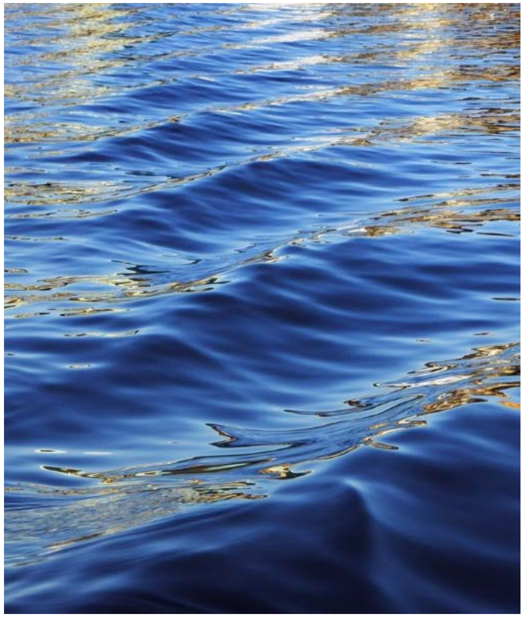
Co-funded by the
Erasmus+ Programme
of the European Union

ILHAM-EC



Remote sensing for water resources management

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Faculty of Agriculture
Lab of Remote Sensing and GIS

Research and education in:

- Monitoring of agricultural resources: mapping agricultural crops, digital soil mapping, agricultural water use, mapping aquacultures.
- Monitoring the environmental impacts of agriculture: modeling soil erosion, mapping the degradation of downstream wetlands and aquatic vegetation, monitoring water quality of downstream water bodies.
- Digital image processing techniques and geographic analysis of spatial data for mapping land cover and its temporal changes.
- Remote sensing for mapping agricultural parameters: estimation of crop yield, evapotranspiration, soil moisture, green biomass, leaf area index.

Summary

- Introduction to remote sensing
- Remote sensing applications for water management
- Remote sensing in the MyWater project
- Results from case studies within MyWater
- Discussion

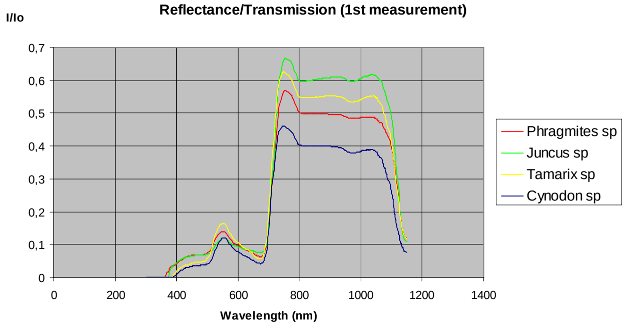
Introduction to remote sensing

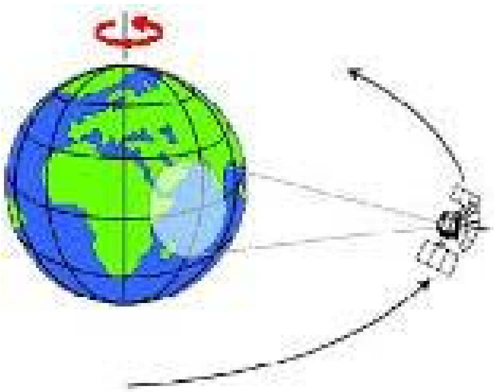
Remote sensing

- Acquisition of information about an object or phenomenon without making physical contact with the object.
- Mapping using air-photos and satellite images

Remote sensing levels of observation

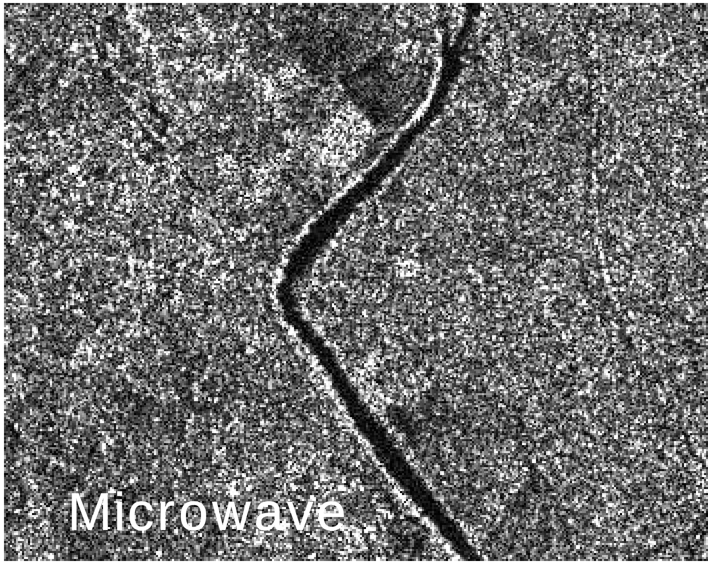
- Handheld / terrestrial
- Low flight UAVs
- Airplanes
- Satellites

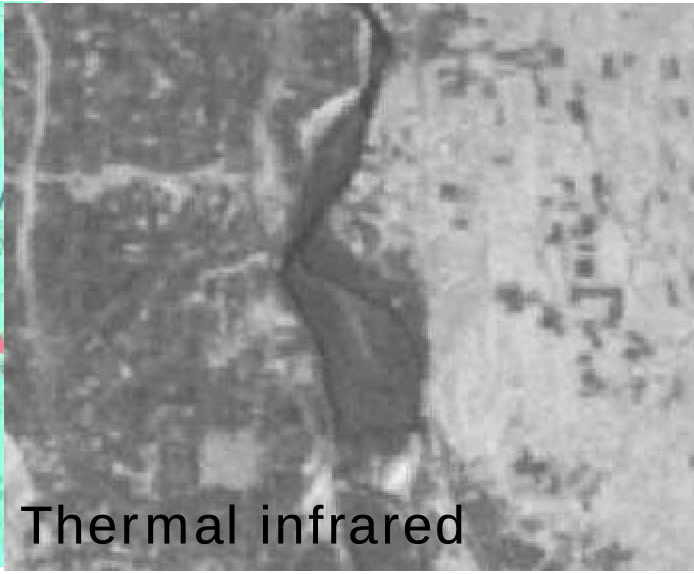




Remote sensing wavelengths

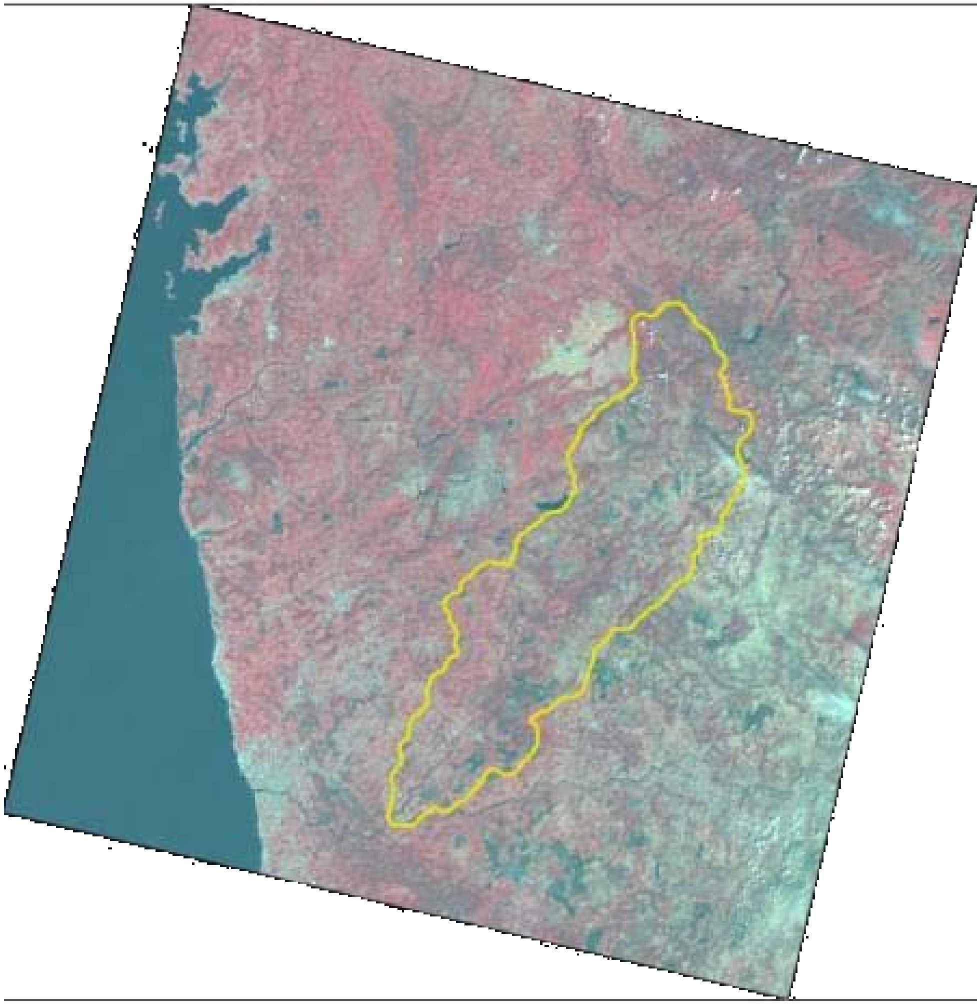
- Visible
- Near infrared
- Shortwave infrared
- Thermal infrared
- Microwave





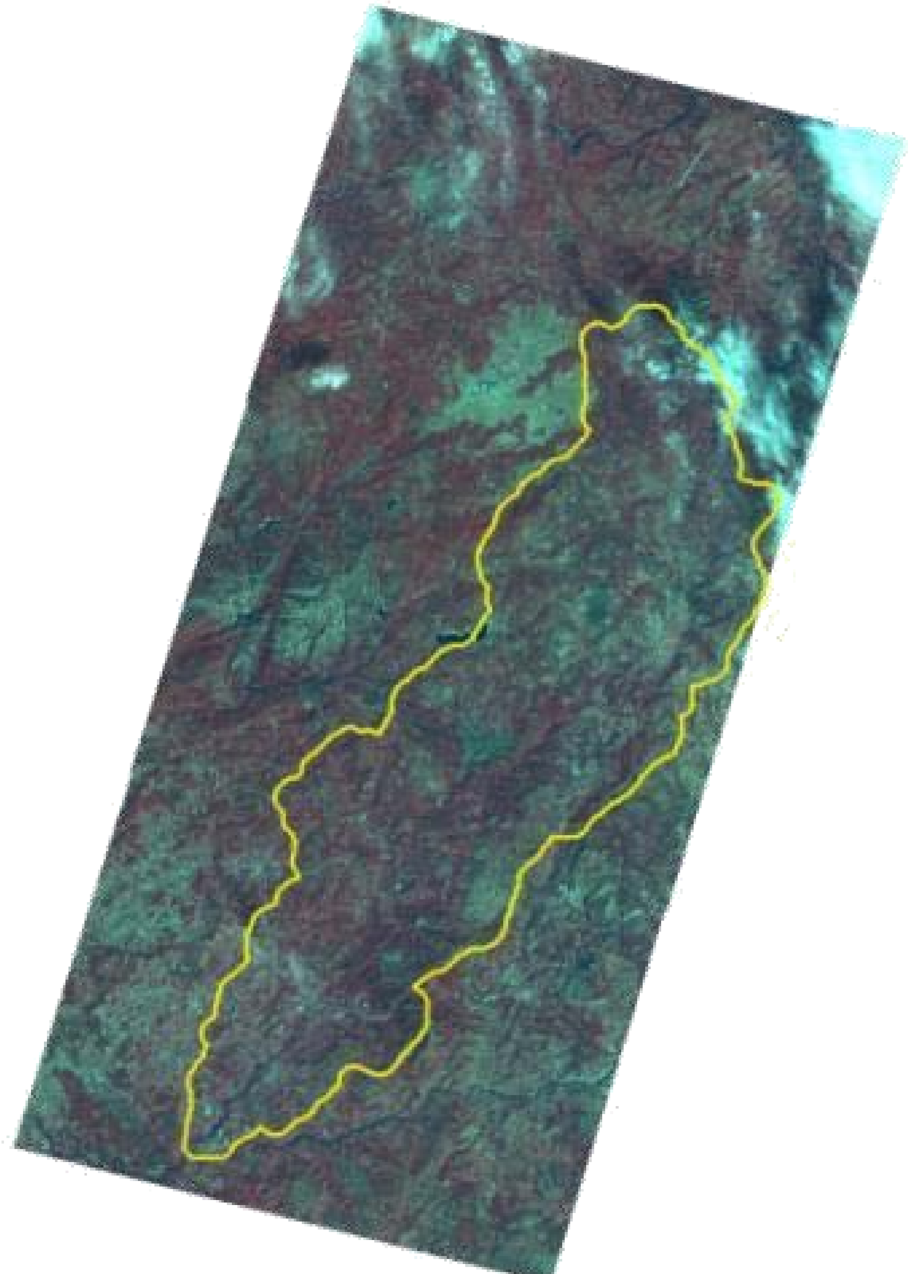
Landsat satellite images

- Landsat 1 (1972) – Landsat 8 (today)
- Landsat 8
  - Coverage 185x185 km
  - Every 16 days
- OLI (Operational Land Imager)
  - 8 bands at 30m (visible, infrared)
  - 1 band at 15 m (pancrhomatic)
- TIRS (Thermal Infrared Sensor)
  - 2 bands at 100m (thermal)
- Cost: 0€



SPOT satellite images

- SPOT 1 (1986) – SPOT 6 (today)
- SPOT 4-6 satellites
  - Coverage 60x60 km
  - Every < 5 days
  - 4 bands multispectral(visible, infrared)
  - 1 band panchromatic
  - Spatial resolution ms/pan:
    - SPOT 4: 20/10m
    - SPOT 5: 10/5m
    - SPOT 6: 8/1.5m
- Cost: 1200-5400€

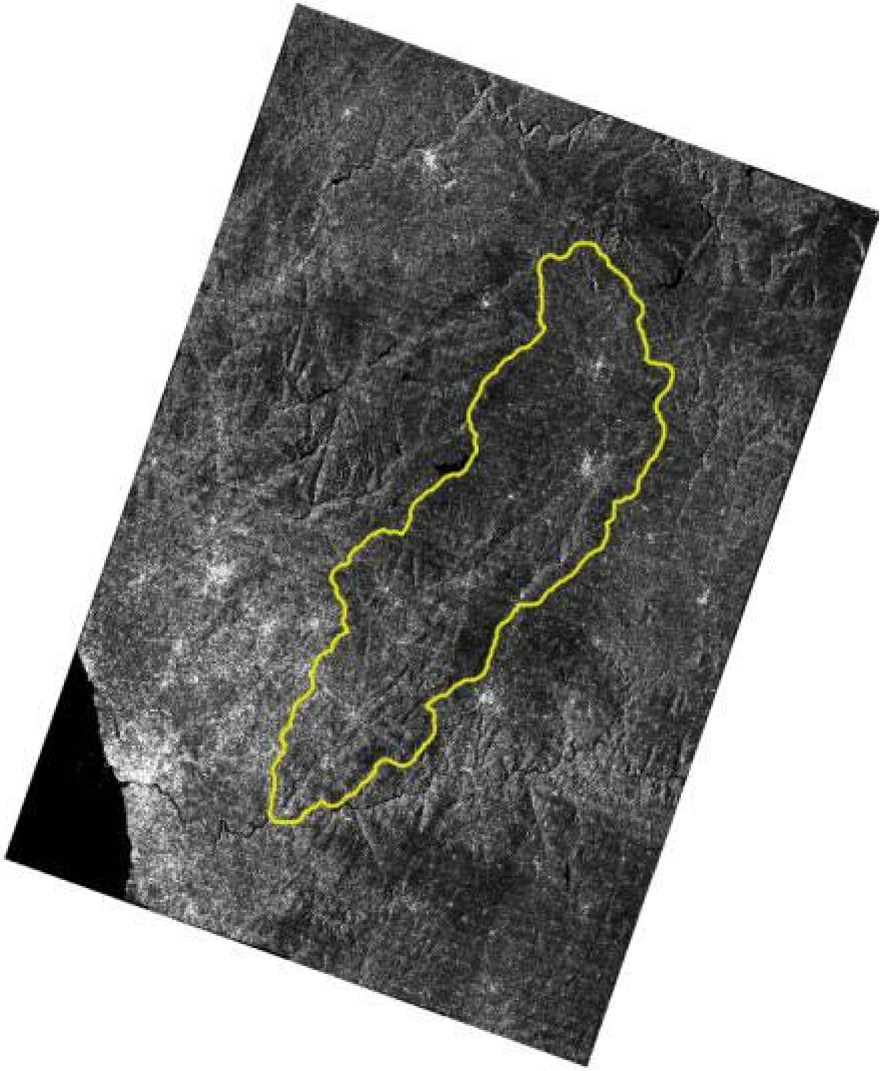


MODIS satellite images

- Terra/Aqua satellites (1999 - today)
- MODIS
  - Coverage 2330km
  - Images every day
  - 36 bands (visible, infrared, thermal)
  - Resolution 250m, 500m, 1000m
- Cost: 0€

COSMO-SkyMed satellite images

- COSMO-SkyMed (2007 - today)
- **CO**nstellation of small **S**atellites for for the **M**editerranean basin **O**bservation
  - Constellation of 4 satellites equipped with a microwave high-resolution synthetic aperture radar (SAR) operating at Xband
  - Resolution 1-100 m
  - Coverage 10-200 km
  - Images almost daily
- Cost 2000€

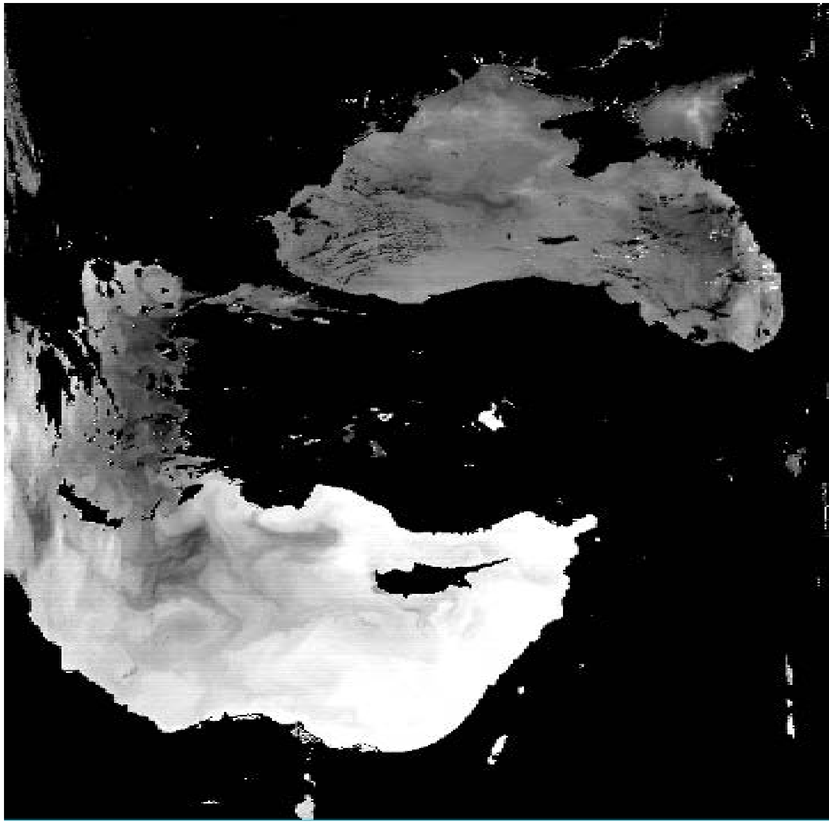


Sentinel satellites

- Sentinel-1
  - C band SAR at 5-40m useful for surface SM
- Sentinel-2
  - VNIR at 10m useful for LULC and LAI
- Sentinel-3
  - TIR at 1km useful for root zone SM
- ...
- Pairs of satellites for higher observation frequency
- Free of charge data distribution, processing tools

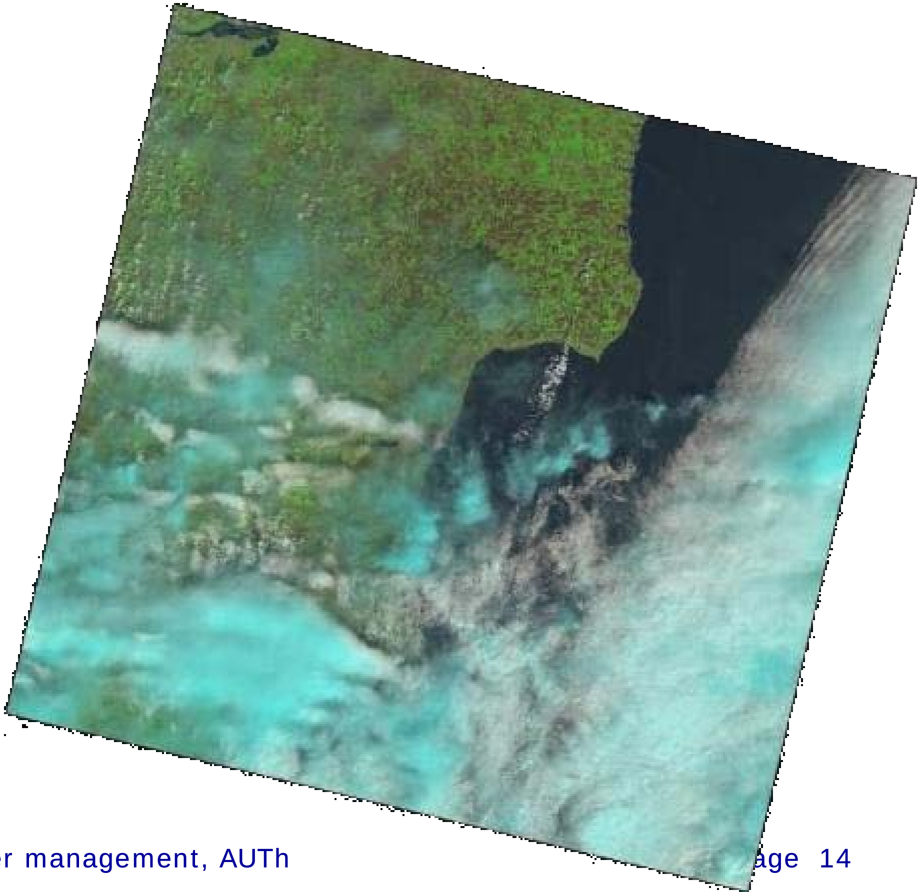
Advantages of remote sensing

- Detailed coverage of large areas at low cost
- Uniform processing of accessible and inaccessible areas
- Ability to collect data repeatedly and non-intrusively
- Access to historical data
- Multispectral nature of the observations



Disadvantages of remote sensing

- Cloud cover obstructs view in visible spectrums
- Not all parameters can be monitored with remote sensing
- Field surveys always required (increased cost)



Remote sensing applications for water management

What can be mapped with remote sensing?

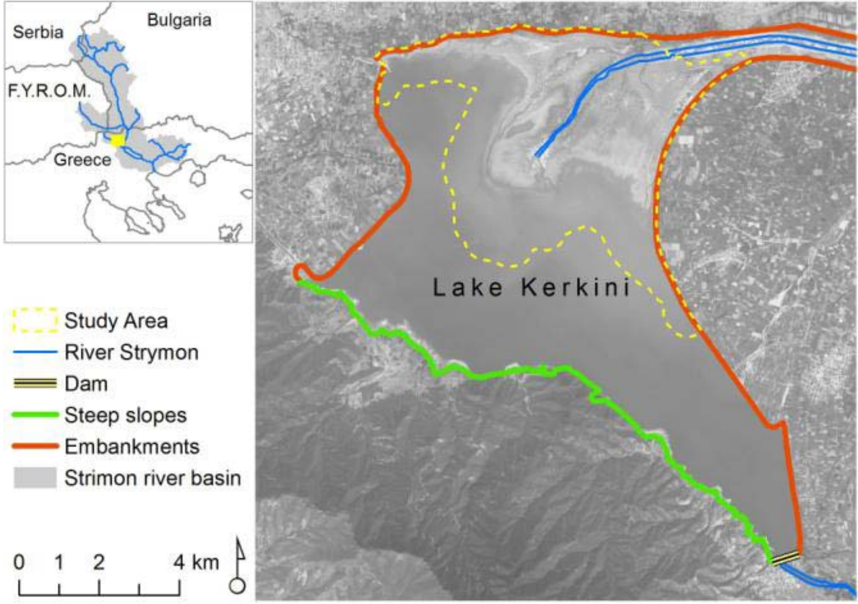
Parameters

- Land use / land cover
- Vegetation cover
- Crop chlorophyll / biomass
- Evapotranspiration
- Rainfall
- Open water surfaces
- Soil salinity

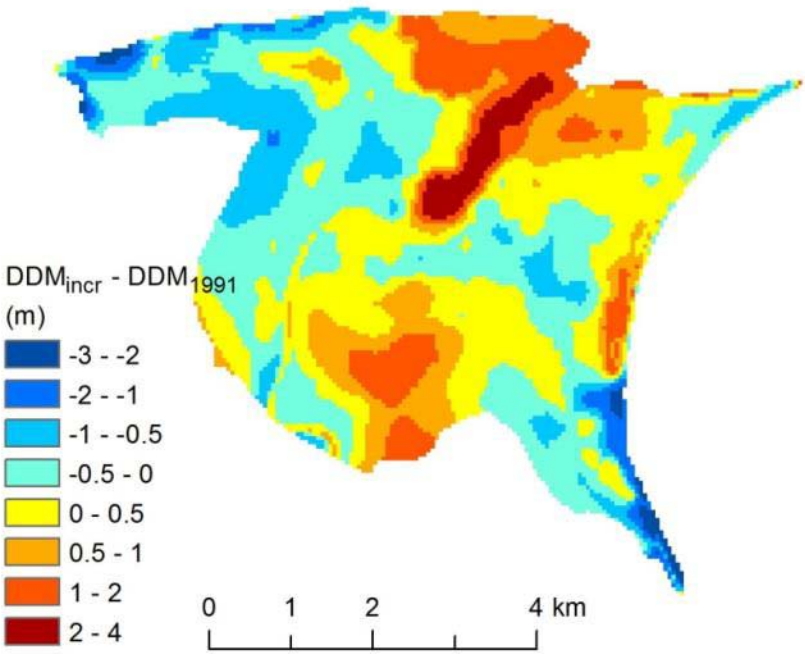
Information

- ⇨ Irrigated area / crop area
- ⇨ LAI
- ⇨ Crop yield
- ⇨ Crop water use / Soil moisture
- ⇨ Effective rainfall
- ⇨ Waterlogging
- ⇨ Soil quality

Applications: Reservoir morphometry

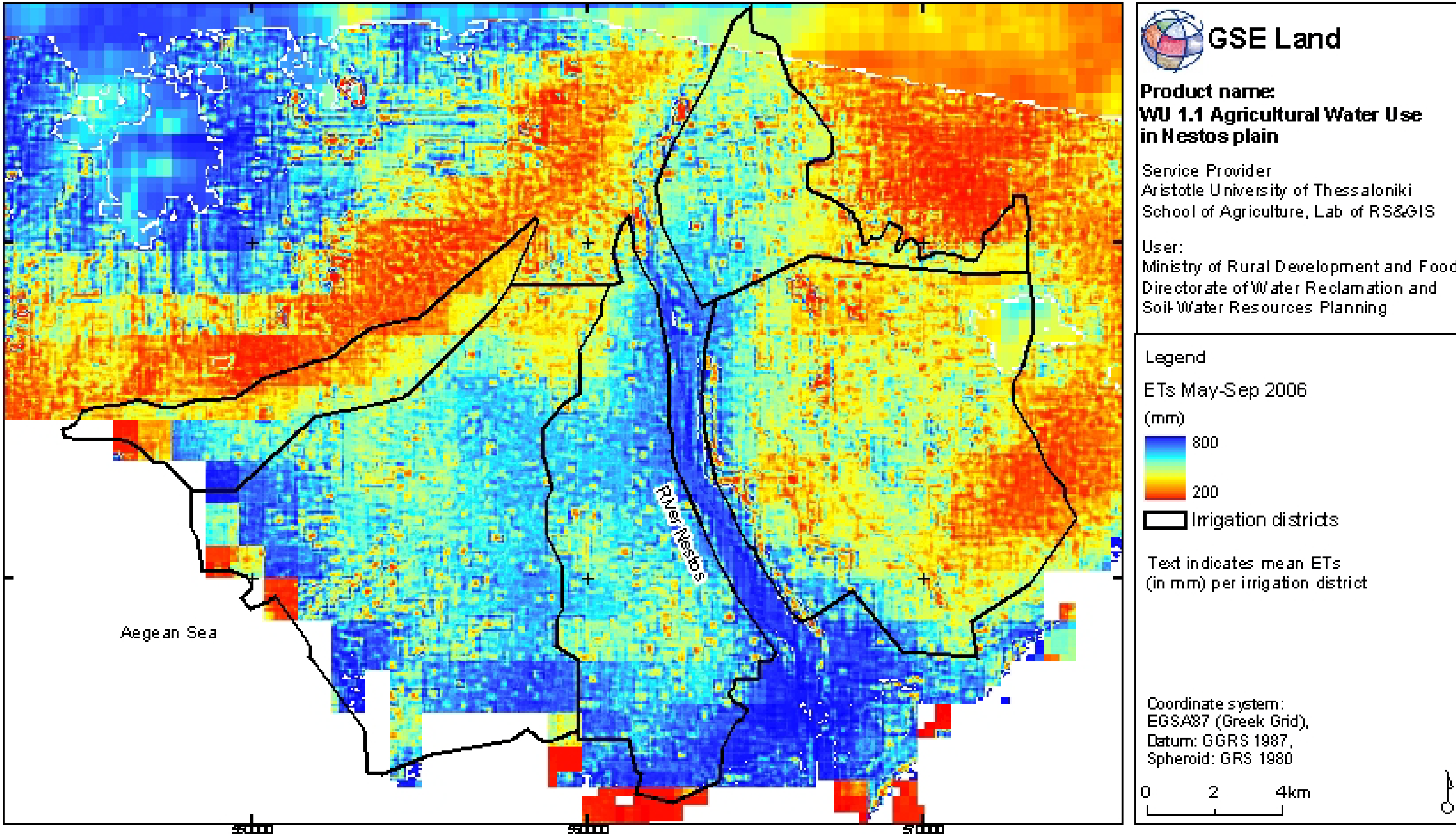


- Proposed methodology for updating a reservoir's digital depth model using time series of MODIS data
- Methods
  - Use of near-infrared to identify shorelines
  - Connect with water level
  - Spatial interpolation to create DDM
- Assessment of sedimentation pattern in Lake Kerkini



Ovakoglou et al., 2016. Use of MODIS satellite images for detailed lake morphometry: Application to basins with large water level fluctuations. International Journal of Applied Earth Observation and Geoinformation, 51: 37-46.

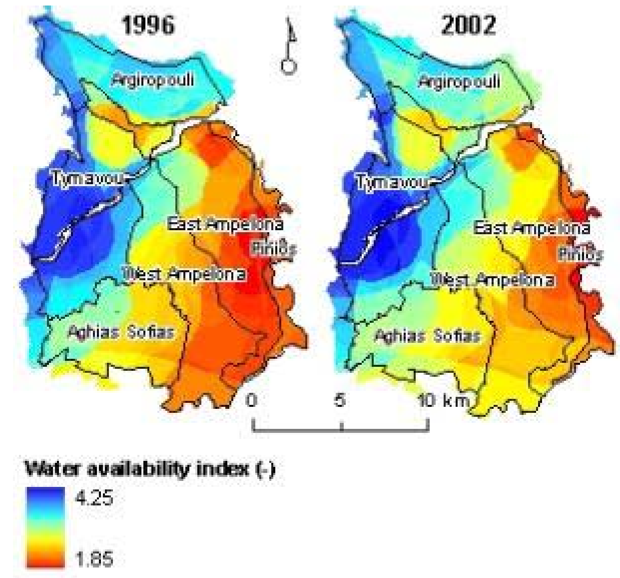
Applications: Crop water requirements



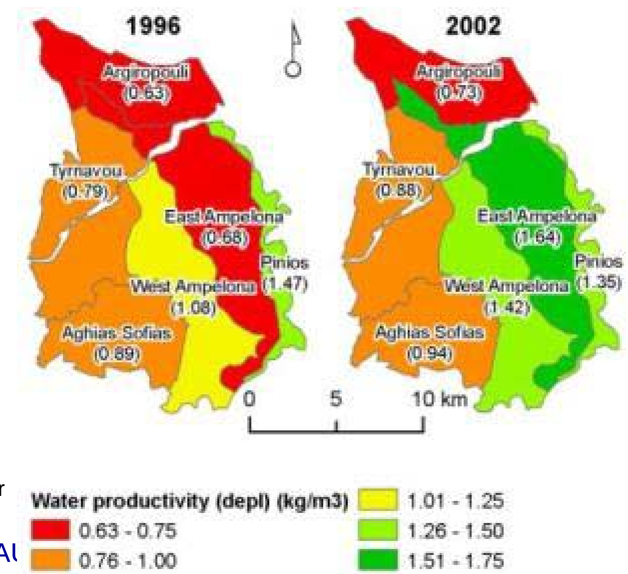
Alexandridis et al., 2009. Integrated Methodology for Estimating Water Use in Mediterranean Agricultural Areas. Remote Sensing, 1(3): 445-465.

Applications:
Assessment of irrigation performance

- Groundwater availability index
  - 3D GIS analysis with hydrogeological and meteorological information



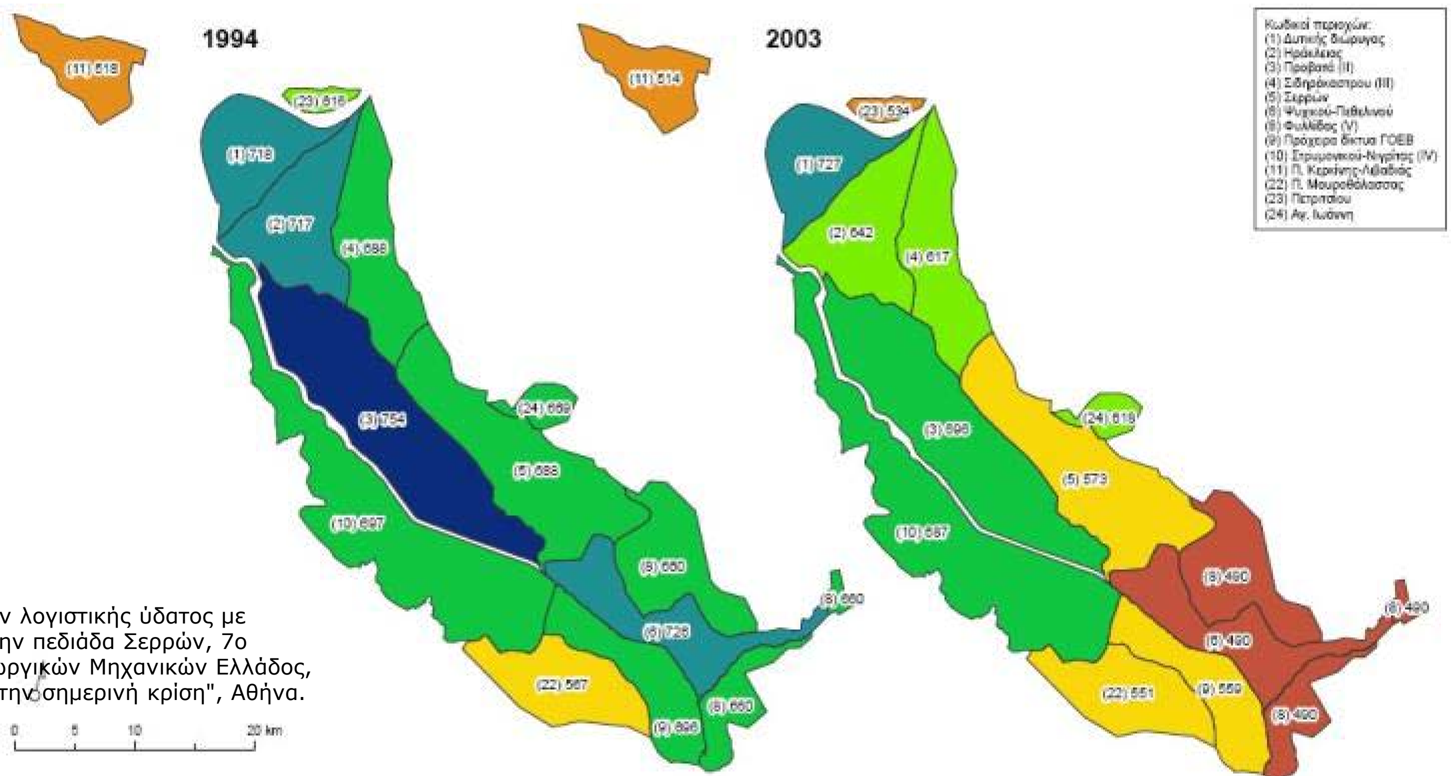
- Irrigation water productivity
  - Yield kg / m^3 water supplied
  - Actual evapotranspiration
  - Biomass development model



Alexandridis et al., 2014. Combining remotely sensed surface energy fluxes and GIS analysis of groundwater parameters for irrigation system assessment. Irrigation Science, 32(2): 127-140.

Applications: Agricultural water valuation

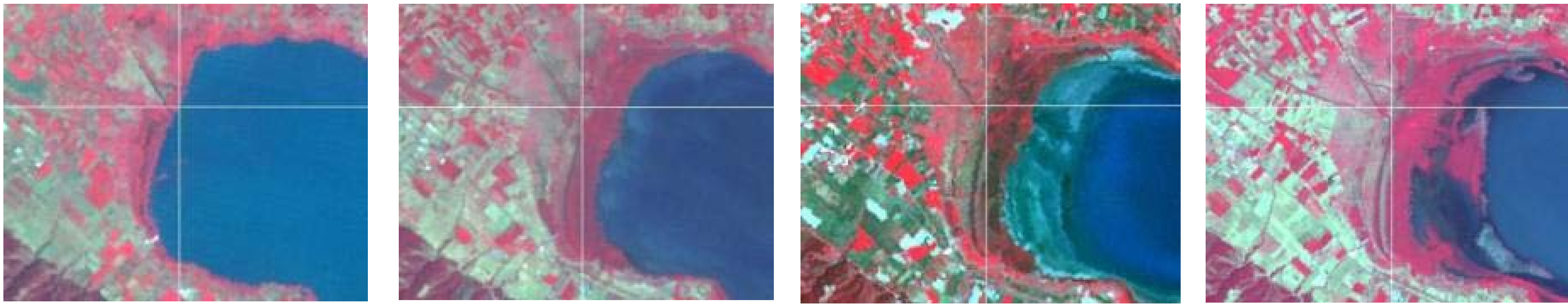
- Water scarcity requires incentives for saving water
- Aim: estimate the true value of water
  - Include the environmental cost
  - Include opportunity cost
- The relevant authorities can suggest a nominal price per m^3



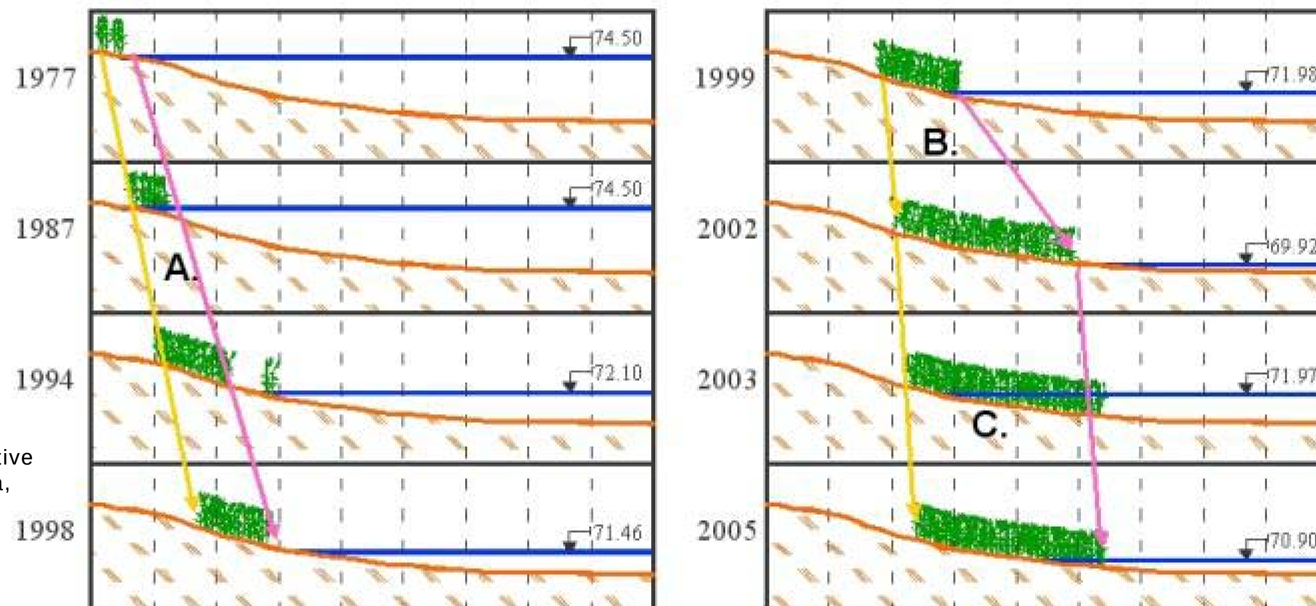
Σταυρινός κ.α., 2011. Εκτίμηση δεικτών λογιστικής ύδατος με δορυφορική τηλεπισκόπηση και GIS στην πεδιάδα Σερρών, 7ο Πανελλήνιο Συνέδριο της Εταιρείας Γεωργικών Μηχανικών Ελλάδος, "Η συμβολή της ΕΓΜΕ στην έξοδο από την σημερινή κρίση", Αθήνα.

Applications:
Lake wetland restoration plan

- Hydroperiod / Ecohydrology



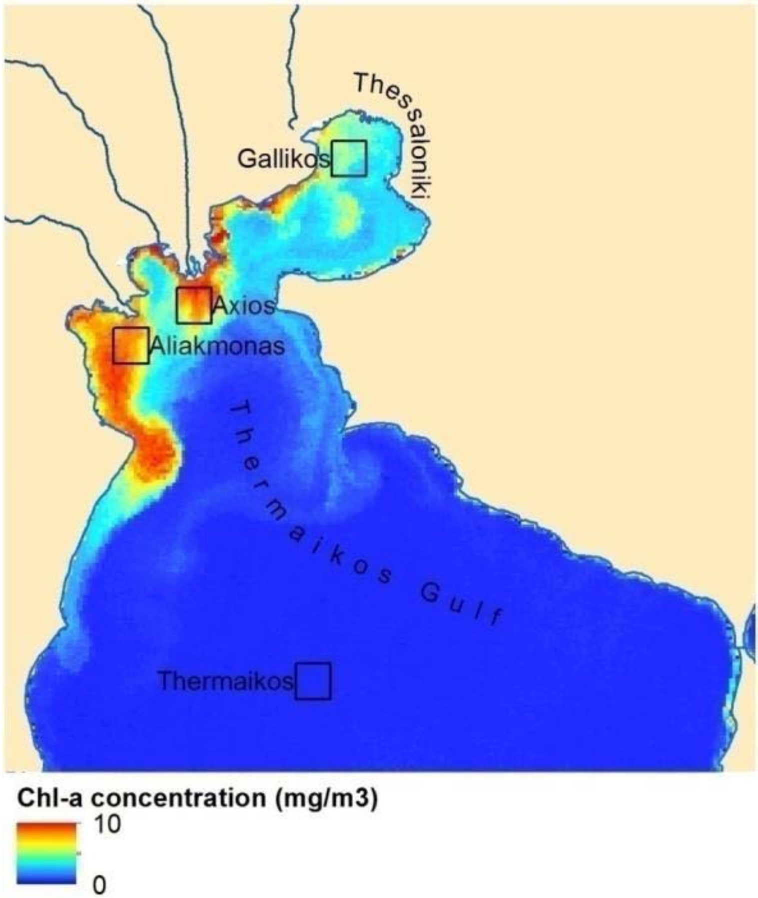
1989 1999 2001 2003

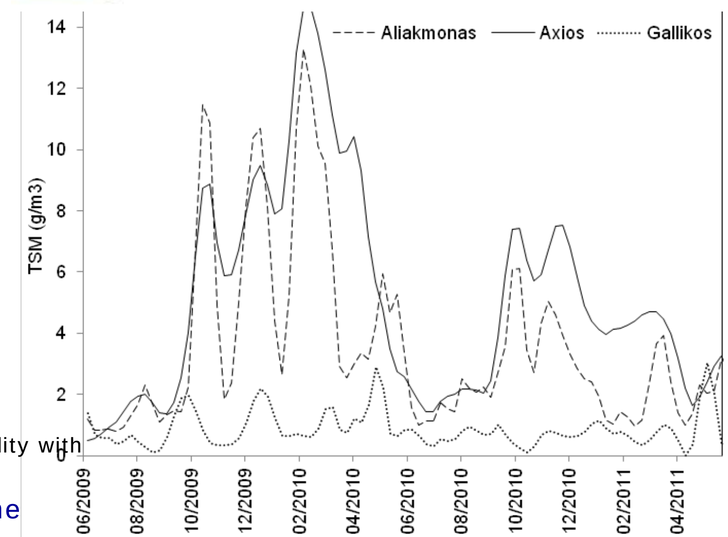


Crisman et al. 2014. Phragmites distribution relative to progressive water level decline in Lake Koronia, Greece. Ecohydrology, 7: 1403-1411.

Applications: Water quality evaluation

- ENVISAT and MODIS satellite images
- Water quality parameters:
  - Total suspended matter
  - Chlorophyll-a concentration
  - Sea surface temperature
- 8 day time-series maps
- Spatio-temporal information
- Connect with upstream soil erosion

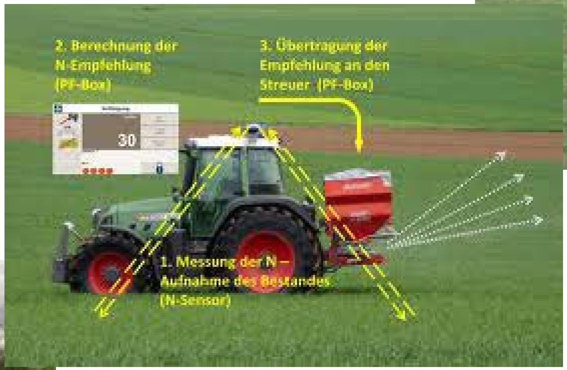


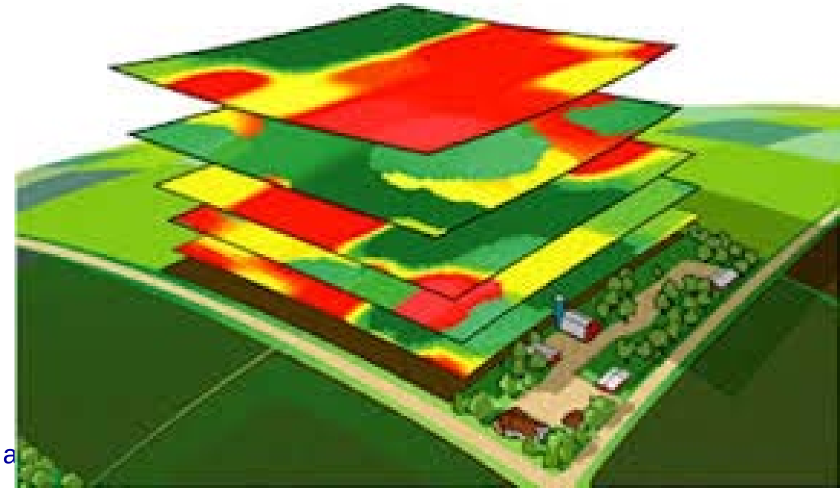


Alexandridis et al., 2015. Investigation of the temporal relation of remotely sensed coastal water quality with GIS modeled upstream soil erosion. Hydrological Processes, 29: 2373-2384.

Applications: Precision farming

- Mapping spatial variability within field
- Sensors: remote and proximal
- Reduced inputs of agrochemicals and water





Remote sensing in the MyWater project

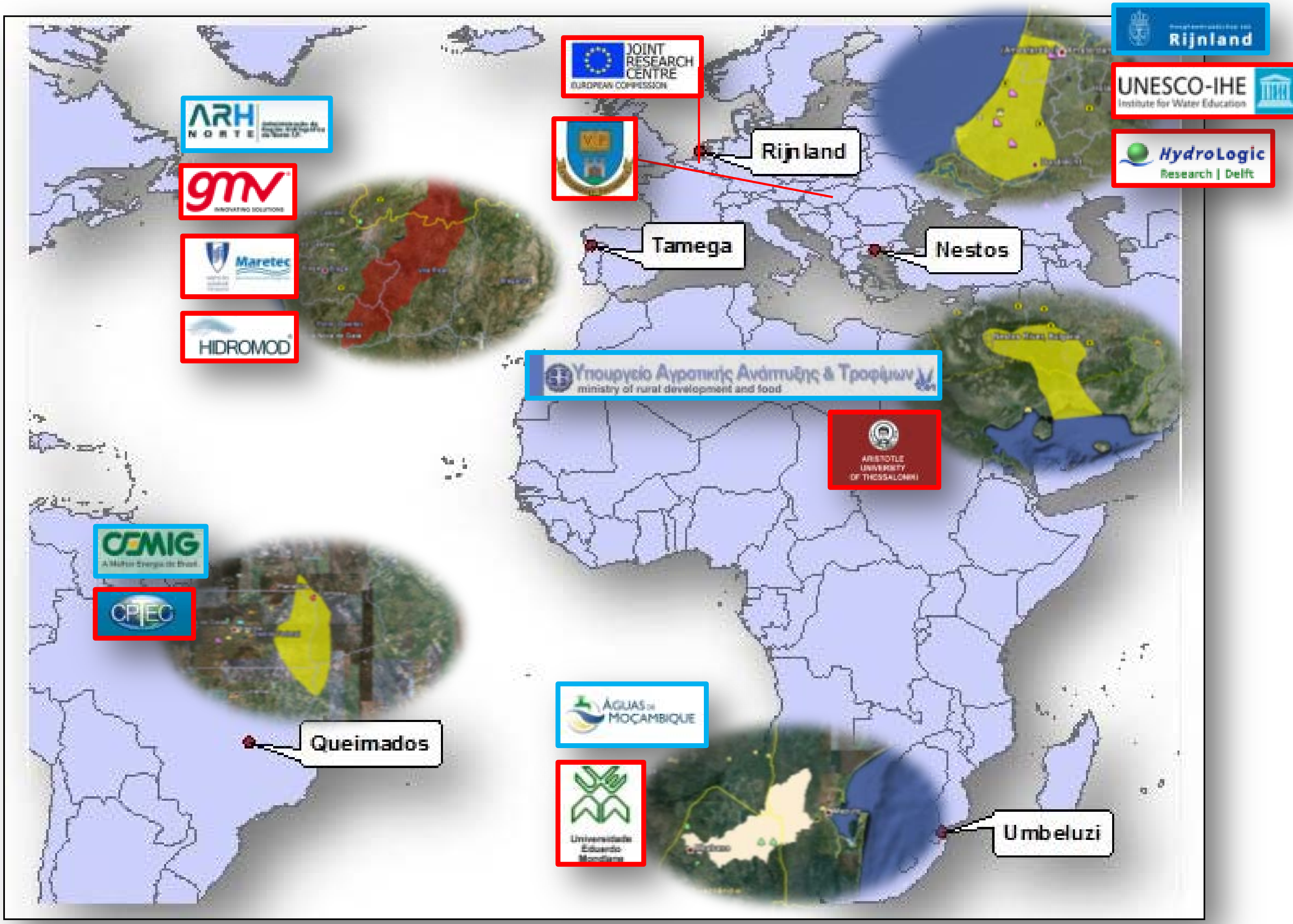
General information

FP7 project MyWater (http://mywater-fp7.eu/)

“Merging hydrologic models and EO data for reliable information on Water”

- 3rd Space Call of the 7th FP - Stimulating the development of GMES services in specific areas: Water
  - Fill the gaps in the European service capacity: Need for reliable information on water and for tools and services for efficient water management
- Project duration: Jan 2011 - Dec 2013
- Total Cost: ≈ **3 M€**, EC Contribution: ≈ **2,3 M€**
- Consortium of 10 partners well geographically spread (Europe, Africa, Latin-America) (GMV is Prime)

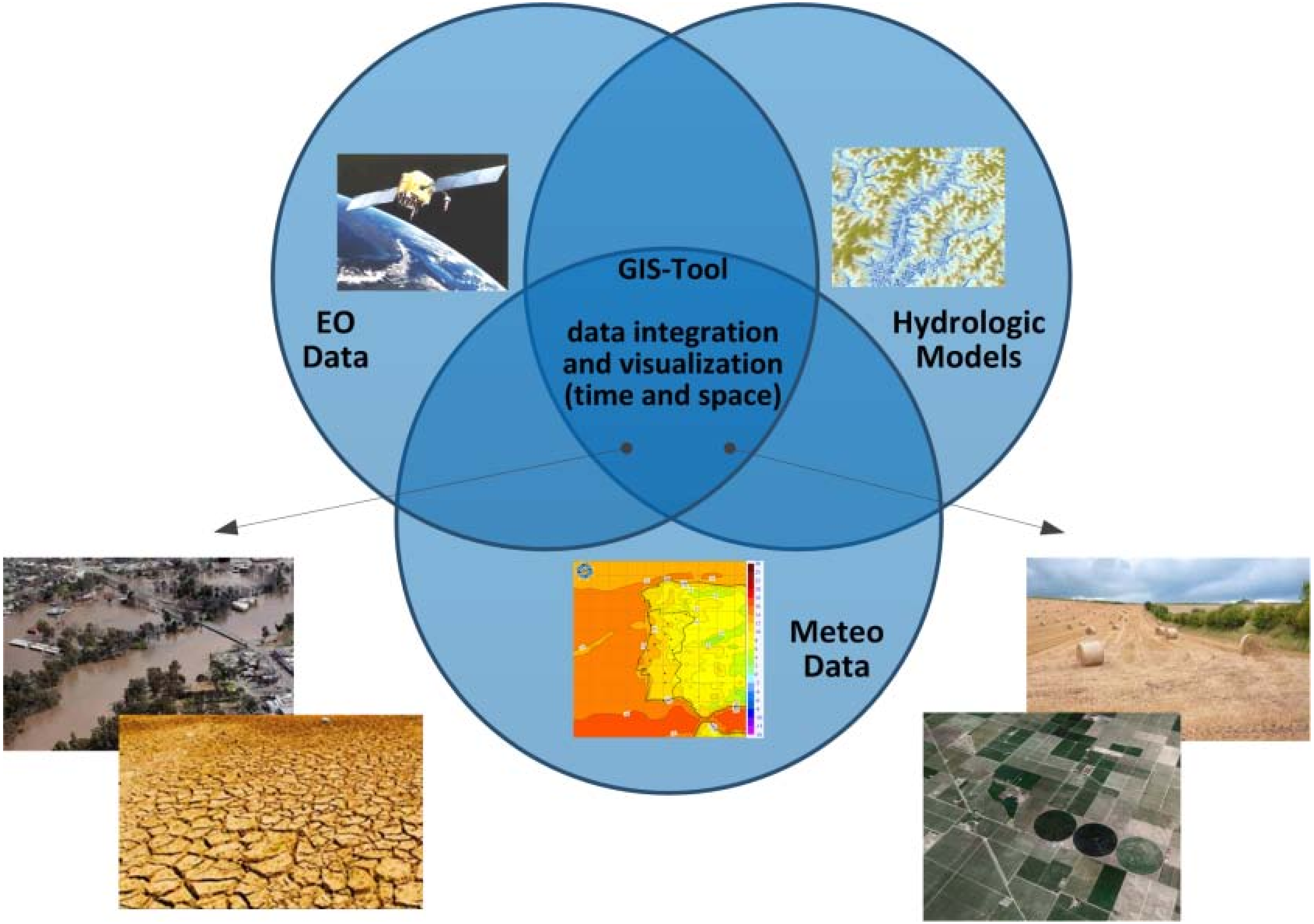
Study sites, Partners and Users



Main Goal

- Development of a tool and services to manage all water cycle related variables in an integrated way in order to obtain reliable information on water quantity, quality and usage for appropriate water management
    - To improve existent knowledge and practices in water resources management
    - To create forecasting capabilities for water managers
    - To optimize the cost/benefit ratio for water resources monitoring

Concept


GIS-Tool
data integration
and visualization
(time and space)
EO
Data
Hydrologic
Models
Meteo
Data

Concept

Focusing on 3 main areas:

Irrigation

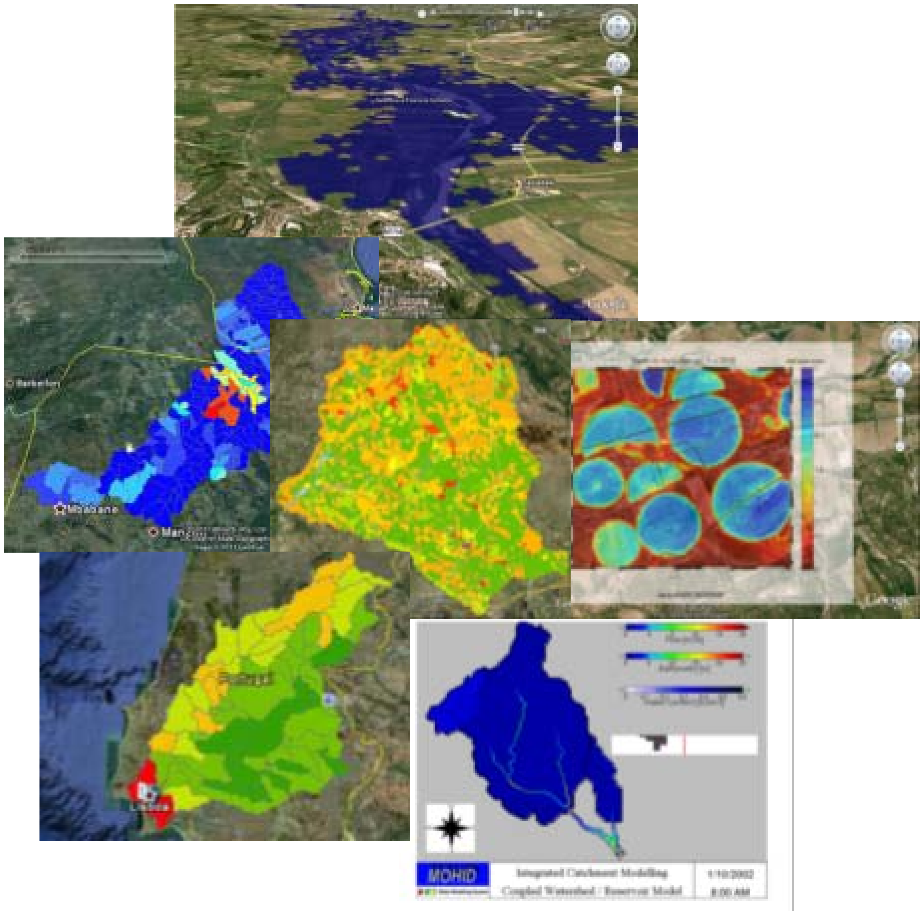
- Water availability and water use

Reservoir management

- Water quality and quantity

Floods

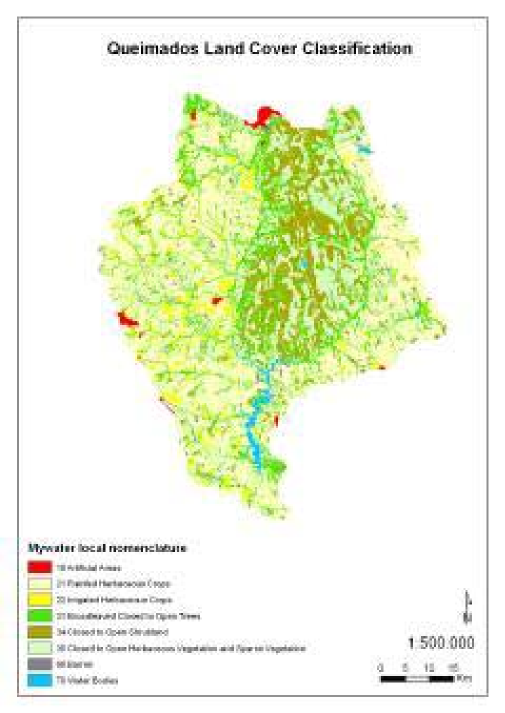
- Prevention and mitigation



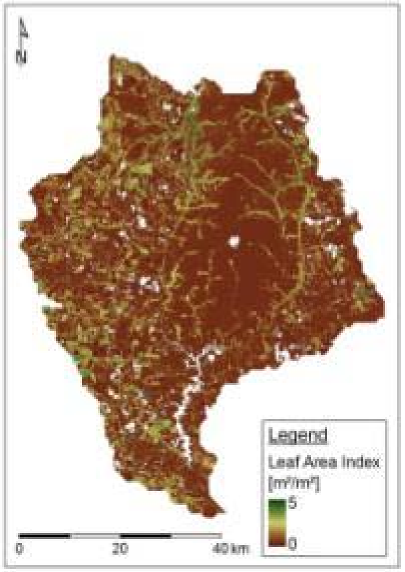
Concept

- EO data will be used to determine:

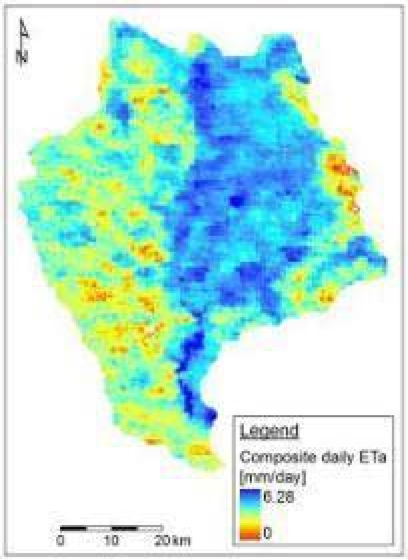
LULC



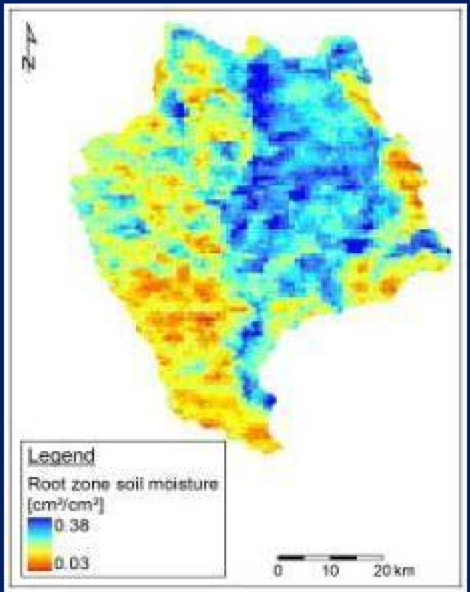
LAI



ETa



Soil Moist



Advantage of using EO data

actual measurements

wall-to-wall coverage

High or low spatial resolution

Concept

- Meteorological information is needed as input to the hydrological models to determine the water availability
  - Precipitation, Temperature, Humidity, Wind speed, ….

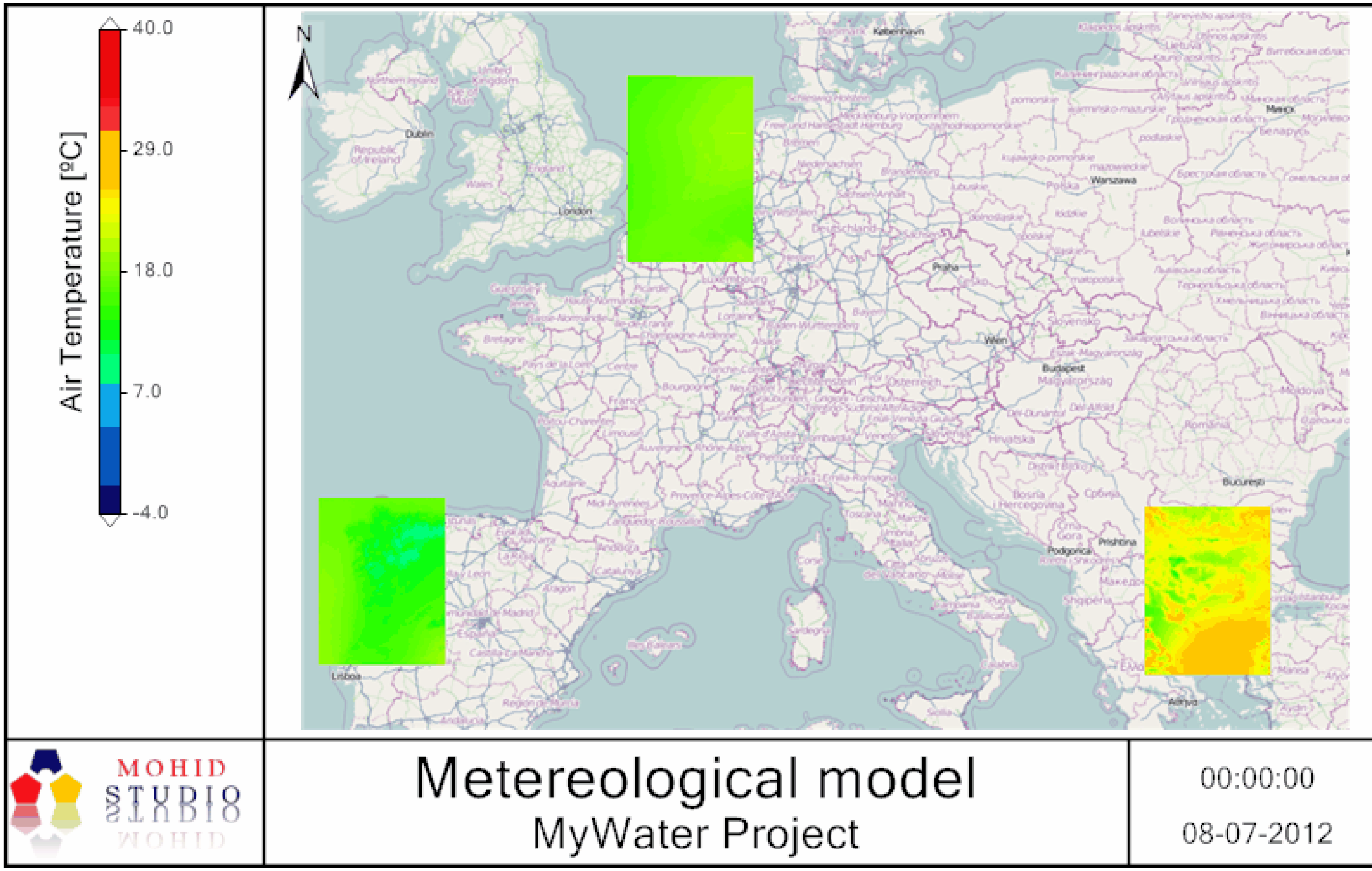
MM5

GFS

CPTEC

WUNDERGRD

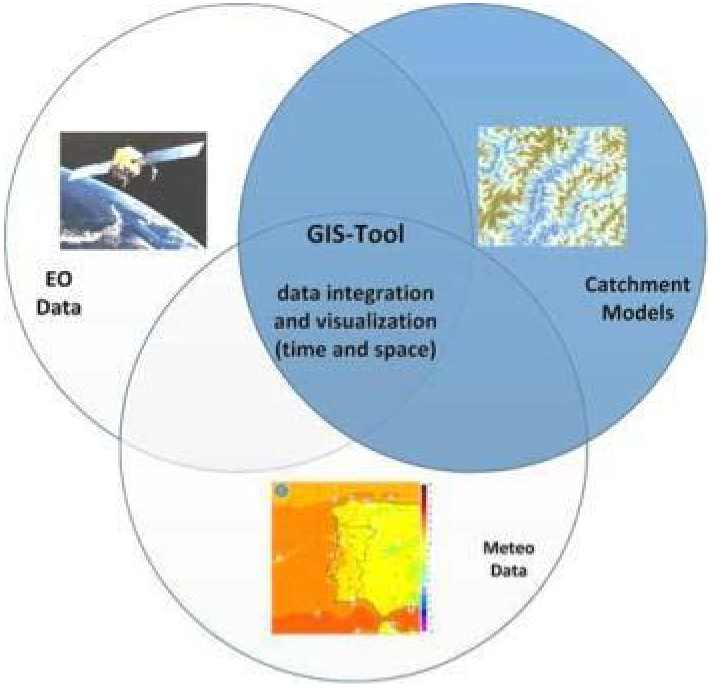
…



Concept

- Hydrologic models will provide information about other water cycle related variables (Water flow, velocities and depths, nutrients, groundwater level, etc)
  - also provide some of the EO data information, contributing to reduced uncertainty and accurate results

- Catchment based Models
  - Simgro (integrated rural-urban water cycle model)
  - Aquarius (lumped physically based hydrological model)
  - SWAT (soil water analysis tool)
  - Mohid Land (distributed physically based catchment model)
- Surface – overland flow Models
  - Price2D (fast 2D hydrodynamic surface routing model)
  - Mohid Water (2D/3D hydrodynamic engine for surface water bodies)
- Drainage Models
  - SWMM (stormwater modeling and management tool)
- Reservoir Models
  - CEQUALW2 (water quality and hydrodynamic model in 2D)



Data integration

- The integration of different nature data sources brings several advantages:
  - more **comprehensive view** of the problem
  - larger amount of data and **guaranteed data availability**,
  - allow to **minimize the uncertainty** of outputs improving the quality of the predictions of the hydrological state at the watershed level **- higher accuracy results**
  - EO data can provide the high spatial resolution and spatially distributed component, while models can provide the high temporal resolution component with forecasting capabilities

Main outcomes

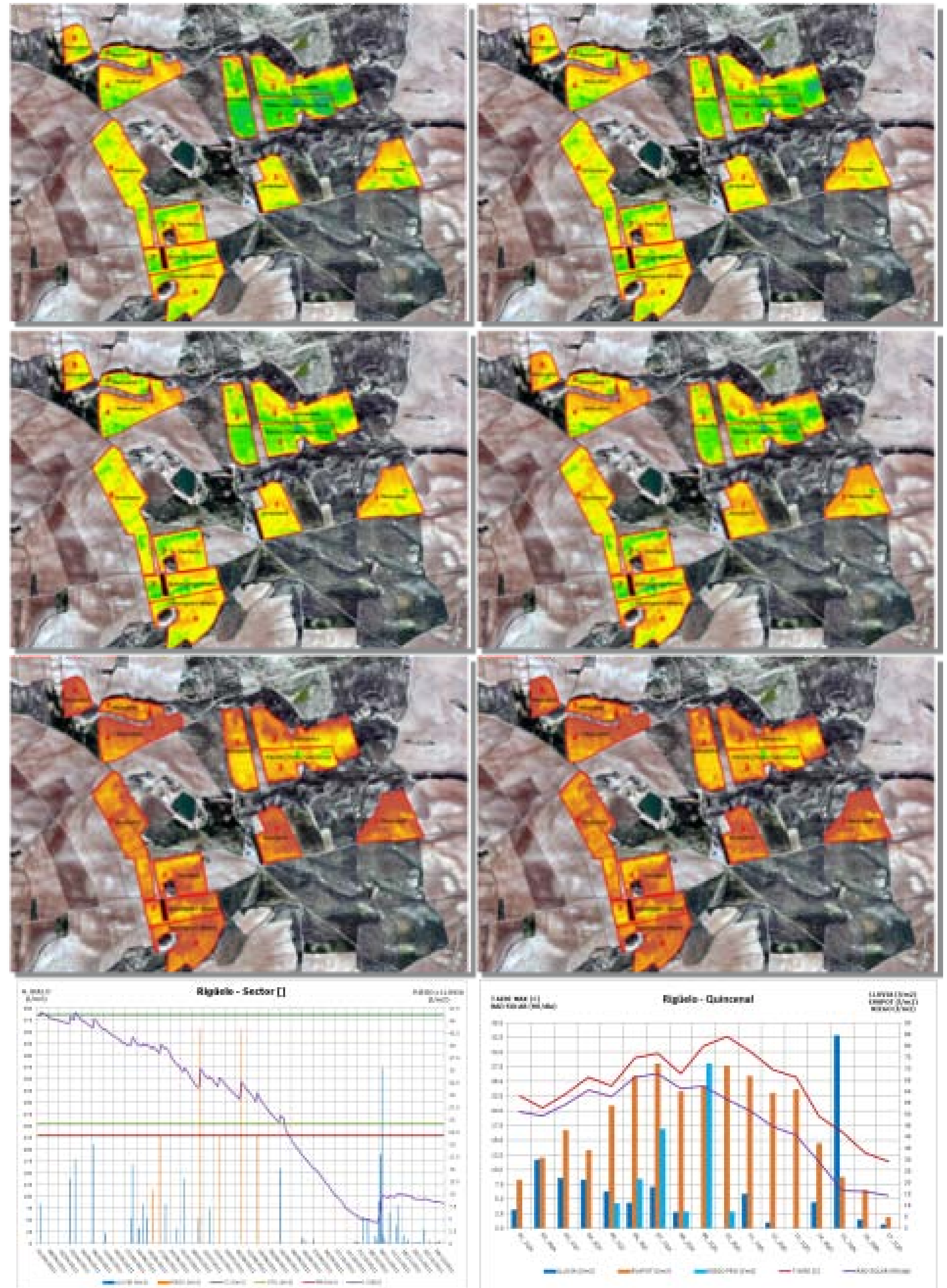
- Improved hydrologic models using EO based data (input/validation/calibration) and meteo data providing outputs on all water-cycle related variables
  - e.g. Surface water flow; Ground water level, storage and re-charge; Hydraulic flow characteristics (flows, velocities and depth); Nutrient loads; Evapotranspiration;
- A web-based tool - Technological MyWater platform – help users managing the data and evaluating the model results in a comprehensible way;
- Services fitted to the needs of the different users.
  - Actual measurements and estimations
  - Forecast and test scenarios
  - Automatic reports, Alerts

User services

Support to irrigation

Maps on agriculture water needs providing information to users about when to irrigate and for how long (this can be provided with alarm generation triggering sms to users)

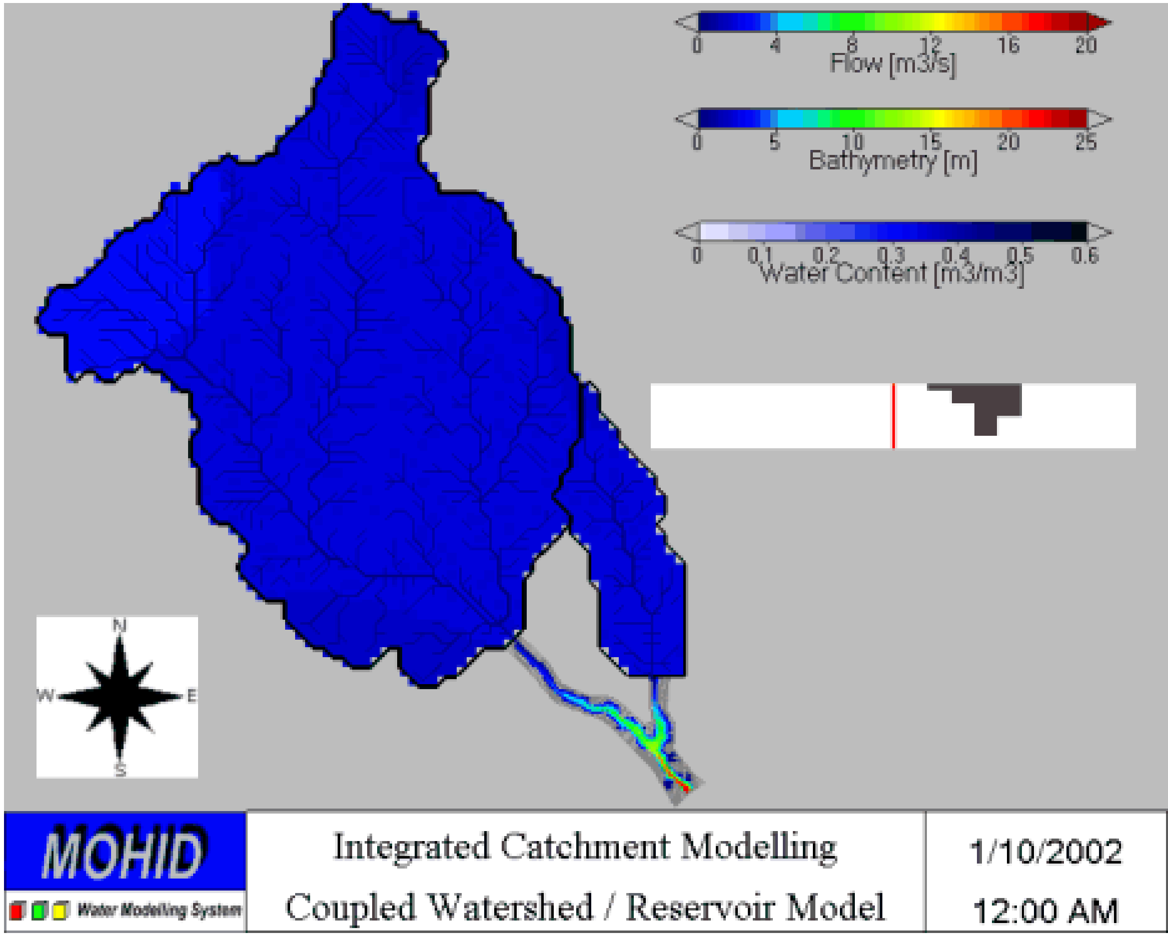
Forecasts for weekly evapotranspiration with time series map production



User services

Reservoir management

Measurements of flow data (nowcasts and forecasts). Provide evaluation on water input to the reservoir

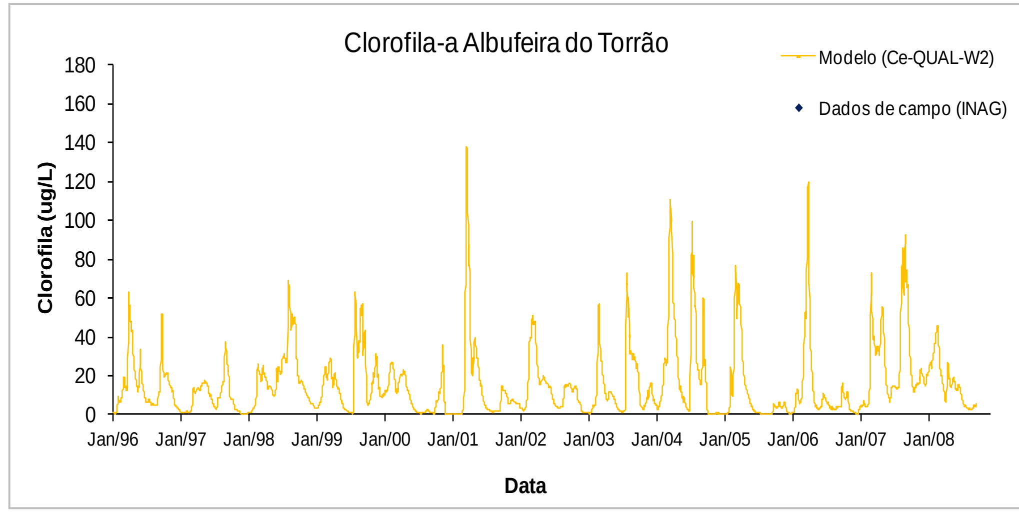


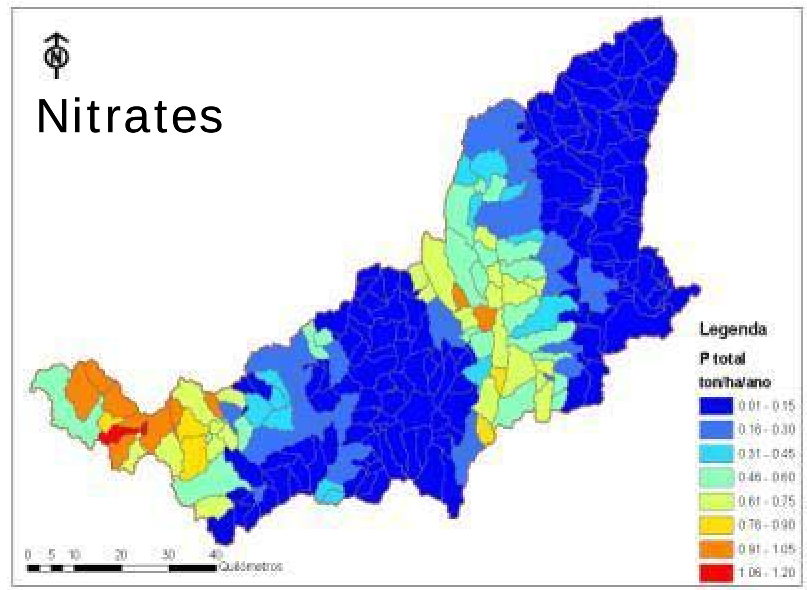
User services

Water quality

Estimation of nutrients loads from diffuse sources that will reduce the water quality (based on land use, soil type, agricultural practices, etc.)

Can support WFD implementation, monitoring, and evaluate mitigation actions





User services

Flood Alert

Daily flood alert with flood risk area mapping

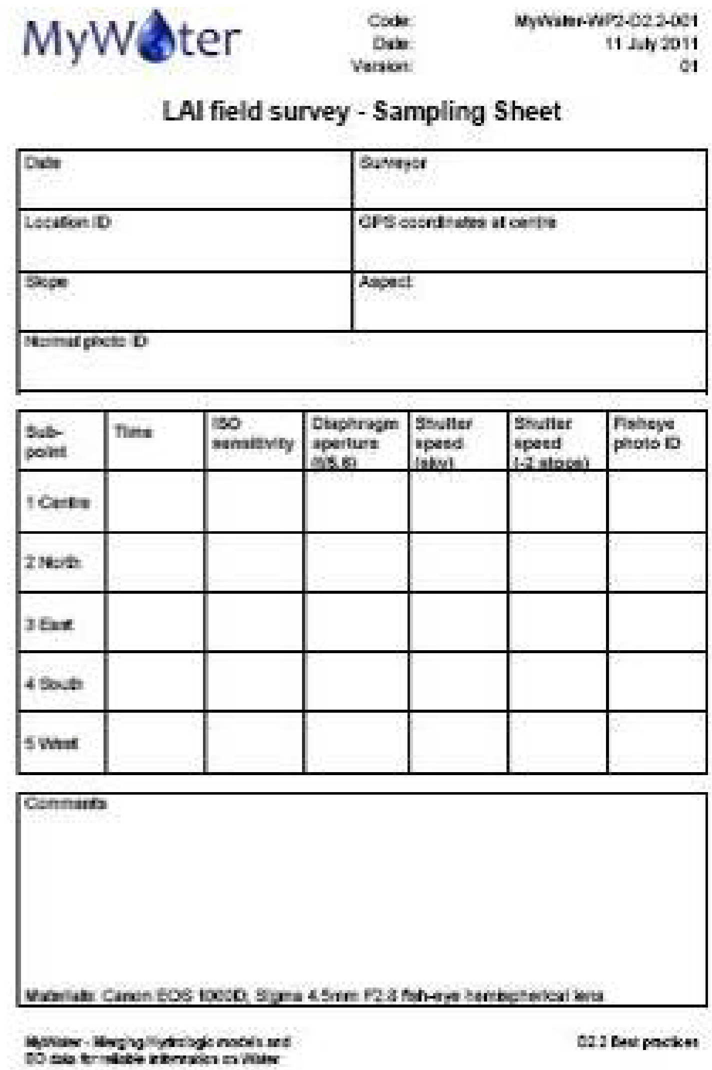
Forecast and simulation capabilities can be used for preparedness and for planning mitigation actions

Hartanto et al., 2017. Data assimilation of satellite-based actual evapotranspiration in a distributed hydrological model of a controlled water system. International Journal of Applied Earth Observation and Geoinformation, 57: 123-135.

Results from case studies within MyWater

Field survey

- Purpose
  - Collection of in-situ data
  - Training and validation
  - Validation and fine-tuning
- Actions:
  - Calibrate instruments
  - Protocols for field survey: LAI, SM and LULC
  - Sampling design
  - Optimal routes
  - Order contemporaneous satellite images



MyWater

Code: MyWater-WP2-D2.2-001
Date: 11 July 2011
Version: 01

LAI field survey - Sampling Sheet

Date	Surveyor
Location ID	GPS coordinates at centre
Slope	Aspect
Normal photo ID	

Sub-point	Time	ISO sensitivity	Diaphragm aperture (f/5.6)	Shutter speed (sky)	Shutter speed (-2 stops)	Fisheye photo ID
1 Centre						
2 North						
3 East						
4 South						
5 West						

Comments

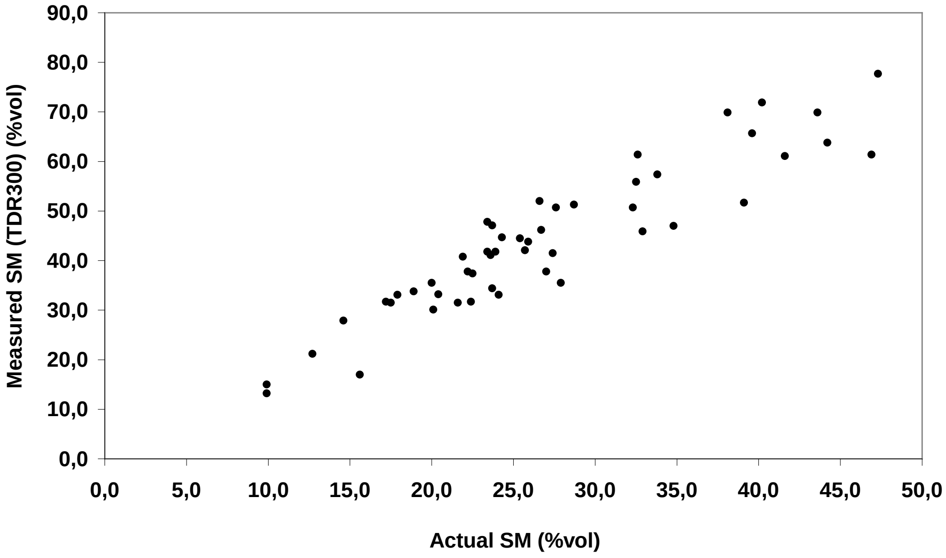
Materials: Canon EOS 1000D, Sigma 4.5mm F2.8 fish-eye hemispherical lens

MyWater - Merging hydrologic models and EO data for reliable information on Water

D2.2 Best practices

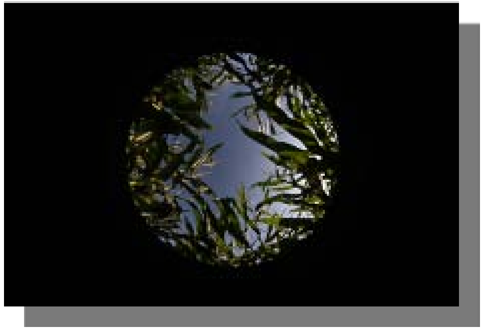
Field survey
Nestos

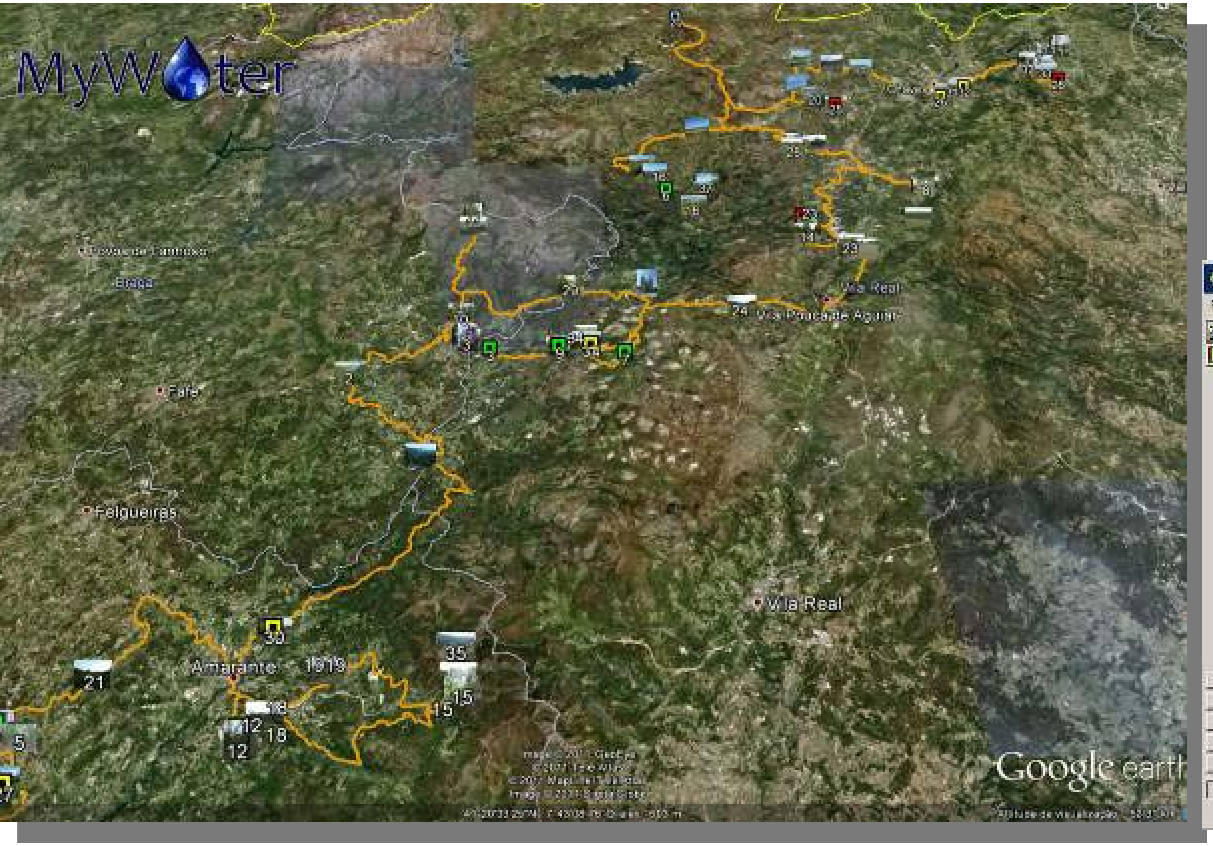
- AUTH

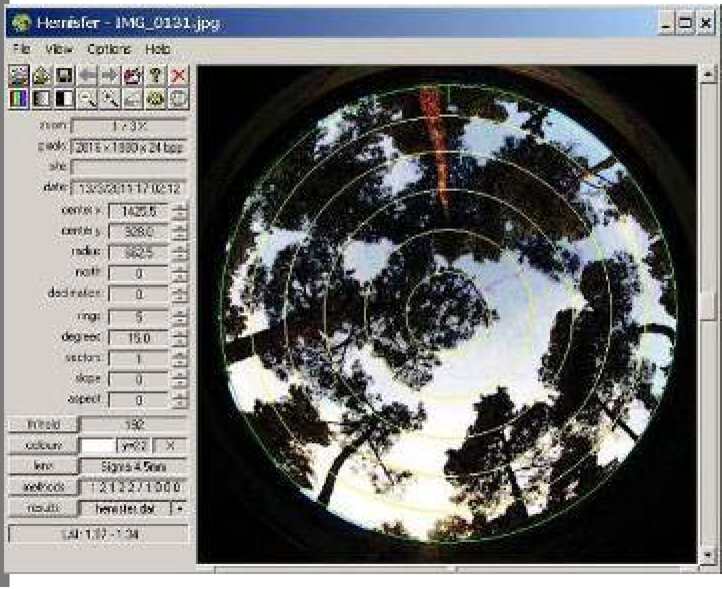


Field survey
Tamega

- GMV



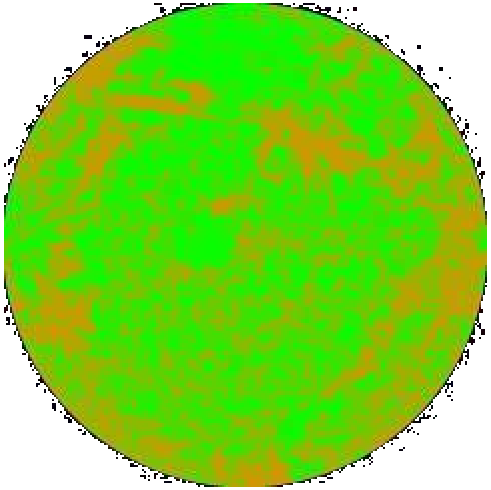




Alexandridis et al., 2013. LAI measurement with hemispherical photographs at variable conditions for assessment of remotely sensed estimations, ESA Living Planet Symposium, Edinburgh, UK.

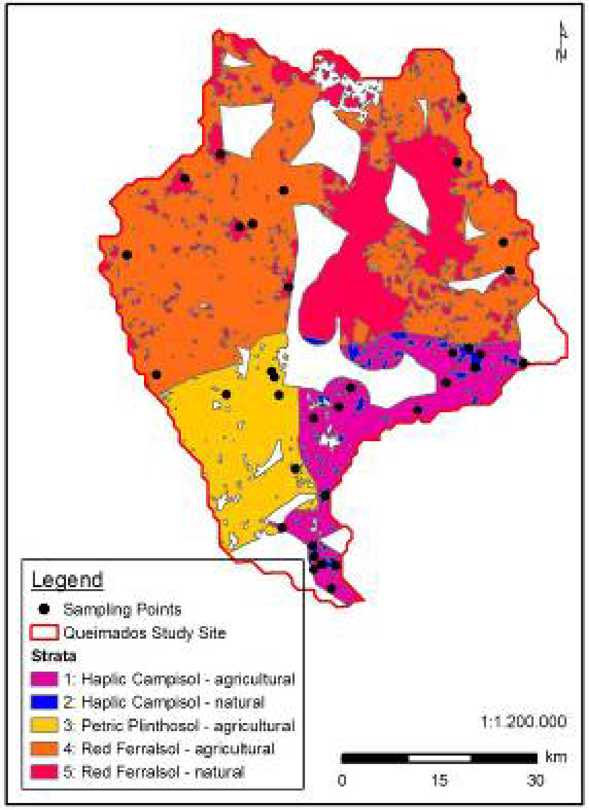
Field survey
Umbeluzi

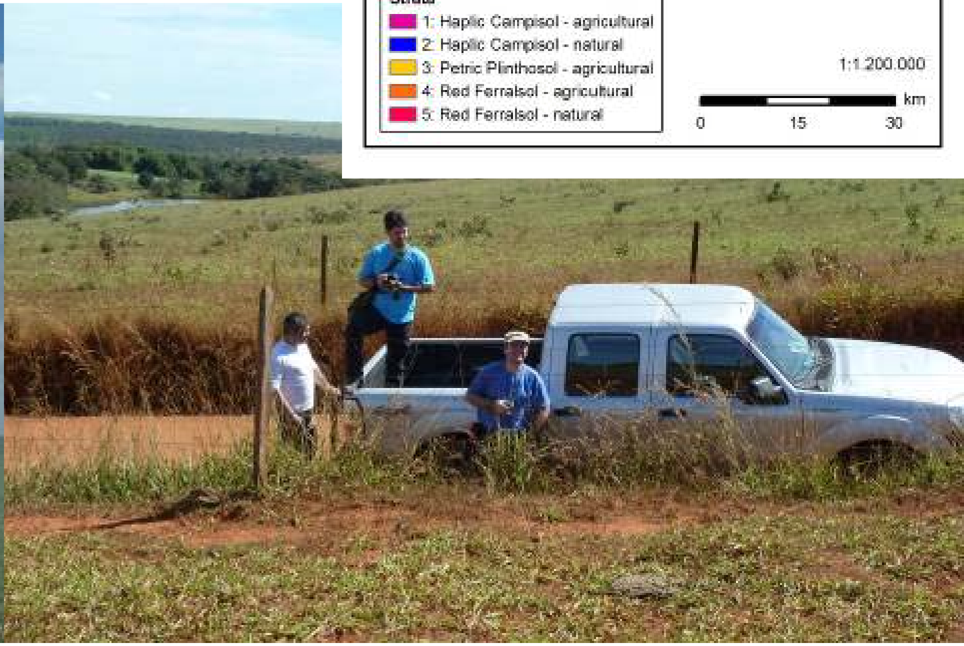
- UEM and ARA-SUL

Field survey
Queimados

- AUTH, CPTEC/INPE and CEMIG





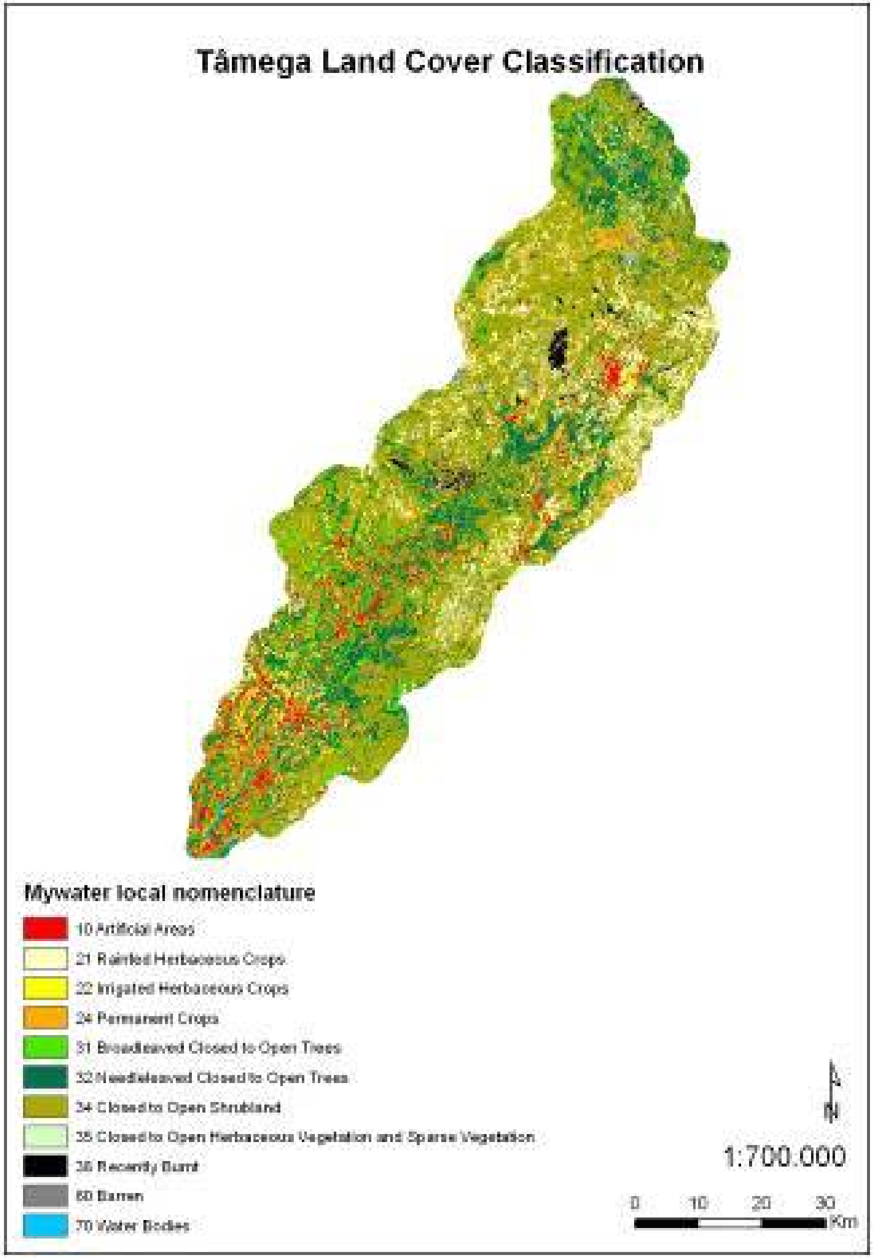
Field survey
Rijnland

- UNESCO-IHE and the Rijnland Water Board

Land Use / Land Cover (LULC)

1:50k scale maps

- Methodology
  - preferably Landsat, or SPOT
  - spectral classification
  - input of various features (bands, NDVI, IHS)
  - aim was 80% accuracy

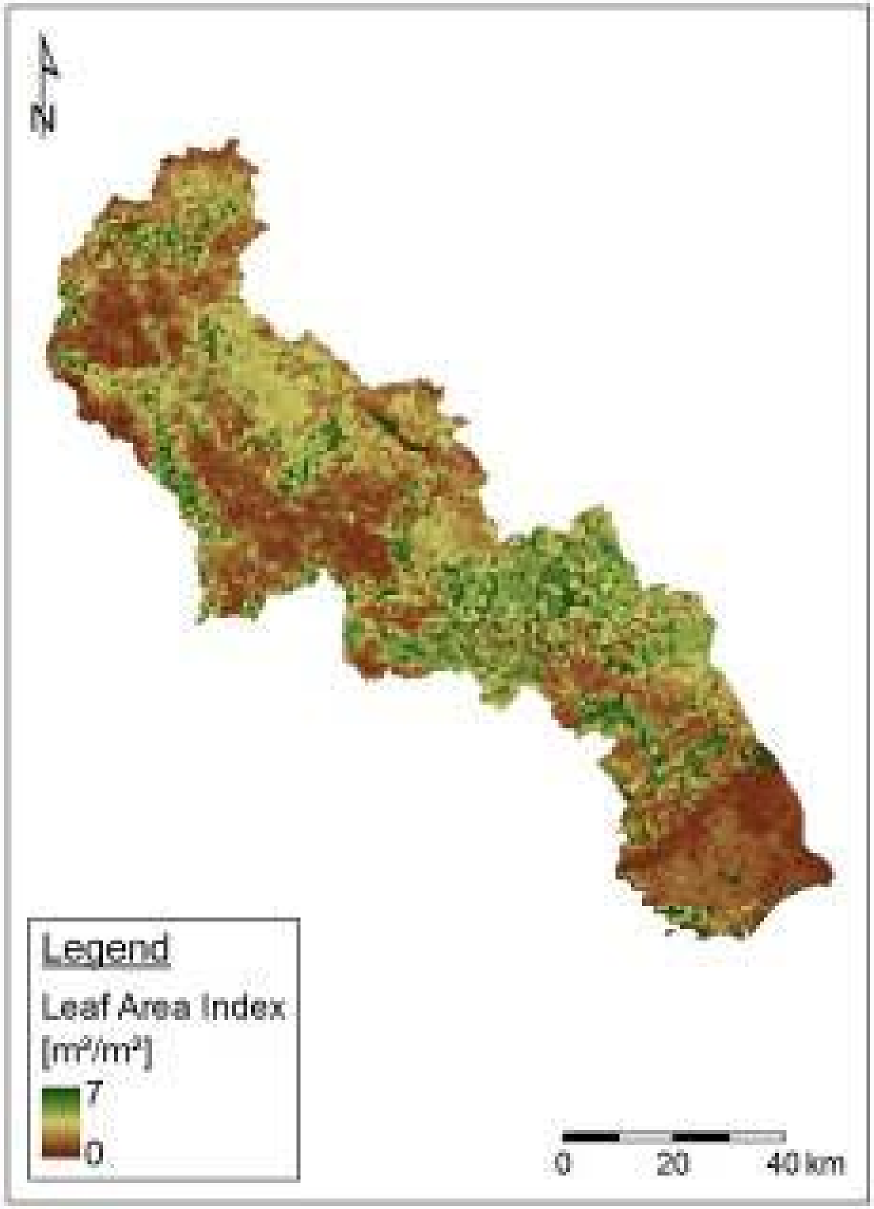


Nunes et al., 2013. Effects of different scale land cover maps in watershed modelling, Geophysical Research Abstracts, Vol. 15, EGU2013-11990, European Geosciences Union General Assembly, Vienna.

Leaf Area Index (LAI)

1:1M scale maps

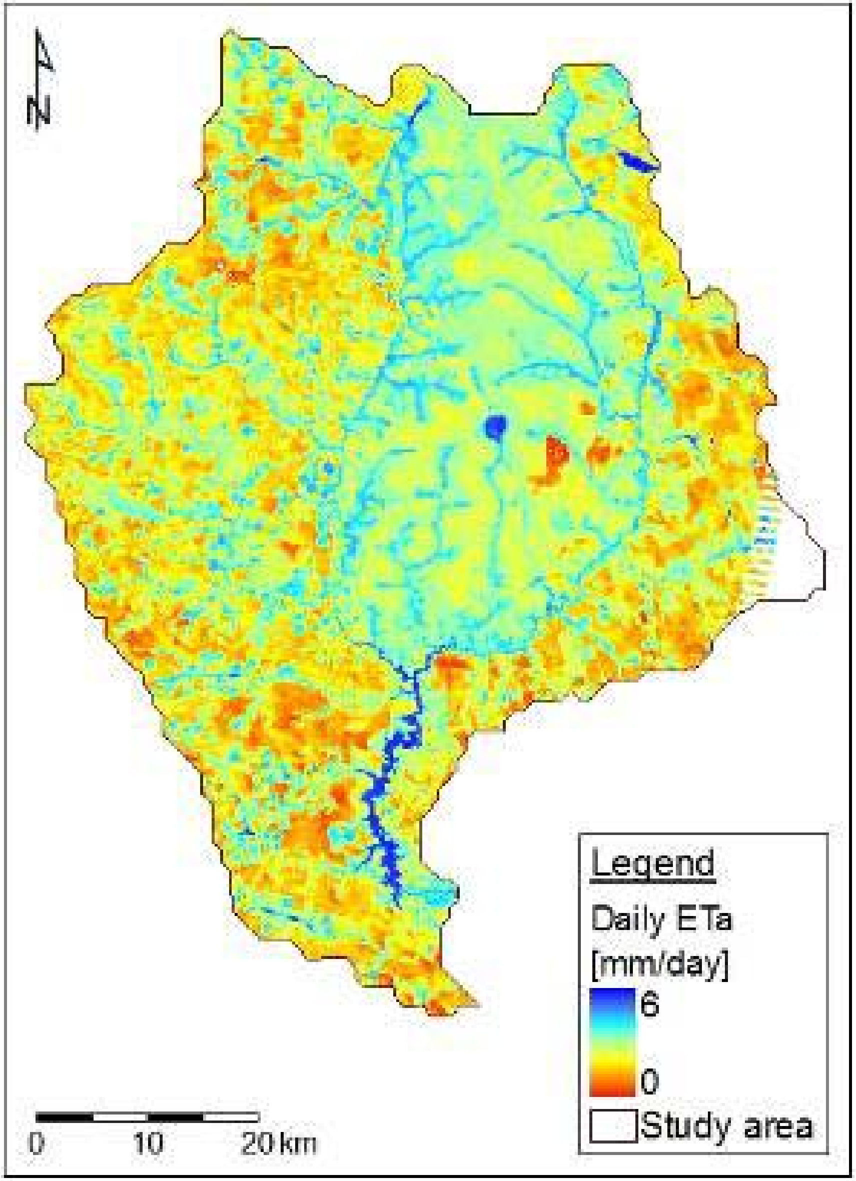
- Methodology
  - MODIS (MOD15A2), every 8 days at 1km resolution
  - downscaling to 250m
  - validation with in-situ measured LAI (fish-eye photos)



Silleos et al., 2014. Weekly time series of LAI maps at river basin scale using MODIS satellite data. In: K. Perakis (Editor), 1st International Geomatics Applications Conference "GEOMAPPLICA", Skiathos, Greece, pp. 293-299.

Actual Evapotranspiration (ETa)
1:50k scale maps

- Methodology
  - ITA-MyWater developed based on SEBAL
  - Data inputs:
    - visible, infrared and thermal bands from Landsat 5, Landsat 7 and Landsat 8 images according to their availability
    - meteorological data from weather forecast models
  - Landsat 7 ETM+ gap-filled data have been successfully tested



Cherif et al., 2015. Improving remotely sensed actual evapotranspiration estimation with raster meteorological data. International Journal of Remote Sensing, 36(18): 4606-4620.

Soil moisture (SM)
1:50k scale maps

- Methodology 1:

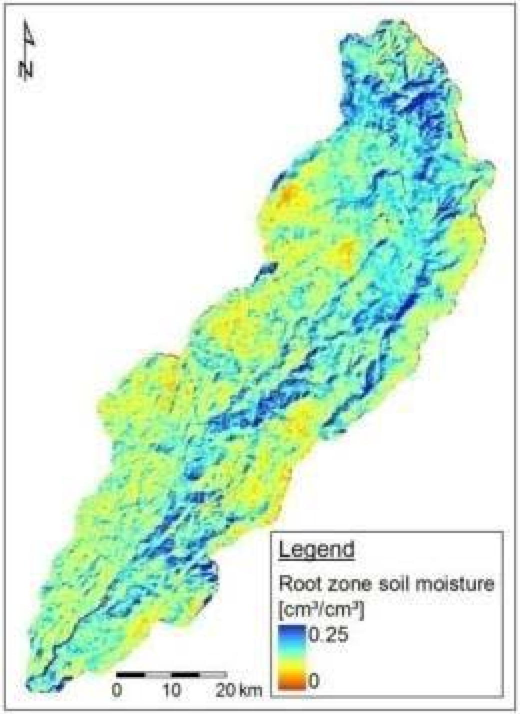
  SM at root zone using thermal Landsat data (similar to 1:1M)

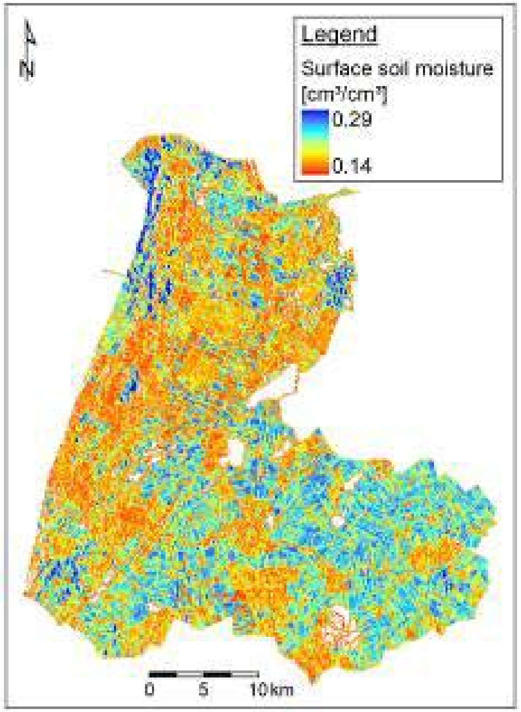
  - Extension of ITA-MyWater to estimate SM at root zone
  - Tested in all sites

- Methodology 2:

  Surface SM using SAR

  - Topsoil moisture
  - Empirical equations using SAR, LAI, slope and TDR300 measurements





Alexandridis et al., 2016. Spatial and Temporal Distribution of Soil Moisture at the Catchment Scale Using Remotely-Sensed Energy Fluxes. Water, 8(1): 32.

Discussion

Issues of operationality

- Methods
  - Accuracy
  - Automation
  - Alternatives
- Sources of data
  - Spatial coverage
  - Repetition
  - Lead time
  - Alternatives

Concluding

- Reliable, accurate, low cost source of data
- Methodologies operational and semi-automatic
- Not all parameters can be monitored
- Results can be merged with hydrological models
- Field survey is useful for fine-tuning algorithms and evaluation of accuracy

Thanks for your attention!

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