Soil moisture and Remote Sensing Applications for Agriculture

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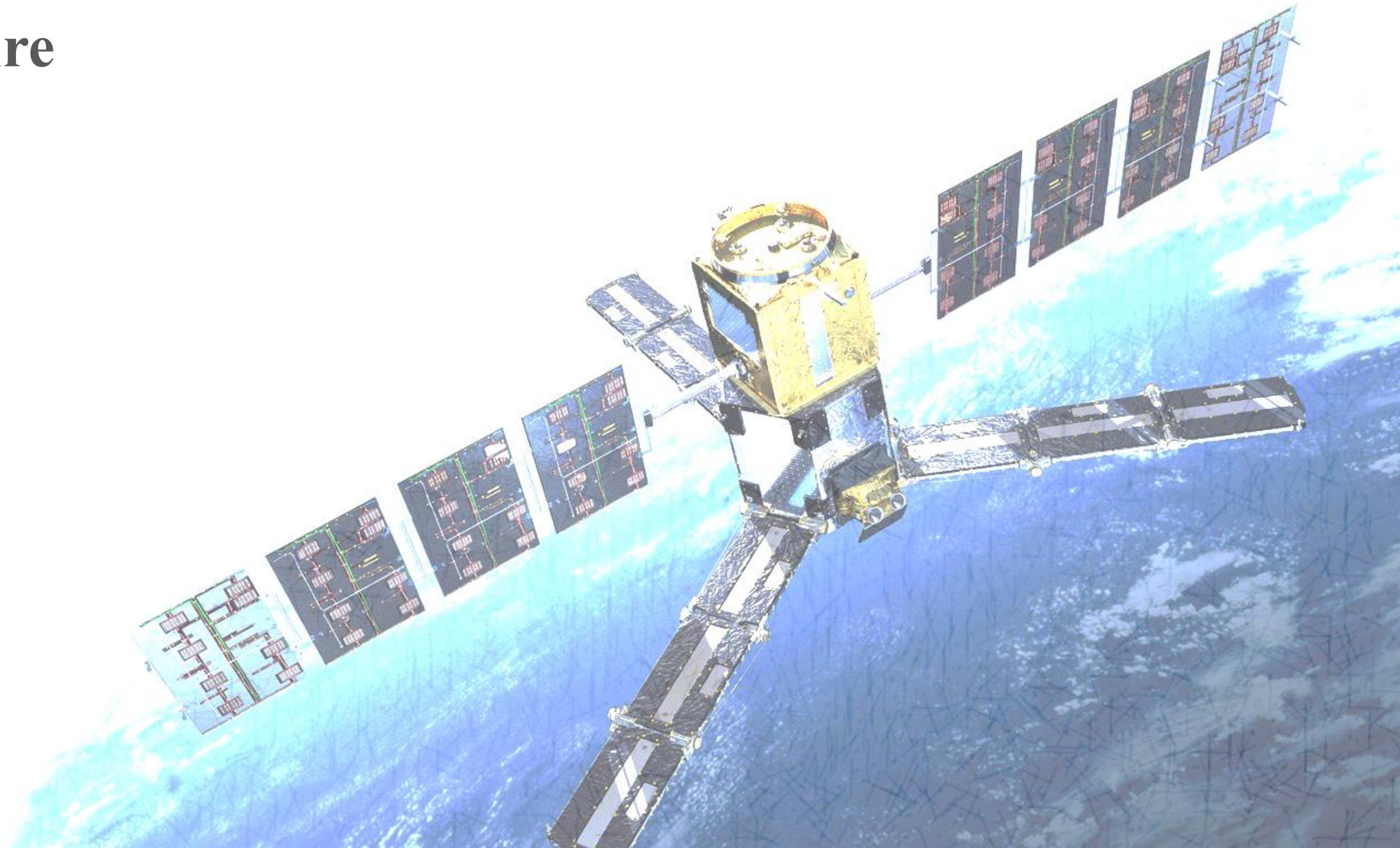
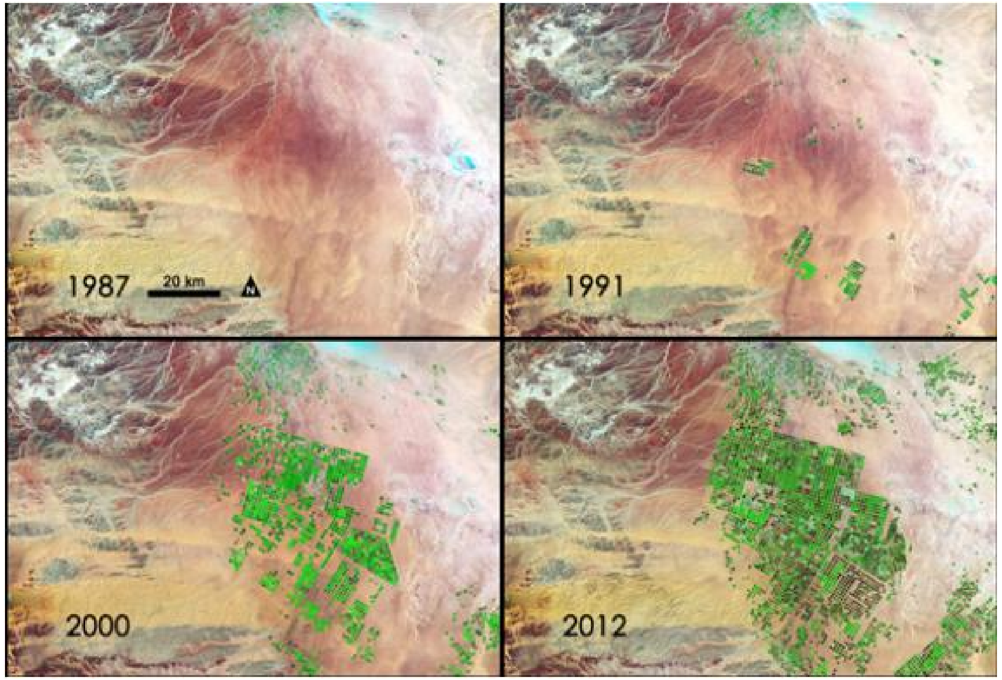
CONTENTS

- Why use satellite remote sensing for agriculture applications?
- Satellites & Sensors for Agricultural Applications
- Soil Moisture for Agricultural Applications
- Method for Measuring Soil Moisture
- Application
  - Irrigation detection
  - Irrigation quantification
  - Irrigation scheduling
  - Drought monitoring
- Future Directions



Why use satellite remote sensing for agriculture applications?

- Local to global coverage
- Frequent monitoring for timely decision-making
- Multi-spectral imaging reveals vegetation health, soil characteristics, and water content
- Remote accessibility allows for data retrieval from anywhere
- Cost-effective alternative to traditional data collection methods

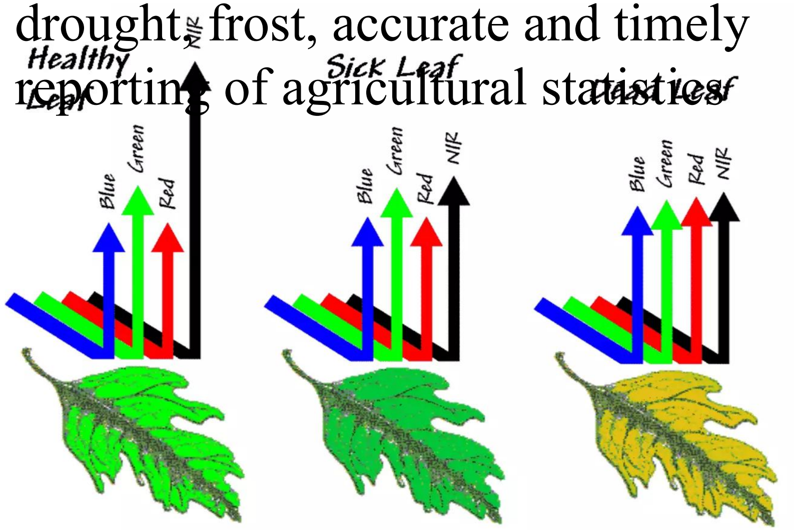


Evolution of agricultural operations in the Wadi As-Sirhan Basin, Saudi Arabia. Captured by Landsat satellites 4, 5, and 7 in 1987, 1991, 2000, and 2012. Image Credit: NASA

Why use satellite remote sensing for agriculture applications?

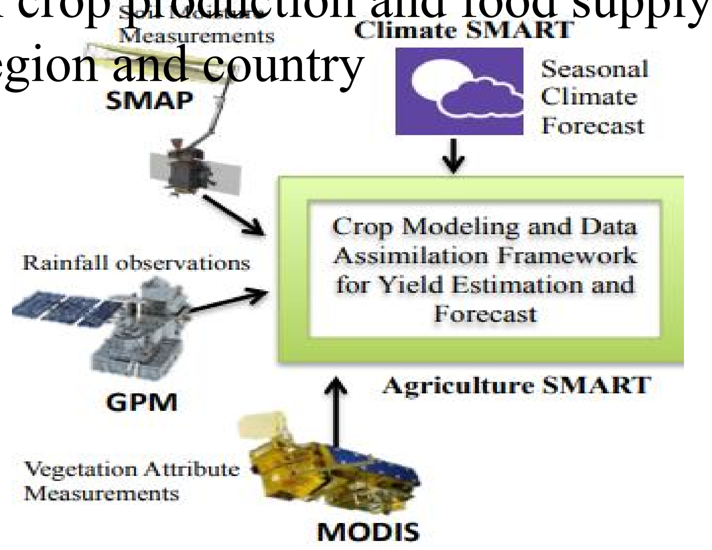
Crop Monitoring

Phenology, crop area, crop type, crop condition, yield, irrigated landscape, flood, drought, frost, accurate and timely reporting of agricultural statistics



Crop Forecasting

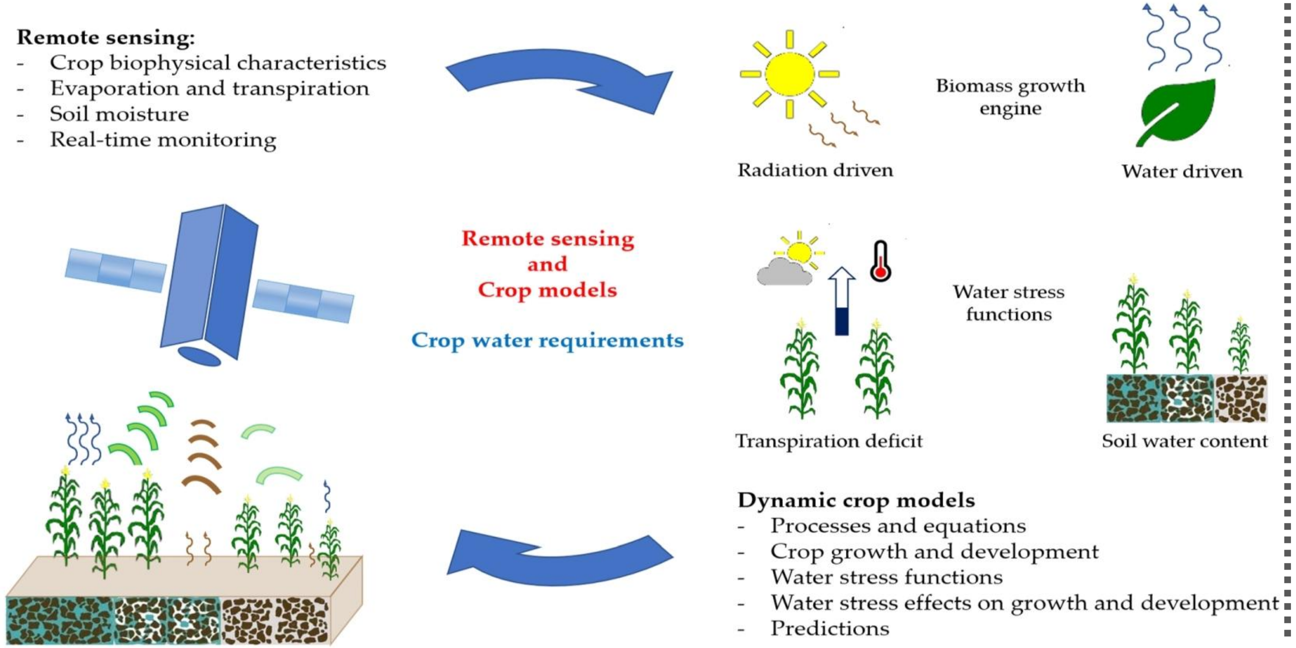
Accurate forecasting of yield or shortfalls in crop production and food supply per region and country

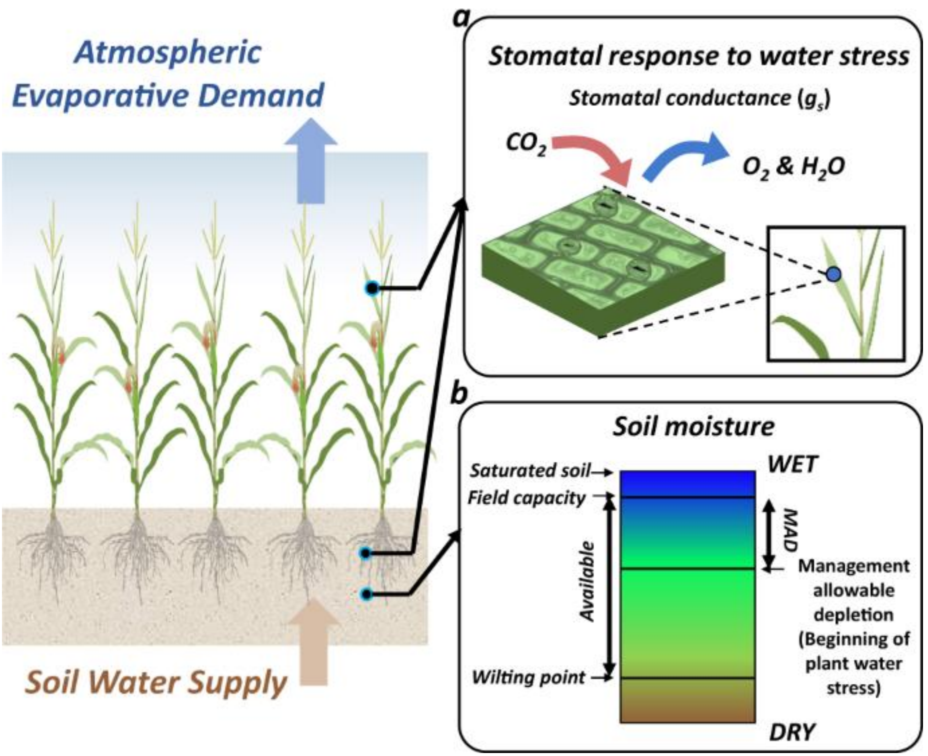


Why use satellite remote sensing for agriculture applications?

Irrigation Scheduling

Facilitates the detection, quantification, and scheduling of irrigation by providing real-time data on soil moisture levels and vegetation health across large agricultural areas.





Satellites & Sensors for Agricultural Applications

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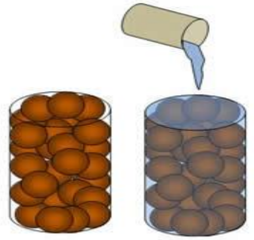
		Scientific products						
Satellite	**Sensor**	**Land surface reflectance**	**Evapotranspiration**	**Land surface temperature**	**Precipitation**	**Soil Moisture**	**Vegetation greenness**	**Structure**
Terra	MODIS	x	x	x			x	
Aqua	MODIS	x	x	x			x	
Suomi-NPP	VIIRS	x		x			x	
NOAA-20	VIIRS	x		x			x	
Landsat 8	OLI	x					x	
Sentinel 2	MSI	x					x	
Landsat 8 &	HLS	x					x	
International Space Station	ECOSTRESS		x					
Land Data Assimilation	Modeled output		x			x		
Global Precipitation	GMI, DPR				x			
CHIRPS	Multiple				x			
Soil Moisture Active Passive	L-band radar					x		
Sentinel 1	C-band radar							x

Click on the link below for a comprehensive list of NASA satellites and sensors for agricultural applications: https://appliedsciences.nasa.gov/sites/default/files/2021-05/NASA_Satellite_Instruments_Relevant_for_Agricultural_Applications.pdf

Soil Moisture for Agricultural Applications

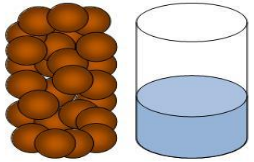
What is soil moisture?

①



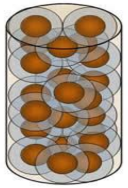
- Imagine a container of soil
- After rain or irrigation, the pores in soil fill up with water

②

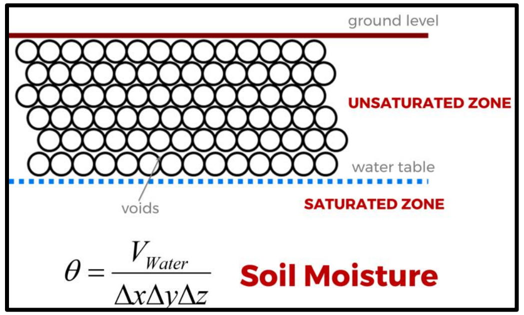


- Maximum amount of water that this soil can ever hold
- Super saturated or waterlogged sample of soil

③

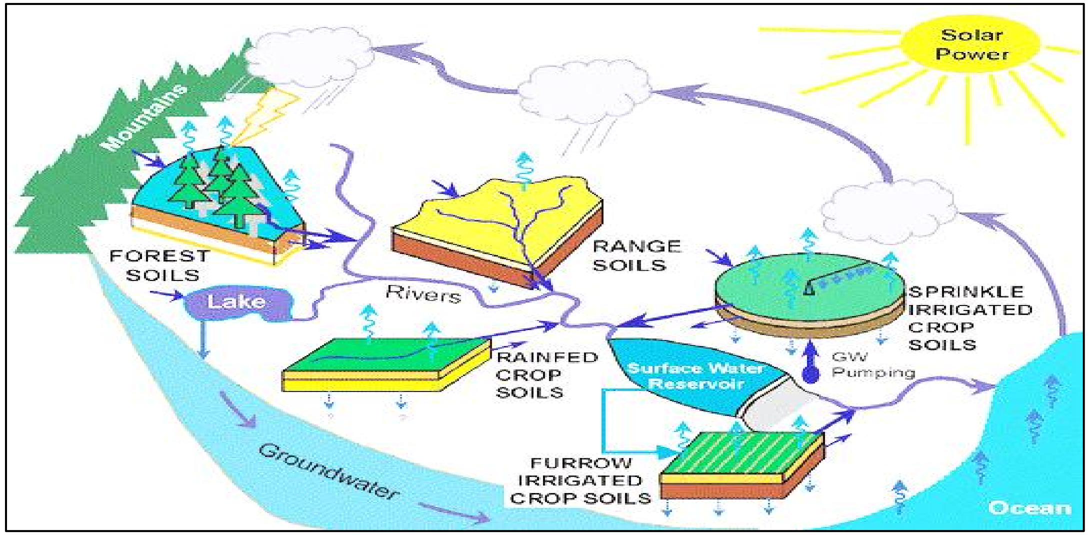


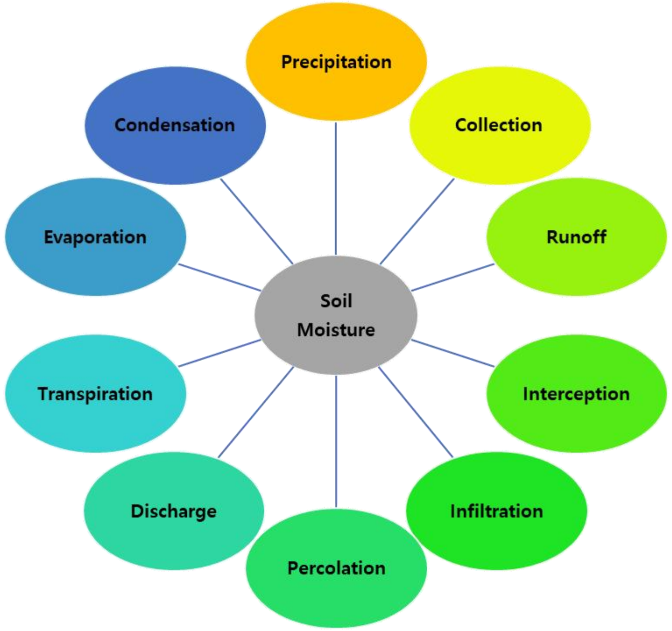
- Not all the water will drain Large amount of it will stay in the soil in the pore spaces



Soil moisture refers to the amount of water stored in the unsaturated soil zone.

Soil moisture and Water Cycle



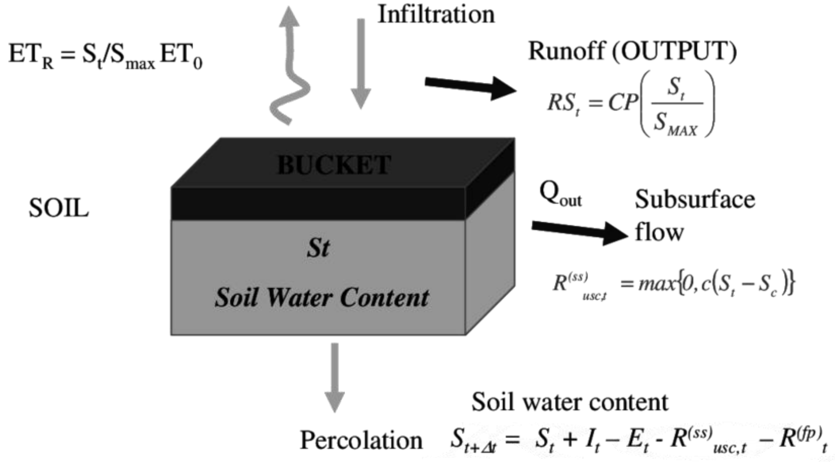


All water cycle variables are highly related to soil moisture

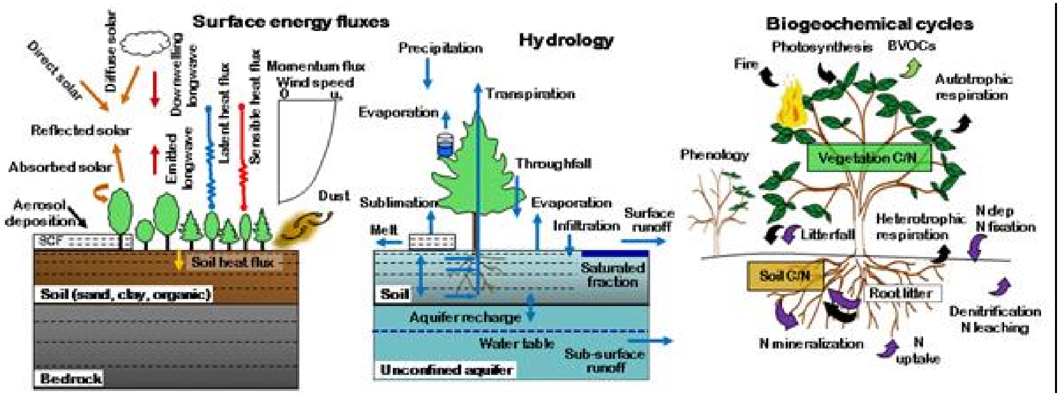
Method for Measuring Soil Moisture

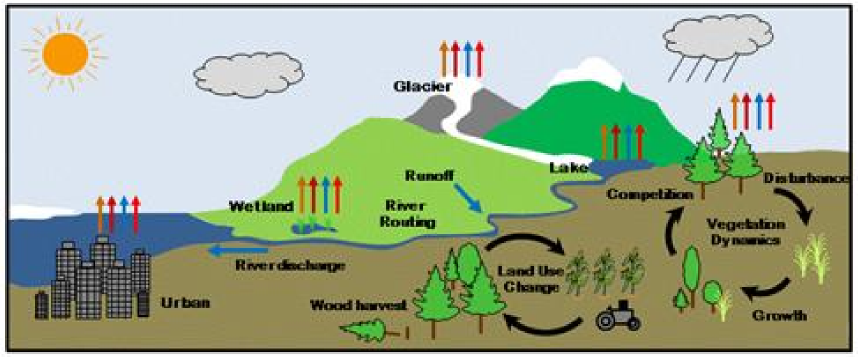
Ground-based measurements

- Sensor measures the **soil water content** by **transmitting** and receiving back reflected. **Time of travel** and **phase change** caused by **dielectric constant** is directly linked to SM content.



Hydrological and Land Surface Model





- Water and energy fluxes equations
- Accuracy depends upon model employed and quality of meteorological observations
- **Limitations**: Assumption made for understanding complex processes, human induced changes not modeled

Method for Measuring Soil Moisture

Ground-based measurements

Advanced Microwave Scanning Radiometer -Earth Observing System (AMSR-E)
Launch : Apr. 2002
Center frequencies (6.92 ~ 10.65 GHz)
Ascending : 13:30 / Descending : 01:30

Advanced Scatterometer (ASCAT)
Launch : Oct. 2006
Center frequencies (5.255 GHz)
Ascending : 21:30 / Descending : 09:30

Advanced Microwave Scanning Radiometer 2 (AMSR2)
Launch : May. 2012
Center frequencies (6.92~10.7 GHz)
Ascending : 13:30 / Descending : 01:30

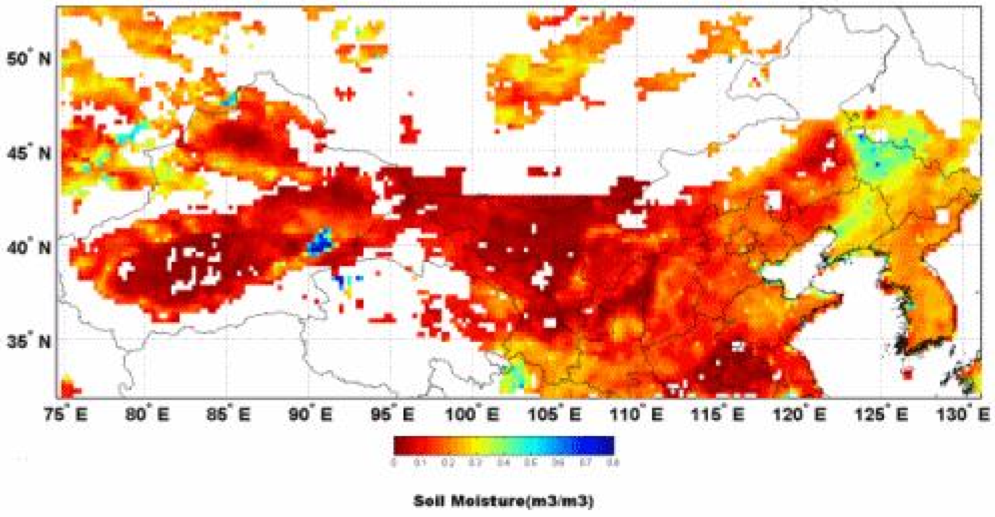
Soil Moisture Active Passive (SMAP)
Launch : Feb. 2015
Center frequencies (1.41 GHz)
Ascending : 06:00
Descending : 18:00

Soil Moisture Ocean Salinity (SMOS)
Launch : Feb. 2009
Center frequencies (1.41 GHz)
Ascending : 06:00
Descending : 18:00

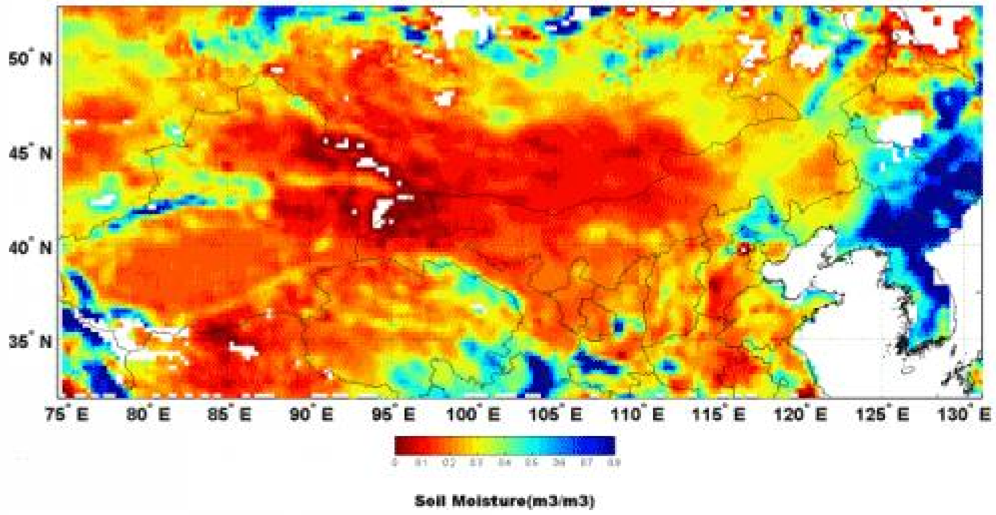
Fengyun-3B (FY-3B)
Launch : May. 2012
Center frequencies (10.65 and 36.5 GHz)
Ascending : 13:40 / Descending : 01:40

Method for Measuring Soil Moisture

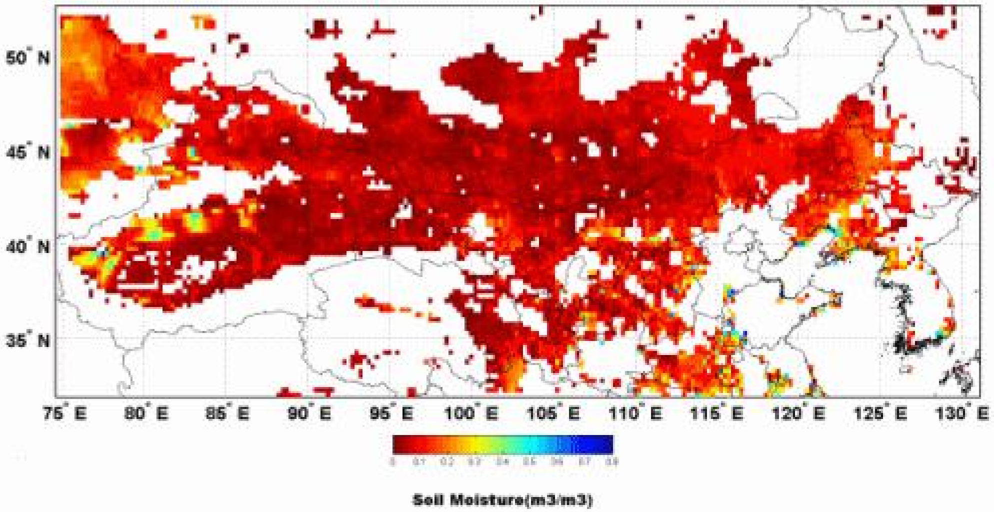
ASCAT (MetOp-A) from April to May



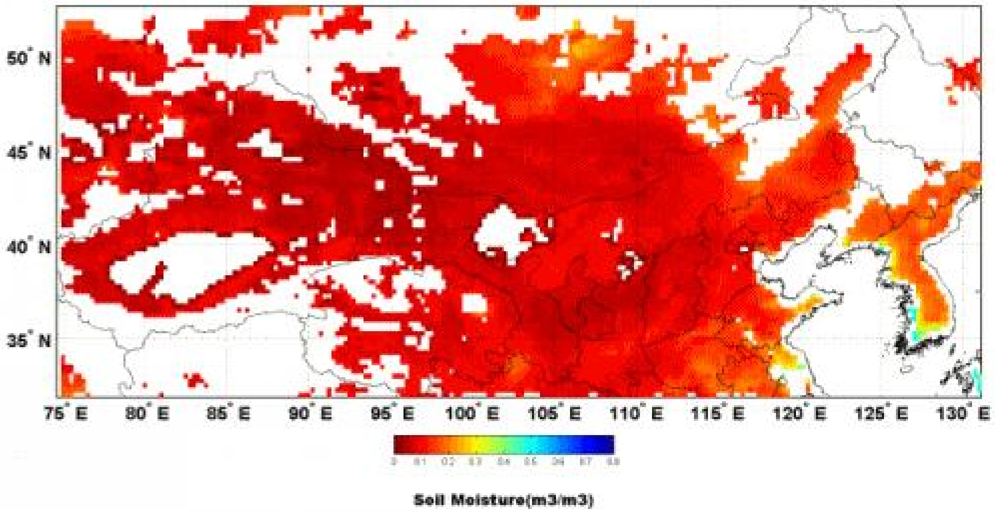
AMSR2 (GCOM-W1) from April to May



MIRAS (SMOS) from April to May

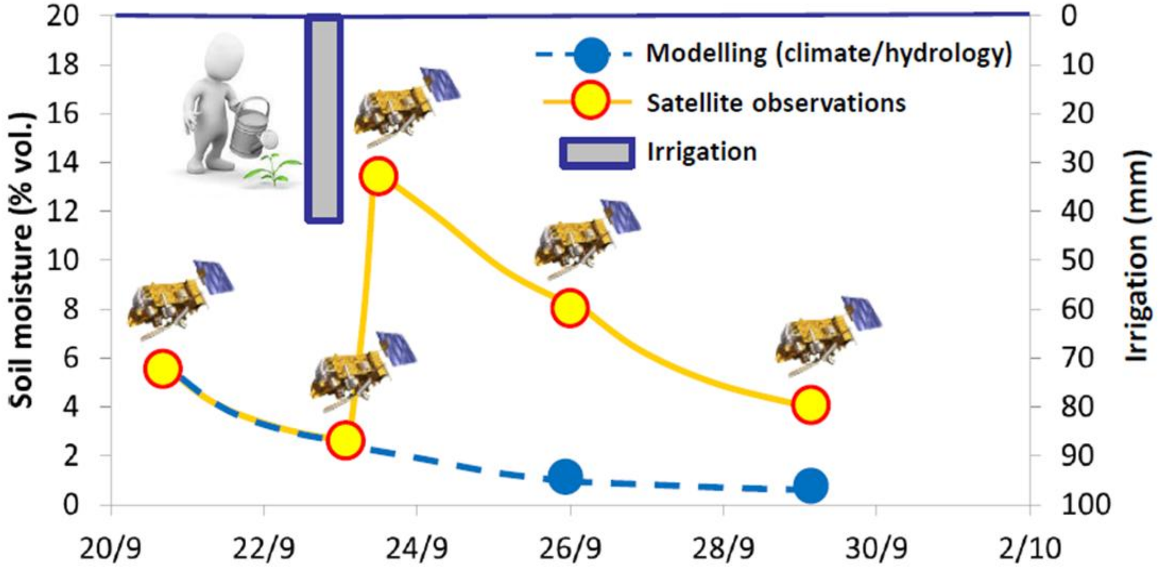


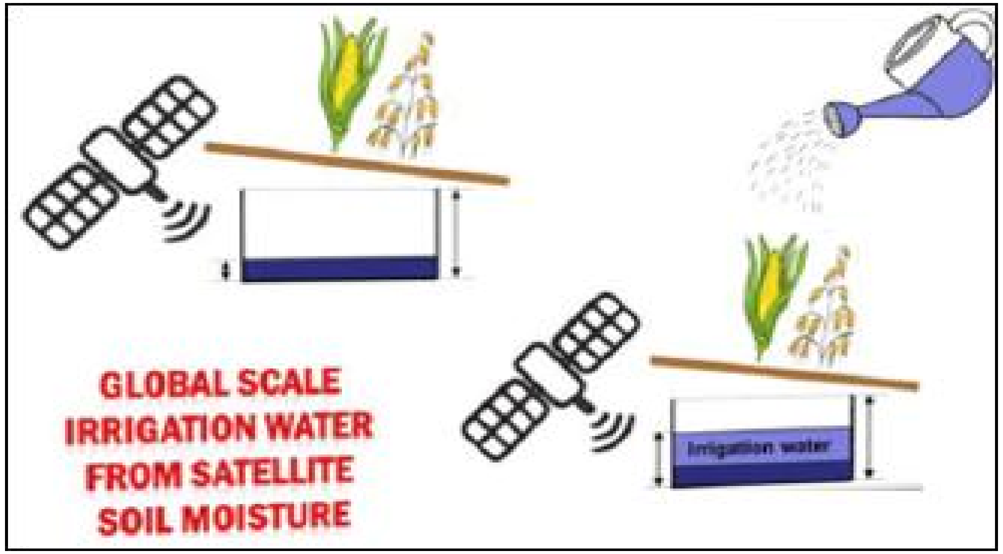
MWRI (FY-3B) from April to May



Application – Irrigation (Global scale analysis)

- Water is essential for all aspects of human life, especially for agricultural production as irrigation
- Irrigation critical **human alteration** to natural land surface processes that modifies energy and water balance
- Currently available land surface models **do not incorporate** irrigation formulation
- Spatiotemporal continuous observations of the earth by satellite remote sensing **potentially capture irrigation**.



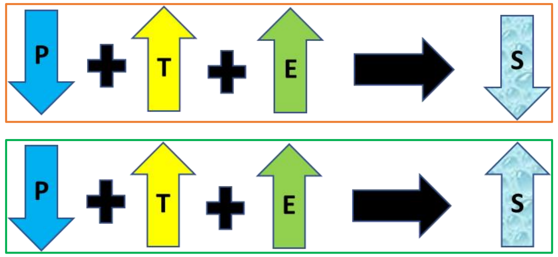


Imperfect model simulations and **strength** of satellite observations utilized to **detect irrigated areas**

Application – Irrigation (Global scale analysis)

Assumption Demonstration

	Normal	Irrigated
$R_{SM\text{-}P}$	+	–
$R_{SM\text{-}T}$	–	+



Journal of Geophysical Research: Atmospheres

RESEARCH ARTICLE

10.1002/2016JD026379

Evaluating the patterns of spatiotemporal trends of root zone soil moisture in major climate regions in East Asia

Muhammad Zohaib[1], Hyunglok Kim[2], and Minha Choi[1]

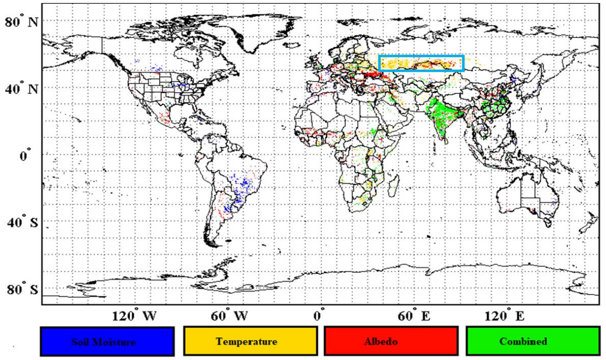
[1]Department of Water Resources, Graduate School of Water Resources, Sungkyunkwan University, Suwon, South Korea, [2]School of Earth Ocean and the Environment, University of South Carolina, Columbia, South Carolina, USA

Key Points:
- The influencing mechanism of precipitation and skin temperature on root zone soil moisture trend is different in different climate regions
- Increasing precipitation, temperature,

Irrigation Detection

Bottom-up approach

Aftereffect of Irrigation



Science of the Total Environment 677 (2019) 679–691

Contents lists available at ScienceDirect

Science of the Total Environment

journal homepage: www.elsevier.com/locate/scitotenv

Detecting global irrigated areas by using satellite and reanalysis products

Muhammad Zohaib[a], Hyunglok Kim[b], Minha Choi[a,*]

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[b] The Department of Engineering Systems and Environment, University of Virginia, Charlottesville, VA 22904, USA

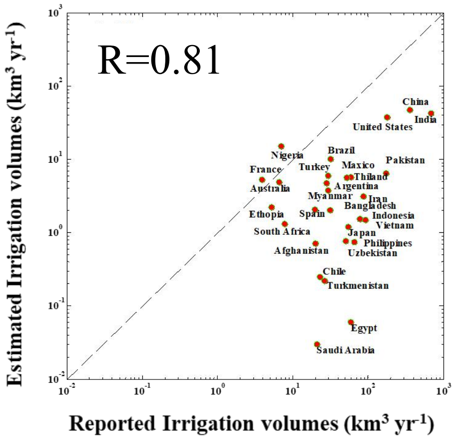
Irrigation Quantification

Water balance equation (Satellite SM)

$$\frac{dSM_{sat}}{dt} = P(t) + I(t) - E(t) - R(t) - \Delta S_{rest}$$

Water balance equation (Reanalysis SM)

$$\frac{dSM_{\text{mod}}}{dt} = P(t) - E(t) - R(t) - \Delta S_{rest}$$



Science of the Total Environment 714 (2020) 136719

Contents lists available at ScienceDirect

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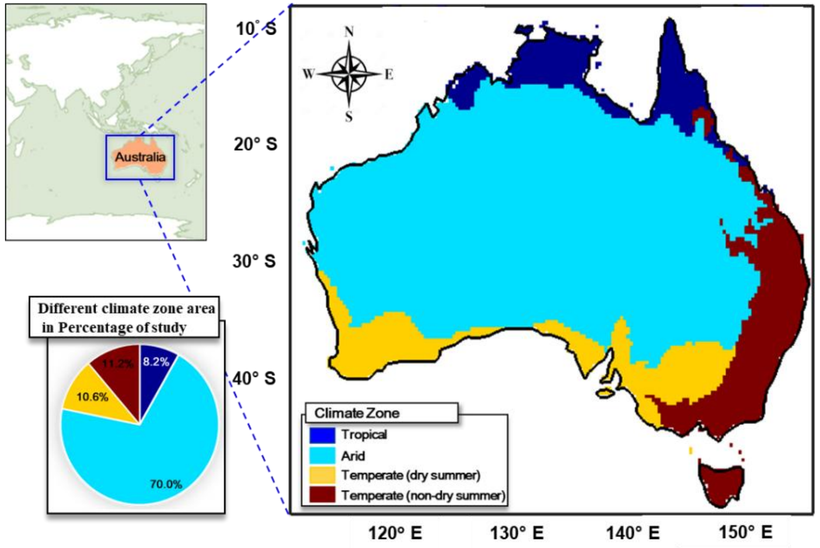
Satellite-based global-scale irrigation water use and its contemporary trends

Muhammad Zohaib, Minha Choi *

Environment and Remote Sensing Laboratory, Graduate School of Water Resources, Sungkyunkwan University, Suwon 440-746, Gyeonggi-do, Republic of Korea

2.3 Application – Drought (A case study in Australia)



Journal of Arid Environments 167 (2019) 43–55

Contents lists available at ScienceDirect

Journal of Arid Environments

journal homepage: www.elsevier.com/locate/jaridenv

Agricultural drought assessment based on multiple soil moisture products

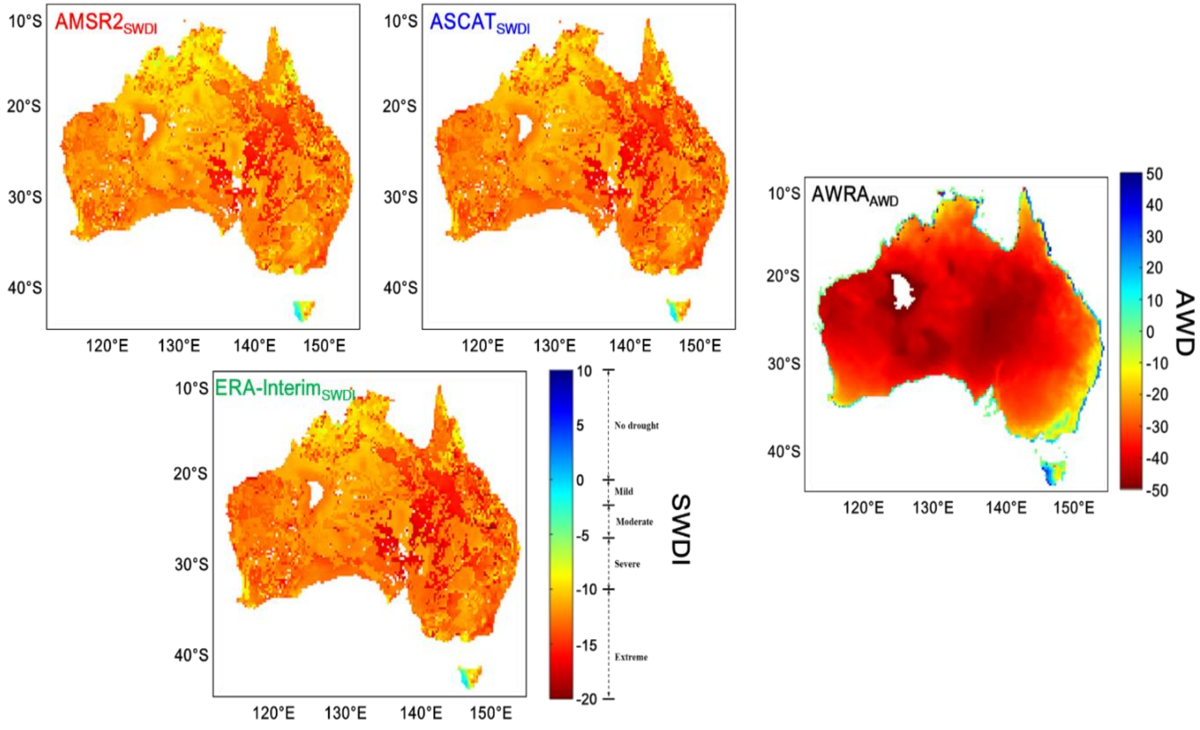
Jongjin Baik[a], Muhammad Zohaib[b], Ungtae Kim[c], Muhammad Aadil[b], Minha Choi[b,*]

[a] Center for Built Environment, The Built Environment Department, Sungkyunkwan University, Suwon, 440-746, Republic of Korea
[b] Department of Water Resources, Graduate School of Water Resources, 440-746, Sungkyunkwan University, Suwon, Republic of Korea
[c] Civil and Environmental Engineering, Cleveland State University, Cleveland, OH 44115, USA

Based on soil moisture characteristics

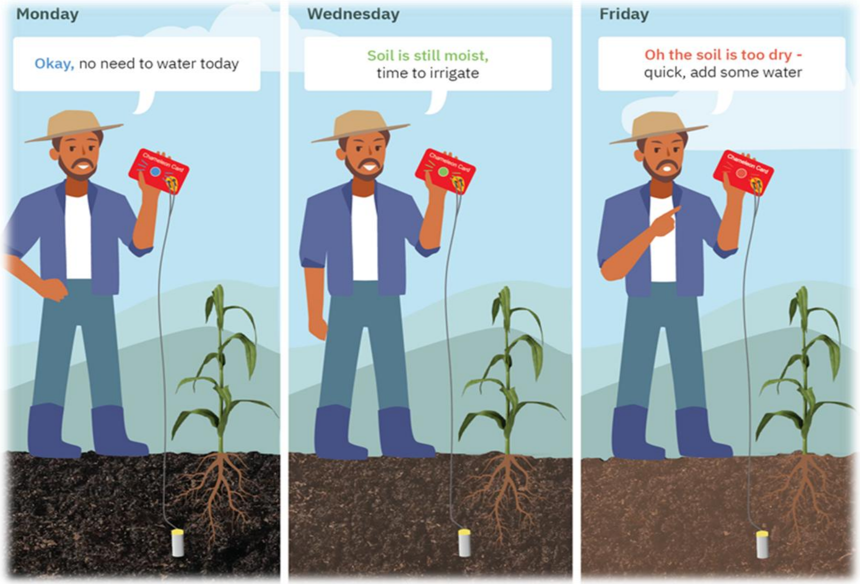
$$SWDI = \left(\frac{\theta - \theta_{fc}}{\theta_{AWC}}\right) \times 10$$

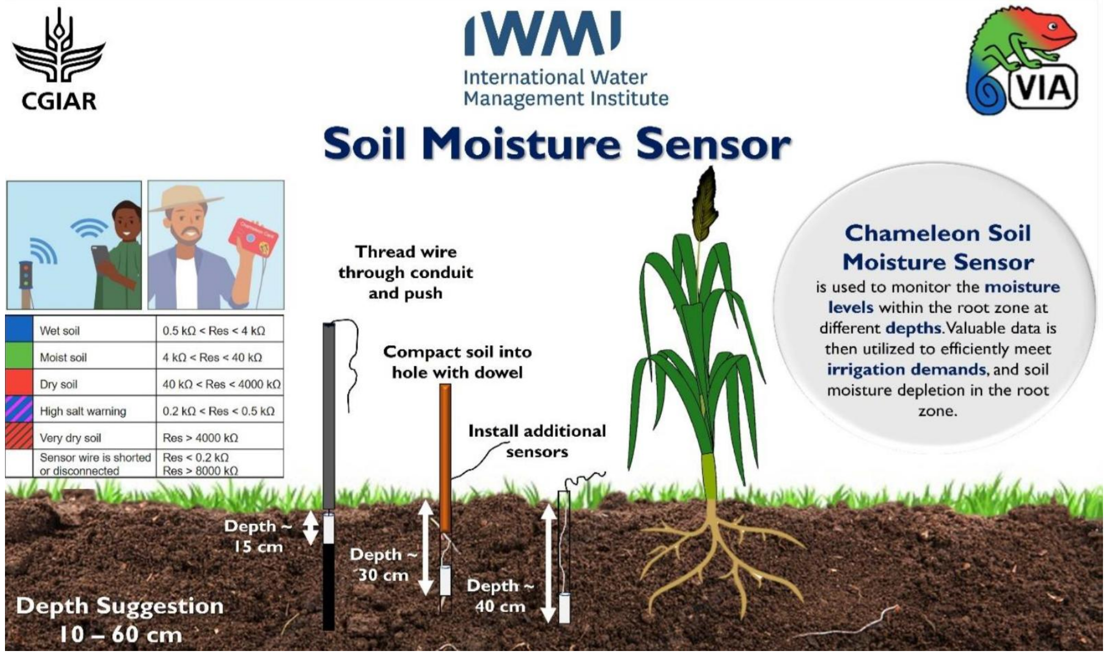
$$\theta_{AWC} = \theta_{fc} - \theta_{wp}$$

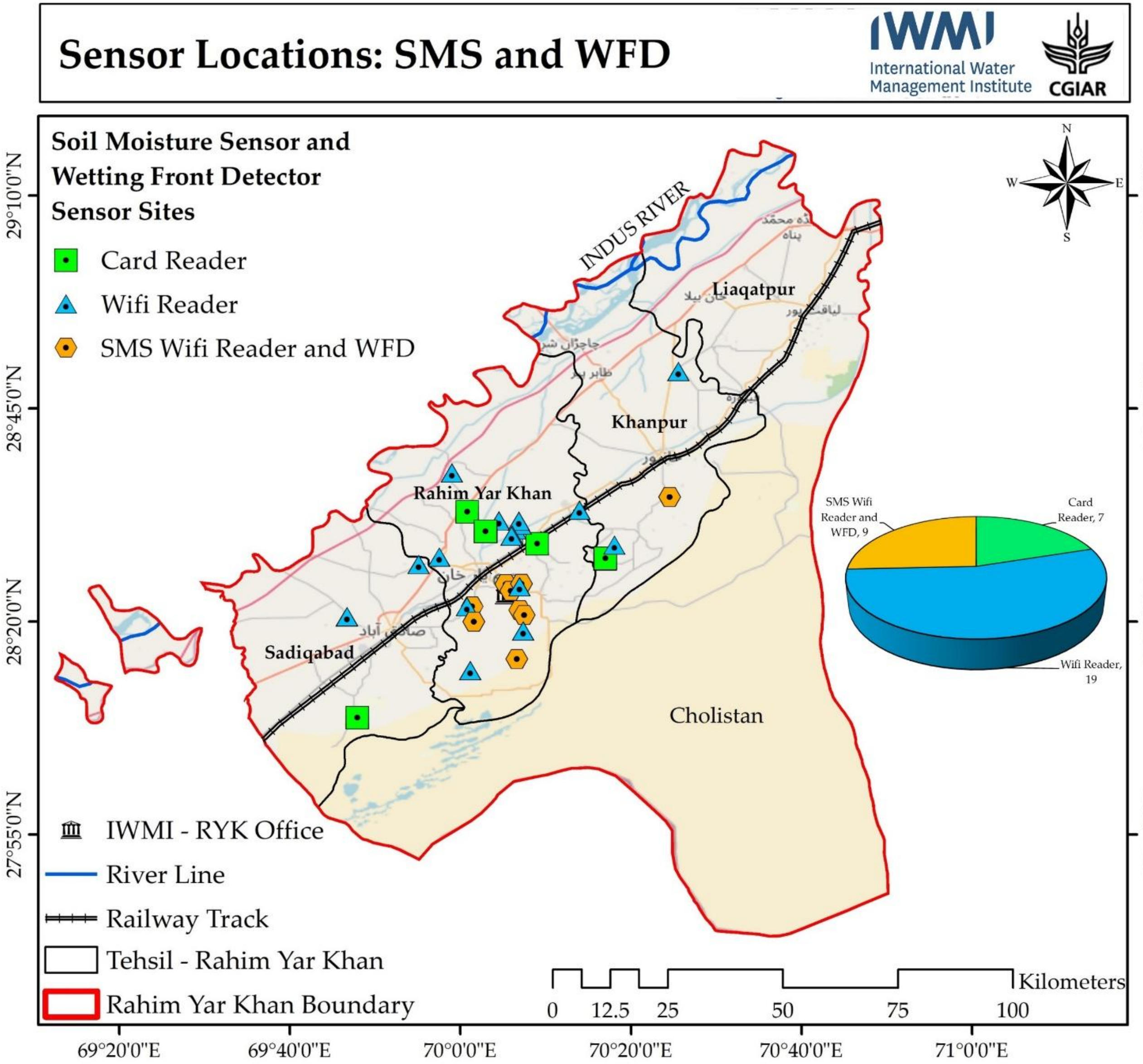


Θ is soil moisture content (m^3/m^3)
Θ_{fc} is SM at field capacity (m^3/m^3)
Θ_{wp} is SM at wilting point (m^3/m^3)
Θ_{awc} is available water content (m^3/m^3)

Application – Irrigation scheduling (District Level - Pakistan)





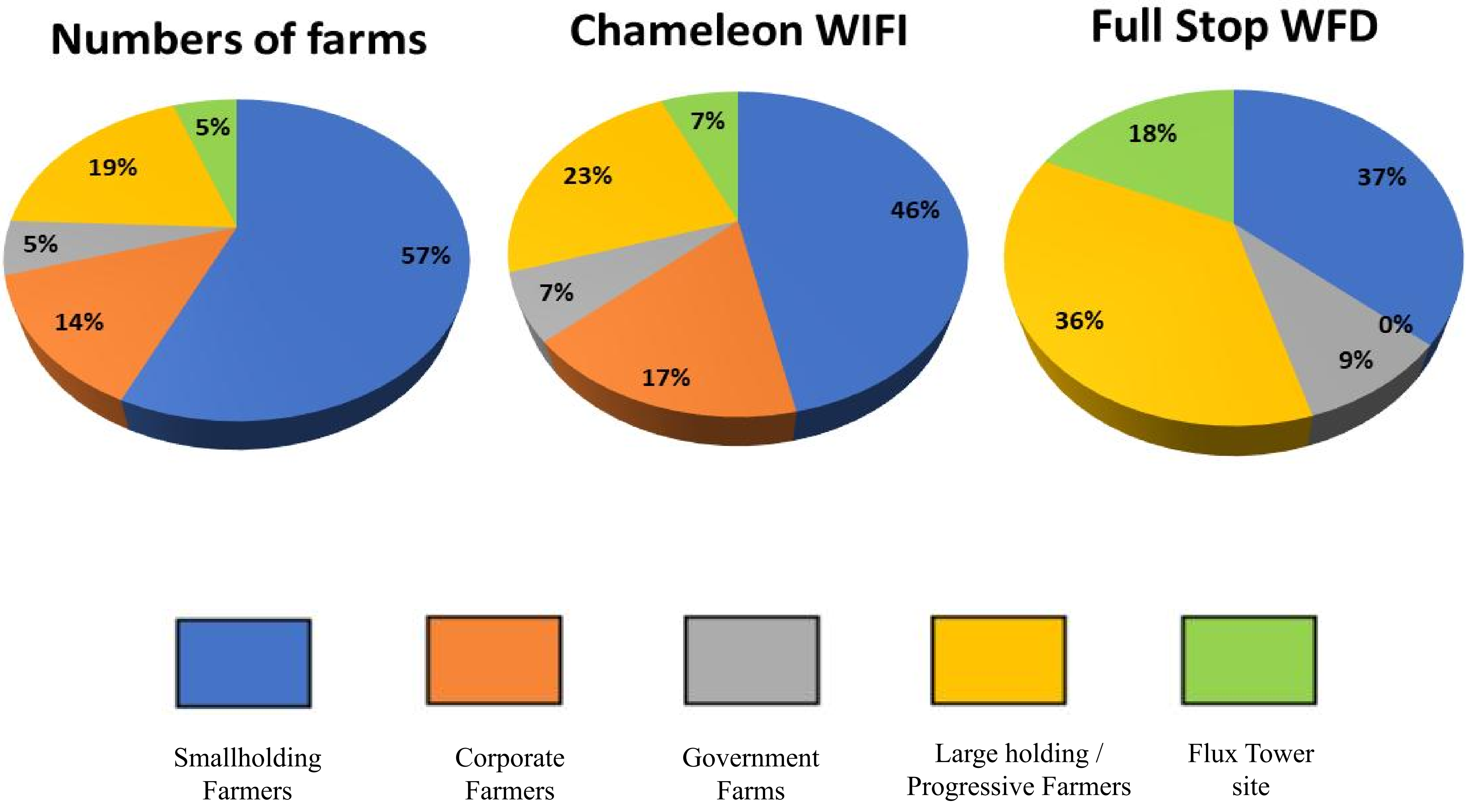


Application – Irrigation scheduling (District Level - Pakistan)

Field Installation Plans

- Consideration for **field selection**:
    - Spatial Extent
    - Cropping pattern
    - Security of sensor
    - Availability of Wi-Fi
- Sensors installed at **3 depths** (Wheat 15, 30, 40 and sugarcane 20, 40, and 60)
- Divide land in **two farms** – traditional irrigation practices vs VIA soil moisture sensor-based irrigation

Application – Irrigation scheduling (District Level - Pakistan)



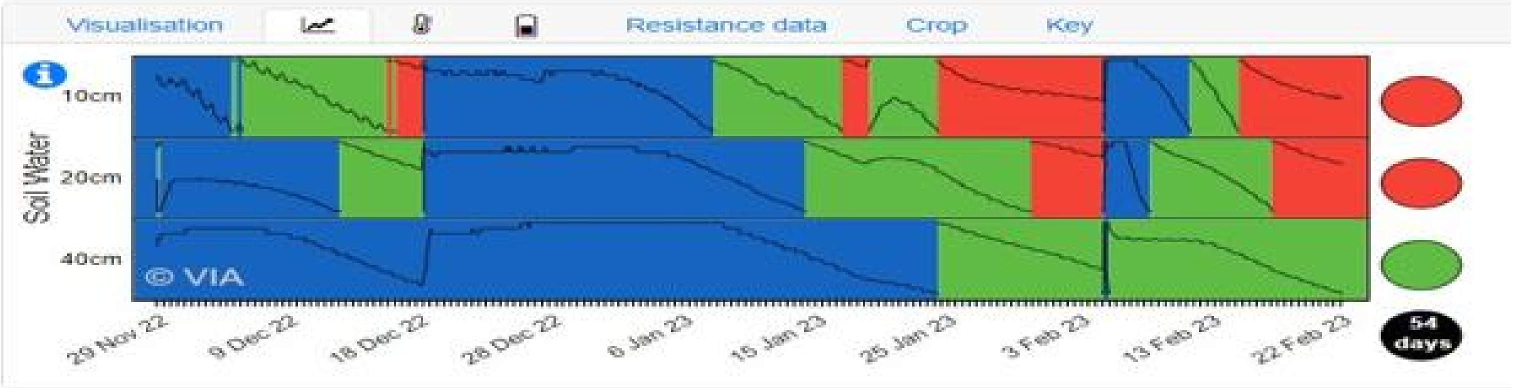
Application – Irrigation scheduling (District Level - Pakistan)

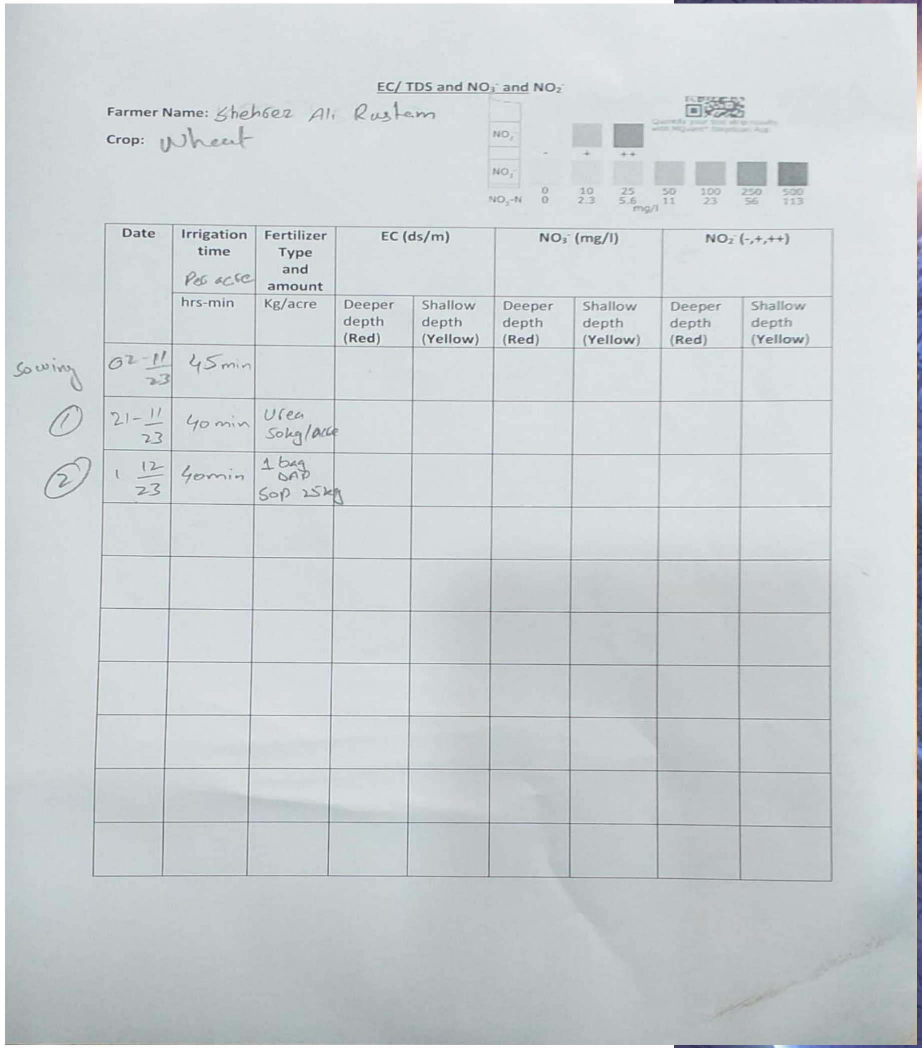
The state-of-the-art sensors provide real-time data on soil moisture, enabling precise irrigation management and water conservation efforts. By accurately measuring soil moisture, the Chameleon sensors help farmers optimize water usage, improve crop yields, and minimize water waste, promoting sustainable agricultural practices in Okara.

100 + farmers are using this approach

Irrigation Bay: Zahid Sharif Mahar

Crop: **Wheat**, Planting date: **2 Nov 22**, Sensor: **Zahid Sharif Mahar**





EC/ TDS and NO_3^- and NO_2^-

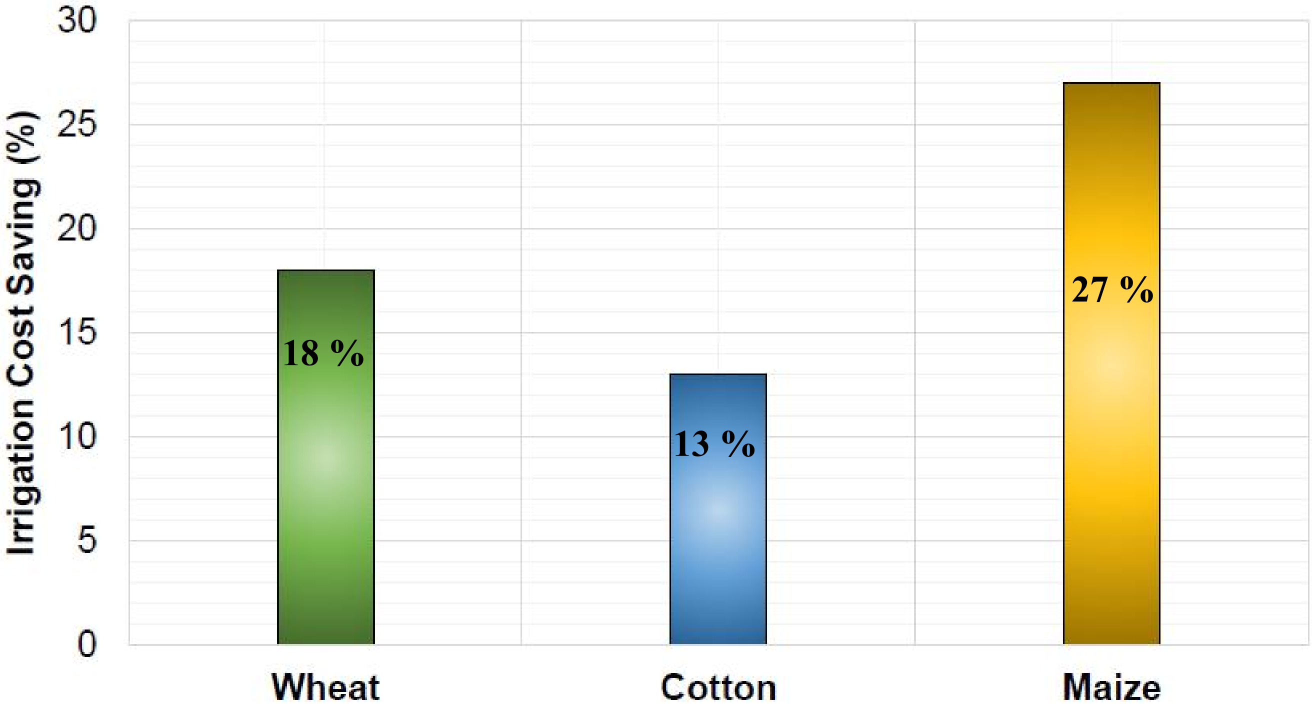
Farmer Name: Shehzez Ali Rustam

Crop: Wheat

	Date	Irrigation time Per acre hrs-min	Fertilizer Type and amount Kg/acre	EC (ds/m) Deeper depth (Red)	EC (ds/m) Shallow depth (Yellow)	NO_3^- (mg/l) Deeper depth (Red)	NO_3^- (mg/l) Shallow depth (Yellow)	NO_2^- (-,+,++) Deeper depth (Red)	NO_2^- (-,+,++) Shallow depth (Yellow)
Sowing	02-11-23	45min							
1	21-11-23	40 min	Urea 50kg/acre						
2	1-12-23	40min	1 bag DAP Sop 25kg						

Application – Irrigation scheduling (District Level - Pakistan)

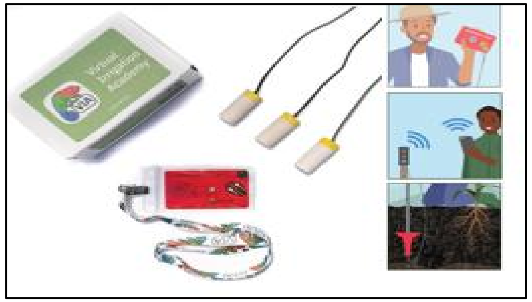
- Before installation, 5-6, 18-20, and 9-10 irrigations for wheat, cotton, and sugarcane, respectively.
- After installation, these numbers decreased to 4-5, 15-18, and 8-9, showcasing a substantial decrease in water consumption.



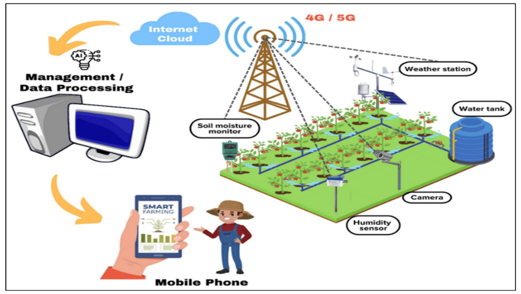
Future Directions

Advancements in Satellite Technology
High spatial, temporal and spectral resolution

Integration with AI and Machine Learning
Accurate and Automated analysis



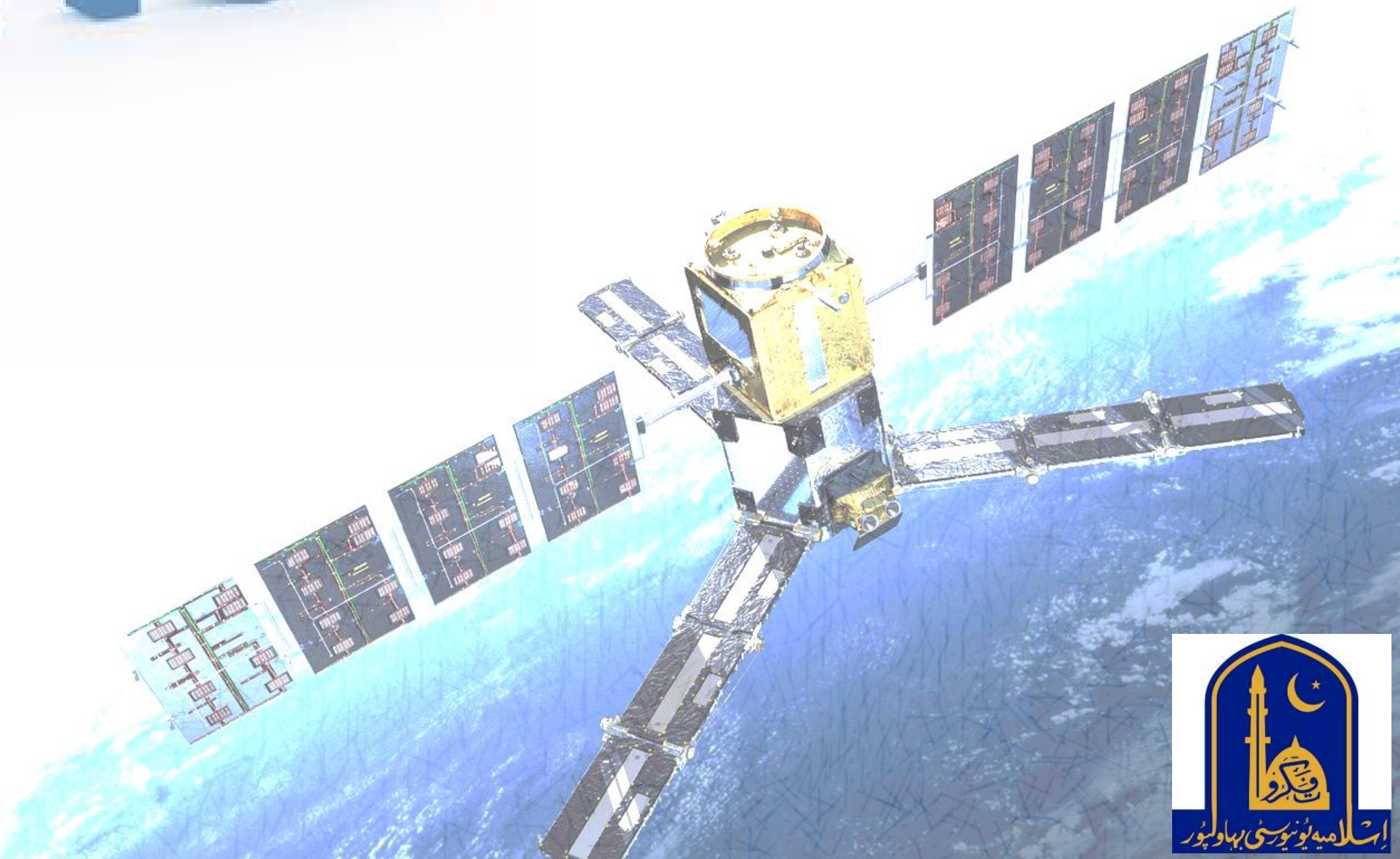
Deployment of Low-Cost Sensors
Empowering smallholder farmers with actionable insights



Fusion with IoT and Big Data Analytics
Facilitate real-time monitoring and decision-making

Emerging Technologies
Hyperspectral imaging, UAVs, and ground-penetrating radar (GPR) - unlock new capabilities for precise and non-invasive measurement

THANK YOU



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