Quantifying Groundwater Use for Irrigation in Arid Regions

Leveraging Remote Sensing ET Data

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Cairo Water Week, ESCWA Team,
October 30 – November 1, 2023

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INTRODUCTION

- **The Importance of Sustainable Groundwater Management**
  - Crucial for ensuring long-term water security in arid regions.
  - Strategies for balancing groundwater extraction with recharge rates.
  - Protect vital water resources for future generations.

Challenges in Quantifying Groundwater Use

- Traditional methods of measuring groundwater use, such as well metering, are often limited in data-scarce regions.
- There is a need for alternative approaches to estimate irrigation water use from groundwater sources.

Monitoring and Improving Irrigation Efficiency

- Identifying areas of excessive water use can guide targeted interventions to improve irrigation practices.
- Enhancing irrigation efficiency can conserve water resources and reduce environmental impacts.

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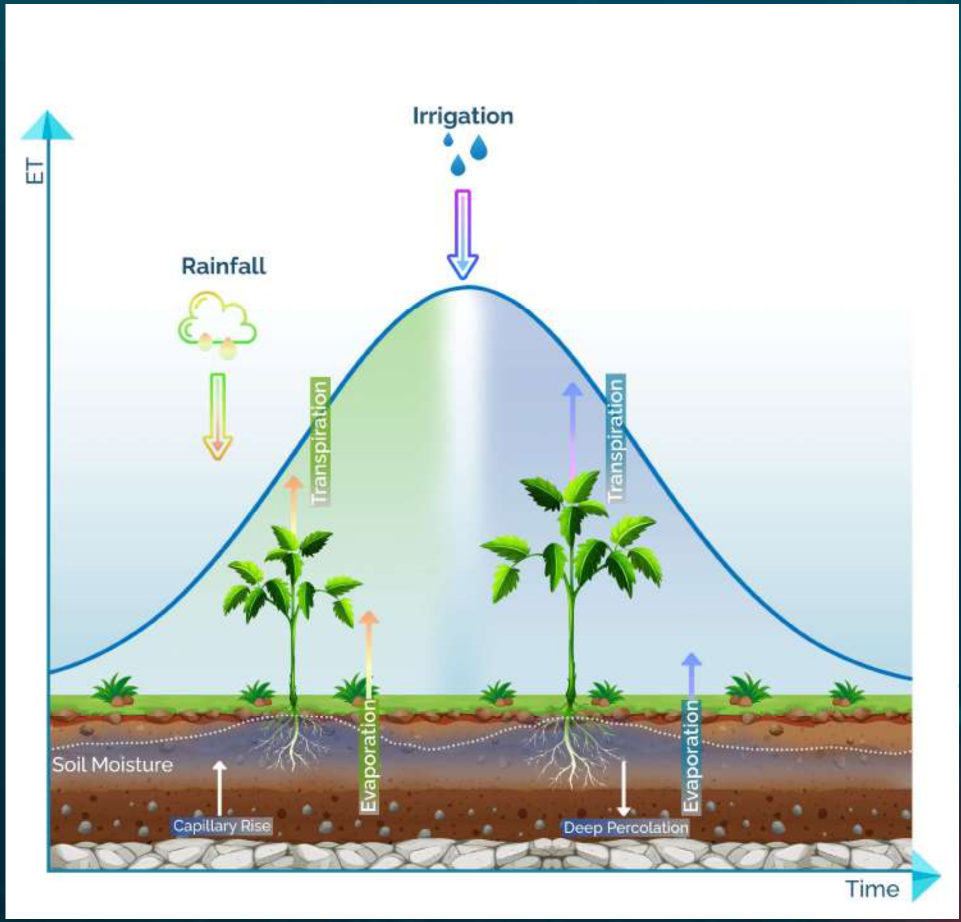
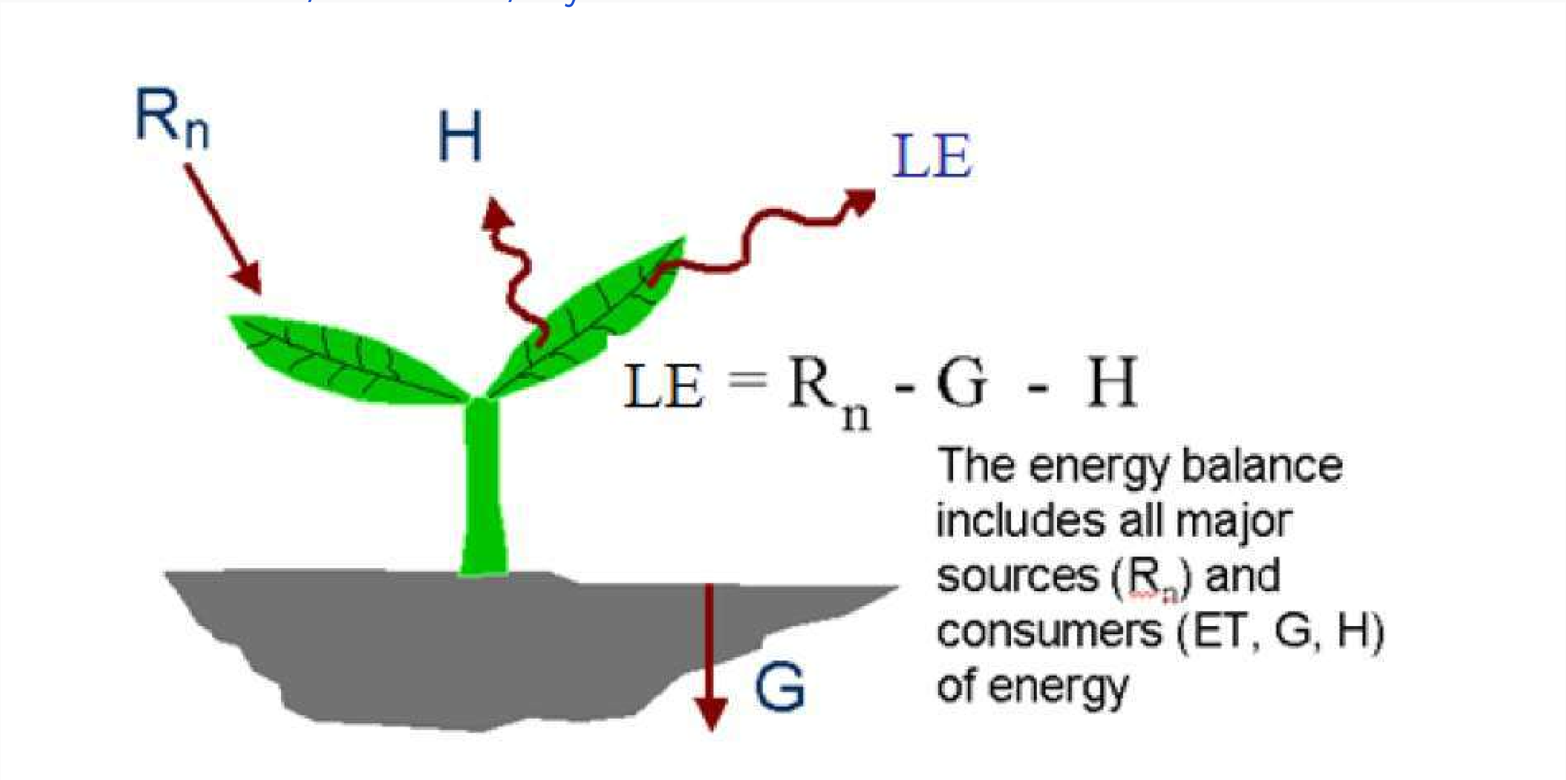
THE ROLE OF REMOTE SENSING Precip and ET DATA

- **Actual Evapotranspiration**
  - The total amount of water vapor released into the atmosphere through the combined processes of evaporation and transpiration.

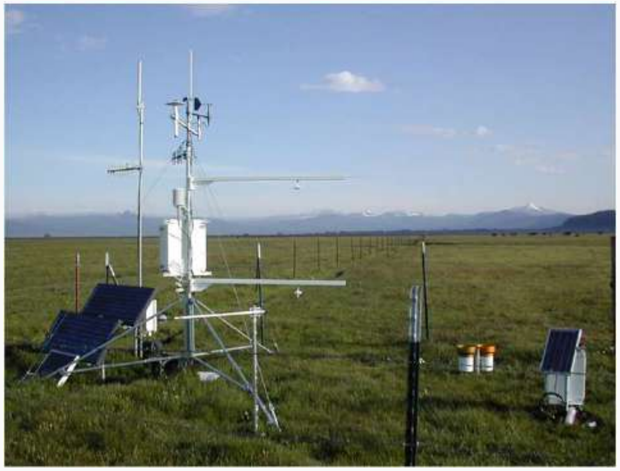


Single Source Energy Balance to estimate water use

- Latent heat of 28 W/m^2 = 1 mm/day



Measuring Water Use- Remote Sensing



- What do we need:
  - Quality weather data
  - Thermal Imagery (Landsat) 30-m applications
  - Proba V or VIIRS Imagery for 100-m 250-m applications
  - A computer Coding the equations (Python, Google Earth Engine)
  - For validation: lysimeter, yield/biomass measurements/, Eddy Covariance flux towers, Bowen Ratio station, Leaf Area Index Meter

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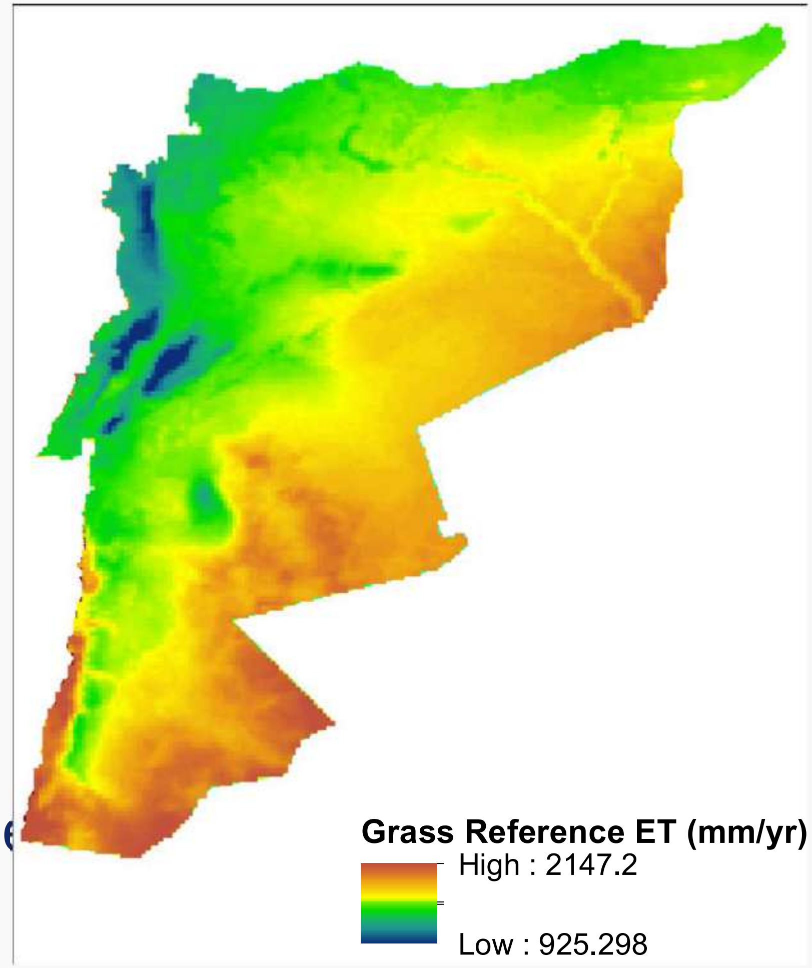
CHALLENGES

- **Challenges**

ET depends on many variables:

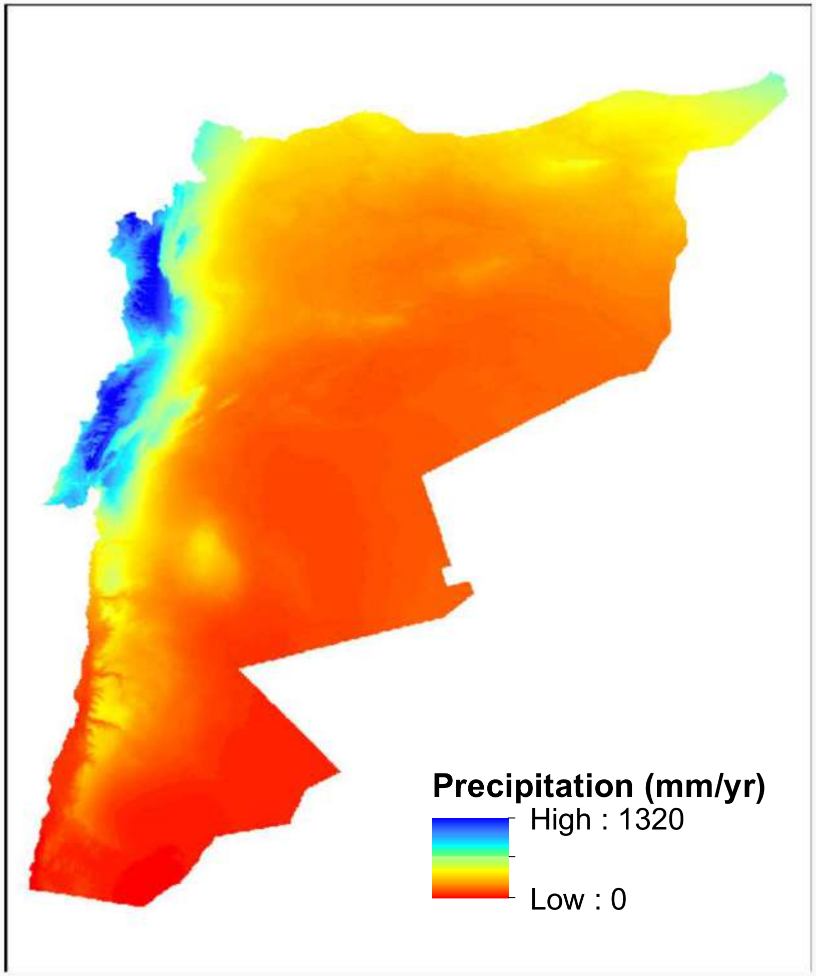
- solar radiation at the surface
- Land and air temperatures
- Humidity
- Surface winds
- Soil conditions
- Vegetation cover and types
- Highly variable in space and time



- **Challenges**

Rainfall data from satellites bears uncertainty

Workaround: use a gauge-corrected Precip. Product
(CHIRPS, IMERG)

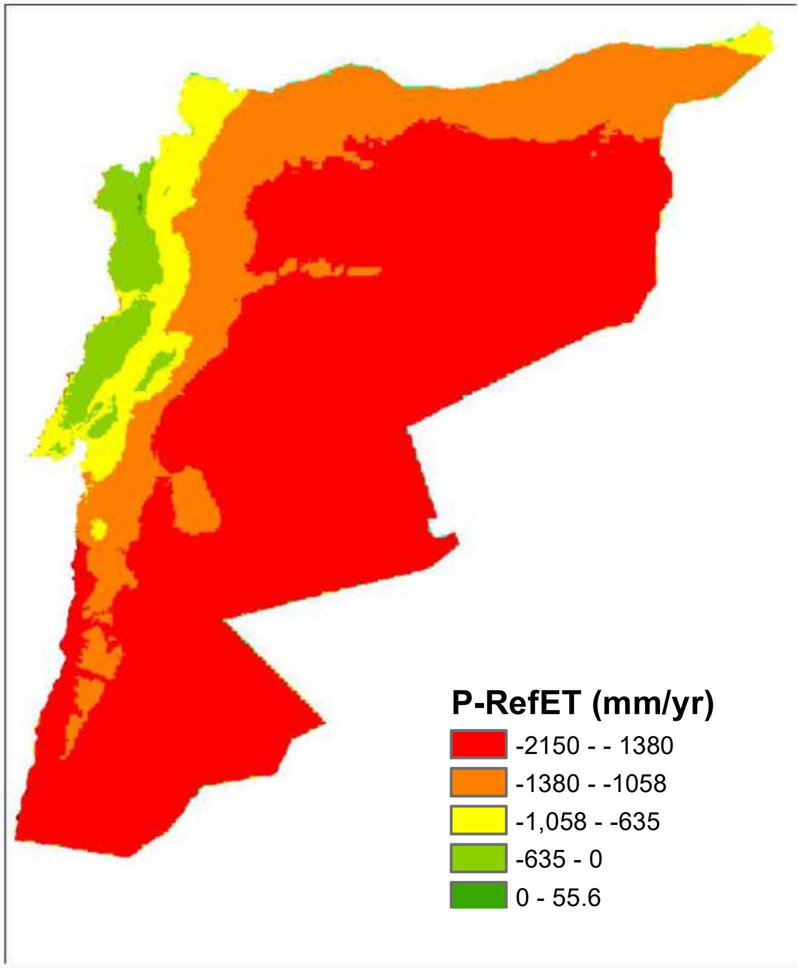


- **Advantages for RS in Estimating Irrigation Water Use**

  - Spatial coverage: ET rates across vast areas, including remote or inaccessible regions.

  - Temporal coverage: acquired regularly, allowing for continuous monitoring of irrigation water use over time.

  - Cost-effectiveness: Remote sensing ET data are more cost-effective than traditional ground-based methods, especially for large-scale assessments.



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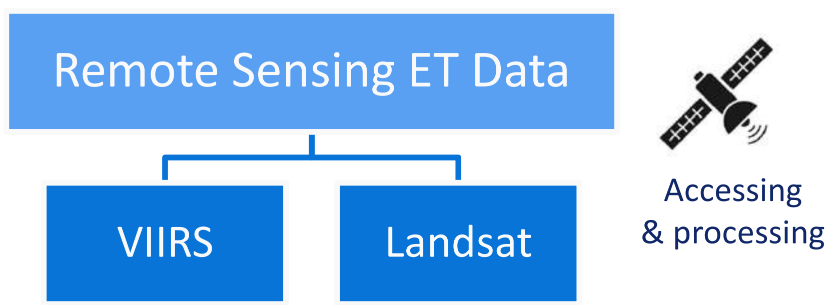
METHODOLOGY

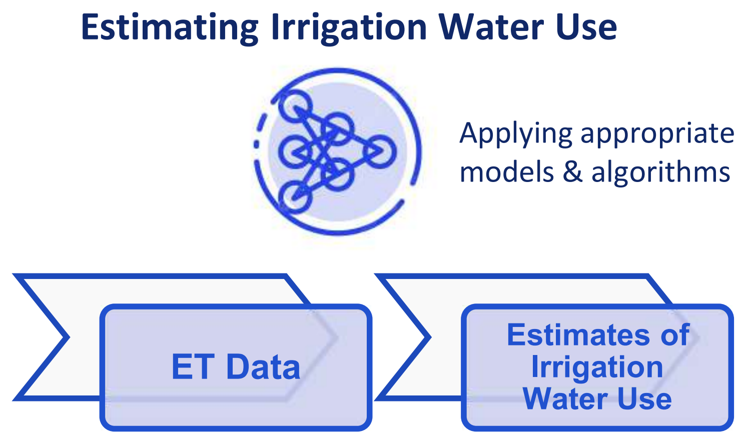
Utilizing Remote Sensing ET and Rainfall Data

- **Remote sensing data** can provide valuable inputs for the **water balance approach**:

- Evapotranspiration (ET) data: Satellite-derived ET data can be used to estimate the **amount of water lost to the atmosphere from the land surface**.
- Rainfall data: Satellite-based rainfall estimates or ground-based rainfall measurements can provide information on the **amount of local precipitation received**.

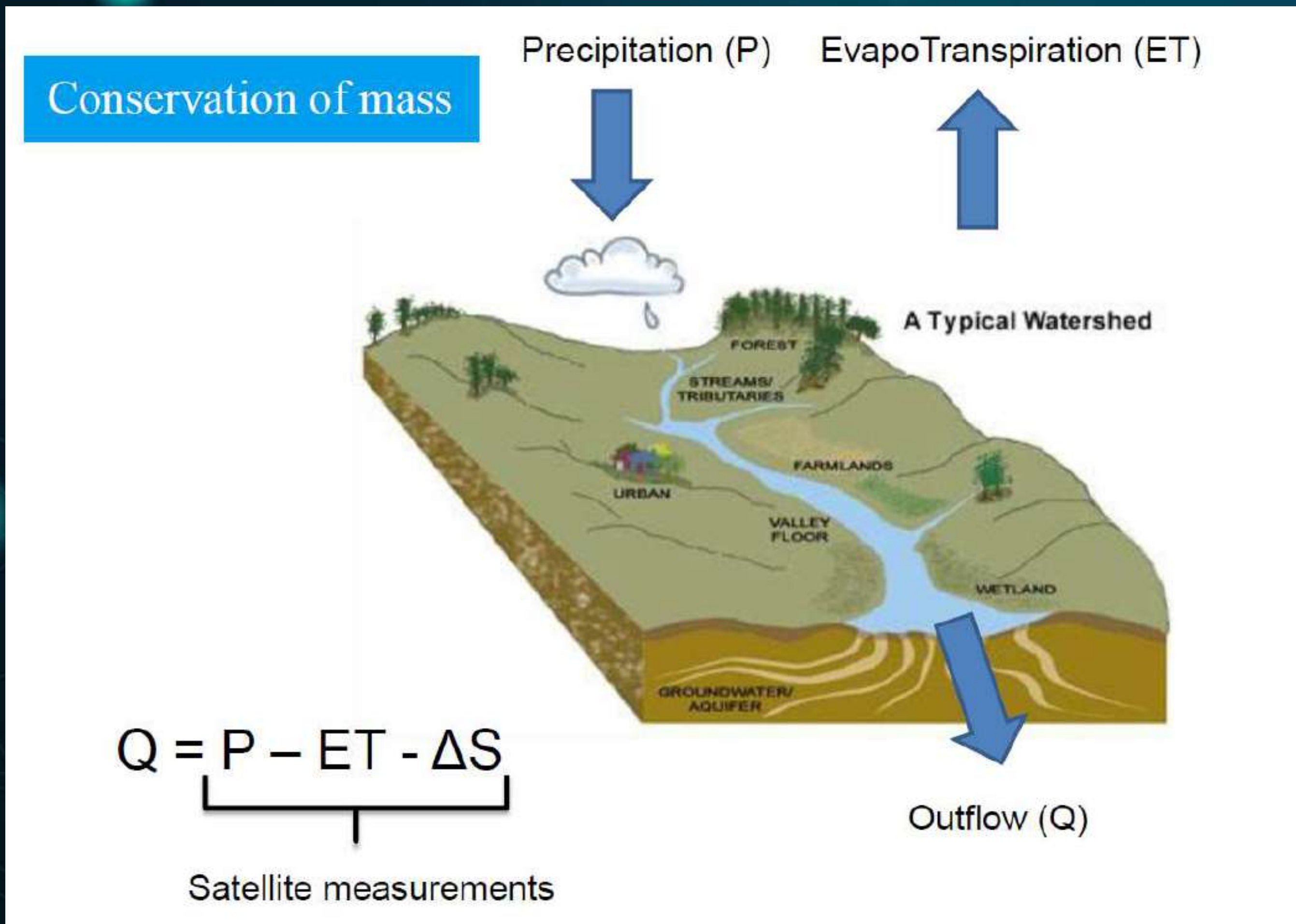
Methodology for Estimating Irrigation Water Use from Remote Sensing ET Data





Addressing assumptions and limitations of the methodology: need to disentangle ET component into two: Green ET and Blue ET

- Green ET ←  Blue ET ← 
- Where no surface water exists, blue ET comes from groundwater in full



Estimate deficit in rainfall to measure change in storage

GW abstractions: evident by drop in water levels

Water Balance Approach for Estimating Groundwater Use

Change in Storage = Precipitation - Evapotranspiration - Runoff - Groundwater Use

↳ **Groundwater Use = Precipitation - Evapotranspiration - Runoff - Change in Storage**

- Over long periods of time, change in storage can be assumed negligible

  ↳ **Groundwater Use = Precipitation - Evapotranspiration - Runoff**

- In dry areas, runoff can be zero (except during flash floods)

  ↳ **Groundwater Use = Precipitation - Evapotranspiration**

Estimating Runoff and Storage Change

- Runoff: using **hydrological models or empirical relationships** based on soil type, topography, and rainfall intensity.

- Storage change: using **groundwater level measurements or models** that simulate groundwater flow and storage dynamics.

Some options - ET

- EEflux (METRIC)- 30 m- Weekly (L8-L9). Download images one by one–takes a lot of time; slow server
- pySEBAL - 30 m- Weekly (L8-L9) for 30m. Can be daily for 300 m VIIRS - Download images one by one–takes a lot of time
- Landsat SSEBOP- need to order 30 m- Weekly (L8-L9). Can be analyzed using any GIS software.
- VIIRS SSEBOP- daily, decadal, monthly, annual- available
- **GEE – my favorite**
- SenET – 5- day Sentinel2. Lag of three months. Two source energy balance available as a plugin in SNAP, Copernicus ESA Software – based on TSEB
    - Need to download images locally one by one.
    - 20-m ET generated for Sentinel 2 scenes using S3 Thermal Imagery sharpened with PyDMS from S2

Some options - Rainfall

- Gauge records
  - Low resolution
  - Point estimates
  - Can be uncertain

- CHIRPS – 7 m resolution, available since 1980 – gauge corrected
- IMERG (NASA – GPM, TRMM)
- Combination

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APPLICATIONS & LIMITATIONS

Applications of the Water Balance Approach

Applications

- Estimating groundwater use for irrigation in data-scarce regions.
- Assessing the sustainability of groundwater resources.
- Evaluating the impact of irrigation practices on groundwater depletion.

Limitations of the Water Balance Approach

Limitations

- Accuracy of ET and rainfall data.
  - Uncertainties in runoff and storage change estimates.
  - Assumptions about the spatial and temporal variability of water balance components.

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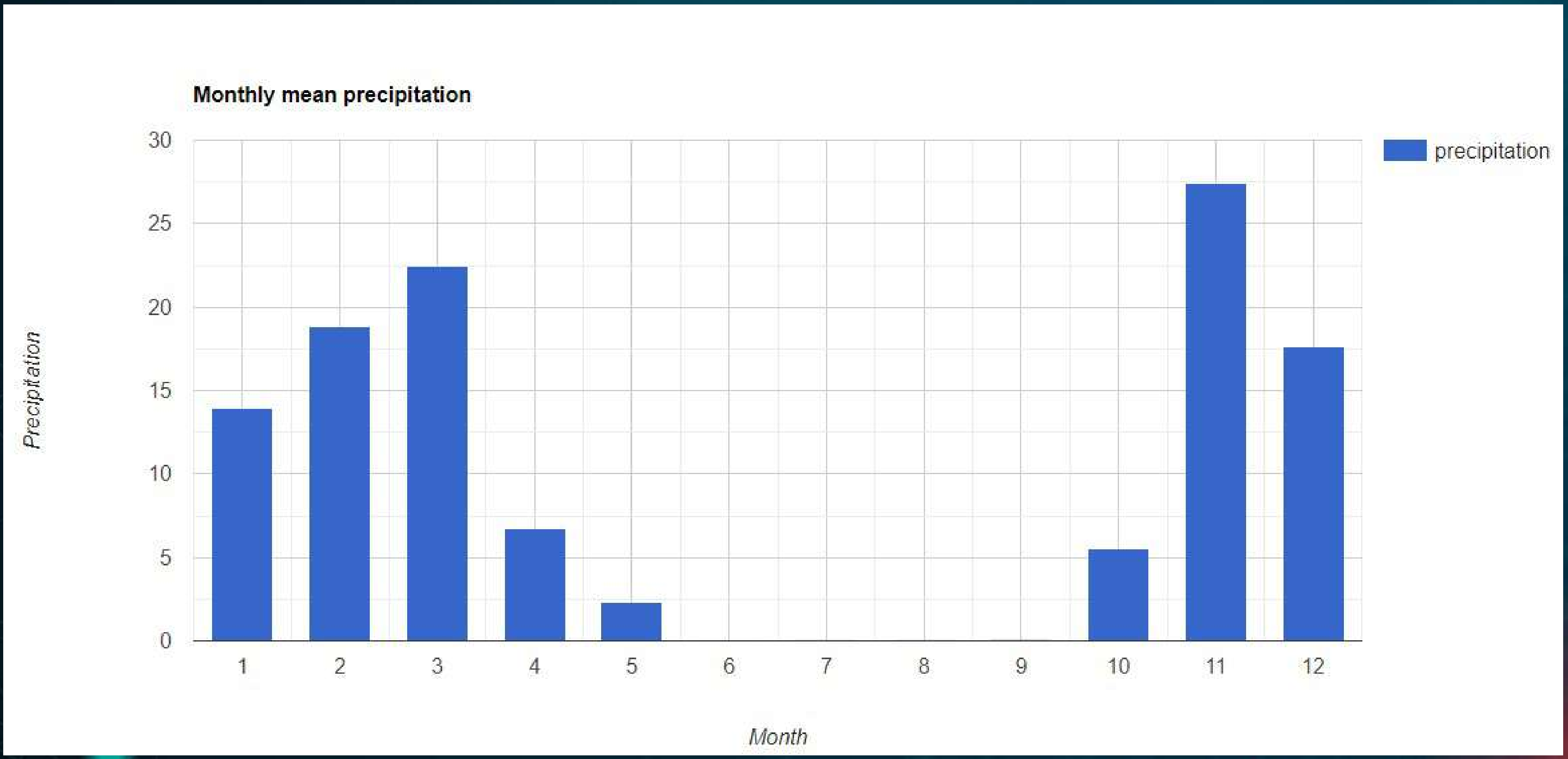
CASE STUDIES

Case Study-Skaka Saudi Arabia

Objectives:

- Present a case study of using remote sensing ET and Rainfall data to estimate groundwater use for irrigation in a specific arid region.
- Showcase the results of the case study, including spatial and temporal patterns of irrigation water use.
- Discuss the implications of the findings for water resource management in the region.



Monthly mean precipitation
precipitation
Precipitation
30
25
20
15
10
5
0
1
2
3
4
5
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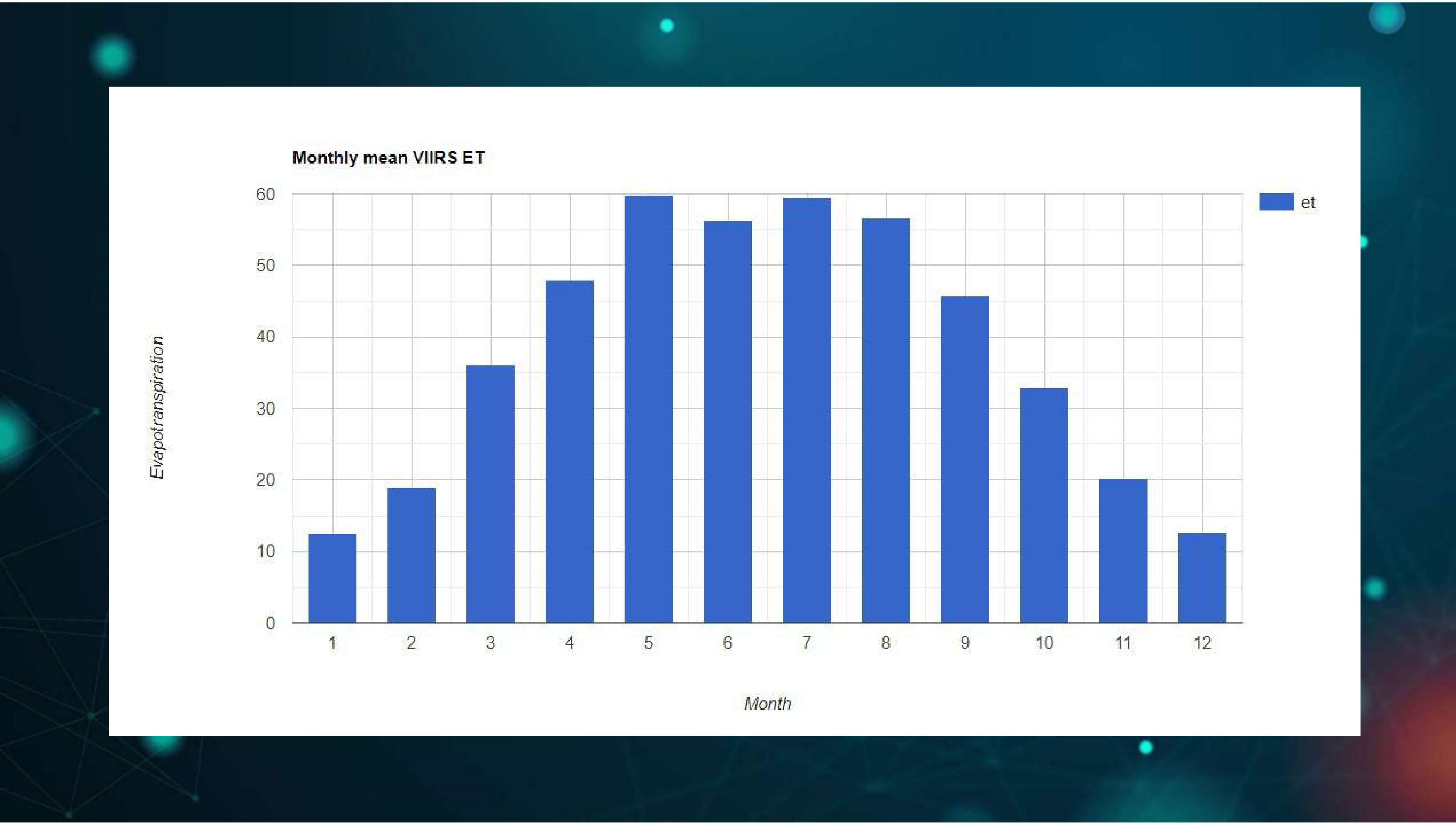
7
8
9
10
11
12
Month


Monthly mean VIIRS ET
Evapotranspiration
Month
et
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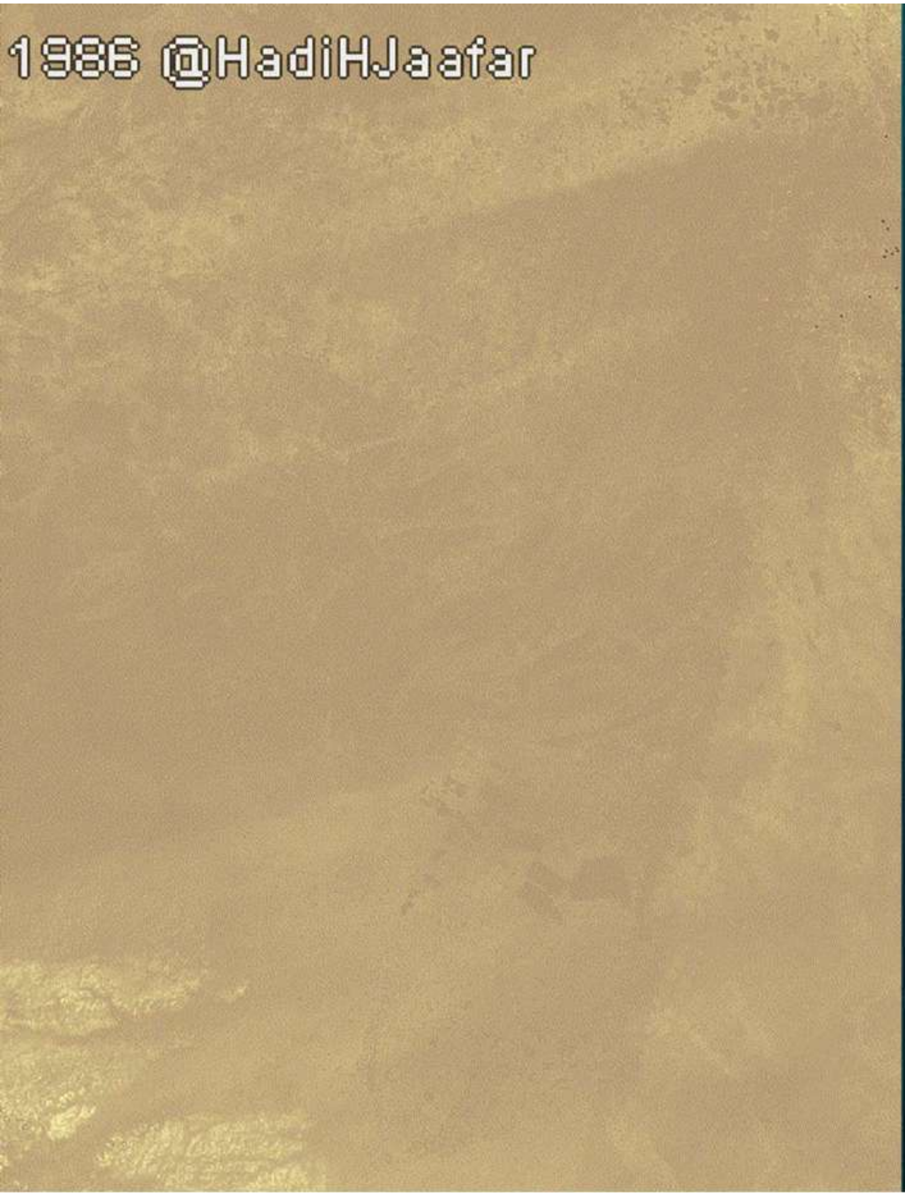
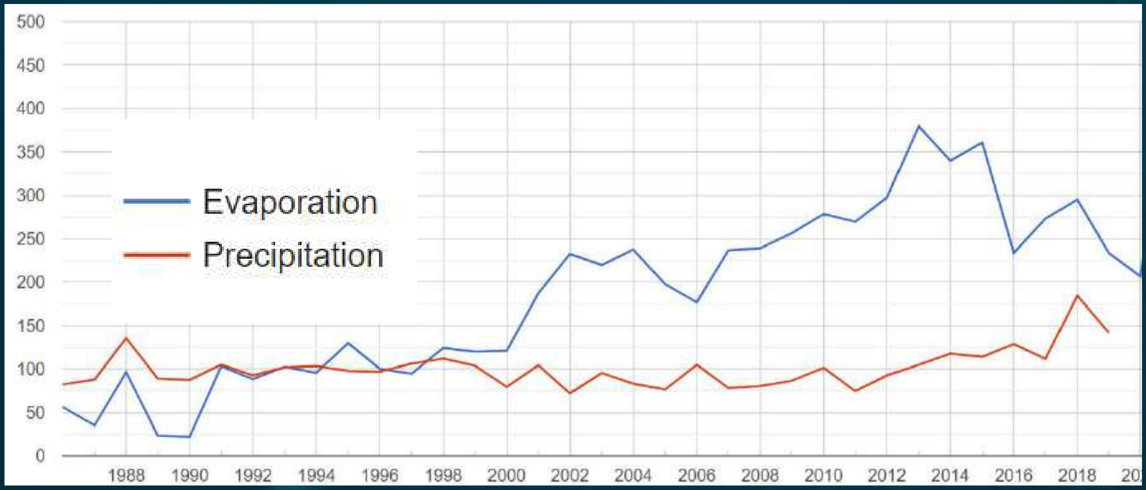
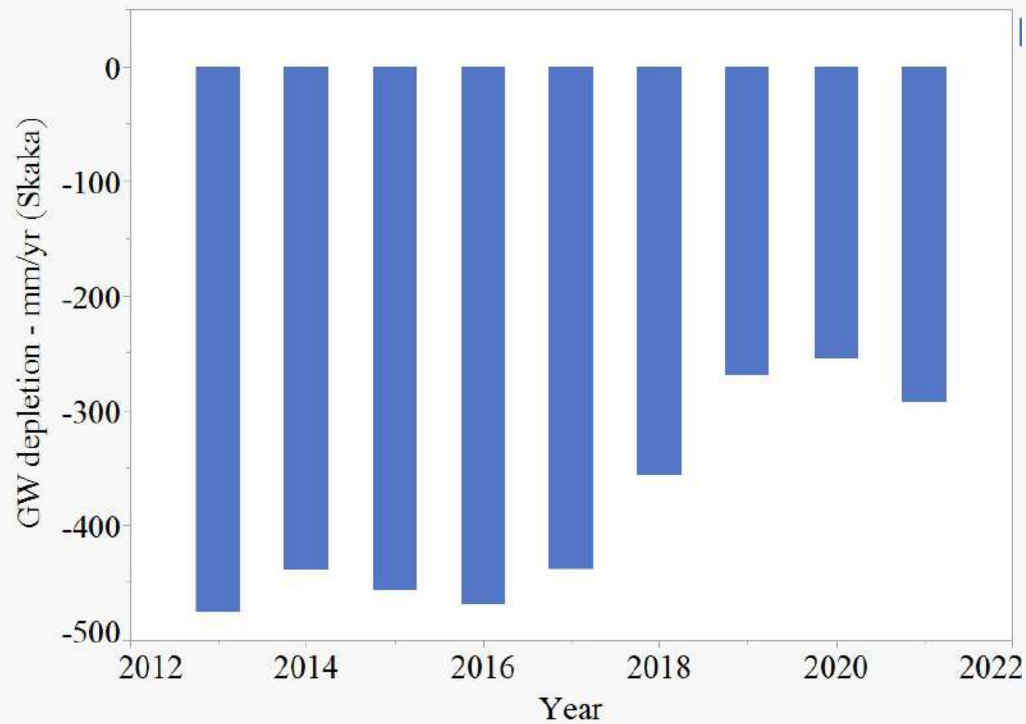


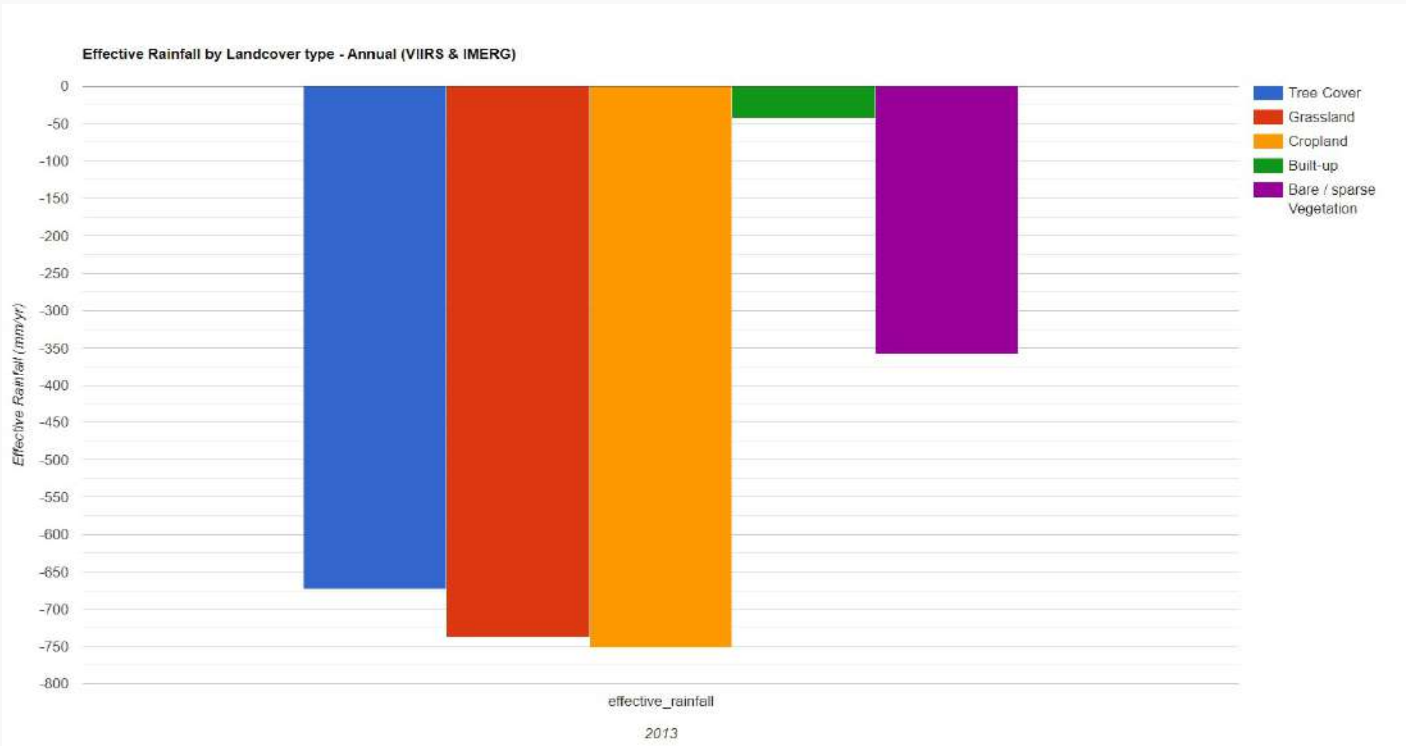
Case Study-Skaka Saudi Arabia



GW use by year for Skaka

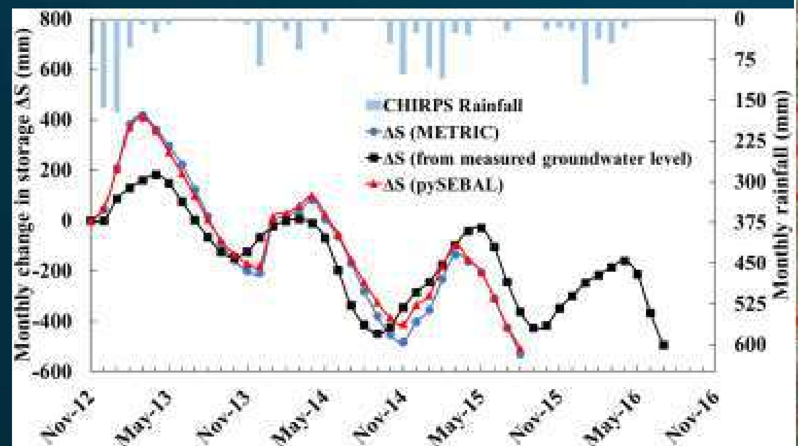


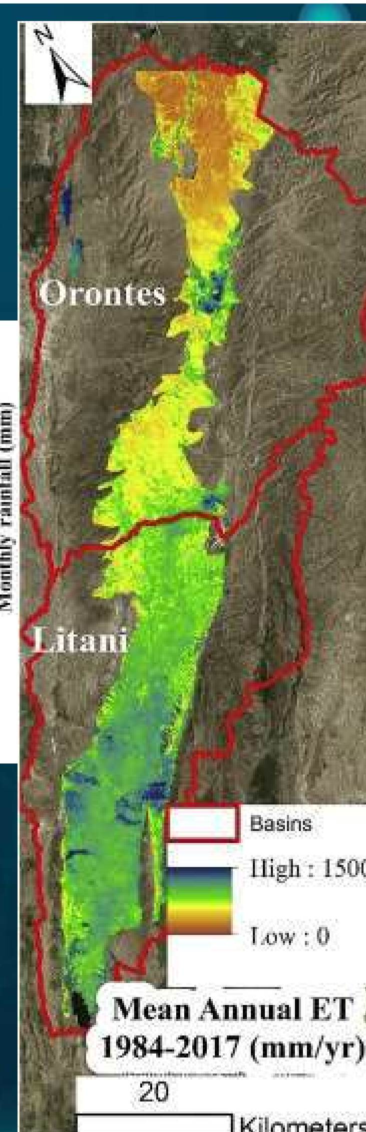
GW use by Landcover or crop type



Case Study II

- Monitor irrigation use from space anywhere anytime at the field scale
- Monitor and forecast yields
- Estimate groundwater pumping from aquifers
- Set policies, determine allocations, assess sustainability

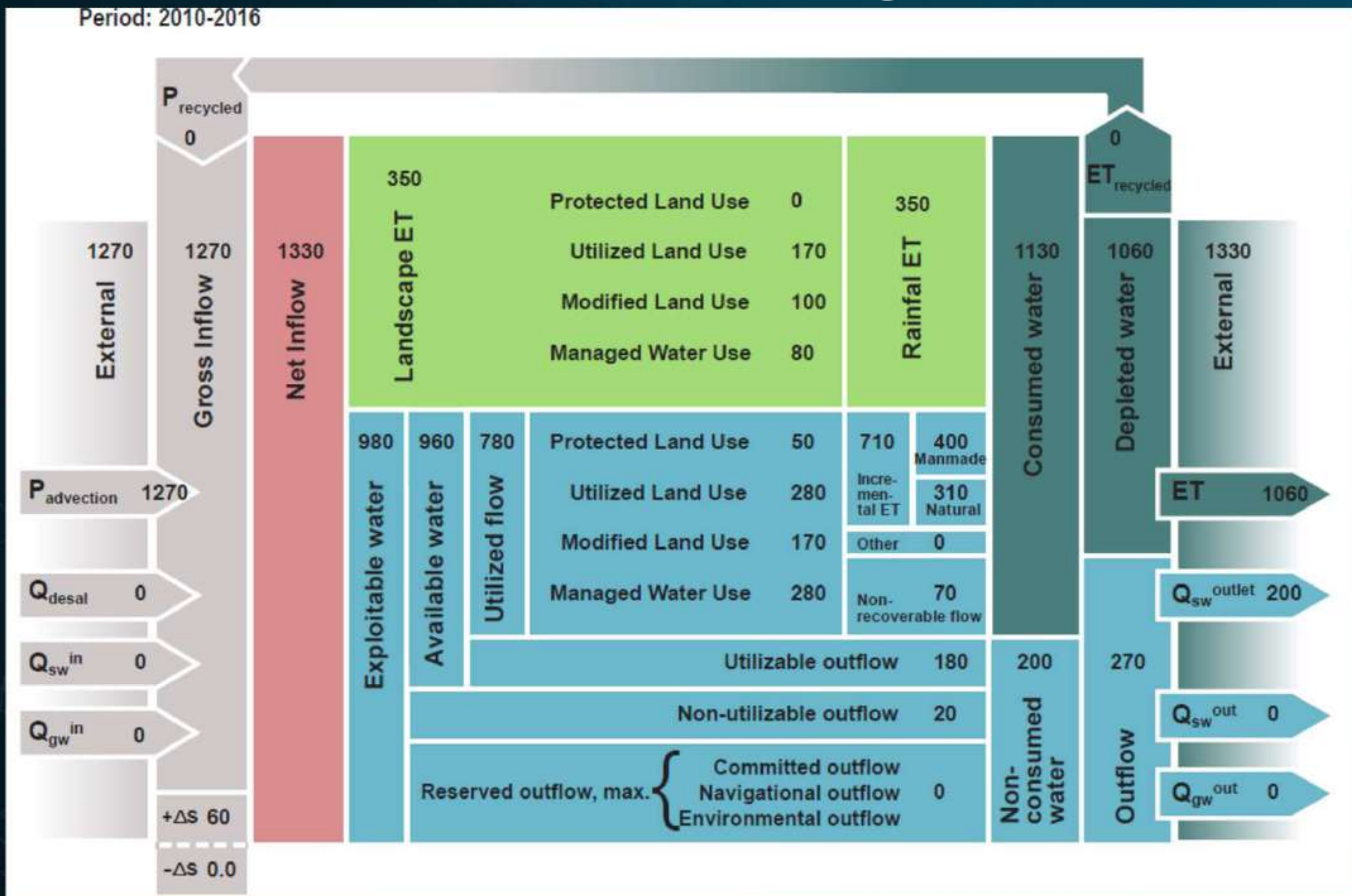




Jaafar, Hadi H., and Farah A. Ahmad. "Time series trends of Landsat-based ET using automated calibration in METRIC and SEBAL: The Bekaa Valley, Lebanon." *Remote Sensing of Environment* 238 (2020): 111034.

Case study- III

Water Accounting



The Litani basin is **losing storage** on the long term, the storage **deficit** is not recovered during the annual cycles

Conclusion

Key Takeaways and Future Directions:

- Remote sensing ET data offers a promising approach for estimating groundwater use for irrigation in arid regions.
- The methodology provides valuable insights into irrigation patterns and water consumption, aiding in sustainable groundwater management.
- Questions and discussion