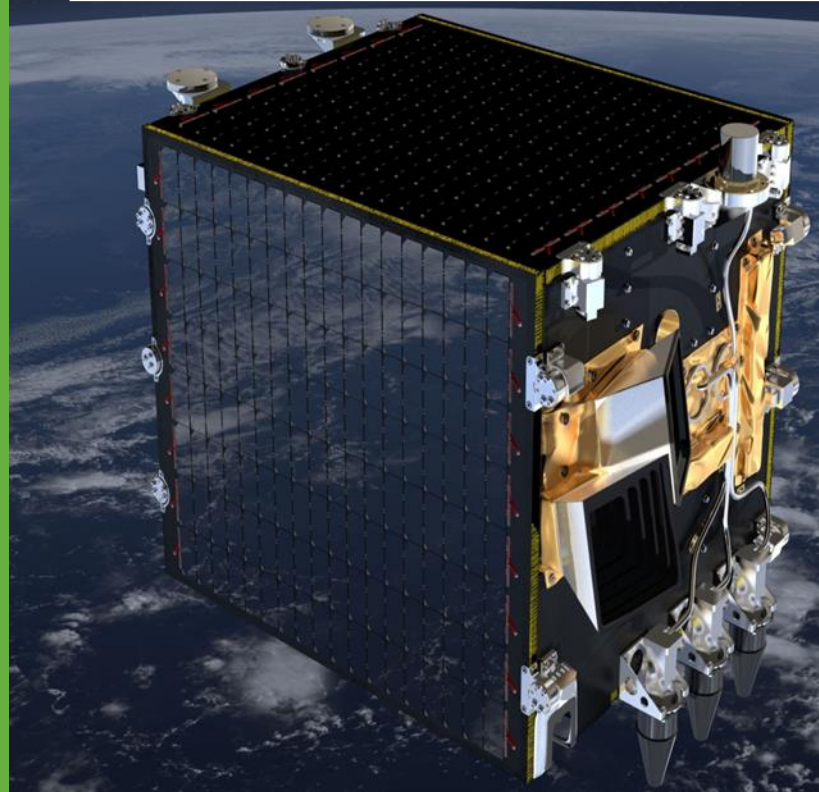
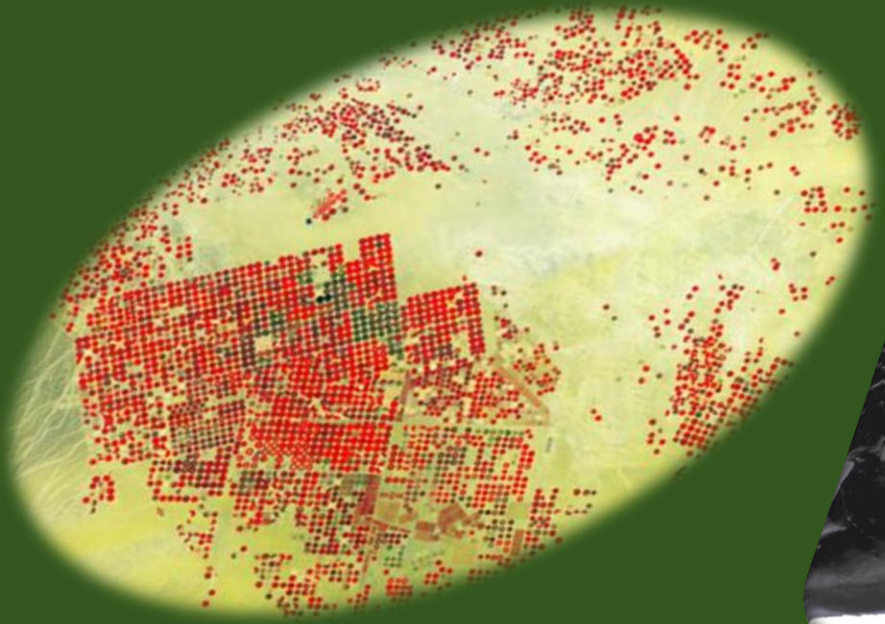
DROUGHT IMPACT: DATA AVAILABILITY AND USE FOR ESTIMATION OF DROUGHT RISK

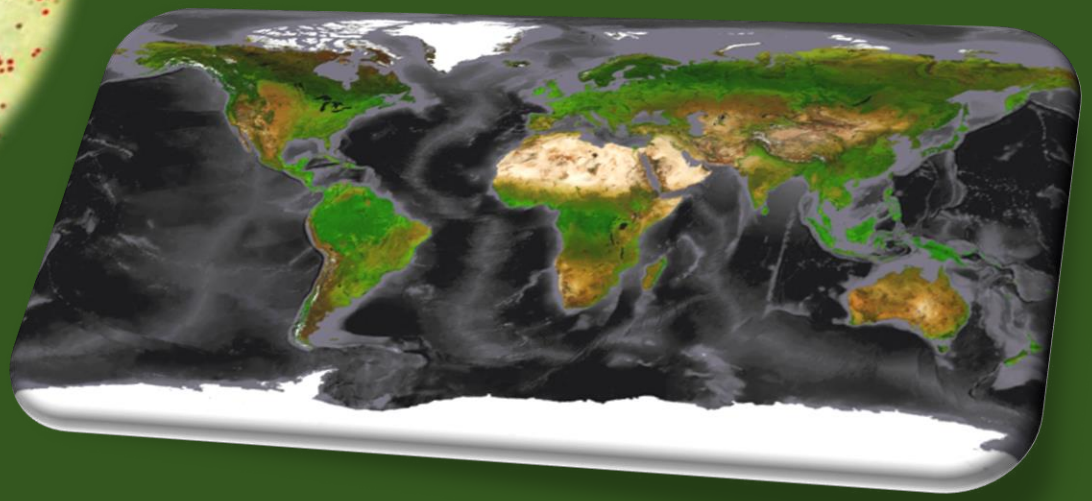
Dr.ir. Anne Gobin

Drought Risk Assessment
6-8 November 2018
Budapest

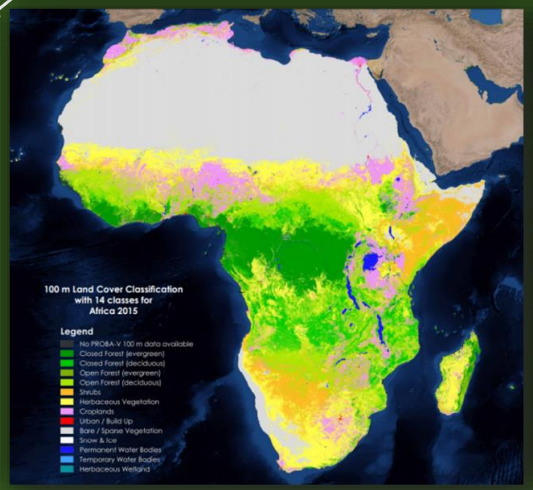


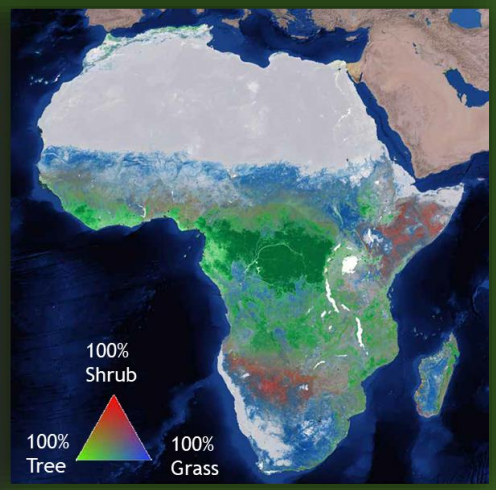
Acknowledgements:
MERINOVA, cordex.be, iPOT, BELCAM, AFTER
Colleagues from VITO Remote Sensing Unit

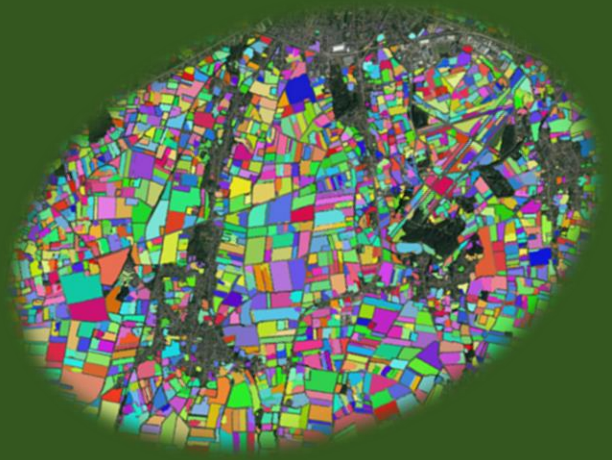




CURRENT DATA SERVICES @ VITO







MONITORING WITH DIFFERENT TYPES OF SENSORS

- Current services range from very high to very low resolution monitoring, increasingly combined with statistical information and other geo-data

RESOLUTION	VERY LOW	LOW	MEDIUM	HIGH	VERY HIGH
Pixel size	±5 km	±1 km	250-500m	10-30m	1-5m
Frequency					
Image size					
Examples					

Scales: Global ← Continental ← National ← Regional ←

Field + *UAV*

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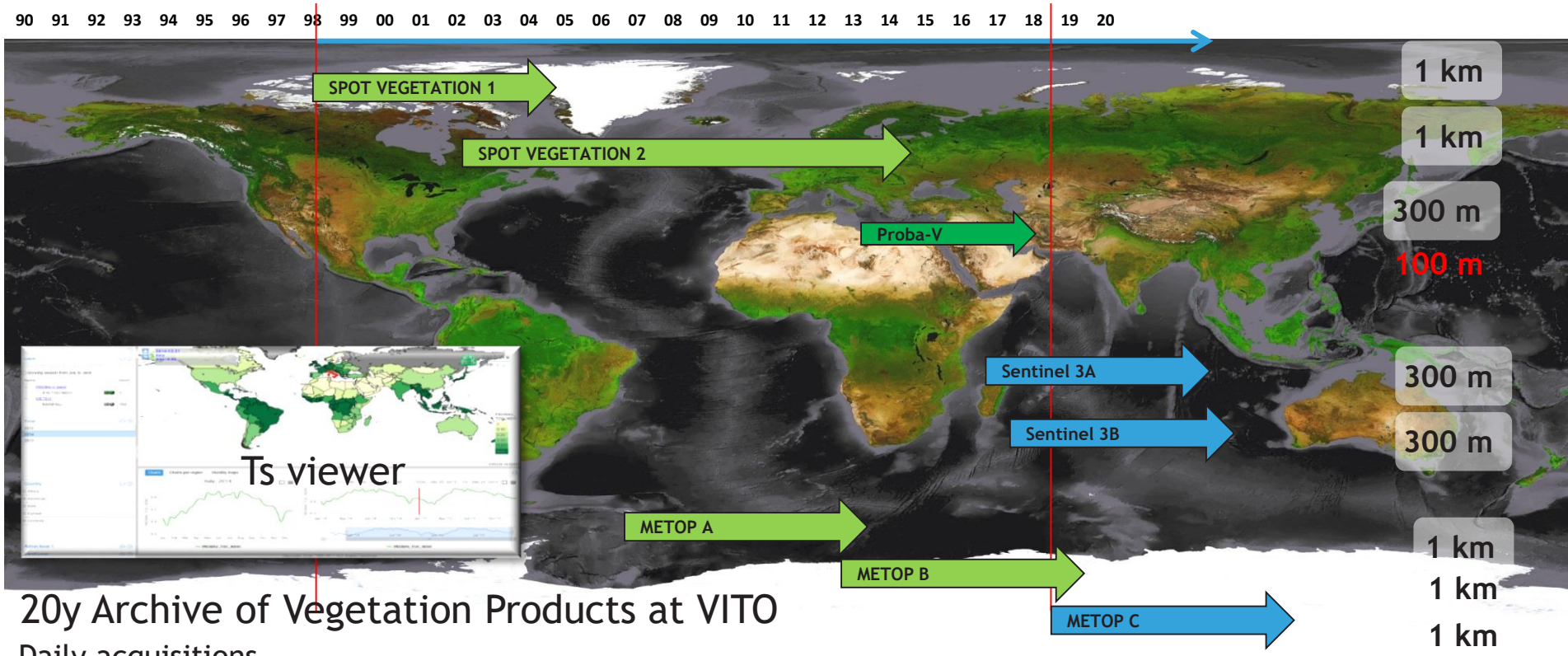
SATELLITE DATA ARCHIVES AT LOW RESOLUTION

http://www.vito-eodata.be (free download of products 5PB)

http://proba-v-mep.esa.int/ (Jupyter Notebooks)



20y Archive of Vegetation Products at VITO

Daily acquisitions
10-daily cloudfree composite
Worldwide harmonised data (cross-boundary)!

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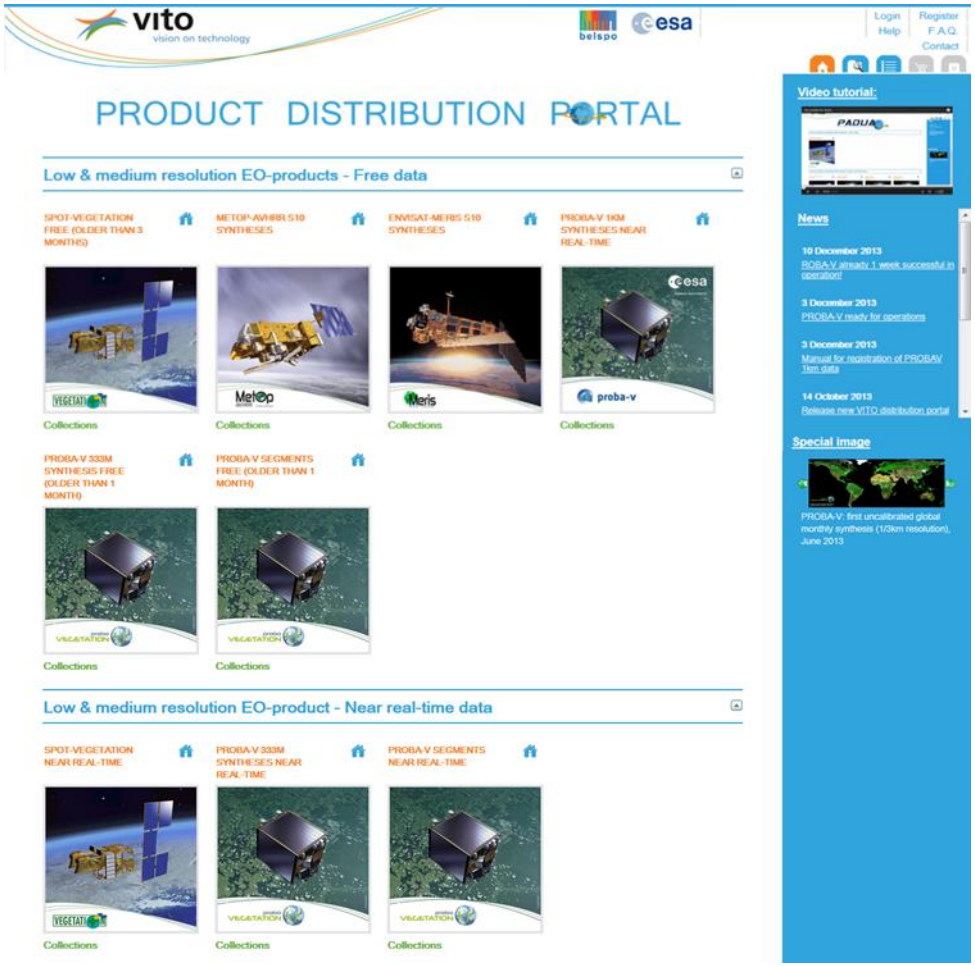
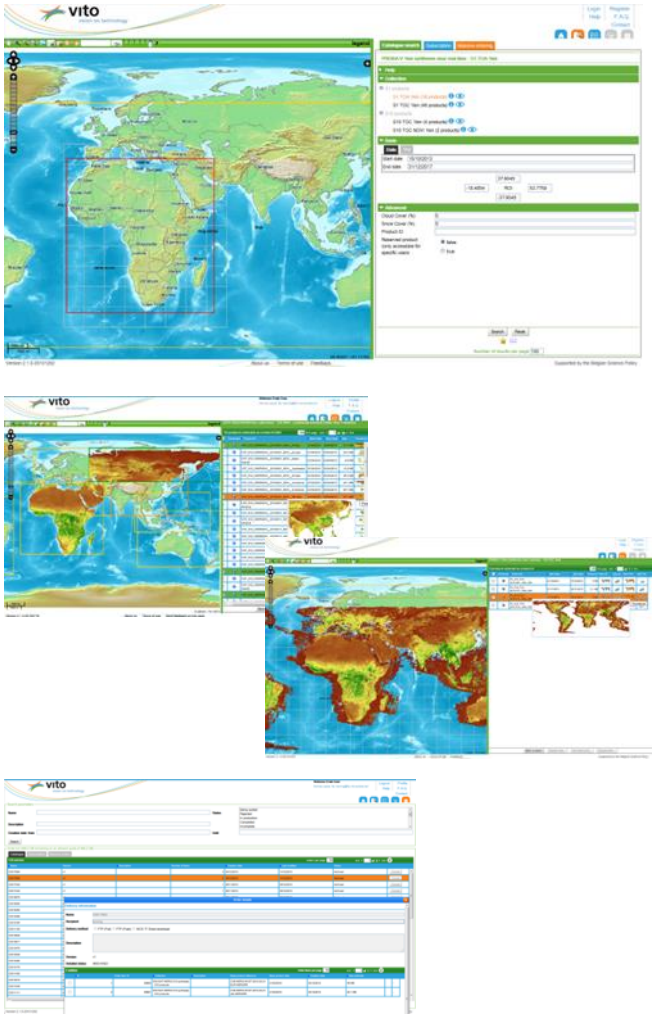
FREE DOWNLOAD OF PRODUCTS

http://www.vito-eodata.be





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COPERNICUS GLOBAL LAND MONITORING SERVICE

https://land.copernicus.eu/

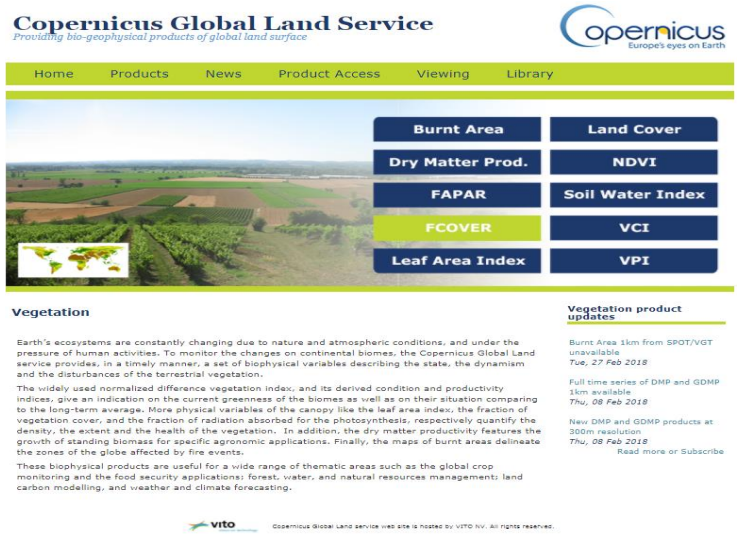

Global


Pan-European


Local


Reference data

- Vegetation
- Energy
- Water
- Cryosphere
- Hot Spots



- Leaf Area Index
- Fraction of Absorbed Photosynthetically Active Radiation (FAPAR)
- Fraction of vegetation cover (FCOVER)
- Normalized Difference Vegetation Index (NDVI)
- Vegetation Condition Index
- Vegetation Productivity Index
- Dry Matter Productivity
- Burnt Area
- Greenness Evolution Index
- Phenology metrics
- Moderate Yearly Land Cover

vegetation, energy budget at surface, water and cryosphere & its distribution component

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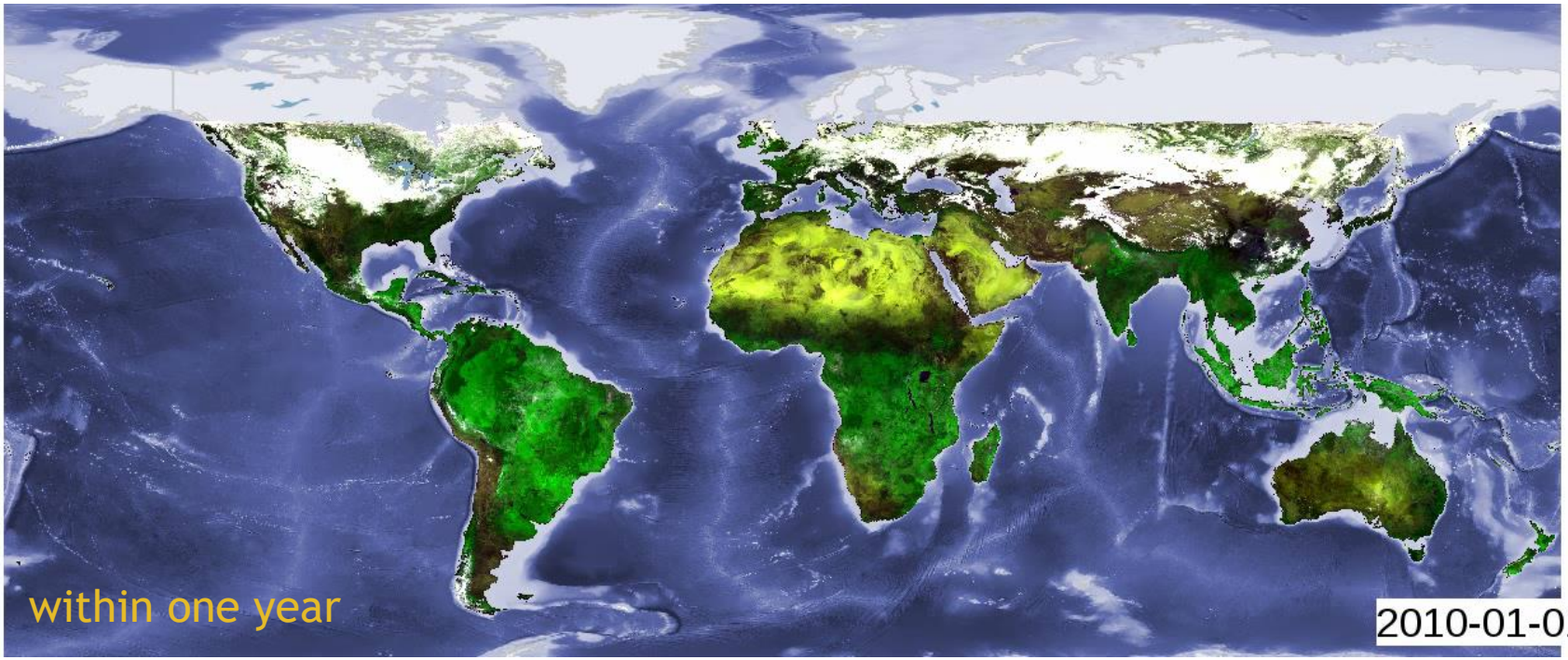
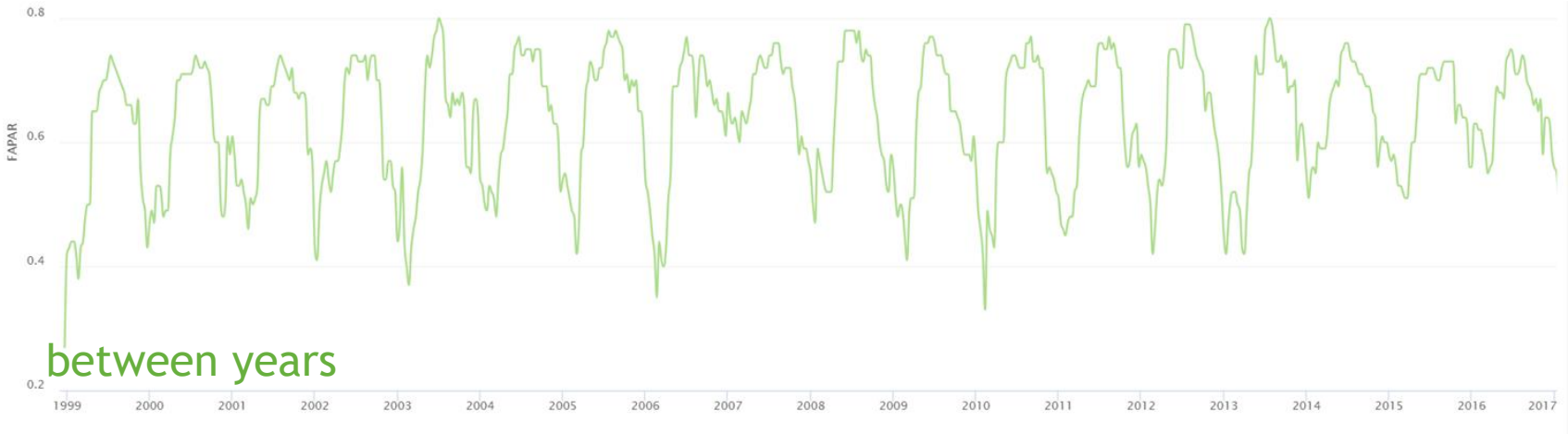
GLOBAL VEGETATION INDEX - SEASONALITY





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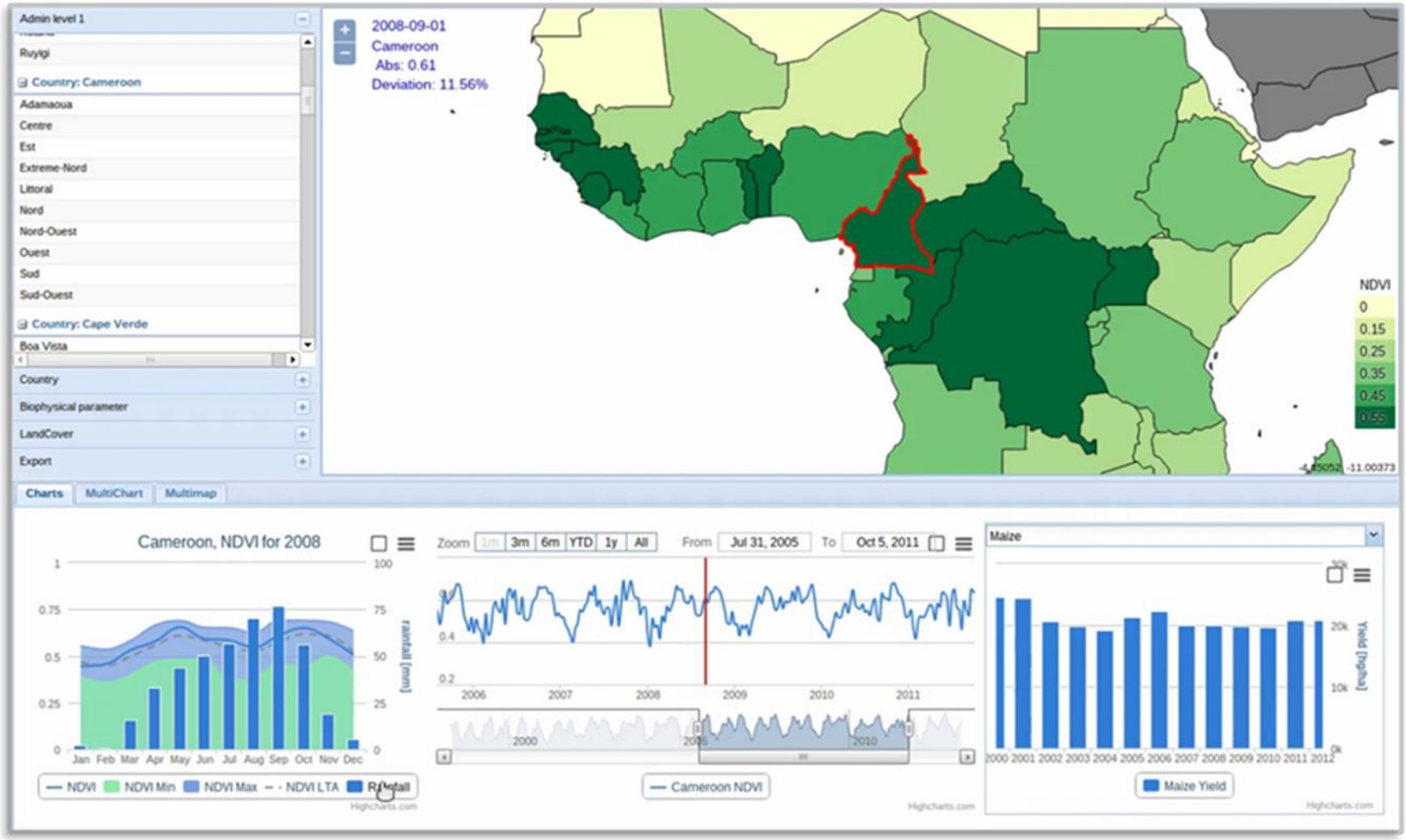
MEP PLATFORM (PRIMARILY FOR PROBA-V)
BIG DATA PROCESSING ON DEMAND



https://proba-v-mep.esa.int/

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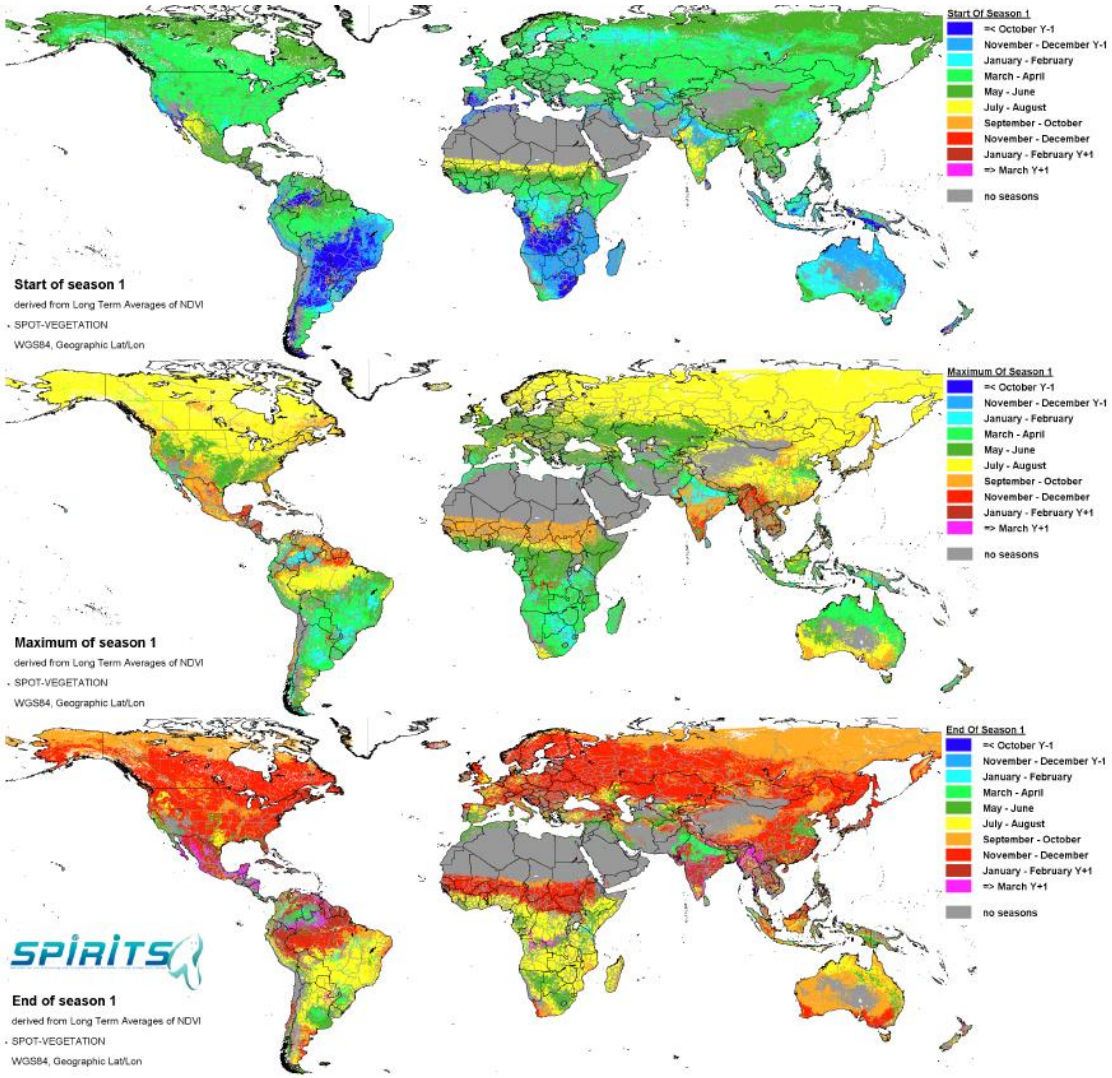
GLOBAL VEGETATION DEVELOPMENT



“Land Surface Phenology”

SPOT-VGT/Proba-V

Indication of Vegetation Development

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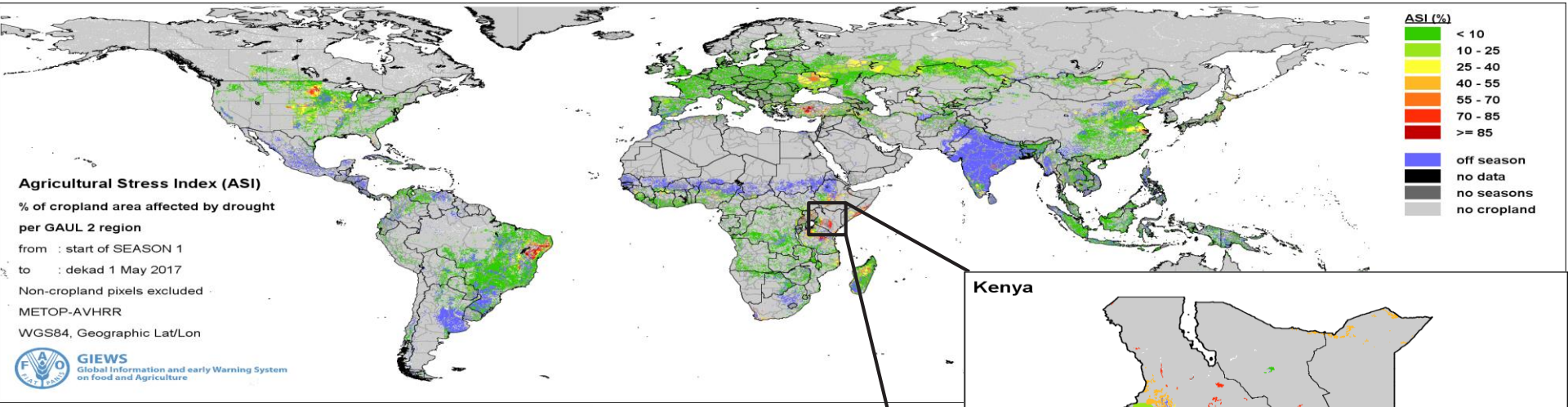
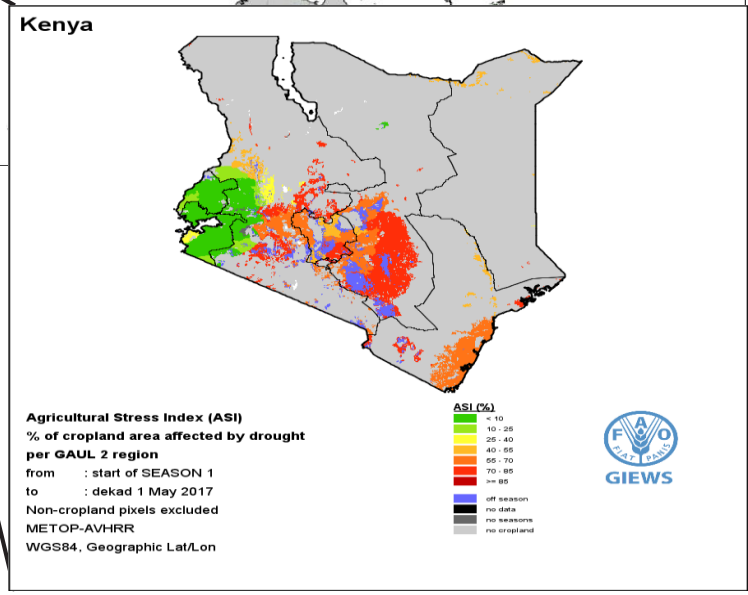
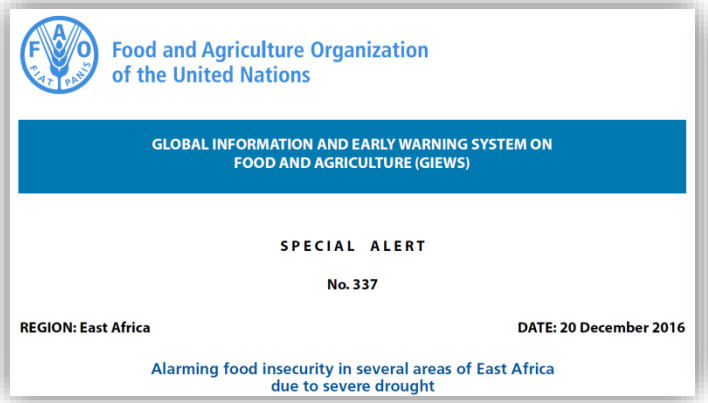
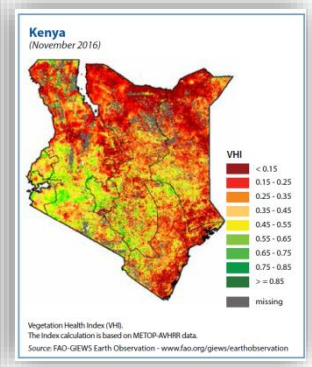
UN-FAO ASIS: AGRICULTURAL STRESS INDEX SYSTEM









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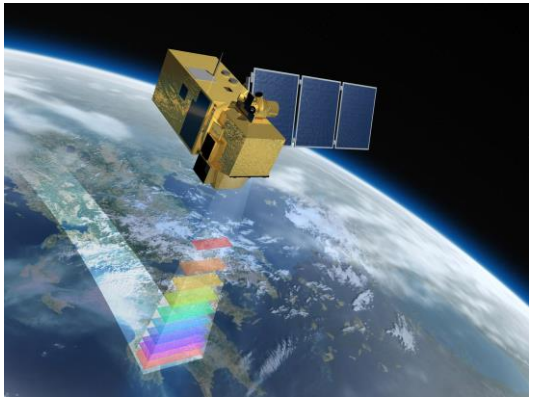
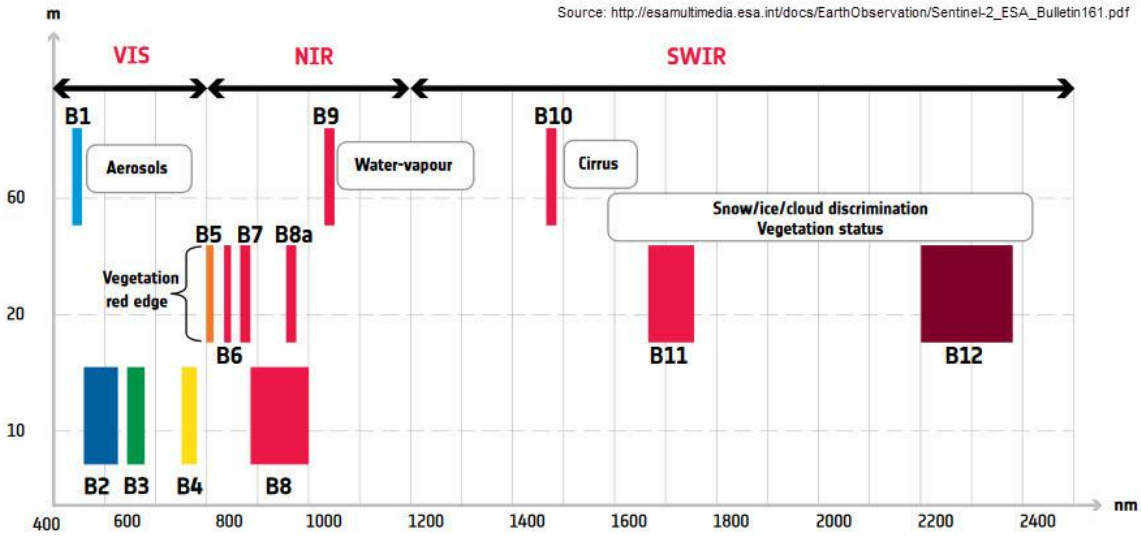
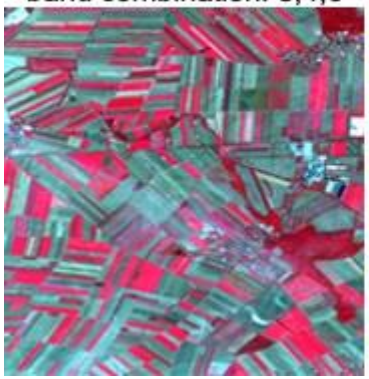
SENTINEL 2 FOR AGRICULTURE – THE GAME CHANGER!



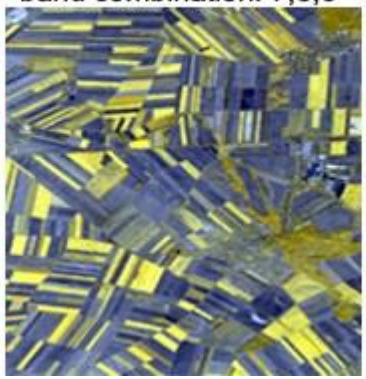


↑ Spatial resolution versus wavelength: Sentinel-2's span of 13 spectral bands, from the visible and the near-infrared to the shortwave infrared at different spatial resolutions ranging from 10 to 60 m on the ground, takes land monitoring to an unprecedented level

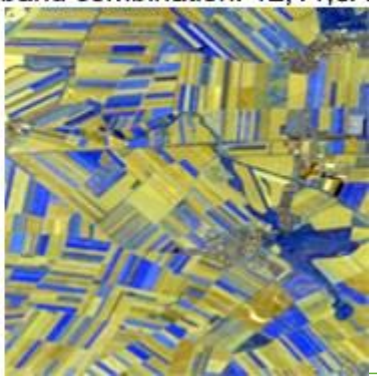
Sentinel-2
band combination: 8,4,3



Sentinel-2
band combination: 7,5,6



Sentinel-2
band combination: 12,11,8A



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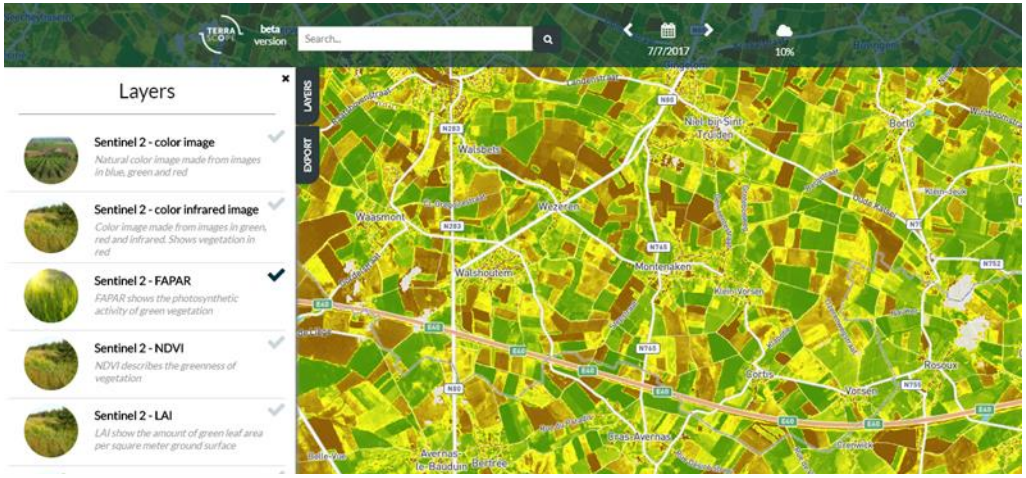
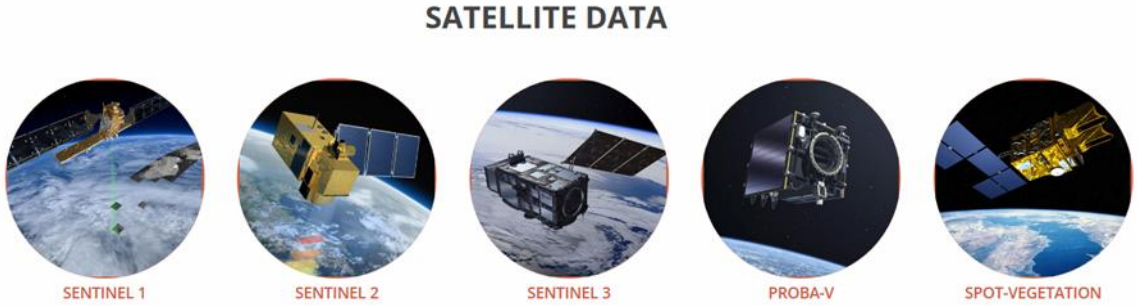
TERRASCOPE

terrascope.be

- Belgian **Collaborative Ground Segment** for Sentinel Data
- Coverage: Belgium
- Processing S2:
  - Geometric correction
  - Cloud/shadow: SEN2COR
  - iCOR for atmospherical correction
  - Biopar (~S2-Toolbox)
- TOC + LAI, FAPAR, FCOVER, NDVI





Powered by vito remote sensing belspo

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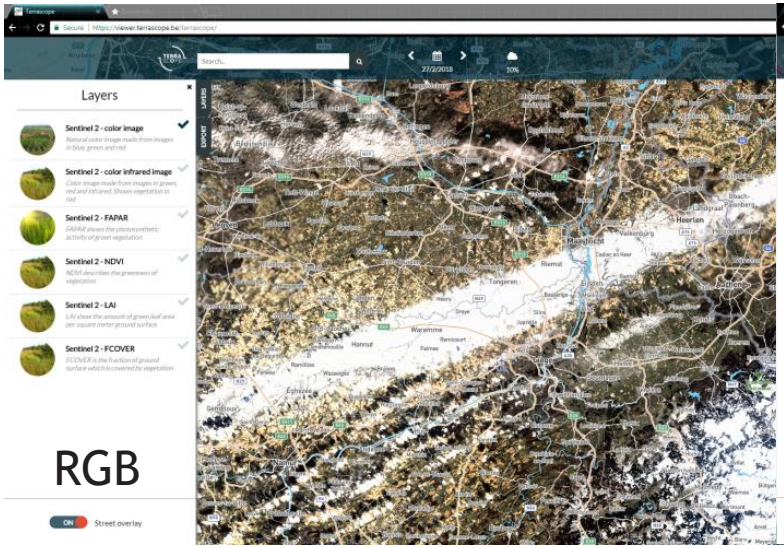
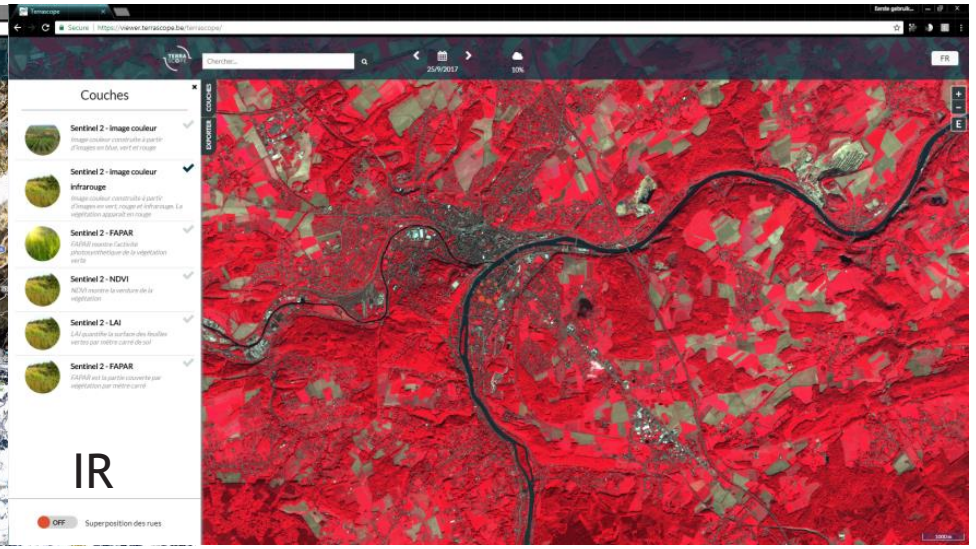
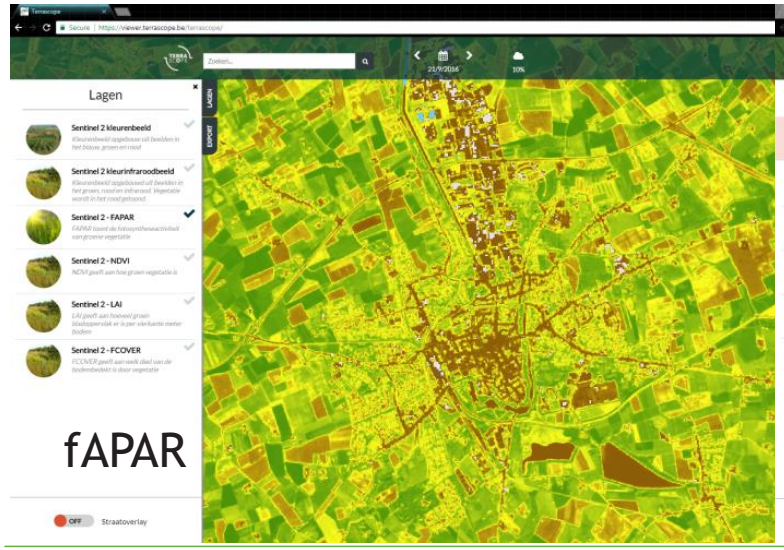
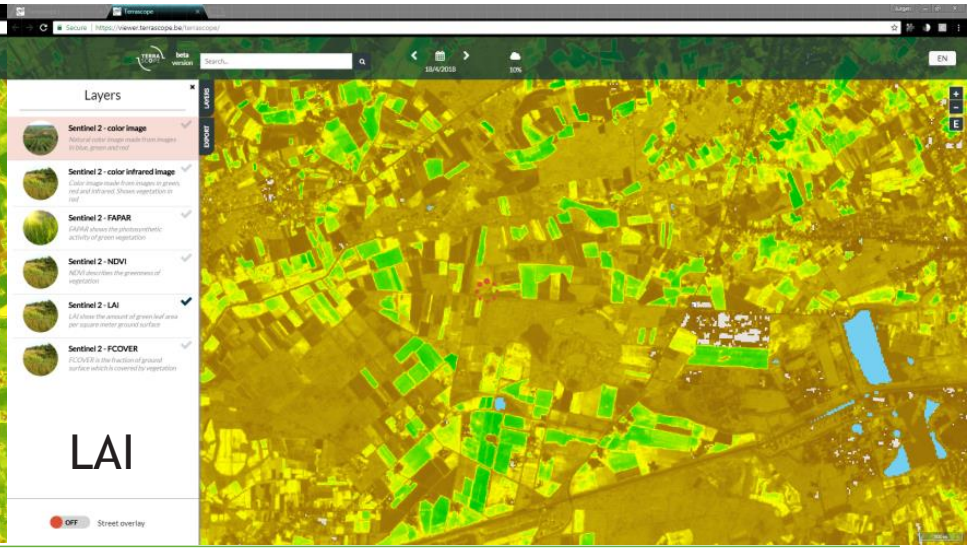
TERRASCOPE: COLLABORATIVE GROUND SEGMENT FOR BELGIUM (COPERNICUS SENTINEL









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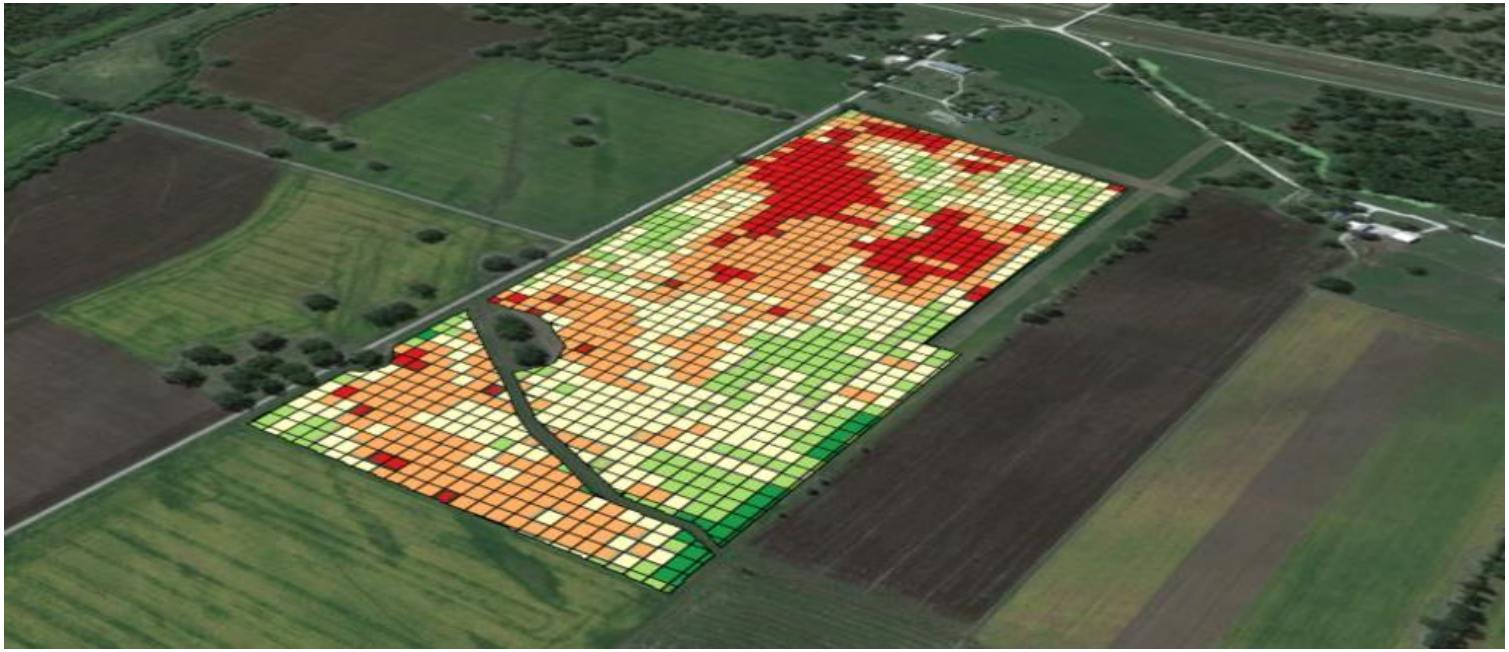
CROP DEVELOPMENT

REMOTE SENSING DERIVED VARIABLES AT THE PARCEL LEVEL

RS data => vegetation variables => Input in soil-crop-atmosphere models



Soil-crop-atmosphere models:

- *Weather time series => bio-meteorological variables*
- *Soil information => water balance*
- *Crop development information*
- *Field management*

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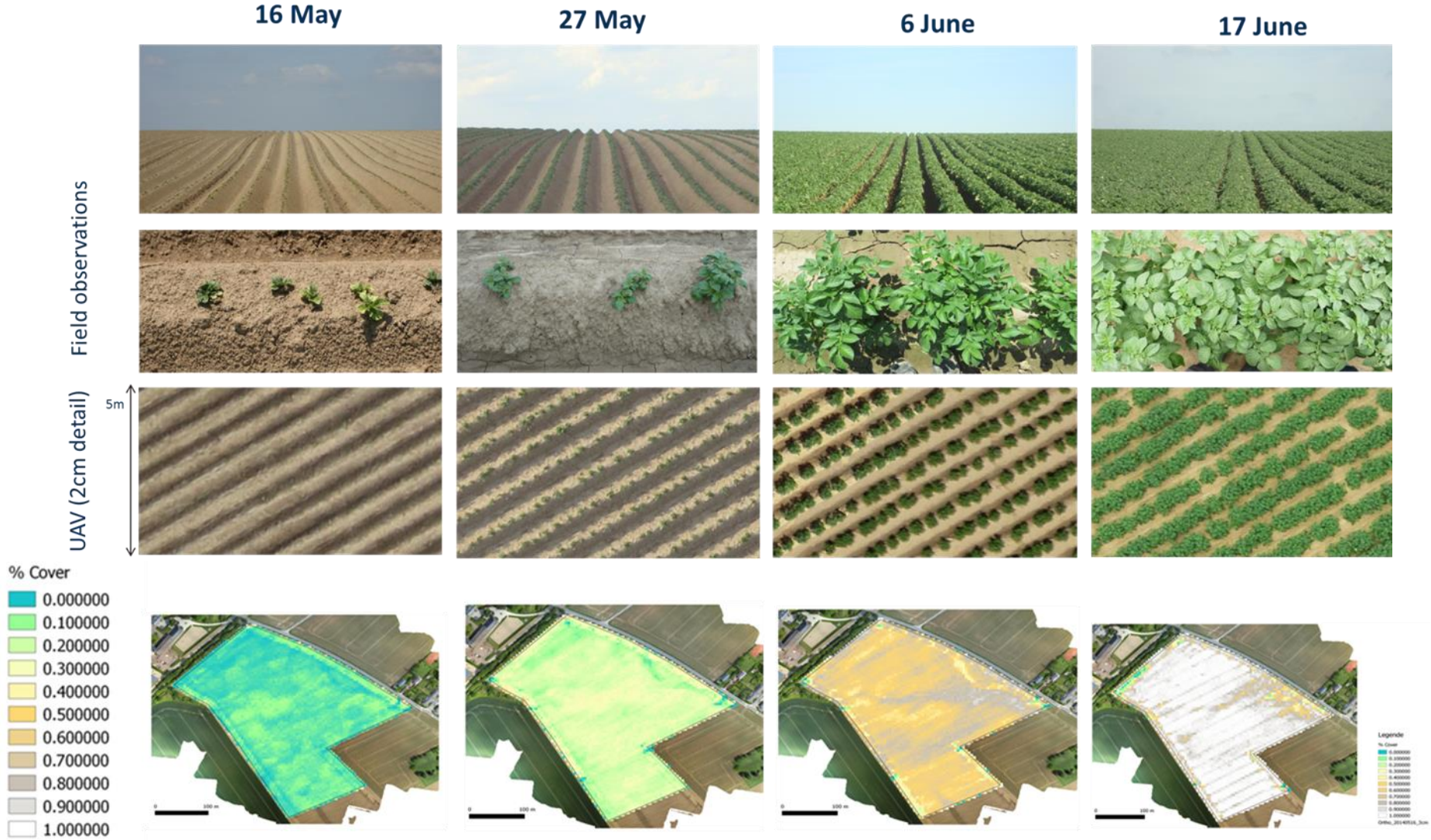
CROP DEVELOPMENT => UAV IMAGERY



16 Piccard, I., Gobin, A., Wellens, J., Tychon, B., Goffart, J.P., Curnel, Y., Planchon, V., Leclef, A., Cools, R., Cattoor, N., 2017. Potato monitoring in Belgium with "WatchITGrow". In Analysis of Multitemporal Remote Sensing Images (MultiTemp), June 2017: 9th International Workshop (pp. 1-4). IEEE; doi: 10.1109/Multi-Temp.2017.8035229.

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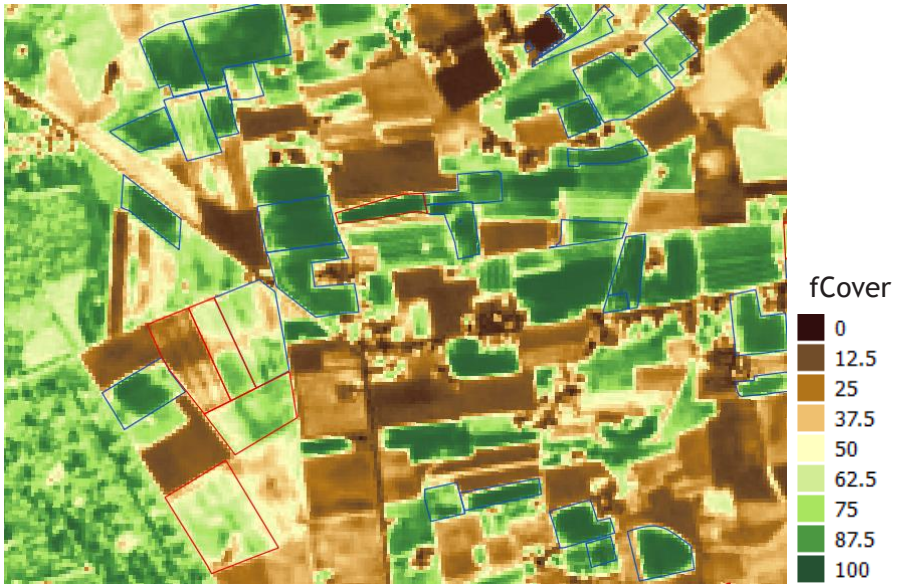
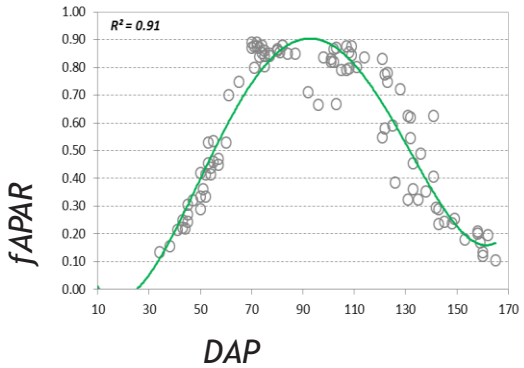
CROP DEVELOPMENT => SENTINEL SATELLITE IMAGERY

Variability inter and intra parcel
Sentinel-2 of 23 June 2016





Opportunities for

- Detecting crops,
- Detecting varieties
- Field zoning for management purposes

17 Piccard, I., Gobin, A., Wellens, J., Tychon, B., Goffart, J.P., Curnel, Y., Planchon, V., Leclef, A., Cools, R., Cattoor, N., 2017. Potato monitoring in Belgium with "WatchITGrow". In Analysis of Multitemporal Remote Sensing Images (MultiTemp), June 2017: 9th International Workshop (pp. 1-4). IEEE; doi: 10.1109/Multi-Temp.2017.8035229.

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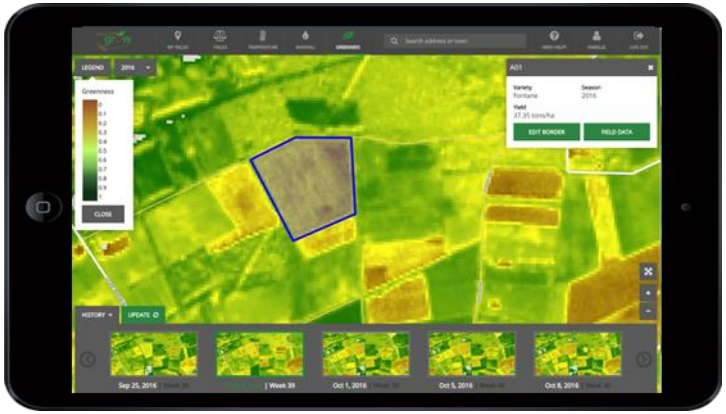
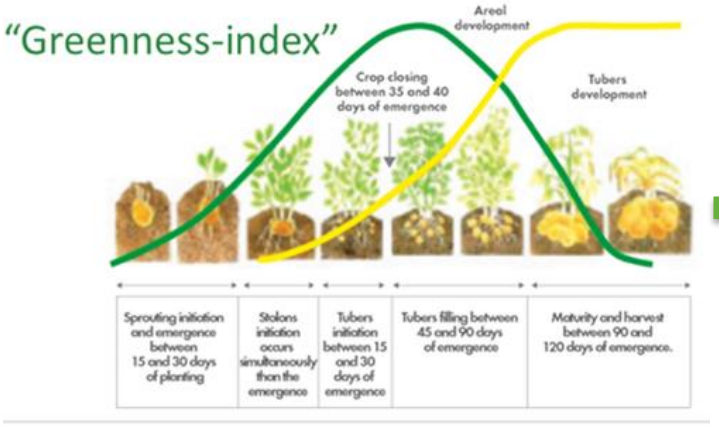
WATCHITGROW www.watchitgrow.be

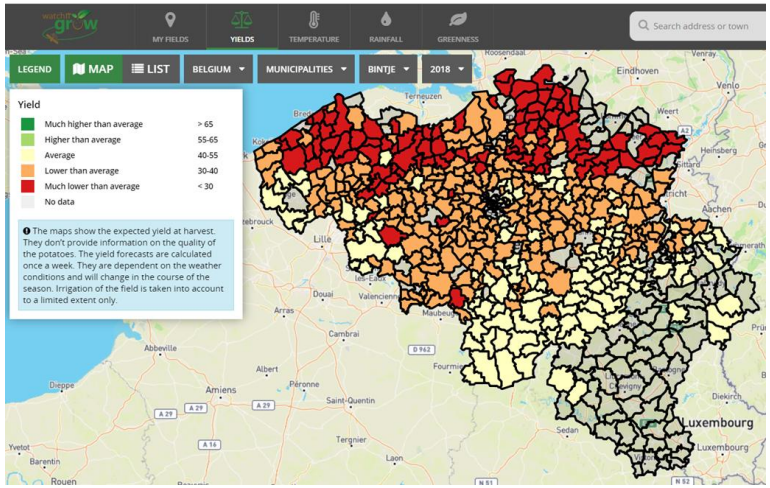
- Crop development monitoring from Sentinel-2 imagery



For potato processing industry
BE: largest exporter of frozen potato products

- Crop yield modelling from meteo, soil, crop characteristics





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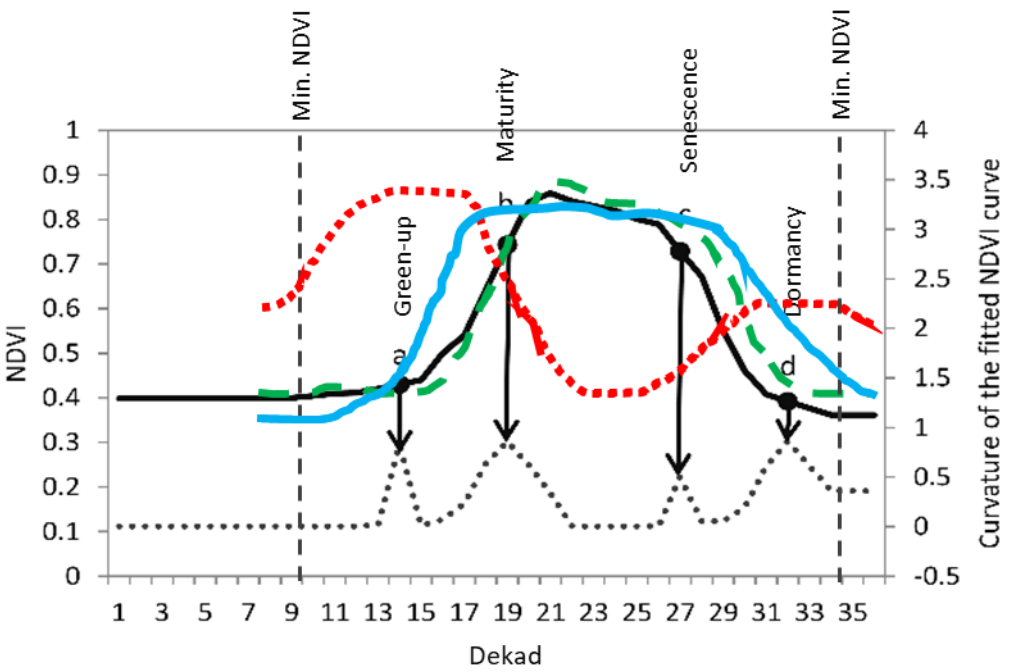
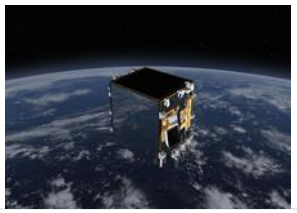
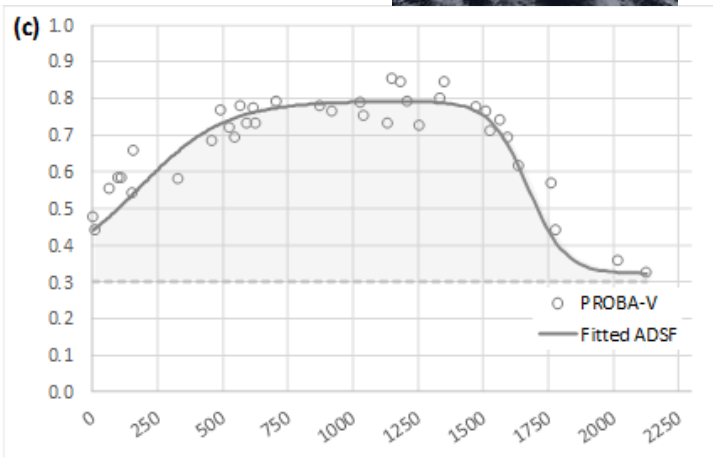
CROP DEVELOPMENT AND PROBA-V IMAGERY

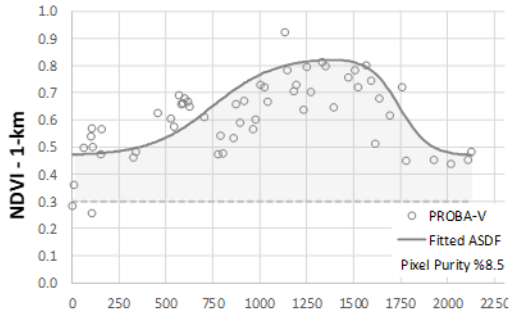


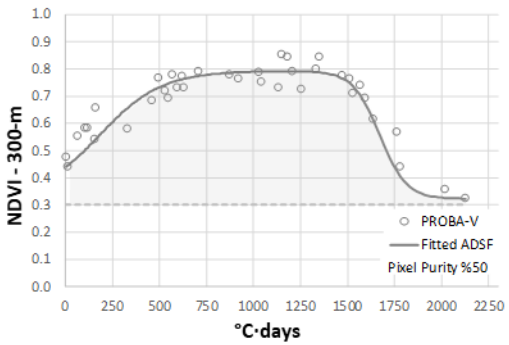
Proba-V
Daily coverage
1km, 300m, 100m

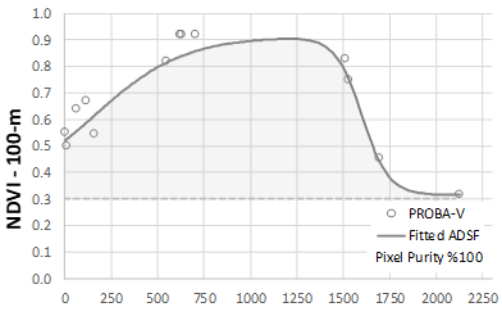




Winter wheat in N-France







19 *Durgun, Y.Ö., Gobin, A., Gilliams, S., Duveiller, G., Tychon, B., 2016. Testing the Contribution of Stress Factors to Improve Wheat and Maize Yield Estimations Derived from Remotely-Sensed Dry Matter Productivity. Remote Sensing 8(3), 170*
Durgun, Y.Ö., Gobin, A., Vandekerchove, R., Tychon, B., 2016. Crop Area Mapping using 100m PROBA-V time series. Remote Sensing 8(7), 585

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DROUGHT MONITORING WITH SENTINEL IMAGERY

20/07/2016

15/07/2018

Drought causes early senescence

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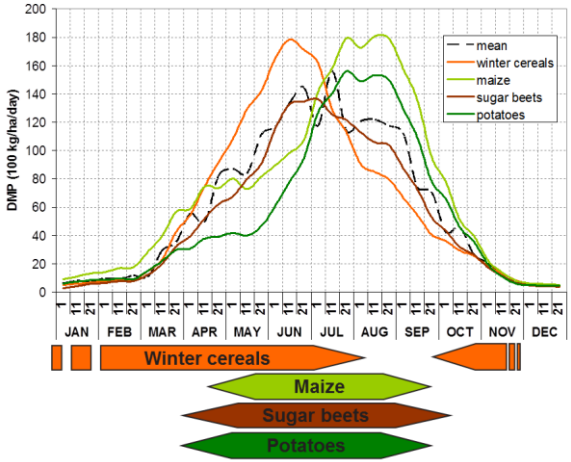
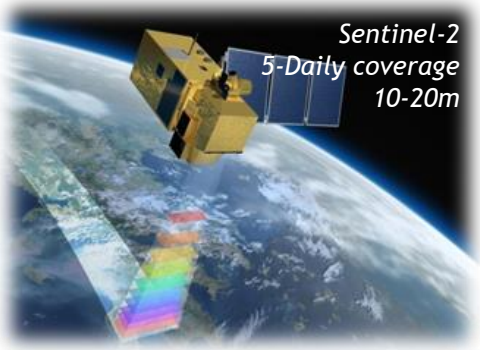
IMPROVED CROP MAPPING

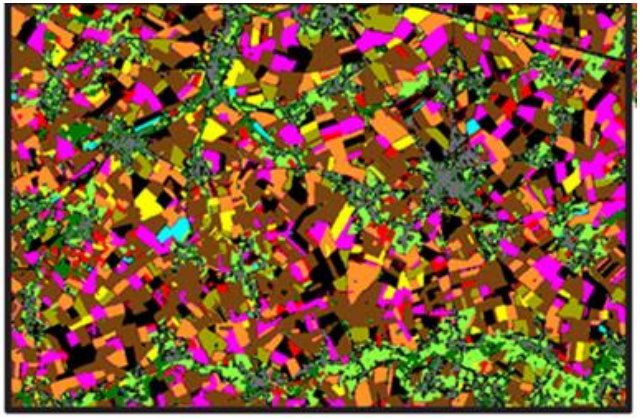
Different phenological activity between crops





Classification Accuracy increases with spectral, spatial and temporal resolution

Optical (DMC)					SAR (Sentinel-1)					OA
8/03	14/04	4/06	11/07	1-7/08	Feb	Mar	Apr	May	Sep	
x										52%
x	x									59%
x	x	x								75%
x	x	x	x							85%
x	x	x	x	x						90%
					x					52%
					x	x				58%
					x	x	x			65%
					x	x	x	x		77%
					x	x	x	x	x	87%
x					x					62%
x					x	x				67%
x	x				x	x				71%
x	x				x	x	x			73%
x	x				x	x	x	x		81%
x	x	x			x	x	x	x		85%
x	x	x	x		x	x	x	x		90%
x	x	x	x	x	x	x	x	x		92%
x	x	x	x	x	x	x	x	x	x	94%



21 *Van Tricht, K., Gobin, A., Gilliams, S., Piccard, I., 2018. Synergistic use of Sentinel-1 radar and Sentinel-2 optical imagery for mapping crops at large scale: a case study for Belgium. Remote Sensing.*
Durgun, Y.Ö., Gobin, A., Vandekerchove, R., Tychon, B., 2016. Crop Area Mapping using 100m PROBA-V time series. Remote Sensing 8(7), 585; https://doi.org/10.3390/rs8070585

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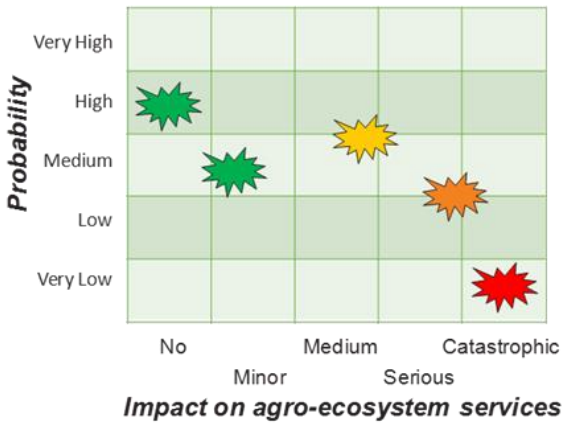
DROUGHT IMPACT ON CROPS

MAGNITUDE OF IMPACT ON AGRICULTURE



- Impact depends on
  - the occurrence of the event during the agricultural season
  - the location of the event vs system
  - the magnitude and duration of the event
  - the vulnerability/resilience of the system
  - Agro-ecosystem component

    yield, biomass, soil quality, soil moisture, greenness, …

Farming calendar

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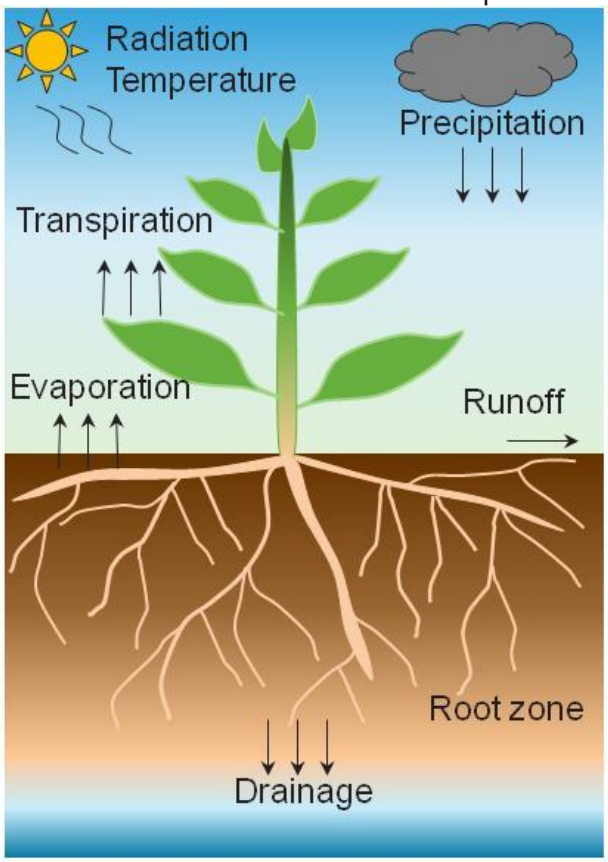
SOIL-CROP-ATM MODELLING TO CAPTURE GROWTH DYNAMICS

Biomass growth & Phenological stadia: in cumulative temperature days with base and maximum temperature & daylength as boundaries of phenological activity



Input
- Climate
- Soil
- Crop

Processes
- Phenology
- Biomass Production
- Water Balance
- Energy Balance

Output
- Waterlogging
- Drought
- Heat stress
- Temperature stress
- Biomass
- Yield

(Gobin, 2010, 2012, 2018)

Gobin, A., 2010. Modelling climate impacts on arable yields in Belgium. Climate Research 44: 55-68.

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ADVERSE WEATHER CONDITIONS ALTER CROP DEVELOPMENT

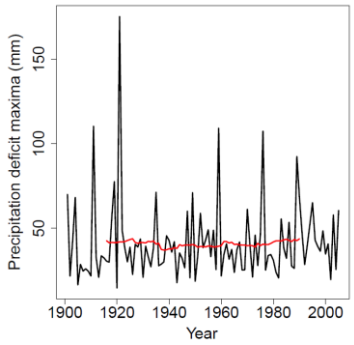
1. Trend analysis of time series and fitting distributions of individual stations

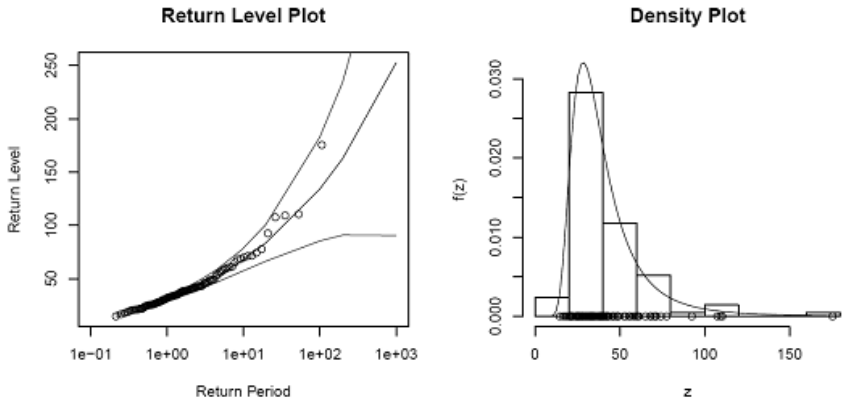
$$G(z;\mu_i,\sigma_i,\xi_i) = exp[-(1+\xi_i(z-\mu_i)/\sigma_i)^{-1/\xi_i}]$$

2. Return period (T) and value (z_T)

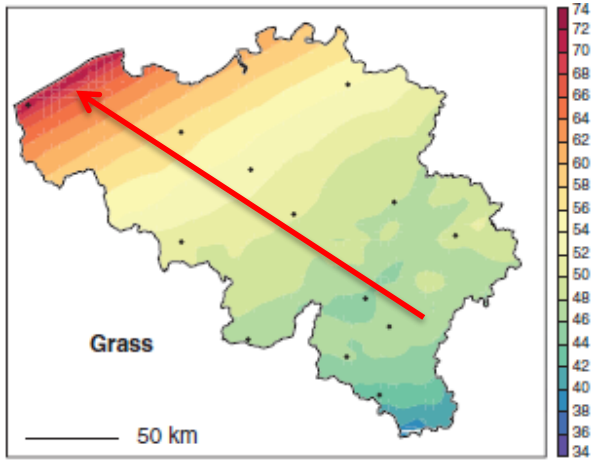
$$z_T = \mu_i - \sigma_i/\xi_i\left(1-[-log(1-1/T)]^{-\xi_i}\right)$$

$$T = 1/\left(1-G(z_T)\right)$$





Cumulative precipitation deficit = f(ET, P)



20y RP for precipitation deficit

Zamani, S., Gobin, A., Van de Vyver, H., Gerlo, J., 2015. Atmospheric drought in Belgium - Statistical analysis of precipitation deficit. International Journal of Climatology 36(8): 3056-3071, DOI: 10.1002/joc.4536.

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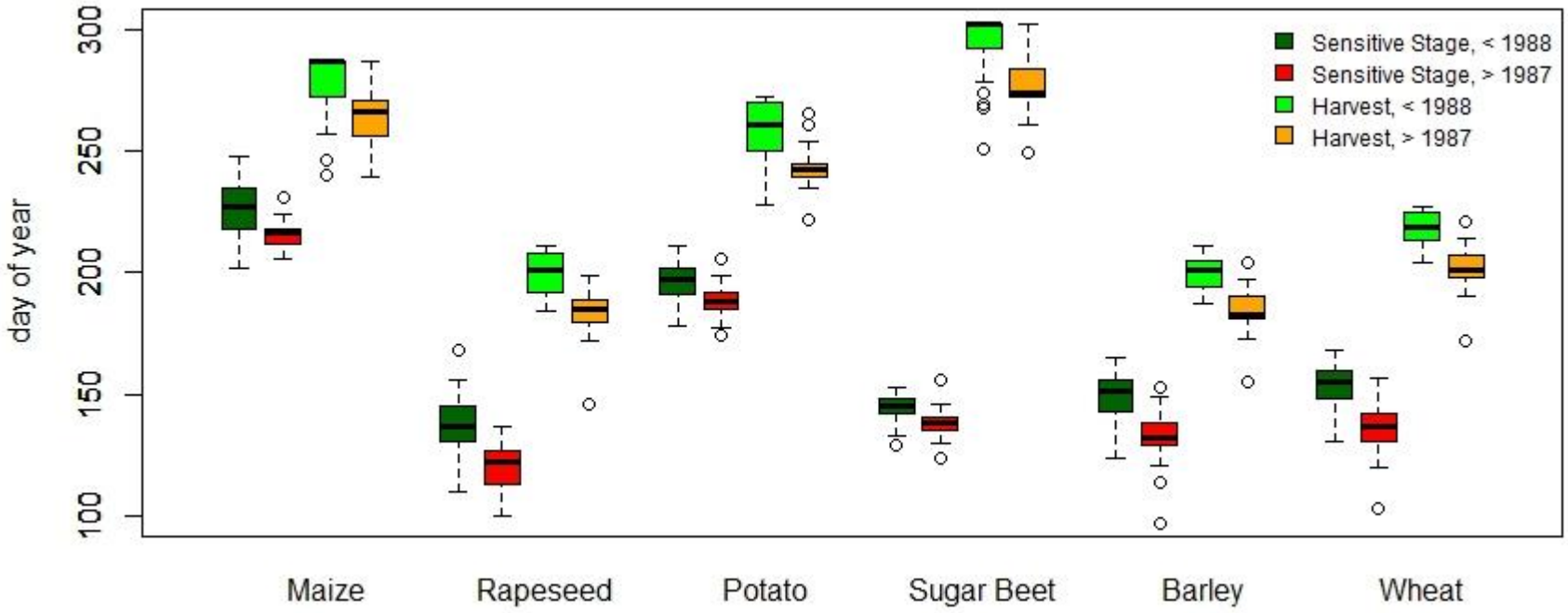
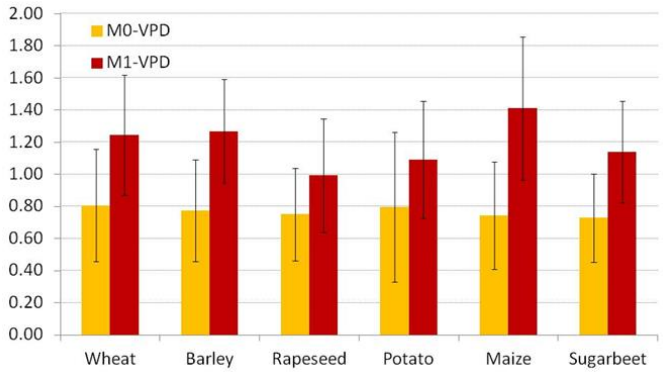
CLIMATE IMPACT: SHIFT IN CROP DEVELOPMENT





Growth stages occur significantly earlier after 1987, shift in phenology!

Implications for the coincidence between an extreme event (heat stress) and the sensitive stage

Gobin, A., 2012. Impact of heat and drought stress on arable crop production in Belgium. Natural Hazards and Earth System Sciences 12, 1911-1922.

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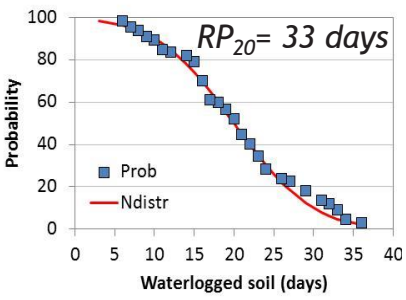
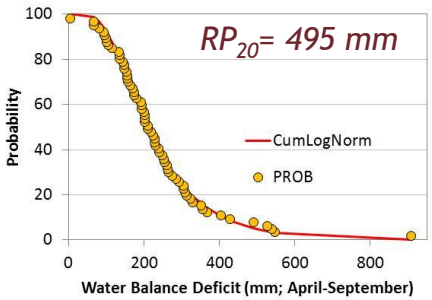
CROP DEVELOPMENT AND WEATHER IMPACT

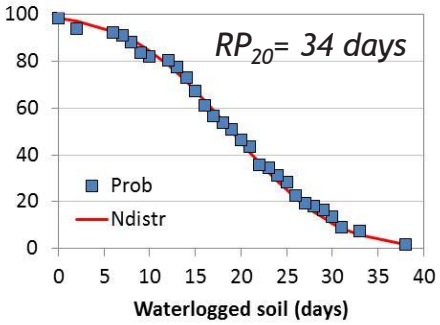
Waterlogging @ planting

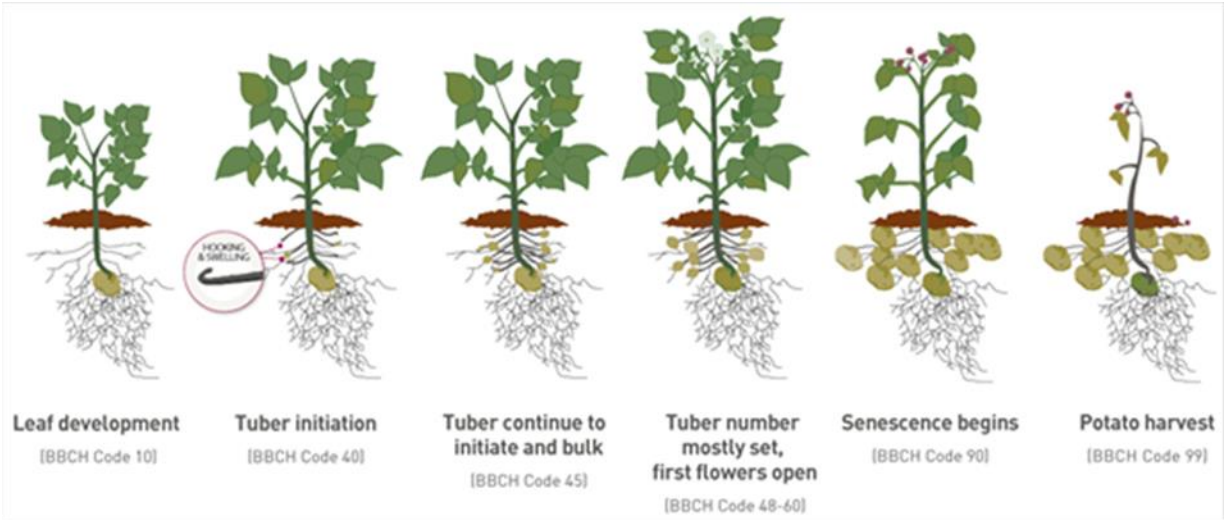


Drought during season



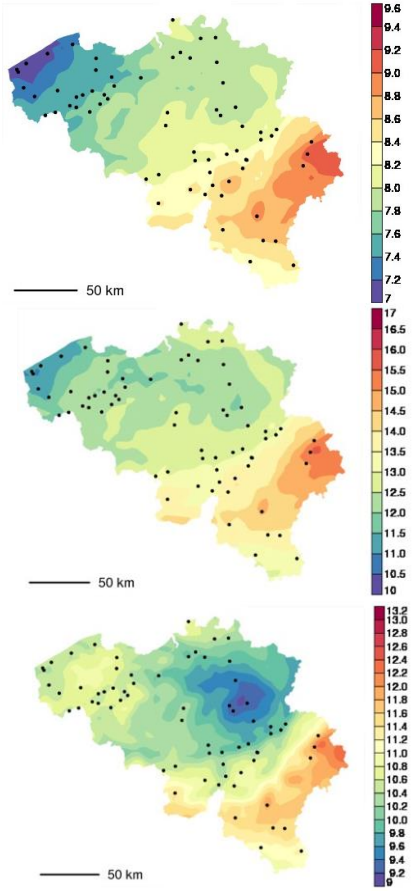
Waterlogging @ harvest





Probability of exceedance and 20-y return period

Consecutive rainy days



Spatial return period

Gobin, A., 2018. Weather related risks in Belgian arable agriculture. Agricultural Systems 159: 225-236. https://doi.org/10.1016/j.agsy.2017.06.009

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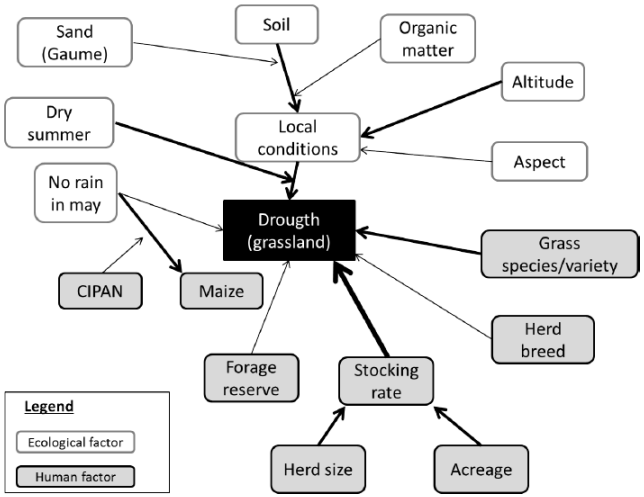
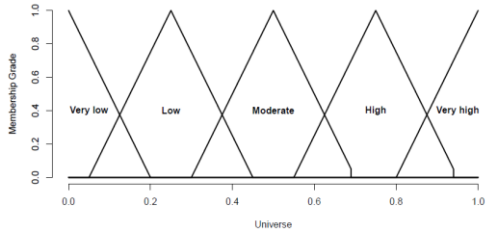
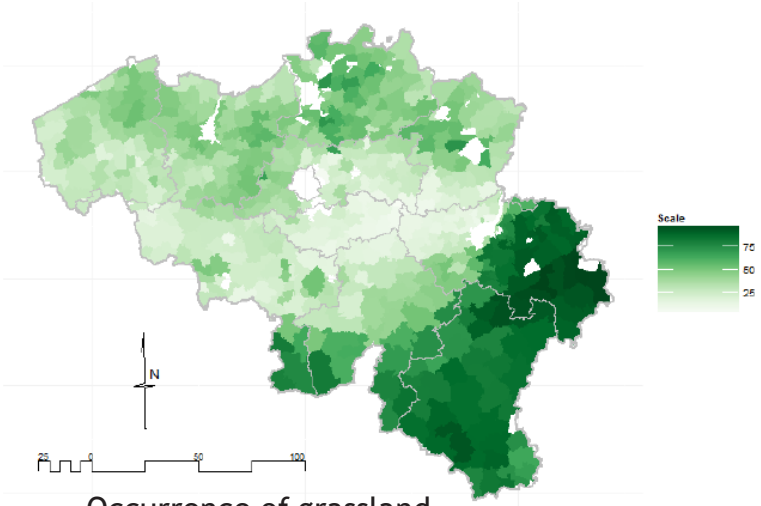
MAPPING VULNERABILITY AND RESILIENCE : e.g. DROUGHT IN GRASSLAND

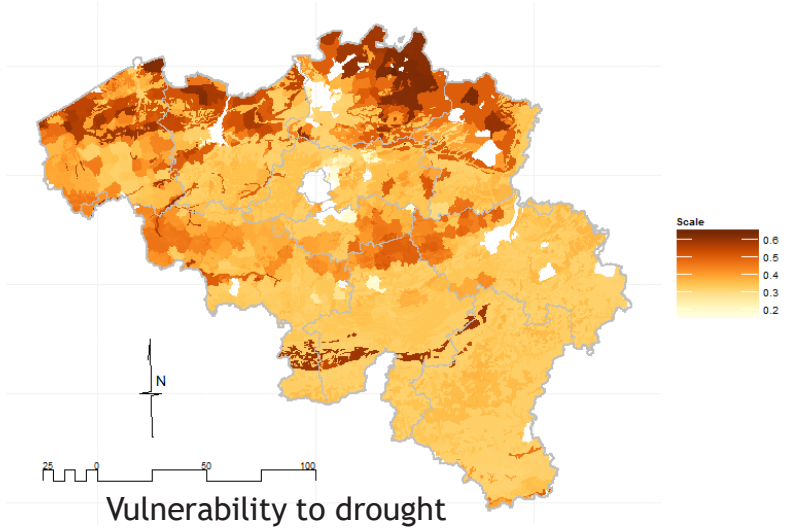


- (Cognitive) map of vulnerability factors
- Vulnerability map: Fuzzy Inference systems + GIS in R
  - membership functions
  - Rules to combine membership data





Occurrence of grassland



Vulnerability to drought

Vanwindekens, F.M., Gobin, A., Curnel, Y., Planchon, V., 2018. New Approach for Mapping the Vulnerability of Agroecosystems Based on Expert Knowledge. Math Geosci (2018). https://doi.org/10.1007/s11004-018-9730-5

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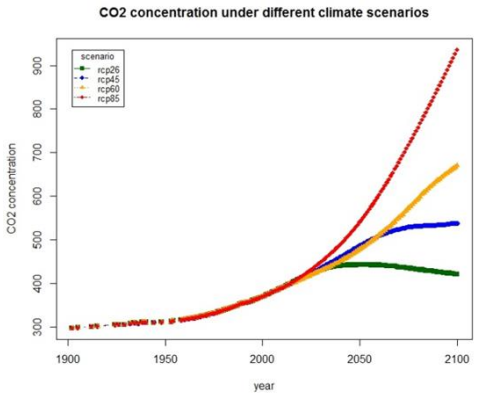
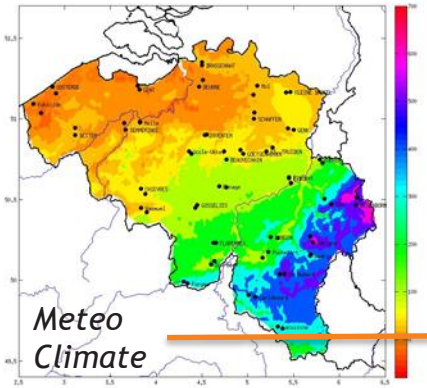
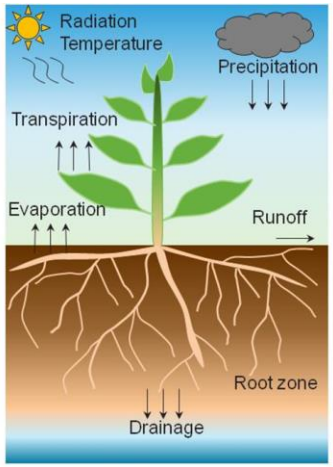
CLIMATE PROJECTIONS & ADAPTATION OPTIONS

CLIMATE IMPACT ON CROP GROWTH (CORDEX.BE)

- Projected shifts - observed weather 1960-1990 (Hist), GCM 1976-2005 (Base), and 2070-2100 (RCP45, RCP85). ALARO 12 km Downscaling. Model runs on locations of synoptic stations across Belgium.







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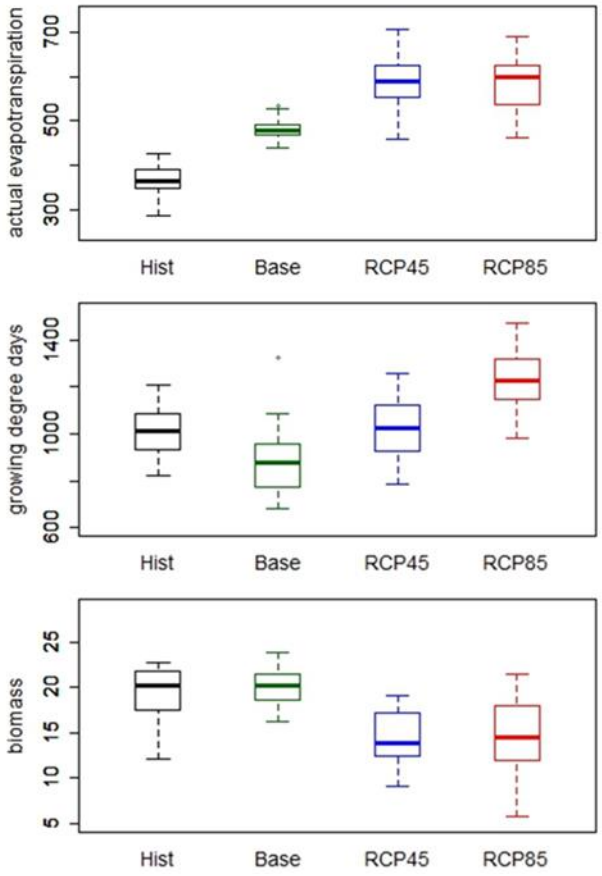
- Energy Balance

Output
- Waterlogging
- Drought
- Heat stress
- Temperature stress
- Biomass
- Yield

(Gobin, 2010, 2012)

Agri-Climatological Functions



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BELGIAN EXPORT PODUCTS AT STAKE? THE FUTURE IS NOW!

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Environment ▸ Climate change | Wildlife | Energy | Pollution

Belgium

The chips are down in Belgium as heatwave hits supply of frites

Reduced yields are putting national dish and 'symbol of Belgium' under threat

Daniel Boffey *in Brussels*

Fri 10 Aug 2018 10.15 BST

2,547

This article is over 2 months old

▲ People eat frites in Belgium. The heat impacts on the yield and size of potatoes. Photograph: Alamy

ARTICLES

https://doi.org/10.1038/s41477-018-0263-1

nature plants

Decreases in global beer supply due to extreme drought and heat

Wei Xie[1*], Wei Xiong[2,3,4], Jie Pan[2], Tariq Ali[1], Qi Cui[5], Dabo Guan[6,7*], Jing Meng[8], Nathaniel D. Mueller[9], Erda Lin[2*] and Steven J. Davis[9,10]

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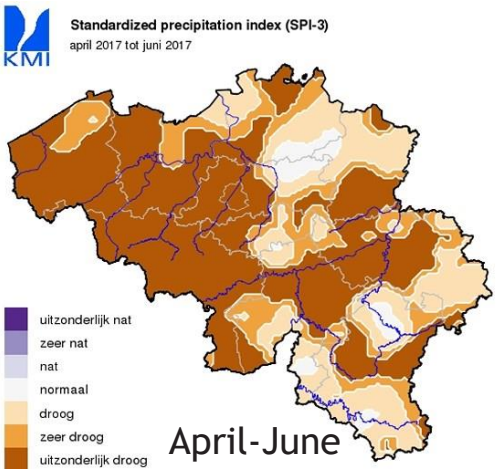
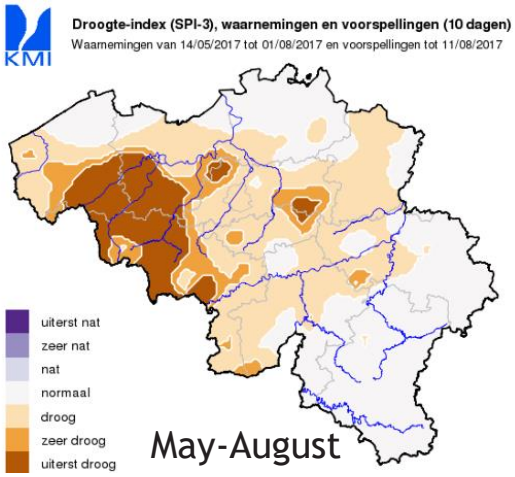
CROP WATER DEMAND AND IRRIGATION – DROUGHT IN 2017



April-June



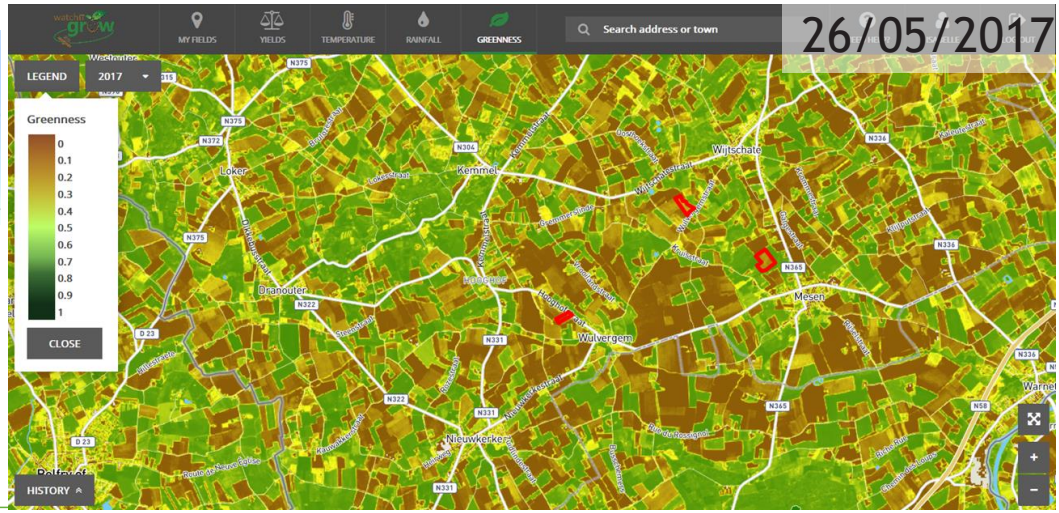
May-August

Wilting crops
Total loss

(insurances)

water supply

(irrigation)



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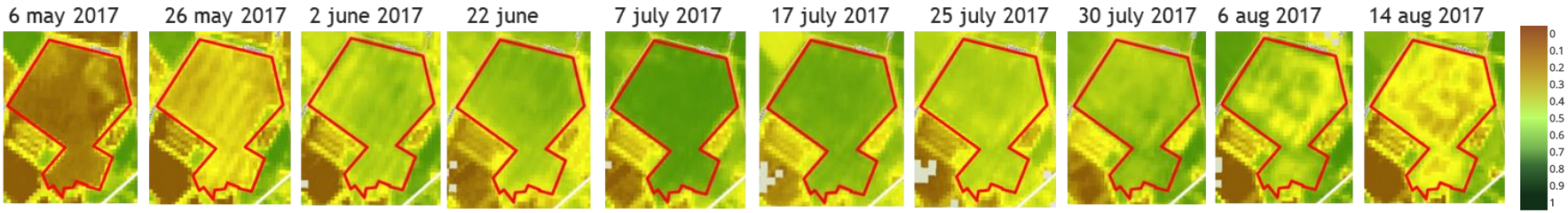
FARM-LEVEL ADAPTATION OPTIONS & MEASURES

- Crop breeding – variety trials!
- Cultivation techniques: irrigation and drainage
- Soil and water conservation measures: capping, mulching,
- Soil care!

Parcel monitoring



De Frutos Cachorro, J., Gobin, A., Buysse, J., 2018. Farm-level adaptation to climate change: The case of the Loam region in Belgium. Agricultural Systems 165, 164-176.

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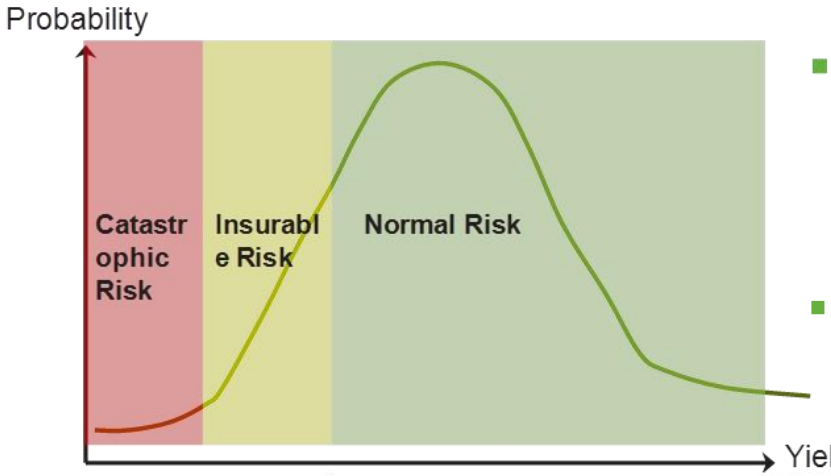
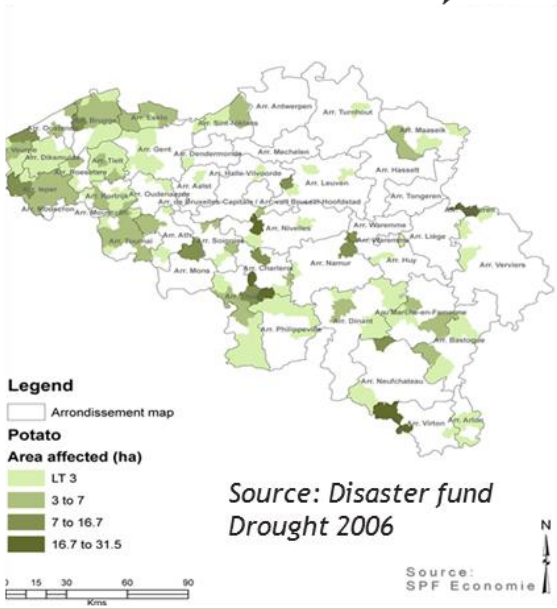
STAKEHOLDERS' PERCEPTIONS

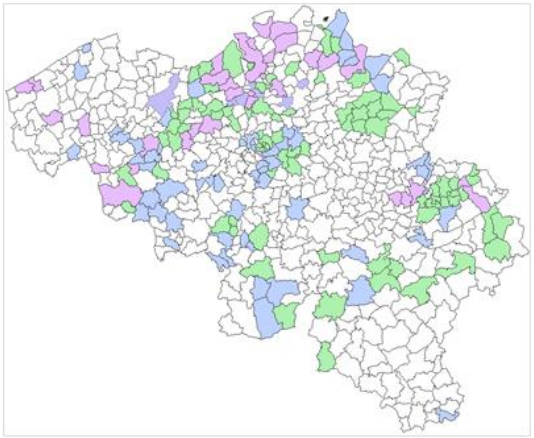
RISK PERCEPTION AND INSURANCES IN BELGIUM



- Risk segmentation
  - Disaster risk
  - Insurable risk
  - Normal to zero risk
- Focus on extreme character of the weather event ~ exceedance of 1:20 return period



Source: Disaster fund Drought 2006



Source:private insurer Excess rain, hail, frost

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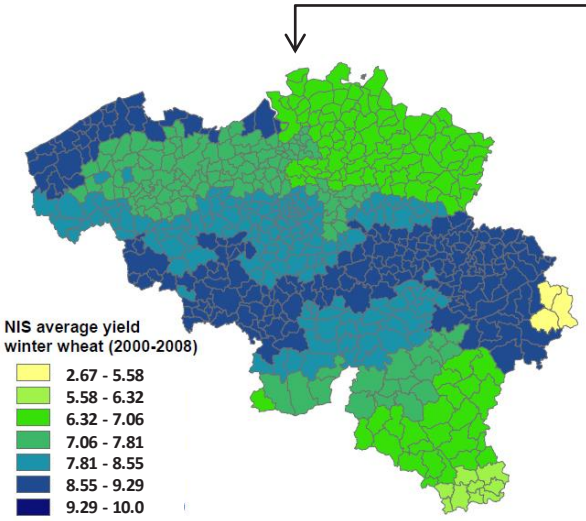
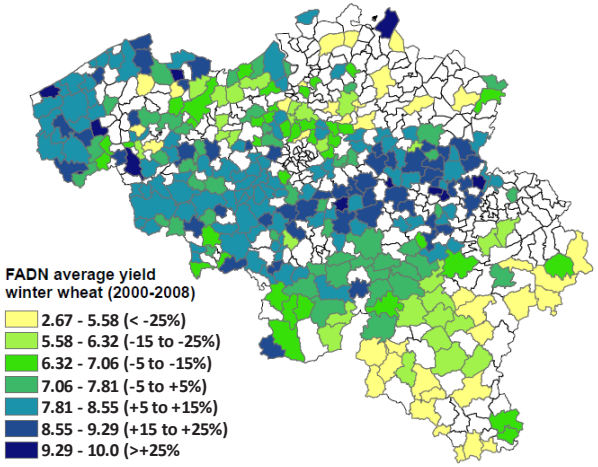
RISK AND INSURANCE: YIELD VARIABILITY

Different yield datasets were used:

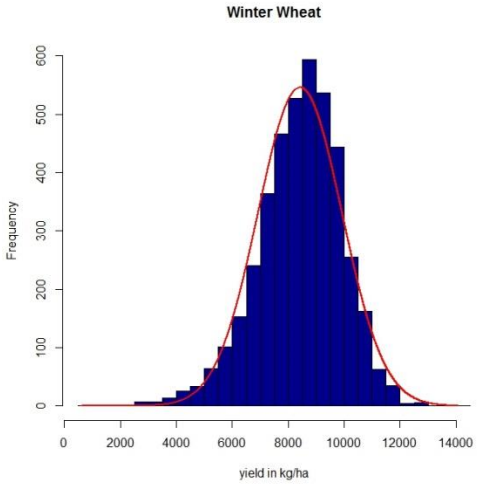
- Spatial yield variability increases at different scales agricultural regions - communities - parcels
- Distributions at the parcel level were used to define low yields for different arable crops



Belgian agricultural regions



Selected farms in communities



Parcels (n~6450)

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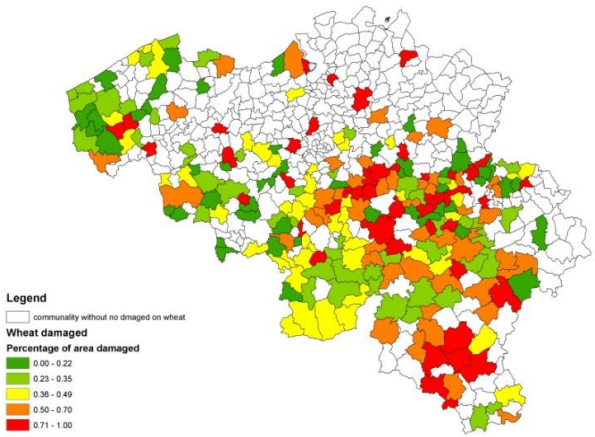
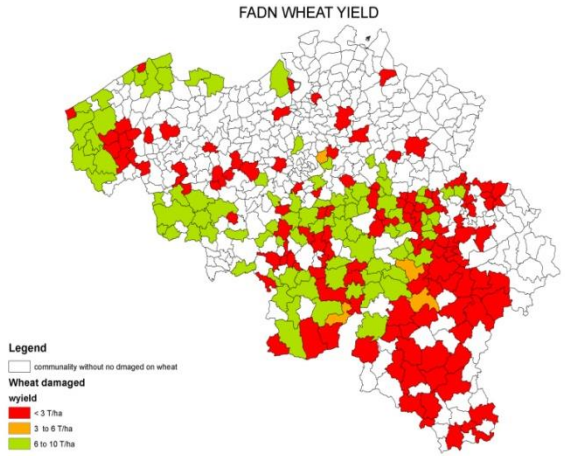
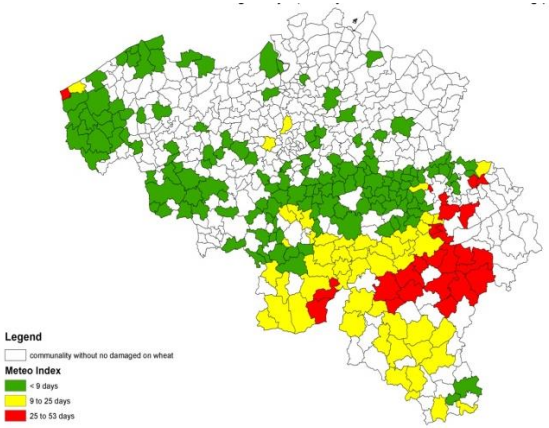
RISK AND INSURANCE – DISASTER FUND



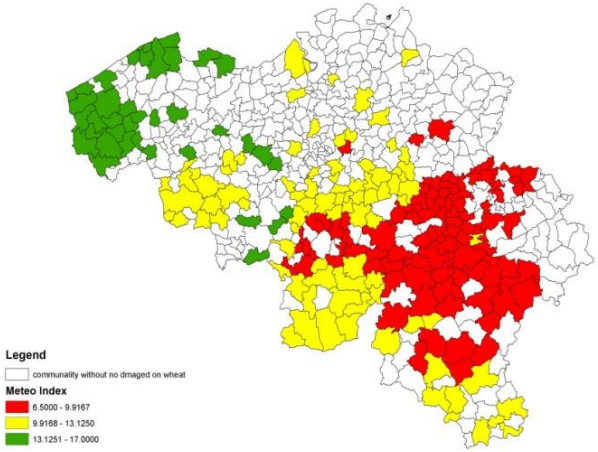
Claims



Yield anomalies



Drought



Extreme rainfall & waterlogging

- Variability in claims
- Relation with yield ?

- Model allows for analysing weather impacts during sensitive growth stages

Relation with extremes during the growing season is clear

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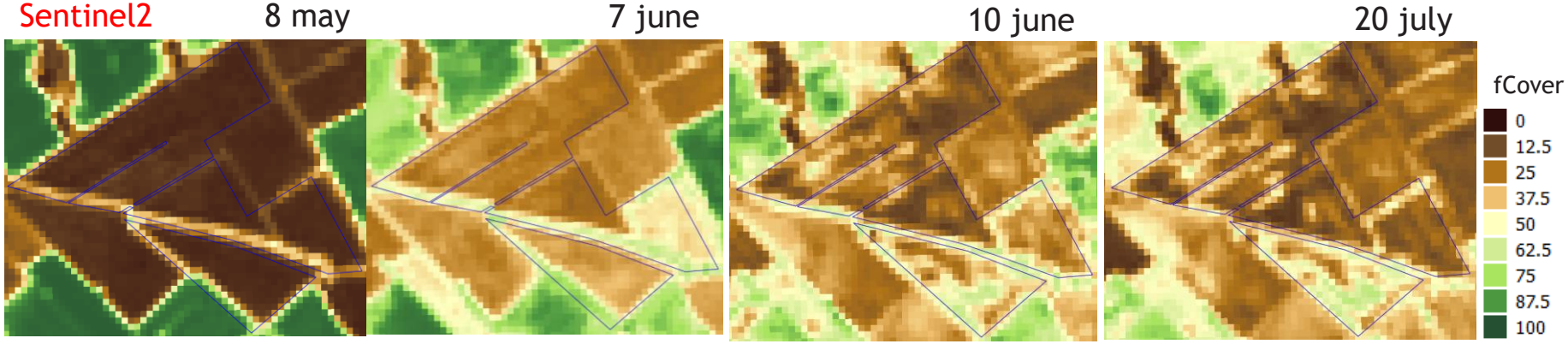
RISK AND INSURANCE: DAMAGE ASSESSMENT

Heavy rainfall of > 50mm/day: end May, 21 June, 23-24 June 2016

Sentinel2



Cover remains low in july due to waterlogging

Drone Imagery

38 *Gobin, A., 2018. Weather related risks in Belgian arable agriculture. Agricultural Systems 159: 225-236. https://doi.org/10.1016/j.agsy.2017.06.009*

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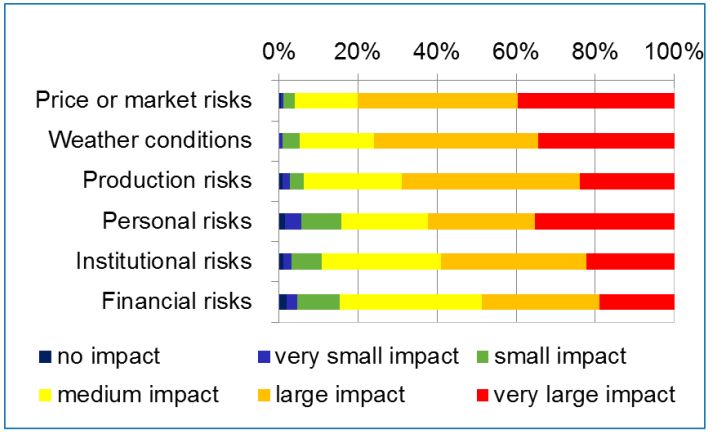
RISK PERCEPTION: FARMERS

Eliciting farmers perceptions using participatory techniques:

- *Focus group discussions*
- *Risk matrices*
- *Interviews, terrain visits*
- *Formal questionnaires*

- Farmers perceive an increased risk:
  - Increase in extreme weather and adverse weather conditions in a changing climate
  - Decrease in direct income support
  - Directive on agricultural damage
    - Payment is reduced to 50% unless the farmer has a private insurance



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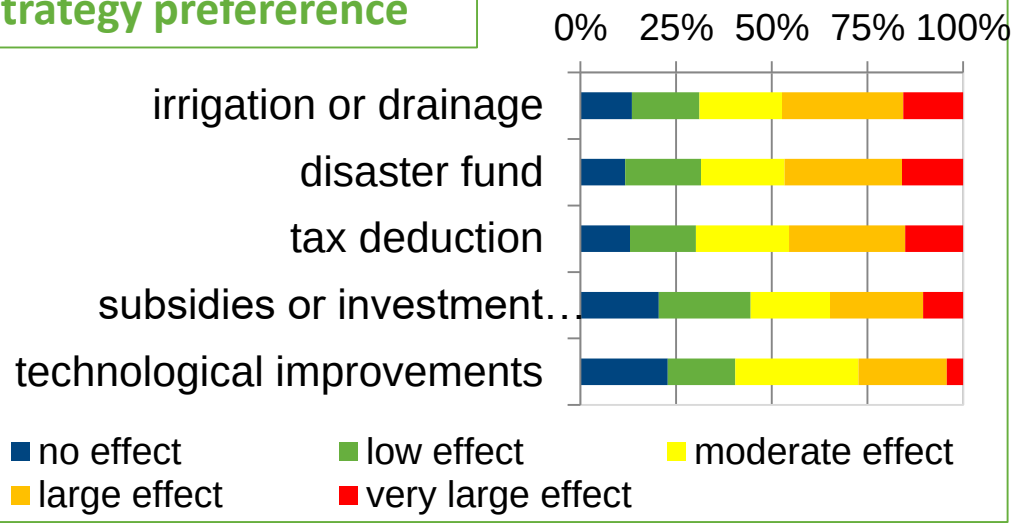
RISK PERCEPTION AND ACTION: FARMERS

Strategy implementation

- Dependent on type of EWE
- Mostly on-farm strategies
- Market based strategy: hail insurance
- 1 policy strategy in the TOP 5

Mostly ON-FARM strategies

Strategy prefererence



POLICY strategies more EFFICIENT ?

Insurances do not restrict on-farm measures!

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DATA AVAILABILITY AND USE FOR ESTIMATION OF DROUGHT RISK

- Large archives of **global harmonised data** available at low resolution (< 1km)
  - Global LUCC is possible, also at the country scale
  - Vegetation indices as input into vegetation development monitoring
  - Portals for free download of products
  - Cloud computing

- Links between **low and high resolution** (10-20 m) at the global scale!!!
  - Sentinel suite of satellites: Unprecedented high temporal, spatial and spectral resolutions, including radar, at the global scale
  - Identification of crop area, crop types, crop development, …
  - Assessment of hot spots in terms of stress, changes, degradation, ...

- Synergy between **monitoring and modelling**
  - Monitoring: time series of vegetation indices
  - Modelling: input to soil-crop-atmosphere models in combination with soil and meteorology

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CONCLUSION

- **Hazard characterisation (Meteo)**

  rainfall excess, drought, temperature

  extreme events, adverse weather

- **Impact (Remote Sensing)**

  crop development

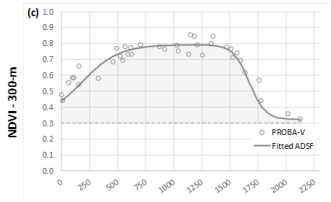
  damage assessment

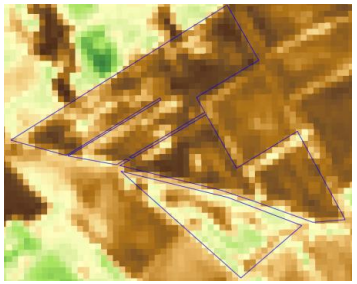
- **Adaptation (Modelling)**

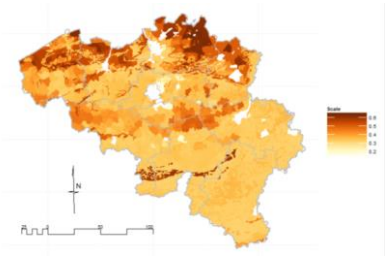
  soil and water **resources use**

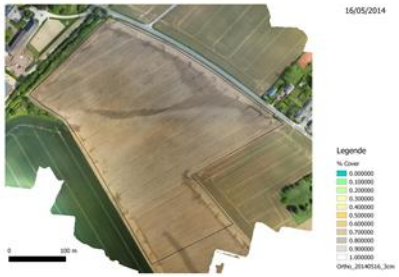
  Vulnerability; Measures & Options

winter wheat









Paradigm shift to data rich environments with unprecedented possibilities to monitor crop status at higher spatial, temporal and spectral resolutions

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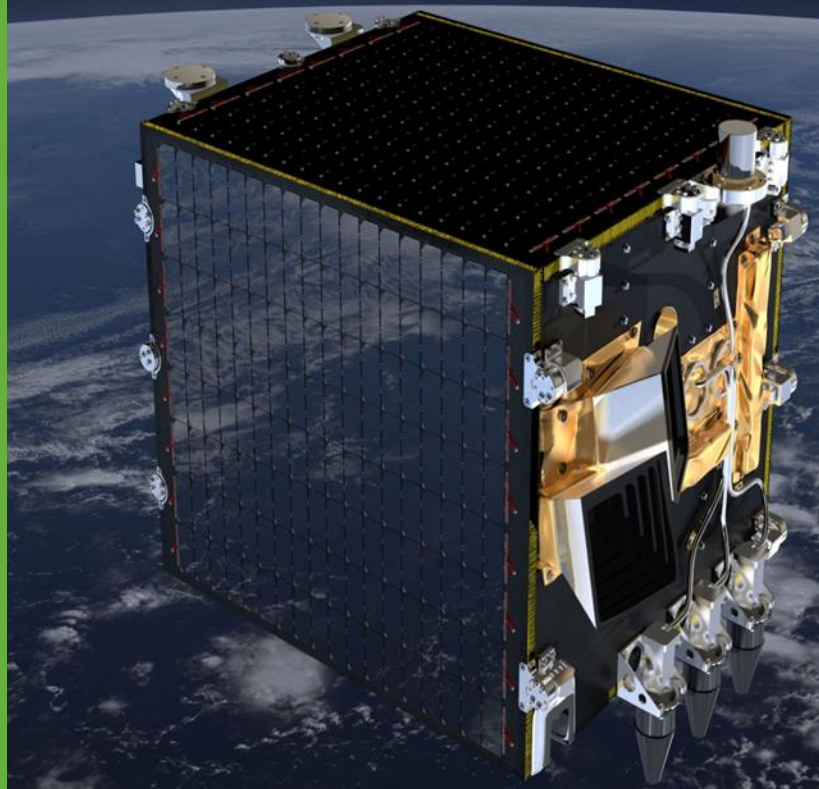
DROUGHT IMPACT: DATA AVAILABILITY AND USE FOR ESTIMATION OF DROUGHT RISK

Dr.ir. Anne Gobin

Drought Risk Assessment
6-8 November 2018
Budapest



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