ERMES
AN EARTH OBSERVATION MODEL BASED RICE INFORMATION SERVICE

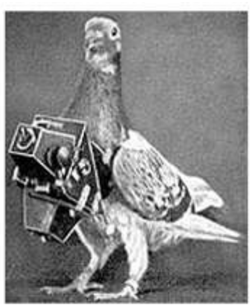
From -omics to phenotyping for crop improvement

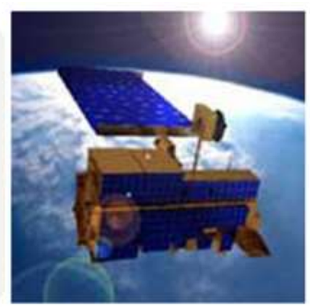
Tuesday 26th-Thursday 28th, June 2018
Aula Maggiore - Via Celoria, 2 (MI)

Earth Observation systems for operational monitoring of crop conditions

Wednesday 27th, June 2018

Mirco Boschetti *CNR-IREA (MI)*




Copernicus

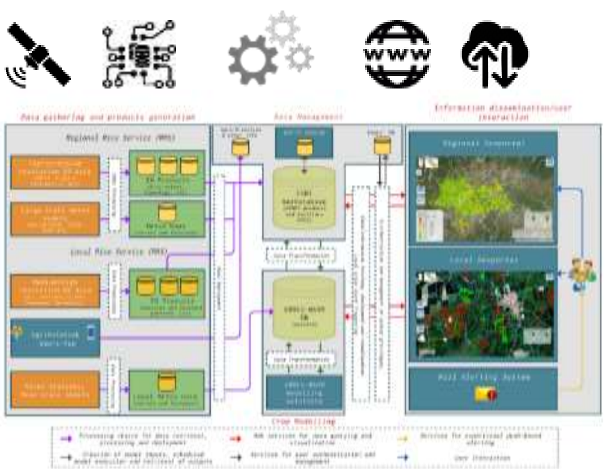
Presentation Layout

- **Intro**
  - Needs of efficient sensing of plants traits
  - From experimental to real farming condition
  - Imaging and remote sensing
- **What is the remote sensing**
  - What can provide for agriculture monitoring
  - Plant spectral response
- **Example of application**
  - Mapping, Monitoring and Modelling → info for science and management
  - Spetroradiometric
  - UAV
  - satellite
- **Towards operational downstream service**

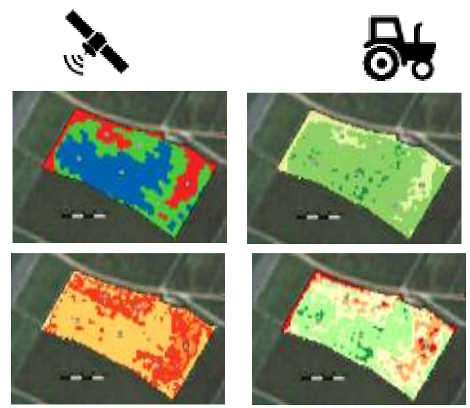
WHO ARE WE: IREA NATURAL RESOURCE MONITORING LABORATORY

- **Institute for Electromagnetic Sensing of the Environment of CNR** develops methodologies and technologies for acquisition, processing, fusion and interpretation of images and data obtained by electromagnetic sensors - operating on satellite, aircraft and in situ
- **NRM_LAB is a multidisciplinary team** working on environmental and agricultural monitoring issues
- We study and develop **solutions and methods to generate and provide end-user value-added information** generated by the acquisition, processing and integration of multisource data
- In Copernicus we are dedicated to the research for the creation of **"Downstream services"** prototypes, especially for the agricultural sector

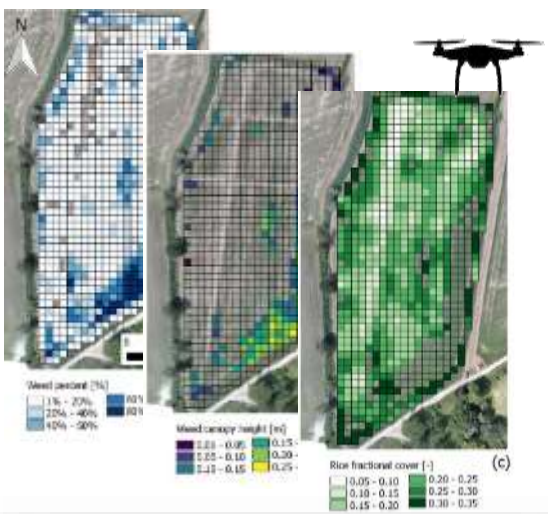
ERMES monitoring systems



Downstream Services for Rice Crop Monitoring in Europe: From Regional to Local Scale
Busetto et al. (2017)
IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing



An operational workflow to assess rice nutritional status based on satellite remote sensing and smart apps
Nutini et al. 2018 (2018)
Computers and Electronics in Agriculture (in press)



Early season weed mapping in rice crops using multi-spectral UAV data
Stroppiana et al. 2018 (2018)
nternational Journal of Remote Sensing

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INTRO:

NEEDS OF EFFICIENT SENSING OF PLANTS RESPONSE TO ENVIRONMENT (G X E)

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WHY REMOTE SENSING: ACQUISITION OF NON DESTRUCTIVE QUANTITATIVE INFO

- Plant genomic technologies are already well developed a **lack of access to plant phenotyping capabilities** limits our ability to dissect the genetics of quantitative traits.

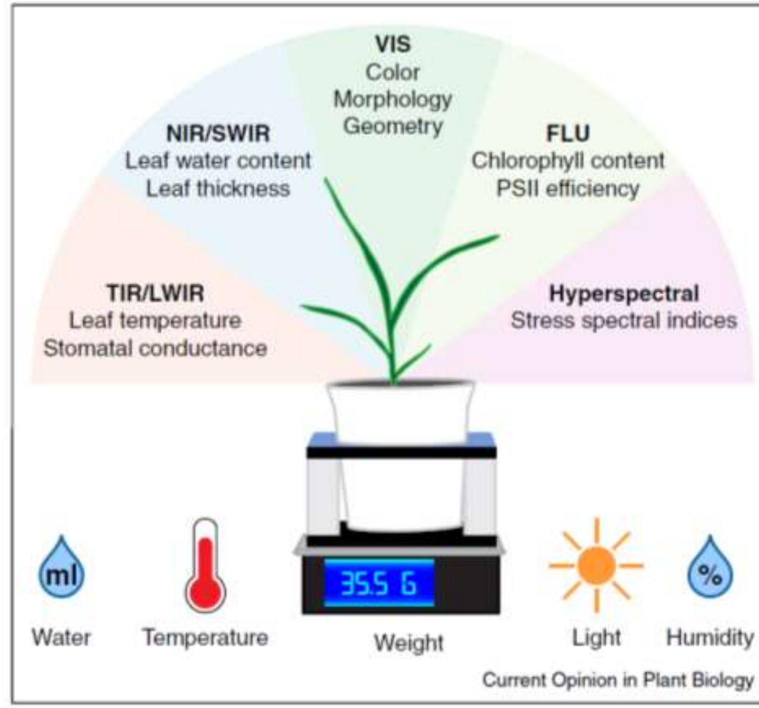
- Current assessments of phenotype characteristics for disease resistance or stress in breeding programs **rely largely on visual scoring by experts**, which is time-consuming and can generate bias between different experts and experimental repeats.

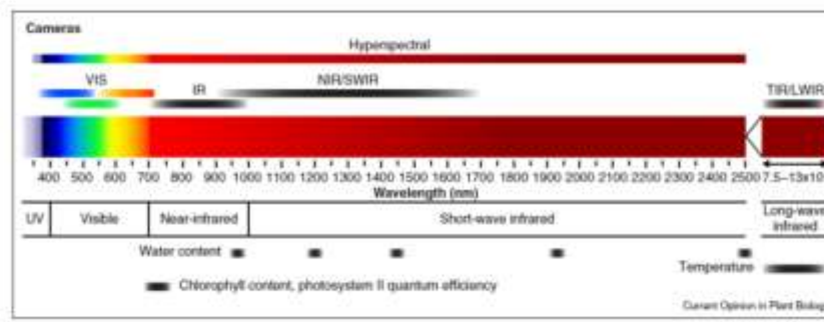
- High-throughput phenotyping platforms have recently been developed to solve this problem **using variety of imaging/sensing methodologies** to collect data for quantitative studies (growth, yield and adaptation to biotic or abiotic stress - disease, insects, drought and salinity).

Lei Li, Qin Zhang and Danfeng Huang (2014) **A Review of Imaging Techniques for Plant Phenotyping** *Sensors* **2014**, *14*, 20078-20111; doi:10.3390/s141120078

IMAGING PLANTS IS MORE THAN JUST ‘TAKING PICTURES’.

- The aim of imaging is to **measure a phenotype quantitatively** through the interaction between light and plants such as reflected photons, absorbed photons, or transmitted photons.
- Each component of plant cells and tissues has wavelength-specific absorbance, reflectance, and transmittance properties.
  - **chlorophyll absorbs** photons primarily in the blue and red spectral region
  - **water** has its primary absorption features in the near and short wavelengths
  - **cellulose** absorbs photons in a broad region between 2200 and 2500 nm.





Noah Fahlgren, Malia Agehan, Ivan Baxter (2015) **Lights, camera, action: high-throughput plant phenotyping is ready for a close-up.** Current Opinion in Plant Biology 2015, 24:93–99

- Such monitoring tools are fundamental for breeders and to support phenotyping studies → G x E
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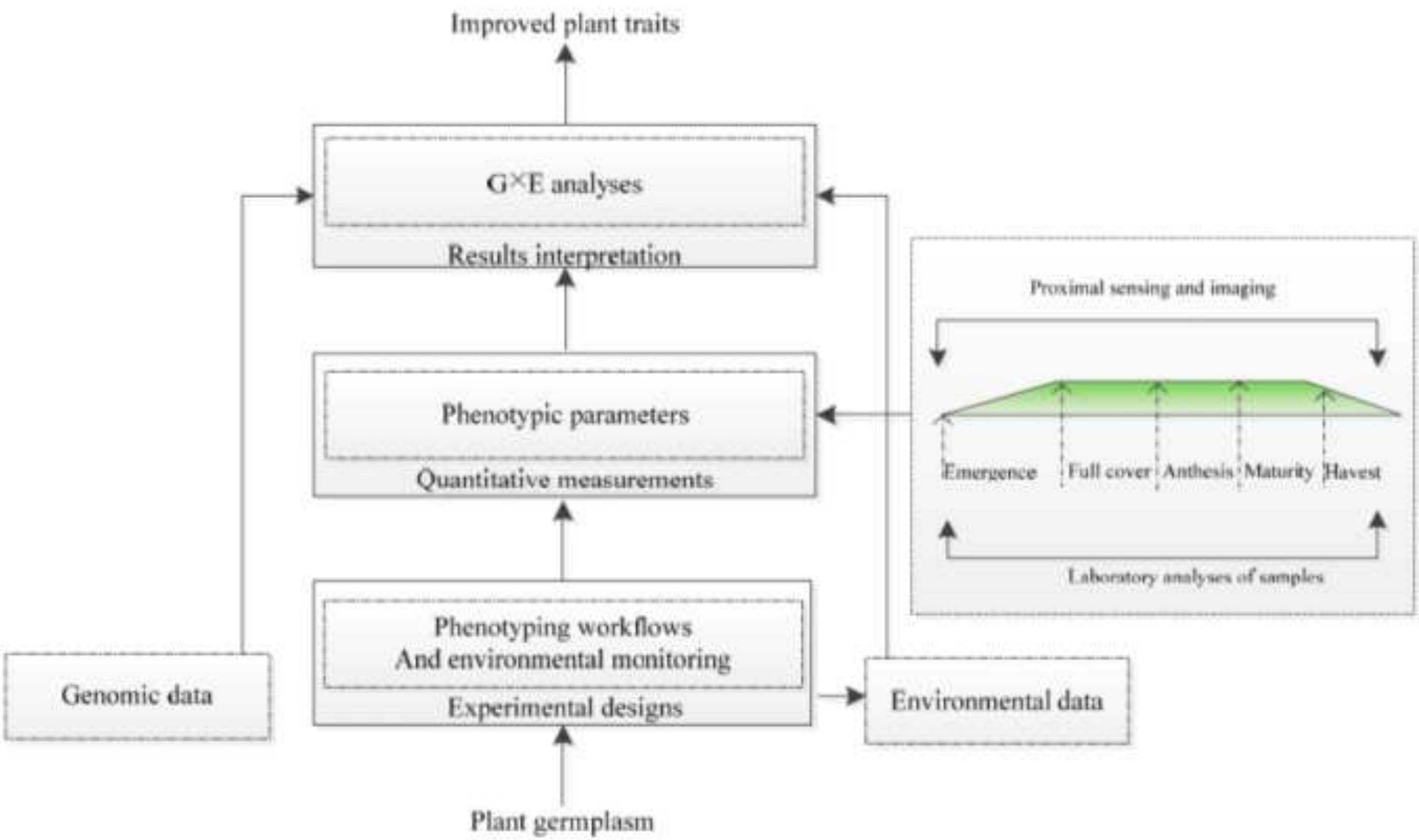

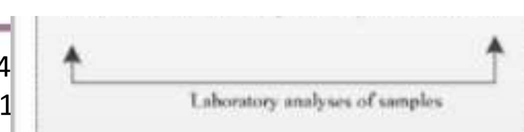

Lei Li, Qin Zhang and Danfeng Huang (2014
Phenotyping *Sensors* **2014**, *14*, 20078-2011

BASIS OF REMOTE SENSING AND EARTH OBSERVATION

REMOTE SENSING → CATEGORICAL & QUANTITATIVE INFORMATION

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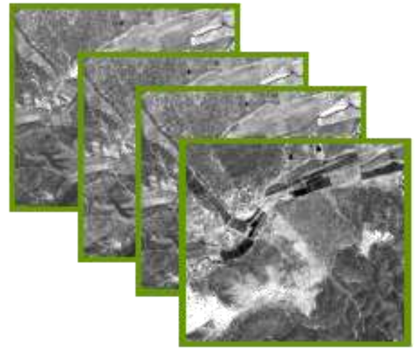
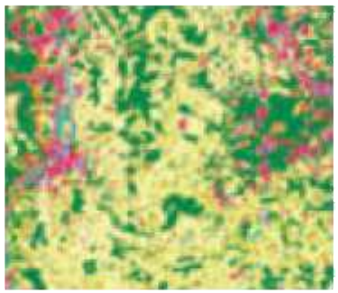


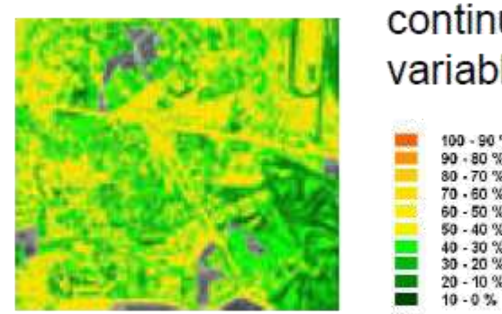
Map of categorical variables

Map of thematic classes



Land cover maps
Burned area maps
Flooded maps
Agriculture maps
Forest maps

Map of continuous variables



Leaf area index
Biomass
Tree volume

Thematic remote sensing

Image classification

Quantitative remote sensing

Modelling

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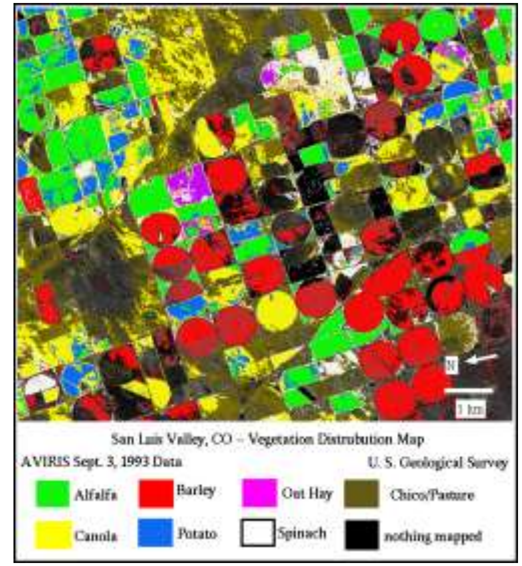
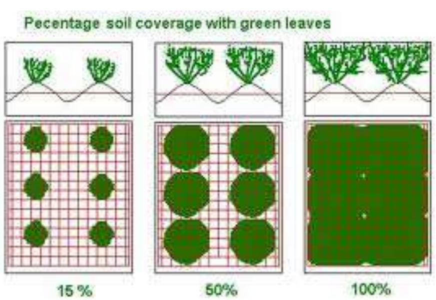
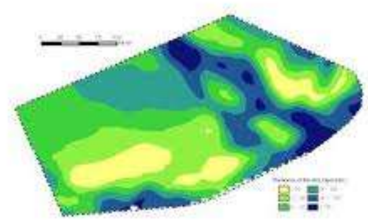
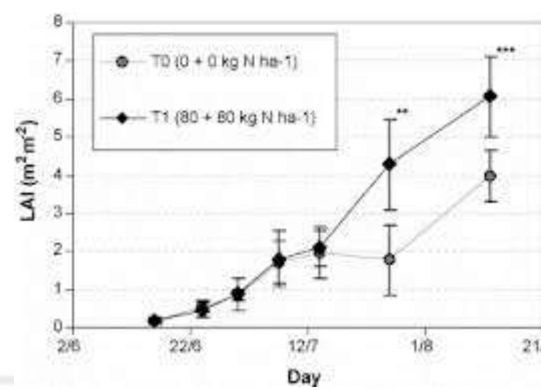
CROP MONITORING QUESTIONS

- **Estimates a variable**
  - categorical: which are the crops in the area?
  - quantitative: how much is the LAI ?
- **Assess the spatial variation**
  - How much the LAI is varying in the field?
  - Where are the hot spot anomalous areas?
- **Quantify the temporal variation**
  - Which is the temporal trend of LAI?



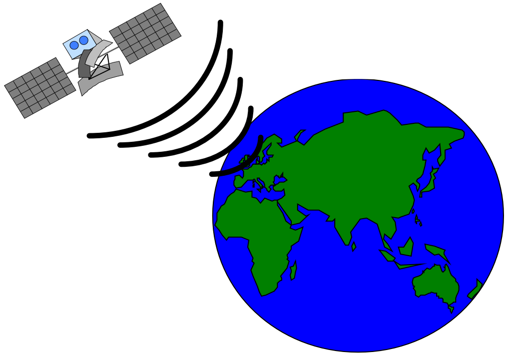




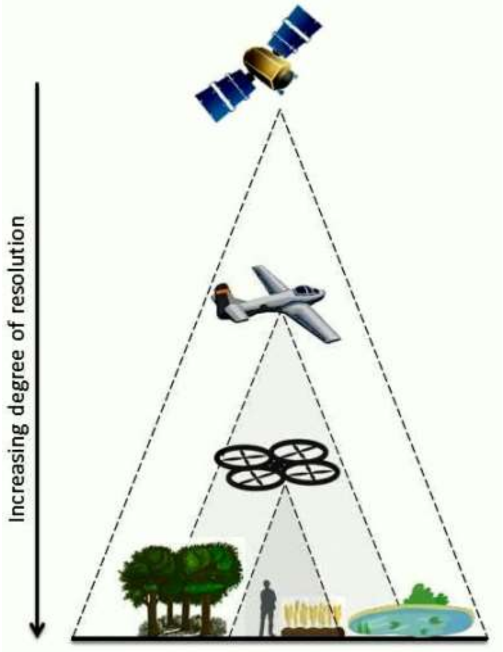


- **RS: an instrument for research and land management**

RS is a science of **obtaining information about an object**, area, or phenomenon through the **analysis of data acquired by a device** that is not in contact with the object, area, or phenomenon under investigation

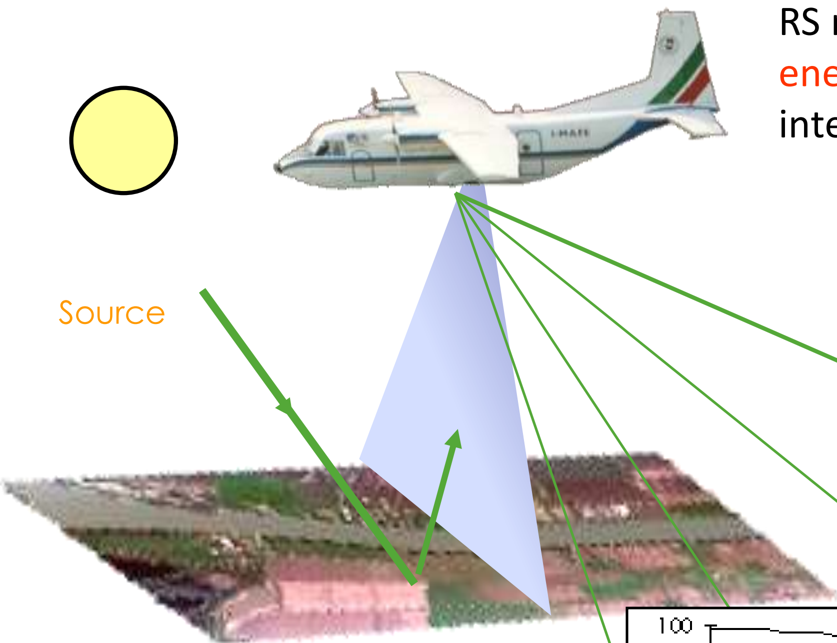


RS is the **non-contact recording** of information from the UV, VIS, NIR, MW of the EM spectrum by means of instruments such as cameras, scanners, lasers, linear arrays, and/or area arrays located on platforms such as aircraft or spacecraft, and the analysis of acquired information by means of visual and digital image processing



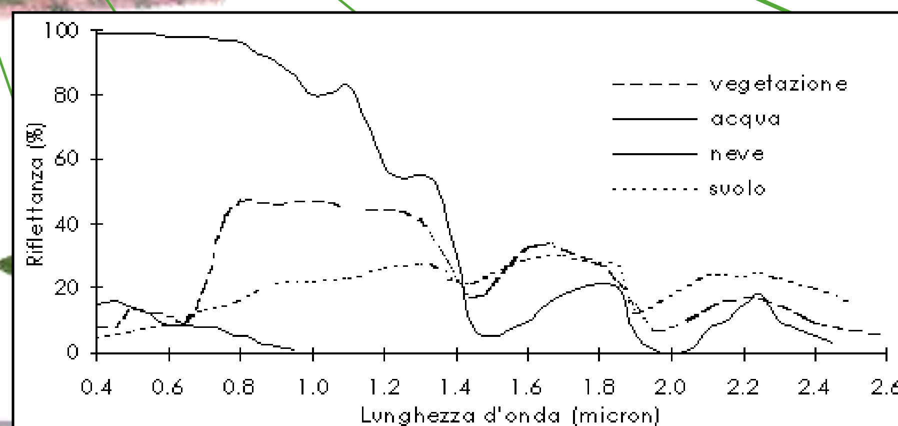
REMOTE SENSING PRINCIPLE

- **Energy and material interaction**



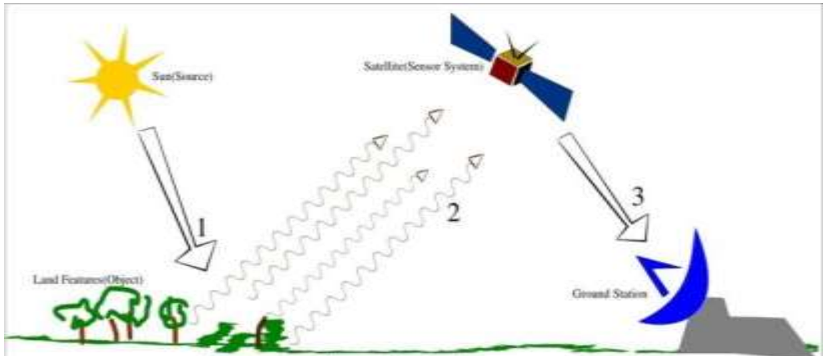
RS measure measure electromagnetic energy reaching the sensor after the interaction with a surface

Different surfaces provide peculiar responce with the EM reflecting, absorbing and emitting in a different way at different wavelength

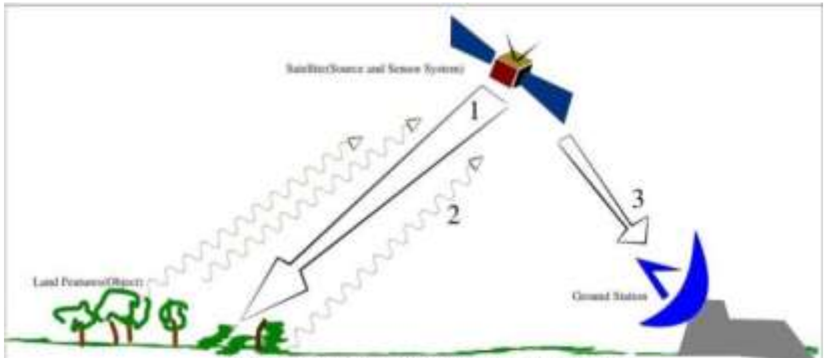


Firme spettrali di alcuni elementi che possono comporre una scena

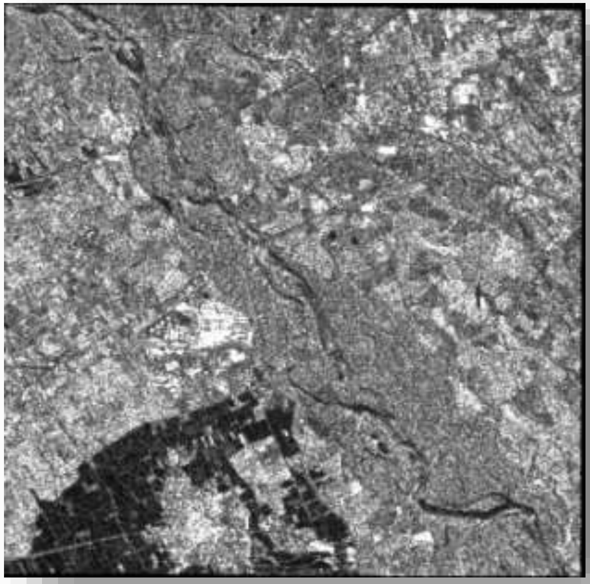
REMOTE SENSING: PASSIVE AND ACTIVE SENSORS



Remote sensing using passive sensor system

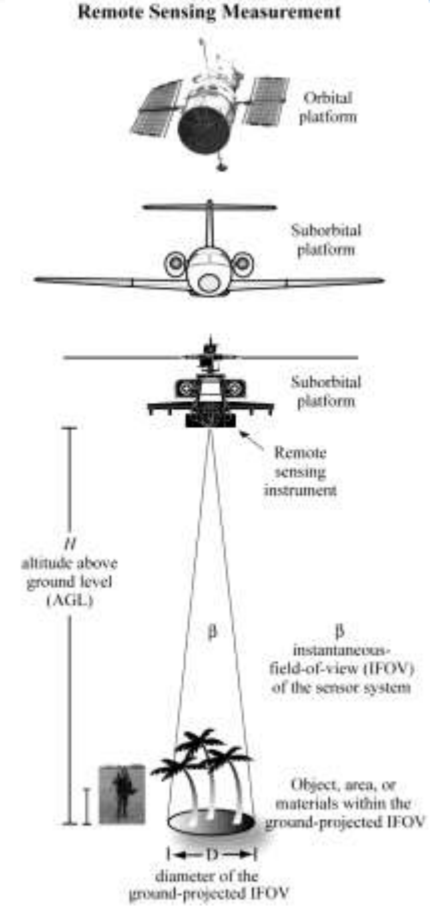


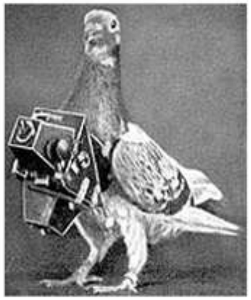
Remote sensing using active sensor system



Remote sensing: history

- **1840** - Hot air balloon with camera
- **1909** - Pigeon, light cameras (70 g)
- **1943** - German missiles V2
- **1957** - Sputnik spacecraft
- **1960** - First meteorological satellites
- **1972** - First Earth-sensing satellite (Landsat)
- **1980** - Specialized Sensors: Coastal Zone Color Scanner (CZCS), Heat Capacity Mapping Mission (HCMM), and Advanced Very High Resolution Radiometers (AVHRR)
- **1999** - Launch of Ikonos, the first high-resolution commercial satellite





DRONE AGE


The Economist | World politics | Business & finance | Economics | Science & technology | Culture

Unmanned aerial vehicles

Welcome to the Drone Age

Miniature, pilotless aircraft are on the verge of becoming commonplace

Sep 26th 2015 | From the print edition

Timekeeper | Like 2.2k | Tweet

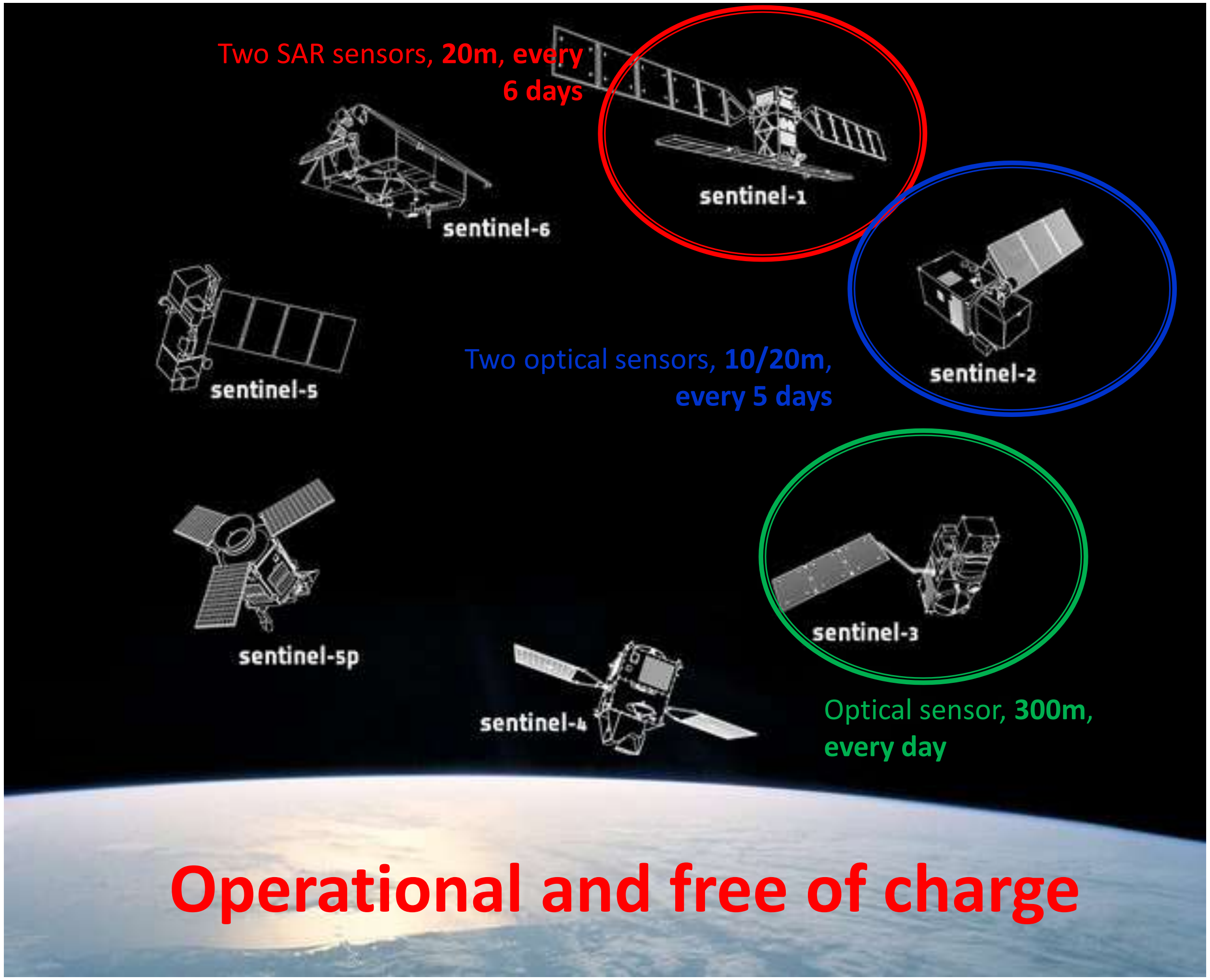
Dave Simonds

THE scale and scope of the revolution in the use of small, civilian drones has caught many by surprise. In 2010 America's Federal Aviation Authority (FAA) estimated that there would, by 2020, be perhaps 15,000 such drones in the country. More than that number are now sold there every month. And it is not just an American craze. Some analysts think the

Many opportunities exist for territorial monitoring with Earth Observation systems in terms of available sensors and international interventions to coordinate spatial policies

Group on Earth Observations (**GEO**) coordina la costituzione del Global Earth Observation System of Systems (**GEOSS**).

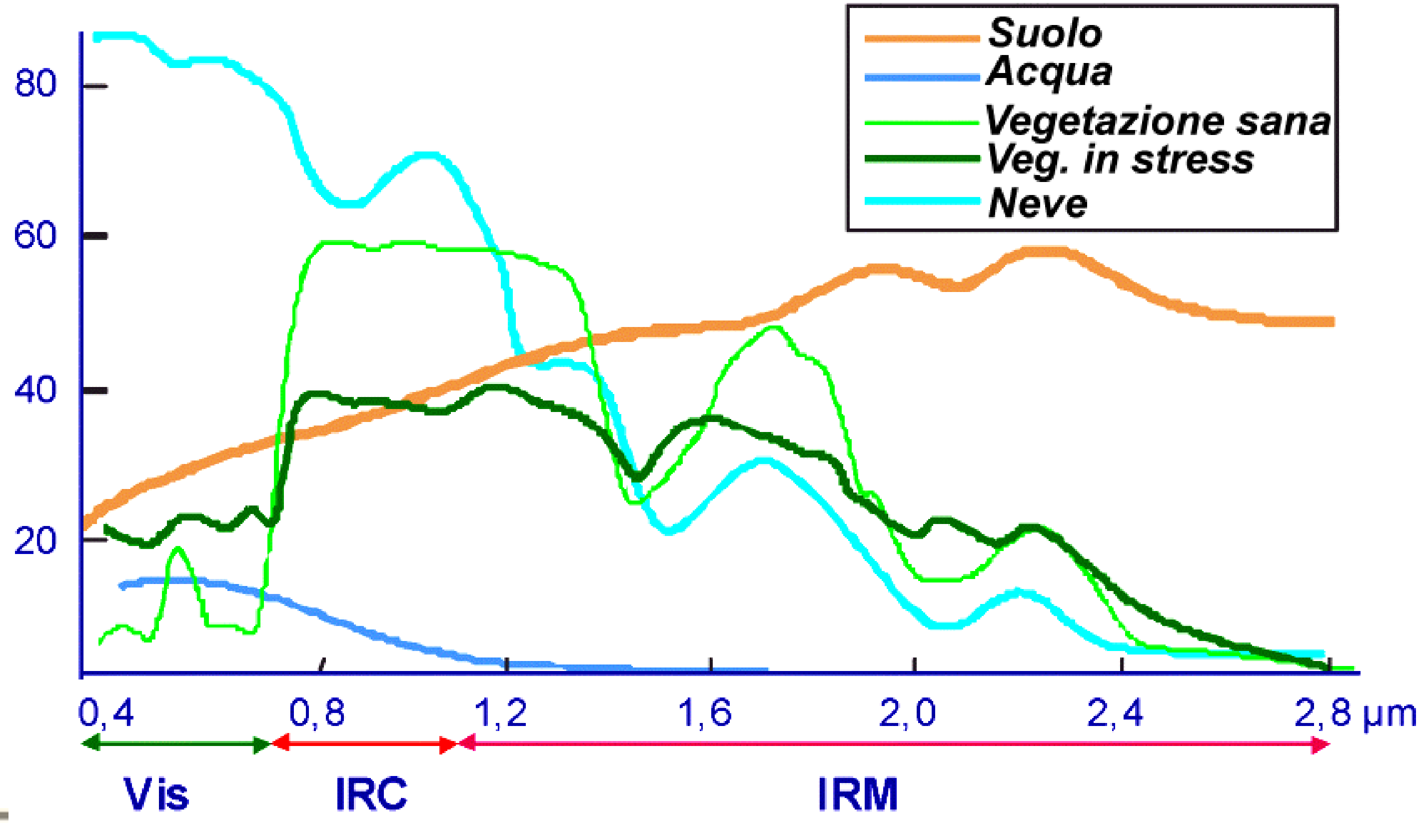
European and Italian context



REMOTE SENSING MEASUREMENTS: PLANT SPECTRAL RESPONSE

SPECTRAL RESPONSE OF SURFACES

It is possible to discriminate in an image a large number of elements (soil, vegetation, water, etc.) and to recognize their characteristics (humidity, state of health, nutrient concentration, etc.) by analyzing the different spectral behavior in the various lengths of wave or their spectral signature

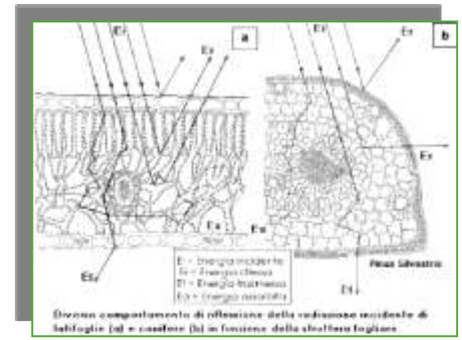


VEGETATION SPECTRAL RESPONSE

Spectral behavior of vegetation depends mainly on two factors:

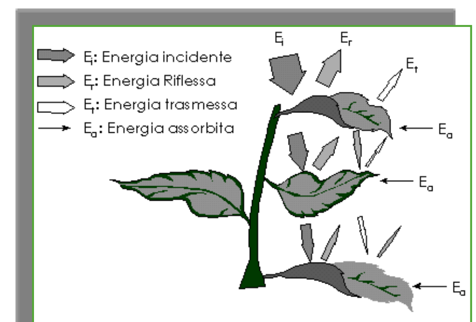
→ the **chemical / physical characteristics of the leaves** and other components of the plant

- Chlorophyll content
- Cellular structure
- Water content



→ the **aggregation of the individual elements** (leaves, branches) and the overall structure of the plant (canopy)

- Degree of coverage
- Amount of green biomass
- Architecture of the foliage
- Presence and type of background (soil and weeds)
- phenology
- Health state
- External factors (morphology, source-object-sensor geometry, atmosphere ...)

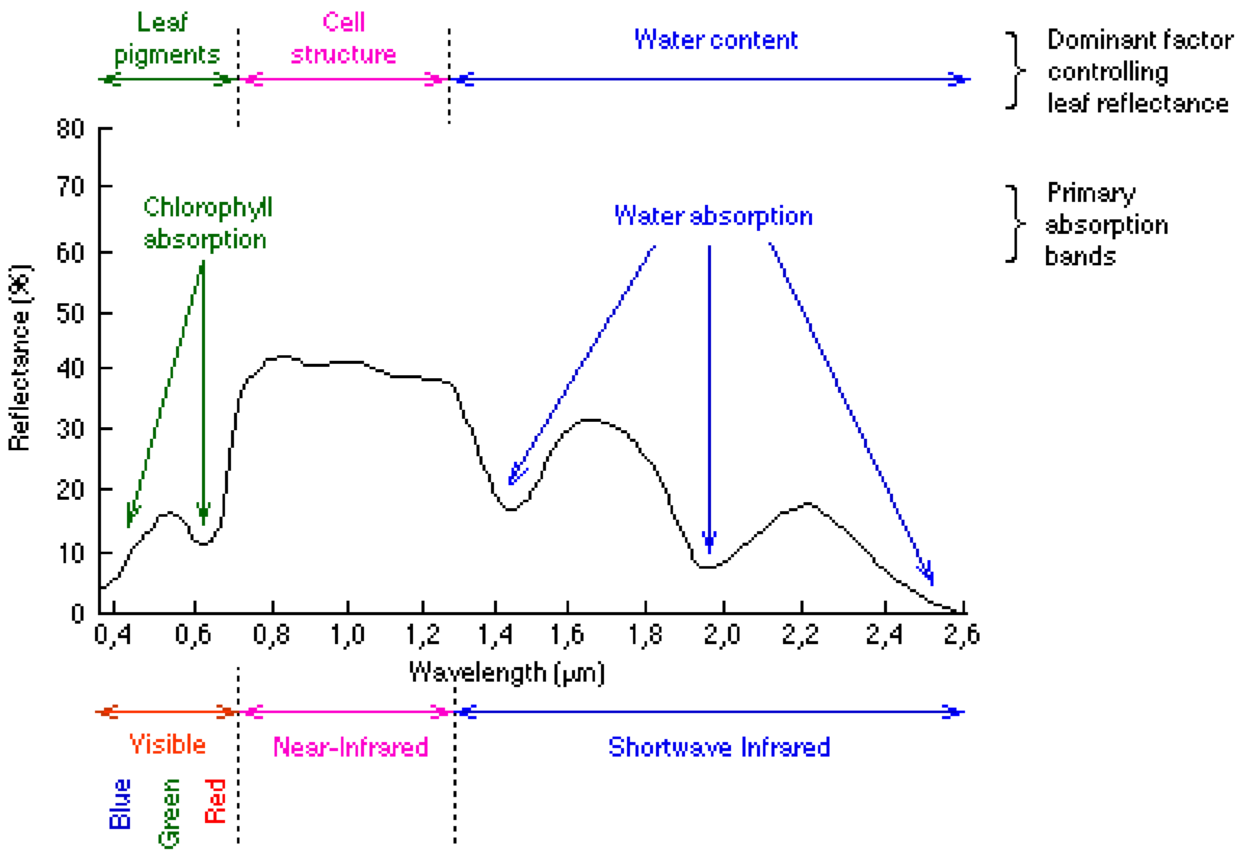


Rappresentazione schematica dei meccanismi di riflessione, trasmissione e assorbimento dell'energia radiante incidente sulla vegetazione.

M.A. Gomarasca, 1998

VEGETATION SPECTRAL RESPONSE

- **foliar pigments** absorb in the wavelengths of blue and red and reflect in those of the green and it is precisely for this reason that our eyes identify the vegetation of this color
- **structure** of the vegetation instead implies that this reflects highly in the near infrared, determining a typical platò in the signature



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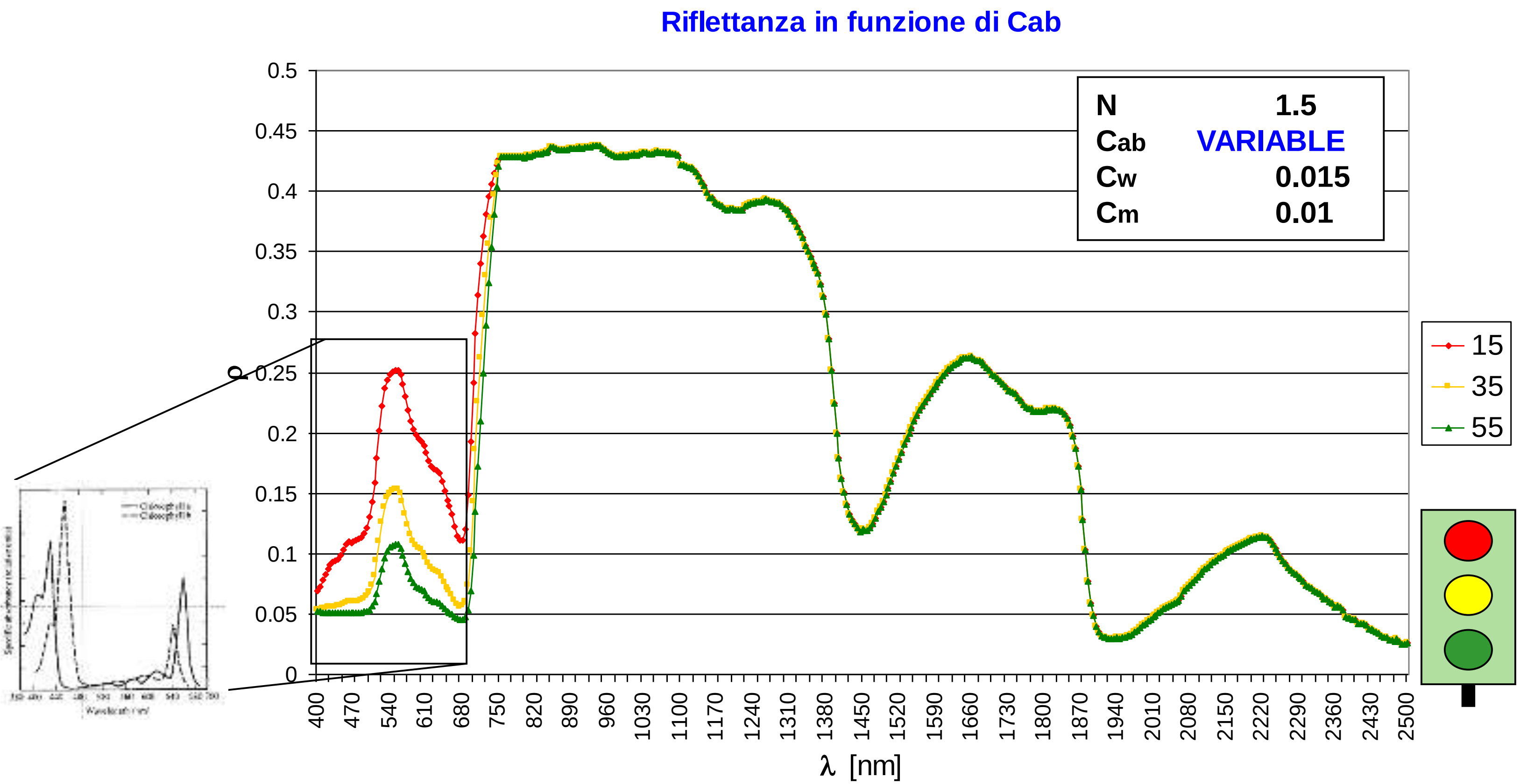
Leaf chemestry

- graph shows the trend of spectral signatures of vegetation as the **chlorophyll** content changes

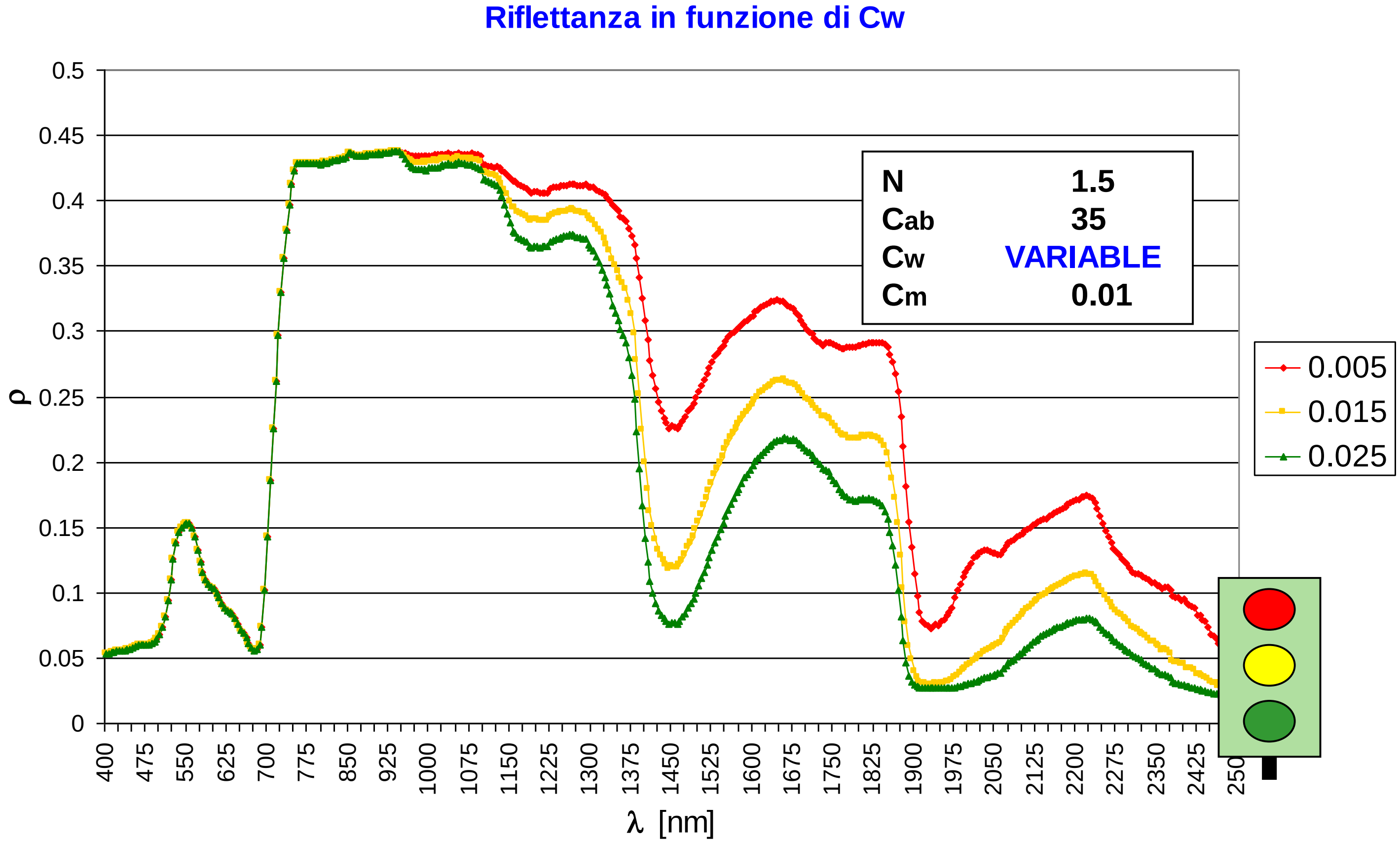


The signatures are the results of the model (PROSPECT) of the leaf's behavior

M. Meroni, 2001 Lezioni Corso di Telerilevamento Scienze Ambientali Unimib

Leaf chemestry

- The graph shows the trend of the spectral signatures of vegetation as the **water content** changes



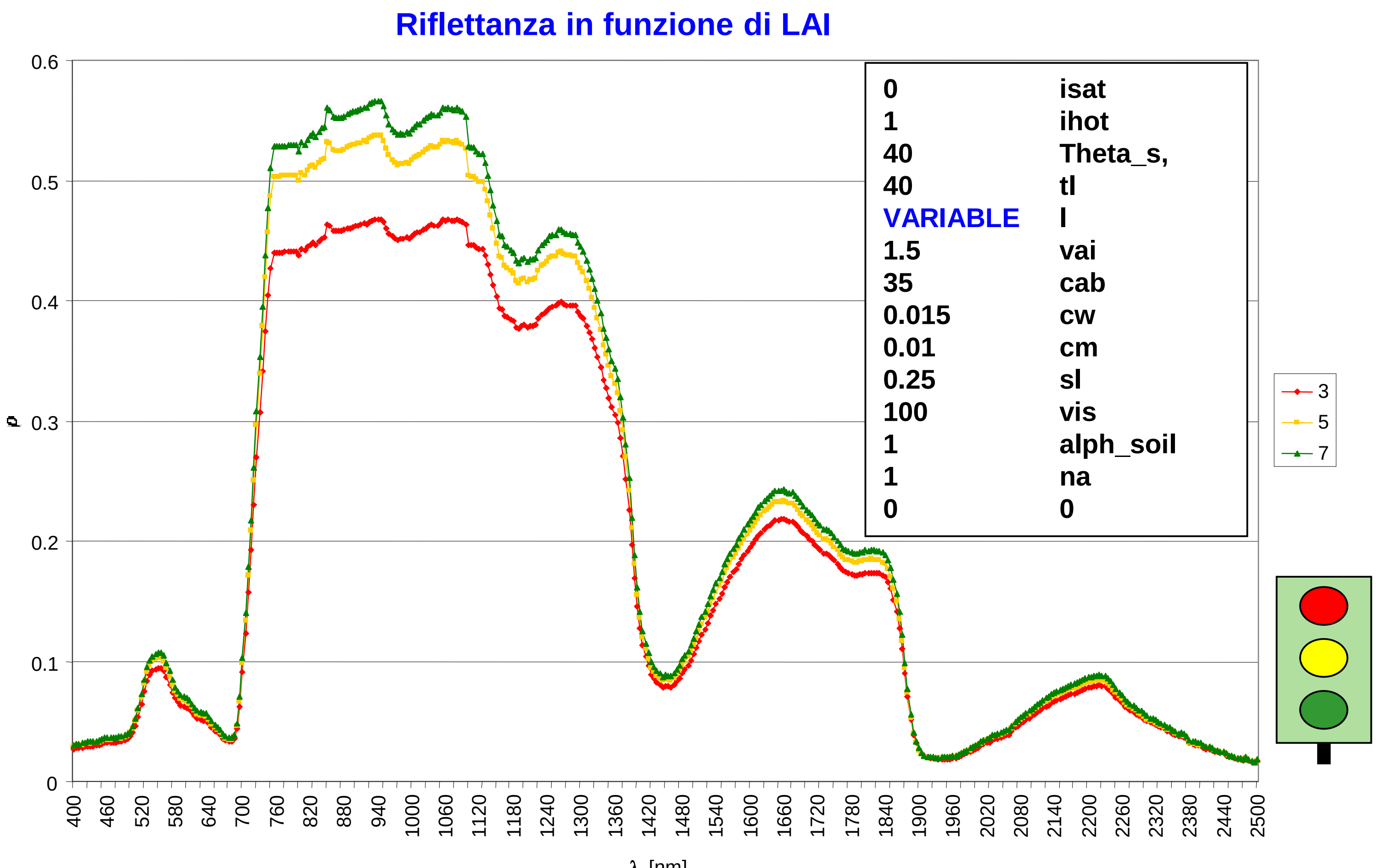
The signatures are the results of the model (PROSPECT) of the leaf's behavior

M. Meroni, 2001 *Lezioni Corso di Telerilevamento Scienze Ambientali Unimib*

VEGETATION SPECTRAL RESPONSE

Plant structure

- graph shows the trend of vegetationspectral signatures of as a function of **LAI**



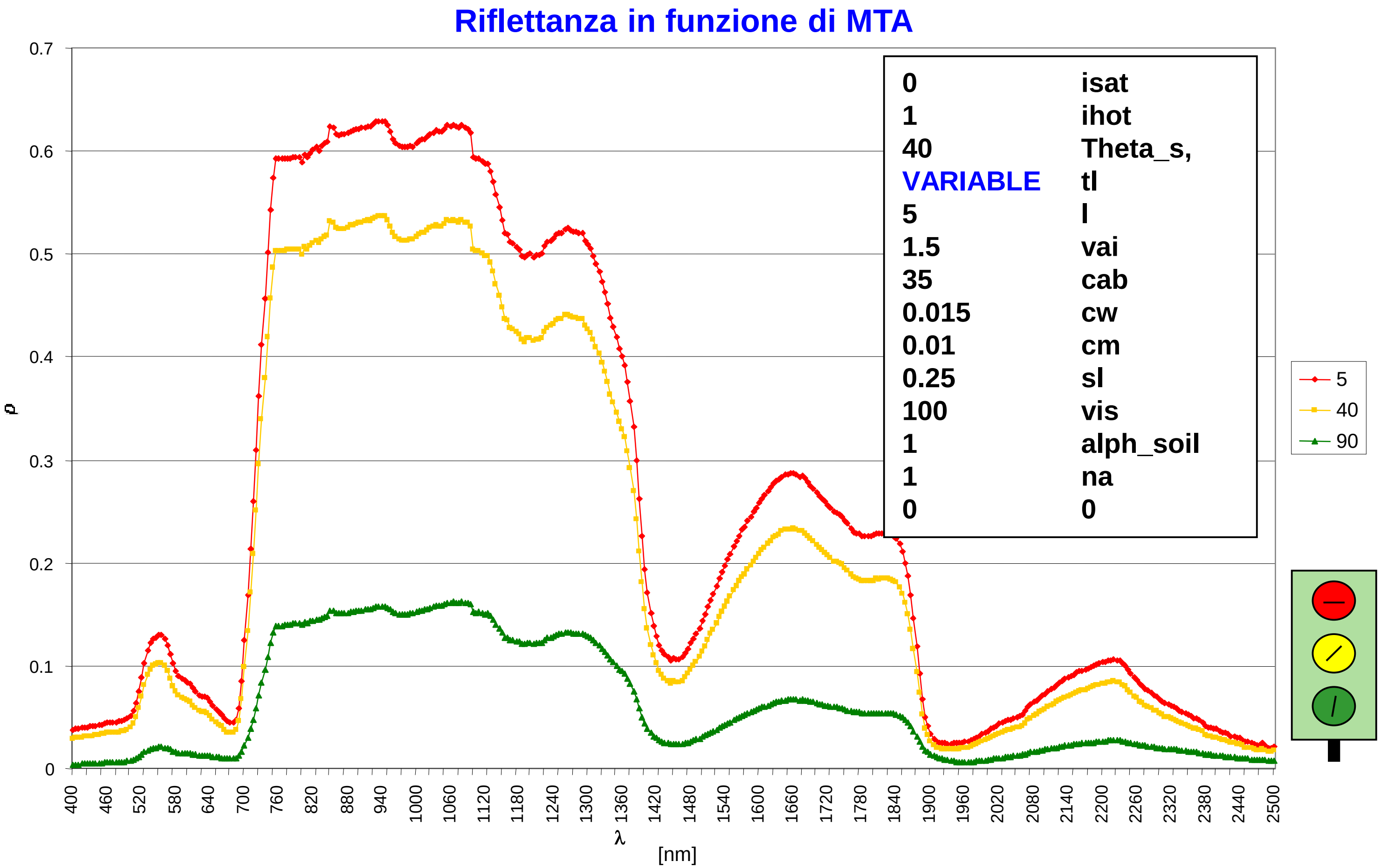
The signatures are the results of the model (SAIL) of the Canopy behavior

M. Meroni, 2001 Lezioni Corso di Telerilevamento Scienze Ambientali Unimib

VEGETATION SPECTRAL RESPONSE

Plant structure

- graph shows the trend of vegetationspectral signatures of as a function of **leaf angles**



The signatures are the results of the model (SAIL) of the Canopy behavior

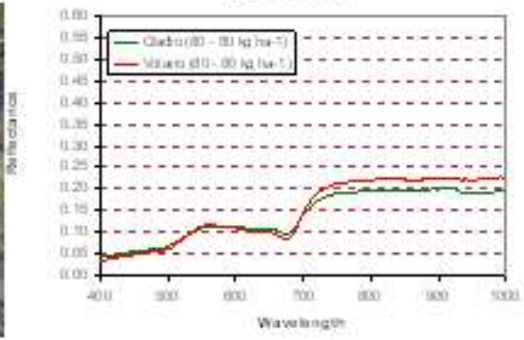
M. Meroni, 2001 Lezioni Corso di Telerilevamento Scienze Ambientali Unimib

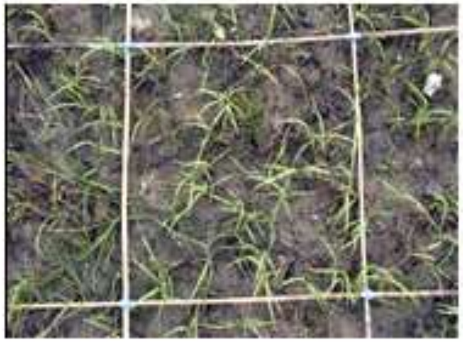
VEGETATION SPECTRAL RESPONSE: TEMPORAL DYNAMICS

Gladio

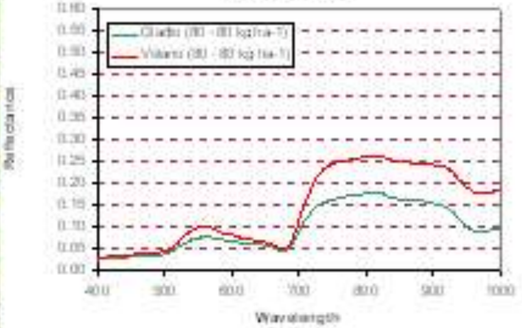
16 June

Volano





24 June



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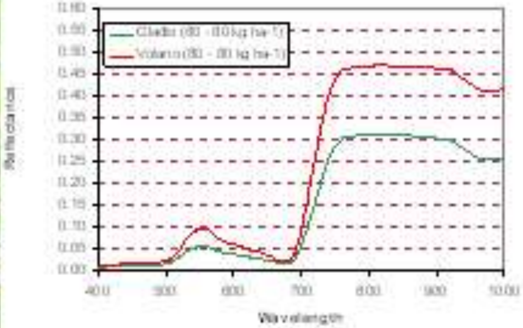


VEGETATION INDICES

From the study of the spectral behavior of vegetation a series of **quantitative relationships** have been defined between remote sensing data and vegetation parameters through indices based on the relationship between the typical absorption and reflection bands

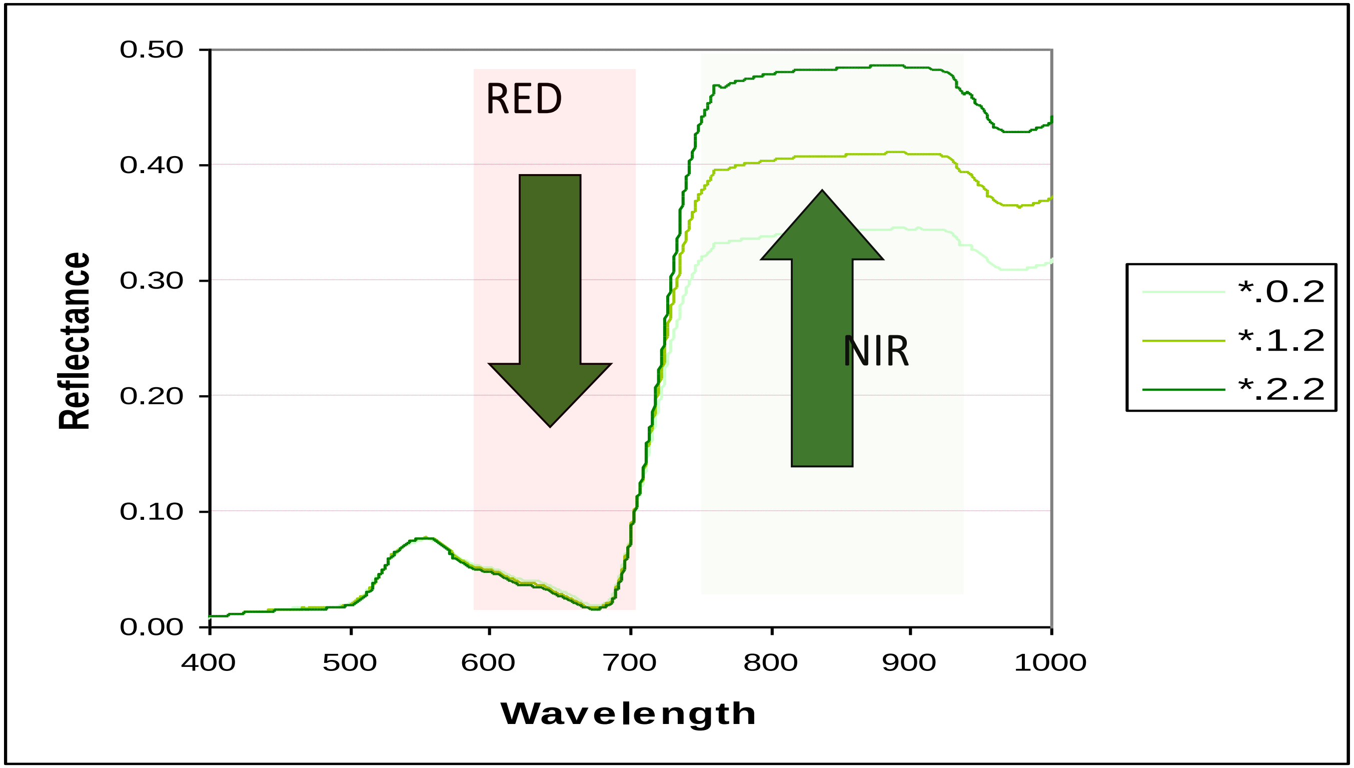
These algebraic relationships are referred to as **vegetation indices (VI)** and are based above all on the **red and near IR wavelengths** (wide or narrow band)

The VIs are related to the amount of **plant biomass, LAI, chlorophyll concentration, water content** etc. and give indications on the state of health, on crop productivity, on density and coverage and on nutritional status etc.

VEGETATION INDICES

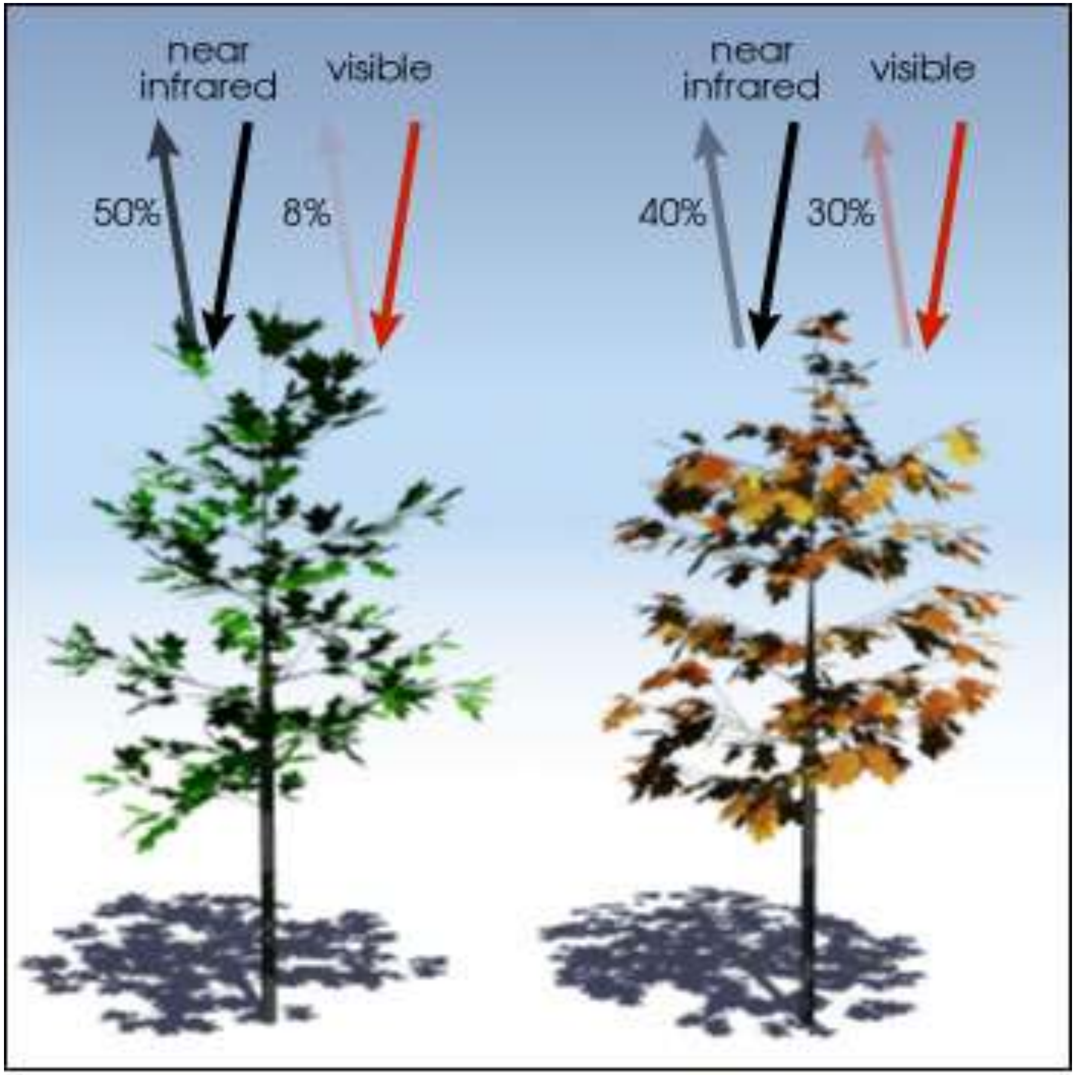
Vegetation index	Equation
Structural indices	
Normalized Difference Vegetation Index (NDVI)	$NDVI = (R_{NIR} - R_{red})/(R_{NIR} + R_{red})$
Modified Triangular Vegetation Index (MTVI1)	$MTVI1 = 1.2 \times [1.2 \times (R_{800} - R_{550}) - 2.5 \times (R_{670} - R_{550})]$
Modified Triangular Vegetation Index (MTVI2)	$MTVI2 = \frac{1.5 \times [1.2 \times (R_{800} - R_{550}) - 2.5 \times (R_{670} - R_{550})]}{\sqrt{(2 \times R_{800} + 1)^2 - (6 \times R_{800} - 5 \times \sqrt{R_{670}}) - 0.5}}$
Renormalized Difference Vegetation Index (RDVI)	$RDVI = (R_{800} - R_{670})/\sqrt{(R_{800} + R_{670})}$
Simple Ratio Index (SR)	$SR = R_{NIR}/R_{red}$
Modified Simple Ratio (MSR)	$MSR = \frac{R_{NIR}/R_{red} - 1}{(R_{NIR}/R_{red})^{0.5} + 1}$
Modified Chlorophyll Absorption in Reflectance Index ($MCARI_1$)	$MCARI1 = 1.2 \times [2.5 \times (R_{800} - R_{670}) - 1.3 \times (R_{800} - R_{550})]$
Modified Chlorophyll Absorption in Reflectance Index ($MCARI_2$)	$MCARI2 = \frac{1.5 \times [2.5 \times (R_{800} - R_{670}) - 1.3 \times (R_{800} - R_{550})]}{\sqrt{(2 \times R_{800} + 1)^2 - (6 \times R_{800} - 5 \times \sqrt{R_{670}}) - 0.5}}$
Soil Adjusted Vegetation Index (SAVI)	$SAVI = (1 + L) \times (R_{800} - R_{670})/(R_{800} + R_{670} + L)\ [L \in (0,1)]$
Improved SAVI with self-adjustment factor *L* (MSAVI)	$MSAVI = \frac{1}{2}[2 \times R_{800} + 1 - \sqrt{(2 \times R_{800} + 1)^2 - 8 \times (R_{800} - R_{670})}]$
Optimized Soil-Adjusted Vegetation Index (OSAVI)	$OSAVI = (1 + 0.16) \times (R_{800} - R_{670})/(R_{800} + R_{670} + 0.16)$
Chlorophyll indices	
Greenness Index (G)	$G = R_{554}/R_{677}$
Modified Chlorophyll Absorption in Reflectance Index (MCARI)	$MCARI = [(R_{700} - R_{670}) - 0.2 \times (R_{700} - R_{550})] \times (R_{700}/R_{670})$
Transformed CARI (TCARI)	$TCARI = 3 \times [(R_{700} - R_{670}) - 0.2 \times (R_{700} - R_{550}) \times (R_{700}/R_{670})]$
Triangular Vegetation Index (TVI)	$TVI = 0.5 \times [120 \times (R_{750} - R_{550}) - 200 \times (R_{670} - R_{550})]$
Zarco-Tejada & Miller	$ZTM = R_{750}/R_{710}$
Water indices	
Normalized Difference Water Index (NDWI)	$NDWI = (R_{860} - R_{1240})/(R_{860} + R_{1240})$
Simple Ratio Water Index (SRWI)	$SRWI = R_{860}/R_{1240}$
Plant Water Index (PWI)	$PWI = R_{970}/R_{900}$
Red edge spectral parameters	
λ_p	$\lambda_{p} = \lambda_{max(680-780)};\ \lambda_{p1_1} = \lambda_{max(700-680)};\ \lambda_{p2_1} = \lambda_{max(700-680)}$
R_o	$R_o = R_{min(670-780)}$
R_s	$R_s = R_{max(780-795)}$
σ	σ = shape parameter as defined by the inverted-Gaussian curve-fit model
Other indices mentioned but not used in this study	
Simple Ratio Pigment Index (SRPI)	$SRPI = R_{430}/R_{680}$
Normalized Phaeophytinization Index (NPQI)	$NPQI = (R_{415} - R_{435})/(R_{415} + R_{435})$
Photochemical Reflectance Index (PRI)	$PRI_1 = (R_{528} - R_{567})/(R_{528} + R_{567})\ PRI_2 = (R_{531} - R_{570})/(R_{531} + R_{570})$
Normalized Pigment Chlorophyll Index (NPCI)	$NPCI = (R_{680} - R_{430})/(R_{680} + R_{430})$
Carter indices	$Ctr1 = R_{695}/R_{420}\ Ctr2 = R_{695}/R_{760}$
Lichtenthaler indices	$Lic1 = (R_{800} - R_{680})/(R_{800} + R_{680});\ Lic2 = R_{440}/R_{690};\ Lic3 = R_{440}/R_{740};\ Lic4 = \int_{400}^{480} R$
Structure Intensive Pigment Index (SIPI)	$SIPI = (R_{800} - R_{445})/(R_{800} + R_{680})$
Vogelmann indices	$Vog1 = R_{740}/R_{720};\ Vog2 = (R_{734} - R_{747})/(R_{715} + R_{726});\ Vog3 = (R_{734} - R_{747})/(R_{715} + R_{720});\ Vog4 = D_{715}/D_{705}$
Gitelson and Merzlyak	$G\_M1 = R_{750}/R_{550}$ $G\_M2 = R_{750}/R_{700}$
Curvature Index (Fluorescence)	$CUR = (R_{675} \cdot R_{690})/(R_{683}^2)$
Double-Peak Ratio indices	$DPR1 = D_{\lambda p(680-780)}/D_{\lambda p+12};\ DPR2 = D_{\lambda p(680-780)}/D_{\lambda p+22};\ DP21 = D_{\lambda p(680-780)}/D_{703};\ DP22 = D_{\lambda p(680-780)}/D_{720}$
Area Red Edge Peak (ADR)	$ADR = \int_{680}^{780} D$

NDVI (Normalized Difference Vegetation Index)



A good index has to emphasise the property under investigation minimising the influence from other factors

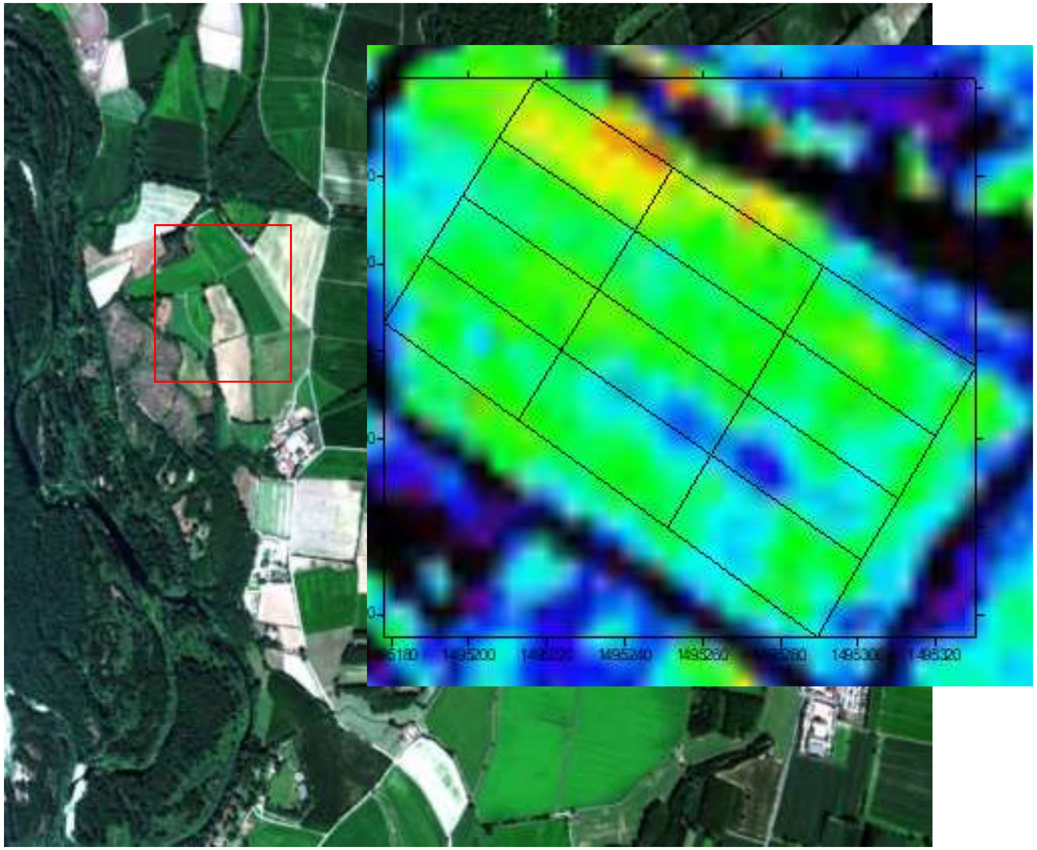
VEGETATION INDEX: NDVI CONCEPT



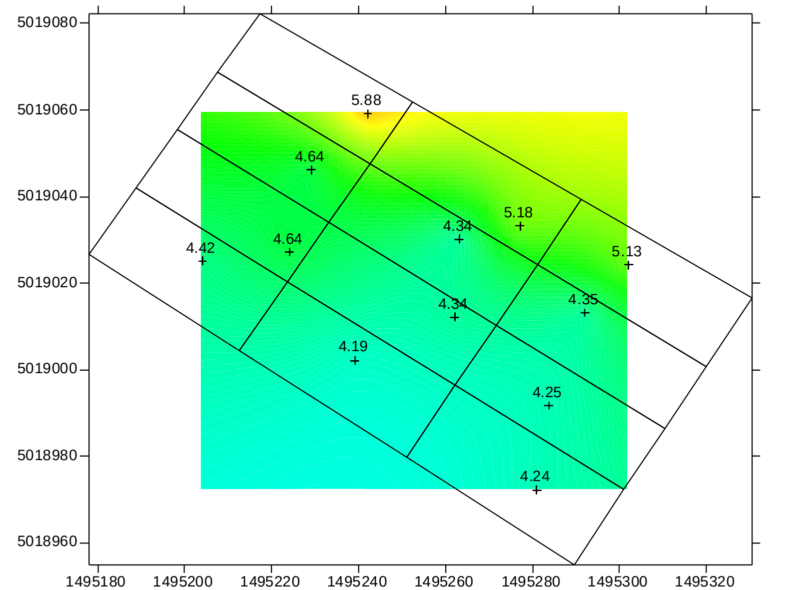
$$\frac{(0.50 - 0.08)}{(0.50 + 0.08)} = 0.72$$

$$\frac{(0.4 - 0.30)}{(0.4 + 0.30)} = 0.14$$

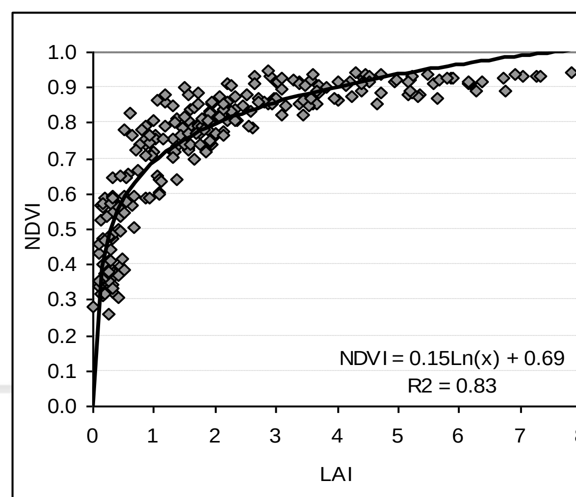
VEGETATION INDEX: NDVI MAPS VS LAI



VI maps from MIVIS sensor (2° of July)



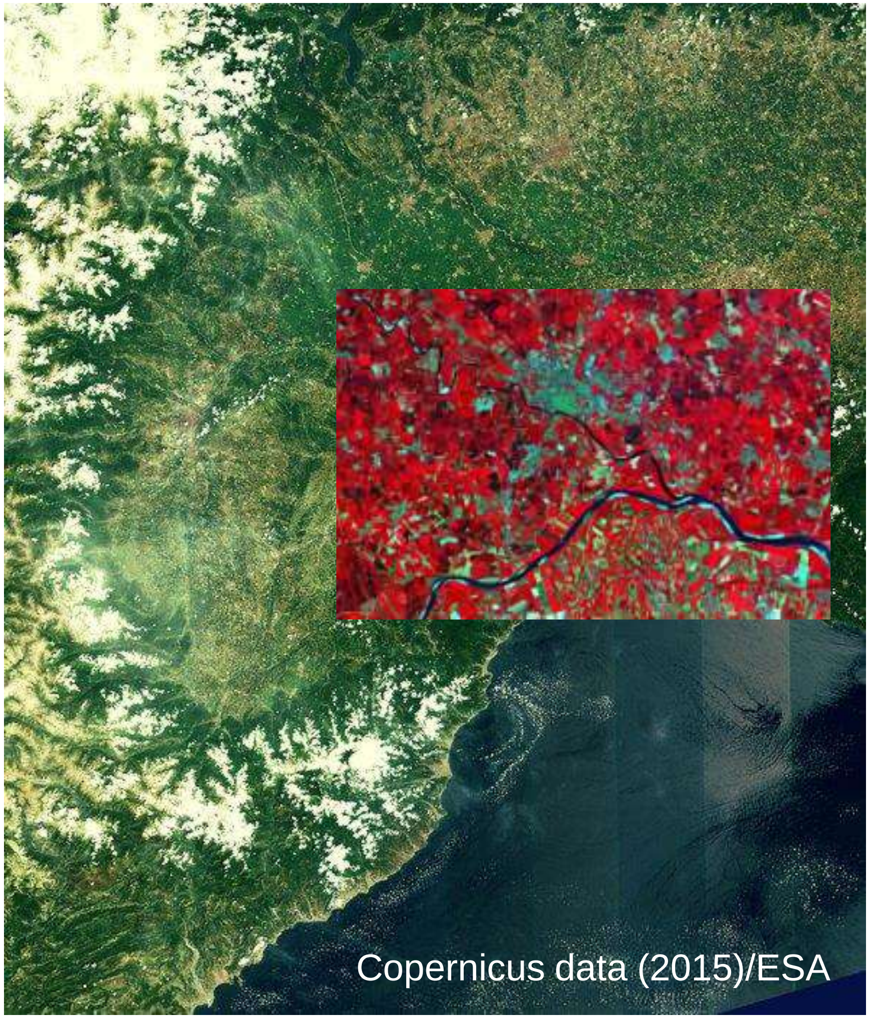
LAI maps from field measurements (1° of July)



Remote Sensing of Agriculture

Earth Observation started with agro-monitoring

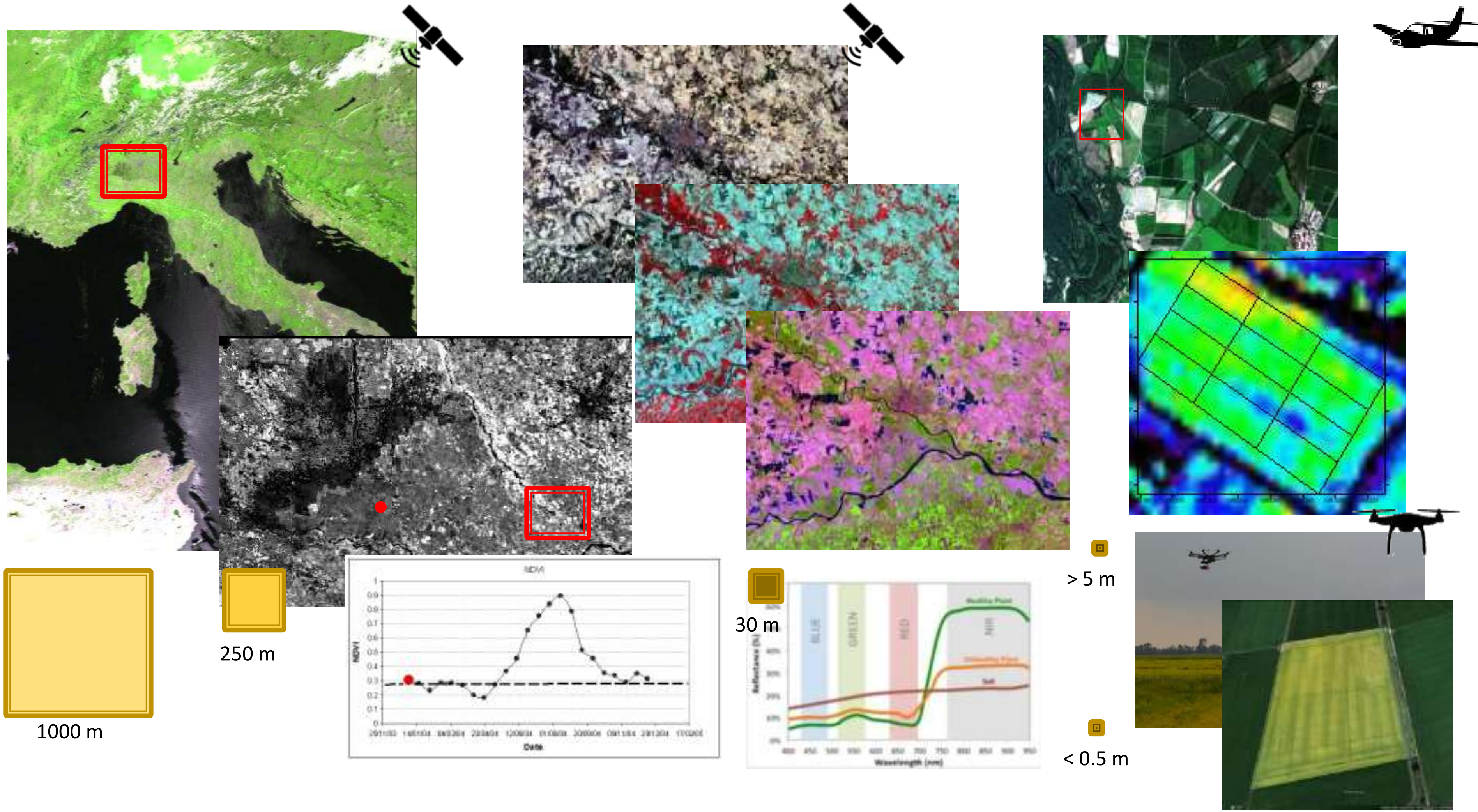
*The first satellite image of Lombardy acquired by Landsat 1 the **14th of August 1972**, **22 days after the launch***



*The first satellite sentinel 2 satellite image acquired the **29th of June 2015** on the* Po Valley, Italy, **6 days after the launch**

EARTH OBSERVATION: CONTRIBUTION TO CROP MONITORING

ERMES
AN EARTH OBSERVATION MODEL BASED RICE INFORMATION SERVICE



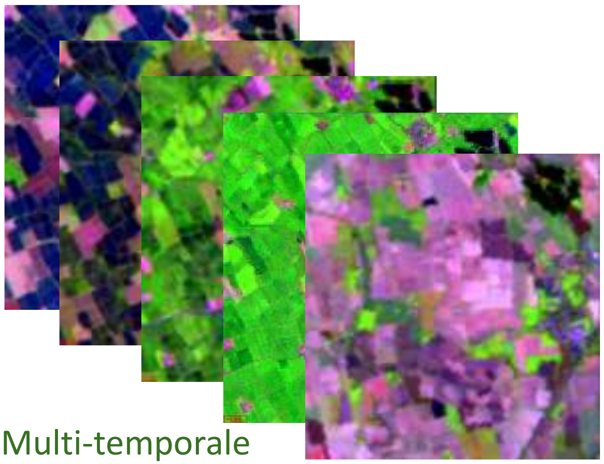
Visione sinottica dall'alto del territorio

Analisi e un monitoraggio multitemporale

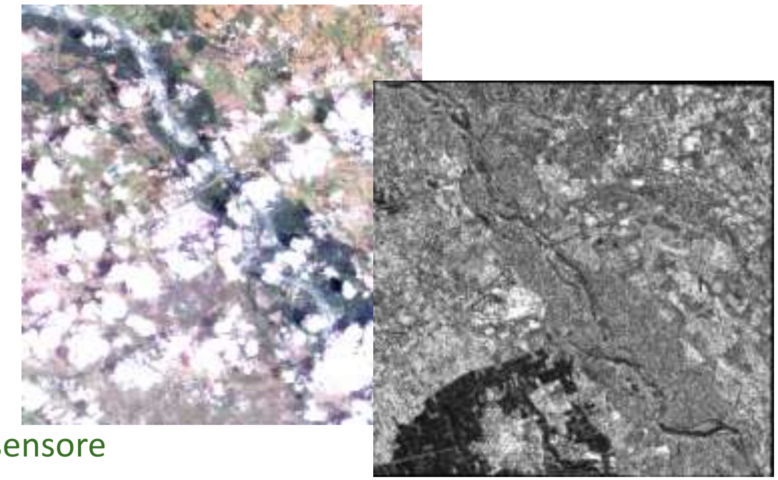
Visione multispettrale dell'oggetto indagato

dimensione spaziale dei fenomeni

EARTH OBSERVATION: CONTRIBUTION TO CROP MONITORING

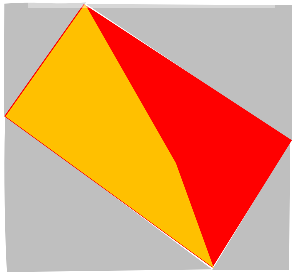


Multi-temporale

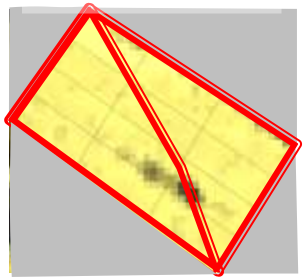


Multi-sensore

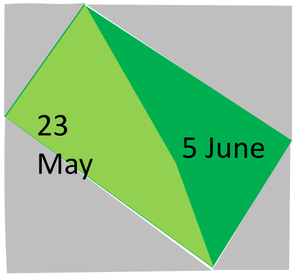
Tipologia delle colture



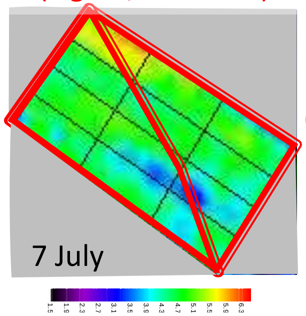
Variabilità dei suoli



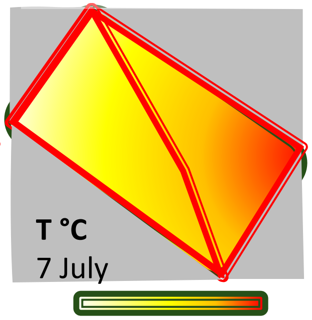
Date di semina e lavorazioni



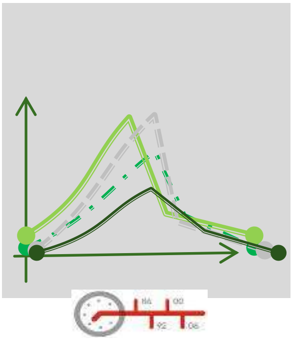
Stato della coltura (vigore/anomalie)



Stato della coltura (stress idrico)

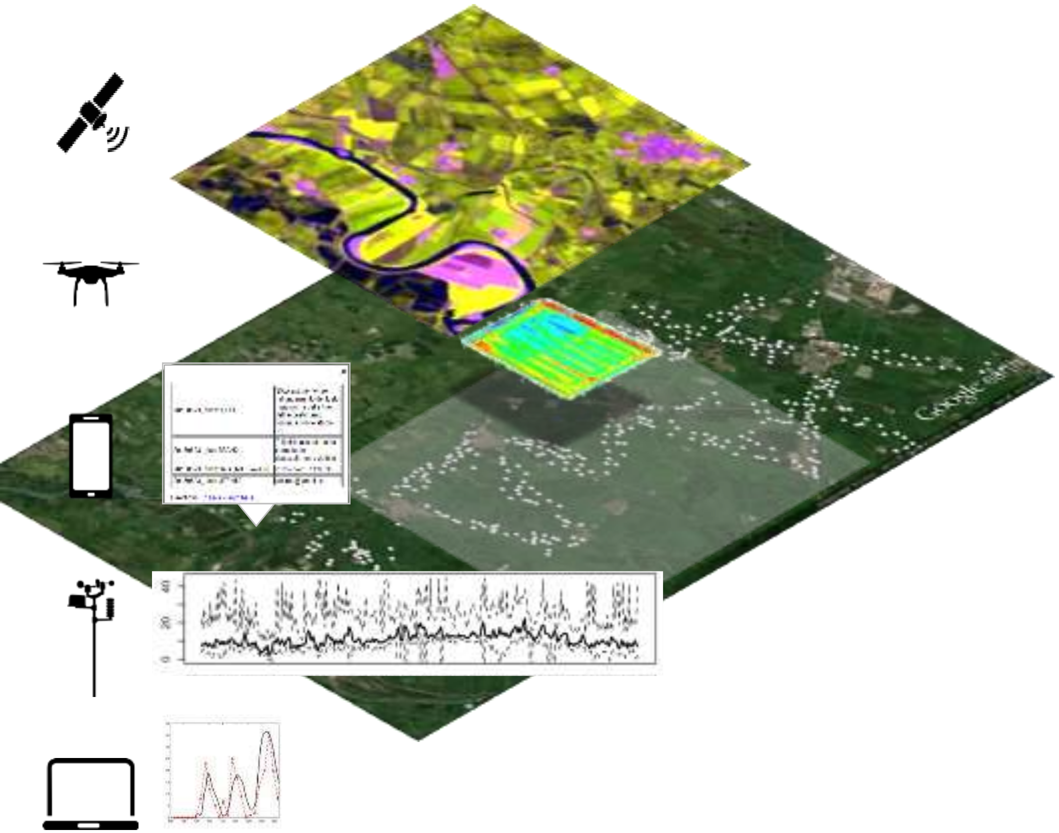


Sviluppo della coltura



APPLICATION DOMAIN

REMOTELY SENSED CROP PARAMETERS



- Phenology

- Anomaly detection

- Nitrogen content
- Canopy structural parameters

- Leaf Pigments

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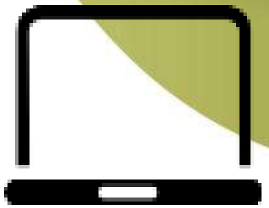
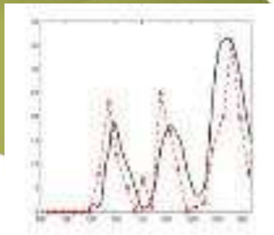
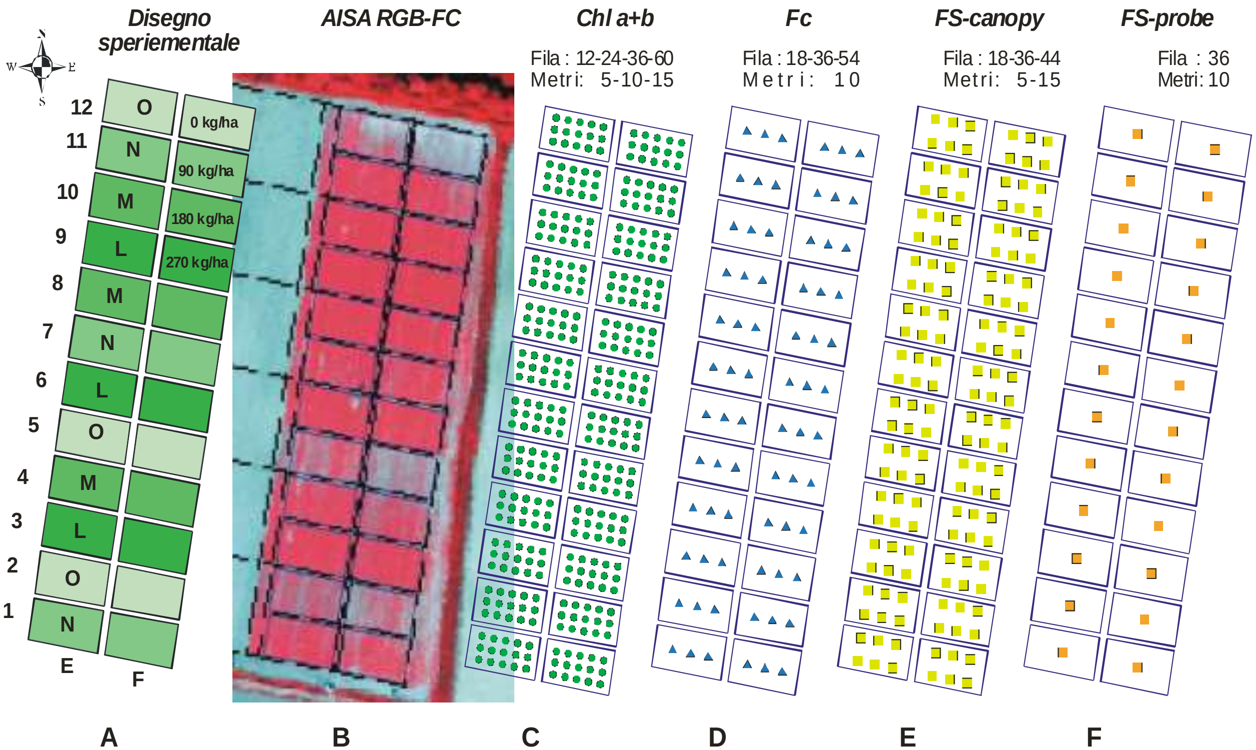
FIELD: SPECTRO RADIOMETRIC MEASUREMENTS





LEAF AND CANOPY MEASUREMENTS: CLOROPHYLL DETECTION

Experimental design: sugar beet



Variabilità controllata generata a seguito di fertilizzazioni differenziate:

- *4 livelli N (0-90-180-270 kg/ha) randomizzati*
- *2 livelli irrigui (blocchi E, F)*
- *3 repliche*
- *tot 24 parcelle 0.06 ha*

Densità semina bietola: interfile di 45 cm, 60 file per parcella

LEAF MEASUREMENTS: CLOROPHYLL DETECTION

Sugar beet (Measuremements acquisition 27/05/05)

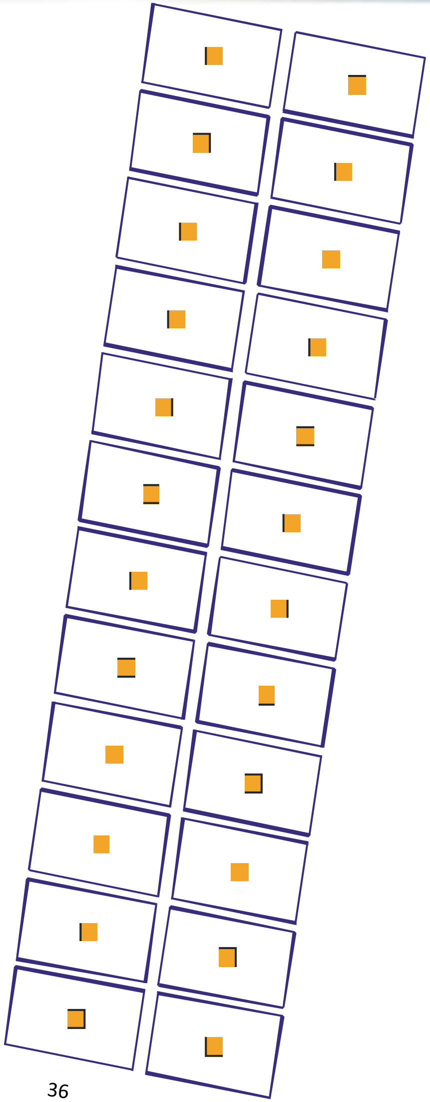
ASD_ FS-PRO (Leaf)

Fila : 36
Metri: 10

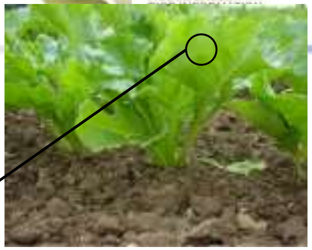
Tot. 24

Conctact probe accoppiato a FS
3 misure spettrali per ogni foglia

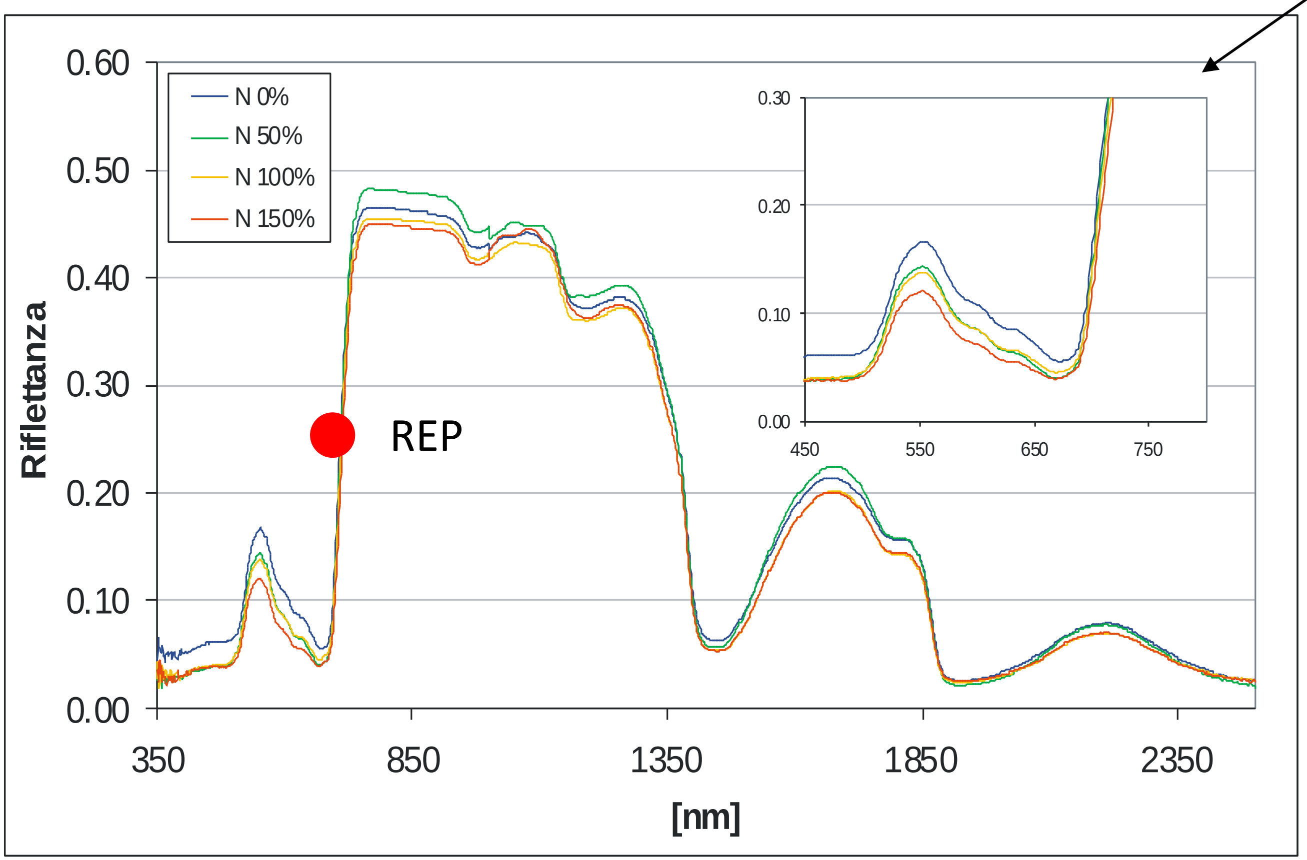
Campionamenti di rondelle fogliari di 18mm diametro in corrispondenza delle misure per estrazione analitica di Chl a+b



LEAF MEASUREMENTS: CLOROPHYLL DETECTION



Leaf spectral responce

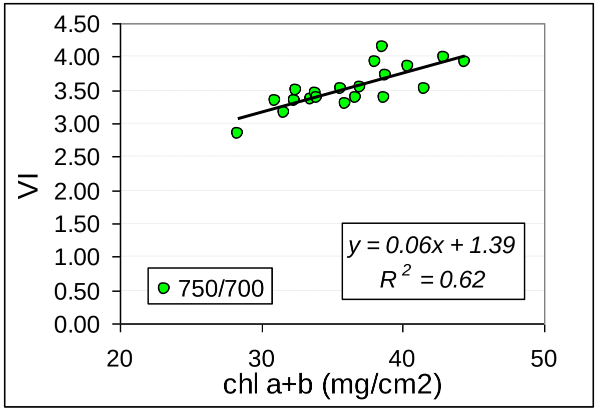


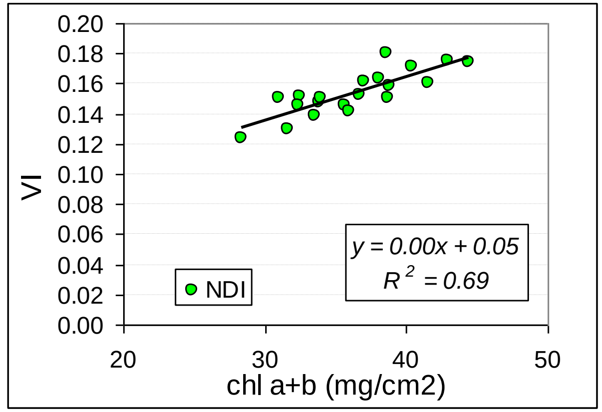
Examples of spectral **signatures acquired with the contact probe on plants of different levels of fertilization.**
Effects in the visible region.

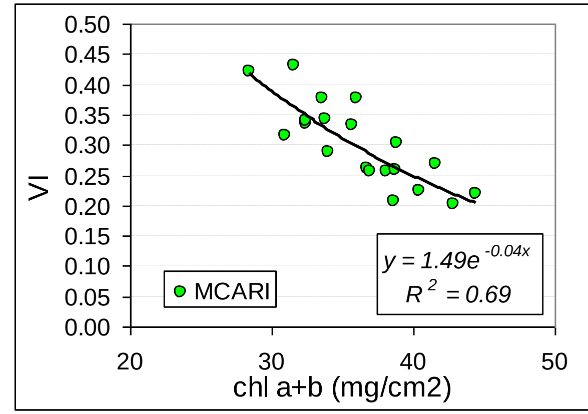
LEAF MEASUREMENTS: RESULTS

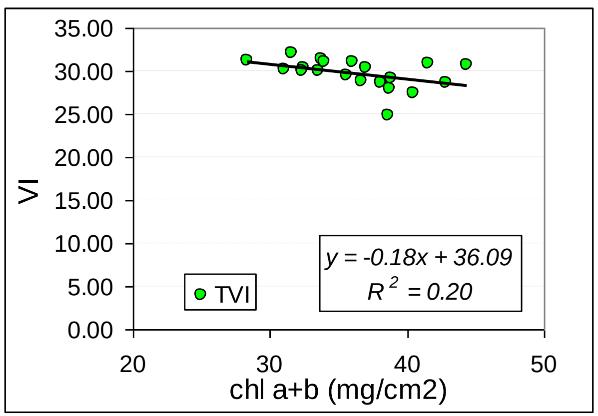

Leaf

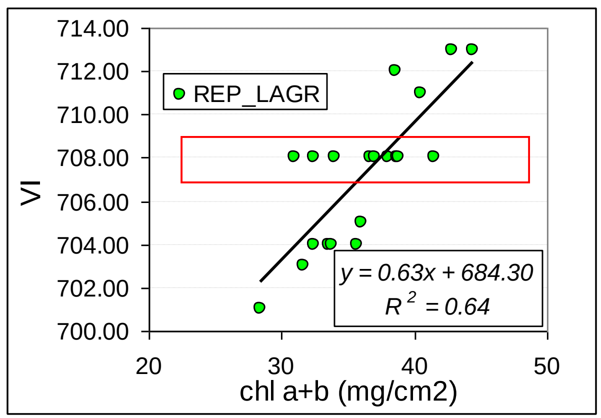
Leaf VIs vs *Chl a+b*

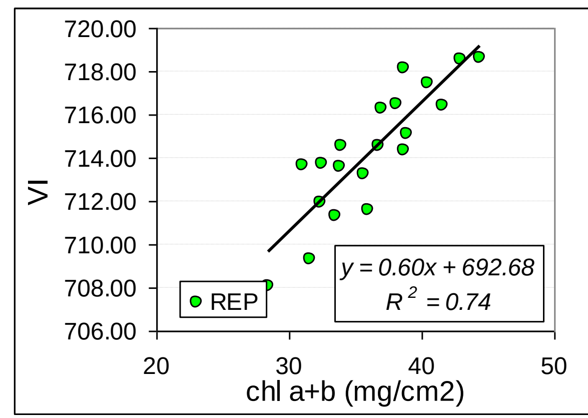












	SR	NDVI	R1	R2	R3	TVI
Chl a+b	ns	ns	0.49	0.55	0.63	0.21
	MTVI2	**MCARI**	**TCARI**	**REIP_lagr**	**REIP_lin**	**-**
Chl a+b	0.32	0.61	0.64	0.68	0.74	-

CANOPY LEVEL: DATA ACQUISITION

Misure radiometriche: 27/05/05 *(sorvolo AISA)*

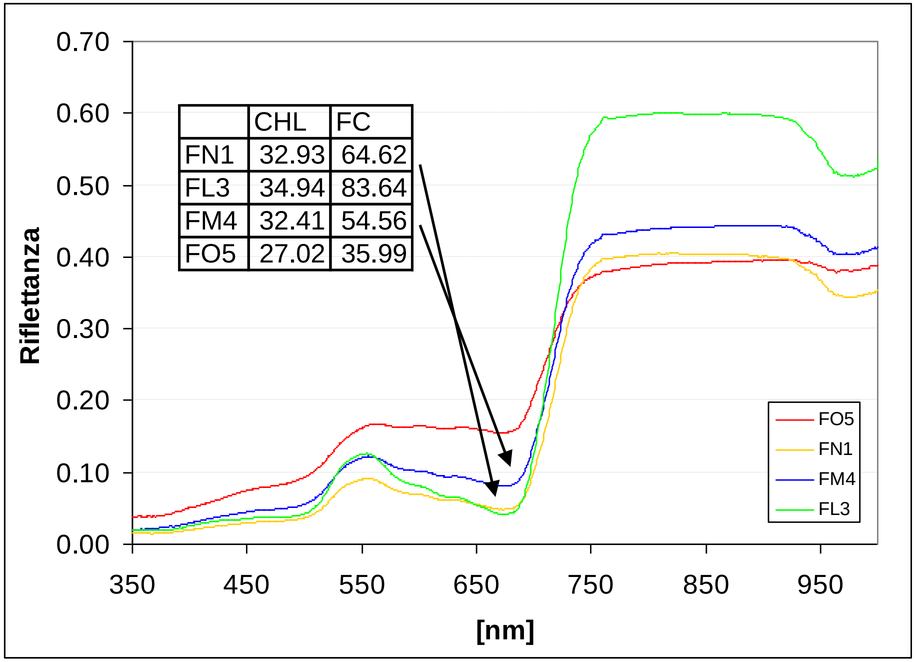
ASD-FS-PRO (Canopy)

Fila : 18-36-44
Metri: 10

Tot. 144

CANOPY LEVEL: DATA ACQUISITION

Canopy VIs vs *Chl-a+b*



Canopy

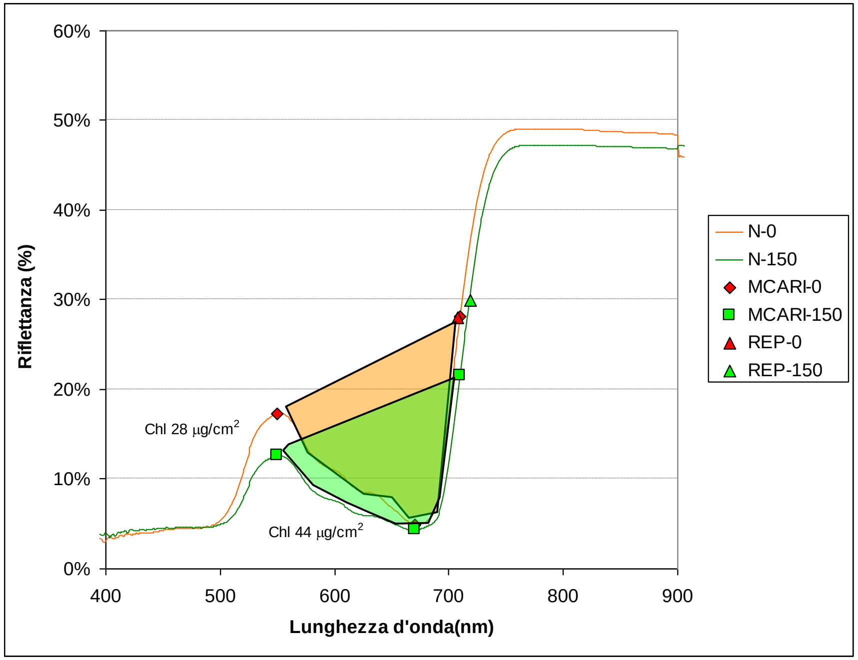
Examples of spectral signatures on plants of different levels of fertilization.
Major effects in the REP and NIR region.
Significant contribution of the soil

- R^2 indici di vegetazione

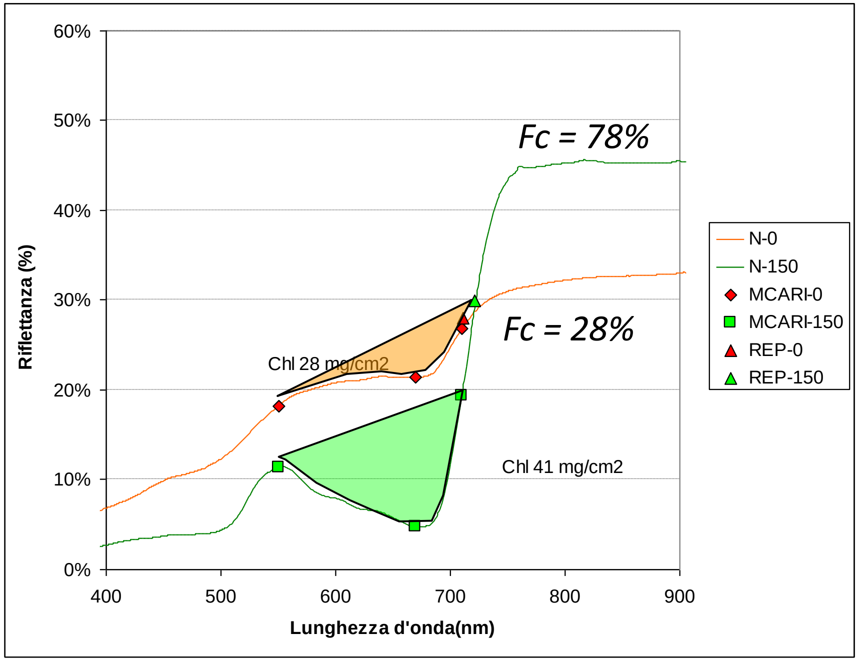
	SR	NDVI	R1	R2	R3	TVI	MTVI2
Chl a+b	0.62	0.69	0.56	0.65	0.66	0.65	0.67
FC	**0.80**	**0.84**	0.6	0.70	0.70	0.62	0.63

	MTVI2	MCARI	TCARI	REIP_lin	OSAVI	TSAVI	TCARI/OSAVI
Chl a+b	0.67	**0.60**	0.6	**0.64**	0.66	0.64	0.35
FC	0.63	**0.46**	0.46	**0.88**	0.72	0.73	0.26

Leaf vs canopy level: complexity of data acquisition



MCARI > MCARI

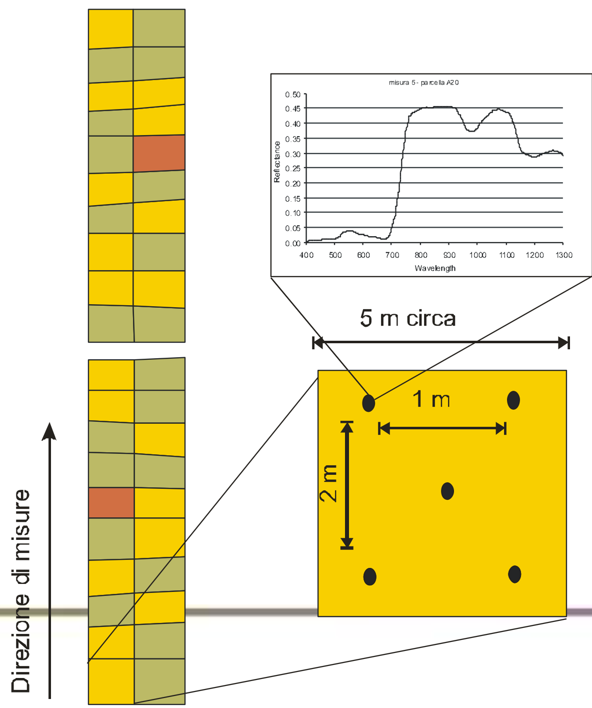


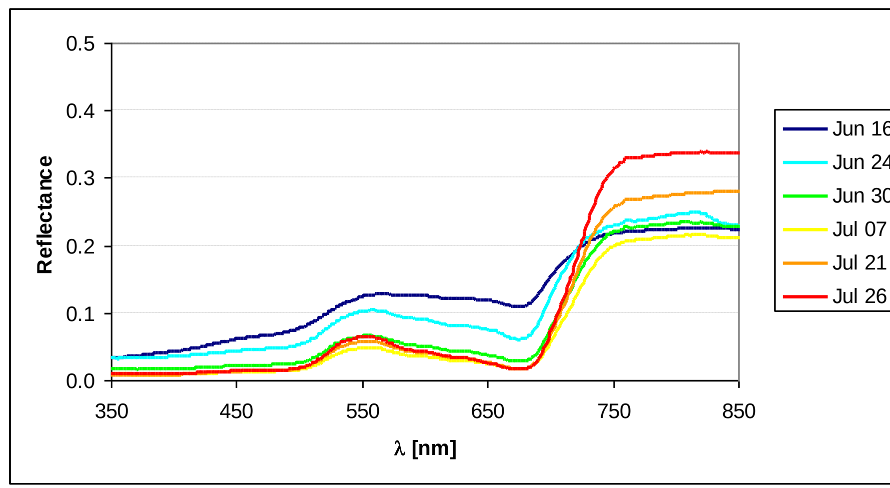
MCARI < MCARI

Experiment:
- Two vaieties (Gladio, Volano)
- Tree fertilization level two time of application (0, 80, 160 kg ha-1)

Agronomic parameters
- LAI (transect LAI2000)
- AGB (samples on 20 plants)
- PNC (samples on 6 plants)

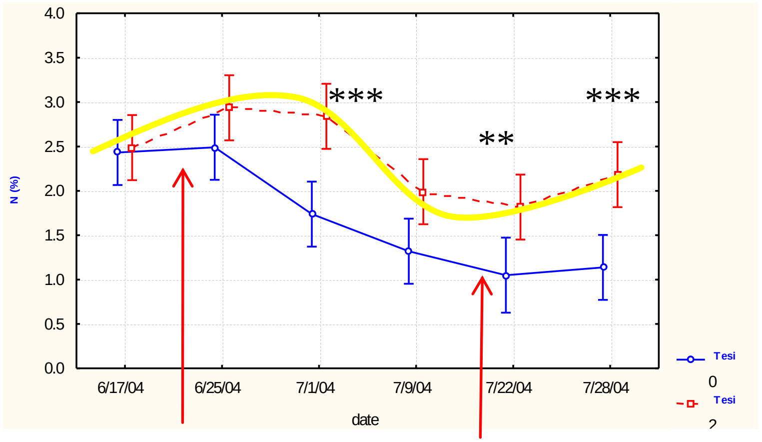
Spectral measumrements
- FieldSpec FR Pro, (ASD)
- 1nm, 4nm, 350-2500 nm
- Five acquisitions per plot





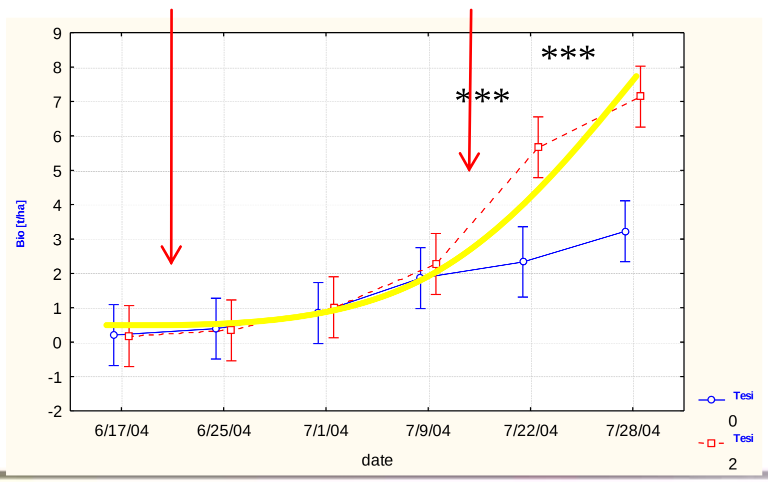
CANOPY MEASUREMENTS: NITROGEN ESTIMATION

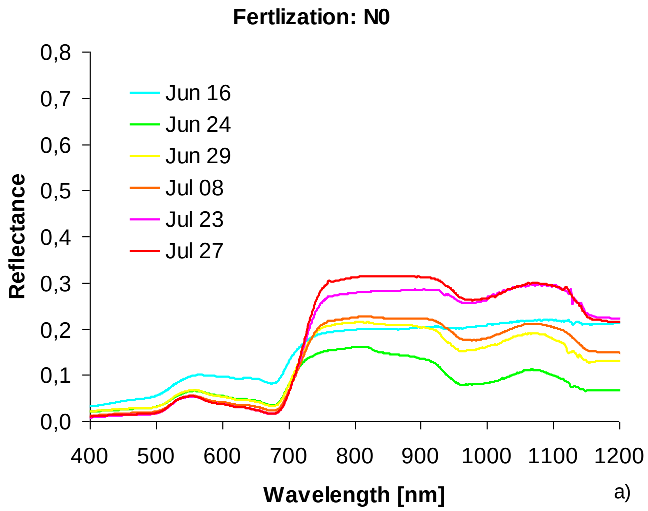
Experiments was aimed to generate plant growing condition with divergent PNC and Biomass trend to be investigated by spectral measurements

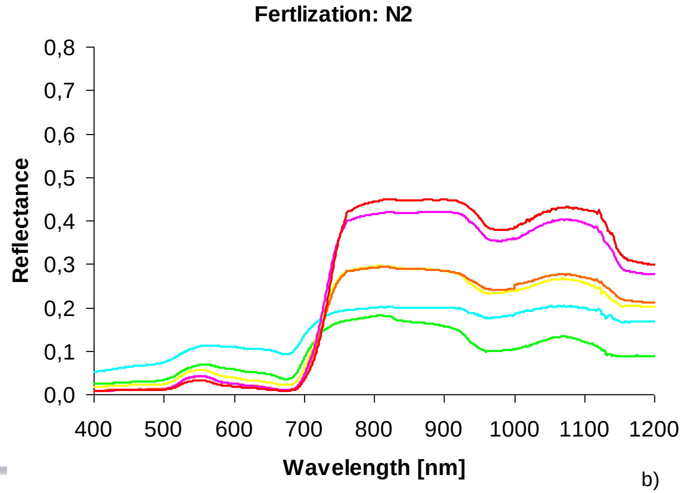


1° fert 22 jun

2° fert 20 Jul.

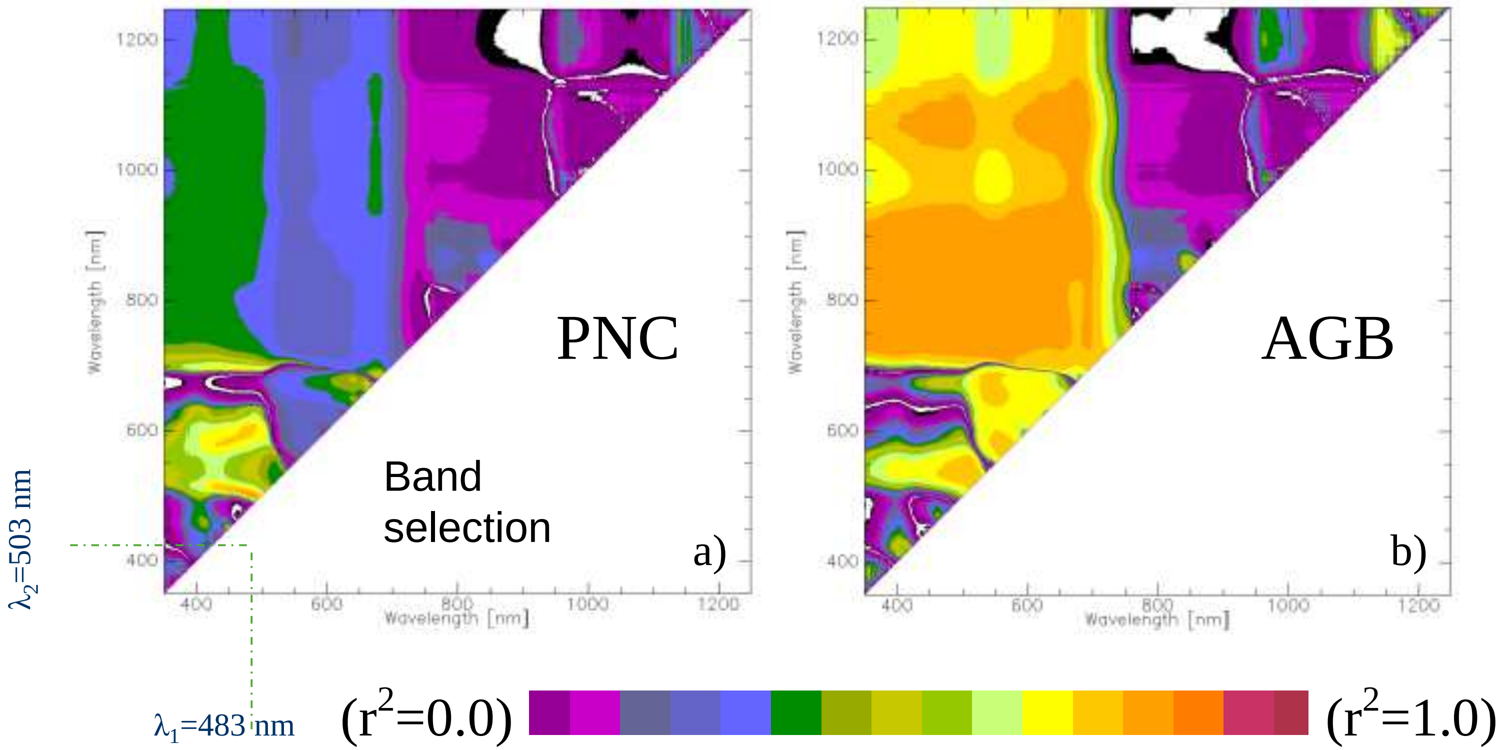






CANOPY MEASUREMENTS: NITROGEN ESTIMATION

NDI (Normalises Difference Index) iperspectral for N estimates



PNC: Optimal combinations fall in the VIS (λ<700 nm) in the blue-green region where the photosynthetic pigments have a strong influence. Best NDI λ2= 503, λ1= 483 (R^2=0.65, ***$p<0.001$)

AGB: High correlation in the VISNIR. Best NDI λ1~800nm and λ2~600nm. (R2> 0.7;)

CANOPY MEASUREMENTS: NITROGEN ESTIMATION

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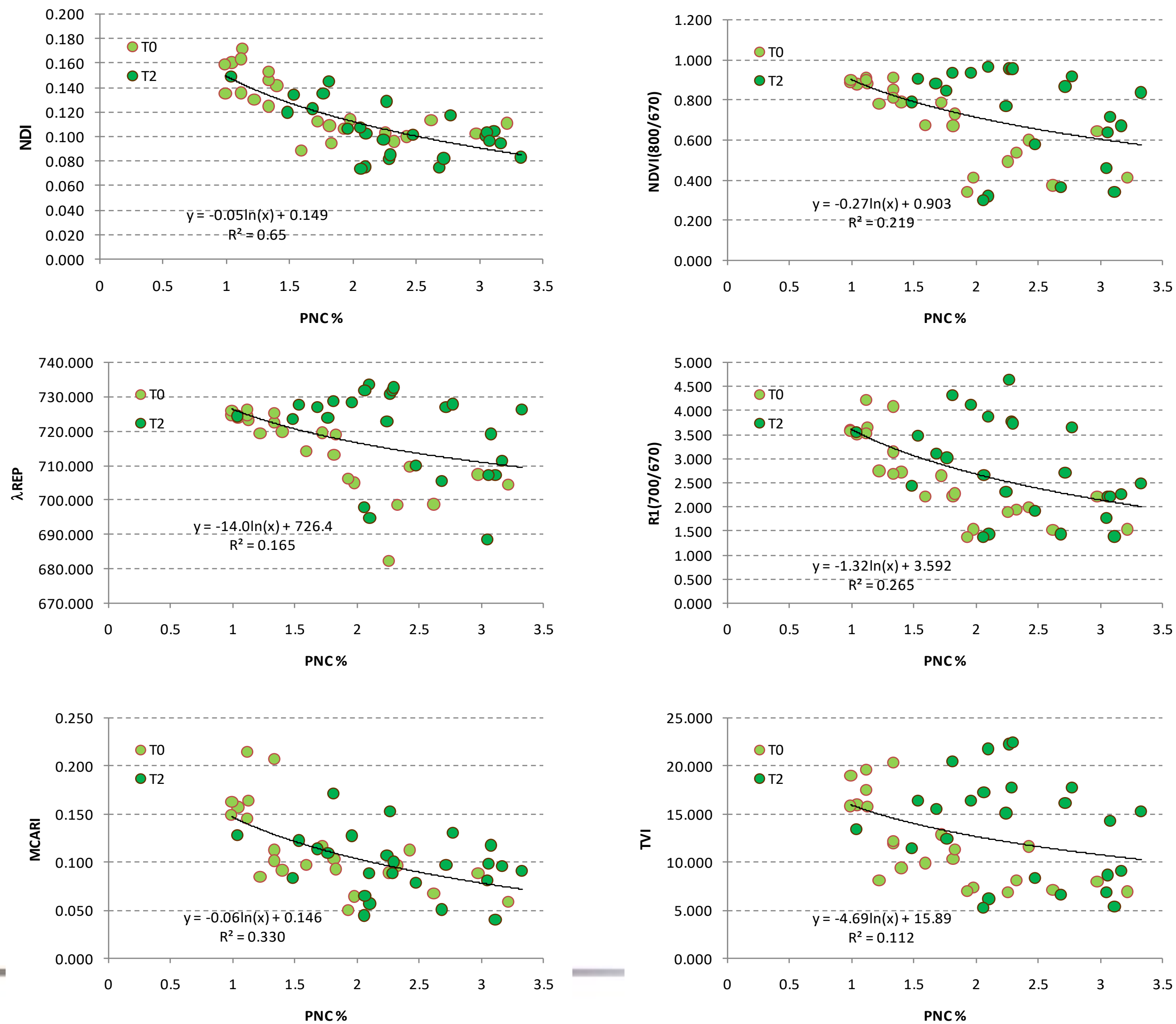
AN EARTH OBSERVATION MODEL BASED RICE INFORMATION SERVICE

NDI vs other indices proposed in literature



CANOPY MEASUREMENTS: NITROGEN ESTIMATION

128 D. Stroppiana et al. / Field Crops Research 111 (2009) 119–129

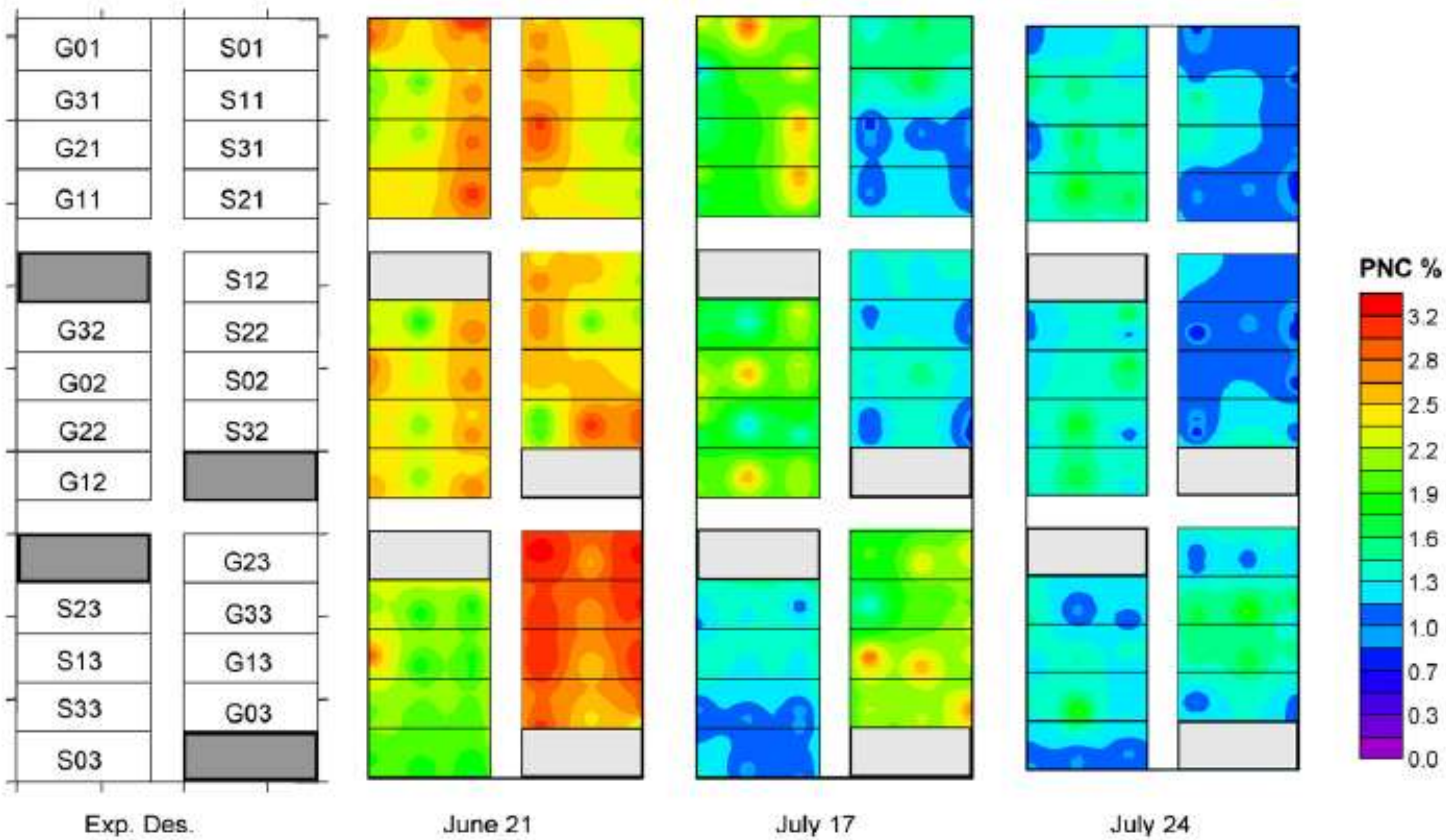
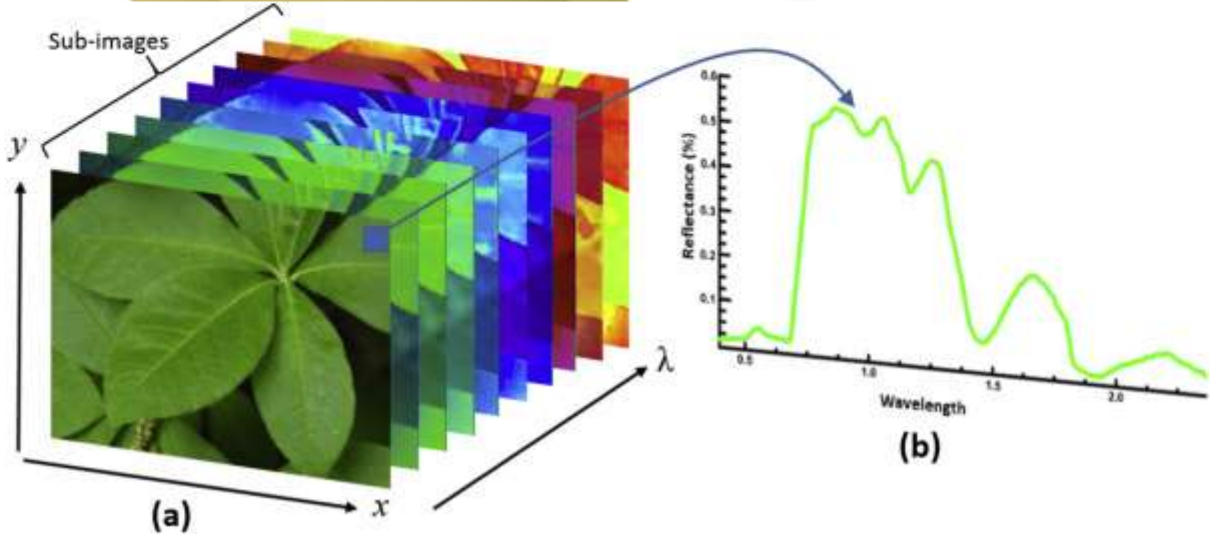


Fig. 9. PNC maps derived from radiometric field measurements for the year 2006; grey blocks identify plots where rice was not sown. A schematic of the experimental design is also shown (*Sij* and *Gij* is Selenio cv. and Gladio cv., respectively, *i* is fertilization level and *j* replicate).

From spectra to images



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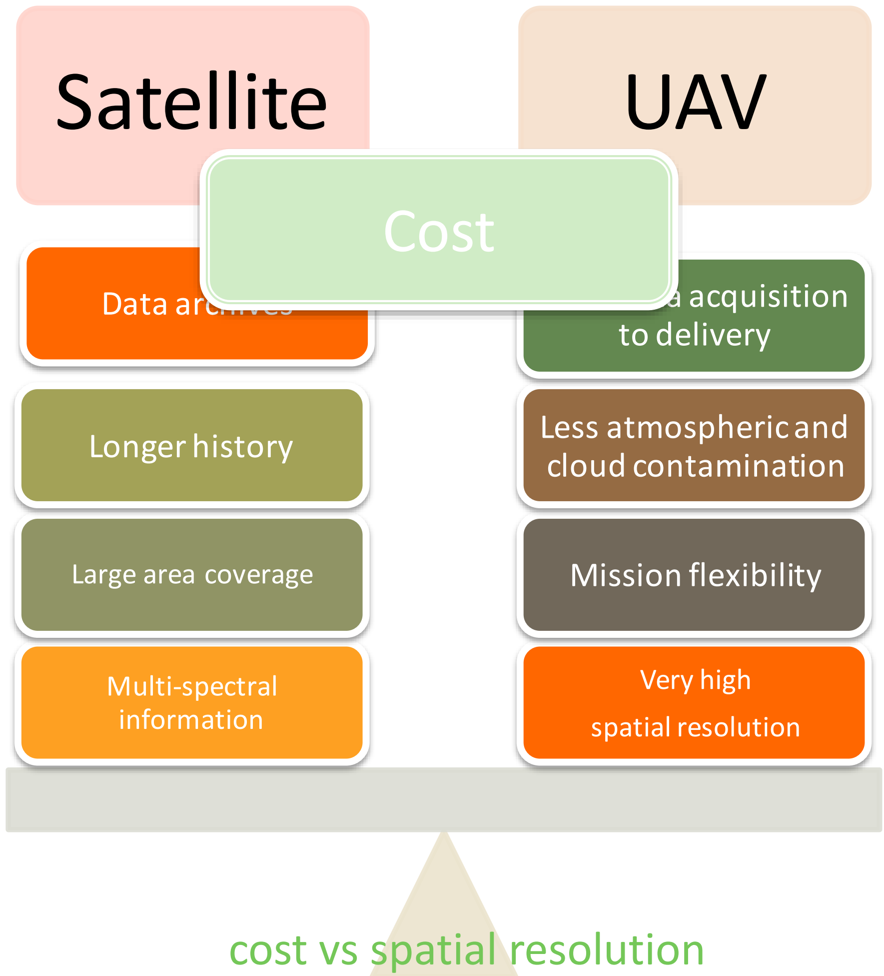
AERIAL: UAV MAPPING

Copernicus



cost vs spatial resolution

ENTE NAZIONALE PER L'AVIAZIONE CIVILE

UAV – Crop development vs N application (Rice)

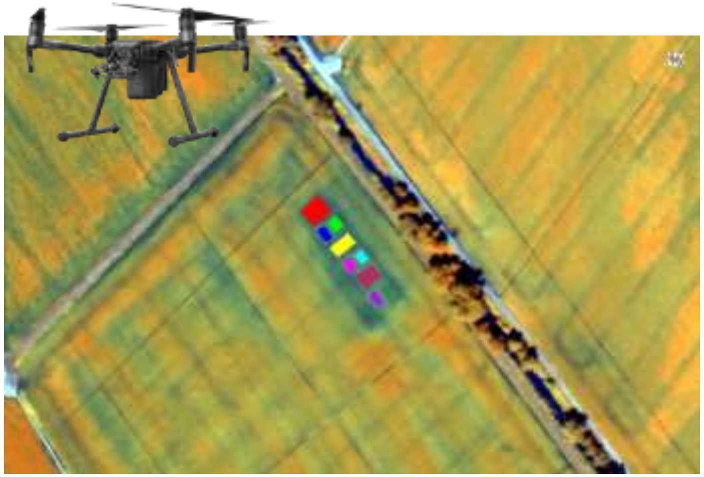
ID Parcella	Kg N/ha 04/06/14	Kg N/ha 15/07/14
N1.1	20	0
N1.2	20	0
N1.3	20	0
N1.4	20	0
N1.5	20	20
N1.6	20	20
N1.7	20	40
N1.8	20	40

ID Parcella	Kg N/ha 04/06/14	Kg N/ha 15/07/14
N2.1	40	0
N2.2	40	0
N2.3	40	0
N2.4	40	0
N2.5	40	20
N2.6	40	20
N2.7	40	40
N2.8	40	40

ID Parcella	Kg N/ha 04/06/14	Kg N/ha 15/07/14
N3.1	60	0
N3.2	60	0
N3.3	60	0
N3.4	60	0
N3.5	60	20
N3.6	60	20
N3.7	60	40
N3.8	60	40

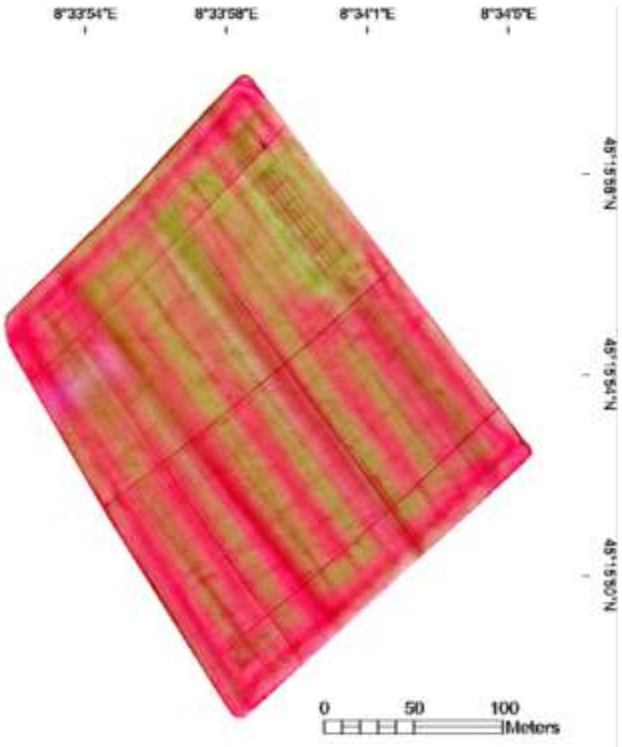
Measurements

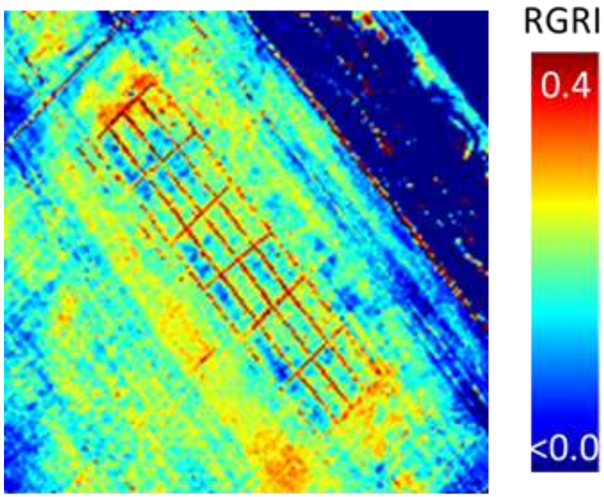
- Crop → Rice volano
- N -> Destructive, Dualex, PocketN
- LAI -> PocketLAI
- Reflectance -> Spectroradiometer SR3500 (15/07/14)
- UAV acquisition (September 24th, 2014) → DJI S1000 Octocopter & Tetracam ADC Micro

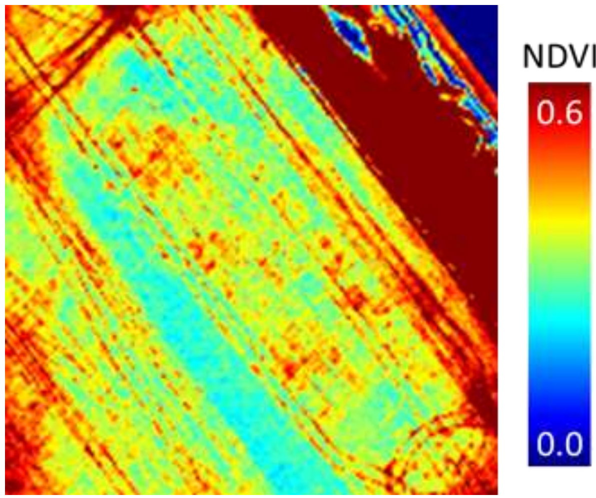


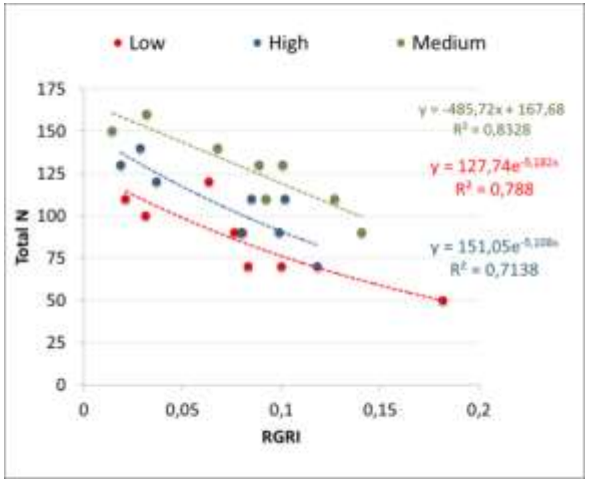
UAV – CROP DEVELOPMENT VS N APPLICATION (RICE)

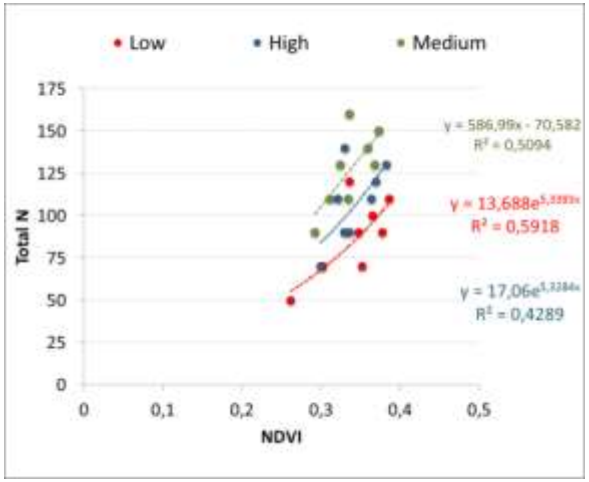
Rice





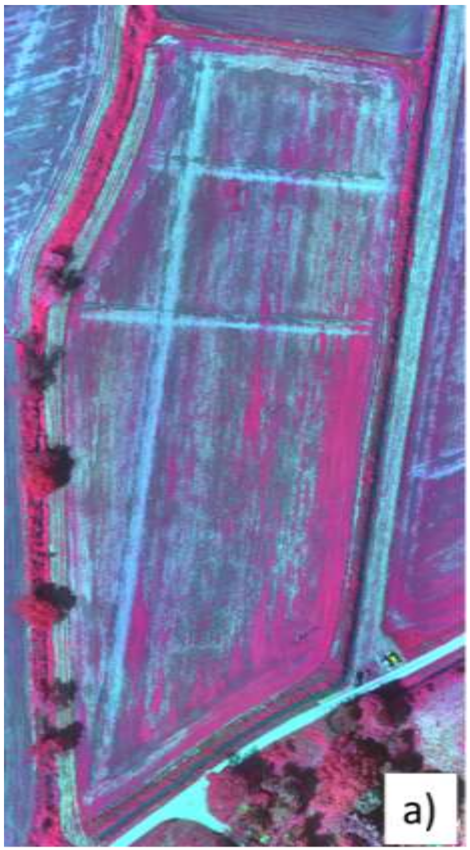




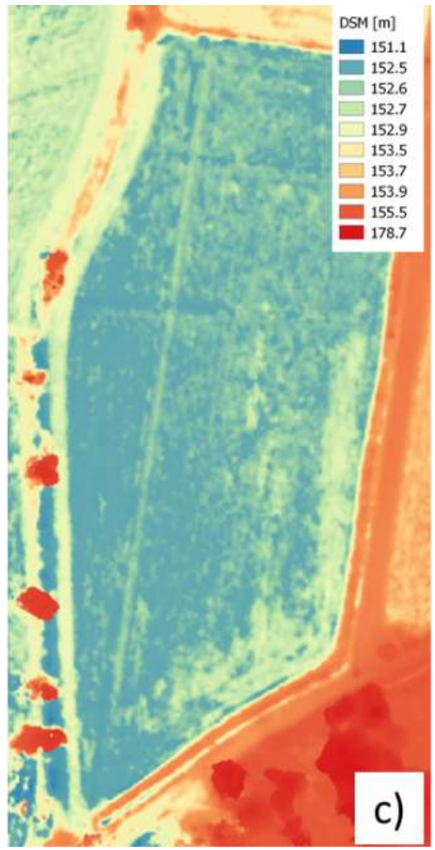


UAV – WEED DETECTION (RICE)

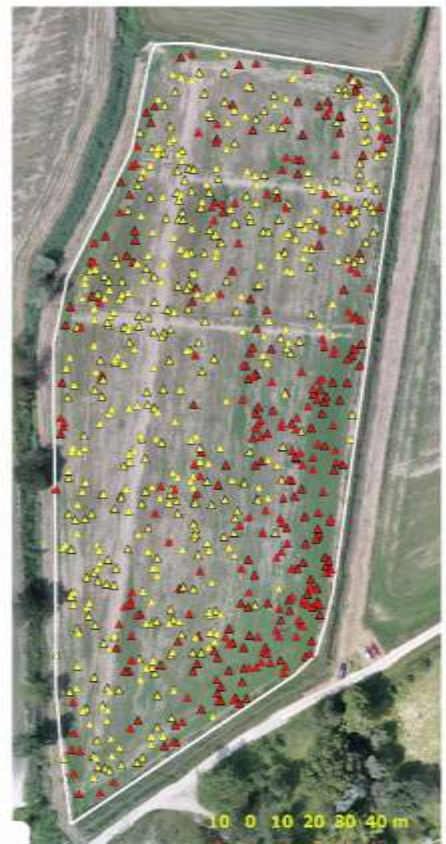
- DJI S1000 Octocopter
- Digital Camera Canon S100
- Tetracam ADC Micro



Mutispectral data



DSM

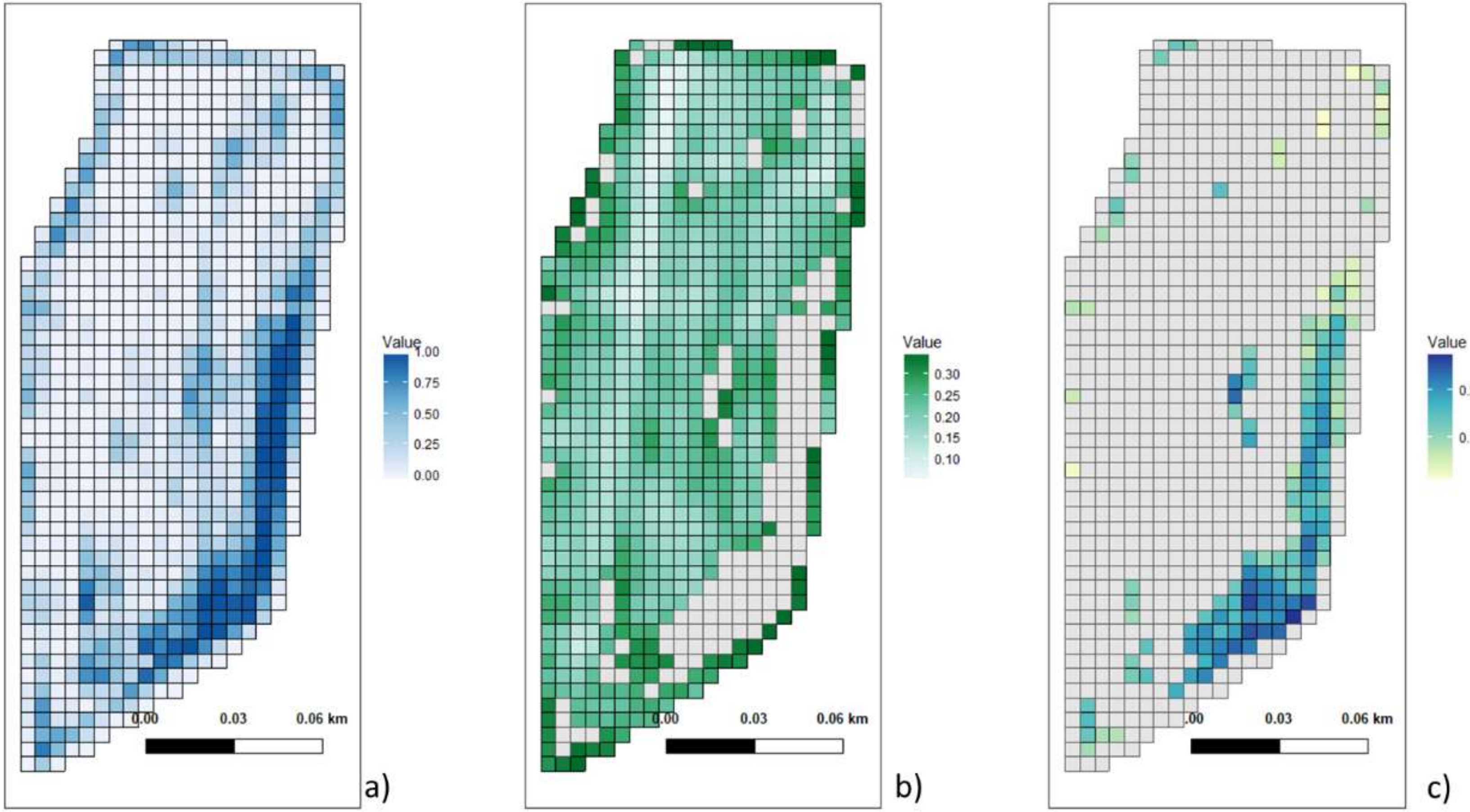


Reference points

No weed

Weed

UAV – WEED DETECTION (RICE)



Weed proportion Fractional Cover Canopy heigth

UAV: DAMAGE ASSESSMENT (RICE)

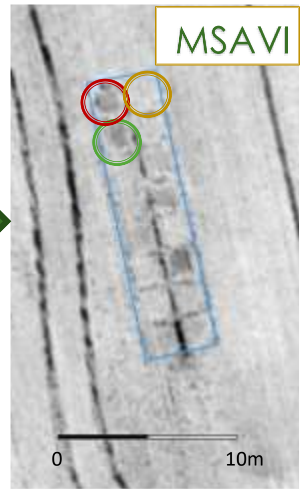
Two experimental fields inVillarasca (PV). (Acqua e Sole S.r.l)

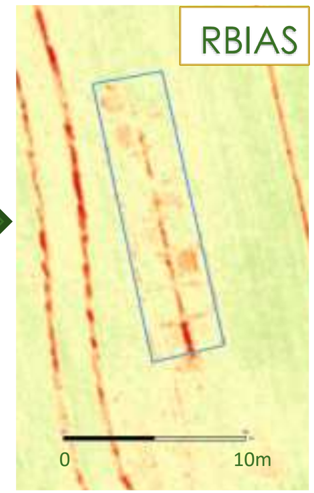
data 10 agosto 2017

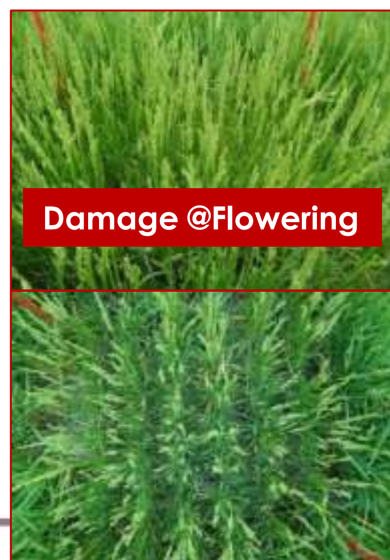
LEGENDA	
I	RISO CL 26
J	RISO CENTAURO
A	ACCESTIMENTO
L	LEVATA
F	FIORITURA
	CORRIDOIO
C1, C2, C3, C4	DEFOGLIAZIONE 0%
100 1, 100 2	DEFOGLIAZIONE 100%
50 1, 50 2	DEFOGLIAZIONE 50 %

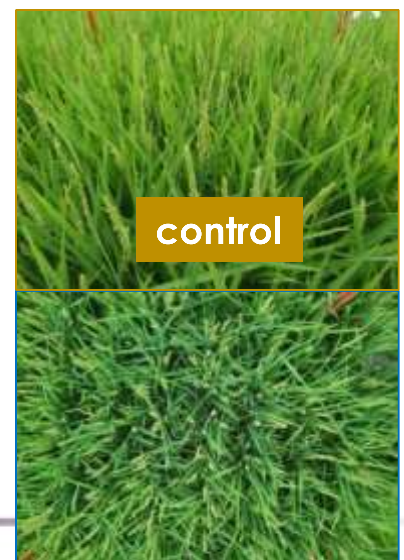
UAV: DAMAGE ASSESSMENT

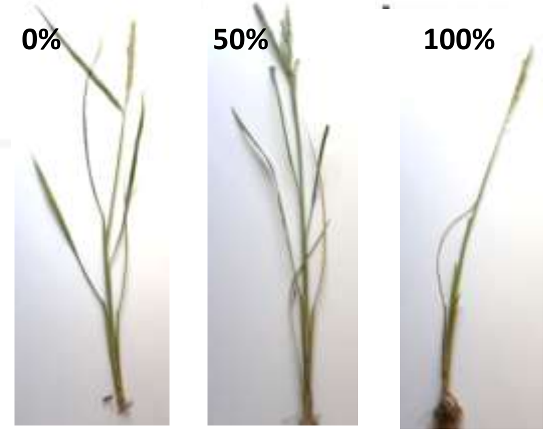
- VI calculation and damage assessment

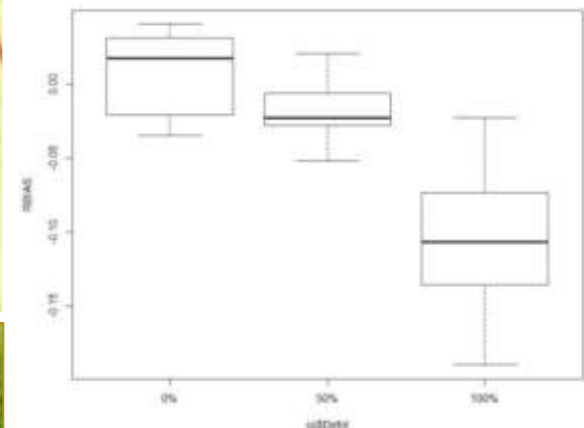












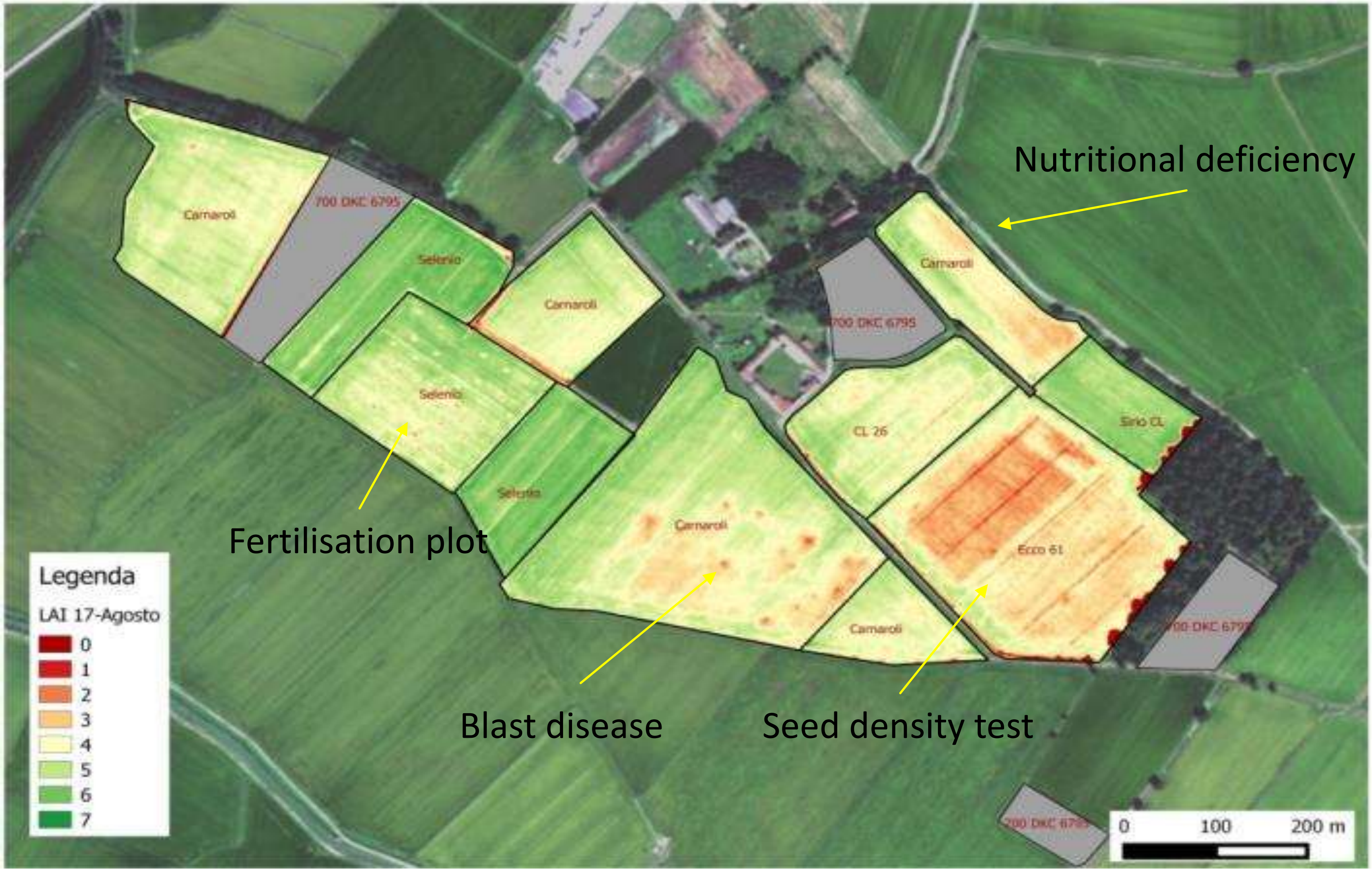
Significant relations between processing of remote sensing data and SAPR (ANOVA):

- % defoliation
- Variety
- Phenological Phase

ERMES

SATELLITE: HIGH RESOLUTION MAPPING

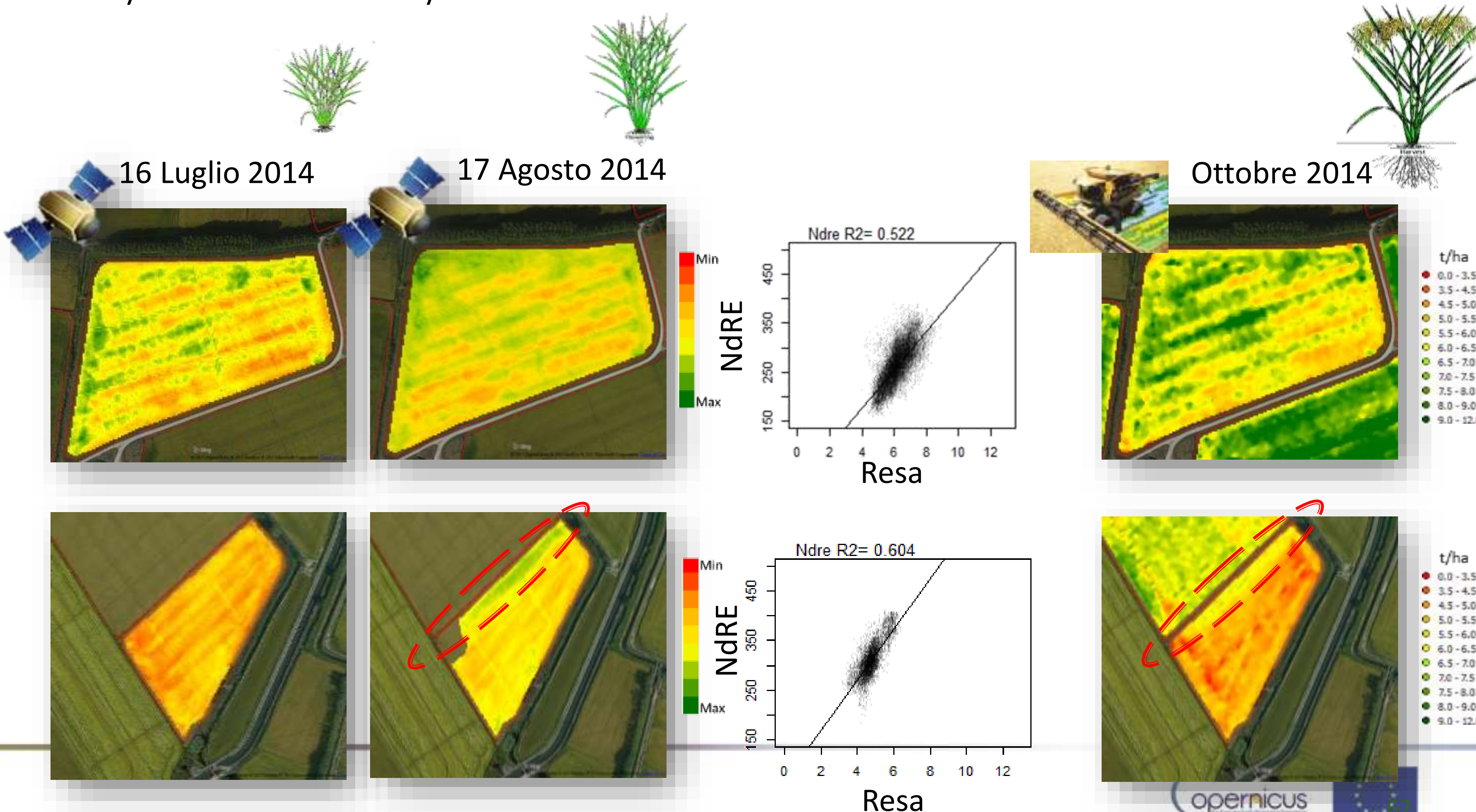
SATELLITE DATA: WITHIN FIELD ANOMALY



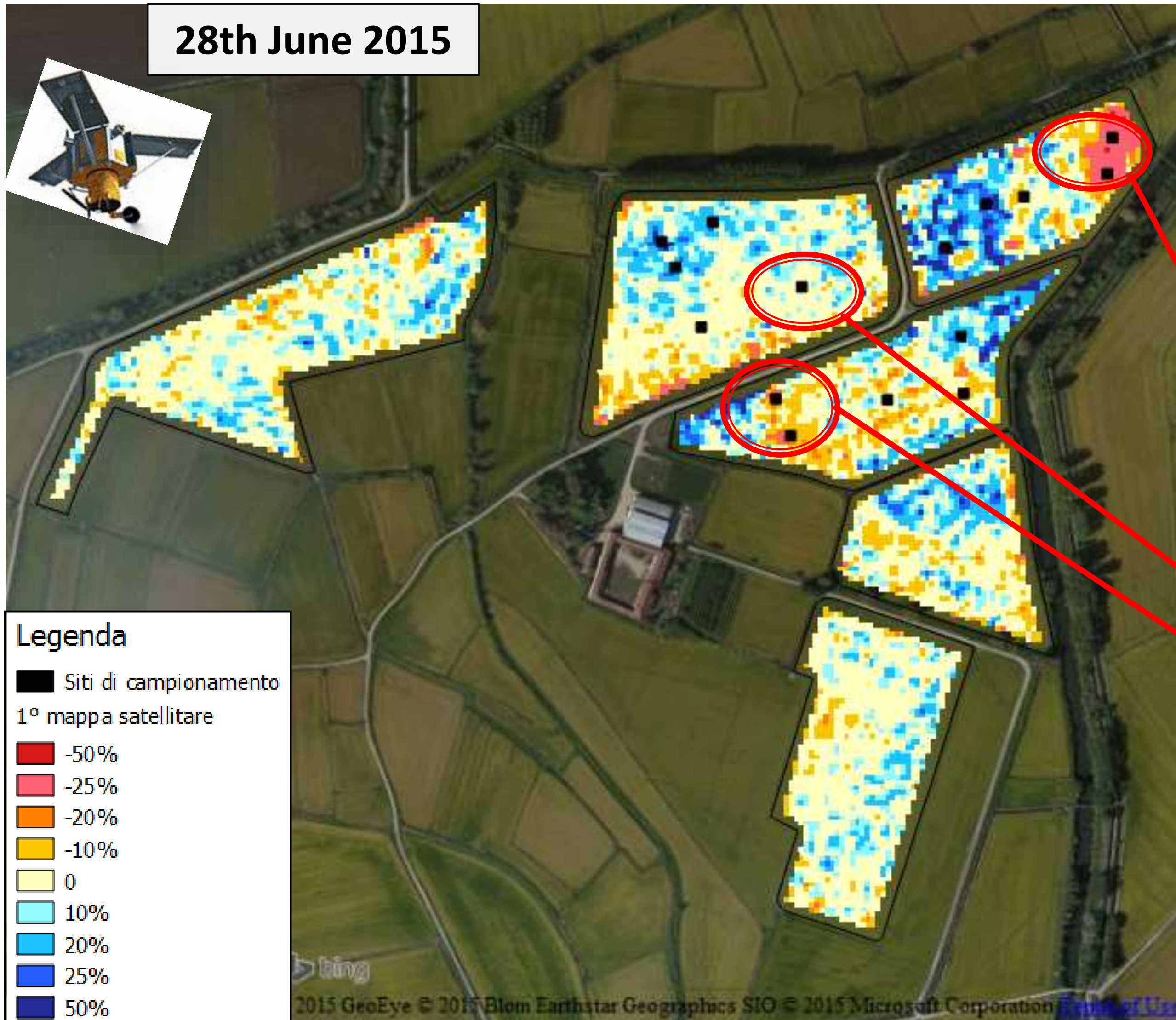
SATELLITE DATA: YIELD VARIABILITY ASSESSMENT

VI maps **Yield maps**

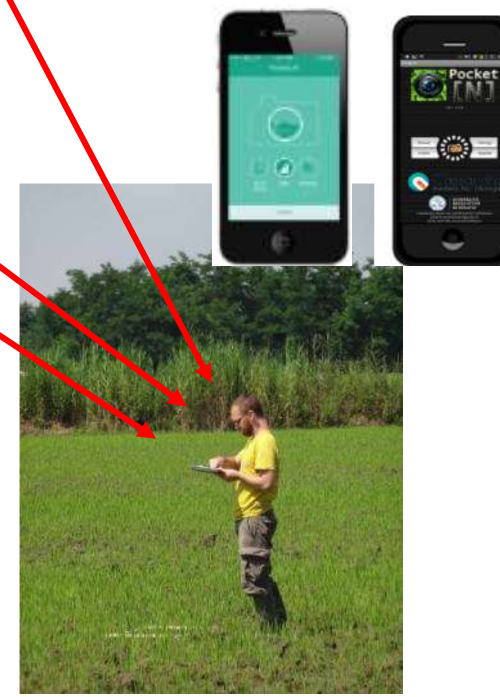
Analysis of satellite images acquired in key phenological phases revelaed significant relation with final yield data measured by a harvester combiner



Satelite data to support smart scouting

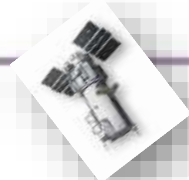


LAI sampling and foliar nitrogen 'driven' by the 1st satellite image acquiresd



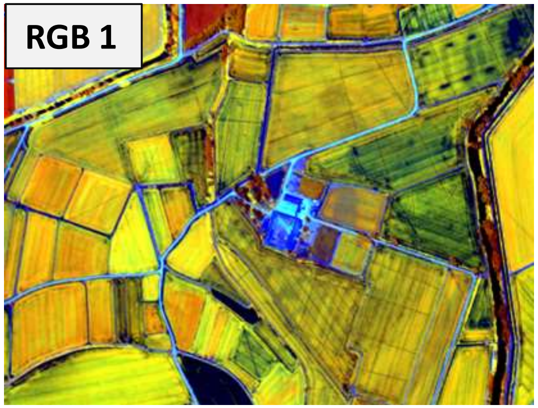
SATELLITE DATA TO NITROGEN NUTRIZION INDEX (NNI)

ERMES
AN EARTH OBSERVATION MODEL BASED RICE INFORMATION SERVICE

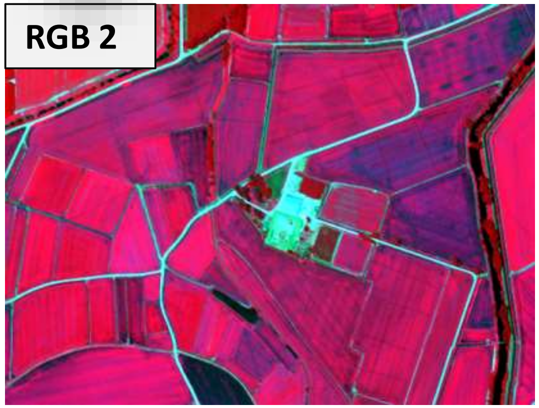


1° July 2015

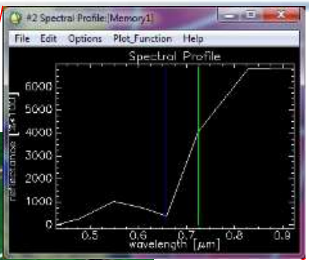
RGB 1



RGB 2



Colori reali



NDVI
(Normalised Different Vegetation Index)

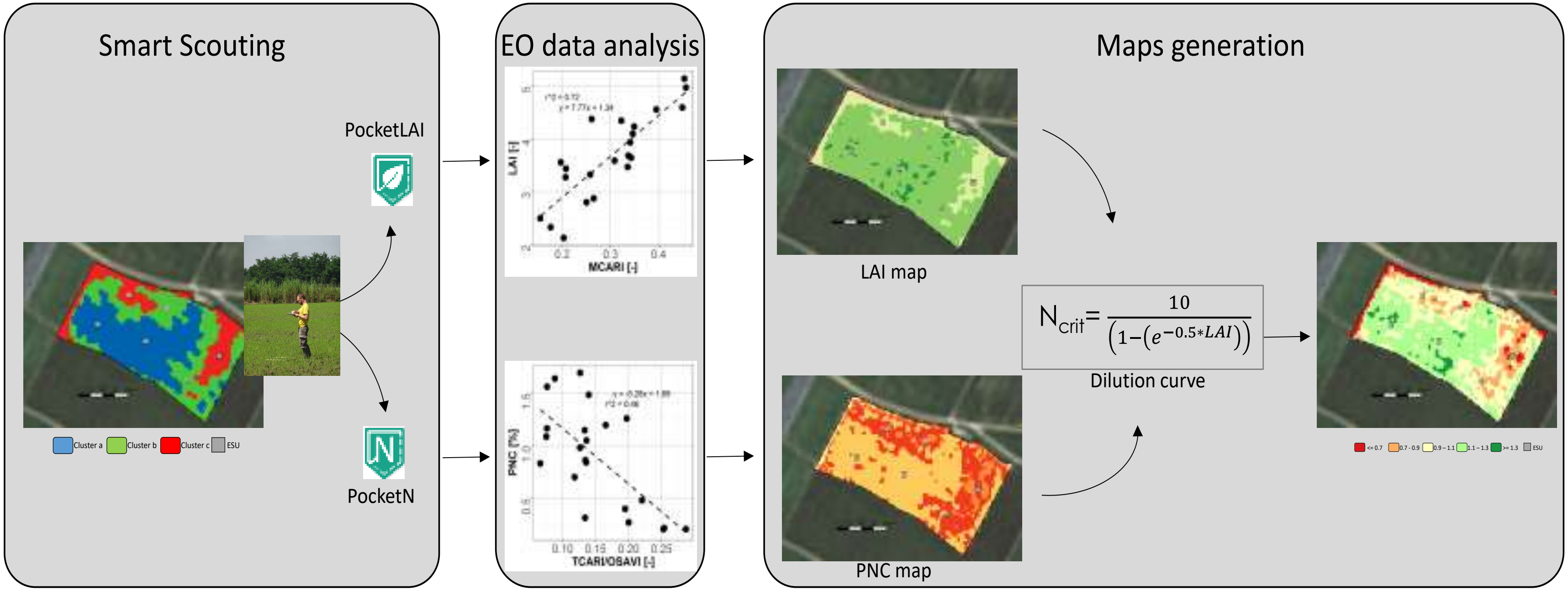
Biomass indicator

CVI
(Chlorophyll Vegetation Index)

Nitrogen content indicator

An operational workflow to assess rice nutritional status based on satellite imagery and smartphone apps

Francesco Nutini [a*], Roberto Confalonieri [b], Alberto Crema [a], Ermes Movedi [b], Livia Paleari [b], Dimitris Stavrakoudis [c] and Mirco Boschetti [a*]

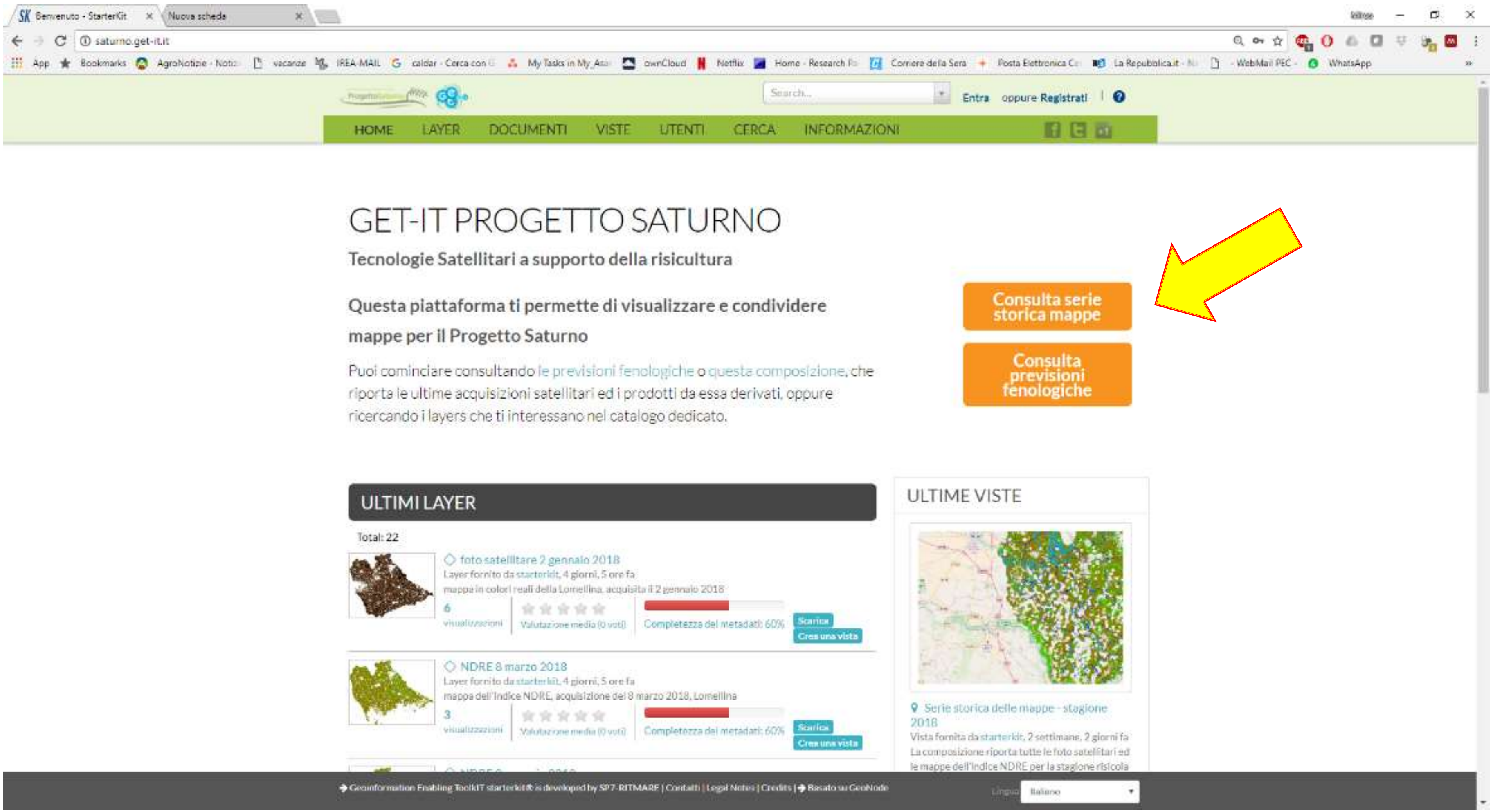


PROJECT SATURNO: SUPPORTING VRT FERTILIZATION

ProgettoSaturno

RegioneLombardia
Direzione Generale Agricoltura

PSR 2014 2020 LOMBARDIA L'INNOVAZIONE METTE RADICI



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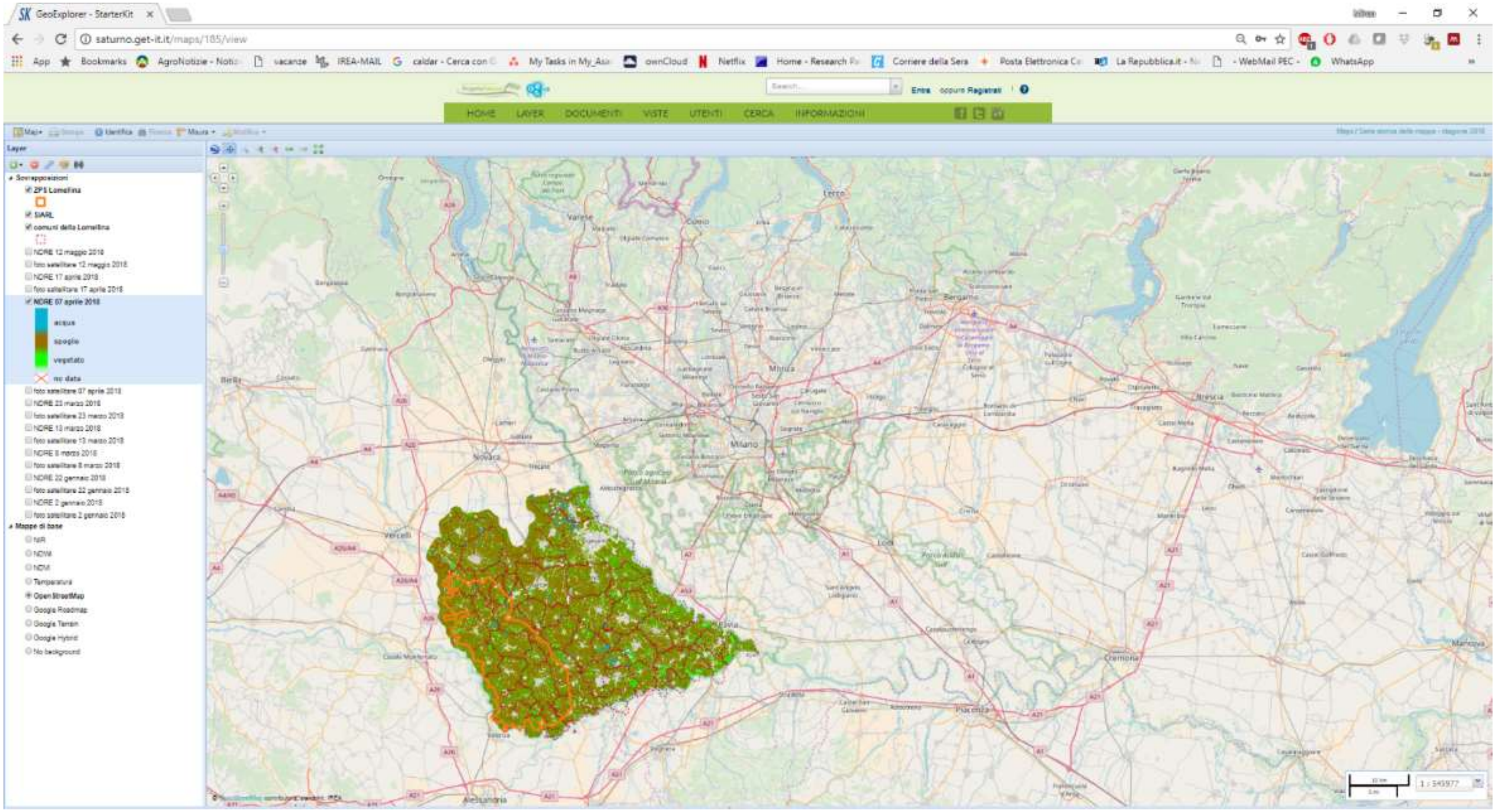
PROJECT SATURNO: SUPPORTING VRT FERTILIZATION

ProgettoSaturno

RegioneLombardia
Direzione Generale Agricoltura

PSR 2014 2020 LOMBARDIA L'INNOVAZIONE METTE RADICI



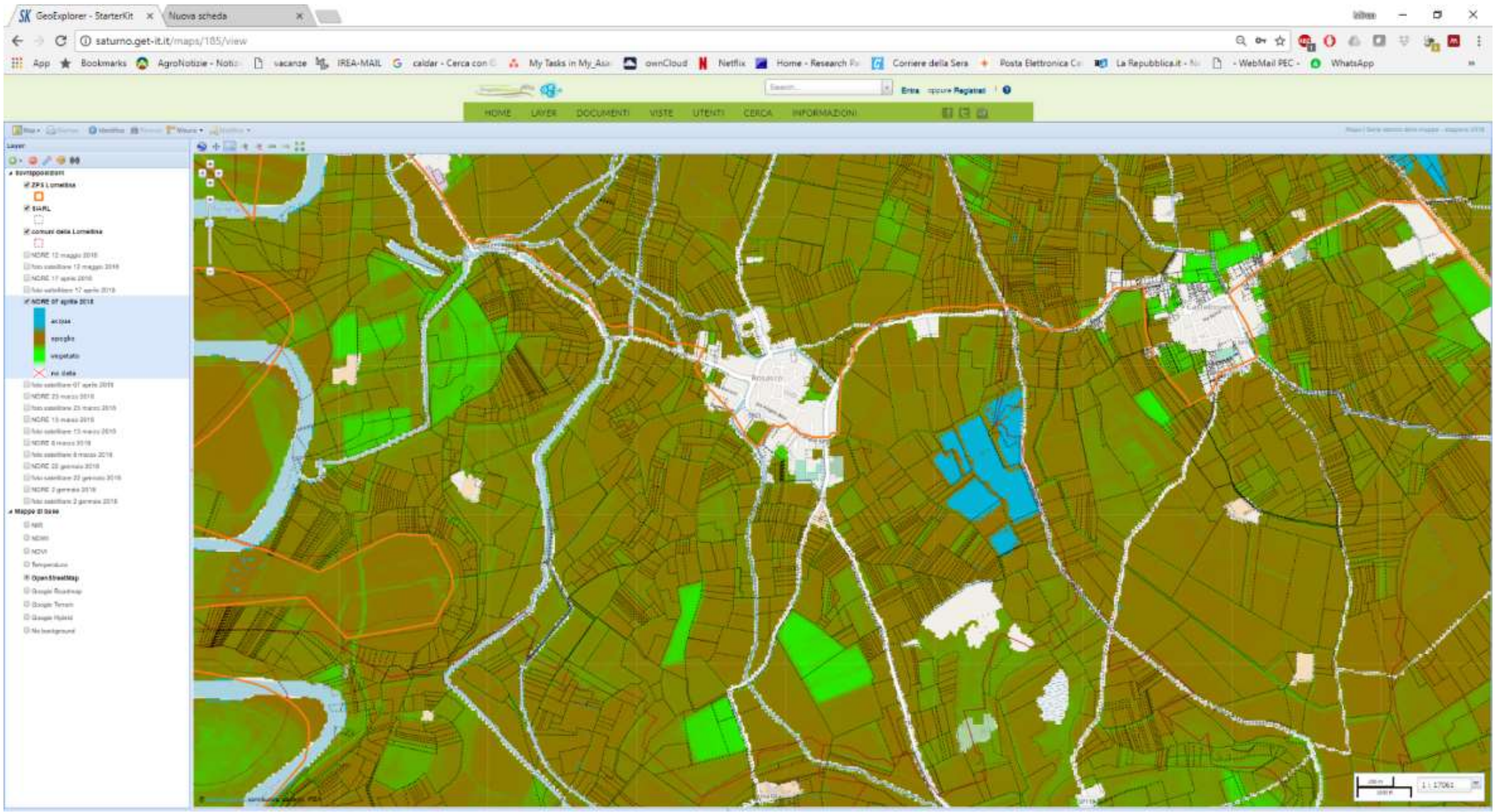
opernicus

PROJECT SATURNO: SUPPORTING VRT FERTILIZATION

ProgettoSaturno

RegioneLombardia
Direzione Generale Agricoltura

PSR 2014 2020 LOMBARDIA L'INNOVAZIONE METTE RADICI



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RegioneLombardia
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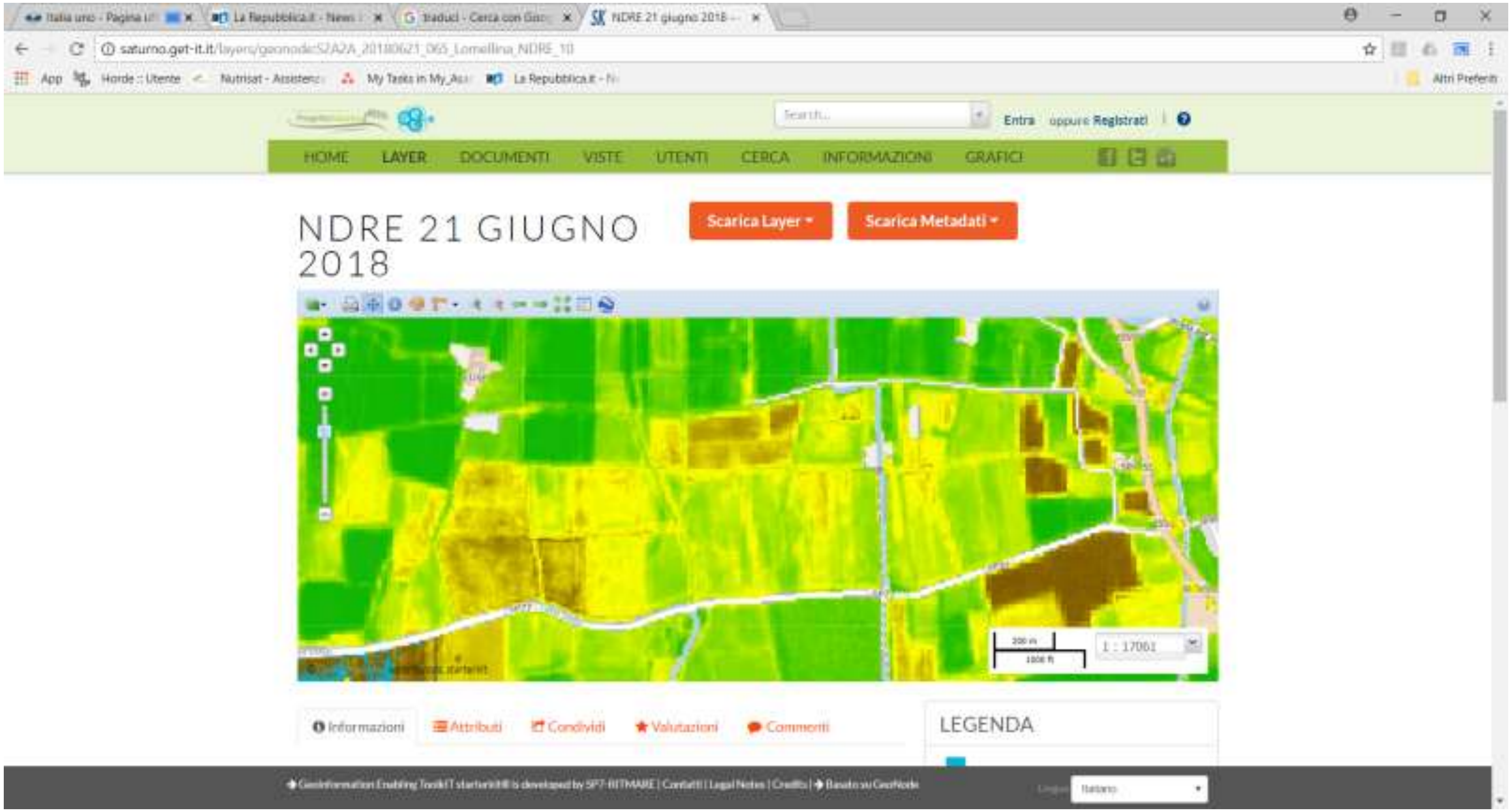
PSR 2014 2020 LOMBARDIA L'INNOVAZIONE METTE RADICI



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PROJECT SATURNO: SUPPORTING VRT FERTILIZATION

ProgettoSaturno

RegioneLombardia
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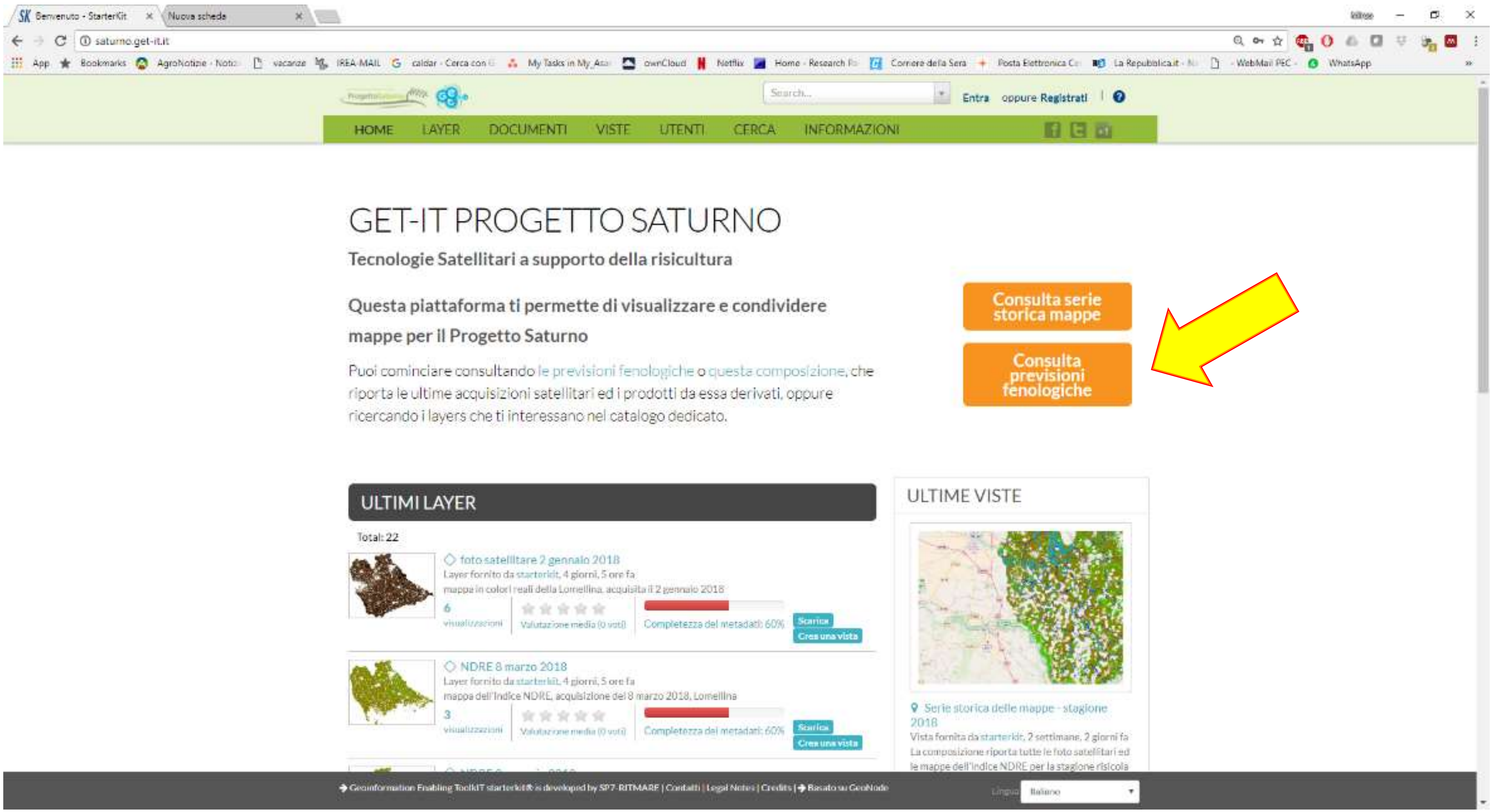
PSR 2014 2020 LOMBARDIA L'INNOVAZIONE METTE RADICI



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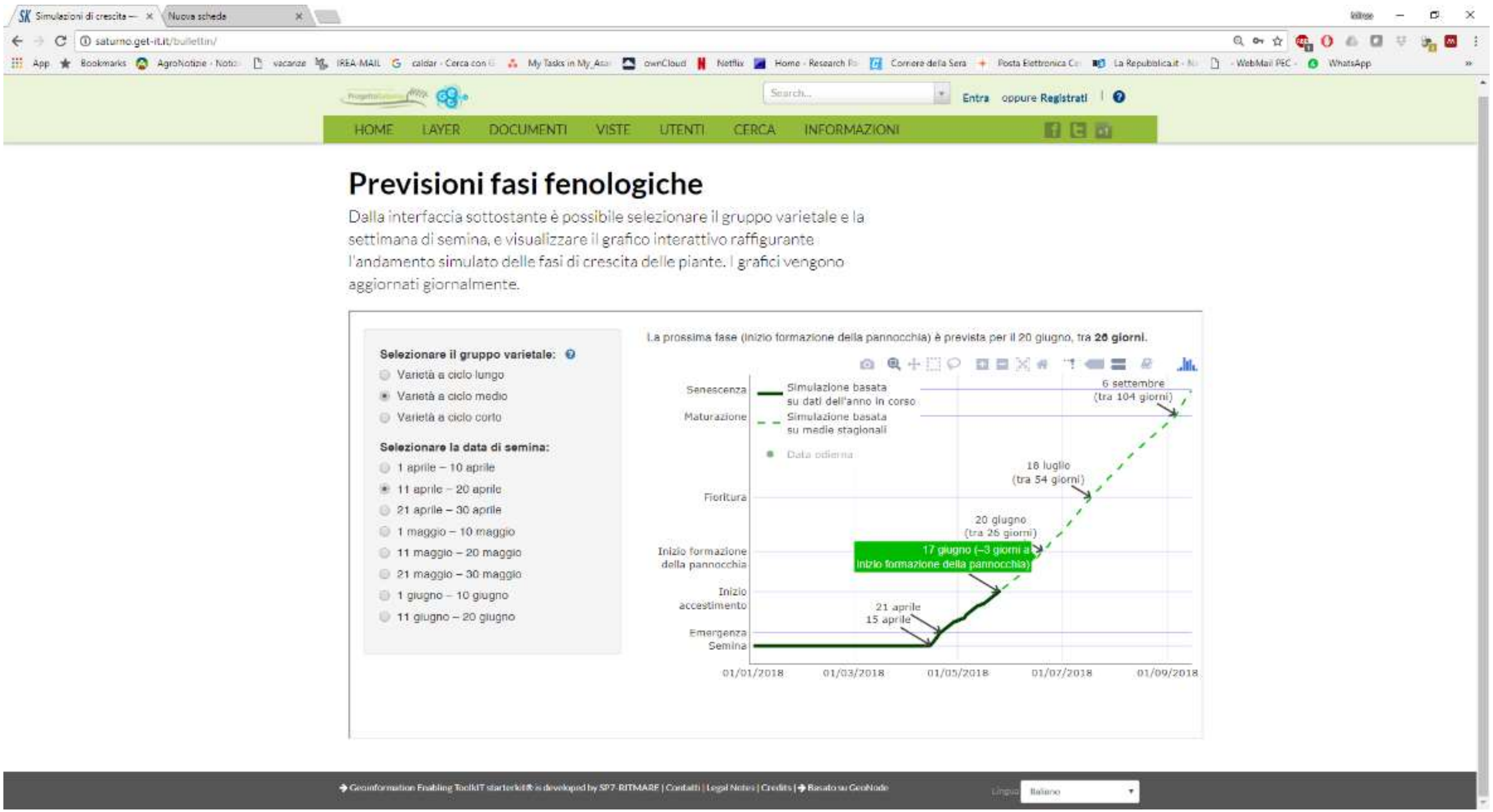
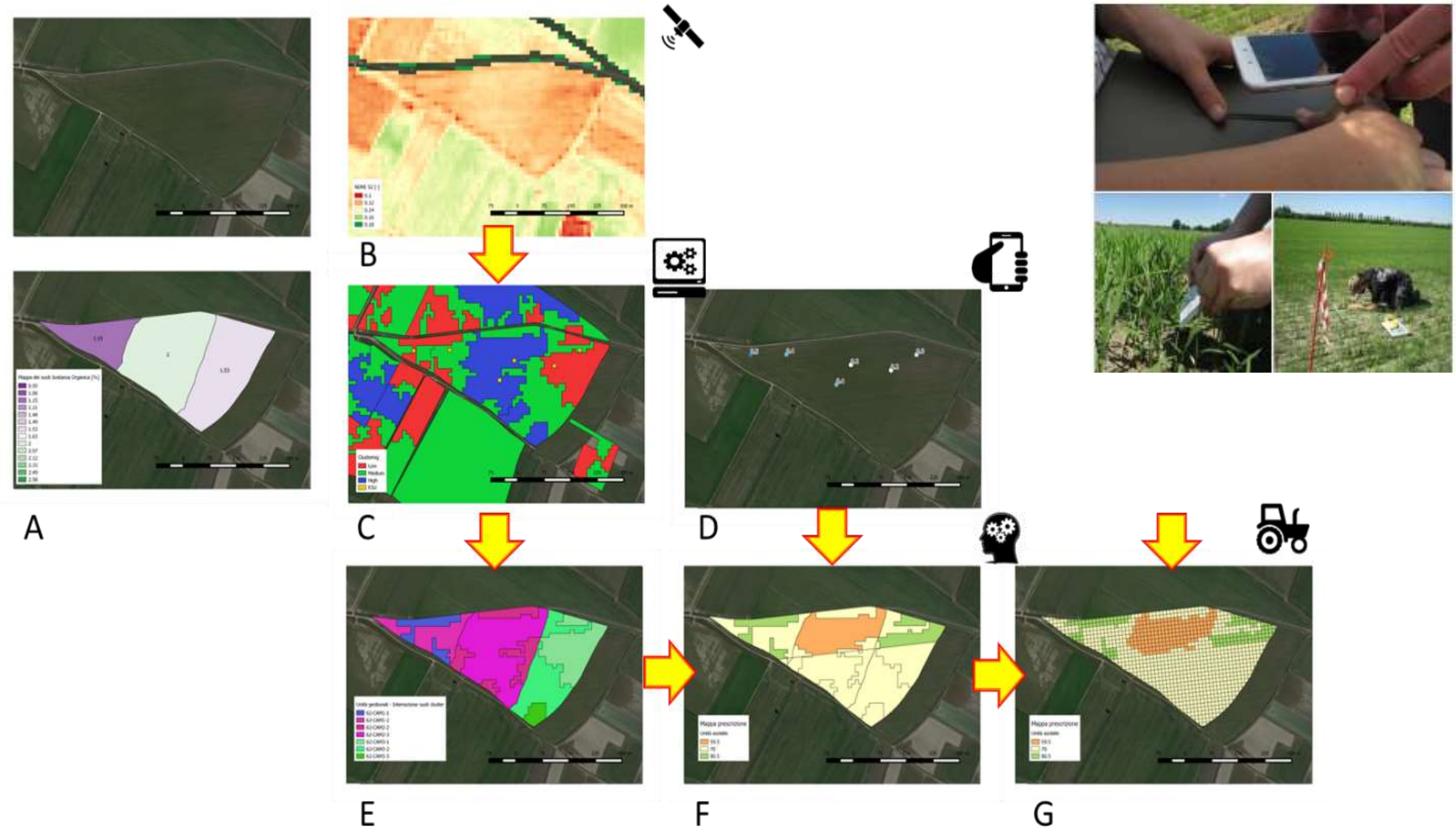
PROJECT SATURNO: SUPPORTING VRT FERTILIZATION

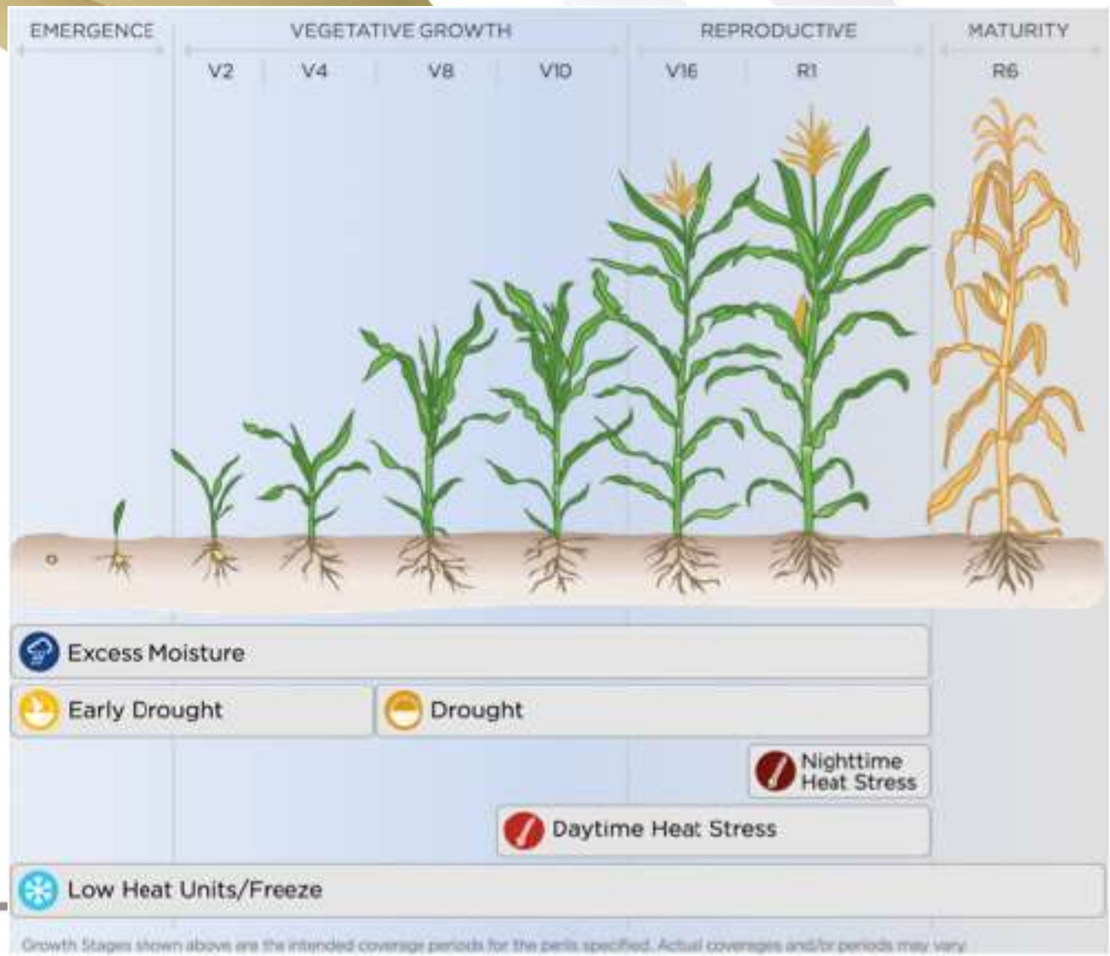


PROJECT SATURNO: SUPPORTING VRT FERTILIZATION

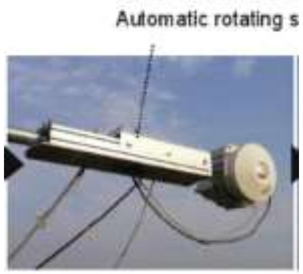


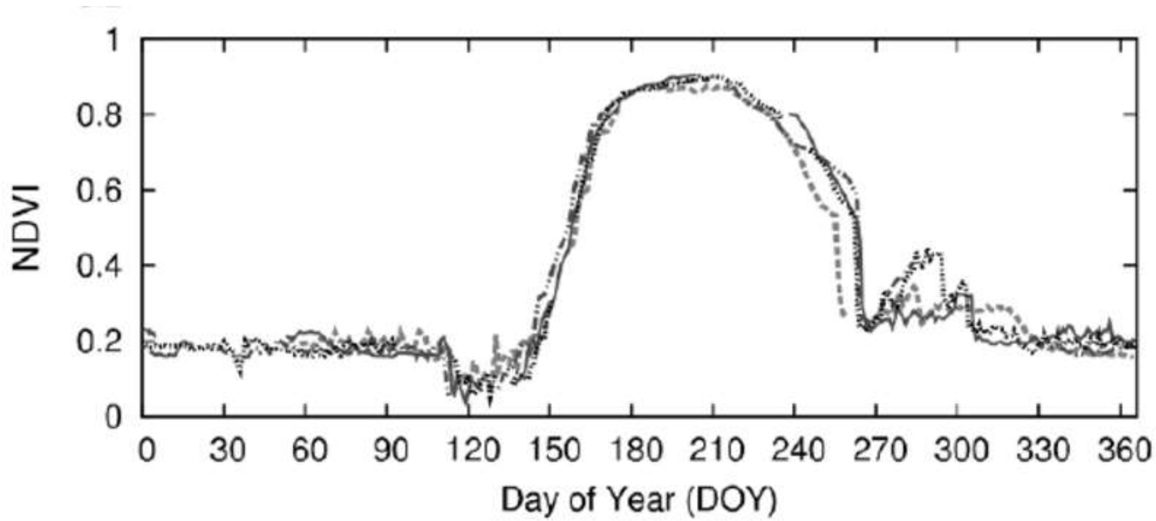
SATELLITE: MODERATE RESOLUTION MONITORING

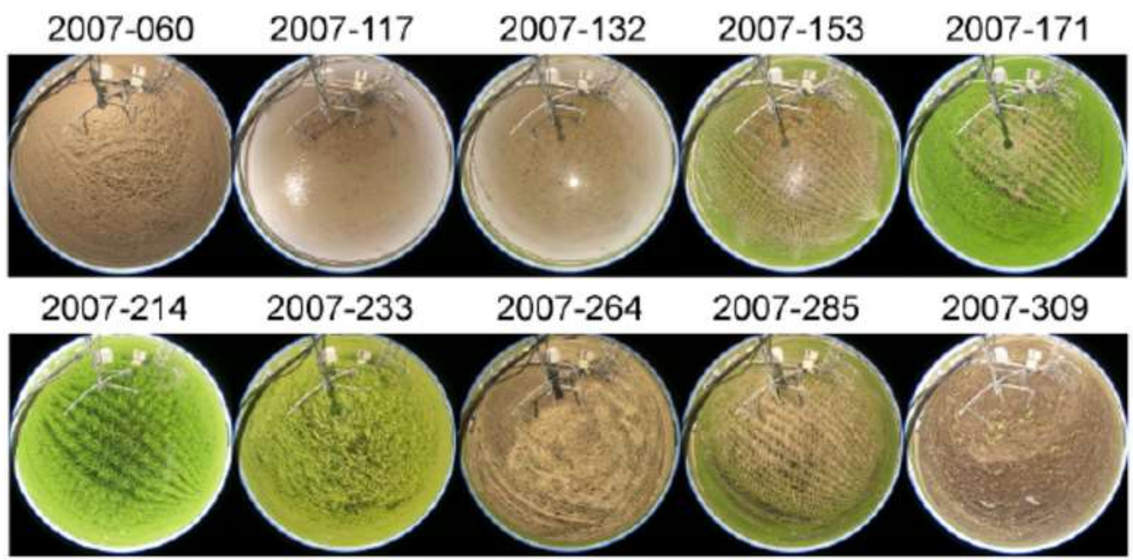
SATELLITE: CROP PHENOLOGY



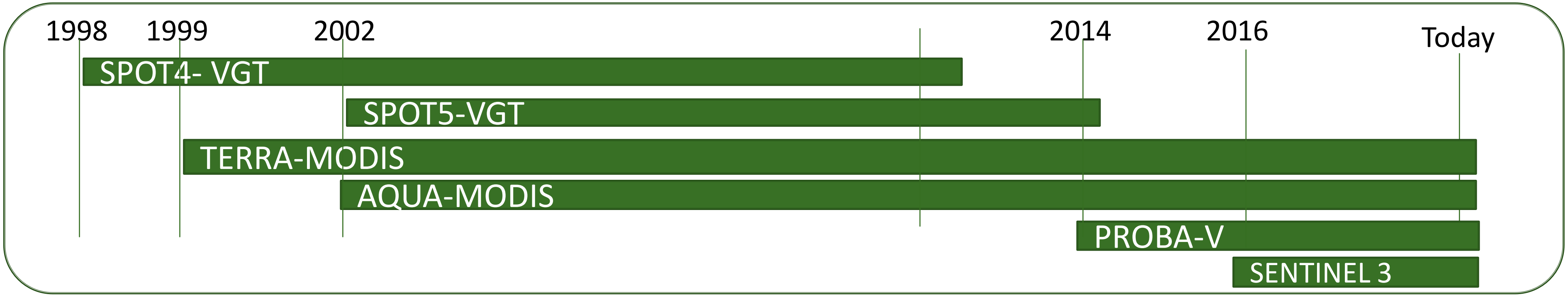
SATELLITE: PHENOLOGICAL ANALYSIS FROM TIME SERIES



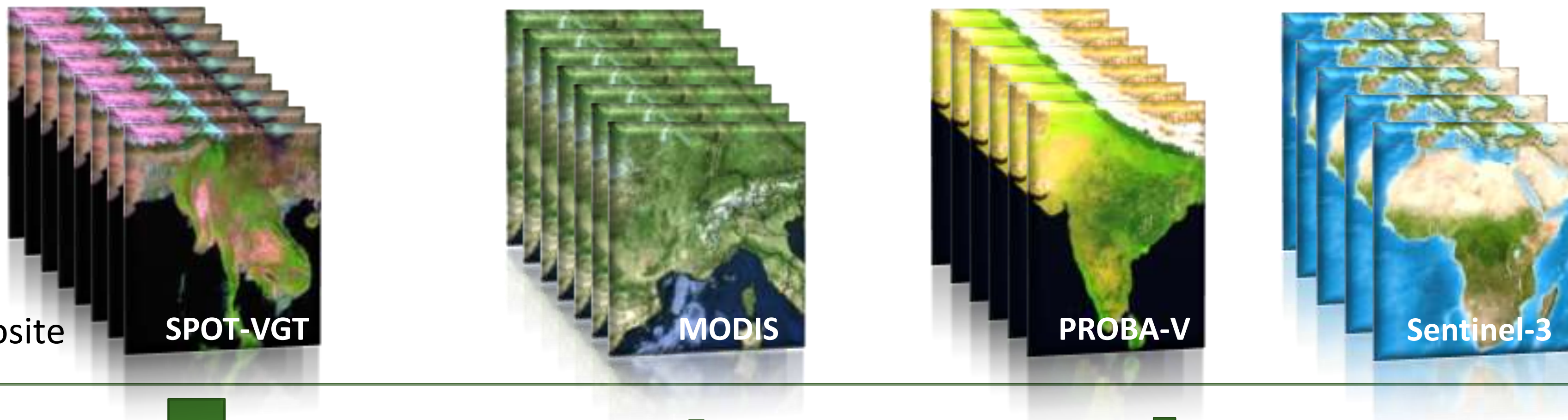




EXISTING DATA AVAILABLE: OPERATIONAL SATELLITE SYSTEMS



Daily
Composite

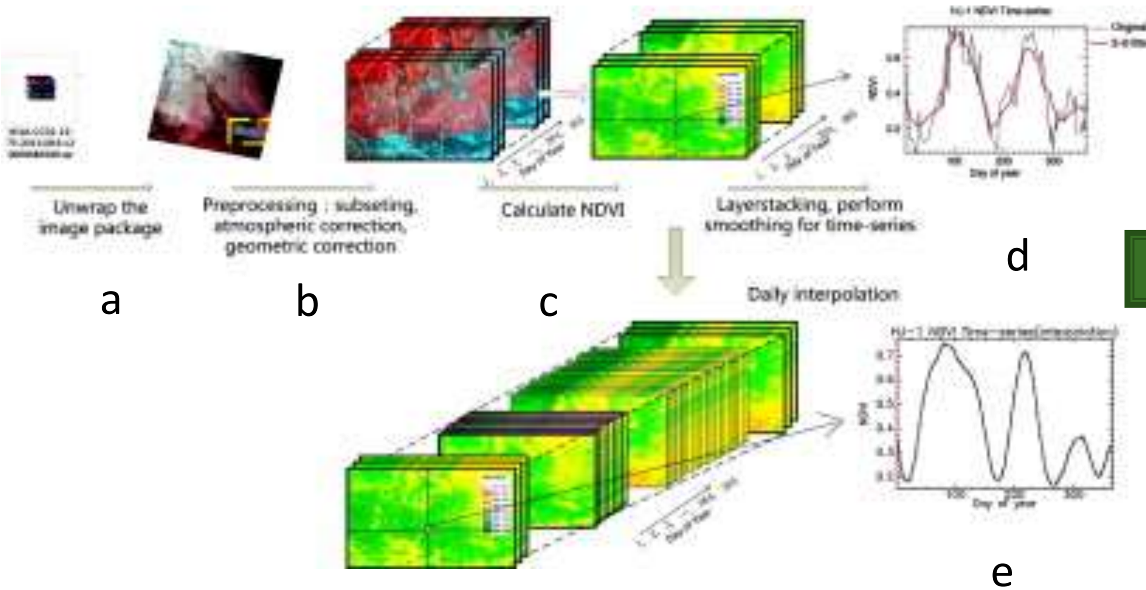


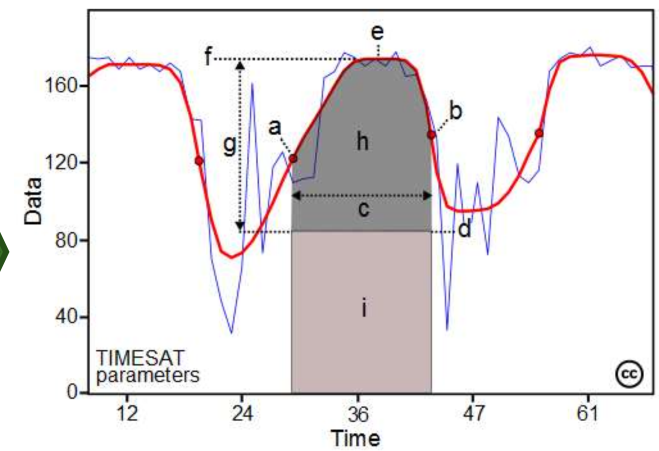
	SPOT-VGT	MODIS	PROBA-V	Sentinel-3
VIS-NIR	1000 m	250 m	333 m	300 m
SWIR	1000 m	500 m	333 m	500 m 1000 m
TIR		1000 m		

Spectral Indices Vegetation growth: NDVI, EVI, etc.- Moisture/water condition: NDWI, NDFI, etc.

TIME SERIES ANALYSIS

- Treat the signal of a vegetation image image stack to estimate information on plant dynamics



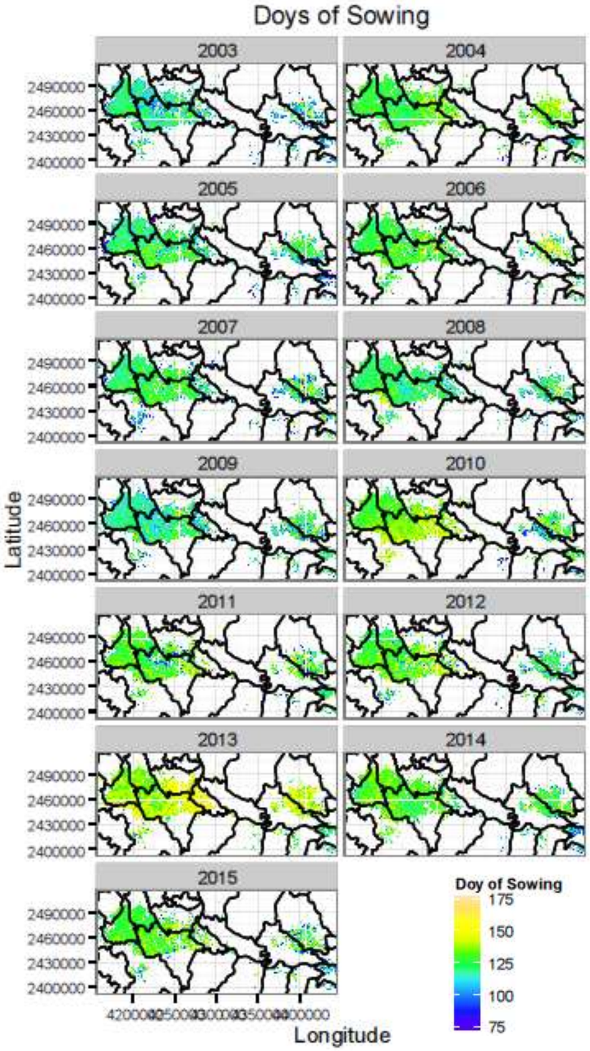


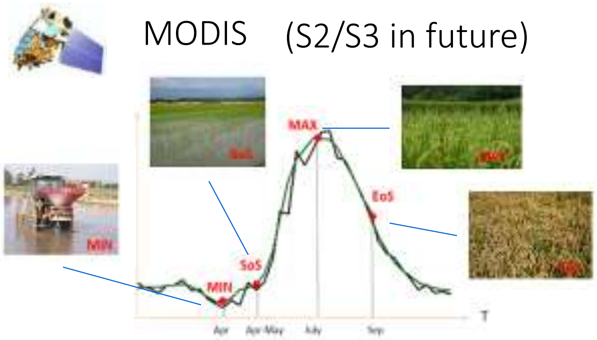
Processing steps:
a) Dowload dati, b) pre-processamento, c) calcolo NDVI, d) smoothing del segnale, e) interpolazione giornaliera

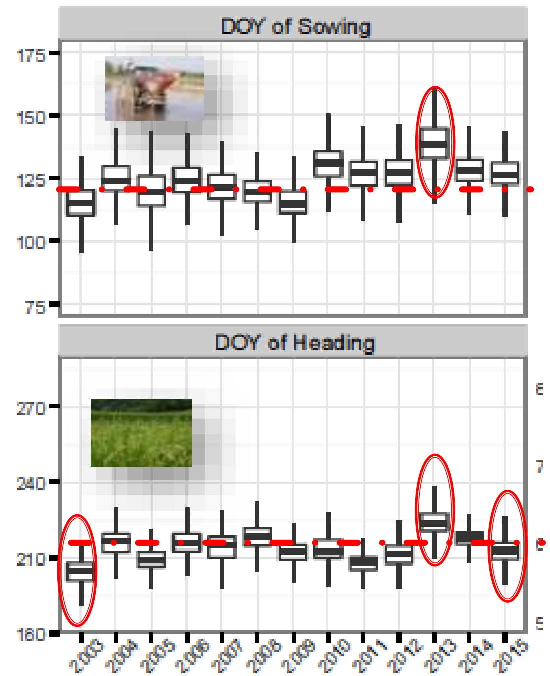
Parameter:
(a) beginning of season, (b) end of season, (c) length of season, (d) base value, (e) time of middle of season, (f) maximum value, (g) amplitude, (h) small integrated value, (h+i) large integrated value.

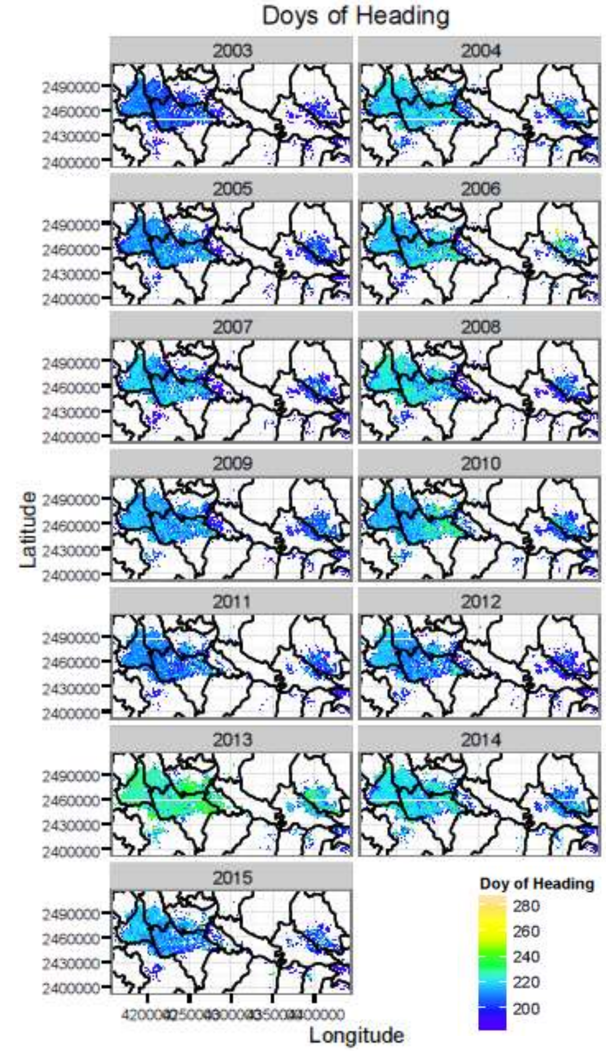
CROP MONITORING: SOWING PERIOD AND PHENOLOGY

- Informazioni sintentiche sulla variabilità spaziale e inter-annuale delle pratiche agricole









CROP MONITORING: SOWING PERIOD AND PHENOLOGY

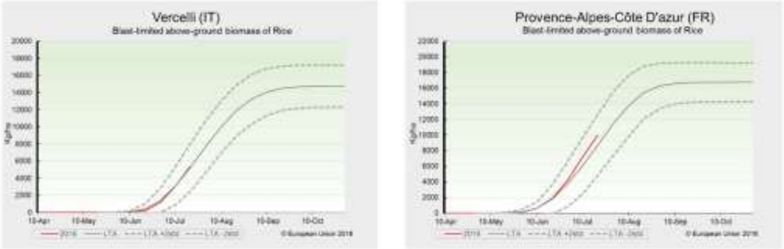
- Informazioni sinte … e pratiche agricole

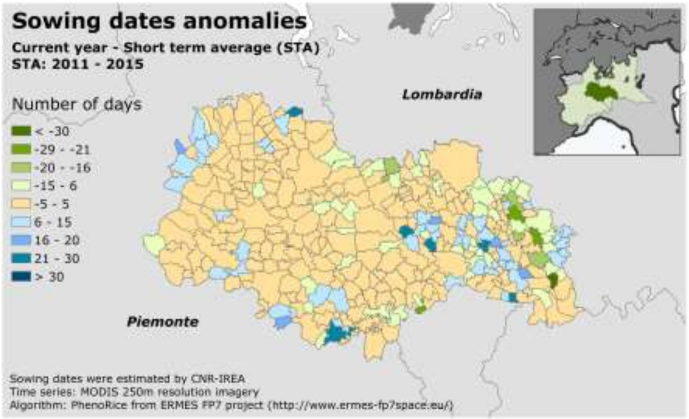
3.2 European Union – rice producing countries

Italy and France

Crop growth conditions close to average

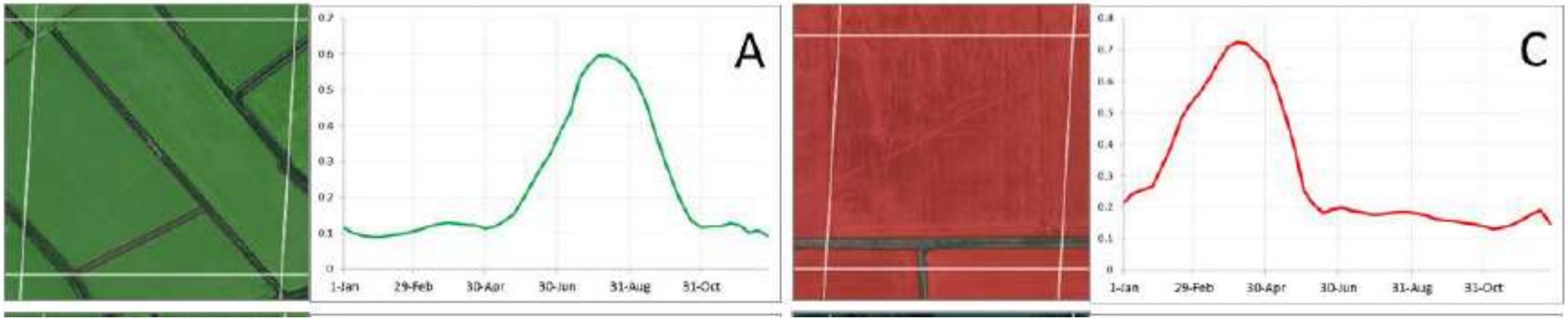
Meteorological conditions during the growing season have been generally favourable in the main rice-producing areas of Italy - *Piemonte* and *Lombardia*. Some temperature fluctuations occurred since the end of June, but cumulated active temperatures during the growing season are close to the long-term average. Rainfall has been near average in Piemonte and above average in *Lombardia*. Rice was sown on time and is still in the vegetative phase, though with some local variations, see map. Reflecting these weather conditions, indicators based on remote sensing analysis and model simulations, such as leaf area expansion, total biomass and risk of fungal disease, are close to seasonal values. Therefore, average yields are expected for these regions. Average meteorological conditions also characterised the main rice-producing areas of France (*Languedoc-Roussillon* and *Provence-Alpes-Côte d'Azur*). There, however, radiation levels were above average, resulting in slightly above-average biomass accumulation and lower risk of blast infection. The yield forecast is still close to the five-year average but well above last year's value.



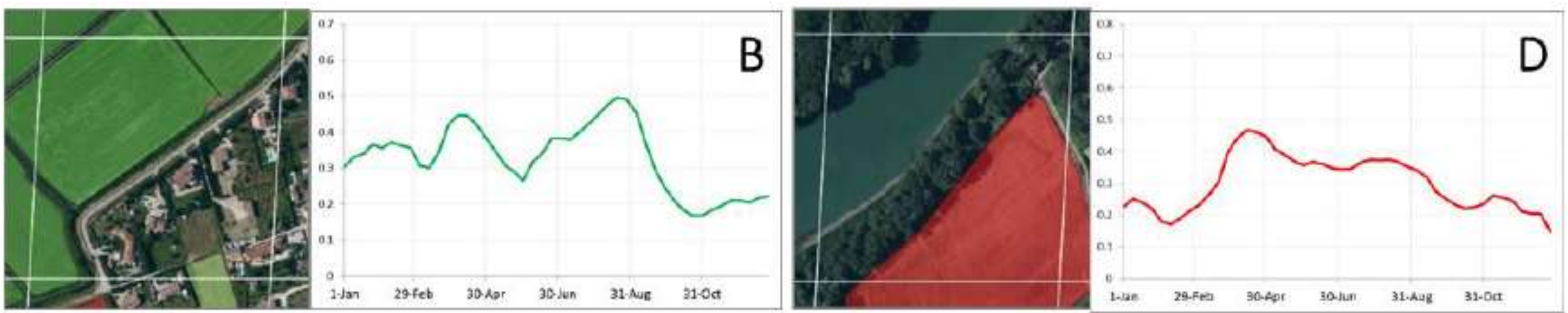


Criticalities for field level monitoring

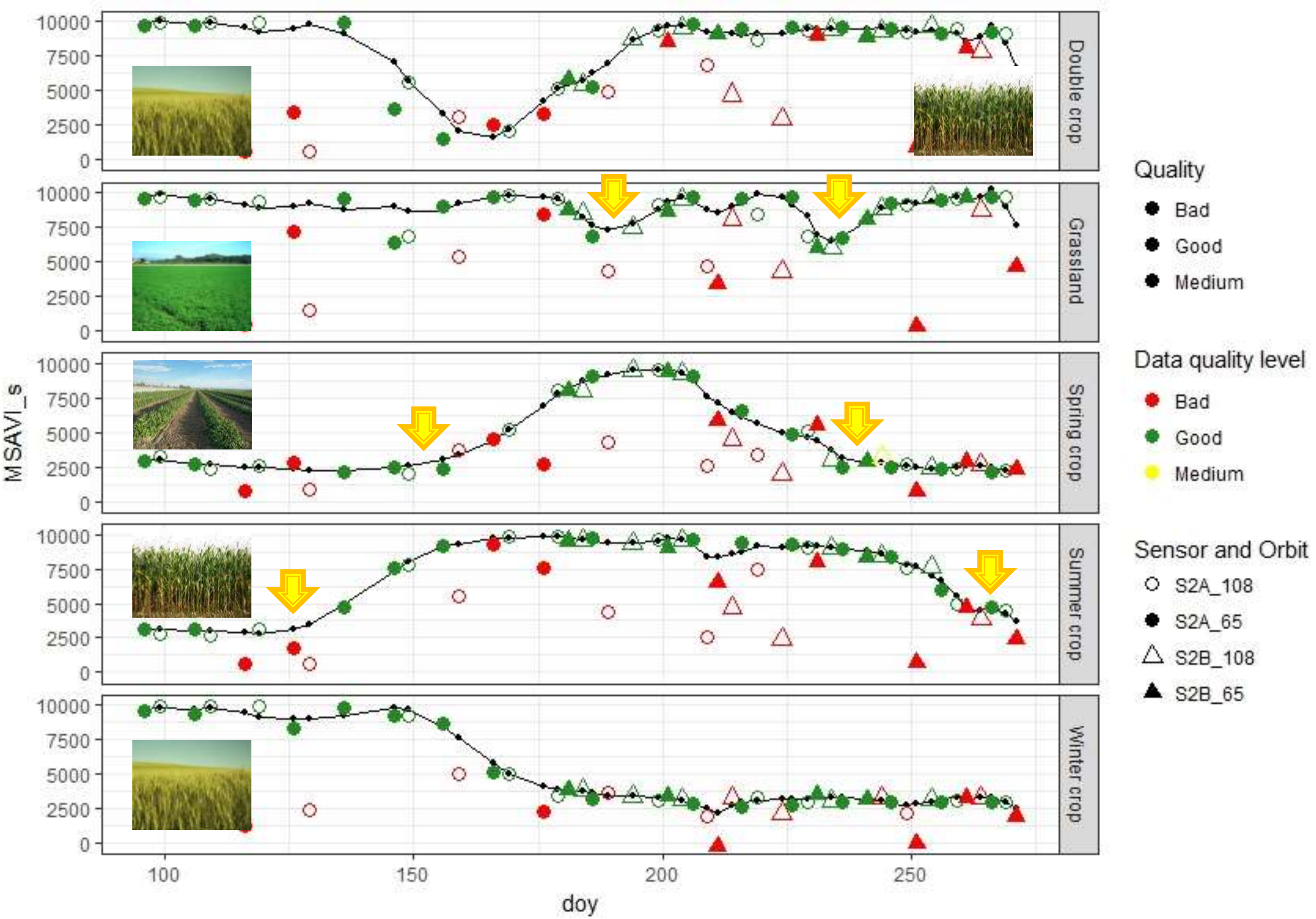
Very good results when crops entirely cover pixe



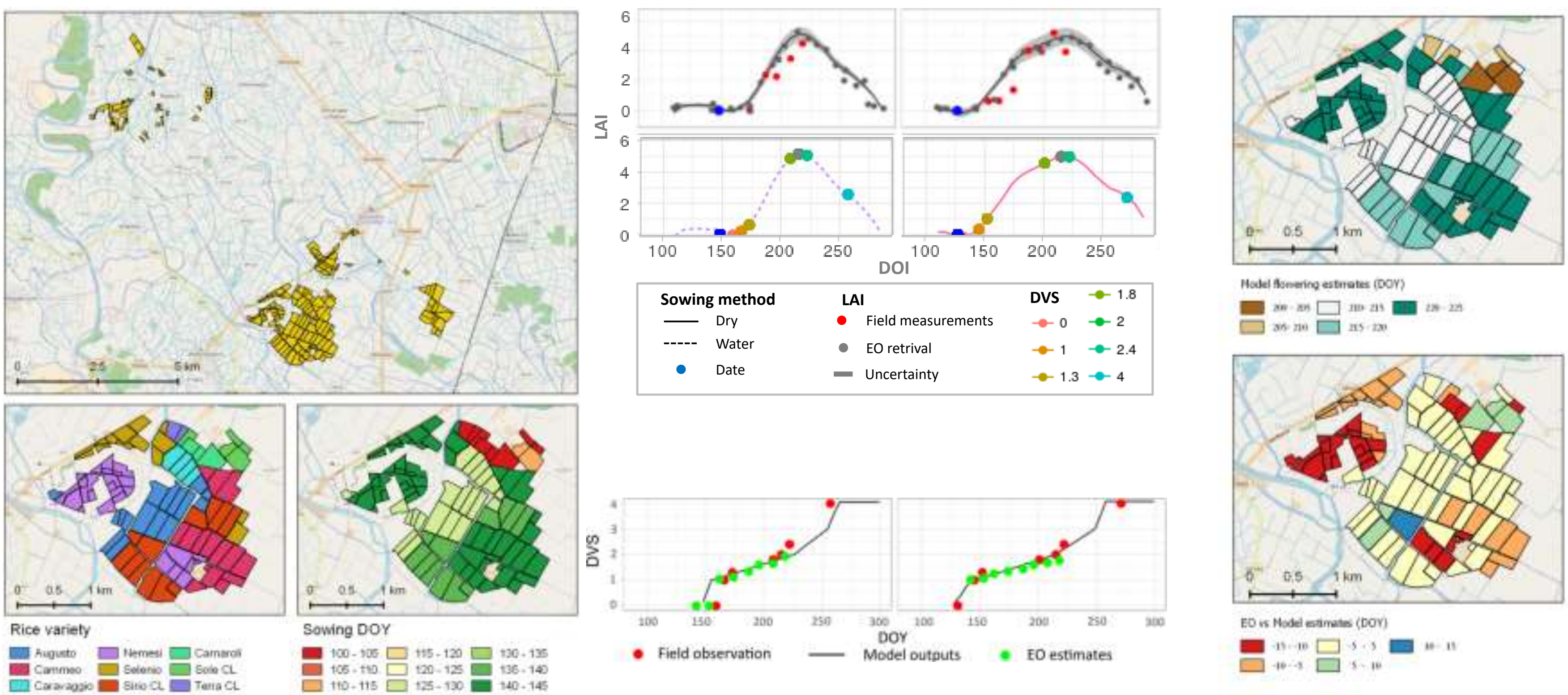
Problems for mixed pixel



Near real time (NRT) crop monitoring at parcel scale

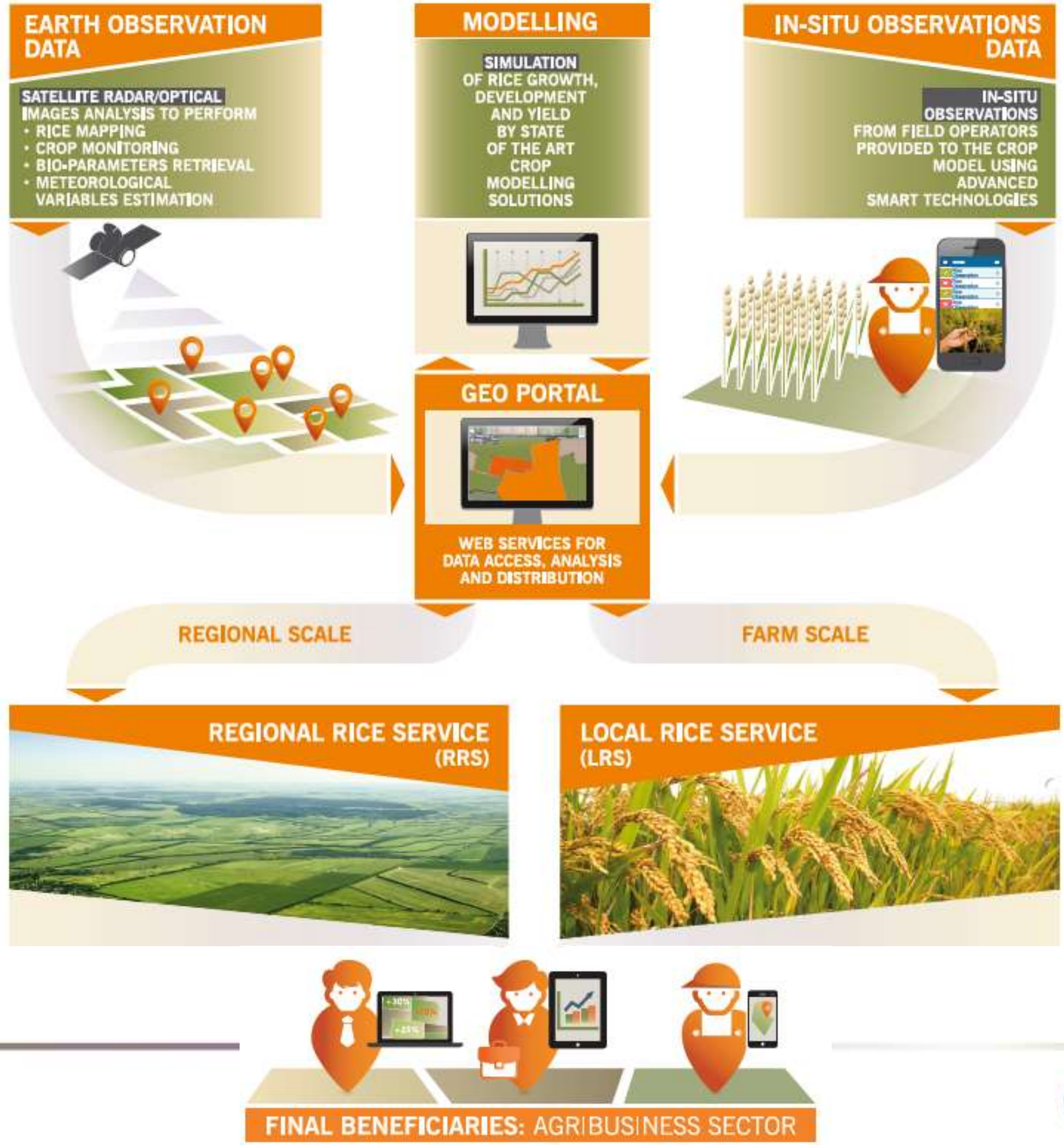


RICE PHENOLOGICAL STAGE OCCURENCE ESTIMATES AT PARCEL LEVEL



Mirco Boschetti; Lorenzo Busetto, Luigi Ranghetti; Francisco Javier García-Haro; Manuel Campos-Taberner; Roberto Confalonieri;
TESTING MULTI-SENSORS TIME SERIES OF LAI ESTIMATES TO MONITOR RICE PHENOLOGY: PRELIMINARY RESULTS – IGARSS 2018

A Copernicus services Concept

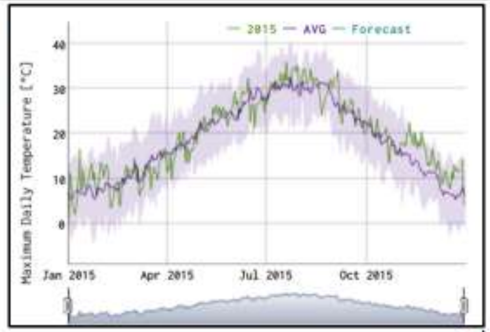


RRS → Crop monitoring platform (http://ermes.dlsi.uji.es/prototype/geoportal/login.html)

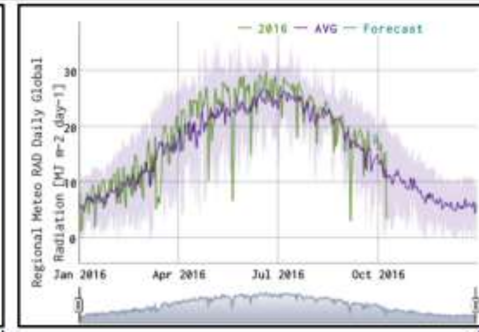
ERMES EARTH OBSERVATION MODEL BASED RICE INFORMATION SERVICE

Crop identification a)

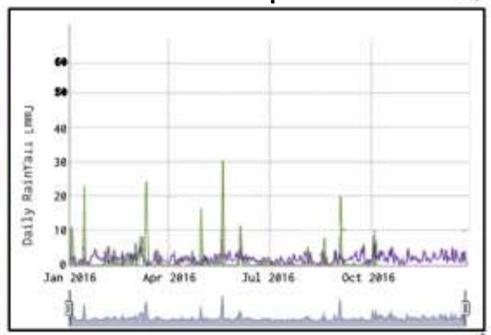
Crop phenology b)



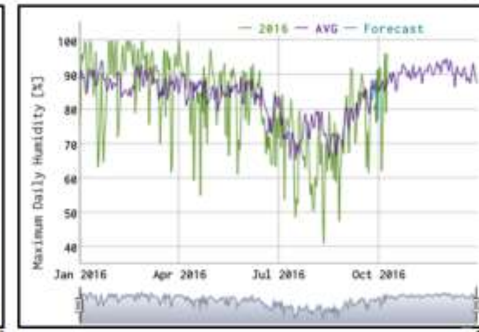
Max Temperature c)



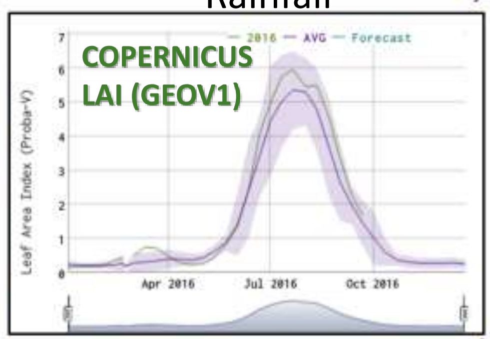
Radiation d)



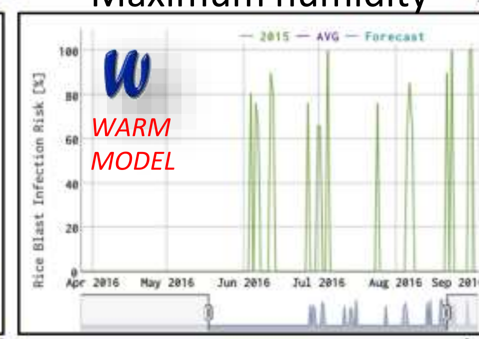
Rainfall e)



Maximum humidity f)



LAI g)



Biotic Risk h)

RRS → FROM DATA TO BULLETTINS

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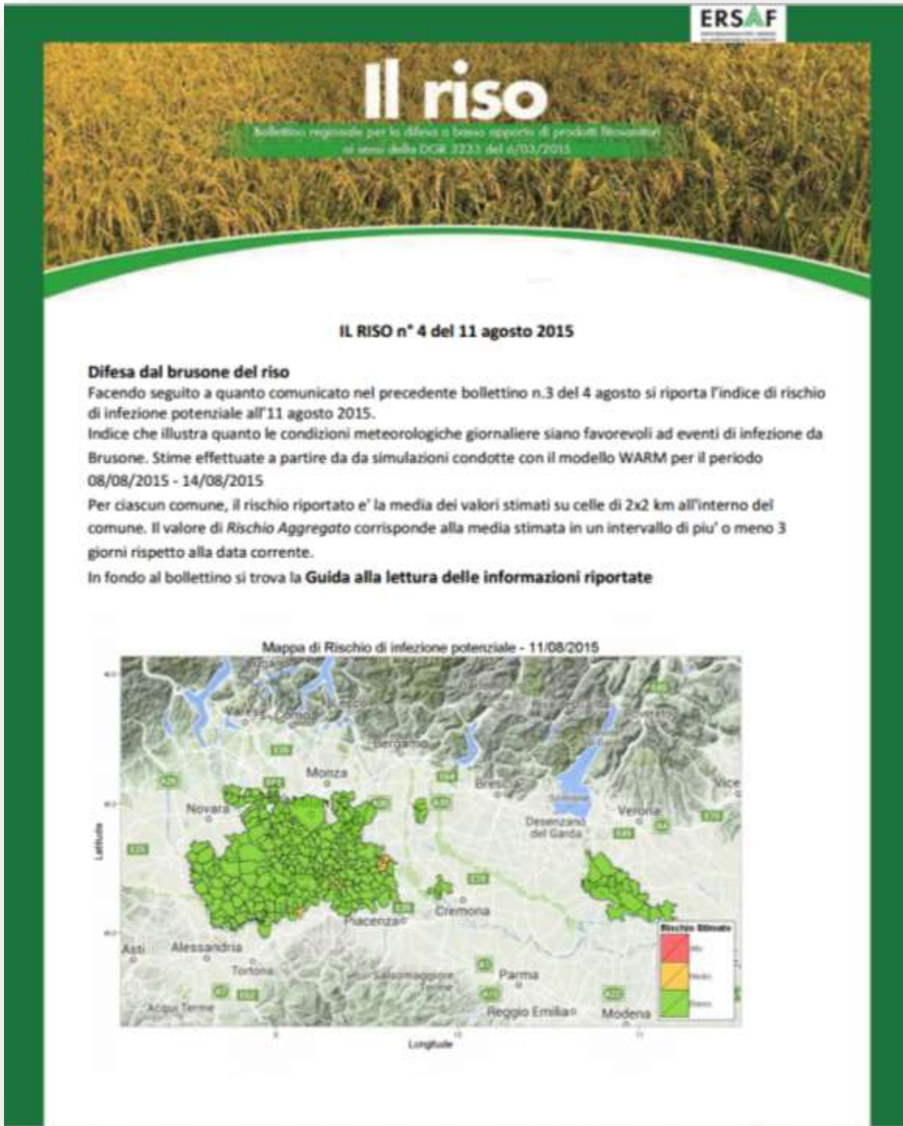
AN EARTH OBSERVATION MODEL BASED RICE INFORMATION SERVICE



ERSAF

Il riso

Bollettino regionale per la difesa a basso apporto di prodotti fitosanitari ai sensi della DGR 3233 del 6/03/2015

IL RISO n° 4 del 11 agosto 2015

Difesa dal brusone del riso

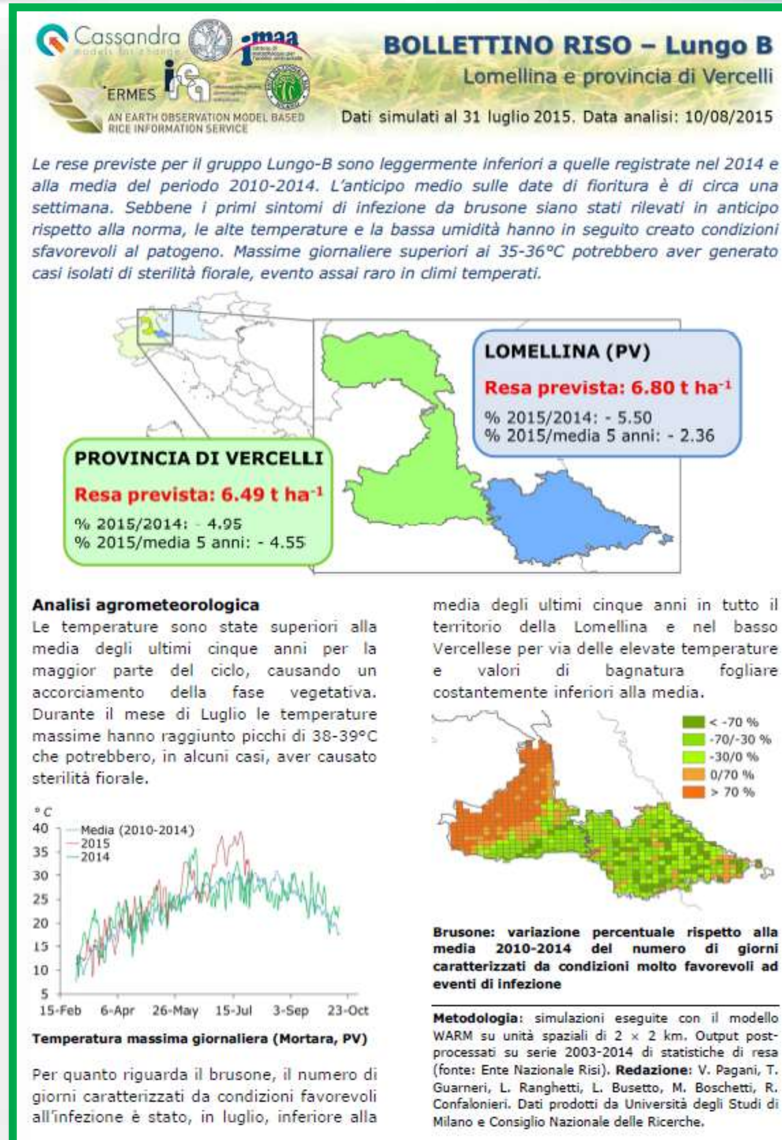
Facendo seguito a quanto comunicato nel precedente bollettino n.3 del 4 agosto si riporta l'indice di rischio di infezione potenziale all'11 agosto 2015.

Indice che illustra quanto le condizioni meteorologiche giornaliere siano favorevoli ad eventi di infezione da Brusone. Stime effettuate a partire da da simulazioni condotte con il modello WARM per il periodo 08/08/2015 - 14/08/2015

Per ciascun comune, il rischio riportato e' la media dei valori stimati su celle di 2x2 km all'interno del comune. Il valore di *Rischio Aggregato* corrisponde alla media stimata in un intervallo di piu' o meno 3 giorni rispetto alla data corrente.

In fondo al bollettino si trova la **Guida alla lettura delle informazioni riportate**

Mappa di Rischio di infezione potenziale - 11/08/2015



Cassandra models for change

ERMES
AN EARTH OBSERVATION MODEL BASED RICE INFORMATION SERVICE

BOLLETTINO RISO – Lungo B

Lomellina e provincia di Vercelli

Dati simulati al 31 luglio 2015. Data analisi: 10/08/2015

Le rese previste per il gruppo Lungo-B sono leggermente inferiori a quelle registrate nel 2014 e alla media del periodo 2010-2014. L'anticipo medio sulle date di fioritura è di circa una settimana. Sebbene i primi sintomi di infezione da brusone siano stati rilevati in anticipo rispetto alla norma, le alte temperature e la bassa umidità hanno in seguito creato condizioni sfavorevoli al patogeno. Massime giornaliere superiori ai 35-36°C potrebbero aver generato casi isolati di sterilità fiorale, evento assai raro in climi temperati.

Analisi agrometeorologica

Le temperature sono state superiori alla media degli ultimi cinque anni per la maggior parte del ciclo, causando un accorciamento della fase vegetativa. Durante il mese di Luglio le temperature massime hanno raggiunto picchi di 38-39°C che potrebbero, in alcuni casi, aver causato sterilità fiorale.

Temperatura massima giornaliera (Mortara, PV)

Per quanto riguarda il brusone, il numero di giorni caratterizzati da condizioni favorevoli all'infezione è stato, in luglio, inferiore alla media degli ultimi cinque anni in tutto il territorio della Lomellina e nel basso Vercellese per via delle elevate temperature e valori di bagnatura fogliare costantemente inferiori alla media.

Brusone: variazione percentuale rispetto alla media 2010-2014 del numero di giorni caratterizzati da condizioni molto favorevoli ad eventi di infezione

Metodologia: simulazioni eseguite con il modello WARM su unità spaziali di 2 × 2 km. Output post-processati su serie 2003-2014 di statistiche di resa (fonte: Ente Nazionale Risi). **Redazione:** V. Pagani, T. Guarneri, L. Ranghetti, L. Busetto, M. Boschetti, R. Confalonieri. Dati prodotti da Università degli Studi di Milano e Consiglio Nazionale delle Ricerche.

Cassandra models for change

Copernicus

LRS: Crop management platform (http://ermes.dlsi.uji.es/prototype/geoportal/login.html)

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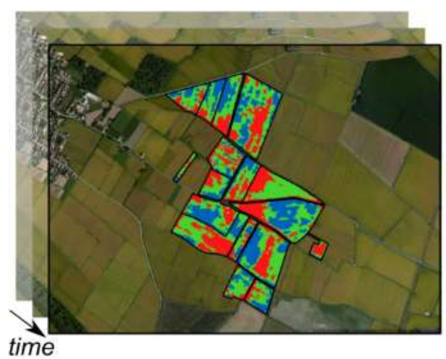
AN EARTH OBSERVATION MODEL BASED RICE INFORMATION SERVICE

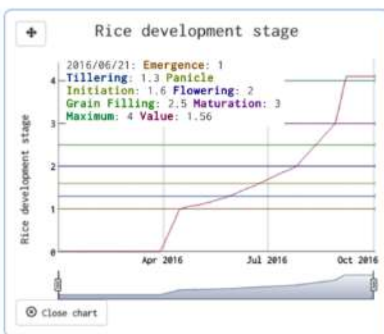
a)

b) Constant Pattern map

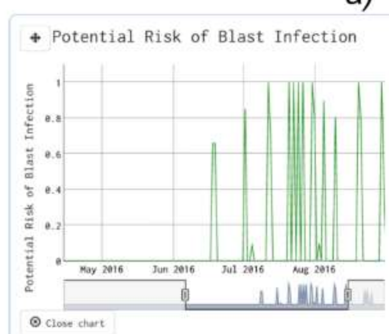
c) Early season field homogenety
SAR data (CSK/S1)



d) Seasonal Pattern maps
Optical data (RE)



Phenological stages e)



Biotic Risk f)

Copernicus