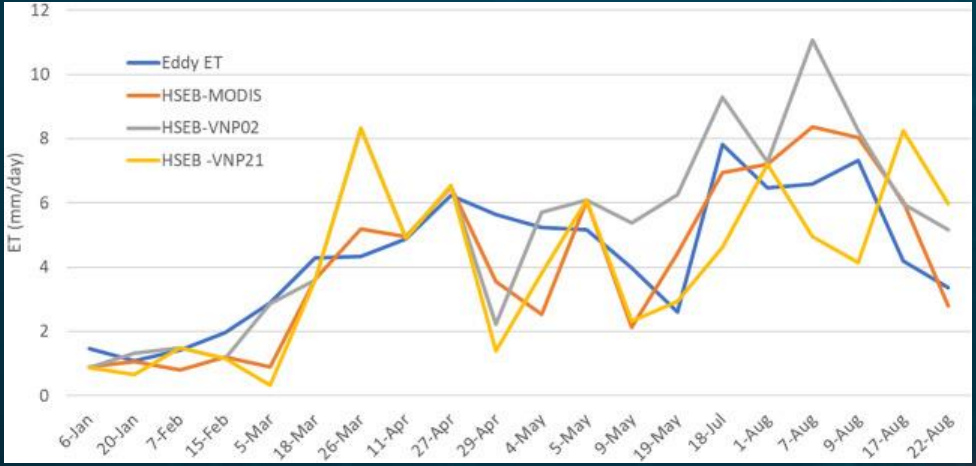


Case Study: potato field at AREC study site in Lebanon (2020 growing season)

Impact of the LST product on HSEB ET results

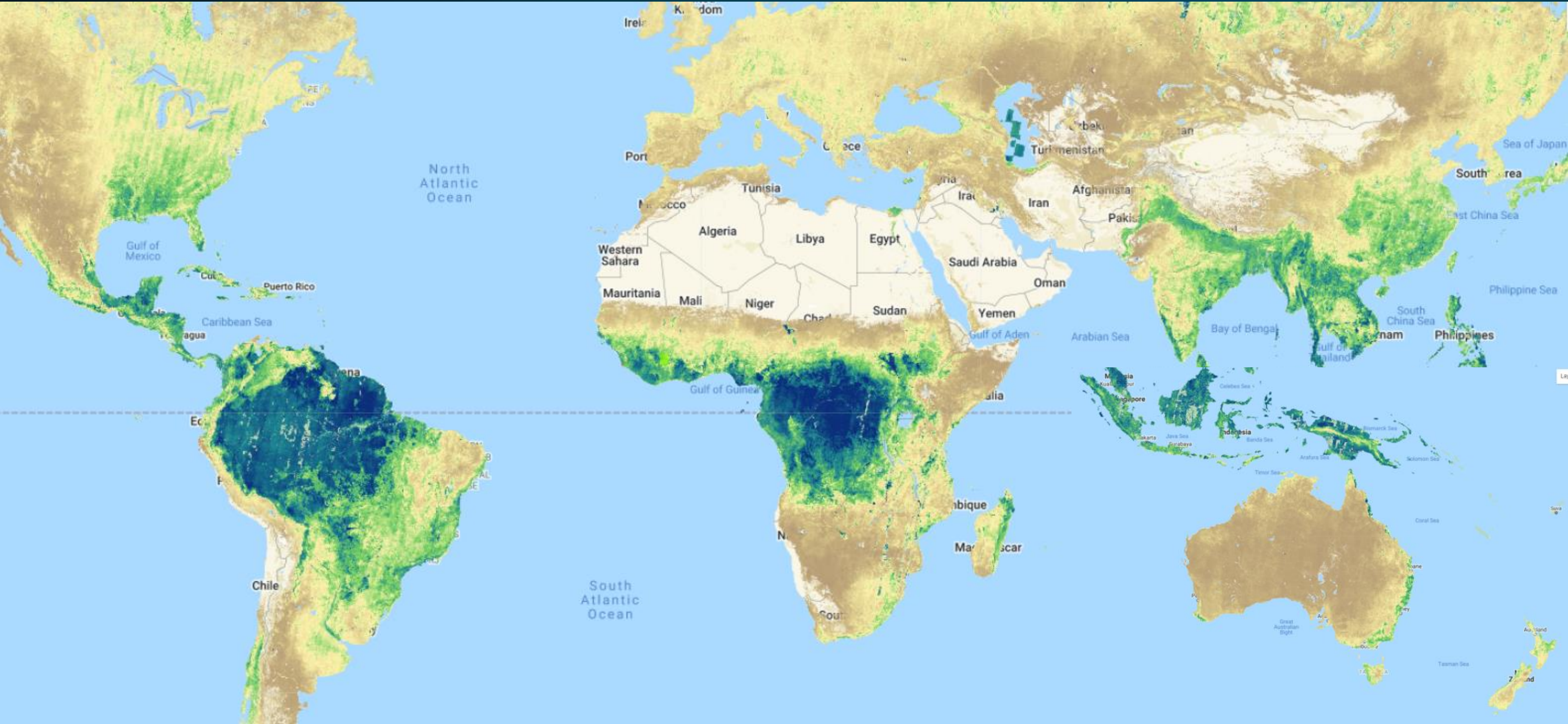
RESULTS

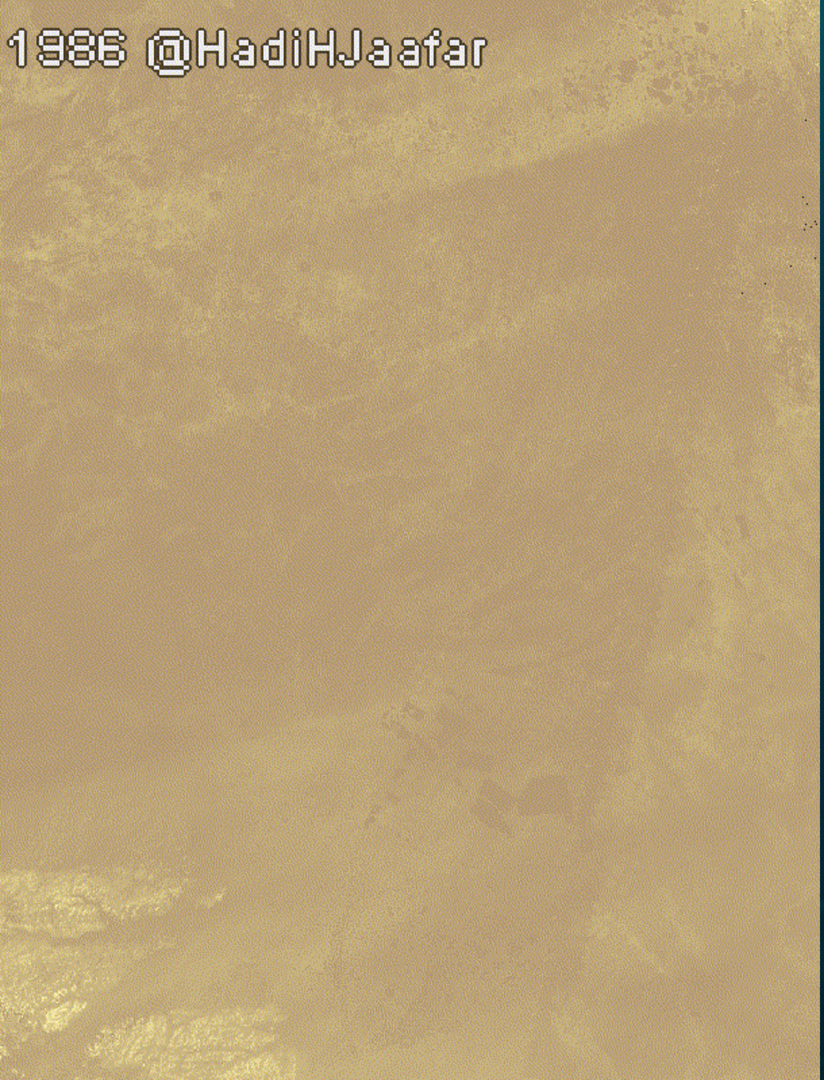
- The analysis of impact of LST product used in HSEB on ET results at US-ARM site showed that HSEB with MODIS LST outperforms LST from VNP02 (an overestimate) and VNP21 (an underestimate).

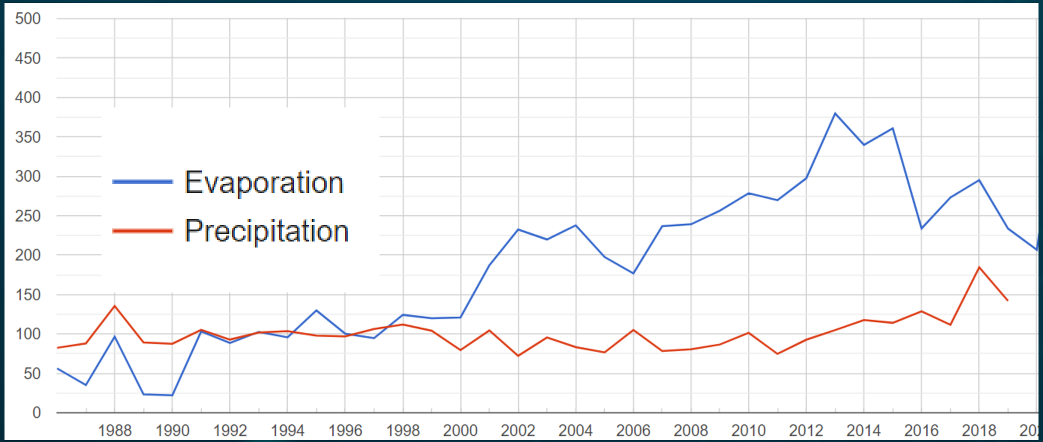


Case Study: HSEB ET time comparison with corrected Eddy ET at the US-ARM site for 2020

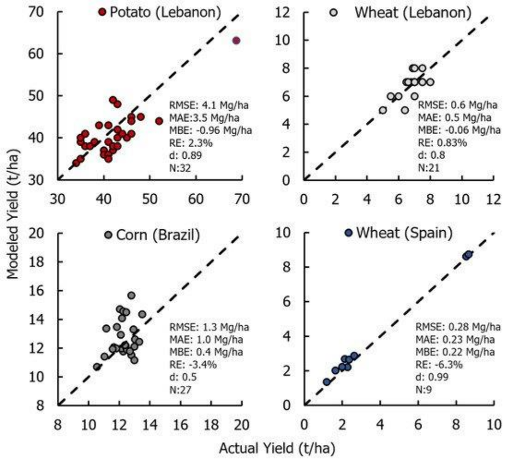
HSEB: Global 30m Landsat-based ET

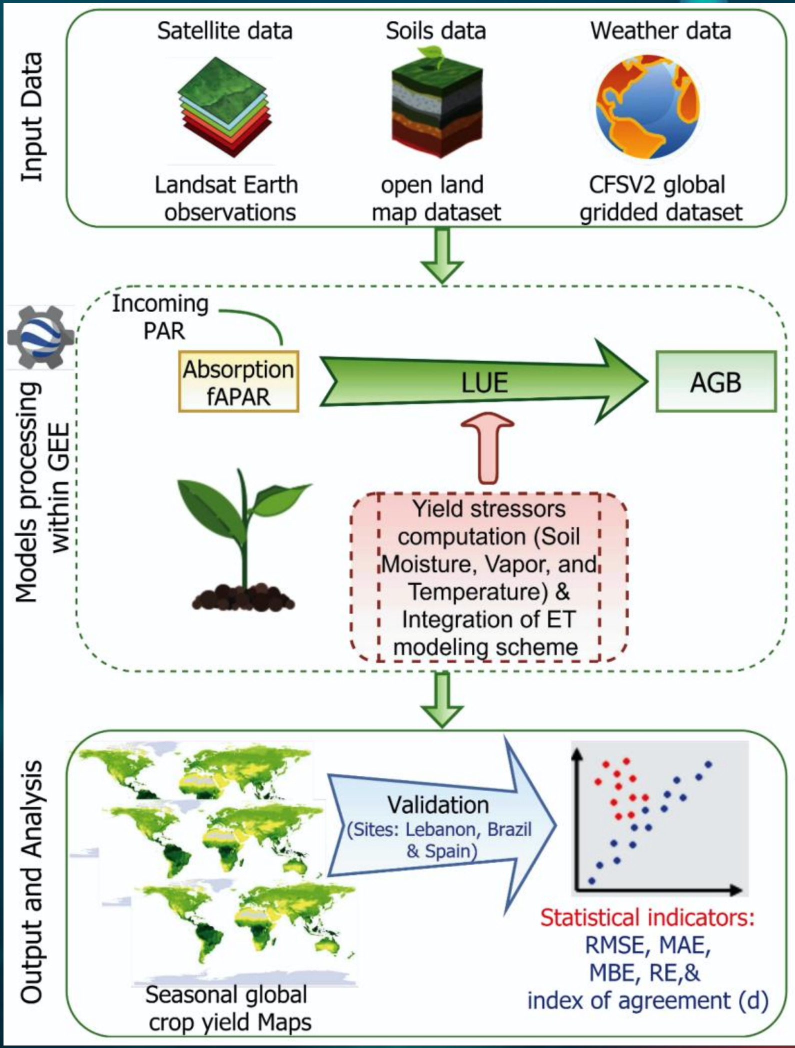



1986 @HadiHJaafar


Evaporation
Precipitation
500
450
400
350
300
250
200
150
100
50
0
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
2018

GYMEE- global water use, biomass, and productivity, at the sub-field level using multisource satellites and GEE





Jaafar, Hadi, and Roya Mourad. "GYMEE: A Global Field-Scale Crop Yield and ET Mapper in Google Earth Engine Based on Landsat, Weather, and Soil Data." *Remote Sensing* 13.4 (2021): 773.

Conclusions

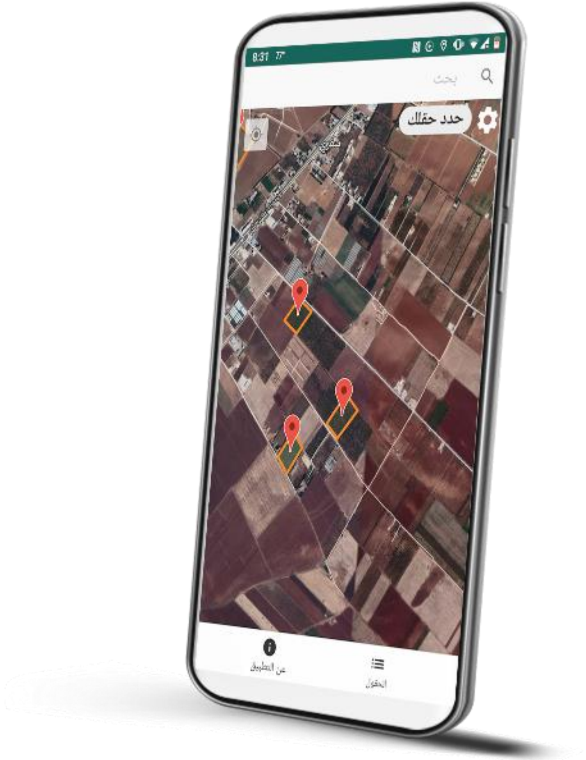
- A robust field-scale global evaporation mapper is presented
- HSEB generates a 2–3-day ET product globally at the 30-m and 10–20-m resolution
- HSEB provides a good representation of daily evapotranspiration and compares well with ECOSTRESS
- HSEB provides reasonably accurate results at the weekly and monthly time-scales
- HSEB has a high capacity to estimate field-scale ET over long periods accurately with high temporal frequency

Changing the Irrigation World

THE HEART OF EFFICENT WATER MANAGEMENT

TO COMBAT WATER SCARCITY

Now available on Google Play



AgSAT

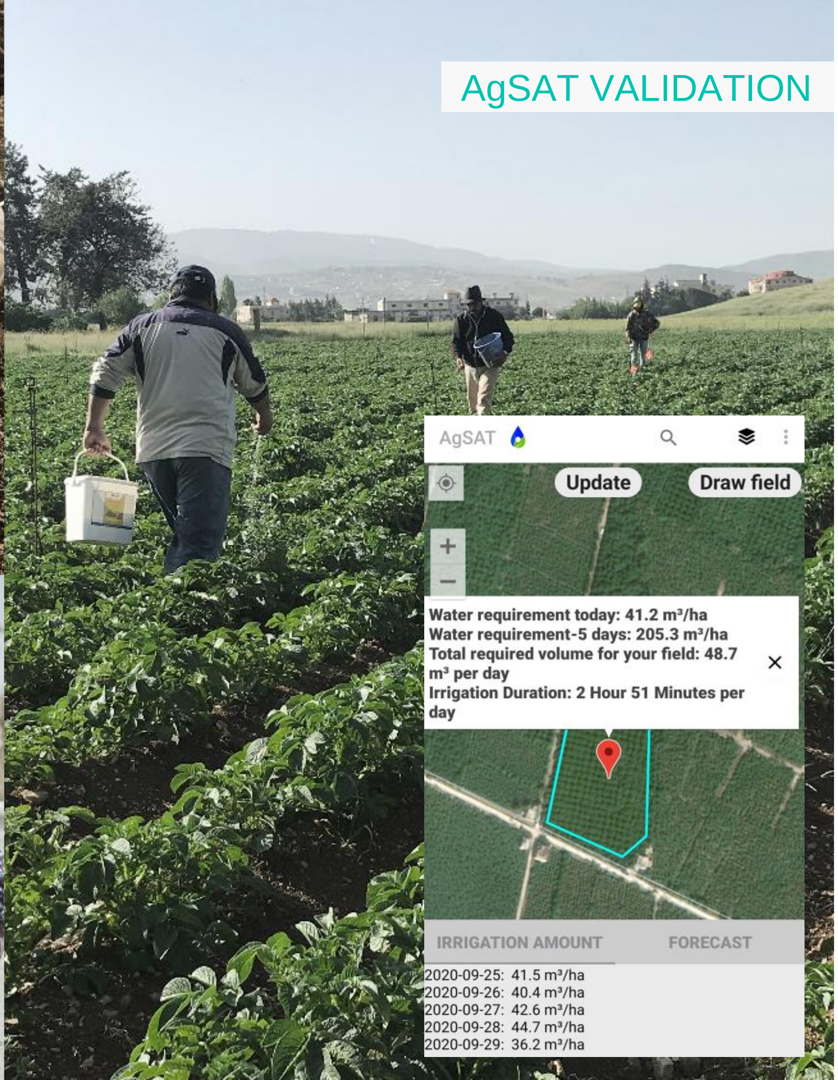
United Nations Educational, Scientific and Cultural Organization

IHE DELFT Institute for Water Education in partnership with UNESCO

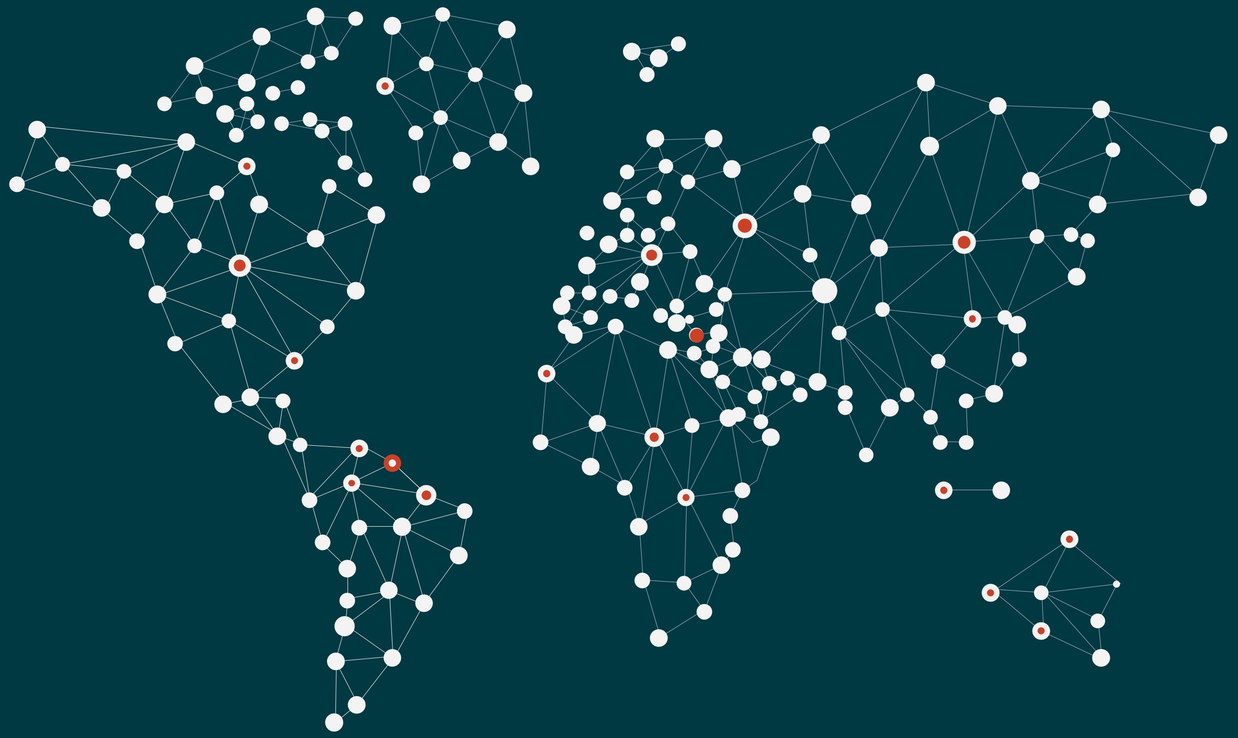
Ministry of Foreign Affairs Netherlands

Google.org

AgSAT VALIDATION



COUNTRIES WHERE AgSAT IS BEING USED



AgSAT

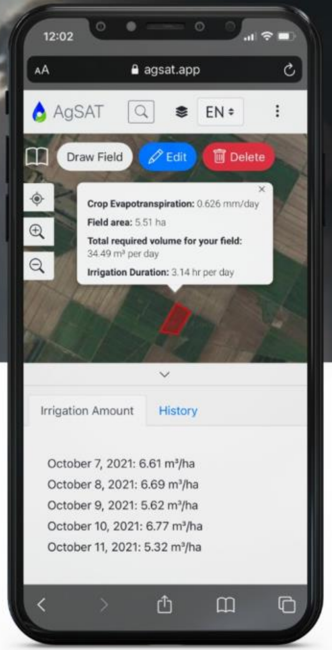
FOR A SUSTAINABLE WORLD

IRRIGATE
MORE **PRECISELY**

Anywhere, Anytime

Increase
CROP YIELD
Save
THE ENVIRONMENT

powered by Google

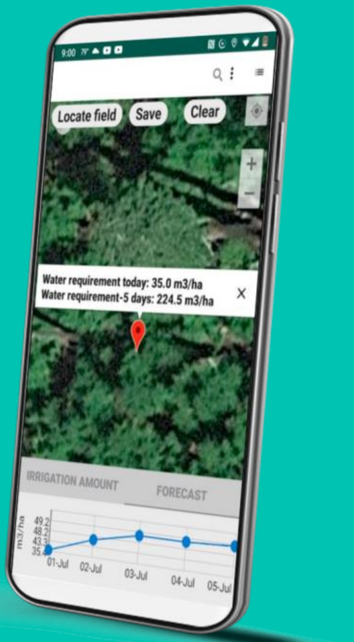


hj01@aub.edu.lb agsat.app

A CASE STUDY

Mobile & web application for water management– AgSAT

- AgSAT—is a mobile app developed at AUB with GEE as a backend
- Calculates daily water requirements using remote sensing and weather data
- to all types of users, from small-holder famers to irrigation districts and regional water planners in the Arab countries
- Farmers input information specific to their farms to receive irrigation water information (volume & run time) based on crop vegetation status, weather conditions, and irrigation system type



AgSAT

https://www.agsat.app/

United Nations Educational, Scientific and Cultural Organization

IHE DELFT Institute for Water Education in partnership with UNESCO

Ministry of Foreign Affairs Netherlands

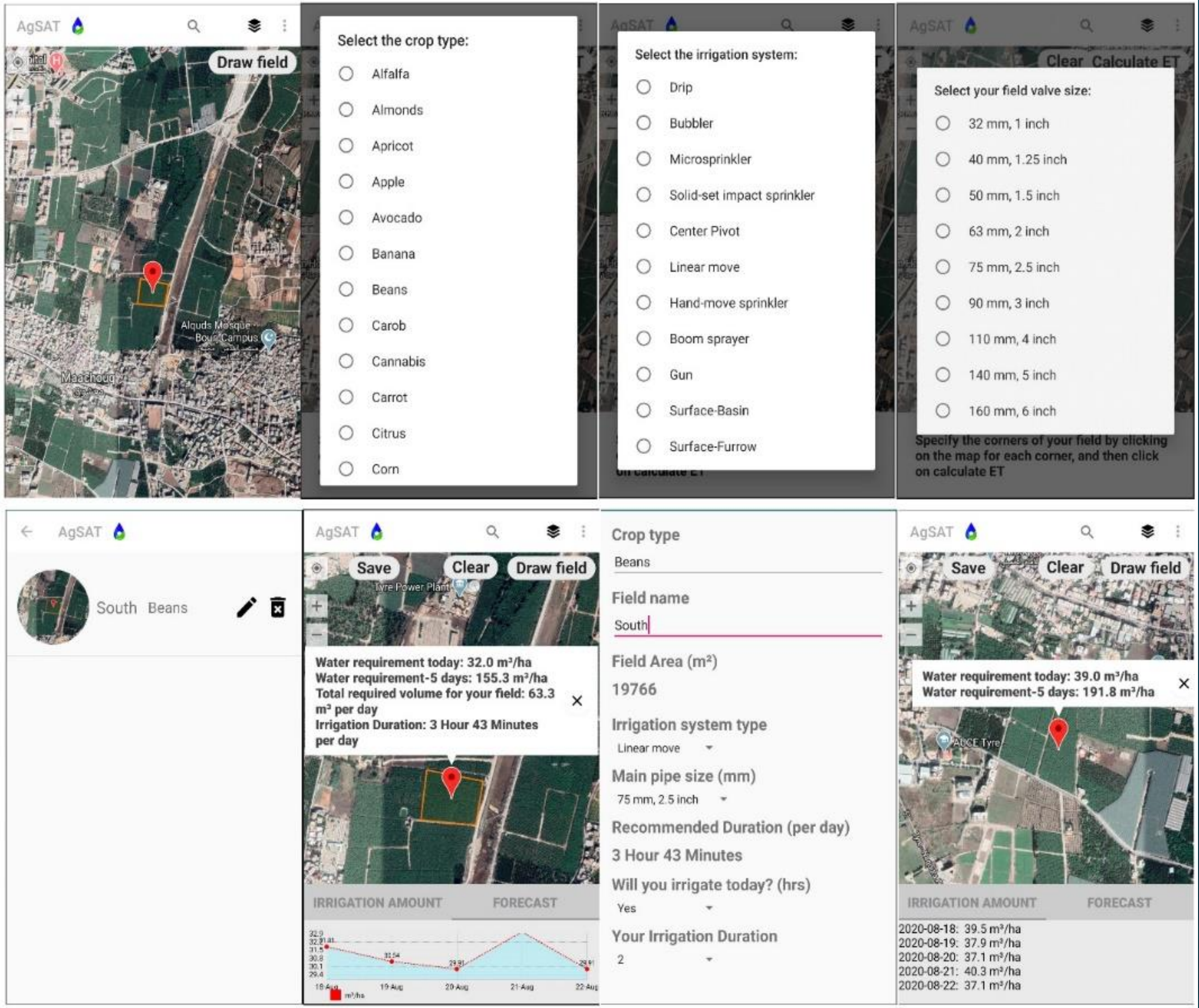
Google.org

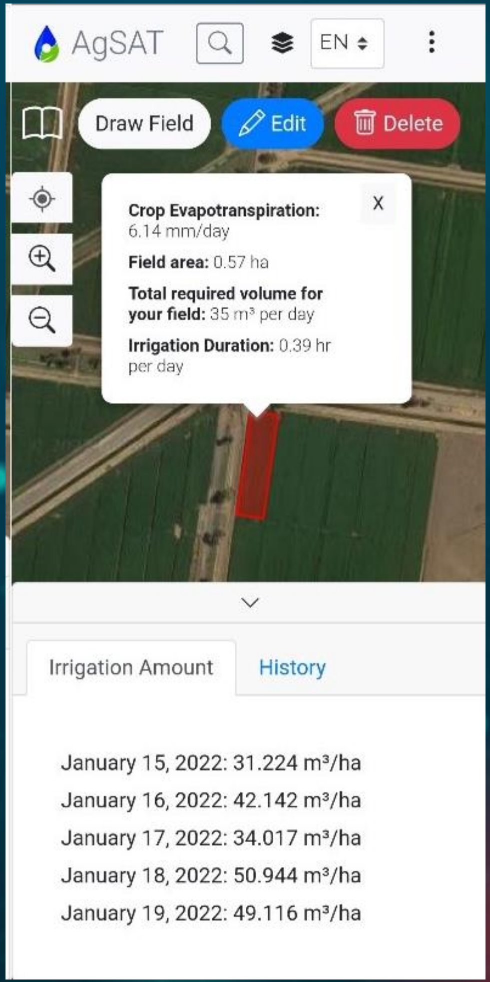
Farmer’s own data

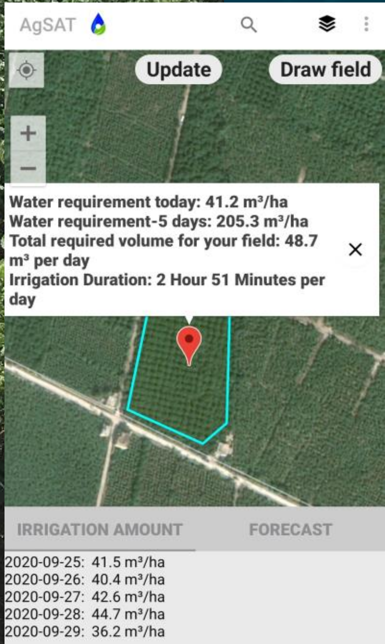
Reflectance-based
Growth Coefficients

ETref

Volumes per ha, Irrigation Run times, 5-Days ETc


AgSAT
Draw field
Alquds Mosque - Bourj Campus
Maachouq
Select the crop type:
Alfalfa
Almonds
Apricot
Apple
Avocado
Banana
Beans
Carob
Cannabis
Carrot
Citrus
Corn
Select the irrigation system:
Drip
Bubbler
Microsprinkler
Solid-set impact sprinkler
Center Pivot
Linear move
Hand-move sprinkler
Boom sprayer
Gun
Surface-Basin
Surface-Furrow
Clear Calculate ET
Select your field valve size:
32 mm, 1 inch
40 mm, 1.25 inch
50 mm, 1.5 inch
63 mm, 2 inch
75 mm, 2.5 inch
90 mm, 3 inch
110 mm, 4 inch
140 mm, 5 inch
160 mm, 6 inch
Specify the corners of your field by clicking on the map for each corner, and then click on calculate ET
AgSAT
South Beans
AgSAT
Save Clear Draw field
Tyre Power Plant
Water requirement today: 32.0 m³/ha
Water requirement-5 days: 155.3 m³/ha
Total required volume for your field: 63.3 m³ per day
Irrigation Duration: 3 Hour 43 Minutes per day
IRRIGATION AMOUNT
FORECAST
19 Aug
20 Aug
21 Aug
22 Aug
m³/ha
Crop type
Beans
Field name
South
Field Area (m²)
19766
Irrigation system type
Linear move
Main pipe size (mm)
75 mm, 2.5 inch
Recommended Duration (per day)
3 Hour 43 Minutes
Will you irrigate today? (hrs)
Yes
Your Irrigation Duration
2
AgSAT
Save Clear Draw field
Water requirement today: 39.0 m³/ha
Water requirement-5 days: 191.8 m³/ha
ALCE Tyre
IRRIGATION AMOUNT
FORECAST
2020-08-18: 39.5 m³/ha
2020-08-19: 37.9 m³/ha
2020-08-20: 37.1 m³/ha
2020-08-21: 40.3 m³/ha
2020-08-22: 37.1 m³/ha

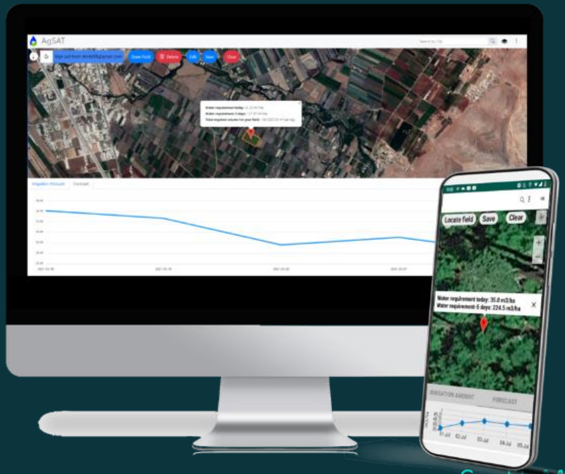

AgSAT
EN
Draw Field
Edit
Delete
Crop Evapotranspiration: 6.14 mm/day
Field area: 0.57 ha
Total required volume for your field: 35 m³ per day
Irrigation Duration: 0.39 hr per day
X
Irrigation Amount
History
January 15, 2022: 31.224 m³/ha
January 16, 2022: 42.142 m³/ha
January 17, 2022: 34.017 m³/ha
January 18, 2022: 50.944 m³/ha
January 19, 2022: 49.116 m³/ha


AgSAT
Update
Draw field
Water requirement today: 41.2 m³/ha
Water requirement-5 days: 205.3 m³/ha
Total required volume for your field: 48.7 m³ per day
Irrigation Duration: 2 Hour 51 Minutes per day
IRRIGATION AMOUNT
FORECAST
2020-09-25: 41.5 m³/ha
2020-09-26: 40.4 m³/ha
2020-09-27: 42.6 m³/ha
2020-09-28: 44.7 m³/ha
2020-09-29: 36.2 m³/ha

WHERE CAN AgSAT BE USED

- Anywhere in all countries where irrigation is practiced
- where cellular network coverage is available
- where farmers have smart phones
- at the district level or water authority level
- Currently the app is being used in Sudan, Egypt, UEA, Saudi Arabia, Lebanon, as well as other countries

Trends in precipitation in the Maghreb region



Credit: Mapio

HOW & WHO CAN UTILIZE AgSAT

- **Ministries** and **Municipalities**
- **Farmers**
- Irrigation **engineers**
- Water **authorities**
- Large and small farming **enterprises**
- **NGOs**
- **Ag companies**
- **Leading organizations** (ESCWA, WB…)

Case study- III

TALANOA-WATER

Integrated management of water resources in the Mediterranean

1866 AUB American University of Beirut

PRIMA PARTNERSHIP FOR RESEARCH AND INNOVATION IN THE MEDITERRANEAN AREA

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THANK YOU!

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