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Conference in  
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Regulation and WFD  
implementation  
- The next steps -



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# ***The use of Earth Observation for the detection of illegal abstraction and over- abstraction of water***

*Enrico Zini, Dario Bellingeri*  
*ARPA Lombardia - Italy*



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# Introduction



- Experiences arisen from IMPEL project WODA "Water Over-abstraction and illegal abstraction Detection and Assessment".
- The aims of WODA are:
  - To improve the capability of IMPEL members to monitor both illegal water abstraction and legal over-abstraction through cost-effective Earth Observation methods.
  - To make IMPEL members aware of the opportunities provided by the Copernicus Earth Observation programme.
- Project period: 2015 - 2016.



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# WODA Partners



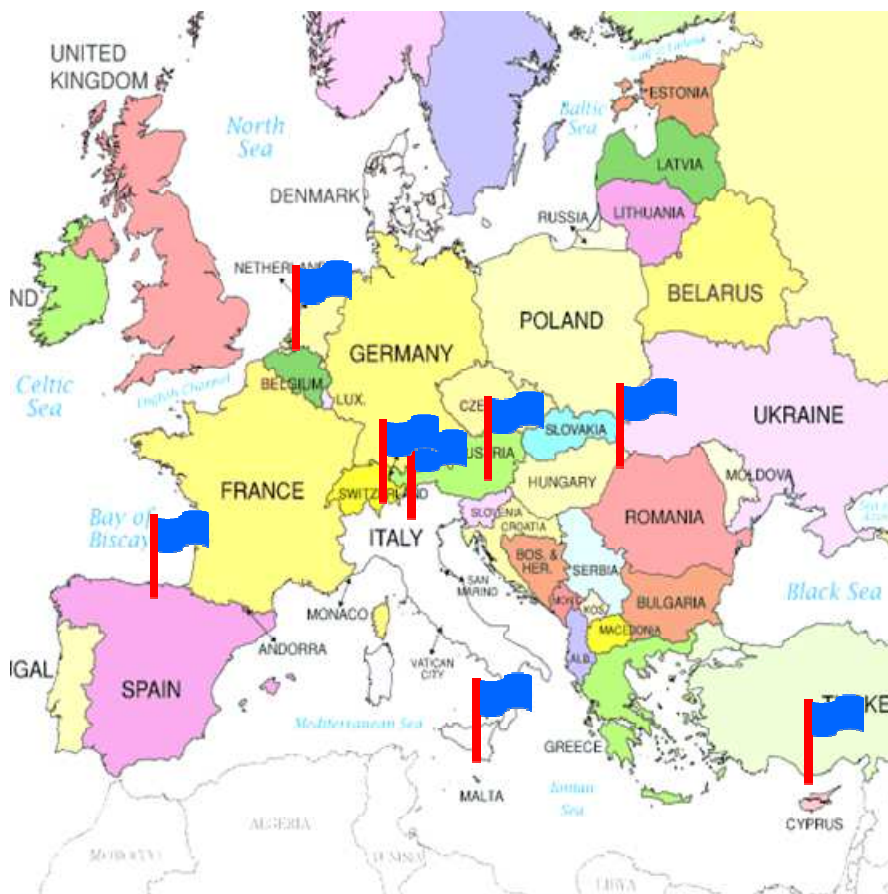
1. **Belgium:** Environment, Nature and Energy Department. Flemish Government.
2. **Cyprus:** Water Development Department, Ministry of Agriculture, Rural Development and Environment, Nicosia
3. **Italy:** ARPA Emilia Romagna (Regional Agency for Environmental Protection of Emilia-Romagna Region)
4. **Italy:** ARPA Lombardia (Regional Agency for Environmental Protection of Lombardy Region)
5. **Malta:** Sustainable Energy and Water Conservation Unit. Ministry for Energy and Health
6. **Romania:** National Environmental Guard - Bihor County Commissariat
7. **Slovenia:** Inspectorate of the RS for Environment and Spatial Planning. Ministry of Agriculture, Forestry and Food
8. **Spain:** Consejero técnico. Confederación Hidrográfica del Miño-Sil. Ourese.



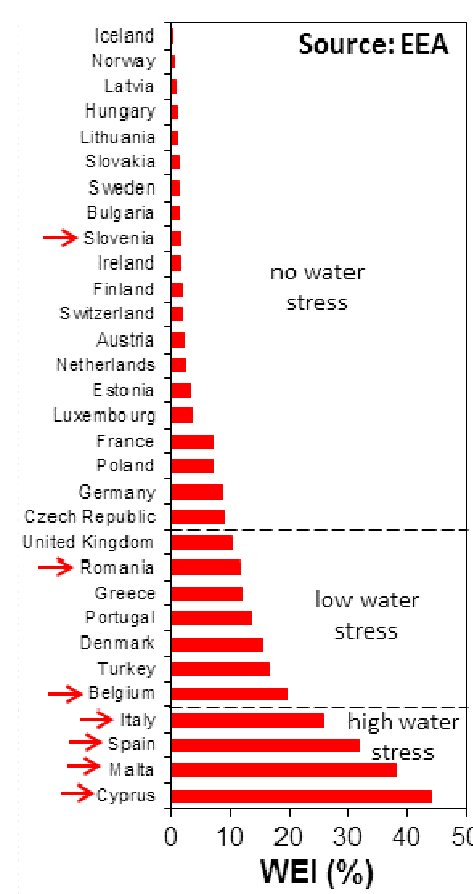
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# WODA Partners



Location of WODA partners



Water Exploitation Index (WEI) per MS  
(red arrows indicate WODA partners)



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# WODA Output



Year	Output	Description
2015	Qestionnaire	Delivered to the WODA partners. To acquire knowledge about the partners' contexts and water management rules.
	Pilot Feasibility Studies Lombardy, Romania and Malta	To assess the feasibility of use of EO over the 3 pilot test sites.
2016	Pilot Study Malta	To test Copernicus data (Sentinel-2A images) in supporting real cases of field inspections.



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# WODA Questionnaire



- **Delivered to: 8 WODA partners**
- **Number of questions: 95**
- **Contents:**
  - Competences of the organization.
  - Description of the context: geography, climate, population, industry, agriculture...
  - Permits and fees criteria.
  - Inspections and monitoring methods.
  - Information systems.
  - Auxiliary data availability (e.g. meteo,...)
  - Earth Observation experiences.
- **Outcome:** huge "biodiversity" of partners (context, organizations, management practices,..)



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# WODA Questionnaire

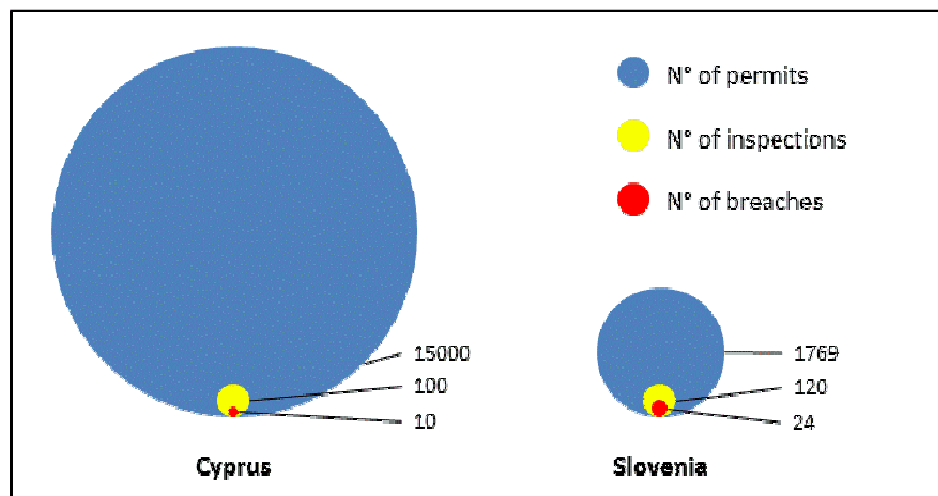
## Partner's competences

	Surface water	Groundwater	Monitoring water quantity	Monitoring water quality	Release of water permits	Inspection on water permits	Assessment/ analysis of water requirements	Development of water policies	Support to development of water policies	Development of River Basin Management Plans	Support to development of River Basin Management Plans	Advice for irrigation	Early warning on unsustainable water uses	Management of drought events	Support to management of drought events	Research and development
Belgium	✓	✓				✓			✓							
Cyprus	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓			✓		
Italy-1	✓	✓	✓	✓			✓		✓		✓	✓			✓	✓
Italy-2	✓	✓	✓	✓			✓		✓		✓		✓		✓	
Malta		✓	✓	✓				✓	✓	✓						
Romania	✓	✓				✓										
Slovenia	✓	✓				✓			✓							
Spain	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	

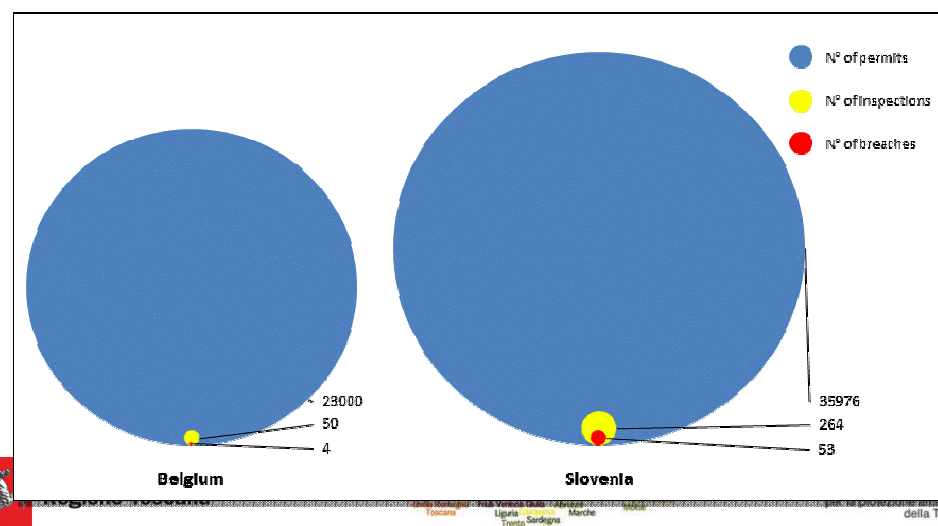
# WODA Questionnaire



## Output of inspections on surface water permits



## Output of inspections on groundwater permits

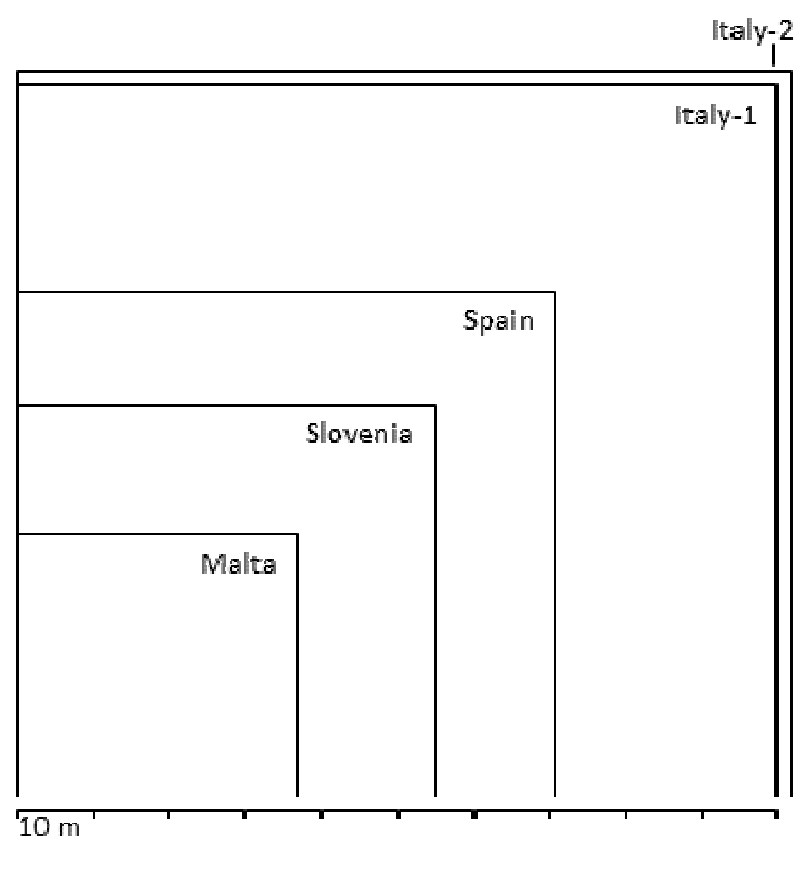


# WODA Questionnaire



## Average agricultural parcel sizes in partner's countries

Partner	Average parcel size (m <sup>2</sup> )
Malta	1 376
Slovenia	3 000
Spain	5 000
Italy-1	10 000
Italy-2	10 400



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# Topics of WODA



- The topics of WODA are:
  - **Illegal water abstraction and legal water over-abstraction.**
  - **Copernicus Earth Observation** programme.
  - **Earth Observation** methods:
    - **optical remote sensing**
    - **SAR interferometry**



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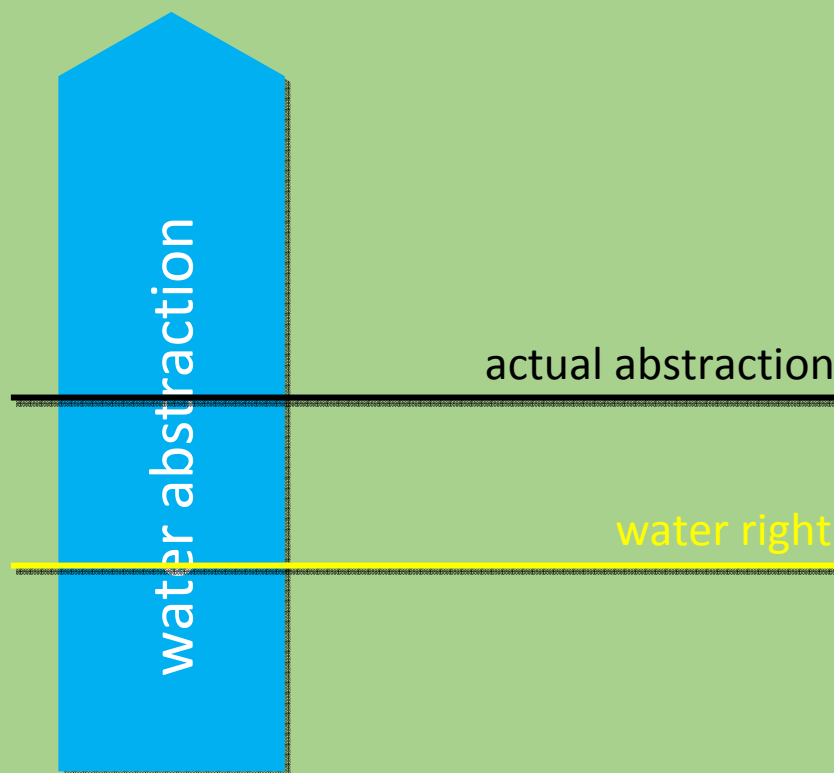
# Illegal water abstraction



(a problem of compliance assurance)

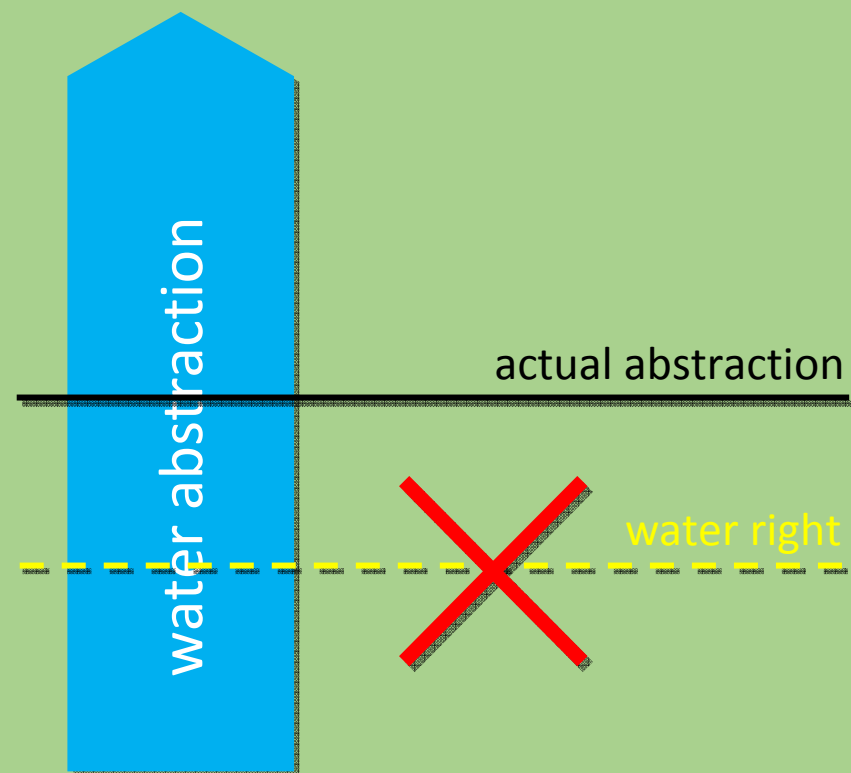
**Case A**

**Abstraction beyond water right**



**Case B**

**Abstraction without water right**



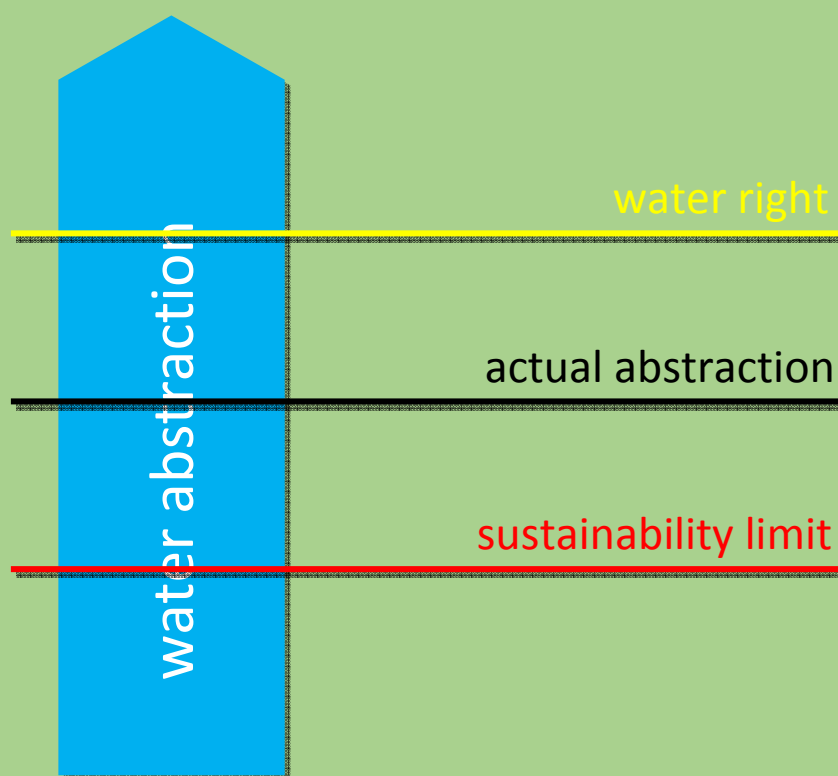
# Legal water abstraction



(a problem of environmental monitoring)

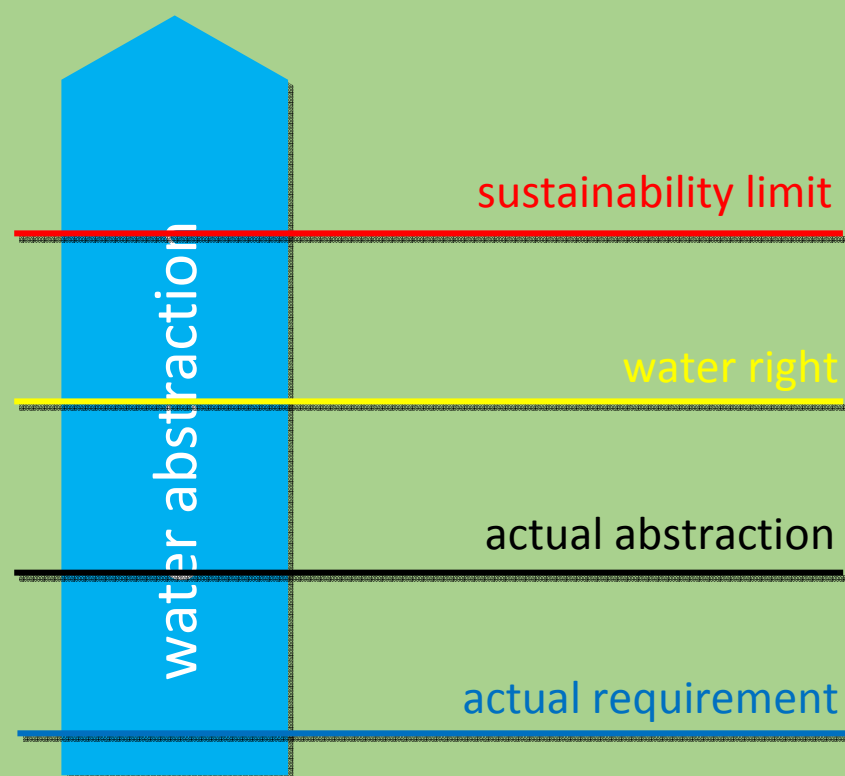
## Case C

Abstraction beyond sustainability  
limit



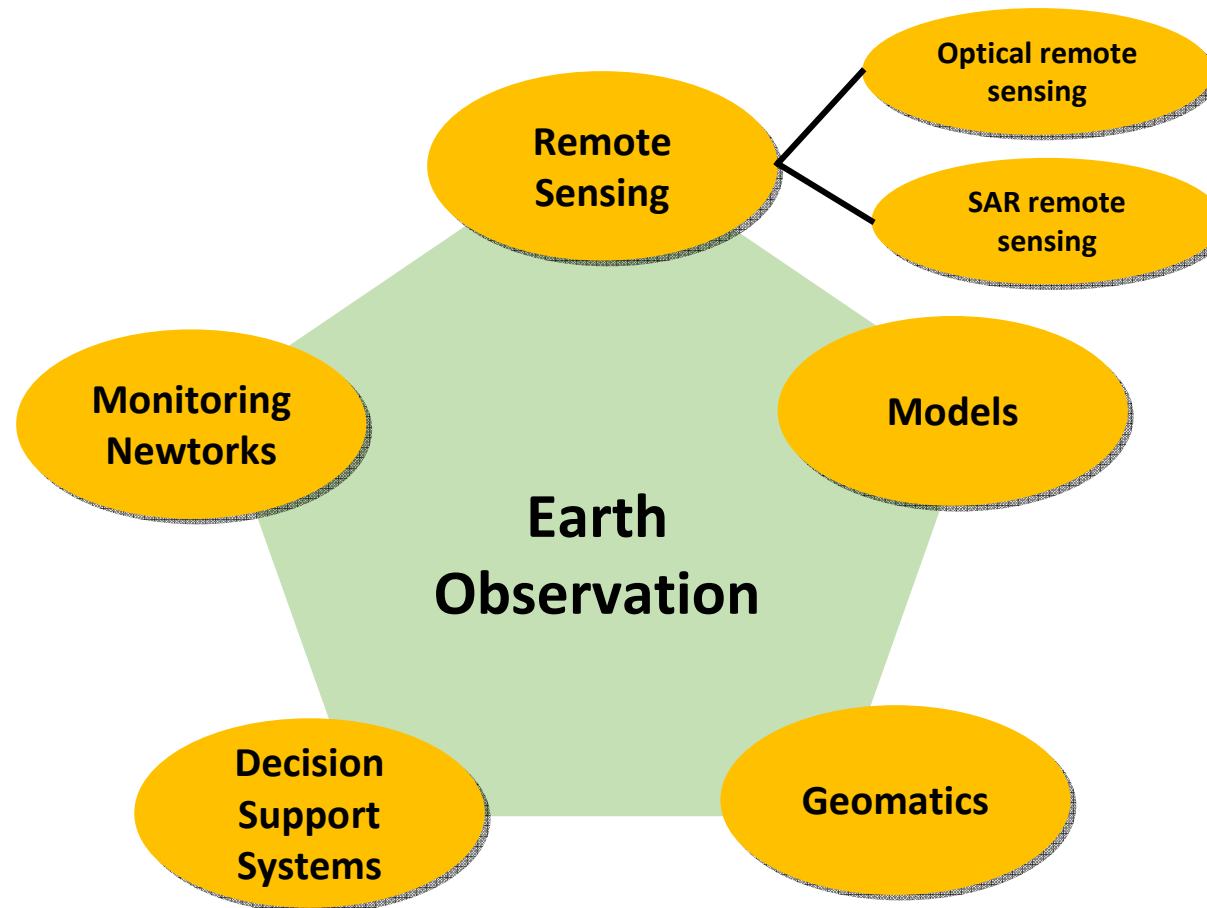
## Case D

Abstraction beyond requirement  
(inefficiency)





## Earth Observation as an ensemble of tools



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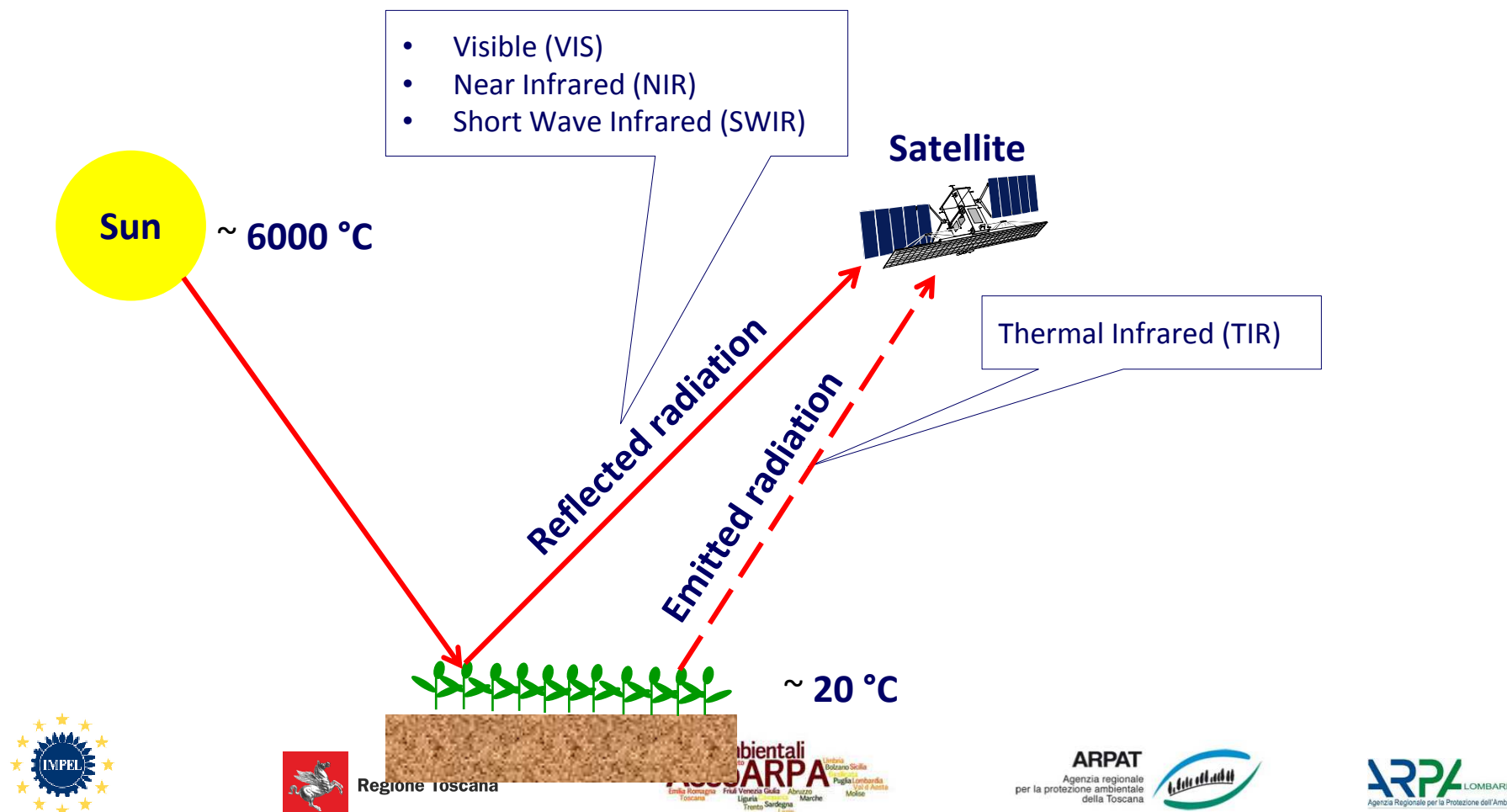


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# EO methods: optical remote sensing

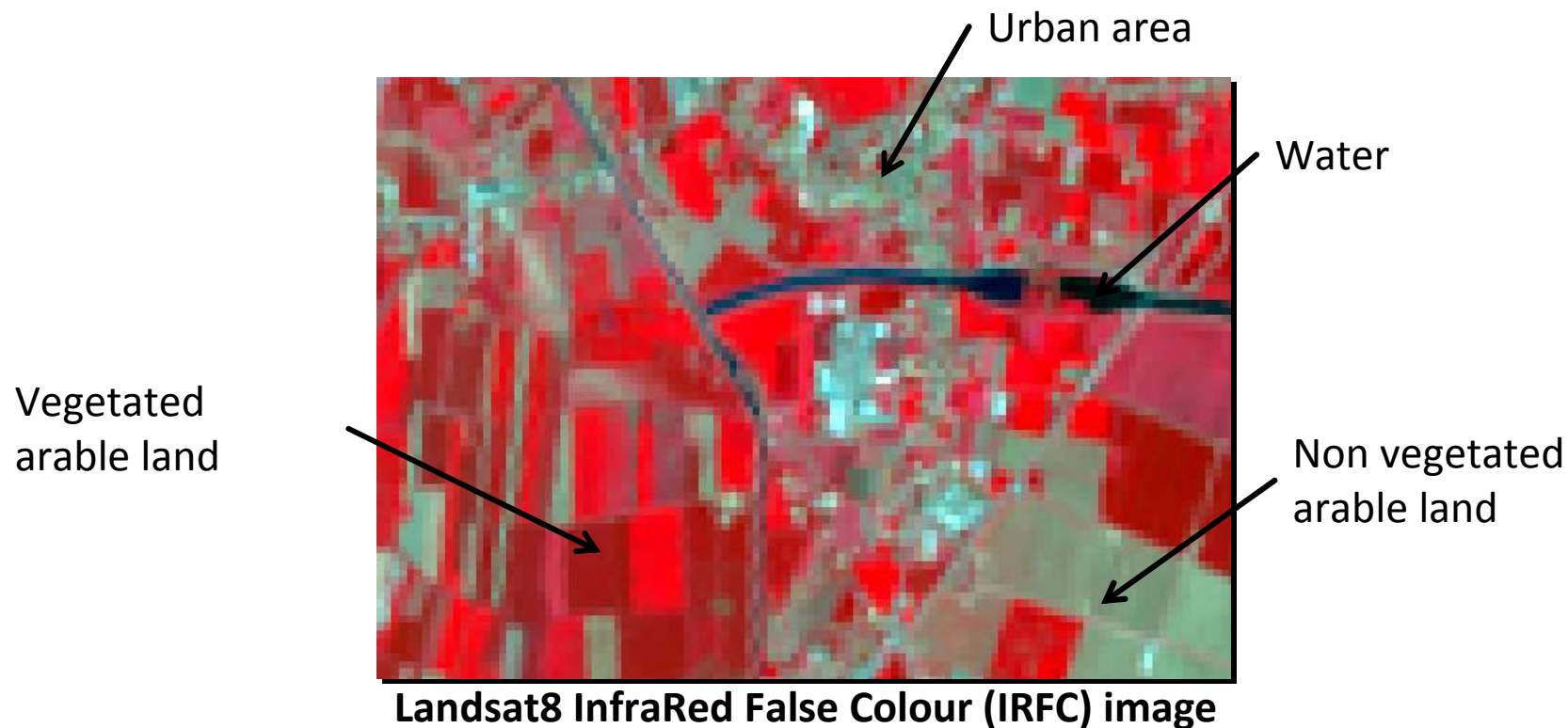


## Interaction between light and Earth surface



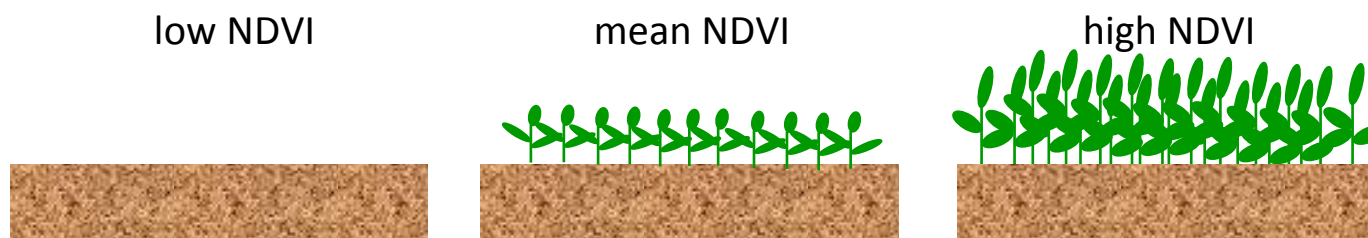
# EO methods: optical remote sensing

## Information from optical remote sensing



# Optical remote sensing: the concept

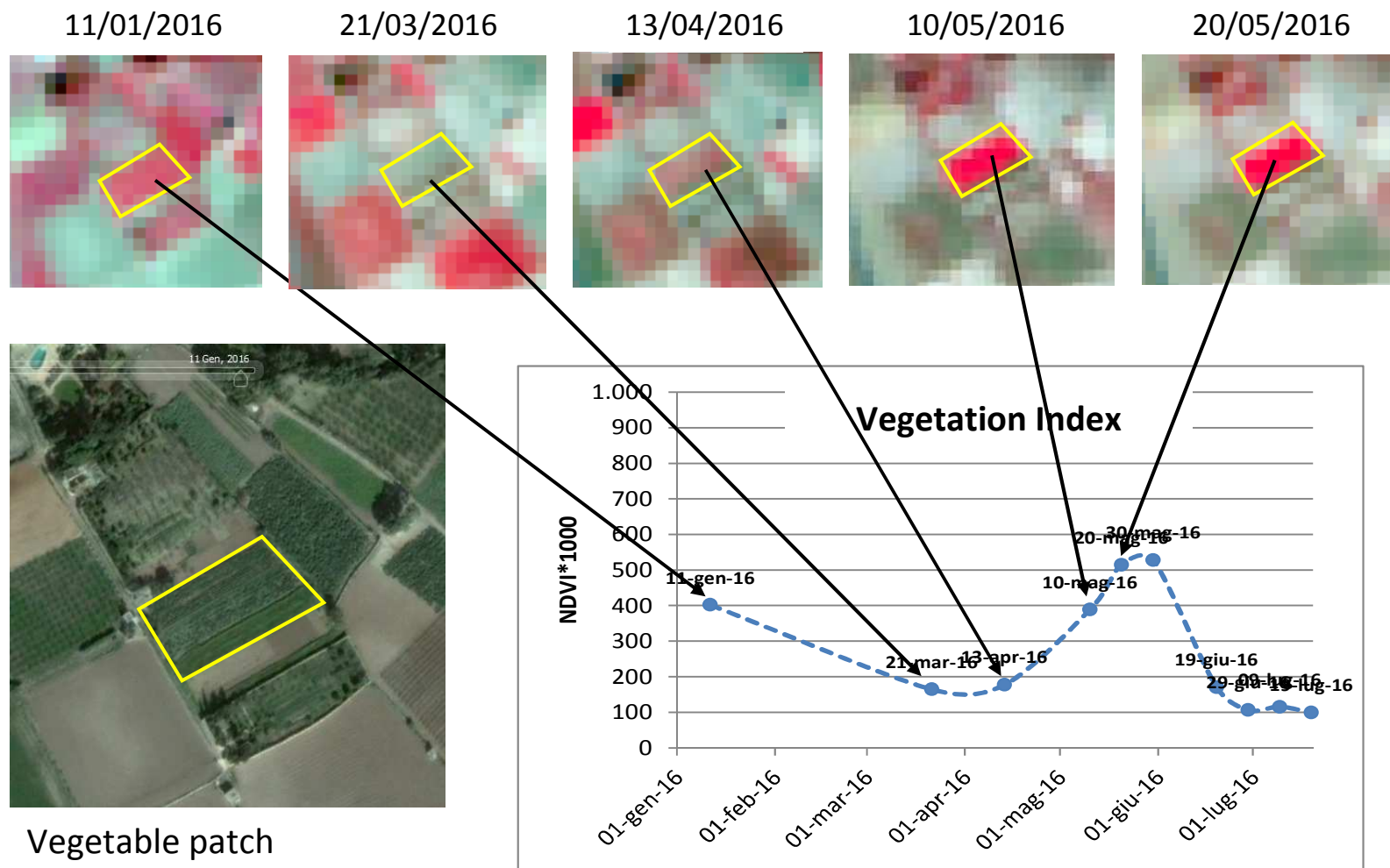
- Optical remote sensing provides information about the growth state of crops through vegetation indexes as NDVI (Normalized Difference Vegetation Index):



# Optical remote sensing: the concept



## Sentinel-2A Infrared False Colour images (IRFC), Pilot Study Malta



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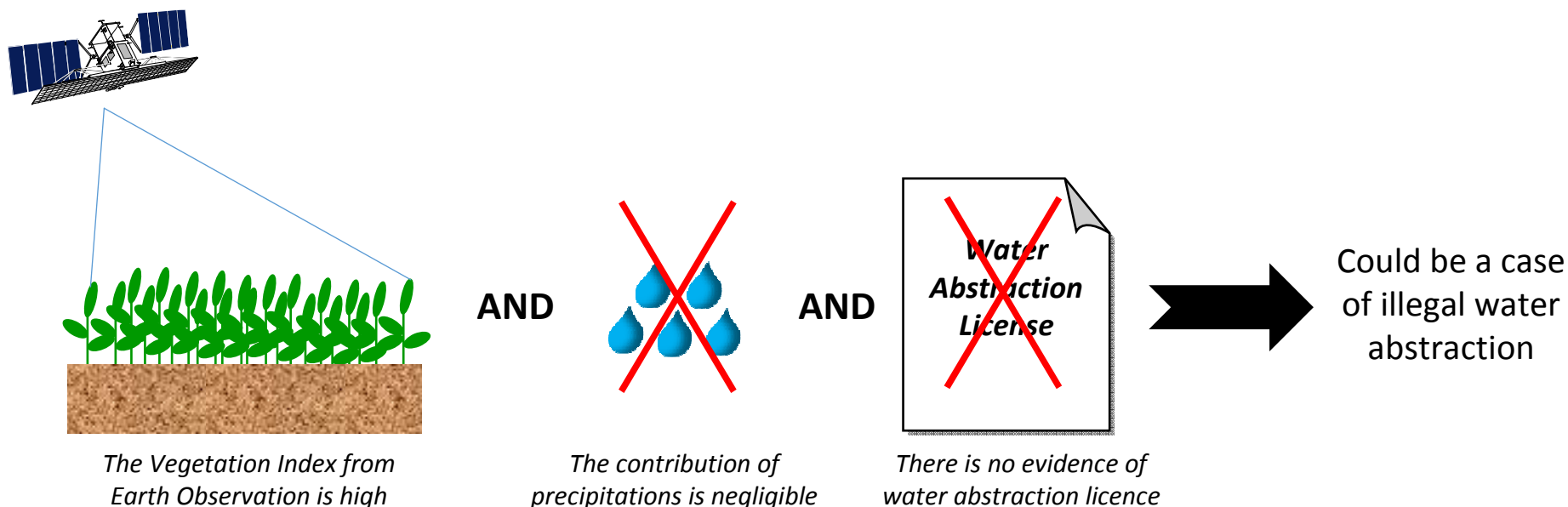


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# Optical remote sensing: the concept



## The concept of detection of illegal water abstraction through optical remote sensing

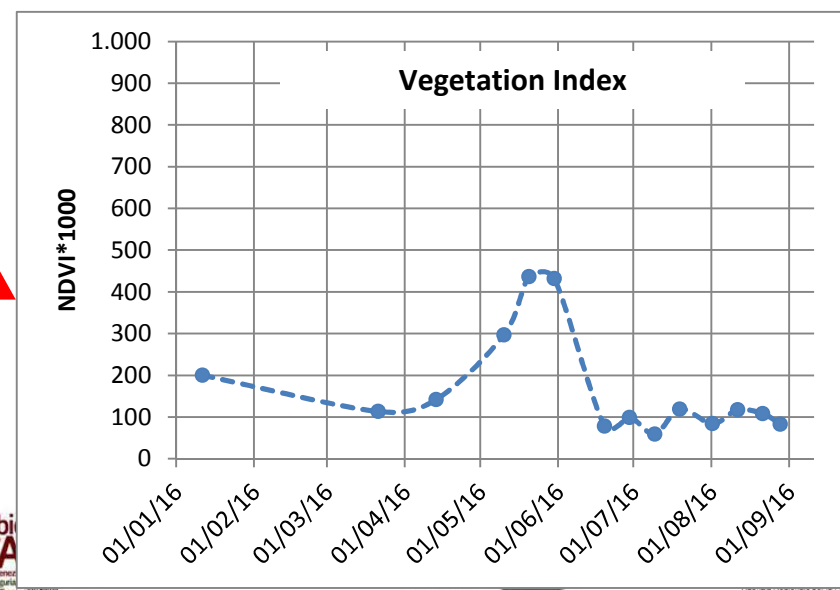
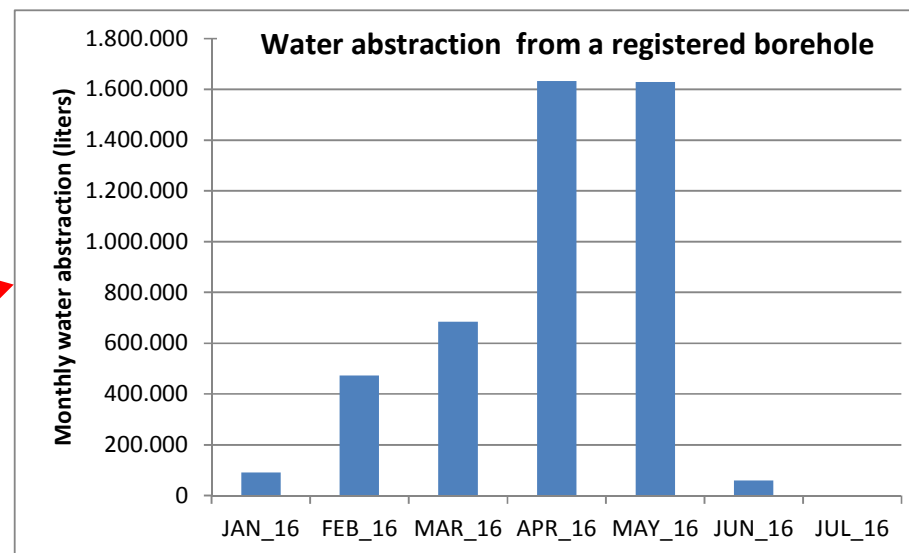


# Optical remote sensing: the concept

## An example of legal water abstraction



Pilot Study Malta, Sentinel-2A image 29/07/16



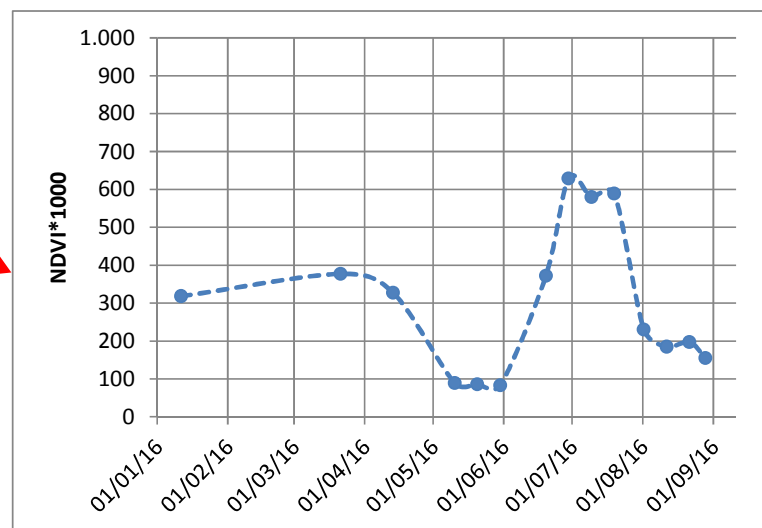
# Optical remote sensing: the concept

## An example of a potentially illegal water abstraction

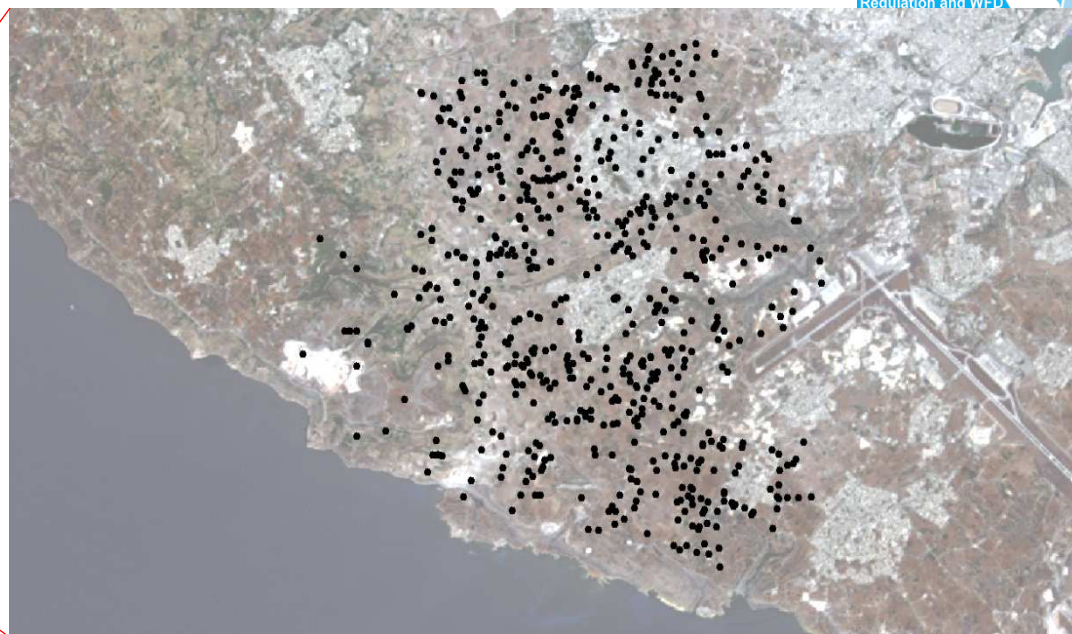
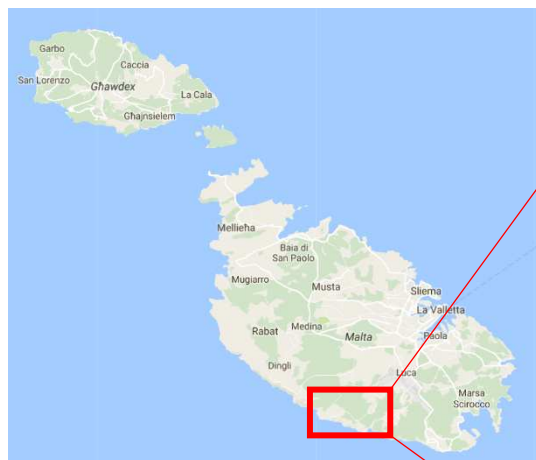


Pilot Study Malta, Sentinel-2A image 29/07/16

No evidence of registered borehole



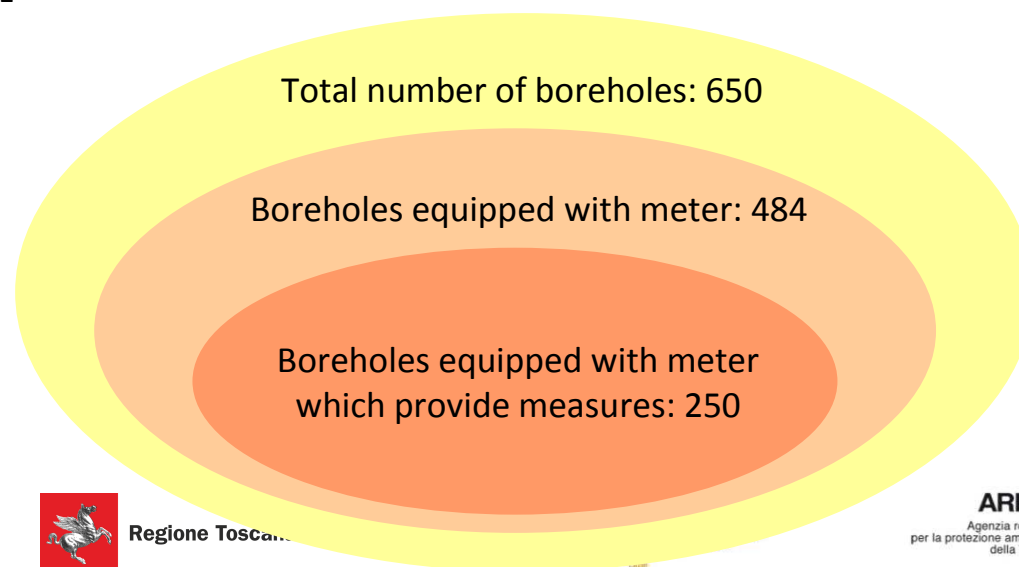
# The Malta Pilot Site



Pilot site:

3 Councils: Siggiewi, Zebbug and Qrendi

Surface: 33 Km<sup>2</sup>



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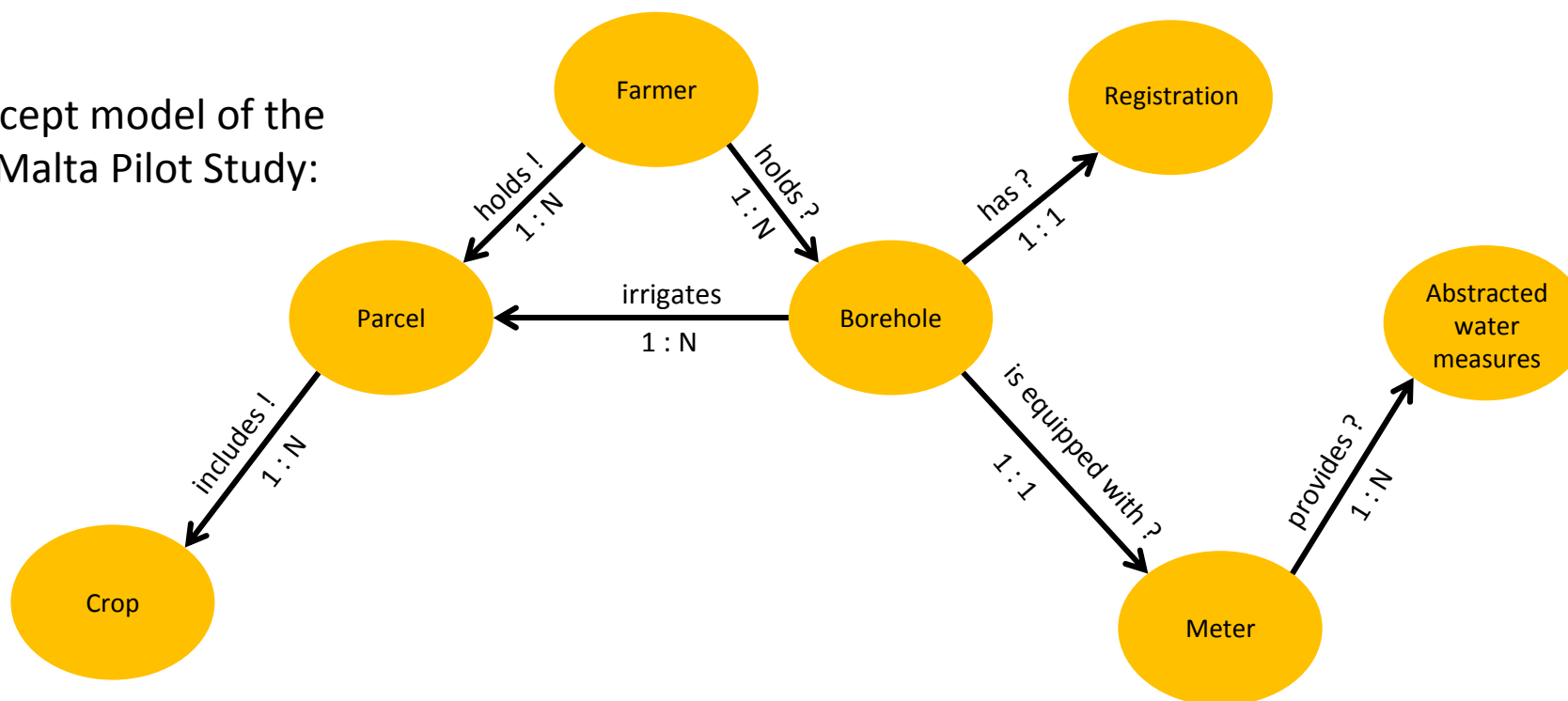


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# The Malta Pilot Site



The concept model of the  
case of Malta Pilot Study:



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# Optical remote sensing: the concept

## Main conditions for the application of optical remote sensing to the detection of illegal water abstraction

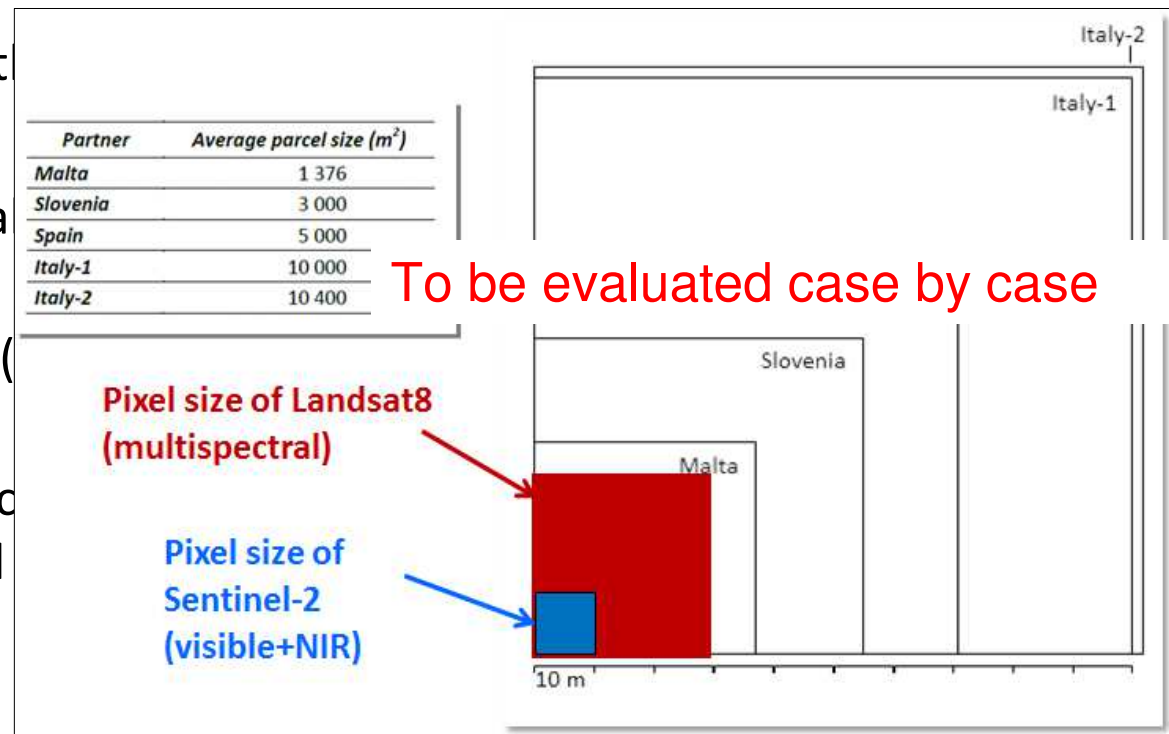
1. Dry seasons where the contribution of precipitations is negligible

OK for  
Mediterranean  
countries

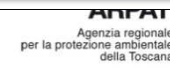
2. Pixel size compatible with

3. Availability of fully digital information about:

- agricultural parcels (types)
- water abstraction locations possibly, abstracted



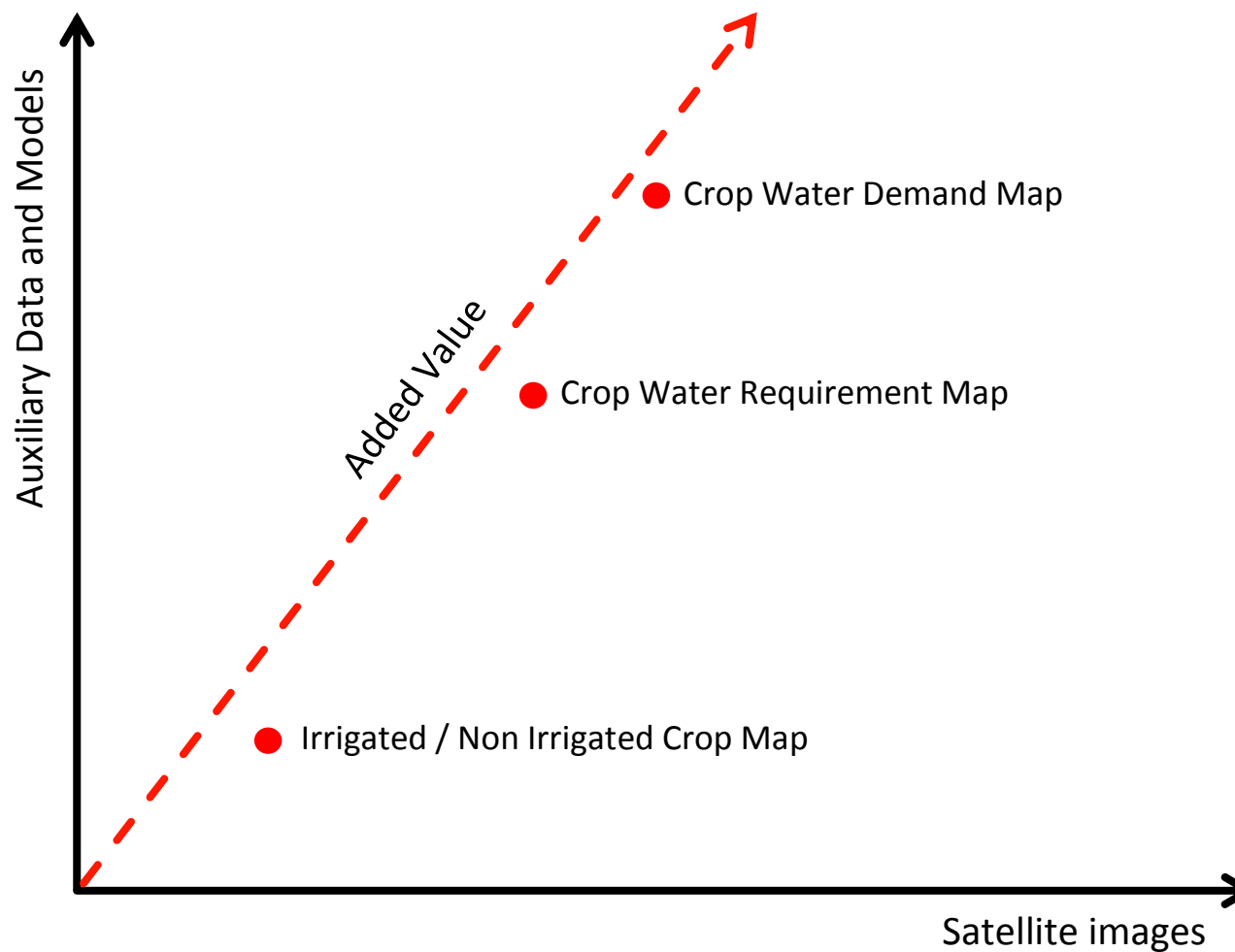
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# EO methods: optical remote sensing















## Services useful for illegal water detection and water overabstraction monitoring



# EO methods: optical remote sensing

## Effectiveness of optical remote sensing

Water use	Surface water		Groundwater	
	Illegal abstraction	Overabstraction	Illegal abstraction	Overabstraction
Agriculture				
Industrial				
Civil				



Feasible



Feasible with difficulty



Not feasible



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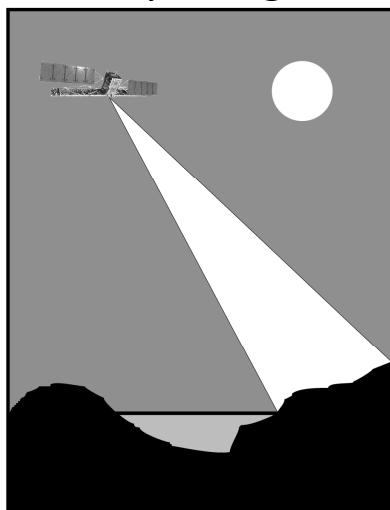


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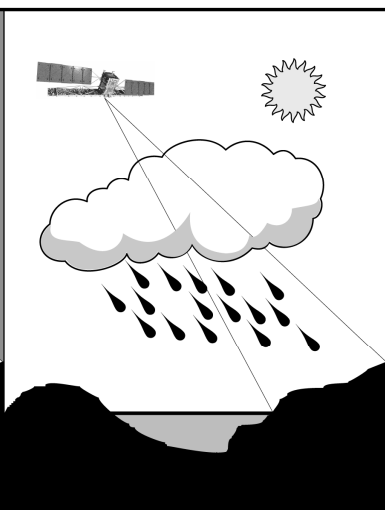
# EO methods: SAR remote sensing



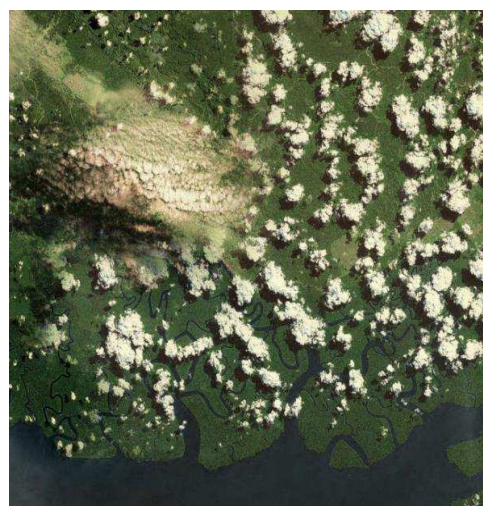
Day & Night



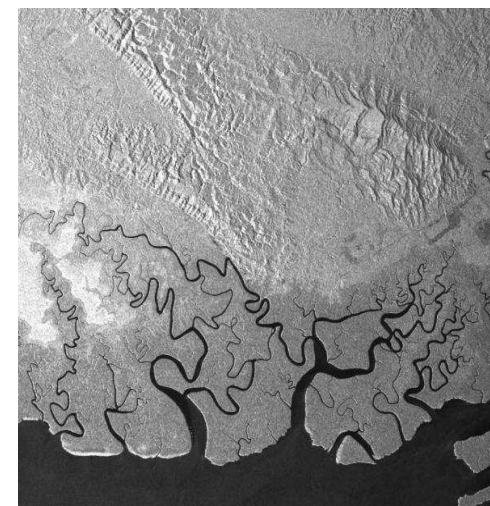
All weather



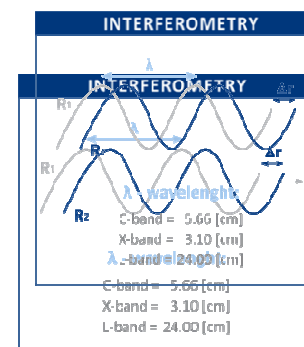
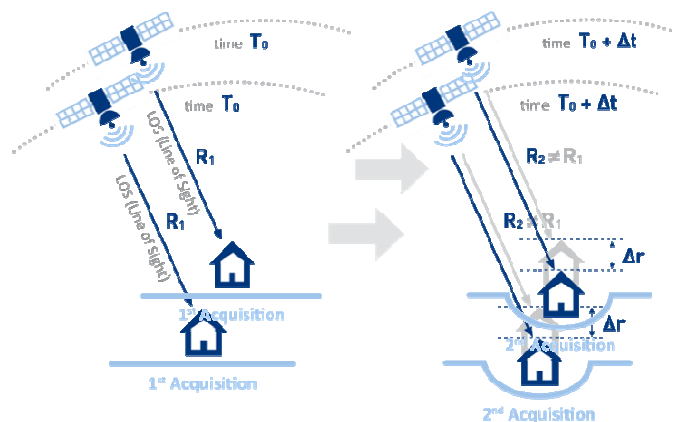
Optical image



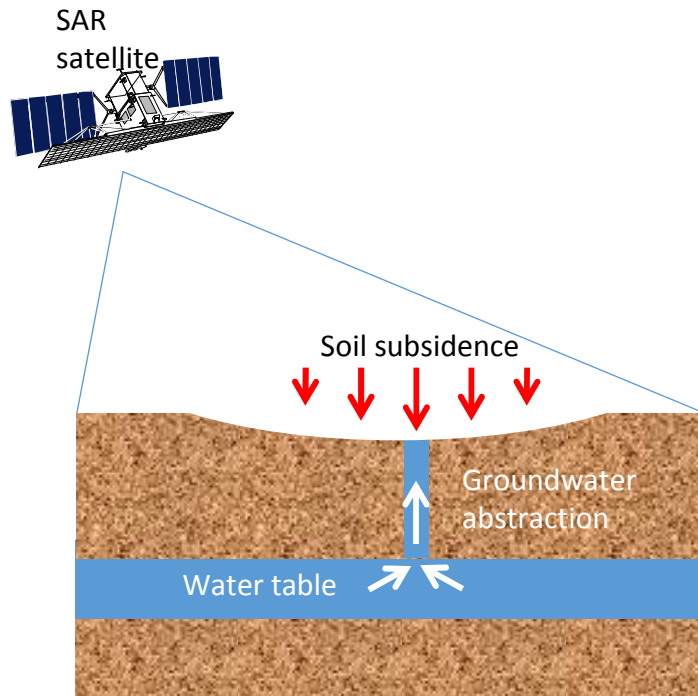
SAR image



## Differential Interferometry



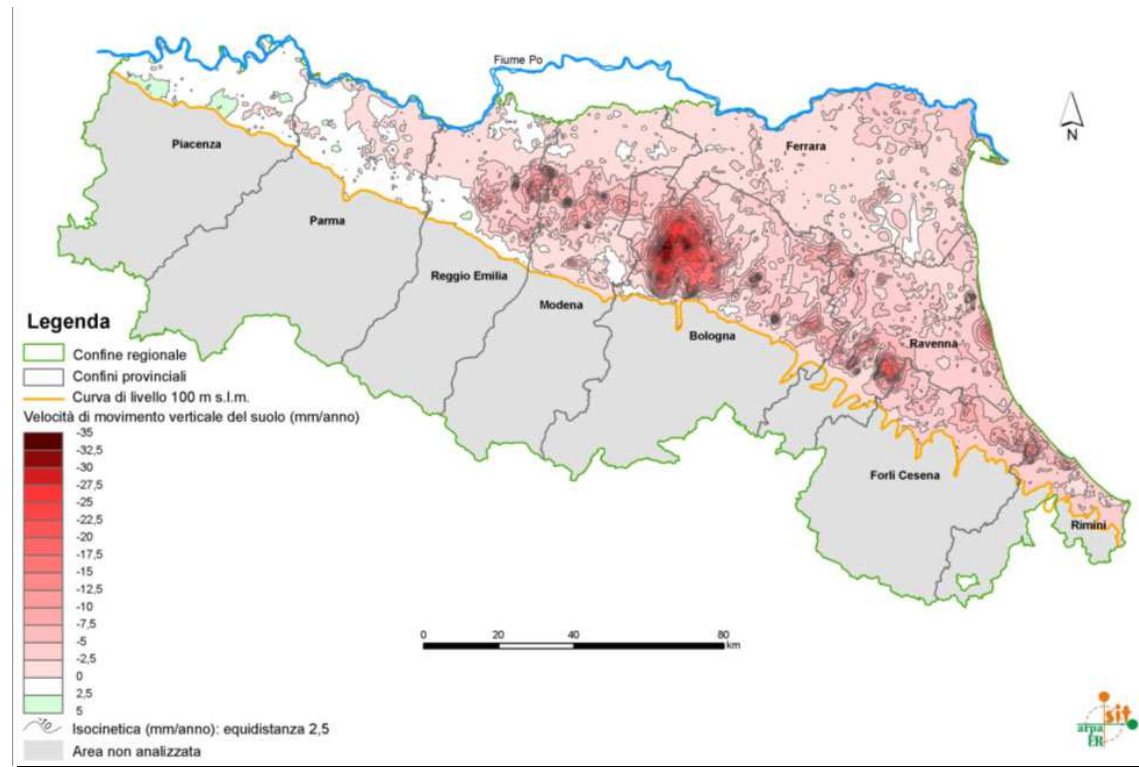
# EO methods: SAR remote sensing



- Groundwater overabstraction is an unbalance between input and output flows.
- As a consequence, the water table lowers.
- Under proper geological conditions (e.g. sedimentary basins), the lowering of the water table causes soil subsidence.
- SAR interferometry is capable to detect vertical movements of soil with millimeter accuracy.
- Thus, measures from SAR interferometry provide a proxy of groundwater overabstraction.

# EO methods: SAR remote sensing

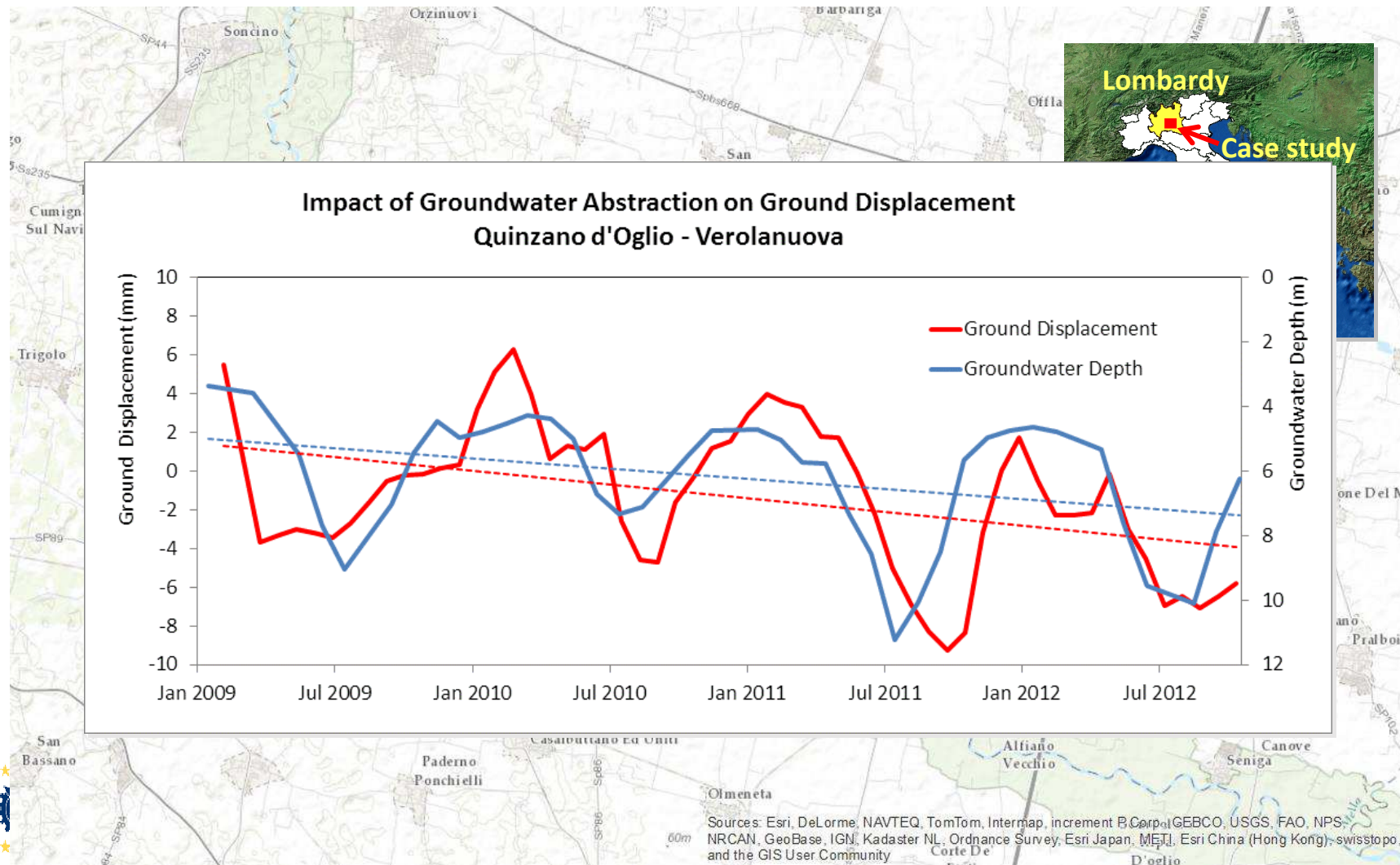
## Monitoring of soil subsidence by SAR interferometry: the experience of ARPA Emilia Romagna



Mean annual rate of vertical soil displacement (mm/year) in 2006-2011 in Emilia Romagna by SAR interferometry (source: ARPA Emilia Romagna).













# EO methods: SAR remote sensing

## Monitoring of soil subsidence by SAR interferometry: the experience of ARPA Lombardia



# EO methods: SAR remote sensing

## Effectiveness of SAR interferometry

Water use	Surface water		Groundwater	
	Illegal abstraction	Overabstraction	Illegal abstraction	Overabstraction
Agriculture				
Industrial				
Civil				



Feasible



Feasible with difficulty



Not feasible



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# EO methods: SAR remote sensing

## Combined effectiveness of optical and SAR remote sensing

Water use	Surface water		Groundwater	
	Illegal abstraction	Overabstraction	Illegal abstraction	Overabstraction
Agriculture				
Industrial				
Civil				



Feasible



Feasible with difficulty



Not feasible



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# Copernicus programme: introduction



- Copernicus is a European Programme for the establishment of a European capacity for EO, launched in 1998 as GMES Programme (Global Monitoring of Environment and Security). In 2014 (Regulation (EU) No 377/2014), new development stage of the Copernicus programme, which will feature new operational services by 2020 and a budget 2014-2020 of EUR 4.3 billion.
- **Objectives**
  - Promoting the use of EO data.
  - Strengthening European EO markets.
  - Supporting the European research.
- **Access to information**
  - Copernicus provides free, full and open access to data and information worldwide.



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# Copernicus programme: Sentinel satellites

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## **Sentinel-1: SAR imaging**

All weather, day & night, interferometry,...  
Revisit time: 1sat: 12days, 2sats: 6 days

Launch Sentinel-1A: 3 April 2014

Launch Sentinel-1B: 25 April 2016



## **Sentinel-2: Land multi-spectral imaging**

Applications: urban, forest, agriculture,...  
Revisit time: 1sat: 10days, 2sats: 5 days

Launch Sentinel-2A: 23 June 2015

Launch Sentinel-2B: planned 2017



## **Sentinel-3: Ocean and Land global monitoring**

Ocean, vegetation, surface temperature,...  
Revisit time: 1sat: 3.8 days, 2sats: 1.9 days

Launch Sentinel-3A: 16 February 2016

Launch Sentinel-3B: tbd



## **Sentinel 4: Geostationary atmospheric**

Atmospheric composition monitoring,  
trans-boundary pollution

Launch Sentinel-4A: tbd

Launch Sentinel-4B: tbd



## **Sentinel 5: Low-orbit atmospheric**

Atmospheric composition monitoring

Launch Sentinel-5A: tbd

Launch Sentinel-5B: tbd



## **Sentinel 6: Altimetry**

Oceanography and climate studies

Launch Sentinel-6A: tbd

Launch Sentinel-6B: ?



UPTD10: 11/2010/0110



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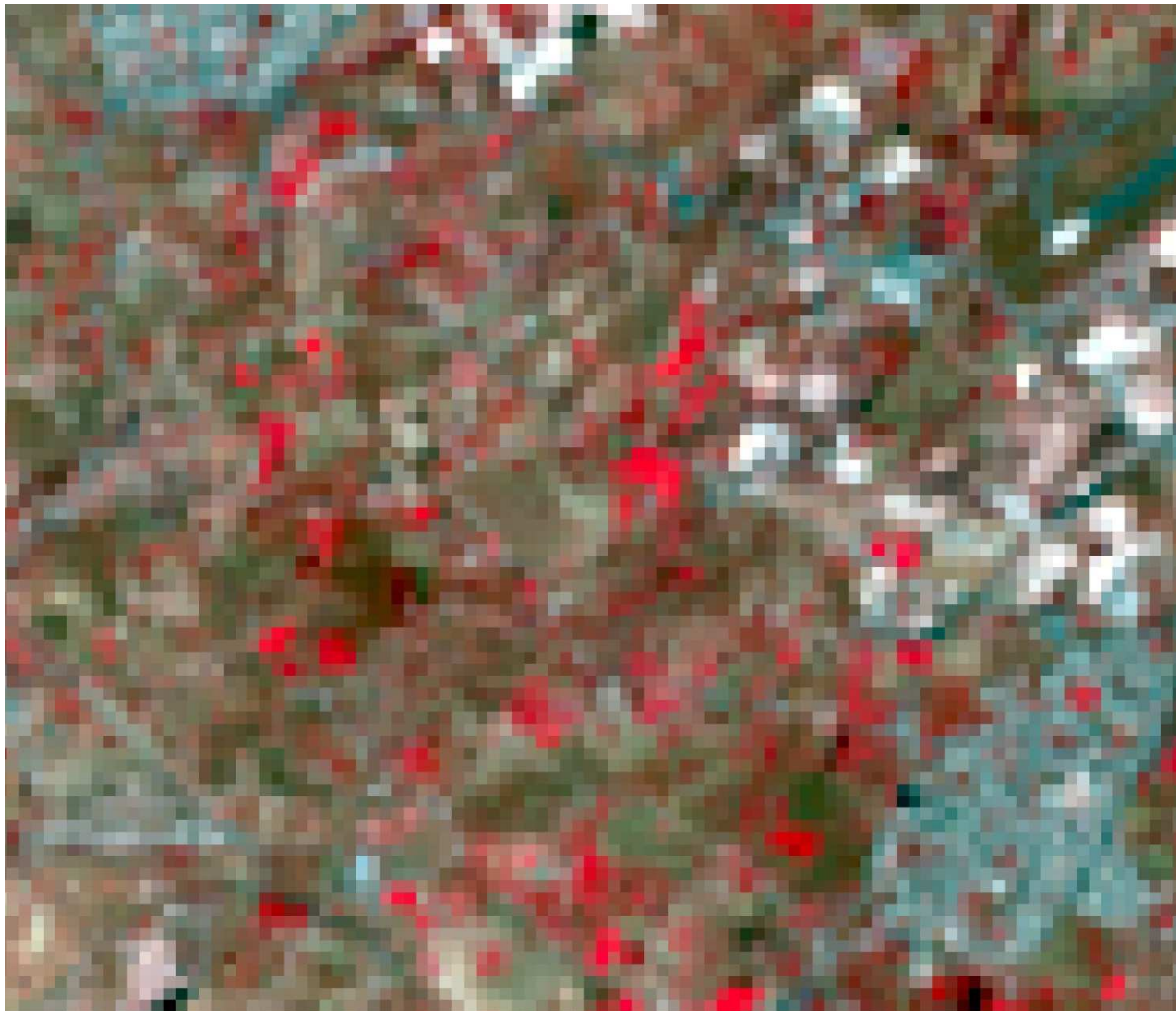
# Copernicus programme: Sentinels satellites

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## Landsat8 / Sentinel-2 comparison



**Landsat8**  
**Pixel: 30m**  
**April 2016**  
**Malta**



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# Copernicus programme: Sentinels satellites

## Landsat8 / Sentinel-2 comparison



**Sentinel-2A**  
**Pixel: 10m**  
**April 2016**  
**Malta**



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## Copernicus Services Implementation Schedule



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# Copernicus programme: services

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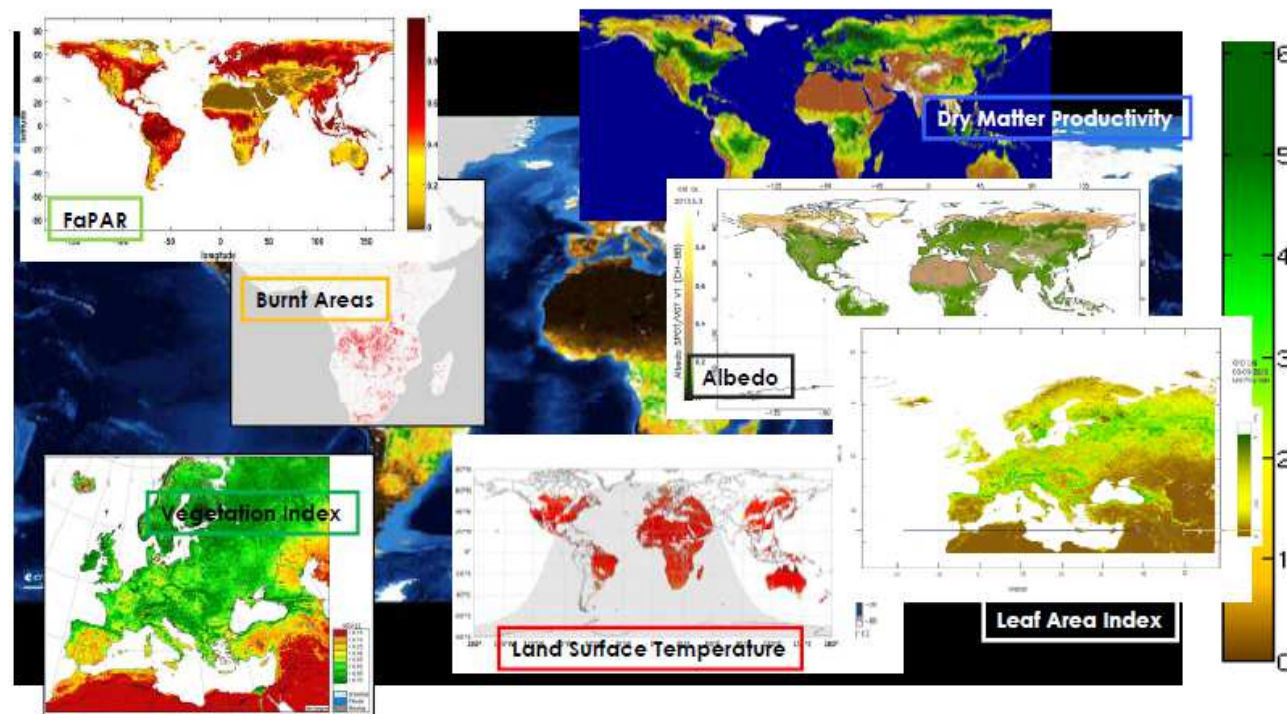
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## Land Monitoring Service Global component



copernicus



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Friuli Venezia Giulia Abruzzo Molise  
Liguria Piemonte Valle d'Aosta Lombardia  
Trentino-South Tyrol Veneto Puglia Basilicata Calabria  
Sardinia Sicily

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# Conclusions



- Optical and SAR remote sensing methods for detecting illegal water abstraction and over-abstraction are mature and reliable.
- The climatic, hydrologic and geological conditions favourable to the application of the EO methods are quite common among the European countries/regions most affected by water scarcity issues.
- Copernicus data from Sentinel-1 and Sentinel-2 have an excellent quality, are free of cost and very easy to access.
- SAR interferometry products derived from Sentinel-1 as soil subsidence are costly and are not available (at least at the moment) from Copernicus. Users communities could urge the Commission to promote the development of a free and standard Copernicus soil subsidence service (taking into account that this service would have many other useful applications).



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# Conclusions



- EO data are of little use if auxiliary data (i.e. agricultural cadastre, water permits, water abstraction, meteo,...) are not fully available on digital format, integrated, georeferenced, validated and easily accessible through Internet.
- Competences on agriculture and water resources management are frequently shared among different organizations. As a consequence, databases have been developed separately and they are still not interoperable (INSPIRE Directive).
- Each country/region features a specific context with agricultural and water management practices frequently dating back to centuries. To make EO methods successful in supporting the controls and the monitoring of water resources is necessary to understand very deeply the local context. Thus it is necessary to develop country/region specific strategies for the implementation of EO methods.



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Thanks for your attention !

Enrico Zini

[e.zini@arpalombardia.it](mailto:e.zini@arpalombardia.it)



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