Earth Observation & Digitalisation in Environmental Studies and Modern Agriculture

- **Ben Jarihani, B. Eng, M. Eng., PhD, Professor**
- **James Cook University**, College of Science and Engineering, Townsville, Australia,
- **EnviroVision** Environmental Consulting
- Central Asian University of Environmental and Climate Change Studies (Green University), Tashkent, Uzbekistan
- National University of Uzbekistan named after Mirzo Ulugbek, Tashkent, Uzbekistan

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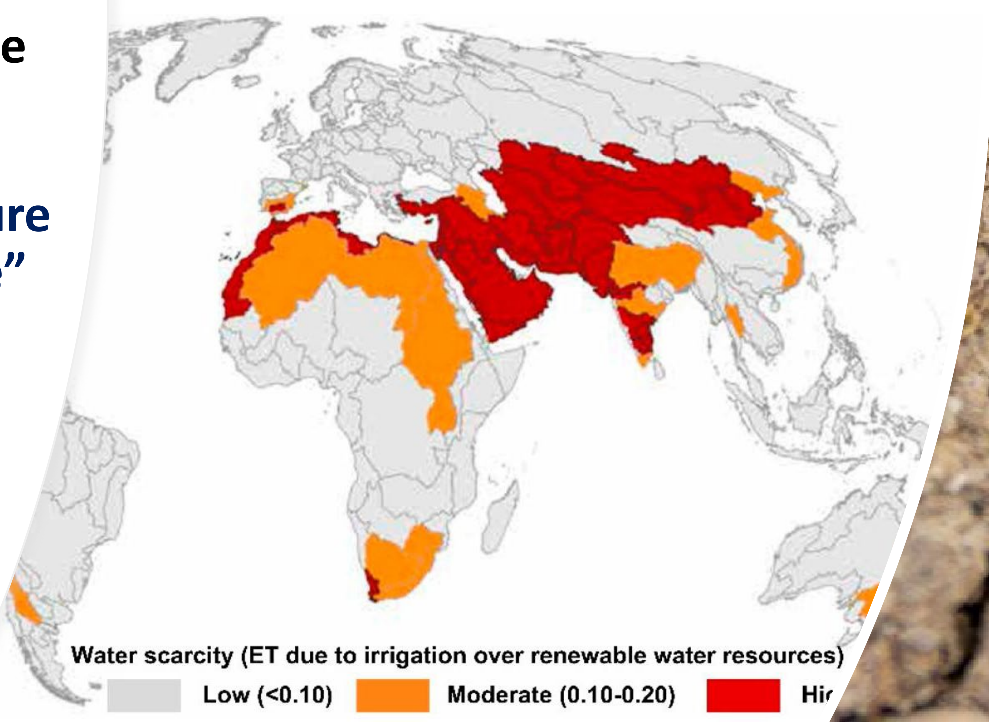
ENVIROVISION
CONSULTING LLC
Empowering Global Change from Central Asia

JAMES COOK UNIVERSITY
AUSTRALIA

Why Digitalisation Matters

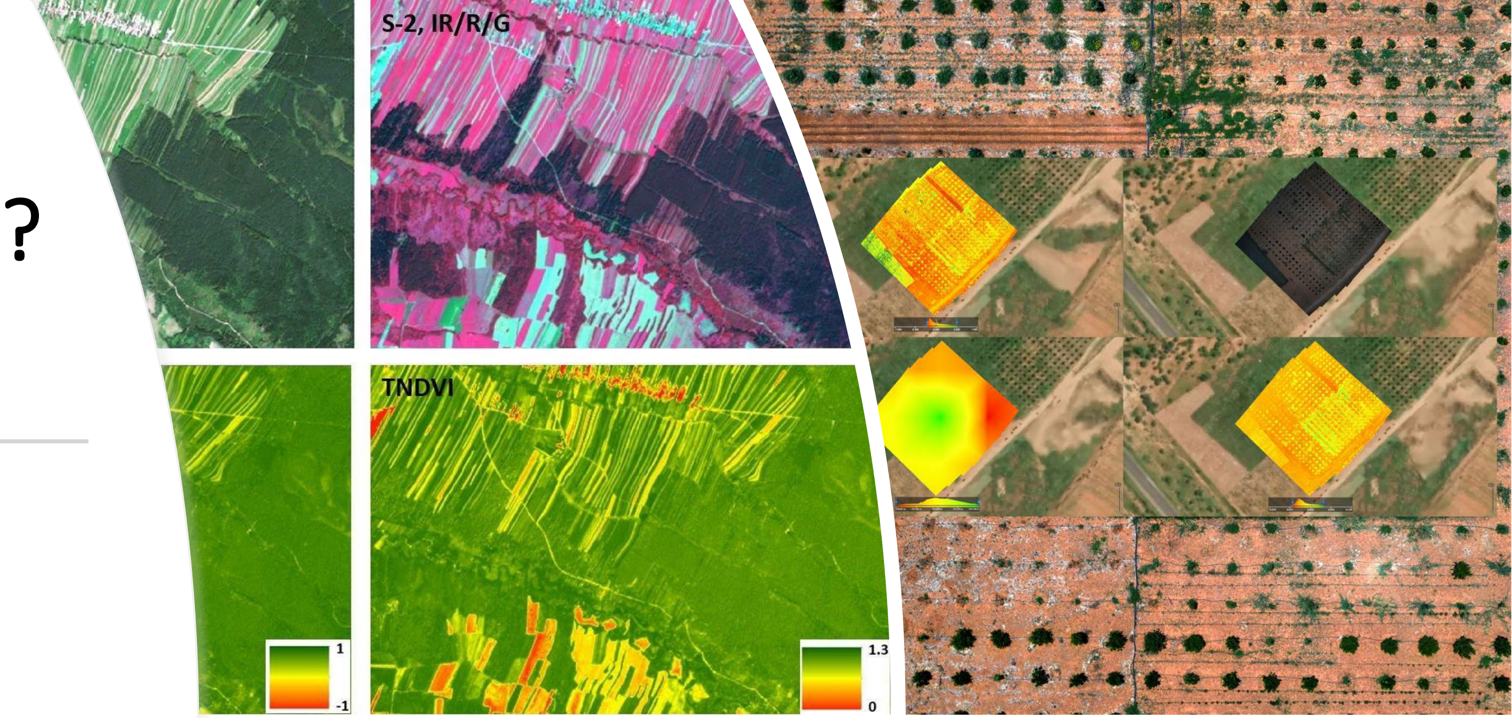
- **Food demand increasing**
- **Water scarcity**
- **Climate change impacts**
- **Need for smart agriculture**

"We need smarter agriculture — not just more agriculture"



What is Earth Observation? (Remote Sensing)

- **Satellites, drones, sensors**
- **Continuous monitoring**
- **Optical, radar, thermal data**
- **Time-series analysis**



Why Earth Observation matters

Large spatial coverage

Continuous observations

Near-real-time updates

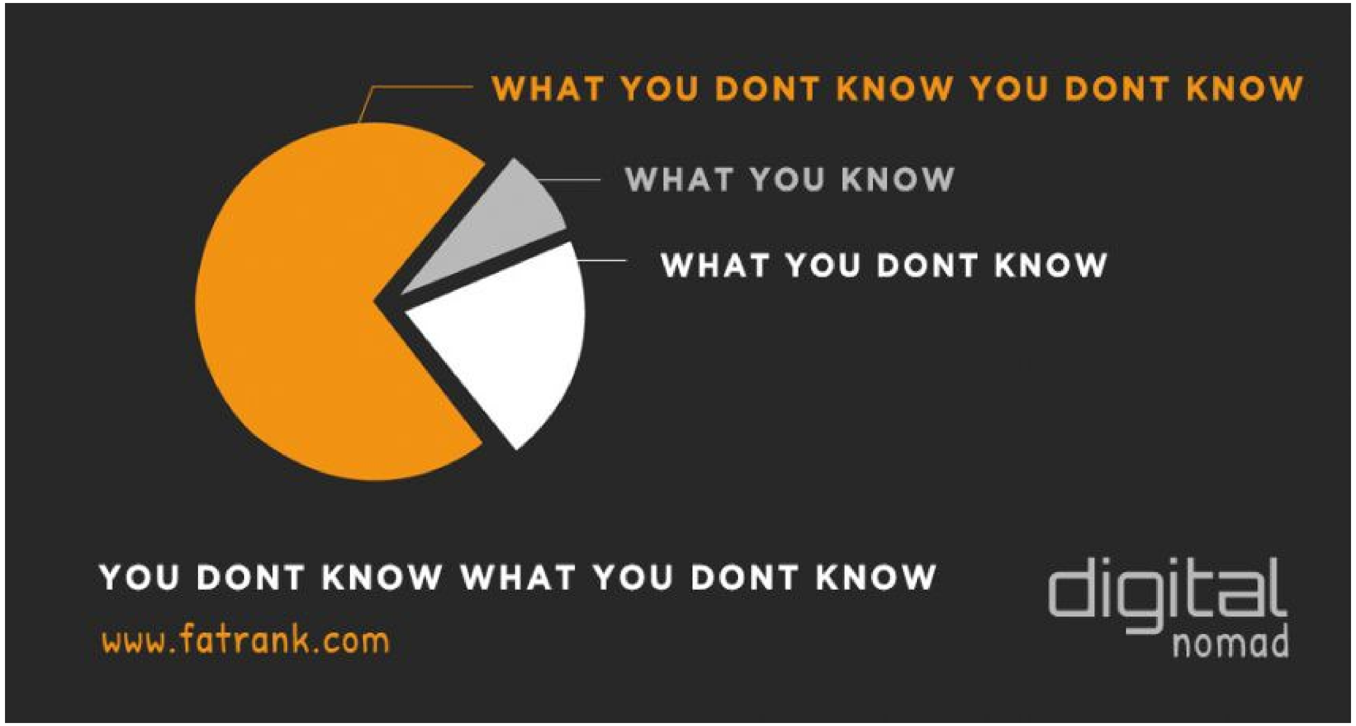
On May 1, 2020, part of an earth-filled dam broke along the Sardoba Reservoir in Uzbekistan, flooding the surrounding landscape.

Evolution of Earth Observation (EO)

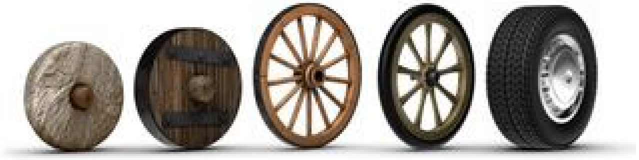
- Satellite-based remote sensing began during the **space race (1950s–1960s)**
- **1957 – Sputnik 1 (USSR):** First artificial satellite launched
- **1960 – Explorer 1 (USA):** Early US satellite mission
- **1960 – TIROS-1:** First successful **meteorological (weather) satellite**
- **1972 – Landsat 1:** First **Earth resource satellite** (originally ERTS-1)
- Landsat program provides **50+ years of continuous Earth observation data**
- **Landsat 8 (2013):** Advanced sensors and improved data quality
- Since 1957, **thousands of satellites** have been launched
- Currently **~3,600 satellites in orbit**, ~**1,400 operational**
- Over **100+ Earth Observation satellites** actively monitoring Earth
- Increasing role of **commercial/private satellite companies**
- EO now essential for **agriculture, water resources, climate, and environmental monitoring**

Geospatial Adoption and Usage:

According to a survey conducted by the American Geosciences Institute (AGI), over 75% of geoscientists regularly use remote sensing and geospatial technologies in their work. A study by the International Society for Photogrammetry and Remote Sensing (ISPRS) found that approximately 80% of geoscientists believe that remote sensing has significantly enhanced their ability to analyse and interpret geological data.



YES, sometimes we reinventing the wheels



2-Electromagnetic spectrum

Figure 1 contains the EMS range from gamma rays to radio waves. In remote sensing, typical applications include the visible light (380–780 nm), infrared (780 nm–0.1 mm), and microwave (0.1 mm–1 m) ranges.

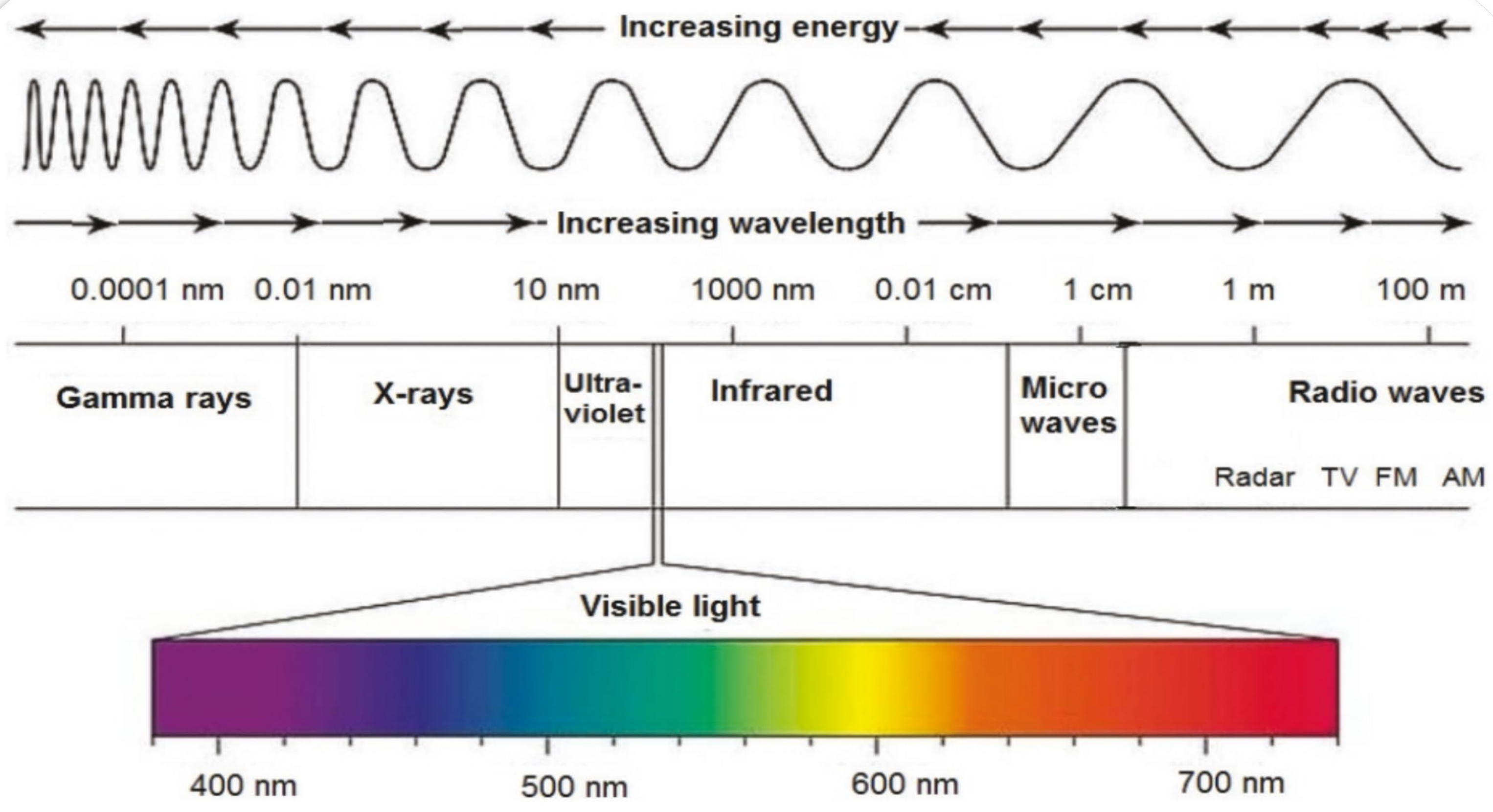
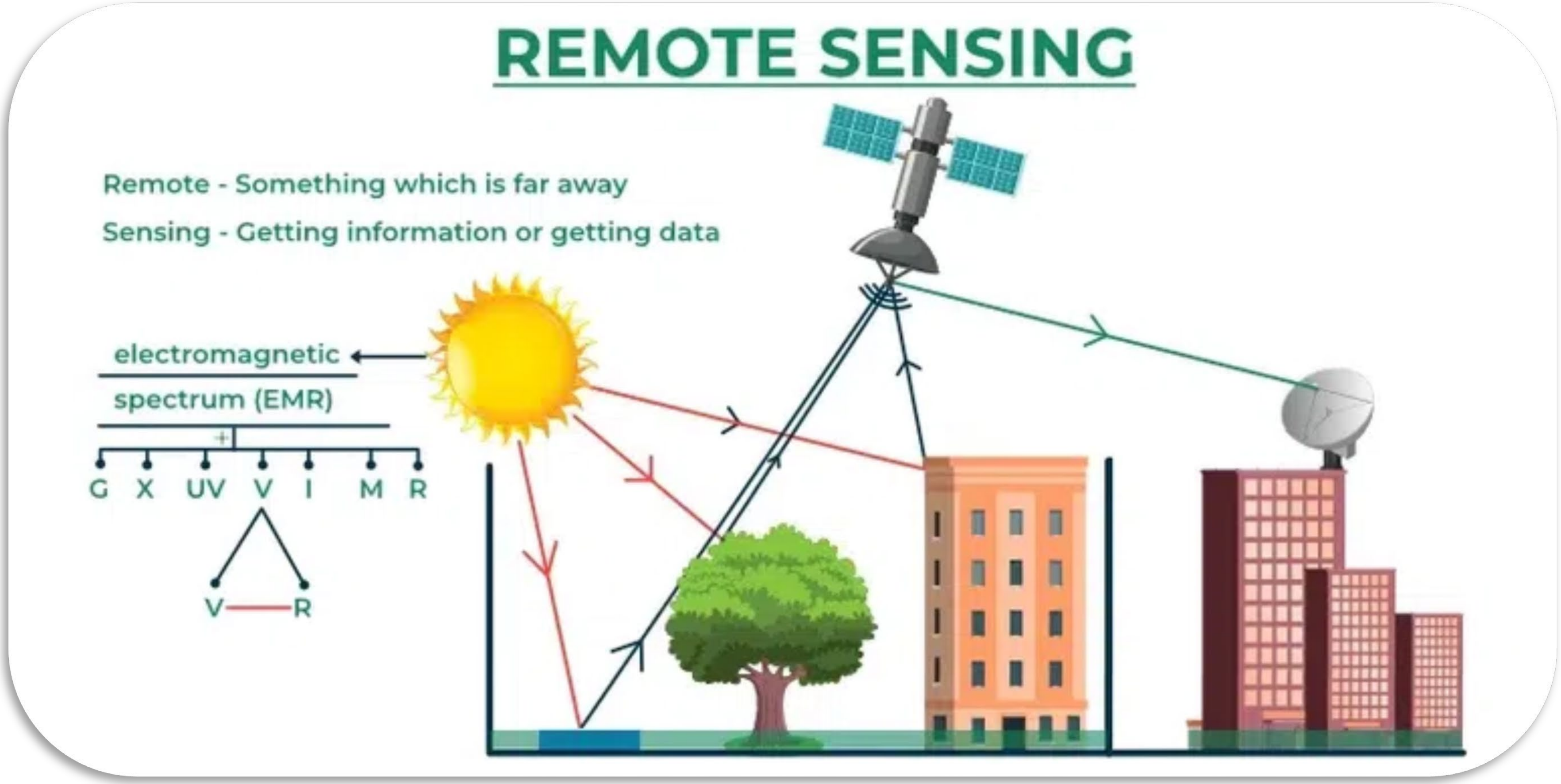


Figure 1. The electromagnetic spectrum. Image from UC Davis ChemWiki, CC-BY-NC-SA 3.0.

3-Characteristics of materials in electromagnetic spectrum (EMS)

Remote sensors remotely interact with objects on the surface of the Earth. Objects on the surface of the Earth generally include terrain, buildings, road, vegetation, and water. The typical materials of these objects that interact with the EMS are categorized into groups: transparent and opaque (partly or fully absorbed).



The physical characteristics of the material determine what type of electromagnetic waves will and will not pass through it.

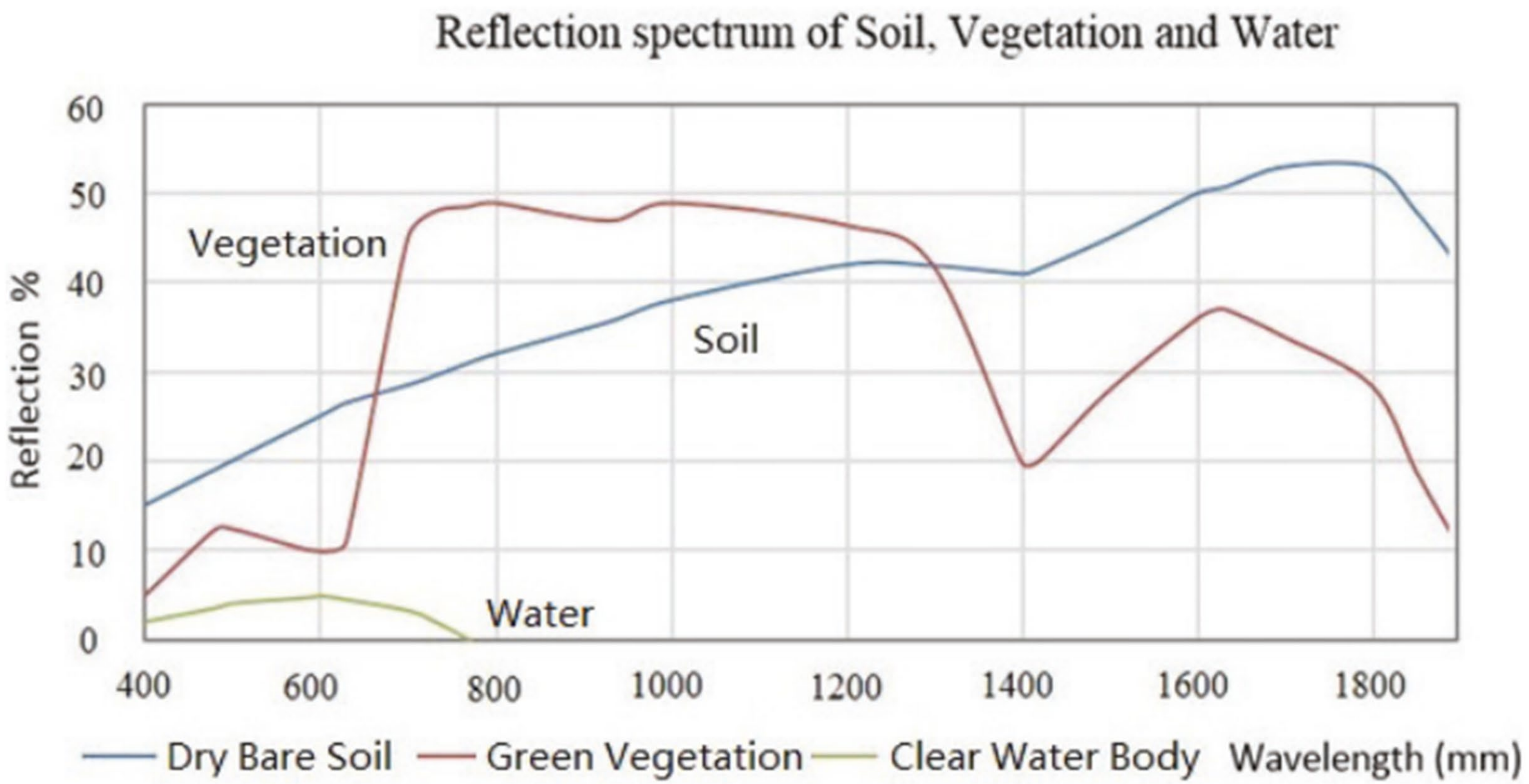
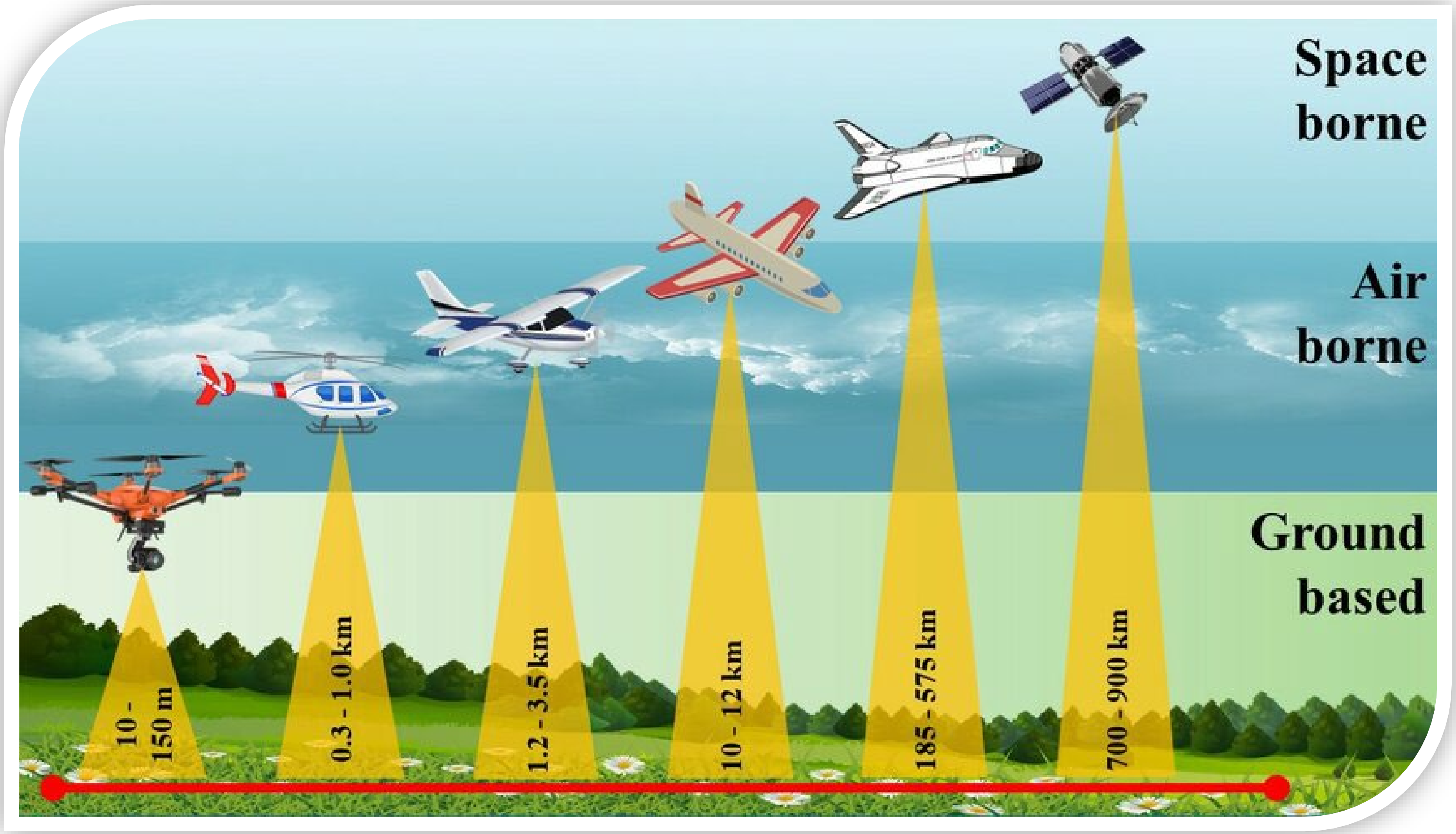


Figure 5. Examples of reflective materials. Image referenced from Wikimedia [26].

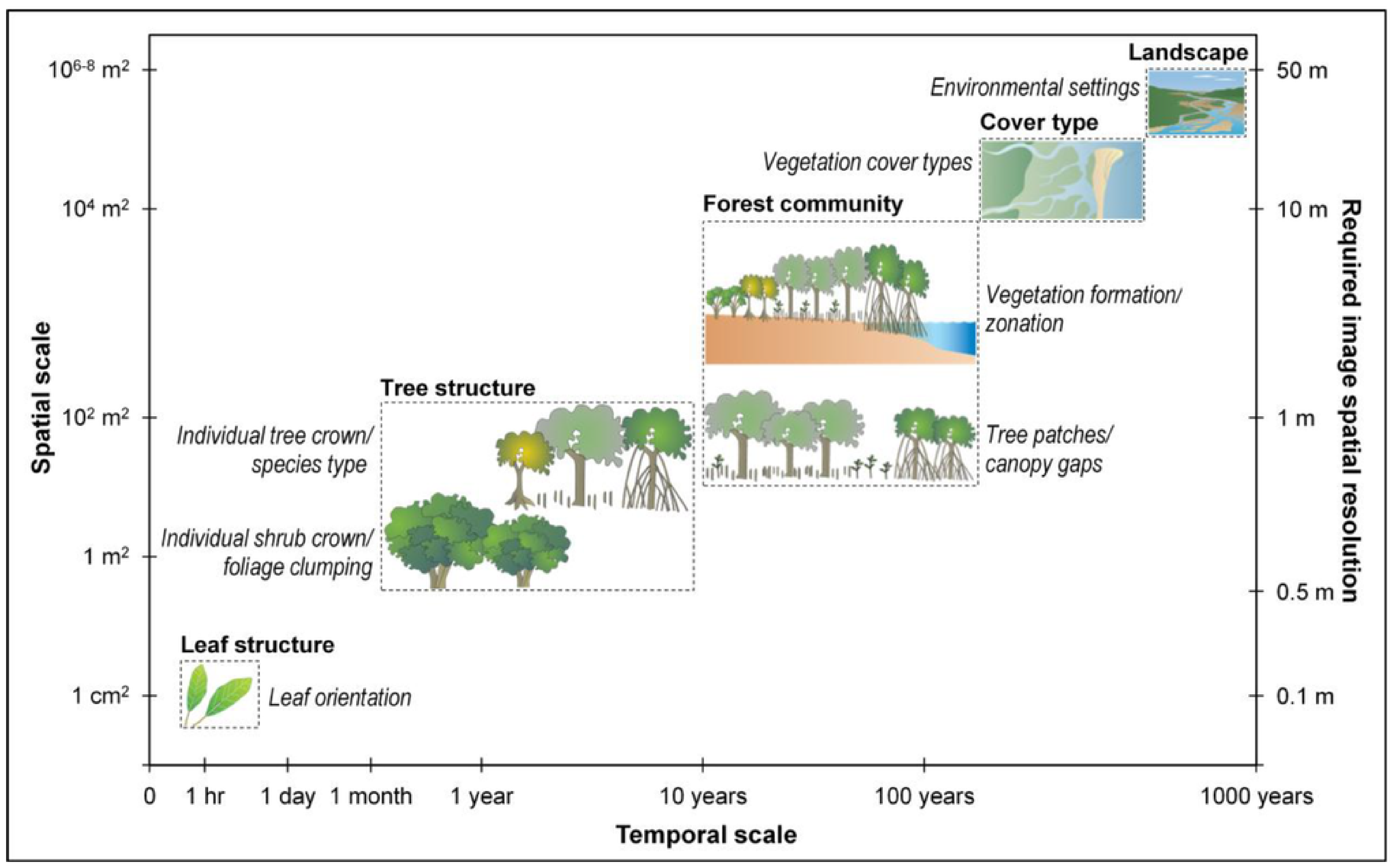
Remote Sensing Sensors Type:

- Optical → crop monitoring (NDVI)
- Thermal → water stress / ET
- Radar → soil moisture, floods
- LiDAR → elevation, structure

5-Remote sensing platforms:



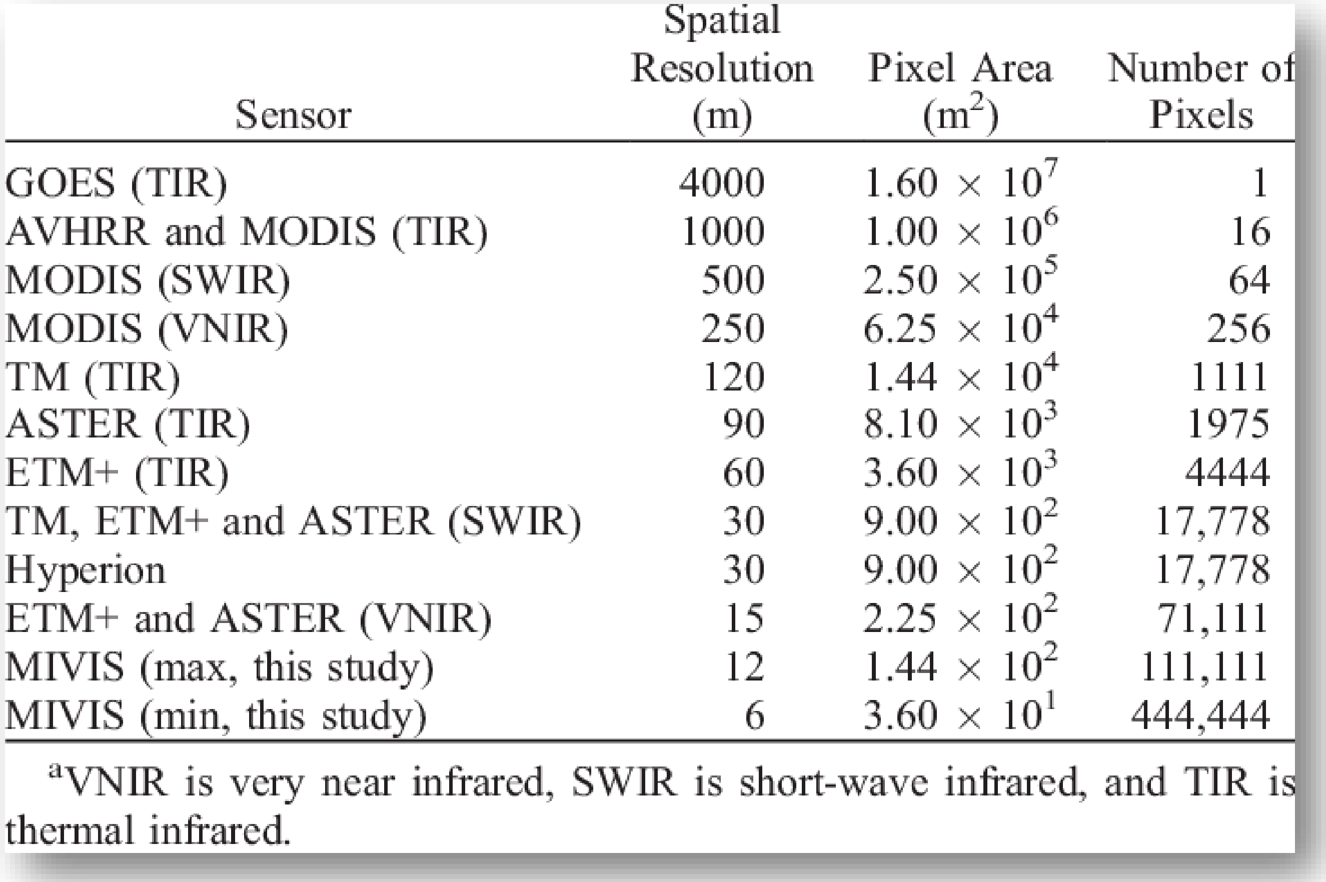
Spatiotemporal scale in remote sensing



Credit: MDPI Remote Sensing 2015

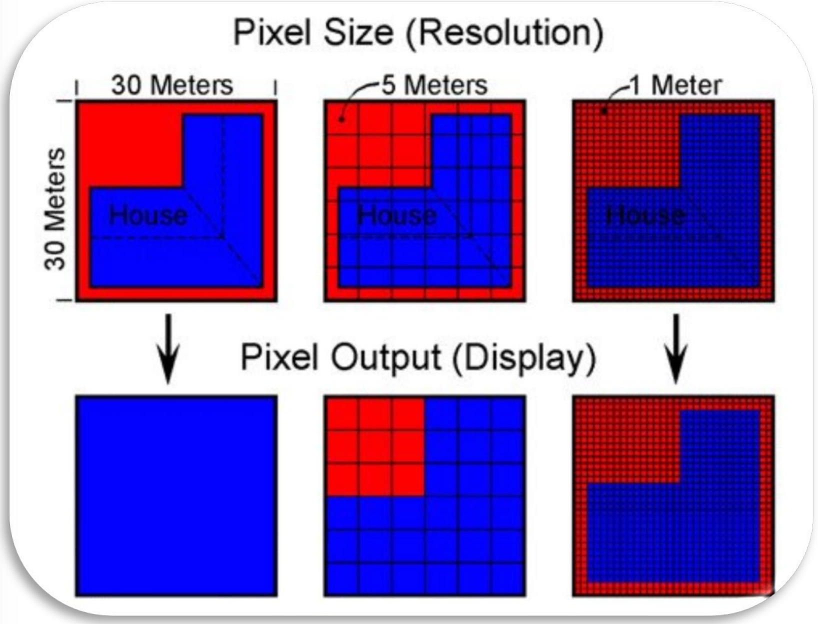
7-Spatial resolution of satellite data

Spatial resolution, also known as pixel size or ground sample distance (GSD), is a metric used to describe the level of detail in satellite imagery



Sensor	Spatial Resolution (m)	Pixel Area (m^2)	Number of Pixels
GOES (TIR)	4000	1.60×10^7	1
AVHRR and MODIS (TIR)	1000	1.00×10^6	16
MODIS (SWIR)	500	2.50×10^5	64
MODIS (VNIR)	250	6.25×10^4	256
TM (TIR)	120	1.44×10^4	1111
ASTER (TIR)	90	8.10×10^3	1975
ETM+ (TIR)	60	3.60×10^3	4444
TM, ETM+ and ASTER (SWIR)	30	9.00×10^2	17,778
Hyperion	30	9.00×10^2	17,778
ETM+ and ASTER (VNIR)	15	2.25×10^2	71,111
MIVIS (max, this study)	12	1.44×10^2	111,111
MIVIS (min, this study)	6	3.60×10^1	444,444

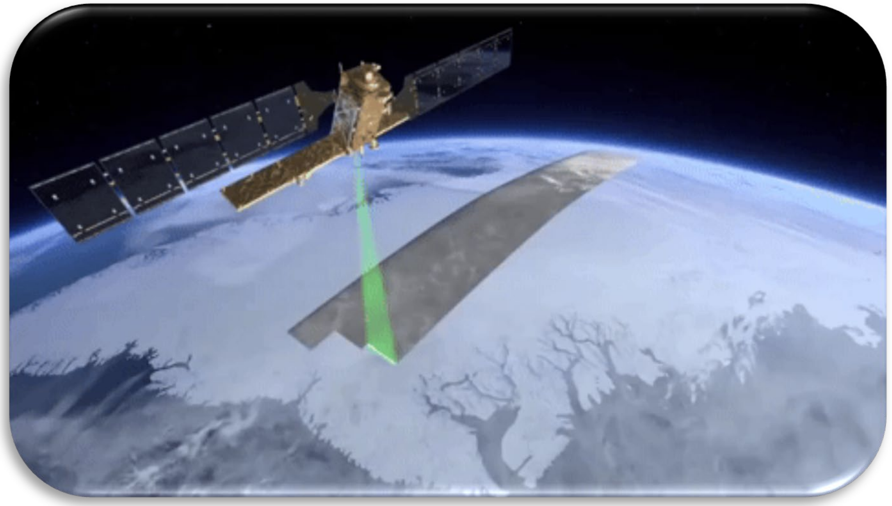
[a]VNIR is very near infrared, SWIR is short-wave infrared, and TIR is thermal infrared.

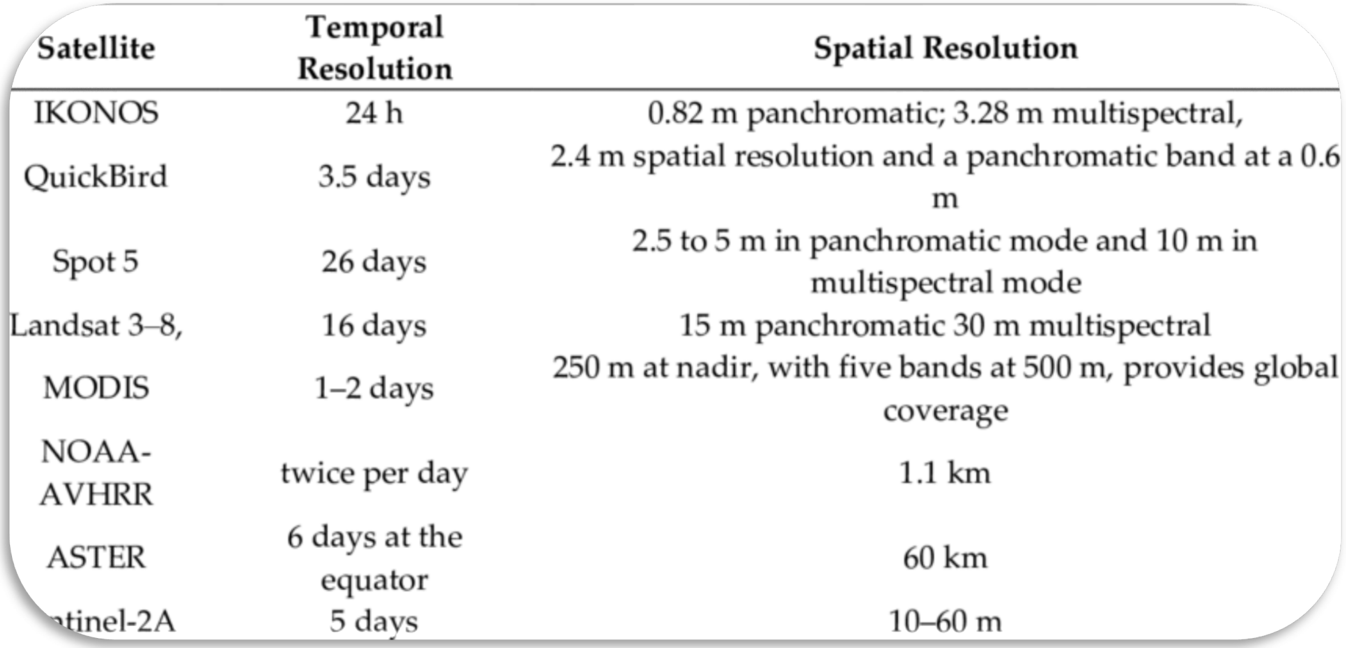


8-Temporal resolution of satellite data

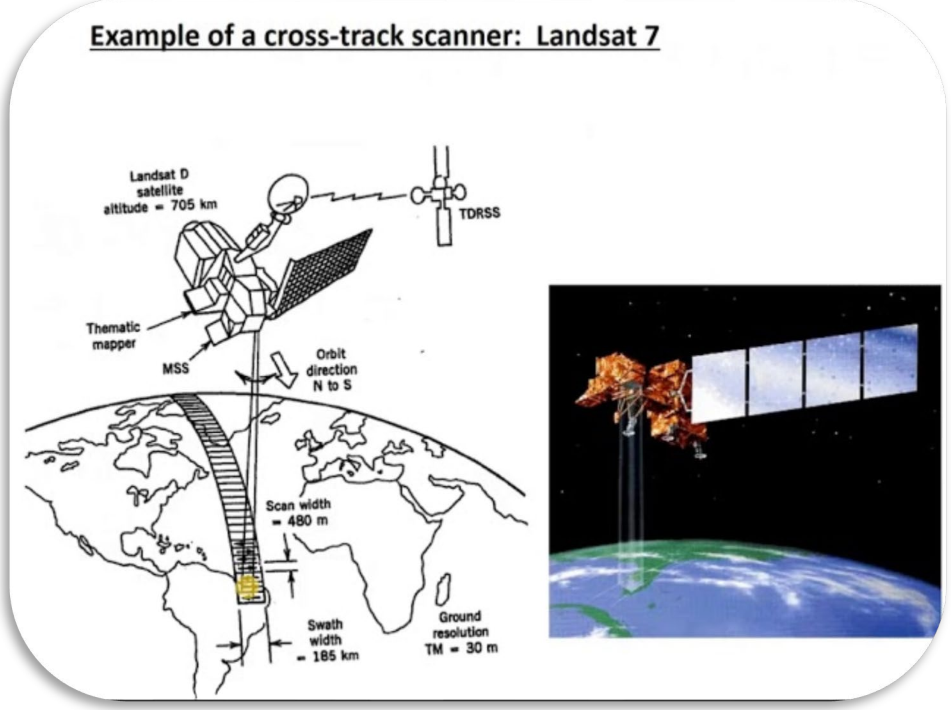
The temporal resolution of a sensor is how often it captures data of the same location, and it varies depending on a number of factors:

•**Sensor capabilities**: The capabilities of the sensor itself
•**Swath overlap**: How much the sensor's swath overlaps with other sensors
•**Latitude**: The sensor's latitude
•**Orbit**: The sensor's orbit
•**Purpose**: The sensor's purpose





Satellite	Temporal Resolution	Spatial Resolution
IKONOS	24 h	0.82 m panchromatic; 3.28 m multispectral,
QuickBird	3.5 days	2.4 m spatial resolution and a panchromatic band at a 0.6 m
Spot 5	26 days	2.5 to 5 m in panchromatic mode and 10 m in multispectral mode
Landsat 3–8,	16 days	15 m panchromatic 30 m multispectral
MODIS	1–2 days	250 m at nadir, with five bands at 500 m, provides global coverage
NOAA-AVHRR	twice per day	1.1 km
ASTER	6 days at the equator	60 km
tinel-2A	5 days	10–60 m



Example of a cross-track scanner: Landsat 7

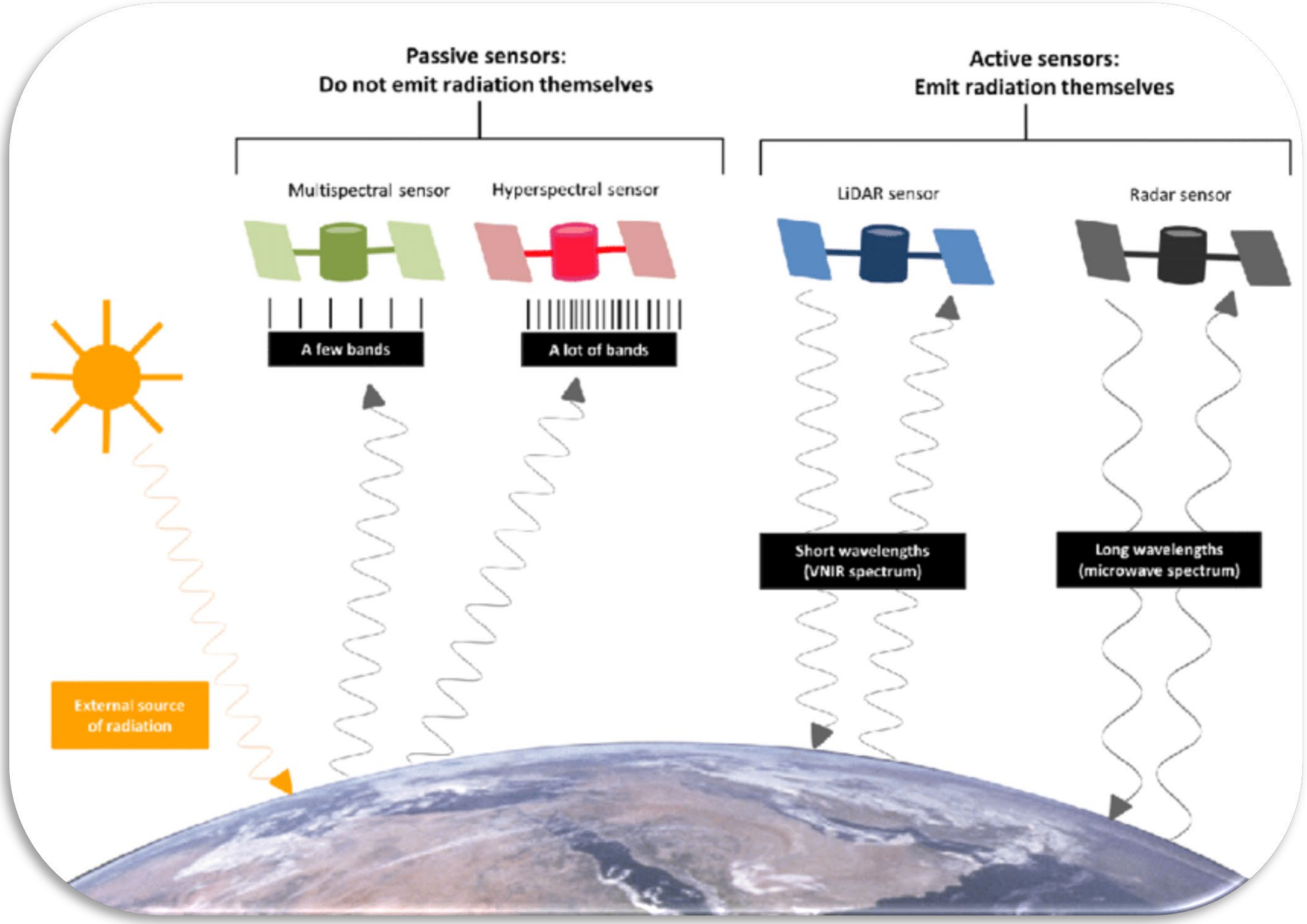
9-Types of remote sensing methods:

1-Passive remote sensing uses natural energy to measure a target, while active remote sensing uses its own energy source to illuminate a target.

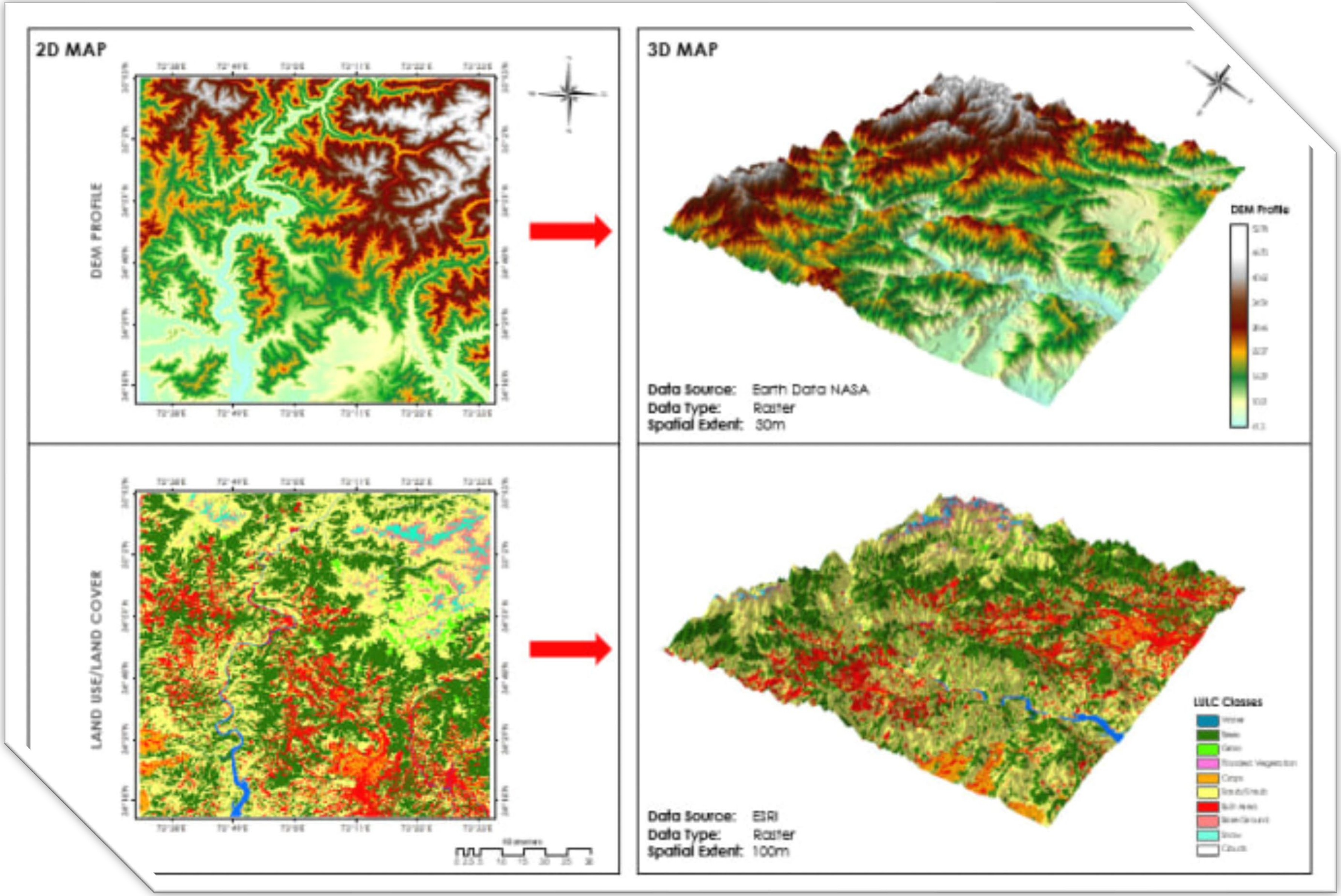
2-Active remote sensing instruments operate with their own source of emission or light, while passive ones rely on the reflected one.

Types of remote sensing:

- Optical remote sensing,
- Thermal infrared imaging,
- LiDAR
- RADAR



10-2d vs 3d maps in remote sensing



Data Source: Earth Data NASA
Data Type: Raster
Spatial Extent: 30m

Data Source: ESRI
Data Type: Raster
Spatial Extent: 100m

14-Spectral bands of ASTER, Hyperion and LANDSAT ETM+

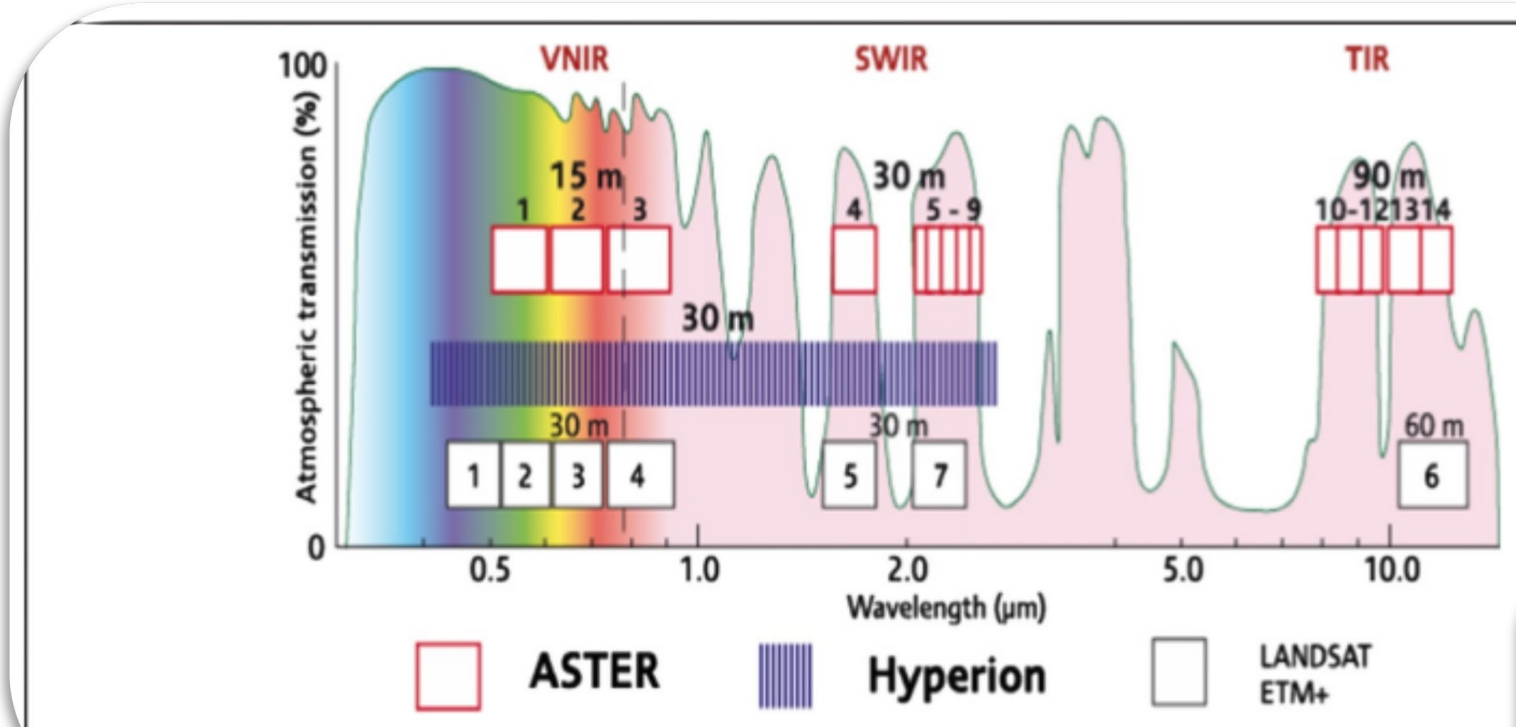
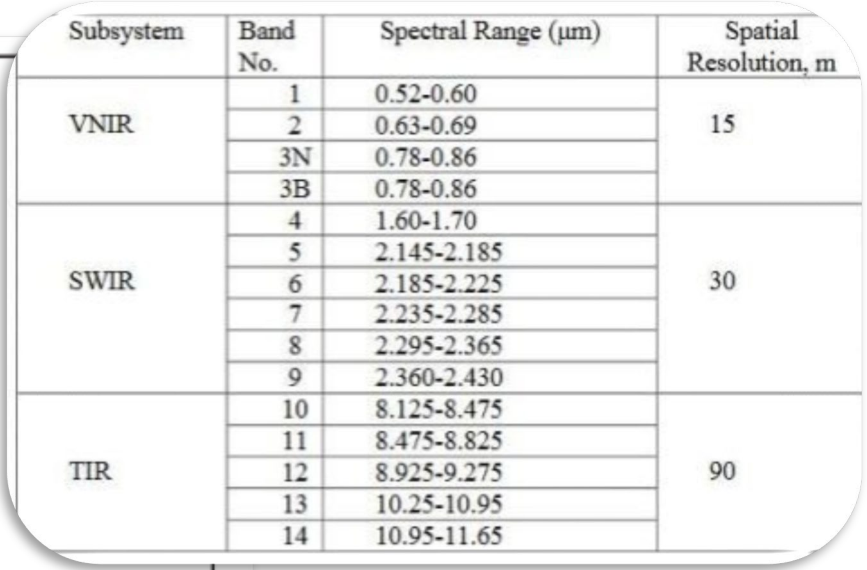
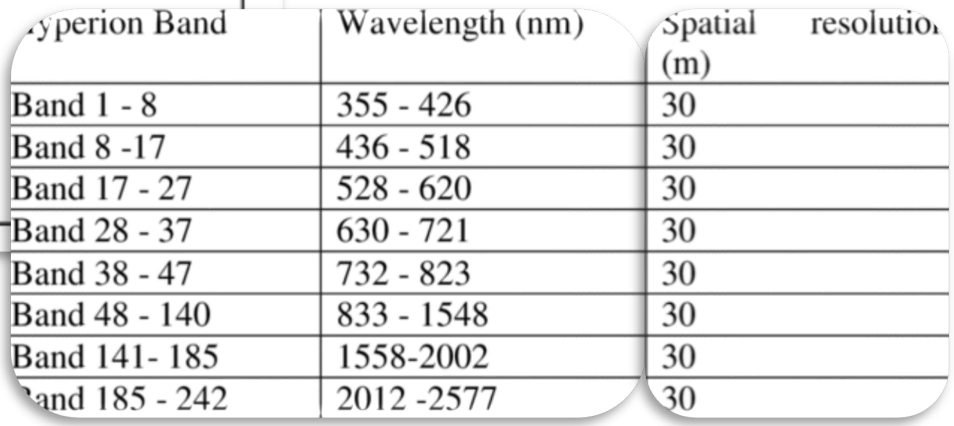


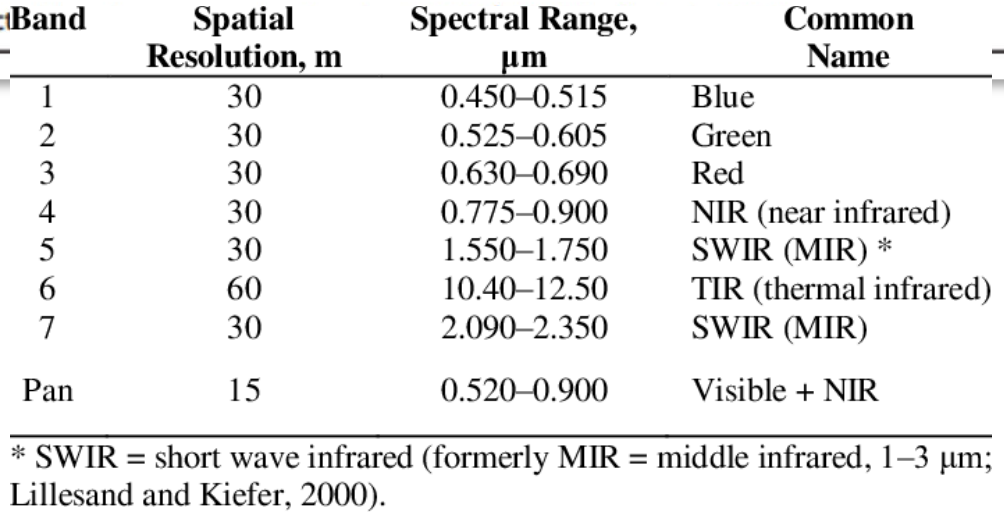
Figure 4 Hyperion and ASTER spec



Subsystem	Band No.	Spectral Range (μm)	Spatial Resolution, m
VNIR	1	0.52-0.60	15
	2	0.63-0.69	
	3N	0.78-0.86	
	3B	0.78-0.86	
SWIR	4	1.60-1.70	30
	5	2.145-2.185	
	6	2.185-2.225	
	7	2.235-2.285	
	8	2.295-2.365	
	9	2.360-2.430	
TIR	10	8.125-8.475	90
	11	8.475-8.825	
	12	8.925-9.275	
	13	10.25-10.95	
	14	10.95-11.65	



yperion Band	Wavelength (nm)	Spatial resolutio (m)
Band 1 - 8	355 - 426	30
Band 8 -17	436 - 518	30
Band 17 - 27	528 - 620	30
Band 28 - 37	630 - 721	30
Band 38 - 47	732 - 823	30
Band 48 - 140	833 - 1548	30
Band 141- 185	1558-2002	30
and 185 - 242	2012 -2577	30

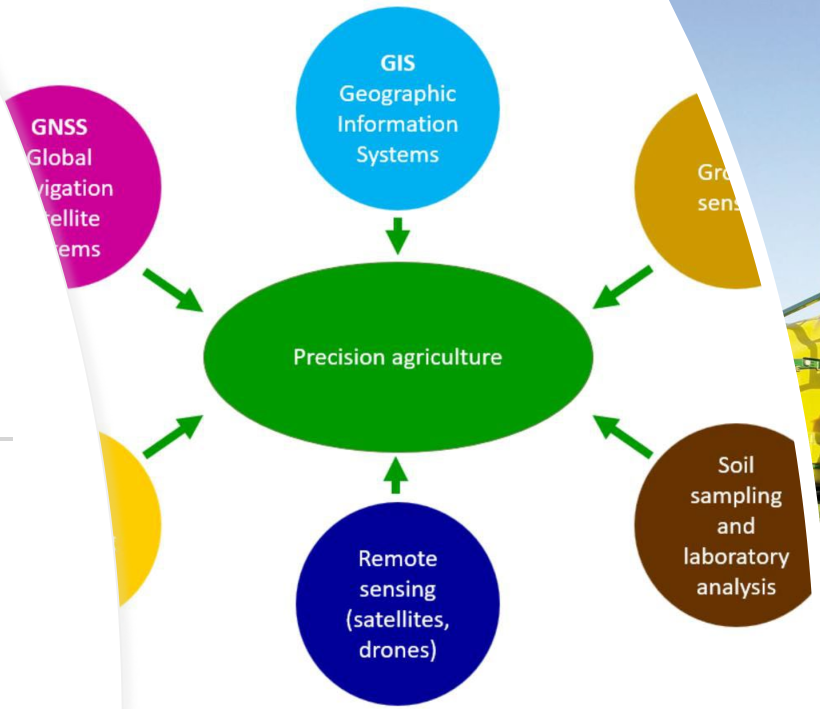


Band	Spatial Resolution, m	Spectral Range, μm	Common Name
1	30	0.450–0.515	Blue
2	30	0.525–0.605	Green
3	30	0.630–0.690	Red
4	30	0.775–0.900	NIR (near infrared)
5	30	1.550–1.750	SWIR (MIR) *
6	60	10.40–12.50	TIR (thermal infrared)
7	30	2.090–2.350	SWIR (MIR)
Pan	15	0.520–0.900	Visible + NIR

* SWIR = short wave infrared (formerly MIR = middle infrared, 1–3 μm; Lillesand and Kiefer, 2000).

Digital Agriculture

- EO + IoT + AI
- Precision farming
- Data-driven decision making



GNSS
Global
vigation
ellite
ems

GIS
Geographic
Information
Systems

Gr
sens

Precision agriculture

Soil
sampling
and
laboratory
analysis

Remote
sensing
(satellites,
drones)

rofile

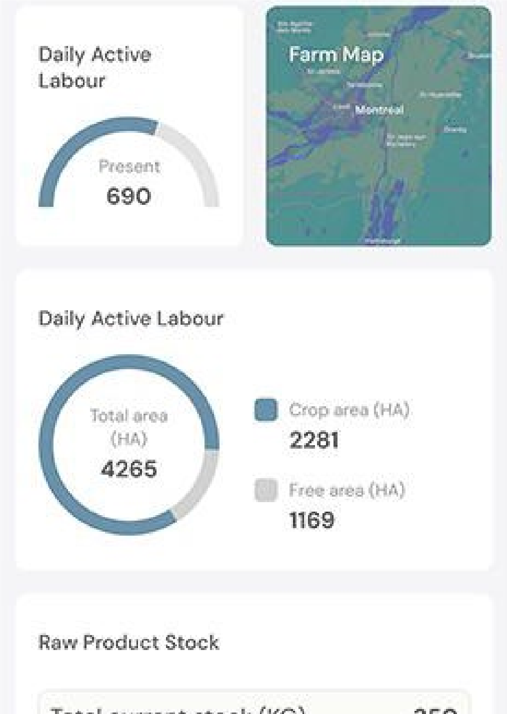
Date	Crop Area	Crop Status
019	34 HA	Active

Crop Name: Mango
Crop Variety: Kesar
Crop Name: 180 Days
Crop Variety: 4200 KGS
Sustainability Score: 90.06

VI .72 0.14
dated on 24 Apr 2019

Growing Degree Days
Starting Day: 15°
Starting Day: 120°

PRODUCTION
4 Tons
3.85 Tons

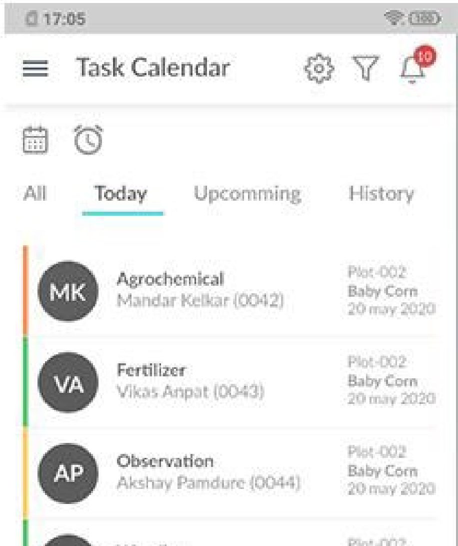


Daily Active Labour
Present 690

Farm Map

Daily Active Labour
Total area (HA) 4265
Crop area (HA) 2281
Free area (HA) 1169

Raw Product Stock



17:05

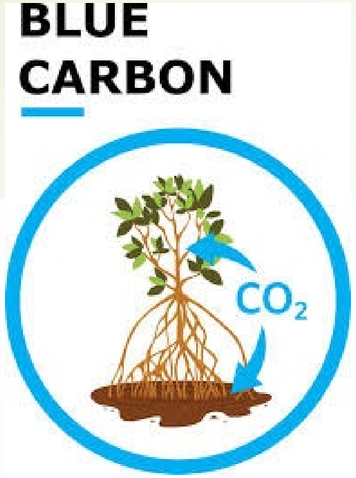
Task Calendar

All | Today | Upcomming | History

MK	Agrochemical Mandar Kelkar (0042)	Plot-002 Baby Corn 20 may 2020
VA	Fertilizer Vikas Anpat (0043)	Plot-002 Baby Corn 20 may 2020
AP	Observation Akshay Pamdure (0044)	Plot-002 Baby Corn 20 may 2020

Crop Monitoring

- **NDVI and vegetation indices**
- **Detect stress early**
- **Monitor growth stages**



Vegetation Mapping

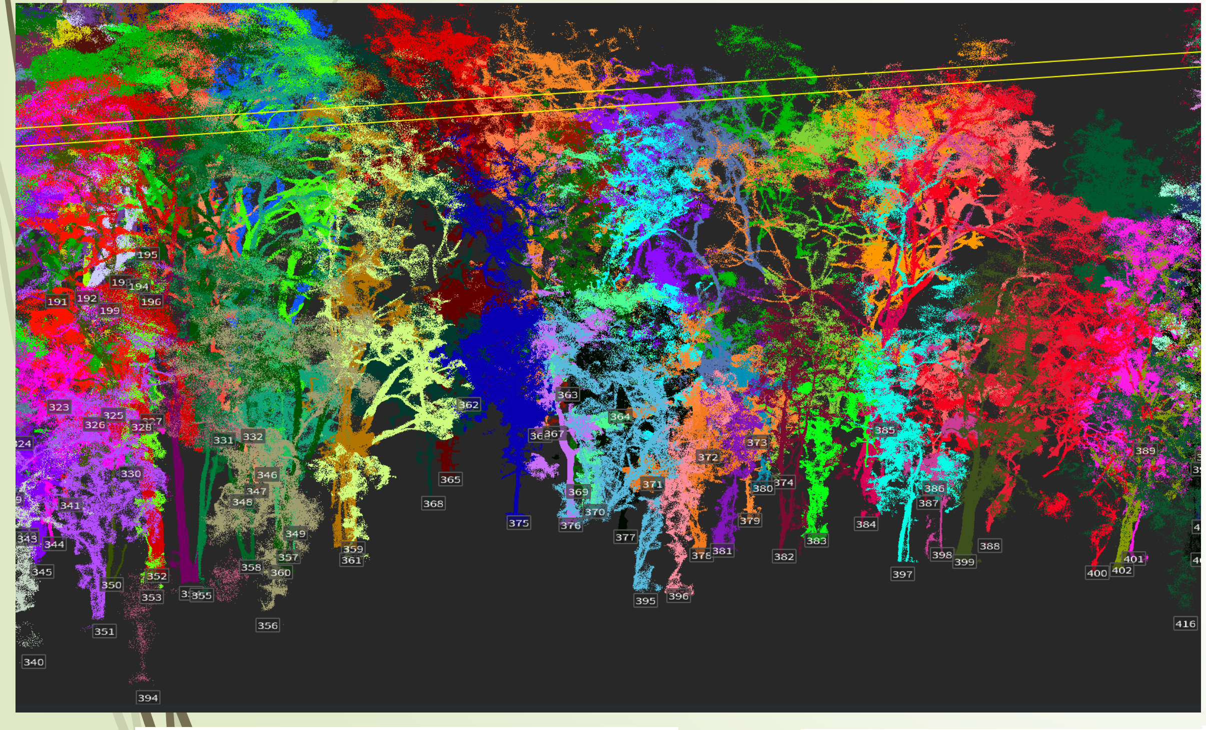
- DEVELOP SCALABLE & COST-EFFECTIVE REMOTE SENSING METHODS FOR BIOMASS ESTIMATION
- QUANTIFY BLUE AND GREEN CARBON STOCKS IN MANGROVES, WETLANDS, AND GRASSLANDS
- ASSESS ECOSYSTEM HEALTH AND VULNERABILITIES
- SUPPORT INFORMED POLICYMAKING AND ACTIONABLE DATA
- ENHANCE DROUGHT RESILIENCE STRATEGIES, THROUGH IMPROVED REMOTE SENSING METHODS

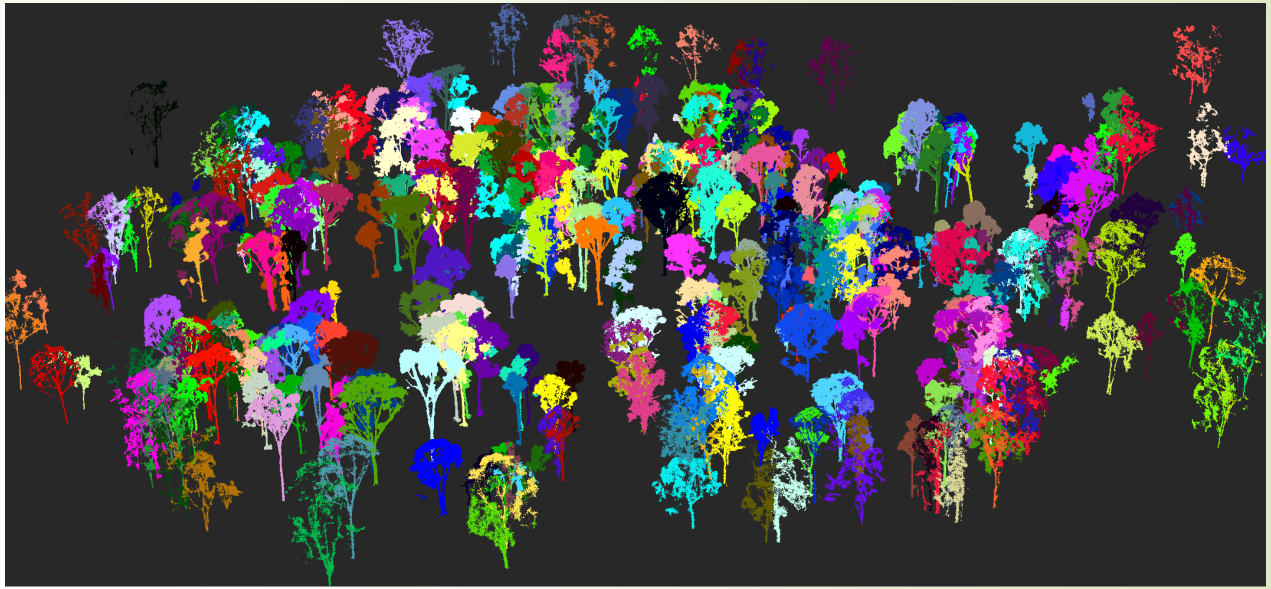
JCU TNQ Drought Hub

Advanced Remote Sensing for Vegetation Estimation & Ecosystem Assessment in Mangroves, Wetlands, and Rangelands, North Queensland, Australia

Edward Venn, Dr Ben Jarihani, Dr Jack Koci, Dr Nathan Waltham

Australian Government
Department of Agriculture, Fisheries and Forestry
Future Drought Fund





Australian Government
Department of Agriculture, Fisheries and Forestry
Future Drought Fund

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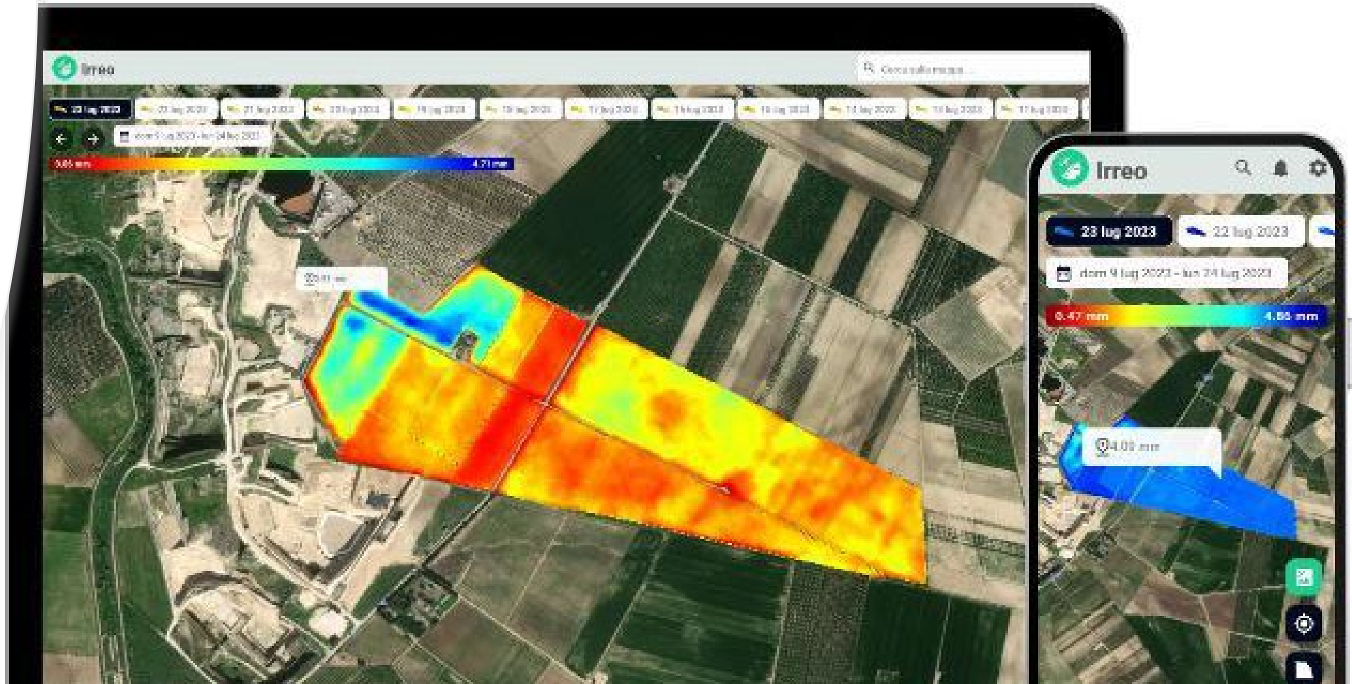
TropWATER

JCU TNQ Drought Hub

Southern Gulf NRM

Water Management

- Precipitation mapping
- Soil moisture monitoring
- Irrigation optimization
- Evapotranspiration mapping



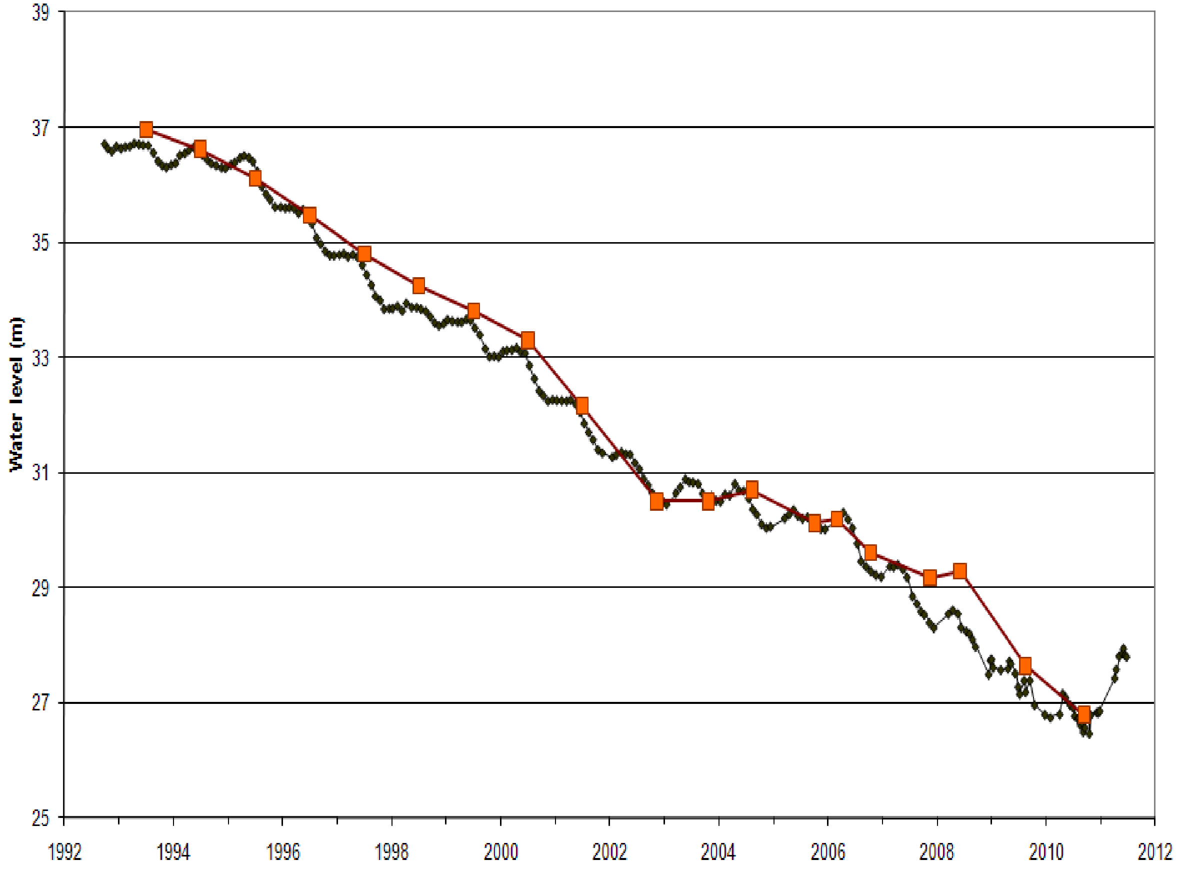
3.1 Flood monitoring

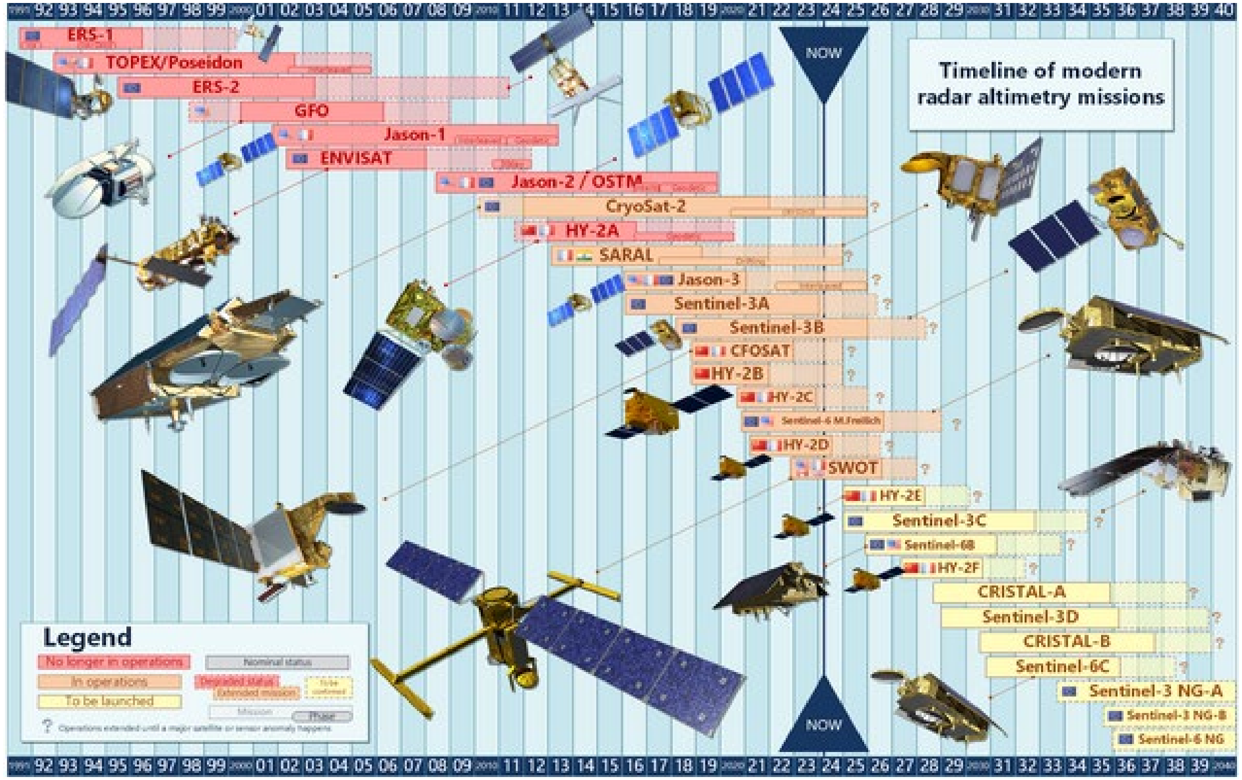
- Floods are driven by snowmelt, glacier melt, and extreme rainfall
- SAR is central for all-weather flood extent mapping
- Optical, snow cover, and precipitation products improve context
- Hydrological models convert EO data into early-warning insight

Key datasets: Sentinel-1, Landsat/Sentinel-2, CHIRPS, GPM IMERG

Floods in Uzbekistan, April 2022. Photo: Ministry of Emergency Situations Uzbekistan

Aral Sea Water Level (Altimetry Satellites):



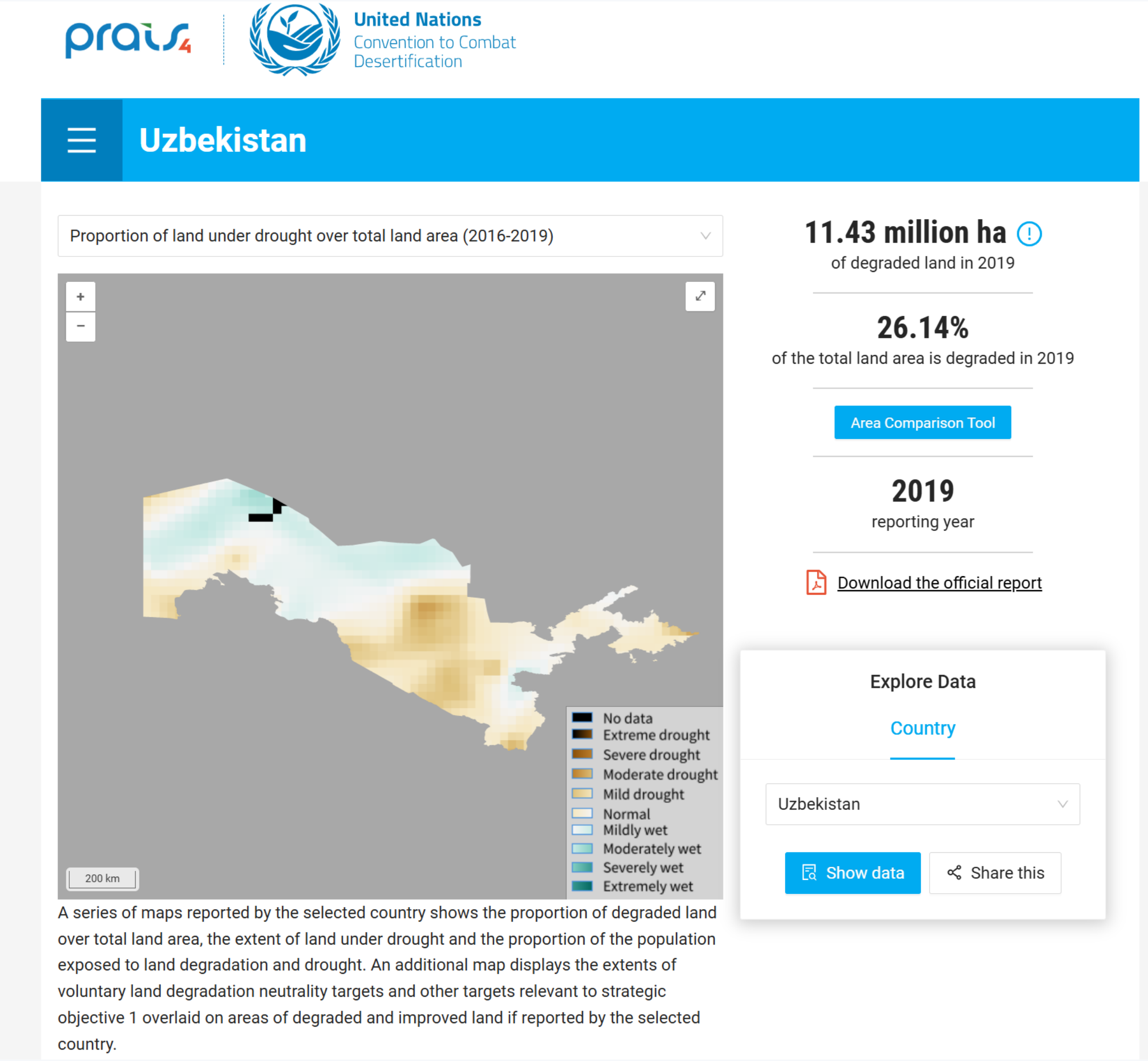


Variations in the water level of the South Aral basins using in situ measurements (annual means, shown in orange) and altimetry measurements (in black). The in situ measurements include data provided by Ashirbekov and Zonn 2003 (1993-2001) and P. Zavialov (2002-2010), personal communication. Credits Legos

3.2 Drought monitoring

- Central Asia is highly drought-sensitive because of continental climate, low precipitation, and rising temperatures
- GRACE/GRACE-FO reveal basin-scale terrestrial water storage decline
- MODIS vegetation indices capture drought stress and ecosystem response
- Integrated products such as FLDAS-Central Asia support food and water security analysis

Future CMIP6 scenarios indicate more frequent and persistent drought



Uzbekistan

Proportion of land under drought over total land area (2016-2019)

11.43 million ha
of degraded land in 2019

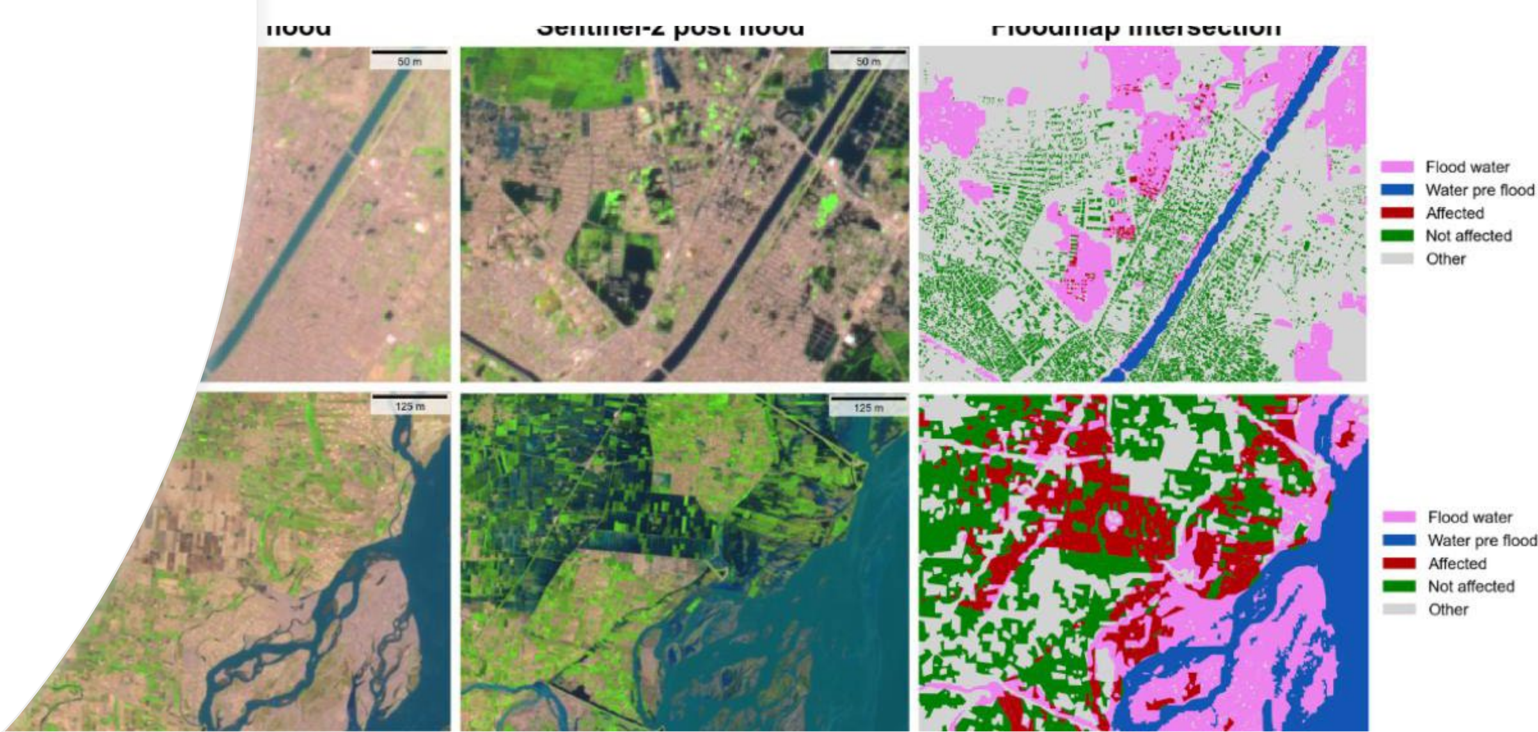
26.14%
of the total land area is degraded in 2019

2019
reporting year

A series of maps reported by the selected country shows the proportion of degraded land over total land area, the extent of land under drought and the proportion of the population exposed to land degradation and drought. An additional map displays the extents of voluntary land degradation neutrality targets and other targets relevant to strategic objective 1 overlaid on areas of degraded and improved land if reported by the selected country.

Climate & Risk

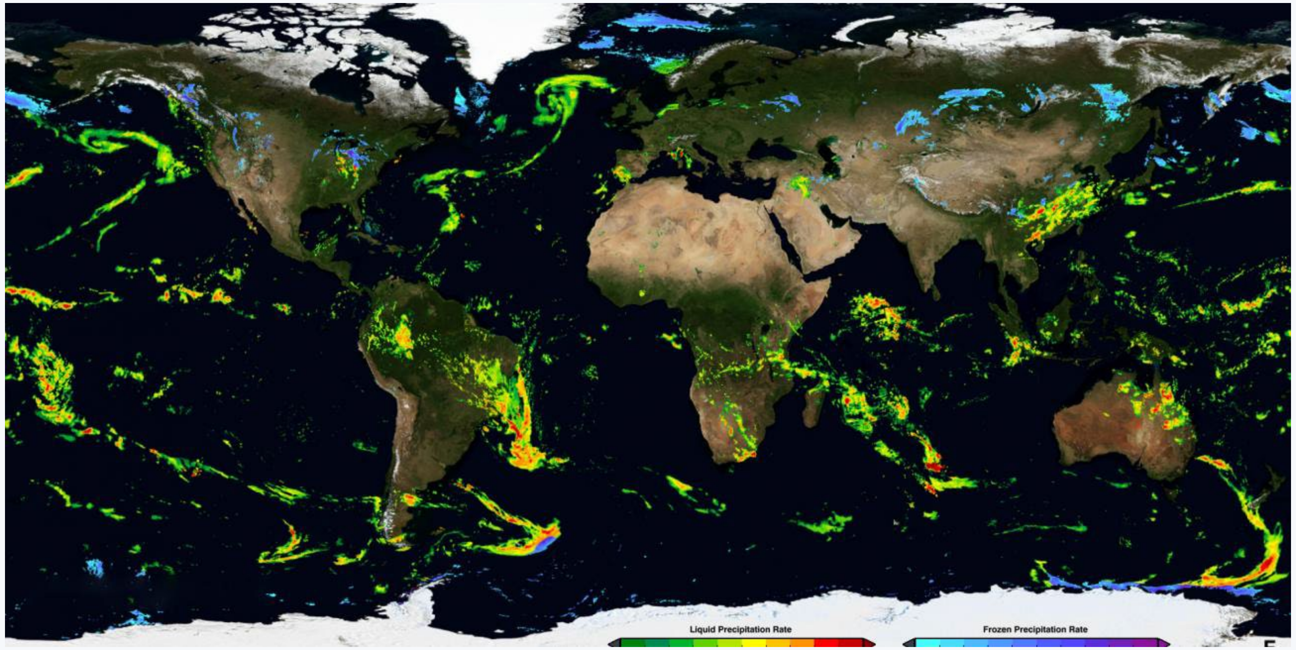
- **Drought monitoring**
- **Flood mapping**
- **Yield prediction**



3.3 Storms and extreme weather

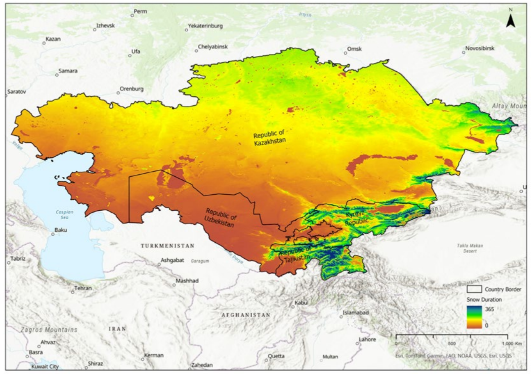
- Dust storms, intense precipitation, and compound climate hazards are increasing across Central Asia
- TROPOMI, CAMS, and MERRA-2 track aerosol intensity and transport pathways
- GPM/IMERG and related datasets reveal stronger precipitation extremes
- EO + reanalysis + ground networks create a layered monitoring framework

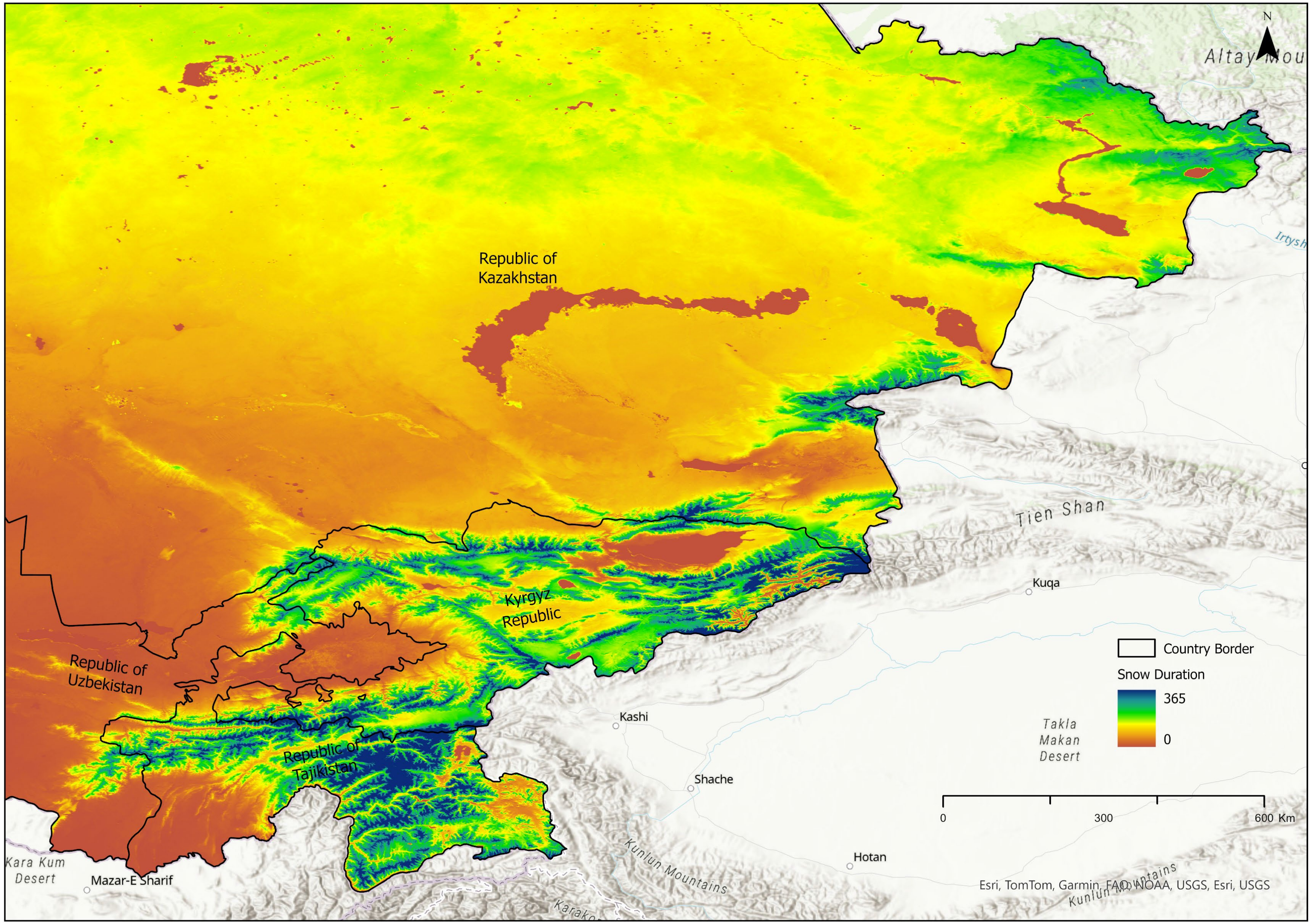
IMERG – Integrated Multi-satellite Precipitation



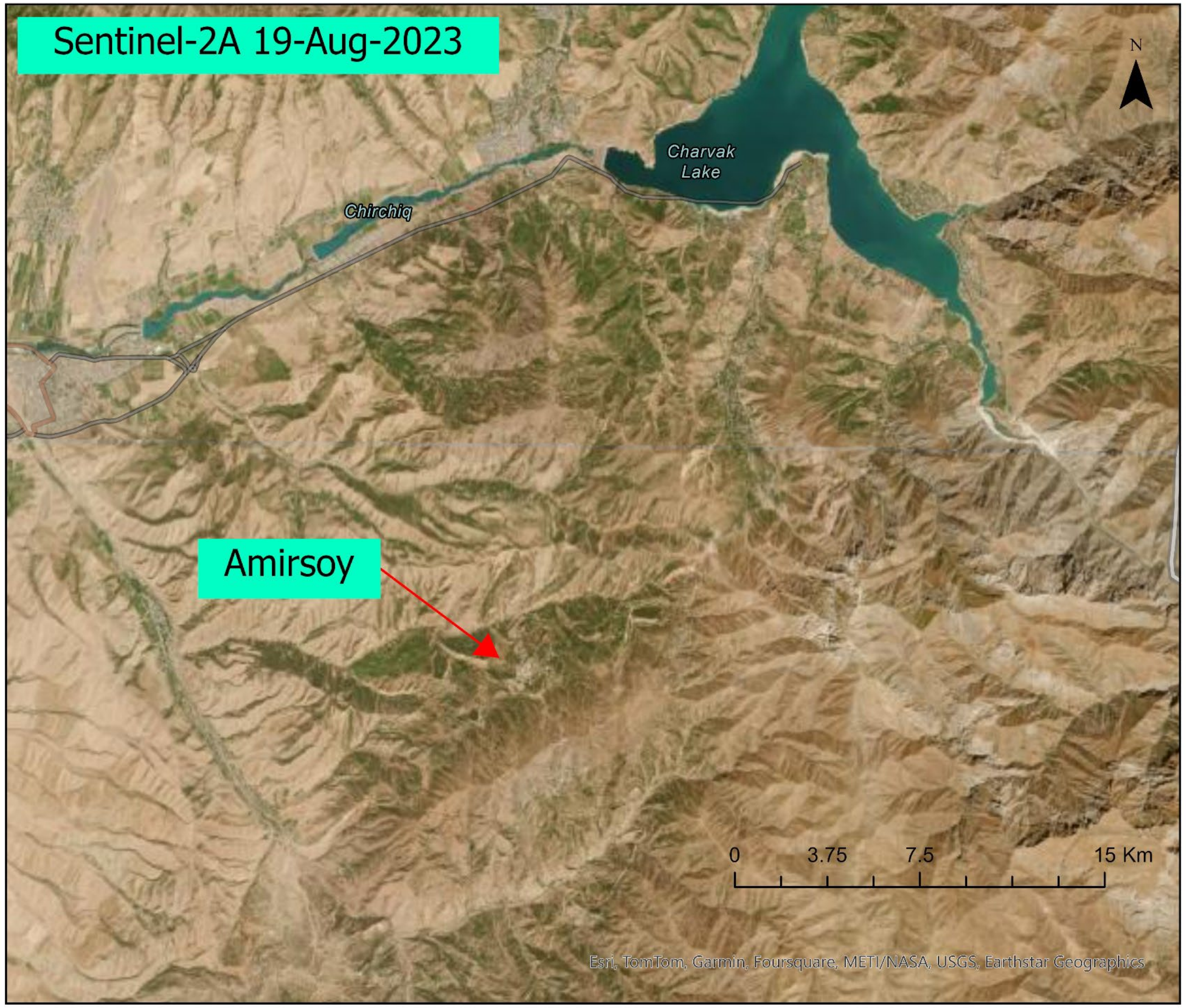
Dust storm over the Aral Sea (located between Uzbekistan and Kazakhstan and Afghanistan

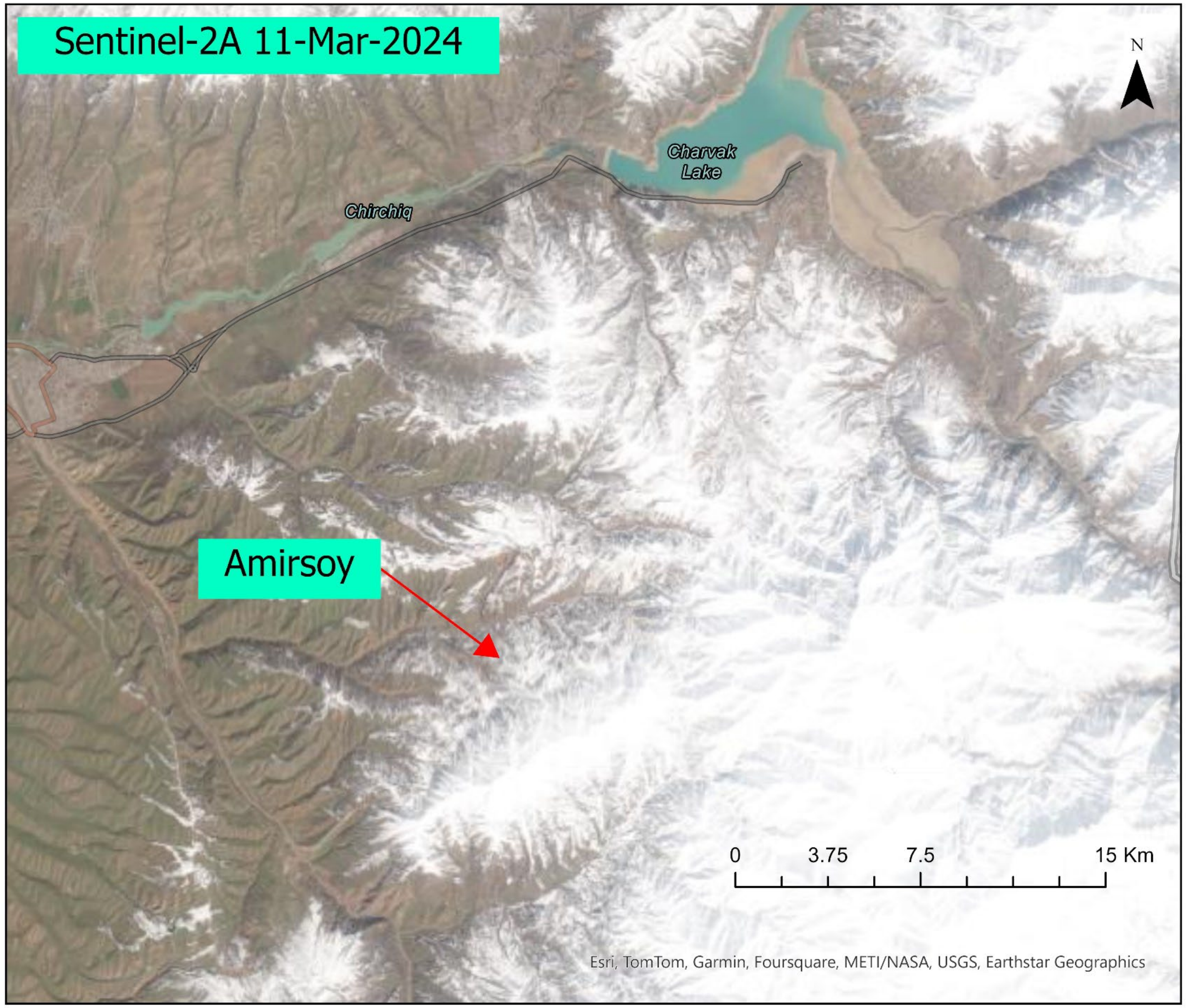
Snow duration





Esri, TomTom, Garmin, FAO, NOAA, USGS, Esri, USGS

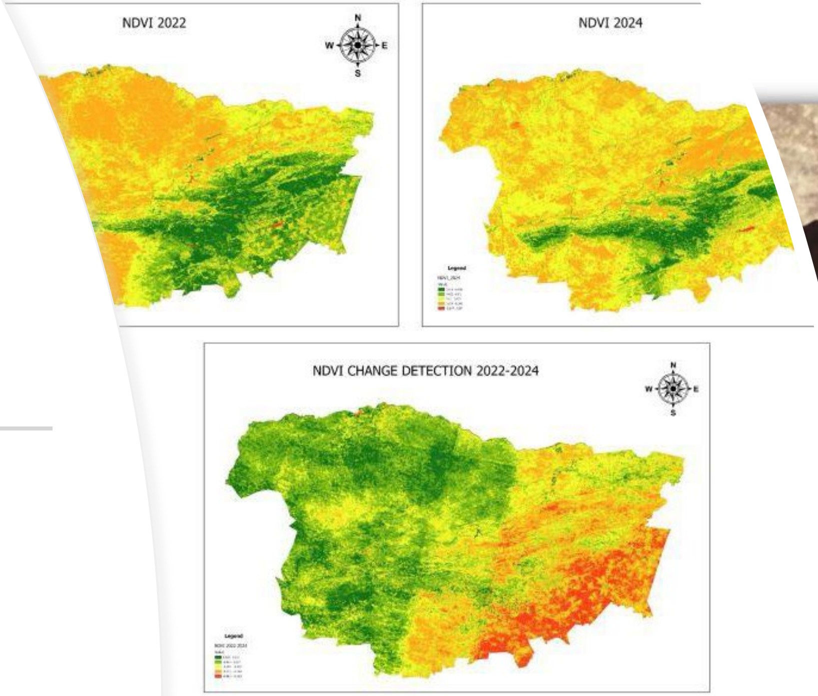


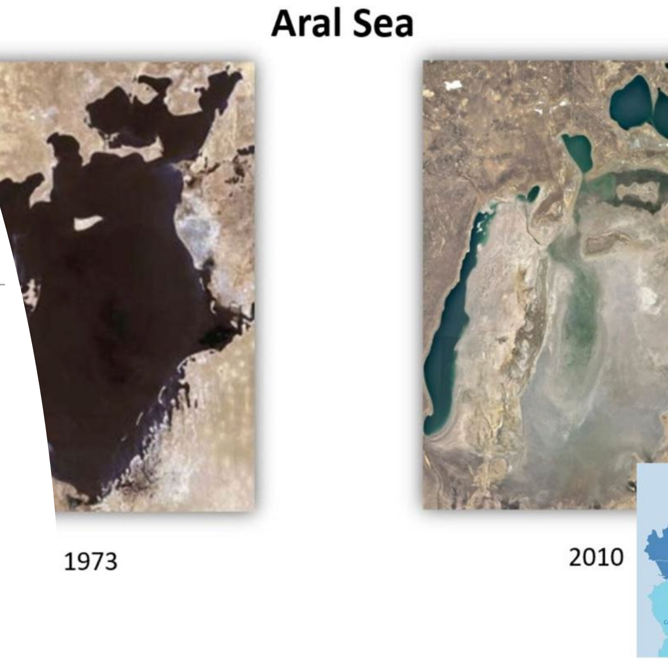


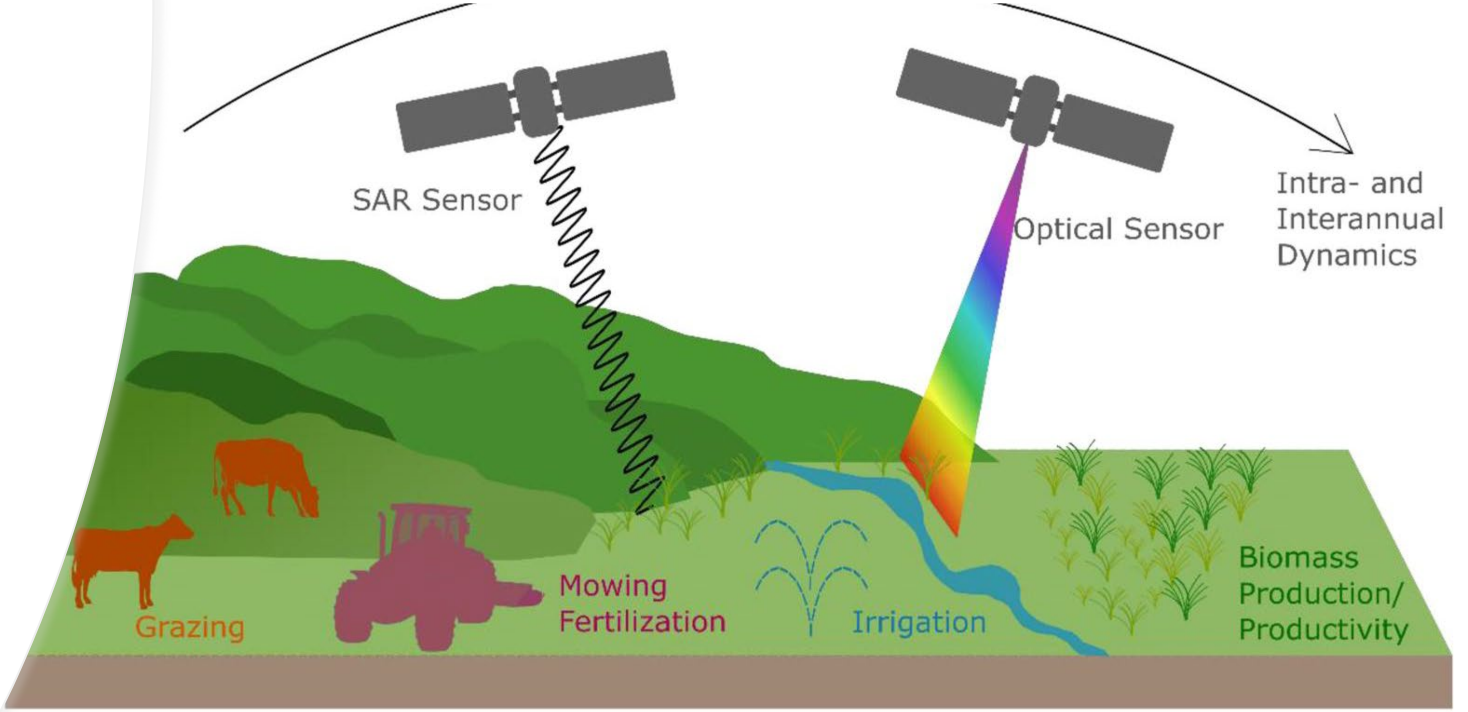
We utilize a time series of satellite images to extract daily snow-covered areas, which we then stack to create monthly and annual snow duration maps. The satellites used include MODIS, Landsat, Sentinel, and Planet.

Land Degradation

- **Soil erosion detection**
- **Vegetation loss**
- **Salinity mapping**





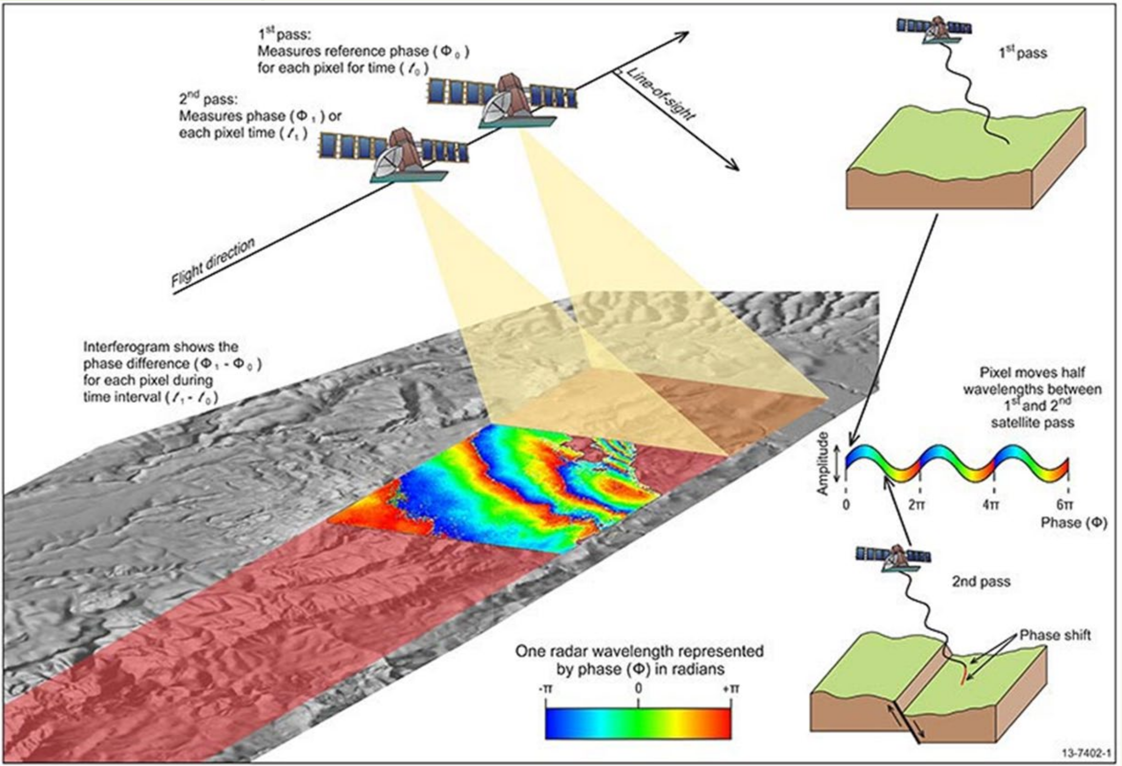


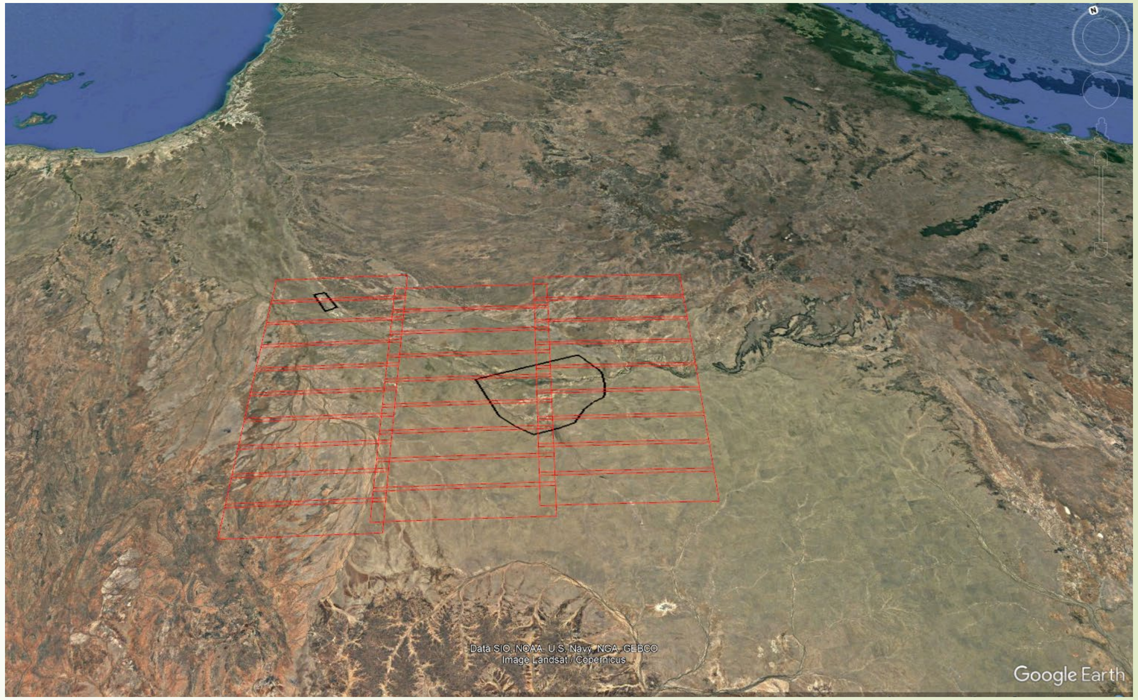
Advanced Remote Sensing Techniques for Soil Erosion and Land Degradation Assessment in North Queensland: 2019 Flood Event: PhD proposal

Laleh Jafari[1], Ben Jarihani[1], Jack Koci[2]

1 College of Science and Engineering, James Cook University, Queensland, Australia

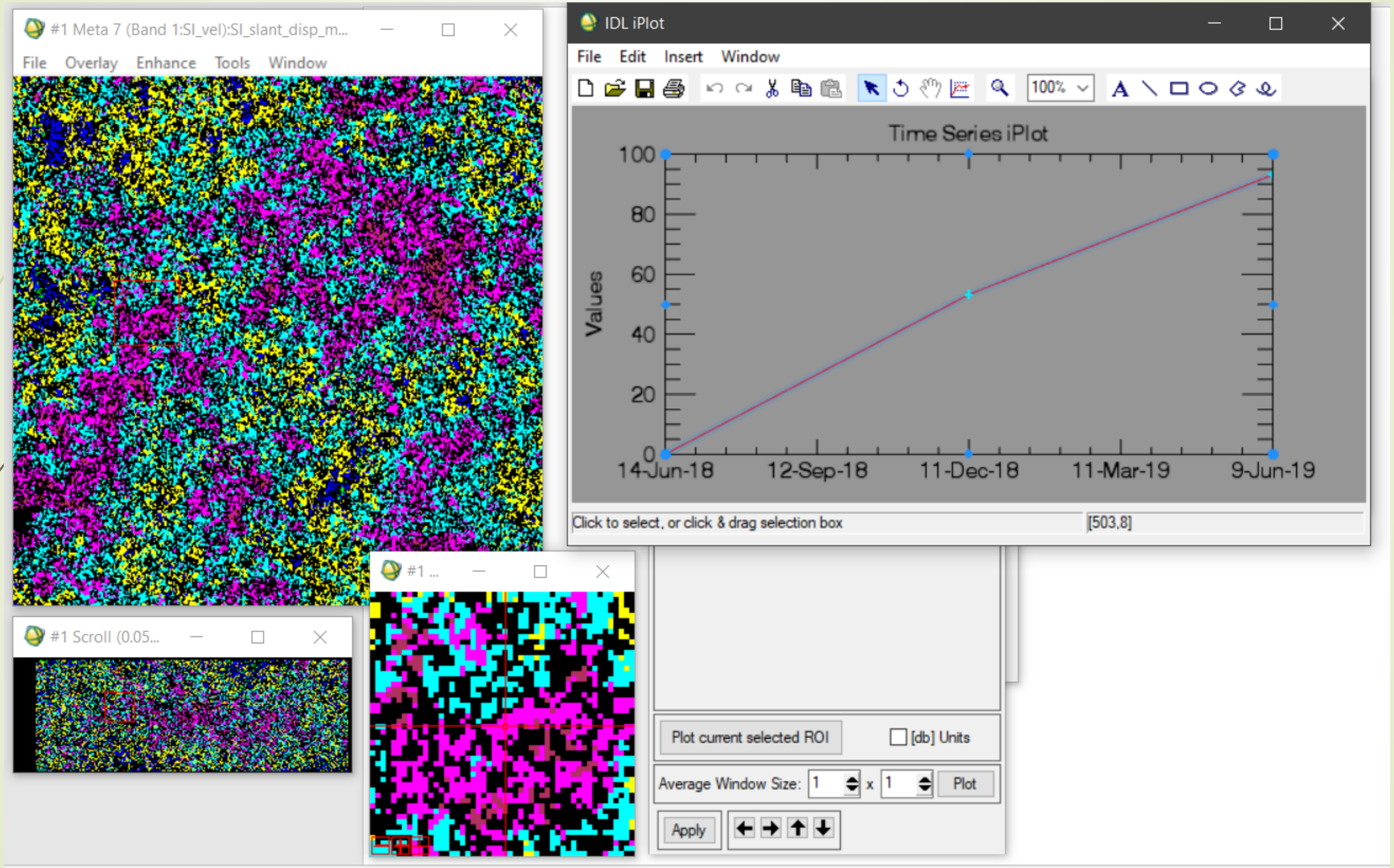
2 TropWATER, James Cook University, Queensland, Australia





Australian Government
Department of Agriculture, Fisheries and Forestry
Future Drought Fund
JCU JAMES COOK UNIVERSITY AUSTRALIA
TropWATER
JCU TNQ Drought Hub
Southern Gulf NRM

Geocoding

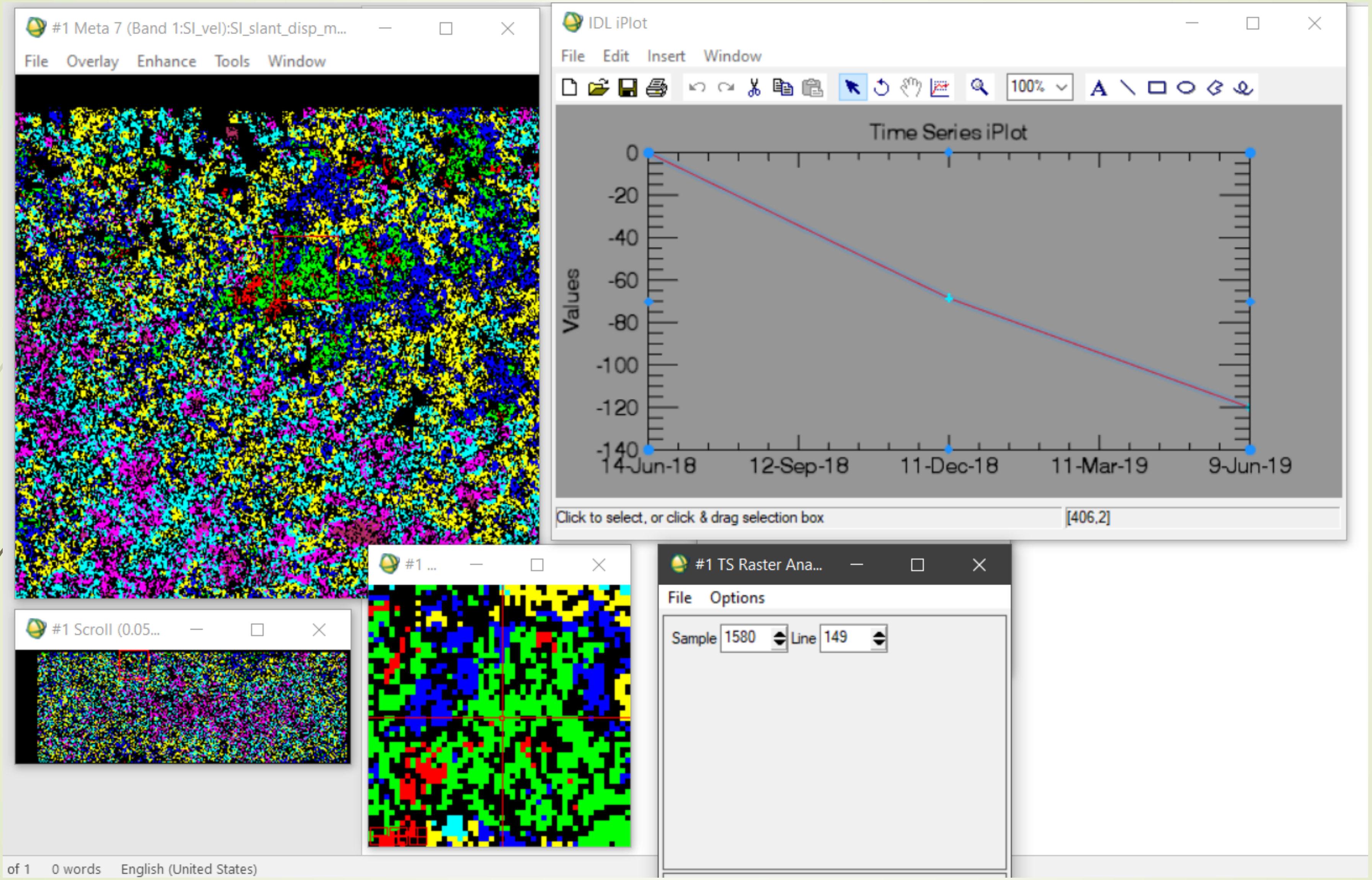


Click to select, or click & drag selection box

[503,8]

Displacement map according to the date of each image in millimeter with atmospheric correction

Geocoding

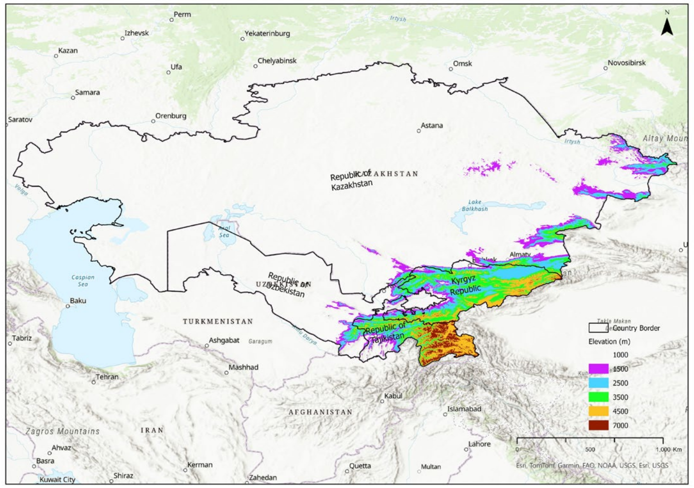


Click to select, or click & drag selection box [406,2]

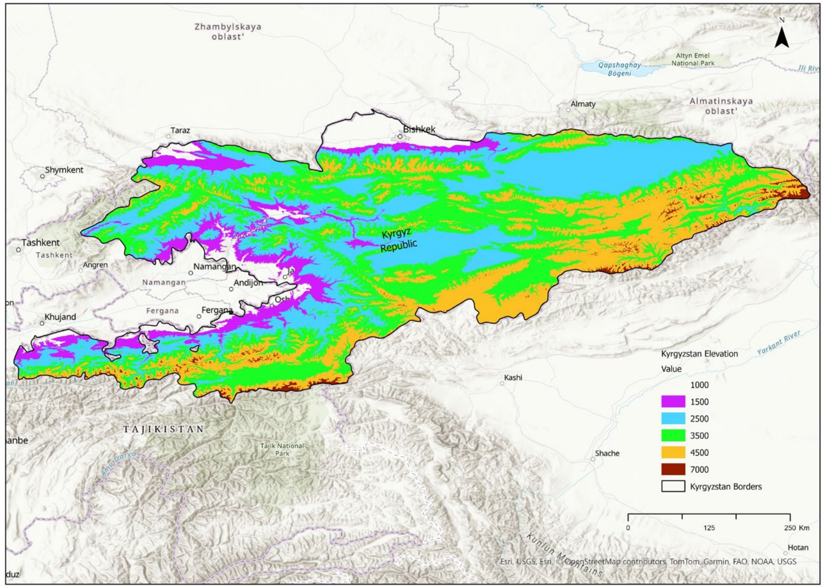
Sample 1580 Line 149

Displacement map according to the date of each image in millimeter with atmospheric correction

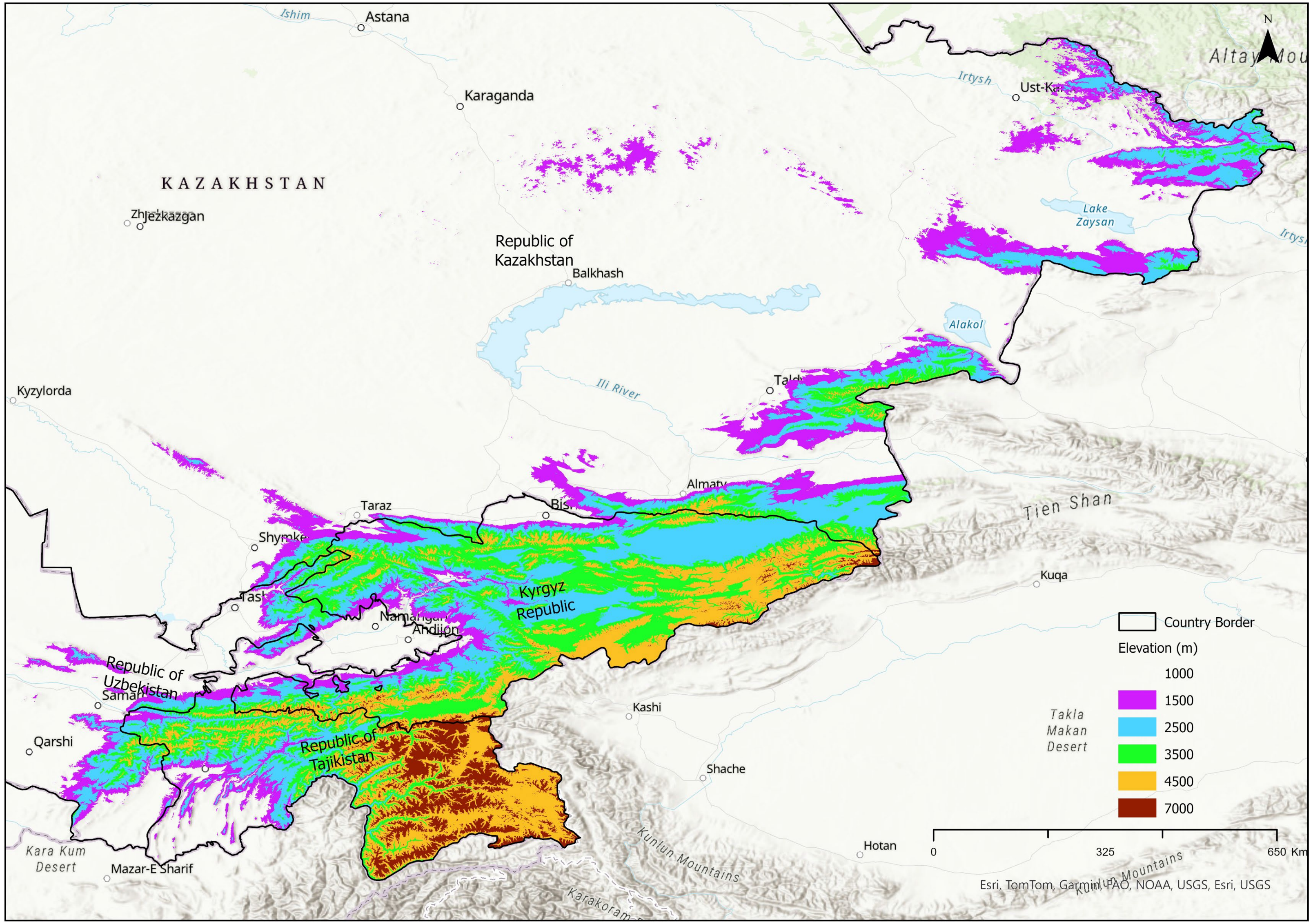
Topography Central Asia:



Esri, TomTom, Garmin, FAO, NOAA, USGS, Esri, USGS



Esri, USGS, Esri, © OpenStreetMap contributors, TomTom, Garmin, FAO, NOAA, USGS



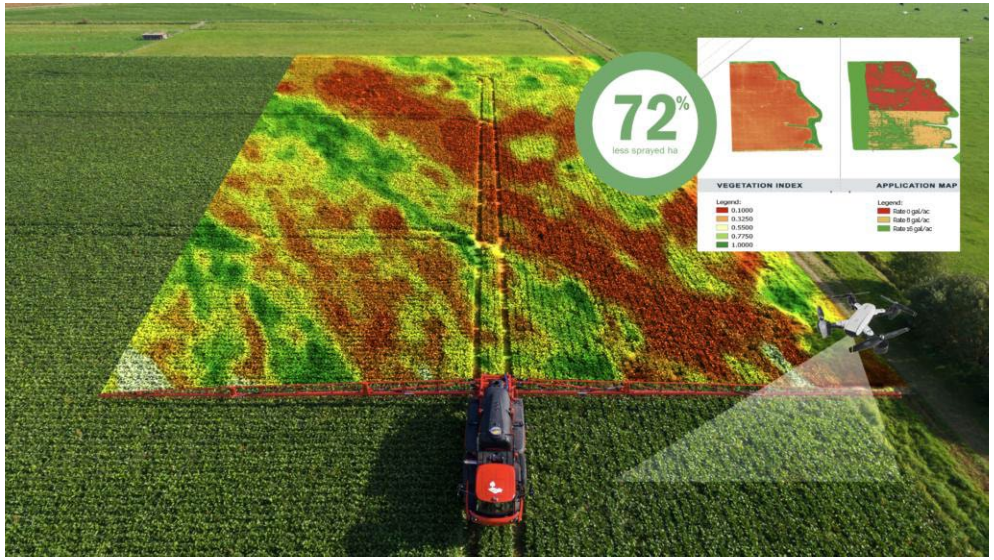
Esri, TomTom, Garmin, FAO, NOAA, USGS, Esri, USGS

Precision Agriculture

- **Variable rate application**
- **GPS-guided machinery**
- **Yield mapping**
- **Weed Spraying**

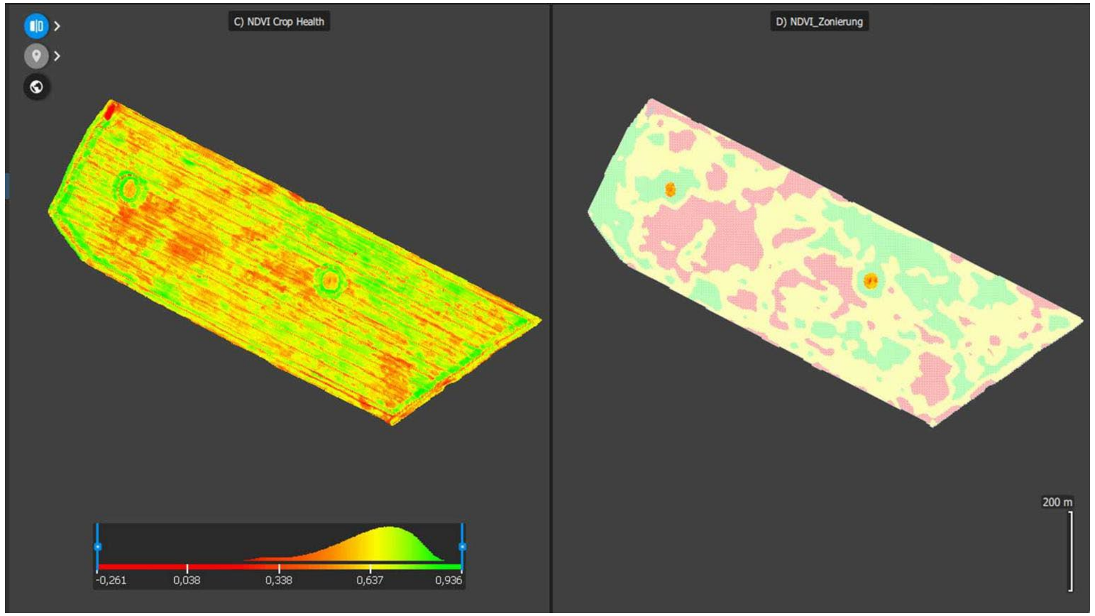
Precision Agriculture Examples

- Laser Weed Control (Chemical-Free Farming)
- Precision Spraying (Variable Rate Application)



Precision Agriculture Examples

- Precision Planting (Smart Seeding)
- Satellite-Based Crop Management Maps



Precision Agriculture Examples

Drone-Based Precision Monitoring & Spraying

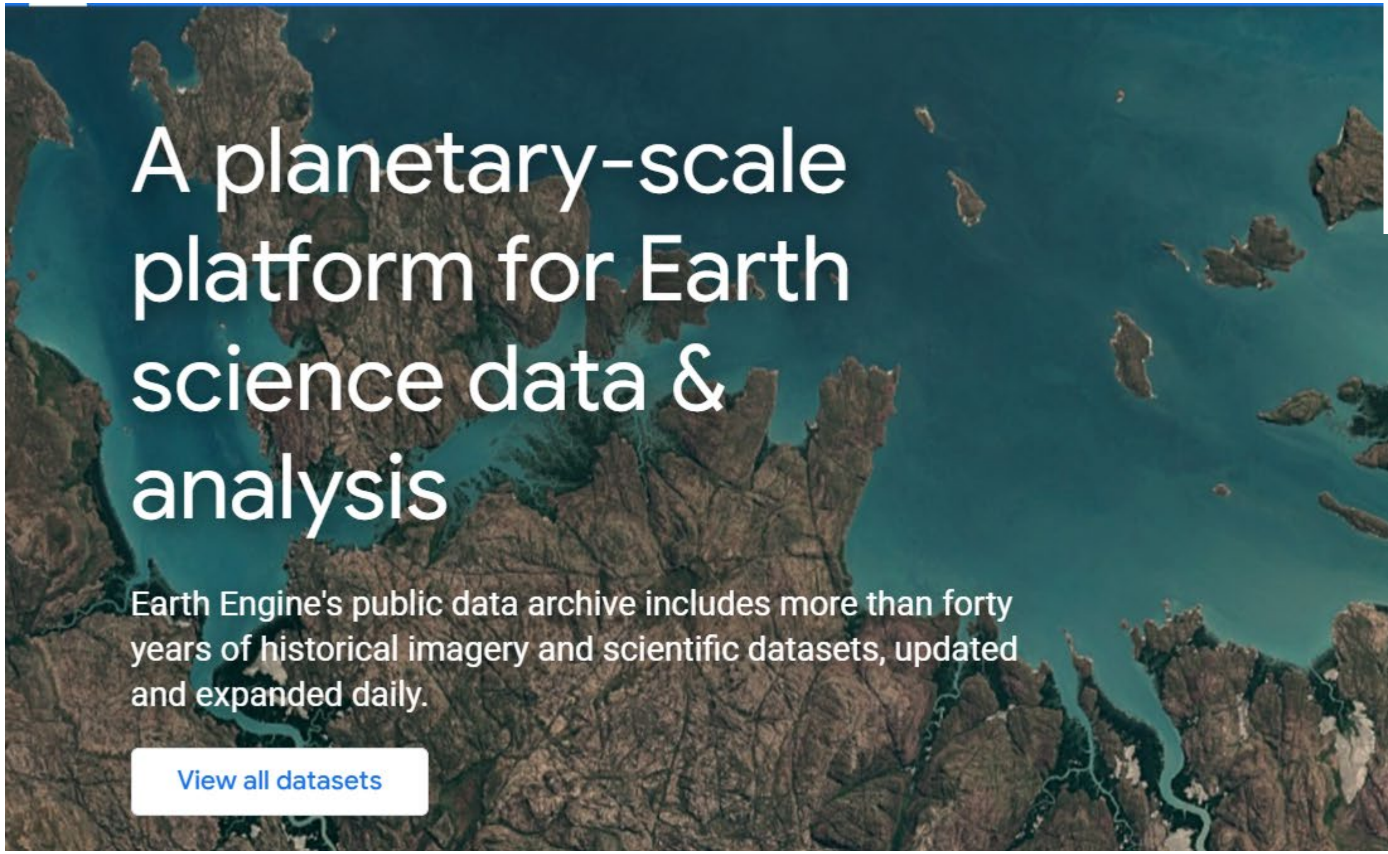
AI & Big Data

- **Machine learning**
- **Google Earth Engine**
- **Automation of analysis**

Major Remote Sensing Data Providers and Platforms

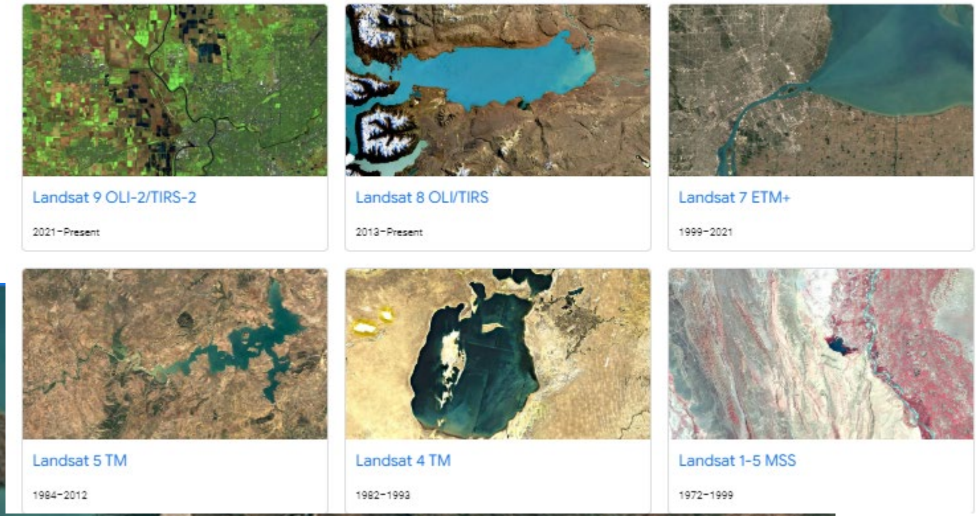
- NASA Earthdata
- ESA Copernicus Open Access Hub
- USGS EarthExplorer
- NOAA NCEI
- JAXA G-Portal
- Geospatial Data Cloud (China)
- EUMETSAT Data Centre
- Planet Labs
- Maxar Technologies
- Sentinel Asia
- Copernicus Marine Environment Monitoring Service (CMEMS)
- Amazon Web Services (AWS) Public Datasets
- ESRI ArcGIS
- Google Earth Engine

Example: Google Earth Engine:



A planetary-scale platform for Earth science data & analysis

Earth Engine's public data archive includes more than forty years of historical imagery and scientific datasets, updated and expanded daily.



Landsat 9 OLI-2/TIRS-2
2021–Present

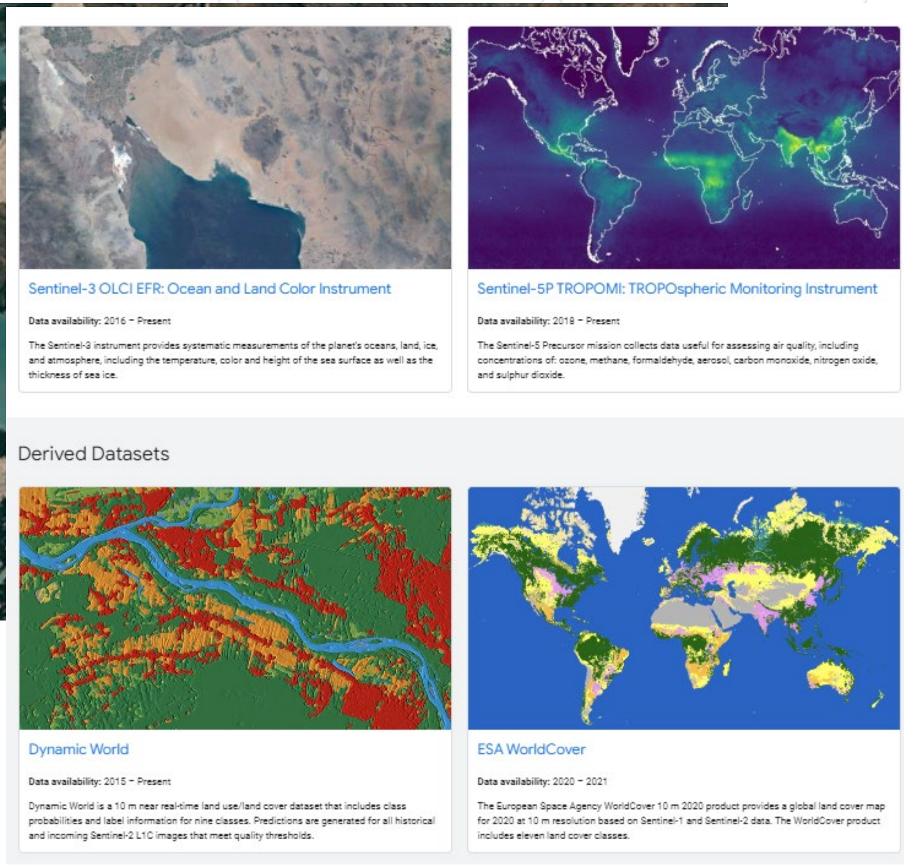
Landsat 8 OLI/TIRS
2013–Present

Landsat 7 ETM+
1999–2021

Landsat 5 TM
1984–2012

Landsat 4 TM
1982–1993

Landsat 1-5 MSS
1972–1999



Sentinel-3 OLCI EFR: Ocean and Land Color Instrument

Data availability: 2016 – Present

The Sentinel-3 instrument provides systematic measurements of the planet's oceans, land, ice, and atmosphere, including the temperature, color and height of the sea surface as well as the thickness of sea ice.

Sentinel-5P TROPOMI: TROPOspheric Monitoring Instrument

Data availability: 2018 – Present

The Sentinel-5 Precursor mission collects data useful for assessing air quality, including concentrations of: ozone, methane, formaldehyde, aerosol, carbon monoxide, nitrogen oxide, and sulphur dioxide.

Derived Datasets

Dynamic World

Data availability: 2015 – Present

Dynamic World is a 10 m near real-time land use/land cover dataset that includes class probabilities and label information for nine classes. Predictions are generated for all historical and incoming Sentinel-2 L1C images that meet quality thresholds.

ESA WorldCover

Data availability: 2020 – 2021

The European Space Agency WorldCover 10 m 2020 product provides a global land cover map for 2020 at 10 m resolution based on Sentinel-1 and Sentinel-2 data. The WorldCover product includes eleven land cover classes.

5. Challenges and future opportunities

Challenges

- Growing volume and complexity of EO data
- Uneven technical capacity and data infrastructure
- Limited ground observations for validation

Future opportunities

- Next-generation radar and hyperspectral missions
- High-frequency constellations and AI-enabled analytics
- Digital twins, IoT sensing, and stronger early-warning systems

Priority for Central Asia: integrate EO, models, and regional monitoring networks into resilient and sustainable food production

Conclusion

- Earth Observation (EO) provides timely, large-scale monitoring of agricultural systems
- Enables early detection of crop stress, drought, and land degradation
- Supports efficient water management through soil moisture and evapotranspiration monitoring
- Drives precision agriculture:
  - Optimised irrigation and fertiliser use
  - Increased productivity and reduced costs
- Integration with AI, IoT, and digital platforms enables data-driven decision making
- EO contributes to:
  - Food security
  - Climate resilience
  - Sustainable land management
- Rapid growth of satellite data and commercial platforms is increasing accessibility

Better EO integration = stronger resilience across Central Asia

Discussion

What would you monitor?

Can EO replace fieldwork?

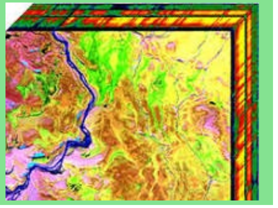
Advanced Mapping & Remote Sensing Capabilities

Data Processing & GeoAI Analytics

- Advanced DEM/DTM generation & terrain modelling
- Vegetation structure & biomass estimation
- Change detection & time-series analysis
- Flood, drought & water dynamics modelling

Hyperspectral & Spectral Analysis

- Hyperspectral data processing (airborne & satellite)
- Mineral mapping & soil characterization
- Vegetation stress & ecosystem health assessment
- Water quality & algal bloom detection
- Spectral unmixing & feature extraction

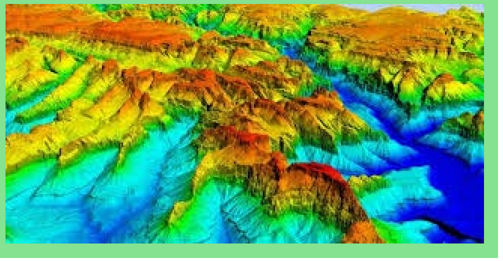


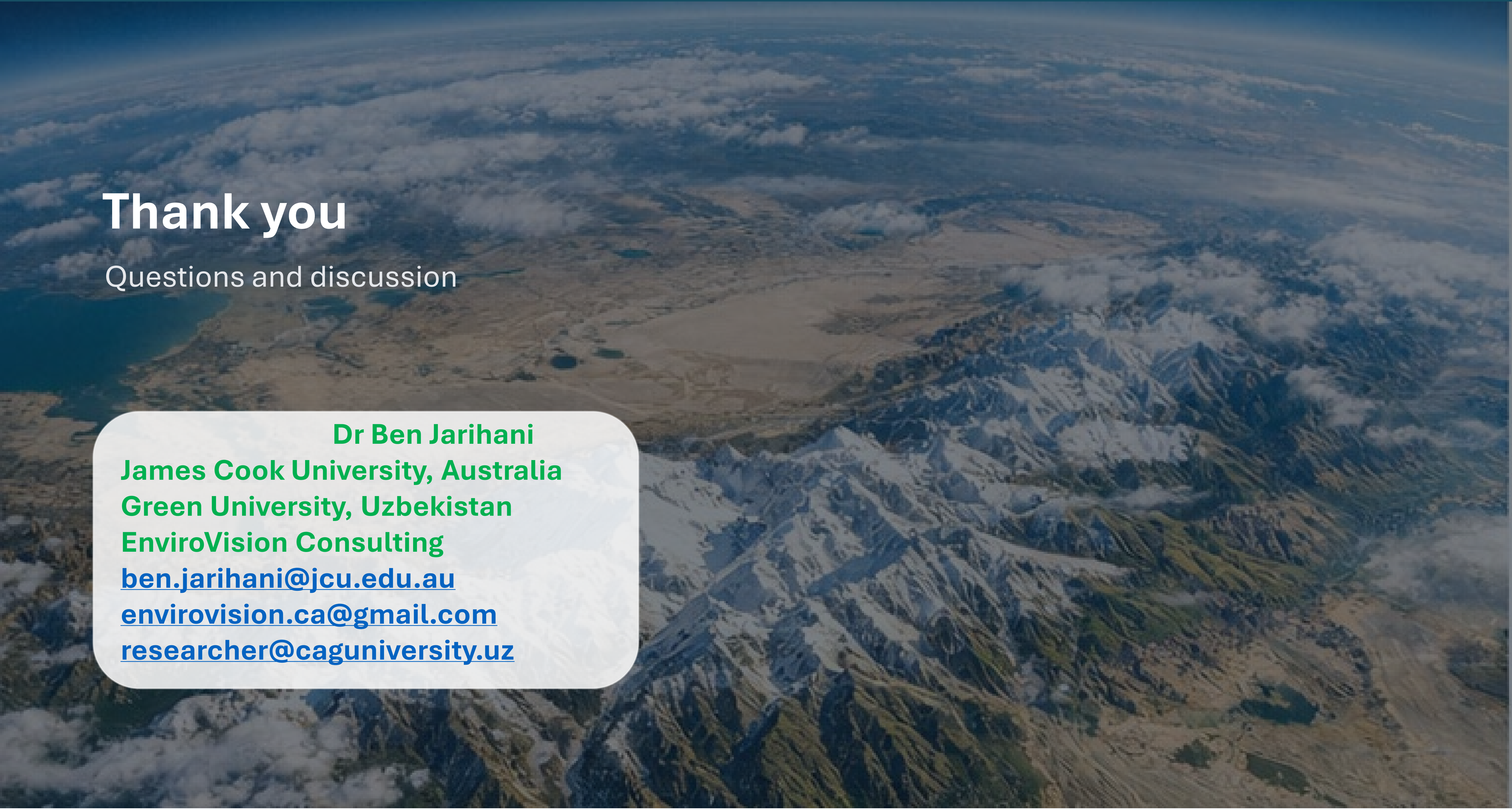
Data Acquisition Platforms

- UAV-based LiDAR (Drone LiDAR)
- Handheld Mobile LiDAR
- RTK-GNSS (Survey-grade GPS)
- Satellite Earth Observation (EO)

Deliverables

- High-resolution maps & 3D models
- Environmental monitoring dashboards
- Spatial decision-support tools
- Technical reports & consulting outputs





Thank you

Questions and discussion

Dr Ben Jarihani
James Cook University, Australia
Green University, Uzbekistan
EnviroVision Consulting
ben.jarihani@jcu.edu.au
envirovision.ca@gmail.com
researcher@caguniversity.uz