Applying EO data for drought monitoring

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Presentation overview

- COPERNICUS PROGRAMME
- Satellites Data for Drought Monitoring
- Sentinel-2 and Landsat
- NOAA AVHRR
- Terra MODIS
- SMOS
- Sentinel-1
- Proba-V
- Modelling

Copernicus Programme

European Commission

Copernicus **in Brief**

- **The Copernicus programme** is a cornerstone of the European Union's efforts to monitor **the Earth** and its many ecosystems, whilst ensuring that its citizens are prepared and protected in the face of **crises** and **natural or man-made disasters**.

- The Copernicus Programme is a tool for **economic development** and a driver for **digital economy.**

- The Copernicus programme places a world of insight about our planet at the disposal of citizens, public authorities and policy makers, scientists, entrepreneurs and businesses on **a full, free and open basis**.

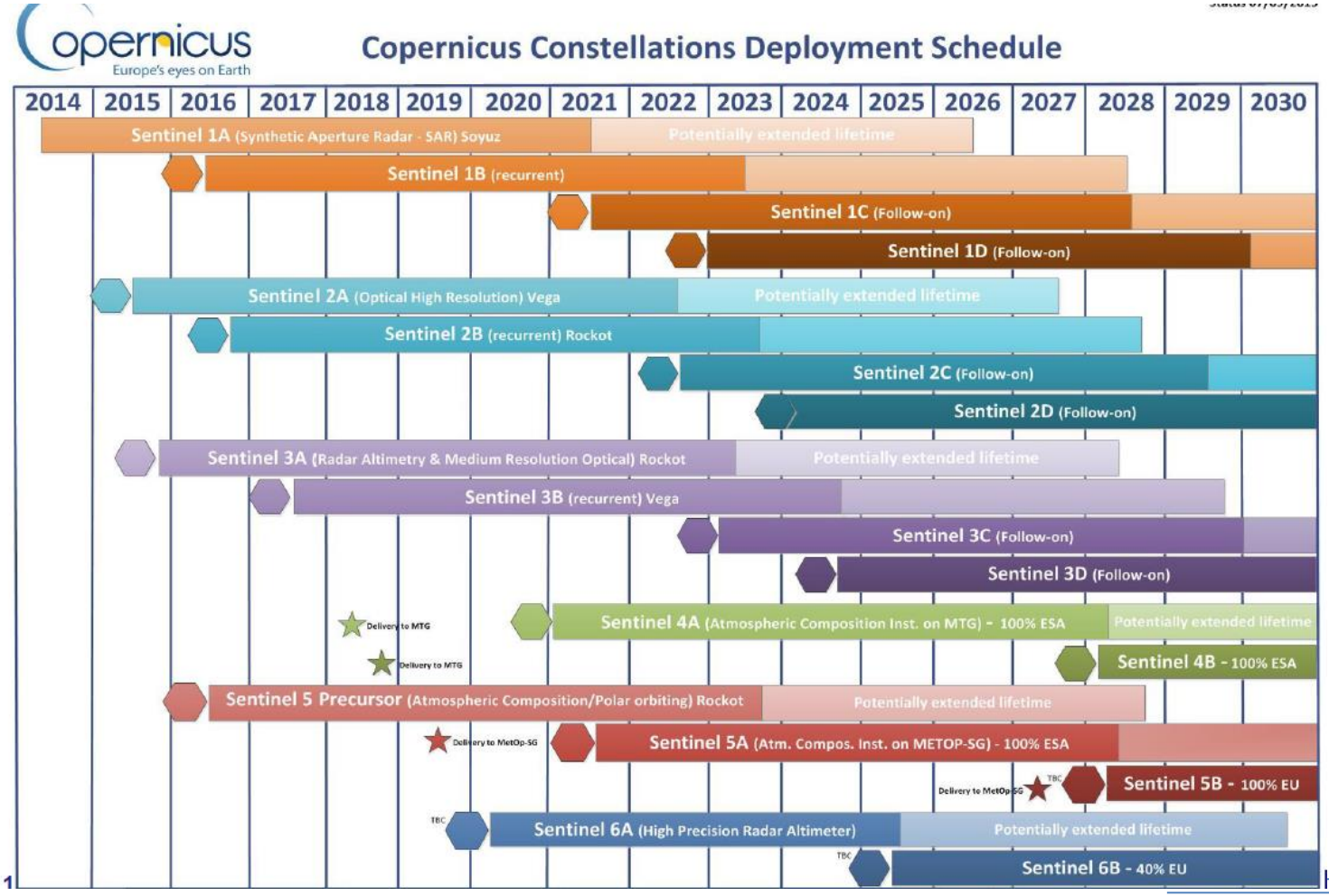
Copernicus Programme

Introduction

- The Copernicus programme entered its **operational phase** with the launch of Sentinel-1A in 2014 and its governance is based on the **Copernicus Regulation** adopted the same year which establishes the Commission as the Programme manager owning the infrastructure and data rights on behalf of the Union;

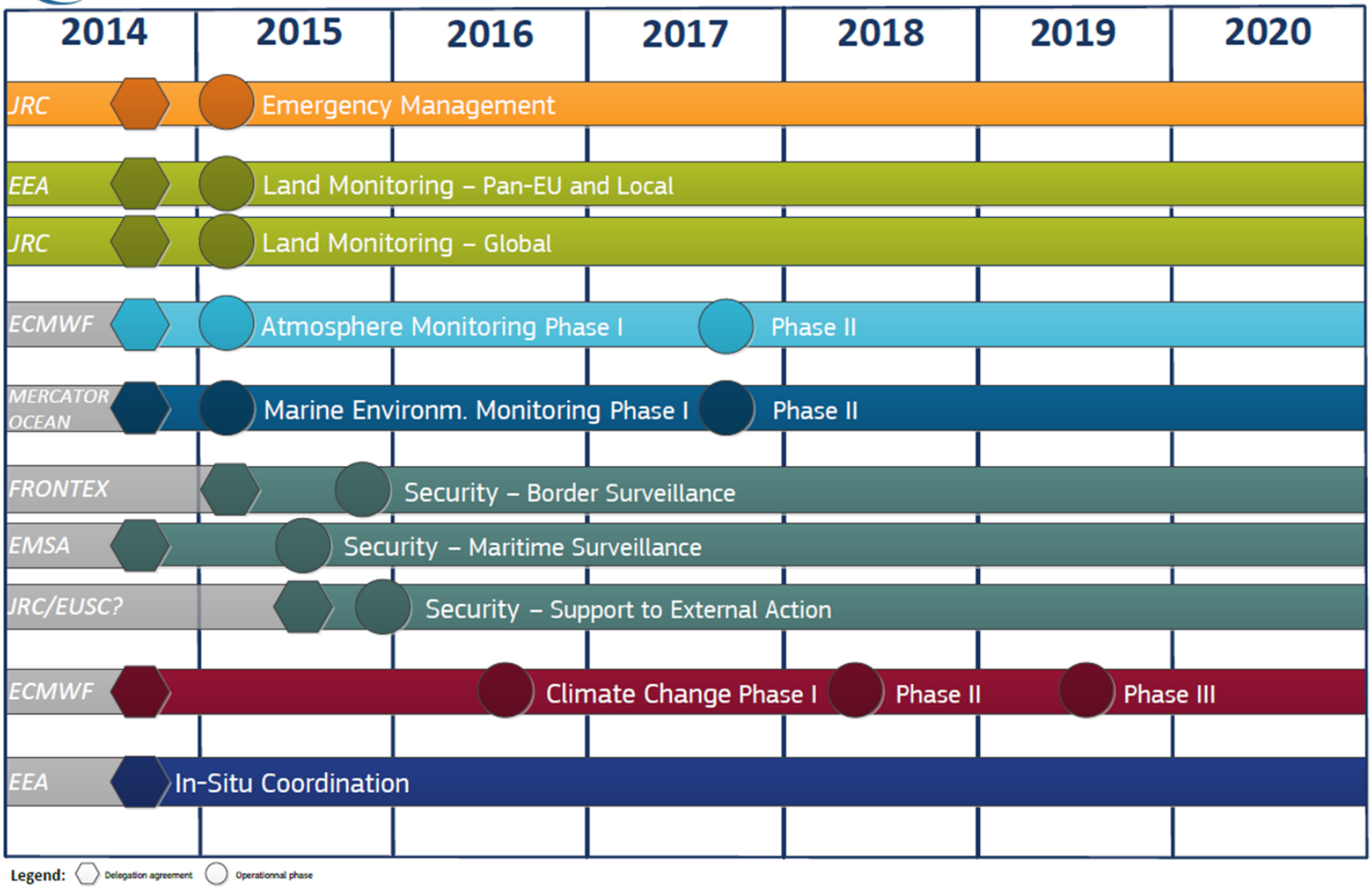
- Copernicus services are based on information from a dedicated constellation of satellites, known as **"Sentinels",** as well as tens of third-party satellites known as **"contributing space missions"**, complemented by ***"in situ"*** (meaning local or on-site) measurement data;

- By making the vast majority of its **data, analyses, forecasts and maps freely available and accessible**, Copernicus contributes towards the development of new innovative applications and services, tailored to the needs of specific groups of users, which touch on a variety of economic and cultural or recreational activities, from urban planning, sailing and insurance to archaeology.


opernicus
Europe's eyes on Earth
Copernicus Constellations Deployment Schedule
2014
2015
2016
2017
2018
2019
2020
2021
2022
2023
2024
2025
2026
2027
2028
2029
2030
Sentinel 1A (Synthetic Aperture Radar - SAR) Soyuz
Potentially extended lifetime
Sentinel 1B (recurrent)
Sentinel 1C (Follow-on)
Sentinel 1D (Follow-on)
Sentinel 2A (Optical High Resolution) Vega
Potentially extended lifetime
Sentinel 2B (recurrent) Rockot
Sentinel 2C (Follow-on)
Sentinel 2D (Follow-on)
Sentinel 3A (Radar Altimetry & Medium Resolution Optical) Rockot
Potentially extended lifetime
Sentinel 3B (recurrent) Vega
Sentinel 3C (Follow-on)
Sentinel 3D (Follow-on)
Delivery to MTG
Delivery to MTG
Sentinel 4A (Atmospheric Composition Inst. on MTG) - 100% ESA
Potentially extended lifetime
Sentinel 4B - 100% ESA
Sentinel 5 Precursor (Atmospheric Composition/Polar orbiting) Rockot
Potentially extended lifetime
Delivery to MetOp-SG
Sentinel 5A (Atm. Compos. Inst. on METOP-SG) - 100% ESA
Delivery to MetOp-SG
TBC
Sentinel 5B - 100% EU
TBC
Sentinel 6A (High Precision Radar Altimeter)
Potentially extended lifetime
TBC
Sentinel 6B - 40% EU

Status 23 June 2014

Copernicus services: Implementation Schedule



Copernicus Services

- Currently, all Copernicus services and projects base their activities on the provision of satellite imagery from contributing missions, made available through the Copernicus Space Component Data Access system operated by ESA since 2008

- global component – producing land information through a wide range of biophysical parameters in near-real time and on 10-day frequency with global coverage.
- These parameters describe the state of vegetation (e.g. leaf area index), the energy budget (e.g. albedo) and the water cycle (e.g. soil moisture index).

The Copernicus Land Monitoring Service

Provides geographical information on:

- land cover, land use, land use change over the years, vegetation state ; the water cycle

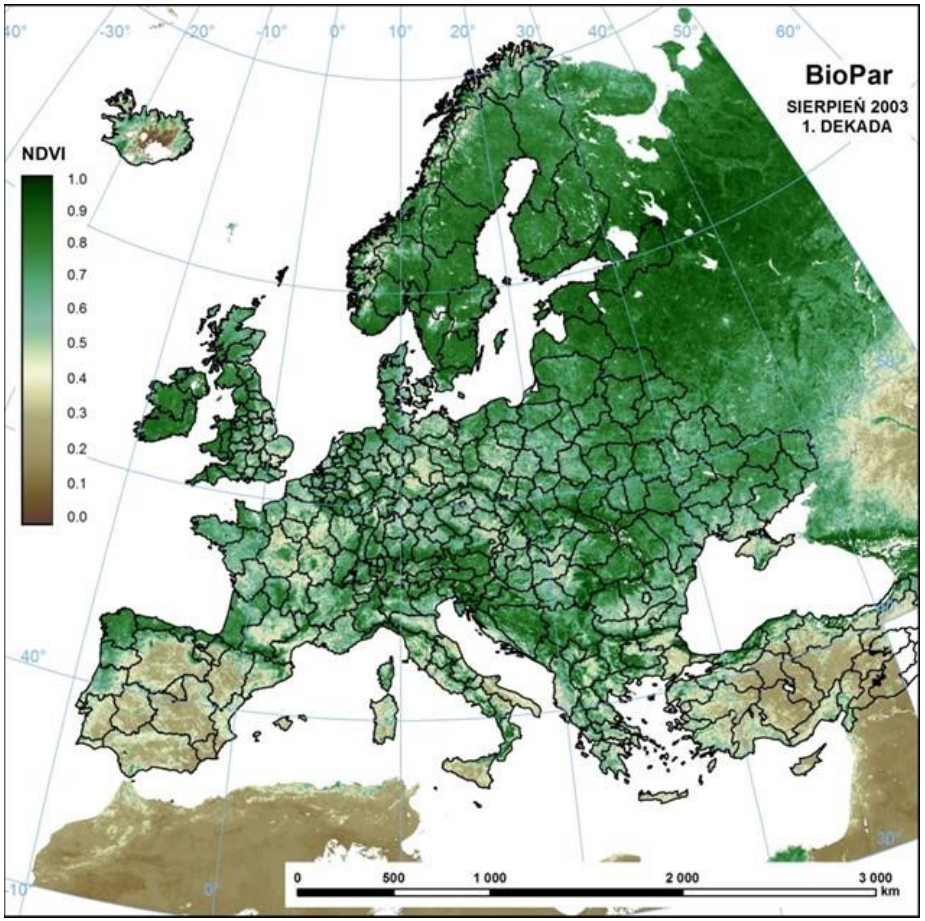
Applications that are built upon and integrate the information supplied by the service can provide support in areas such as:

- spatial planning, forest management, water management, agriculture and food security and emergency management, amongst others.

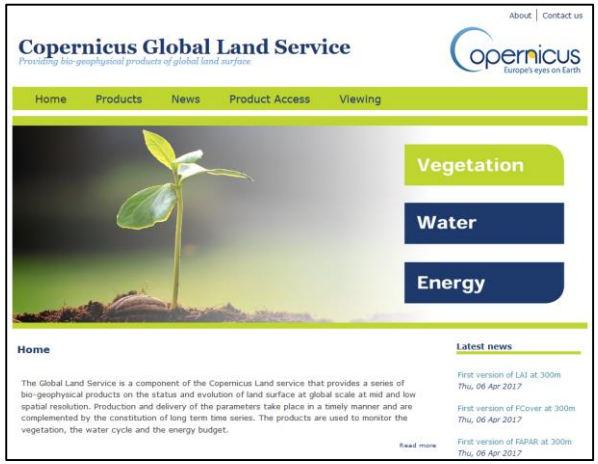
The three main components of the Copernicus Land Monitoring Service are currently:

- A Global component;
- A Pan-European component
- A Local component.

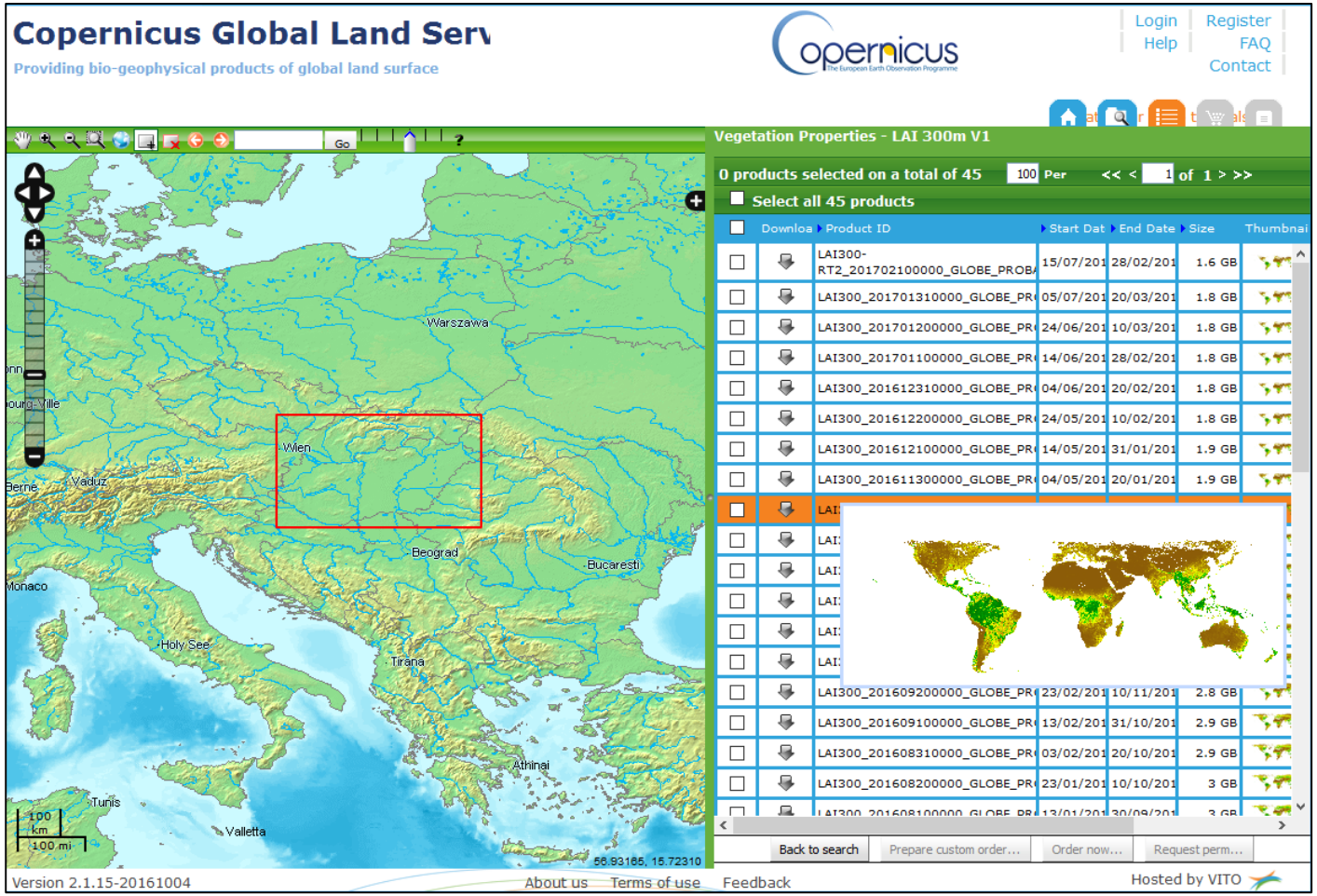
BioPar – Product – NDVI based on SPOT-Vegetation continued using PROBA-V



http://land.copernicus.eu/global/



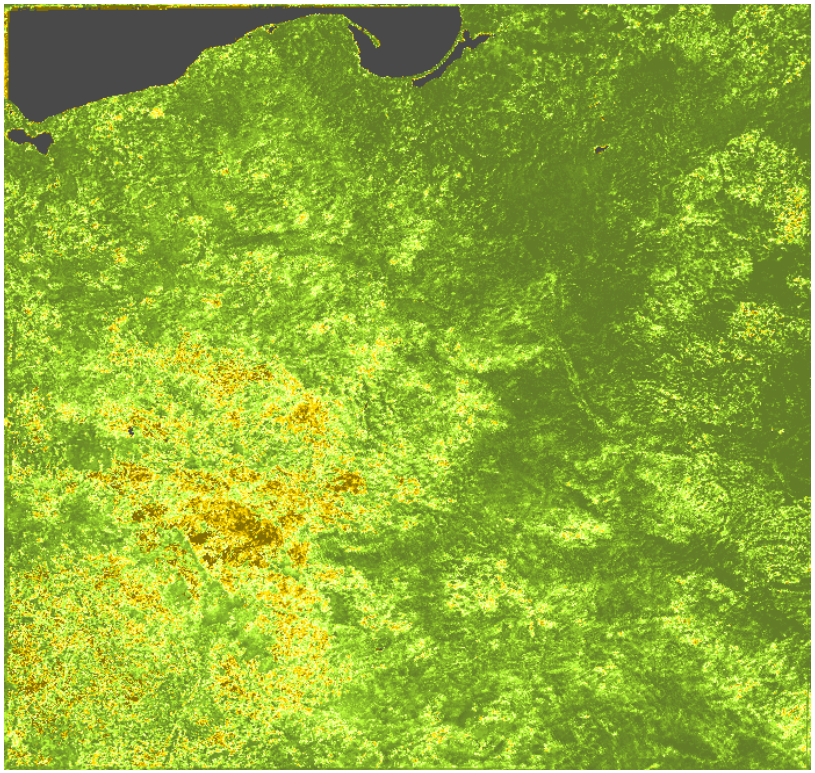
http://land.copernicus.eu/global/



Low Resolution Data NOAA – AVHRR covers all country

NOAA AVHRR Bands	Wavelength (µm)	Resolution at Nadir	Typical Use
1	0.58 - 0.68	1.09 km	Daytime cloud and surface mapping
2	0.725 - 1.00	1.09 km	Land-water boundaries
3A	1.58 - 1.64	1.09 km	Snow and ice detection
3B	3.55 - 3.93	1.09 km	Night cloud mapping, sea surface temperature
4	10.30 - 11.30	1.09 km	Night cloud mapping, sea surface temperature
5	11.50 - 12.50	1.09 km	Sea surface temperature

NOAA - AVHRR



Poland – VCI (year: 2015, decade: 28)

Terra MODIS

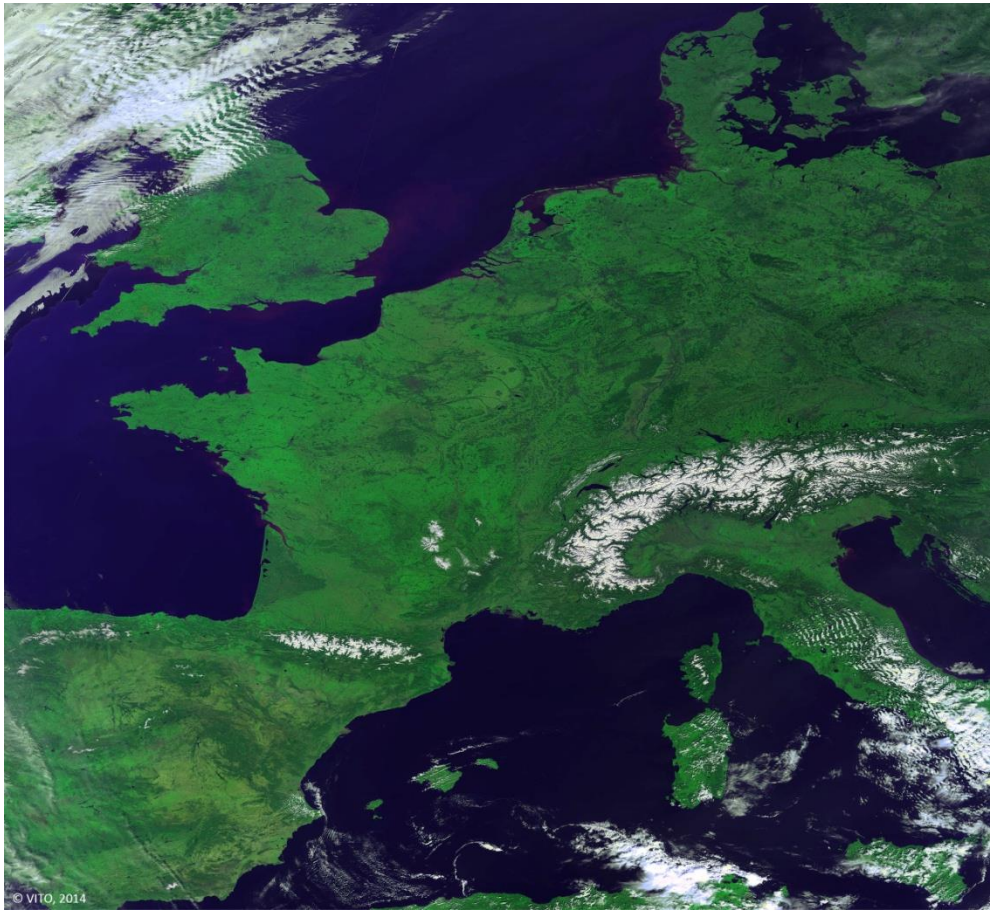
Band	Wavelength (µm)	Resolution (m)	Primary Use
1	620–670	250	Land/Cloud/Aerosols Boundaries
2	841–876	250	
3	459–479	500	Land/Cloud/Aerosols Properties
4	545–565	500	
5	1230–1250	500	
6	1628–1652	500	
7	2105–2155	500	
8	405–420	1000	Ocean Color/ Phytoplankton/ Biogeochemistry
9	438–448	1000	
10	483–493	1000	
11	526–536	1000	
12	546–556	1000	
13	662–672	1000	
14	673–683	1000	
15	743–753	1000	
16	862–877	1000	
17	890–920	1000	Atmospheric Water Vapor
18	931–941	1000	
19	915–965	1000	

Band	Wavelength (µm)	Resolution (m)	Primary Use
20	3.660–3.840	1000	Surface/Cloud Temperature
21	3.929–3.989	1000	
22	3.929–3.989	1000	
23	4.020–4.080	1000	
24	4.433–4.498	1000	Atmospheric Temperature
25	4.482–4.549	1000	
26	1.360–1.390	1000	Cirrus Clouds Water Vapor
27	6.535–6.895	1000	
28	7.175–7.475	1000	
29	8.400–8.700	1000	Cloud Properties
30	9.580–9.880	1000	Ozone
31	10.780–11.280	1000	Surface/Cloud Temperature
32	11.770–12.270	1000	
33	13.185–13.485	1000	Cloud Top Altitude
34	13.485–13.785	1000	
35	13.785–14.085	1000	
36	14.085–14.385	1000	

Proba-V

Proba-V facts and figures	
Launch date:	6/7 May 2013 (04:06:31 CEST 7 May; 23:06:31 local time 6 May)
Mass:	140 kg
Orbit:	Sun-synchronous polar orbit, 820 km altitude, crossing the equator every morning between 10:30 and 11:00 local time
Instrument:	**New version of the Vegetation imager** previously flown on the Spot satellites
Field of view:	**2250 km** wide swath
Spectral bands:	Proba-V that collects light in 4 bands: **blue**, **red**, **near-infrared** and **mid-infrared**
Resolution:	**350 m** (full field of view), **100 m** (at nadir)
Prime contractor:	QinetiQ Space Belgium

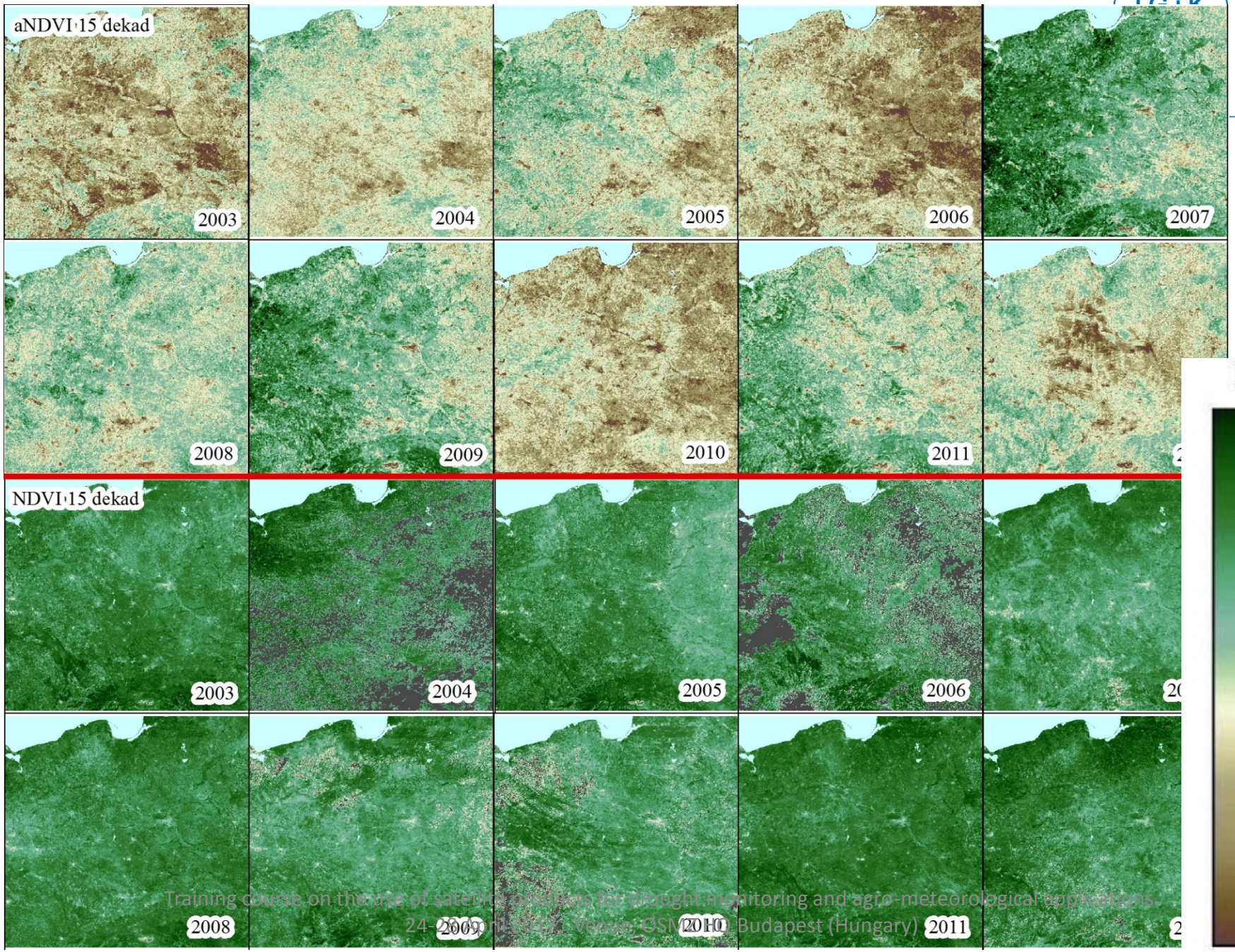
Proba-V



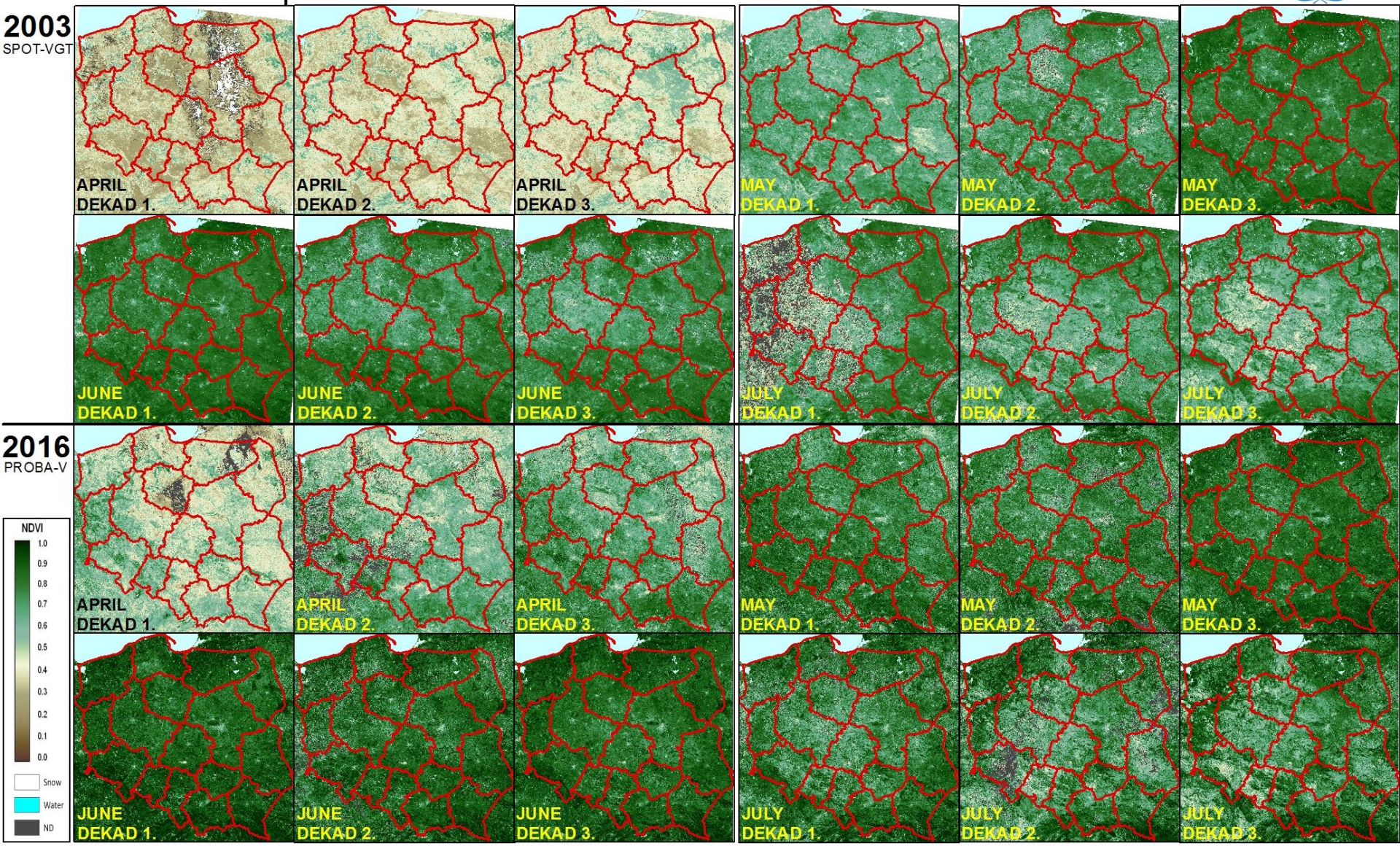
Proba-V image, Europe

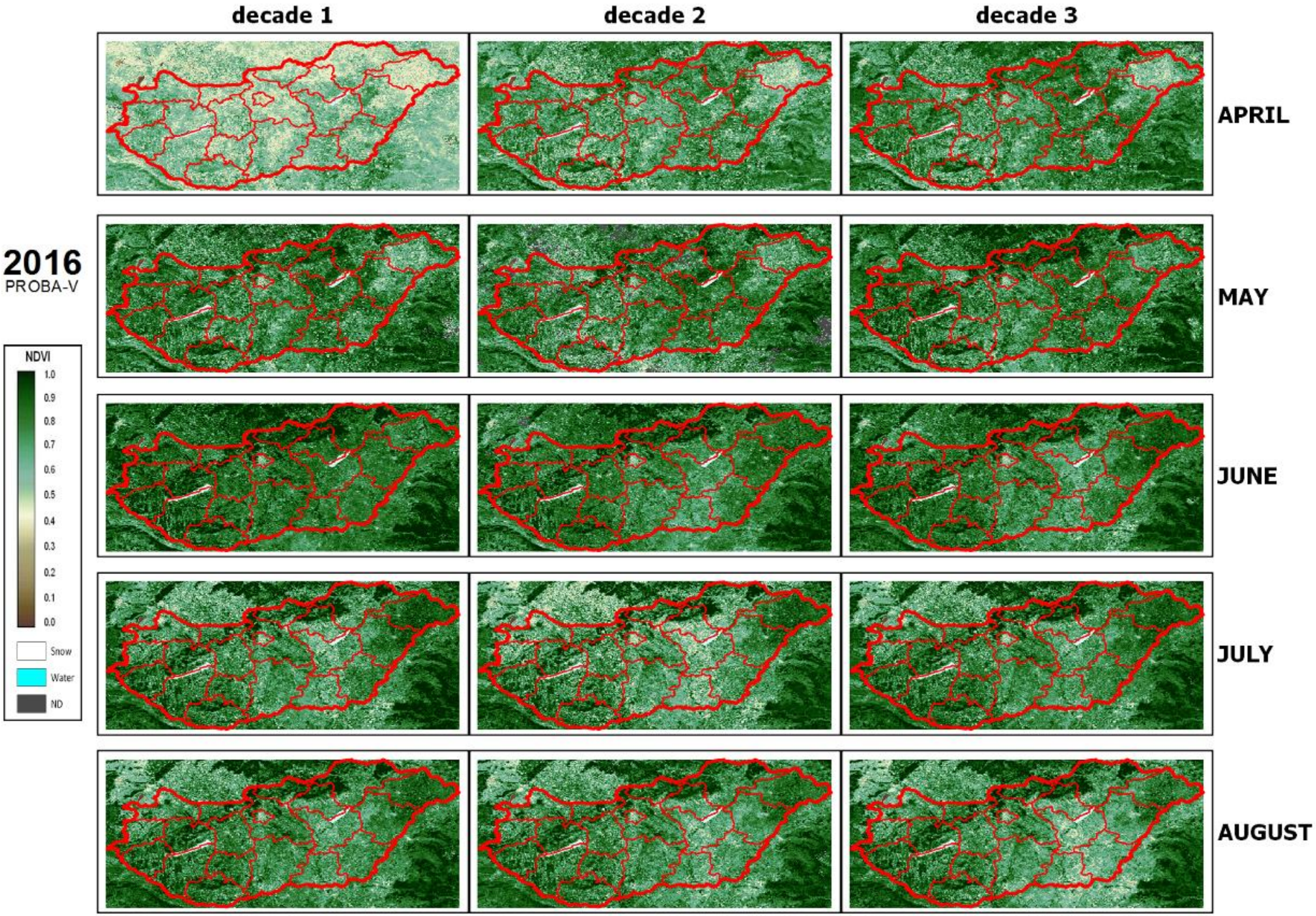
Source: www.esa.int

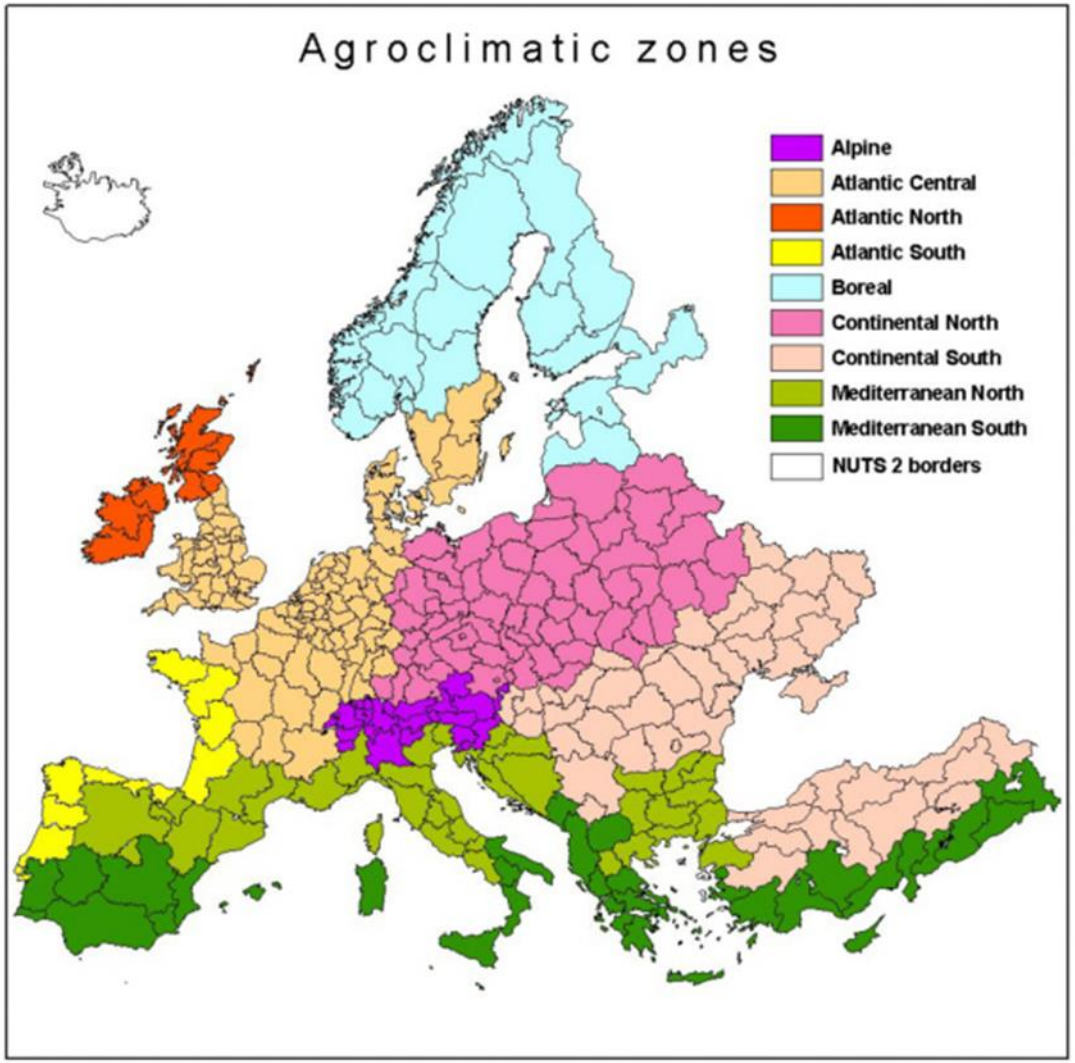
NDVI – MODIS different years – for 15 decade



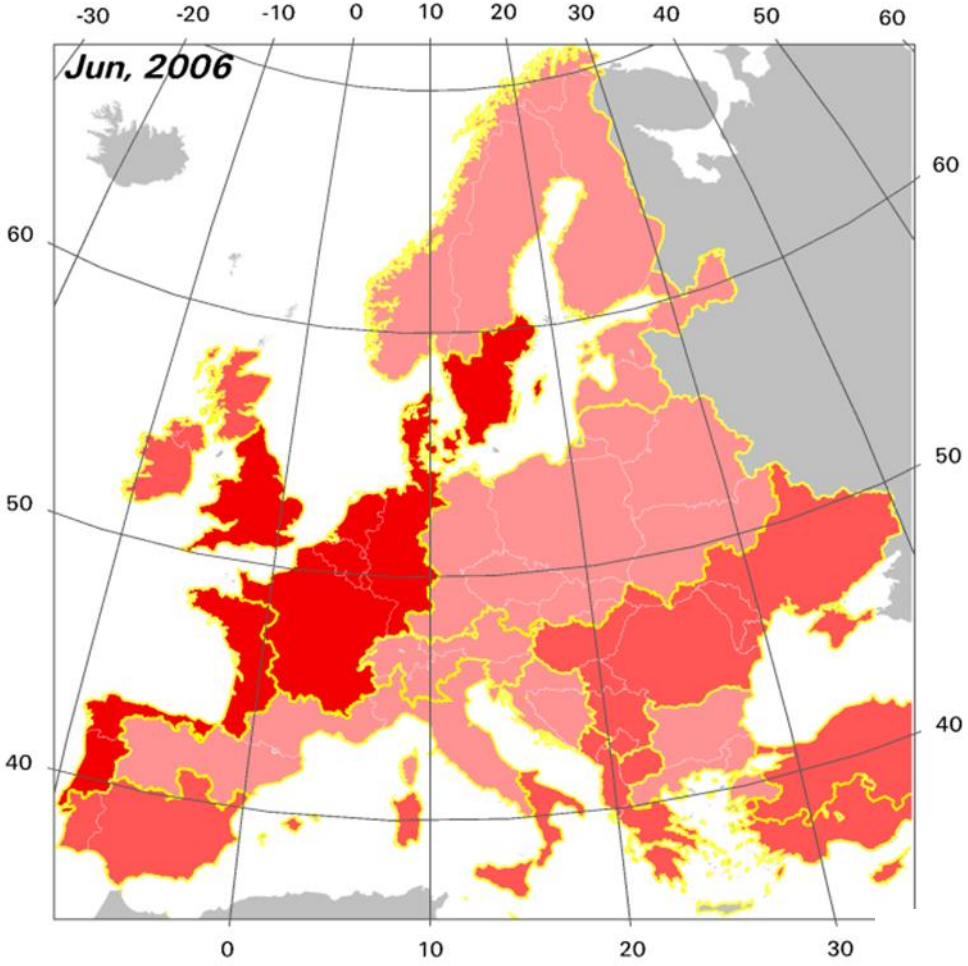
1 June 2014 SPOT VEGETATION finished acqusition



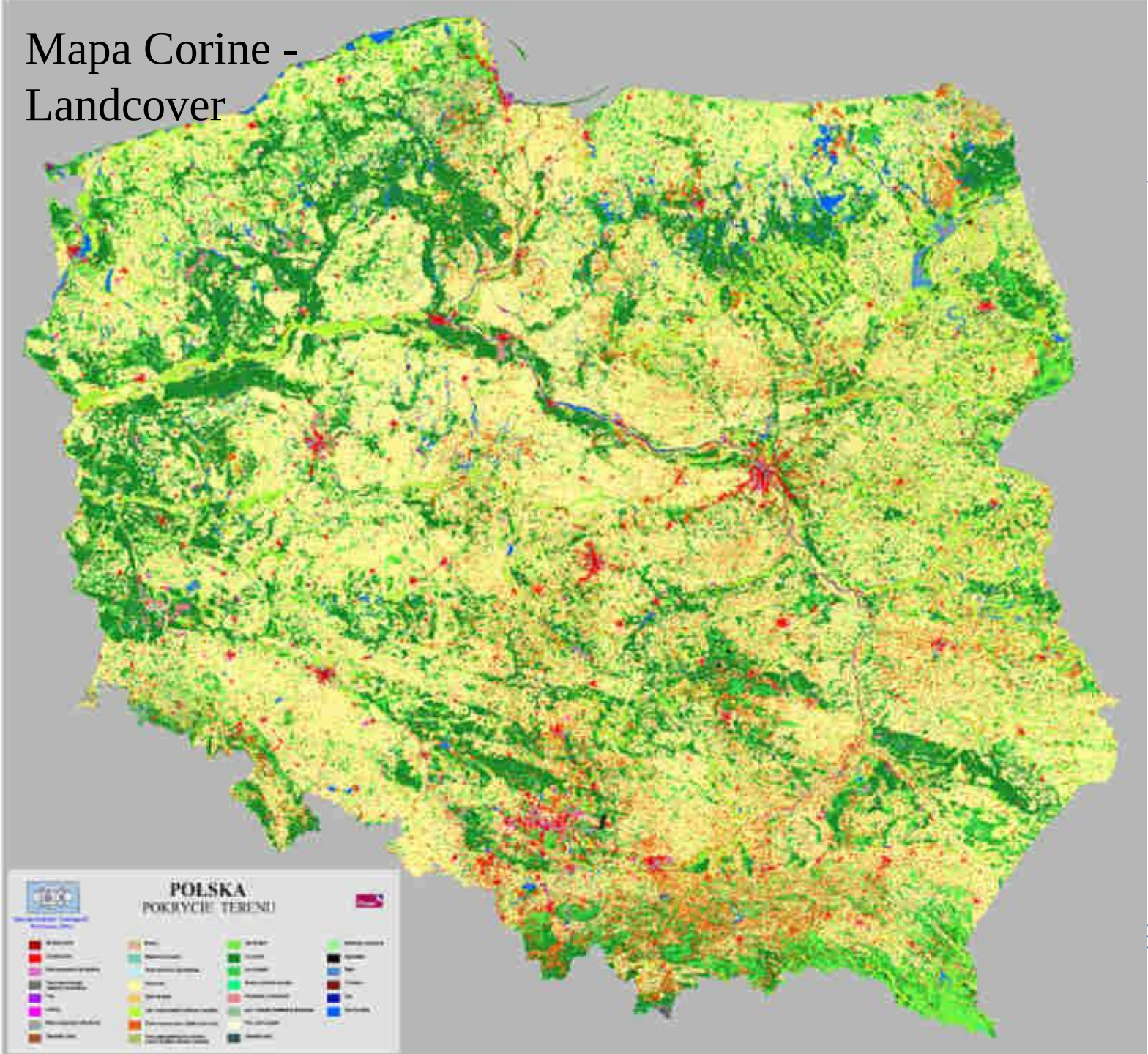

decade 1
decade 2
decade 3
APRIL
MAY
JUNE
JULY
AUGUST
2016
PROBA-V
NDVI
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
Snow
Water
ND


Agroclimatic zones
Alpine
Atlantic Central
Atlantic North
Atlantic South
Boreal
Continental North
Continental South
Mediterranean North
Mediterranean South
NUTS 2 borders

ECMWF data Ta-Ta mean

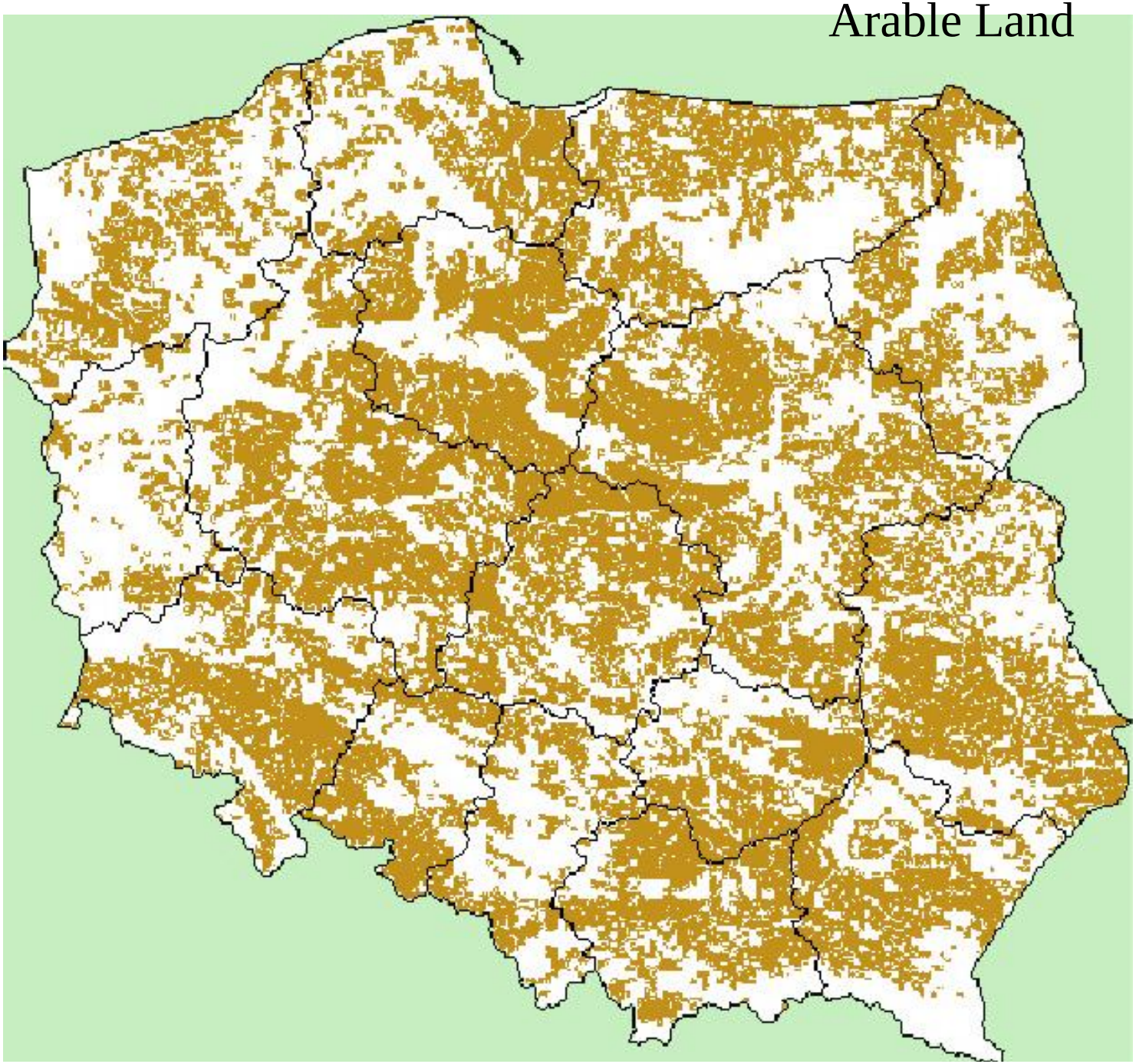


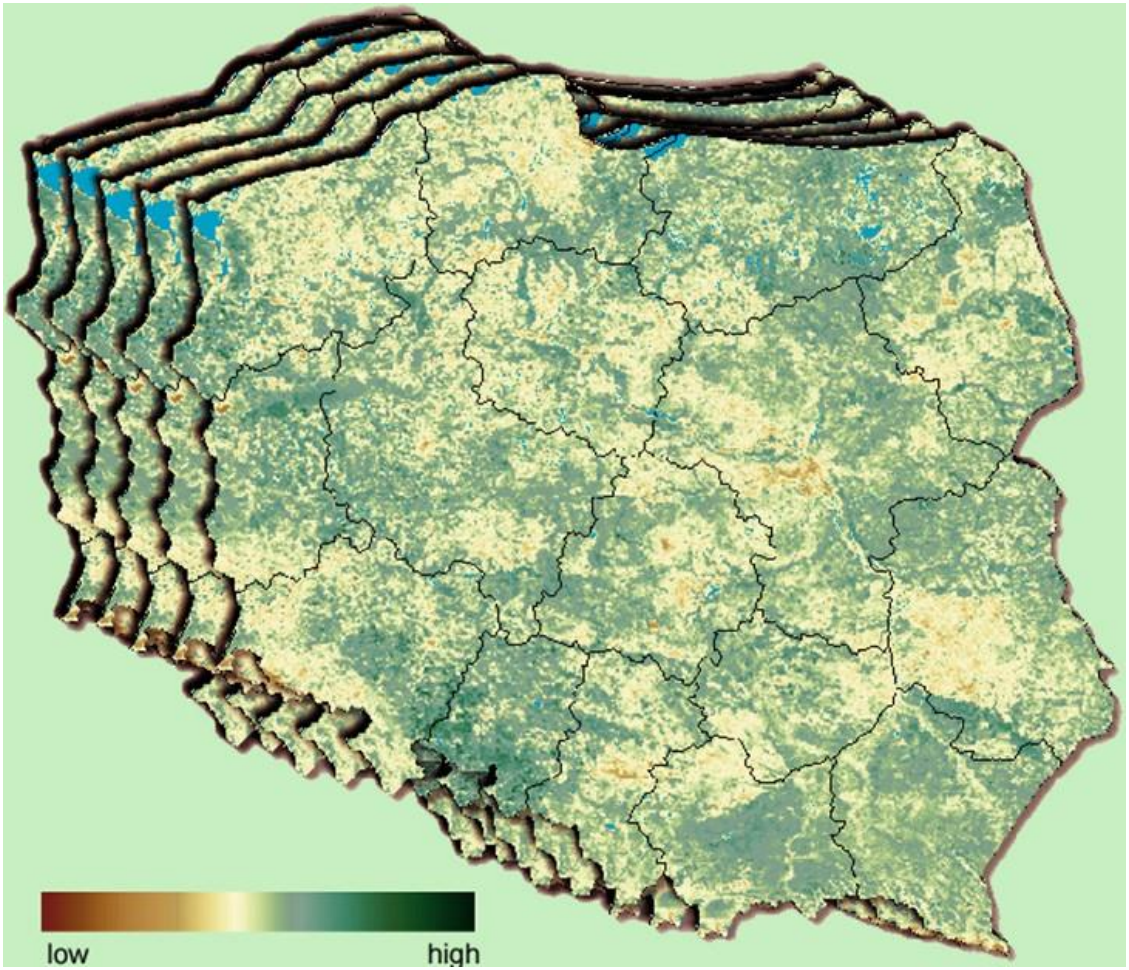
Mapa Corine - Landcover



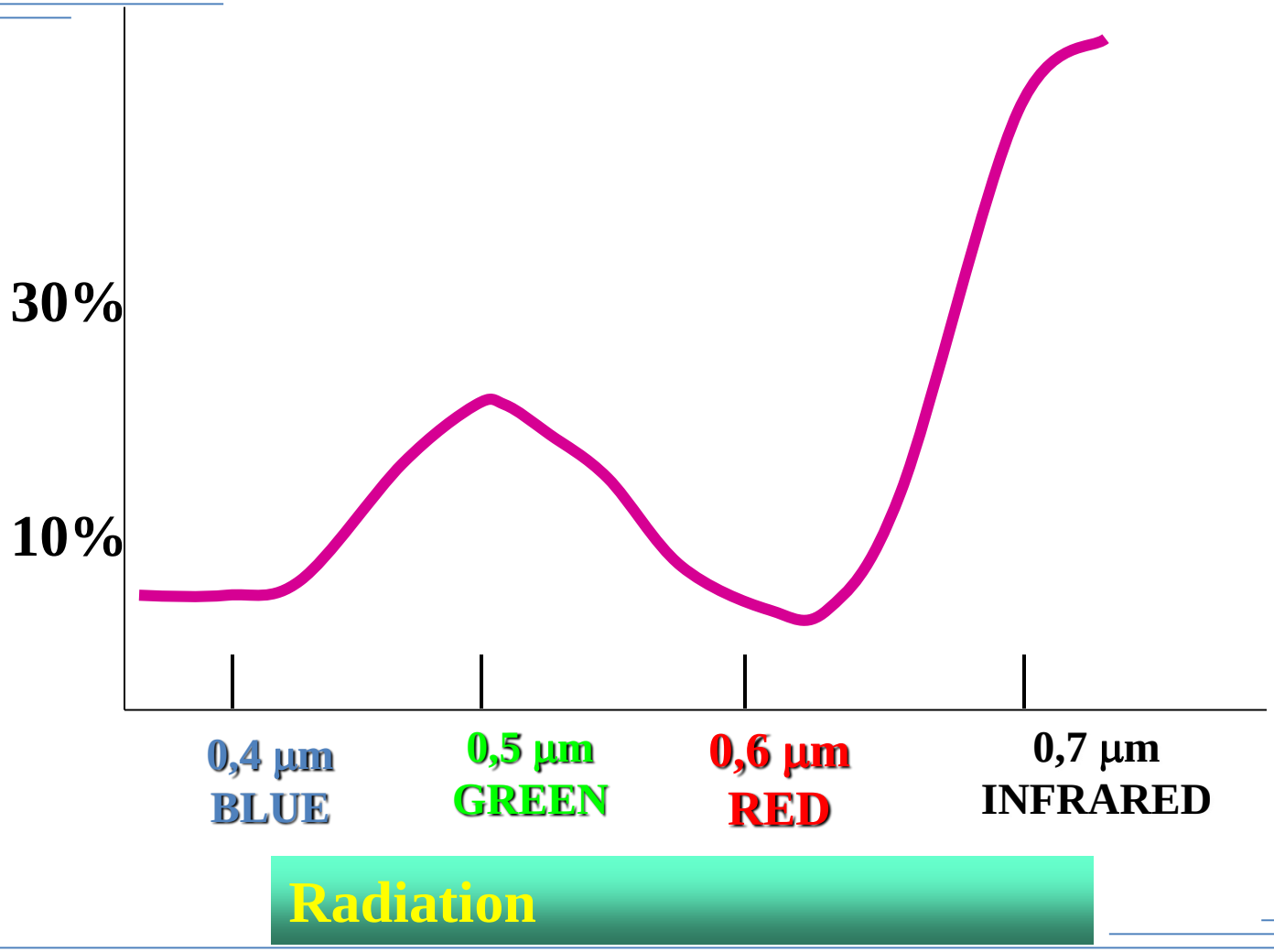
World Meteorological Organization
Weather • Climate • Water

Arable Land



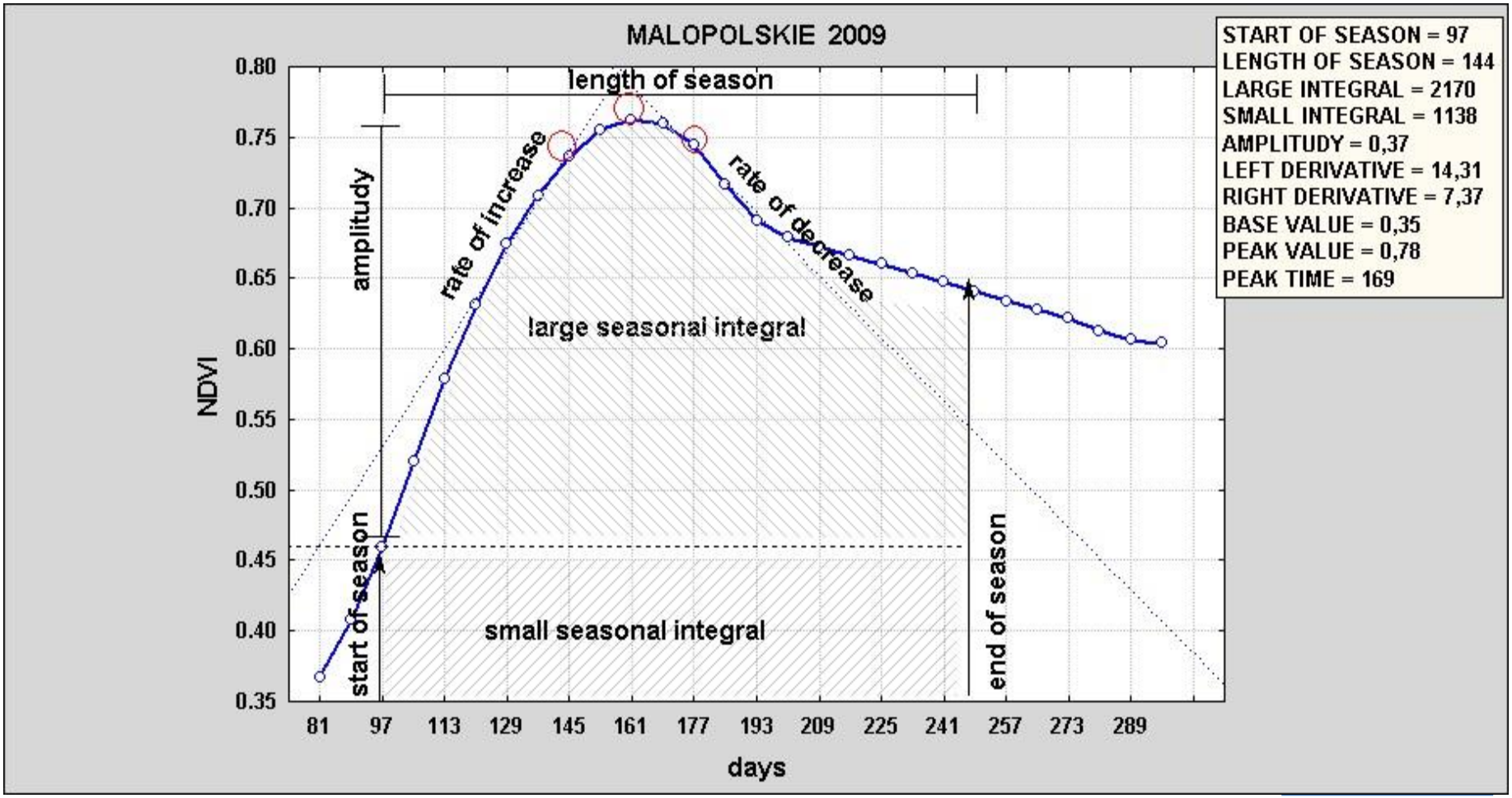

low
high

Reflection in different wave by Vegetation



Normalised Vegetation Index -NDVI

$$NDVI = \frac{K_2 - K_1}{K_2 + K_1}$$


MALOPOLSKIE 2009
START OF SEASON = 97
LENGTH OF SEASON = 144
LARGE INTEGRAL = 2170
SMALL INTEGRAL = 1138
AMPLITUDY = 0,37
LEFT DERIVATIVE = 14,31
RIGHT DERIVATIVE = 7,37
BASE VALUE = 0,35
PEAK VALUE = 0,78
PEAK TIME = 169
length of season
amplitudy
rate of increase
rate of decrease
large seasonal integral
small seasonal integral
start of season
end of season
NDVI
days
0.80
0.75
0.70
0.65
0.60
0.55
0.50
0.45
0.40
0.35
81
97
113
129
145
161
177
193
209
225
241
257
273
289

Vegetation Condition Index (VCI)

$$VCI = 100 \times \frac{NDVI - NDVI_{min}}{NDVI_{max} - NDVI_{min}}$$

NDVI – actual value of Normalized Difference Vegetation Index

$NDVI_{min}$ – minimal value of Normalized Difference Vegetation Index

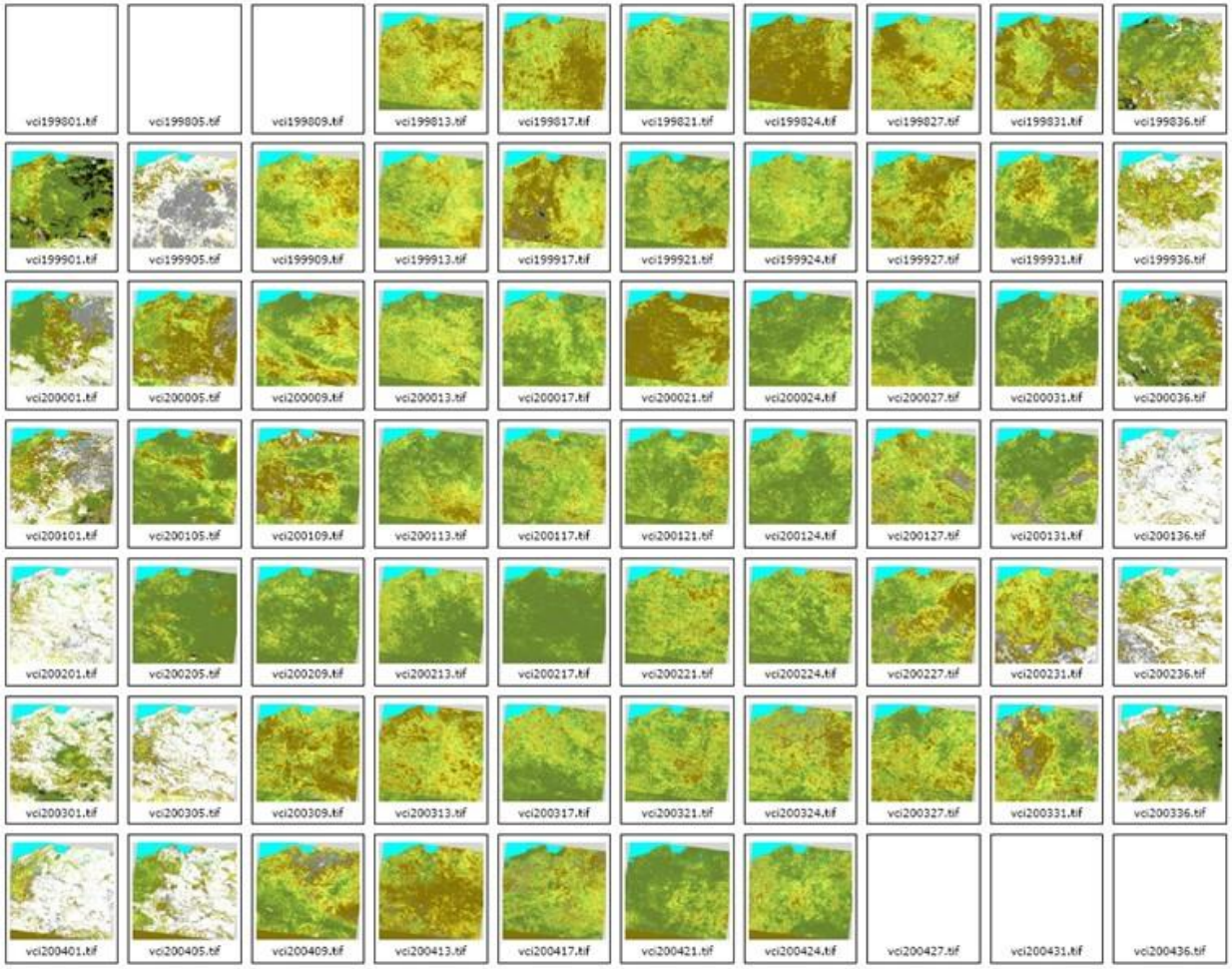
$NDVI_{max}$ – maximal value of Normalized Difference Vegetation Index

SPOT–VEGETATION VCI

1998

2000

2003



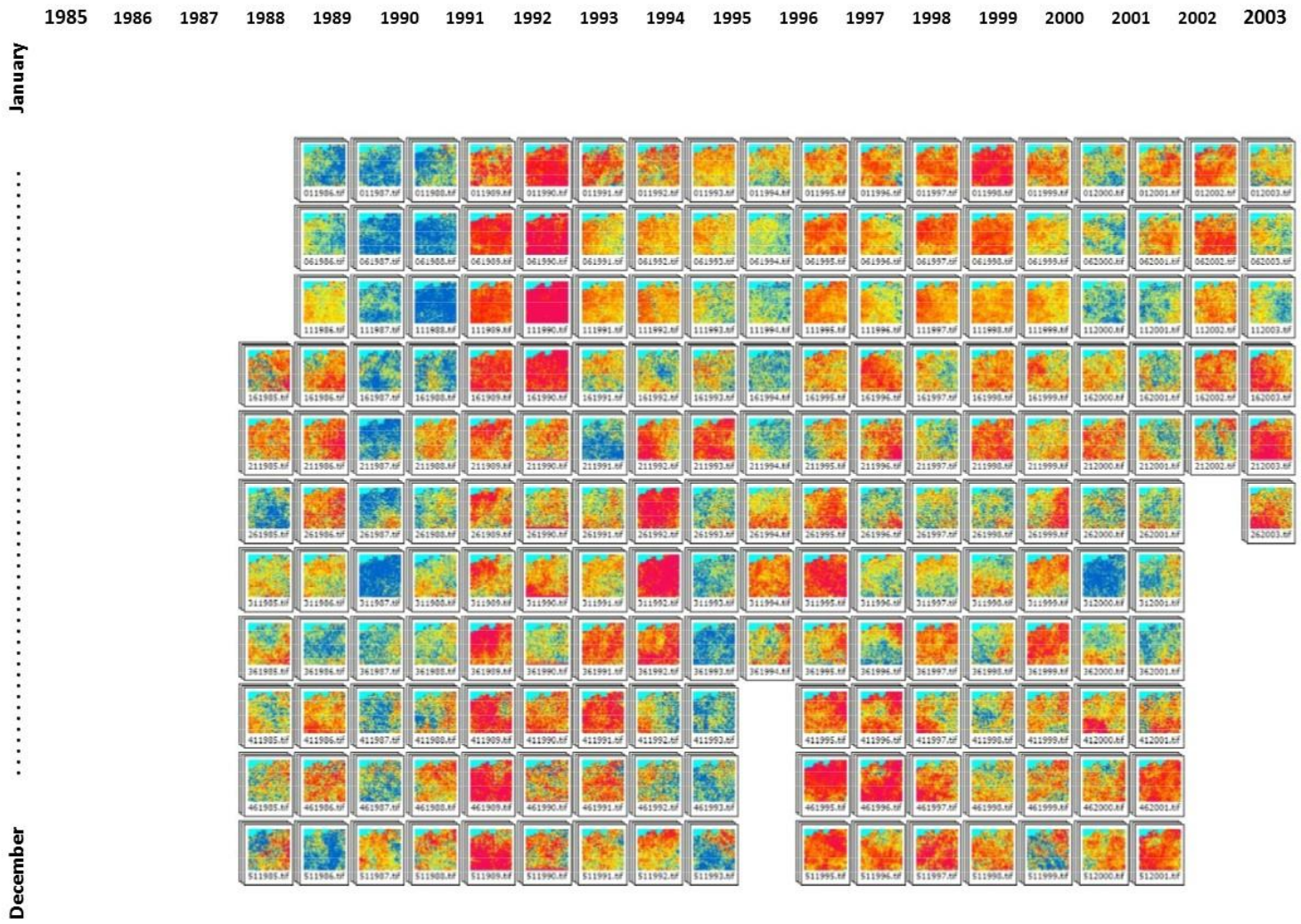
Thermal Condition Index - TCI

$$TCI = 100 \times \frac{T_{max} - T_{akt}}{T_{max} - T_{min}}$$

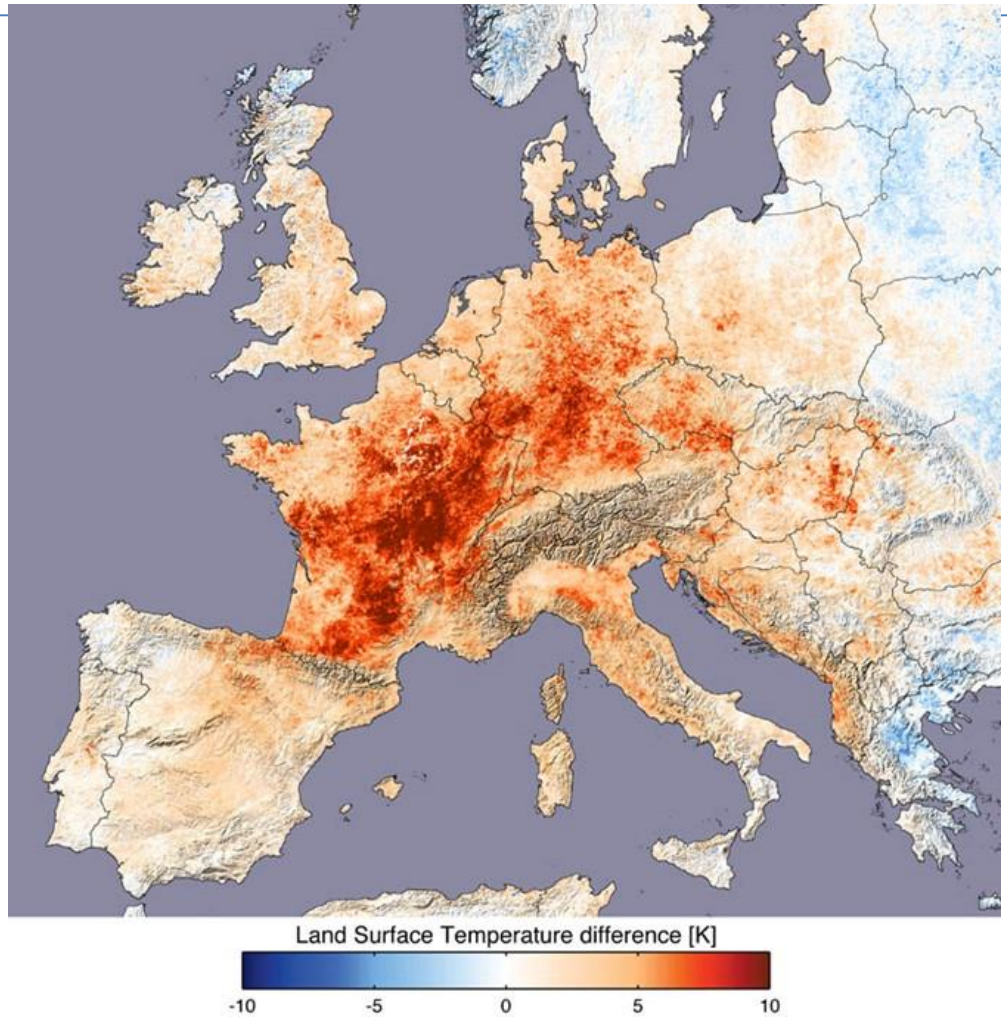
T_{akt} – plants' temperature measured from actual satellite data

T_{max} – maximal plants' temperature in particular time

T_{min} – minimal plants' temperature in particular time

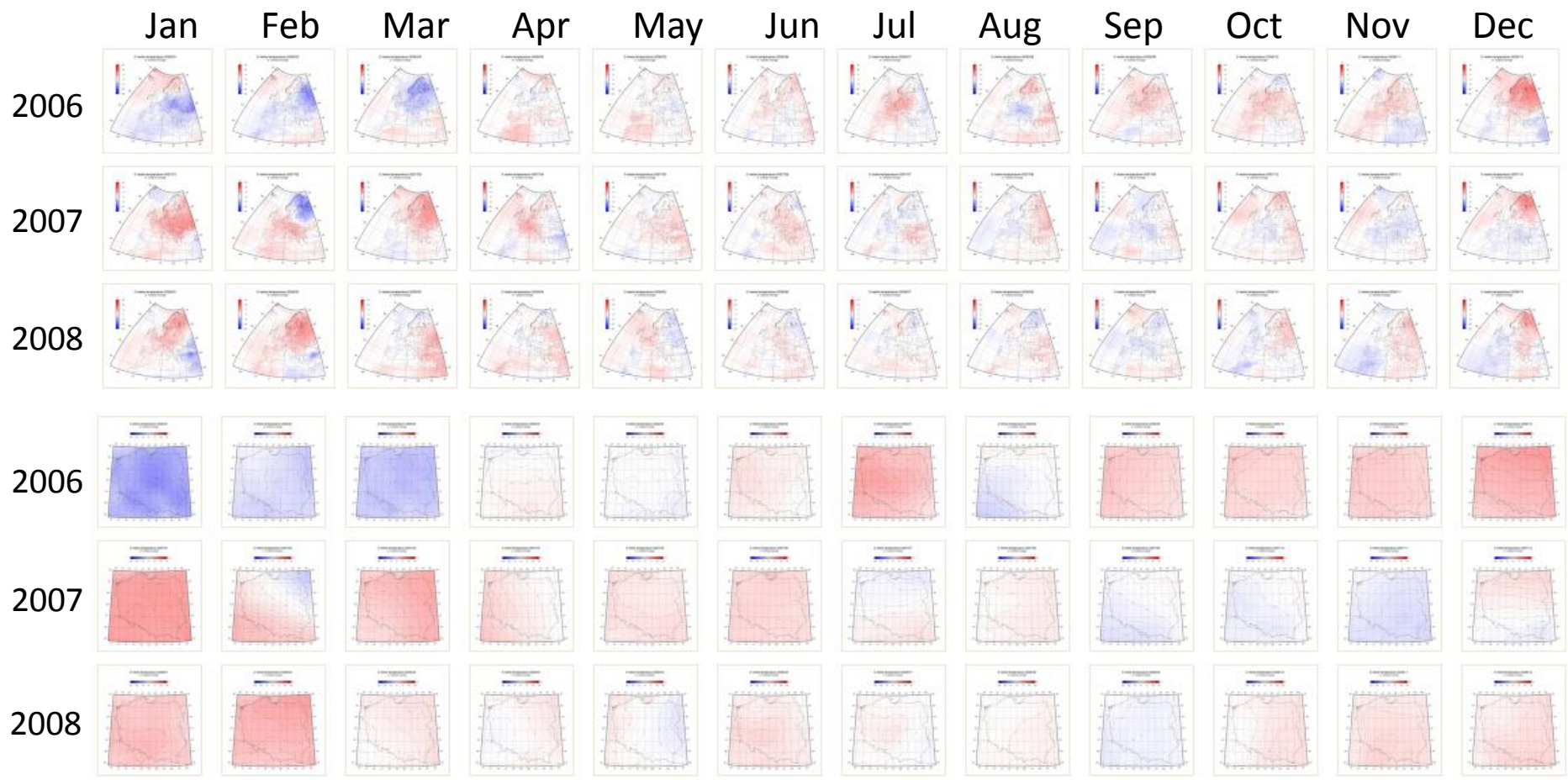

1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
January
December

Drought in Europe 2003 – LST from satellite



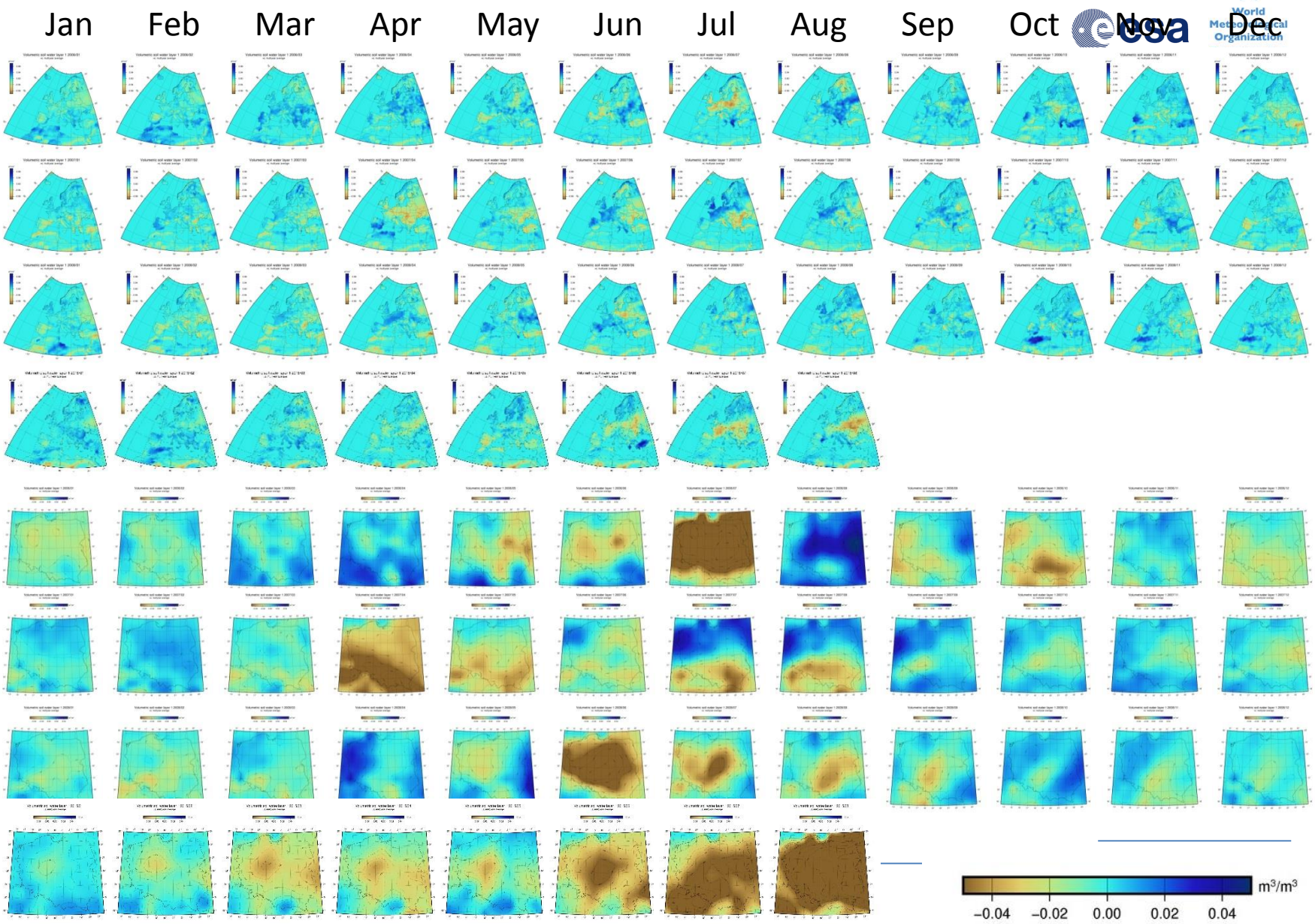
ECMWF DATA

2 meter temperature vs. multiyear average



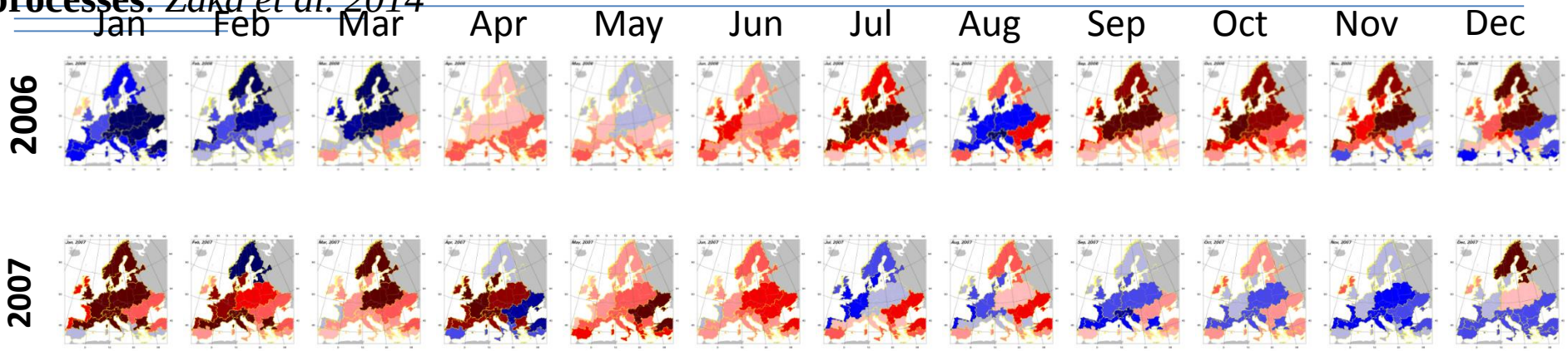
ECMWF DATA

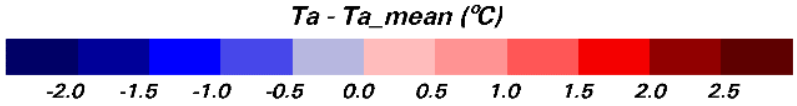
Volumetric soil water layer 1 vs. multiyear average

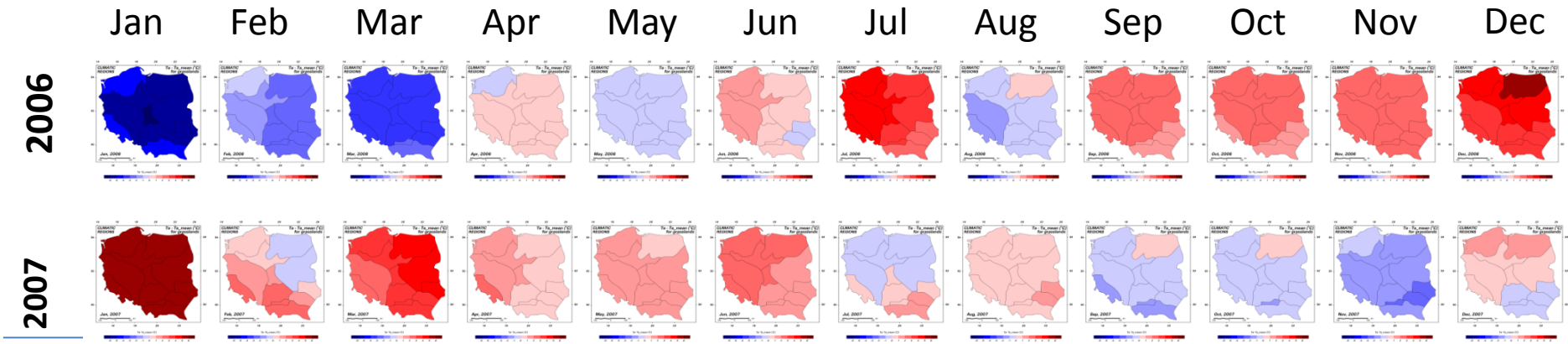


ECMWF DATA (Ta – Ta mean)

Temperature is one of the most important factors affected by climate change and is also one of the most important variables involved in the control of plant developmental processes. *Zaka et al. 2014*

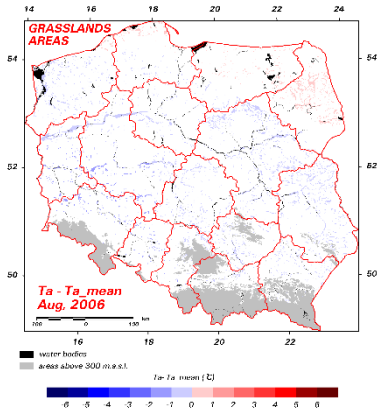


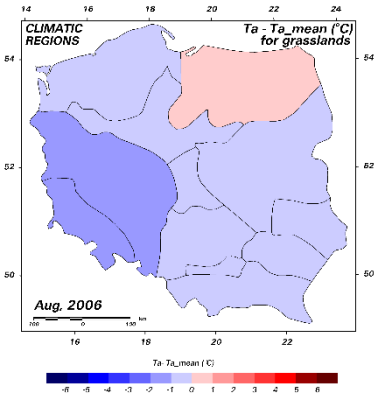


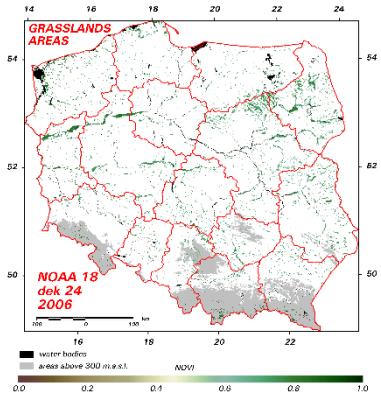


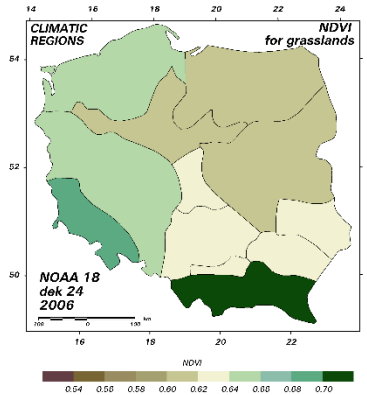
2 meter temperature vs. multiyear average - *ECMWF*

Climatic Zones in Poland

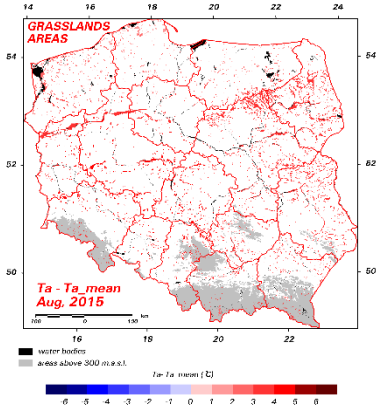


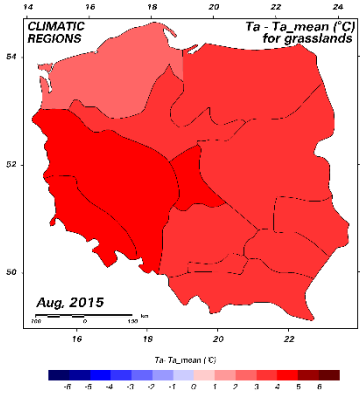


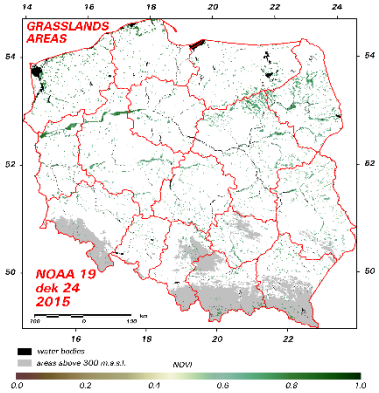


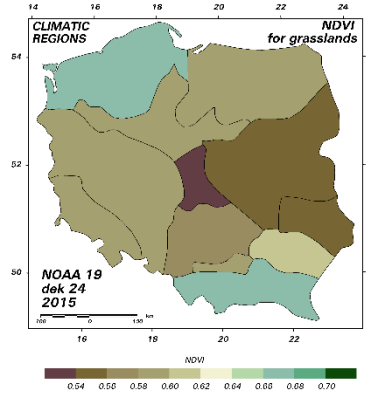


August 2006



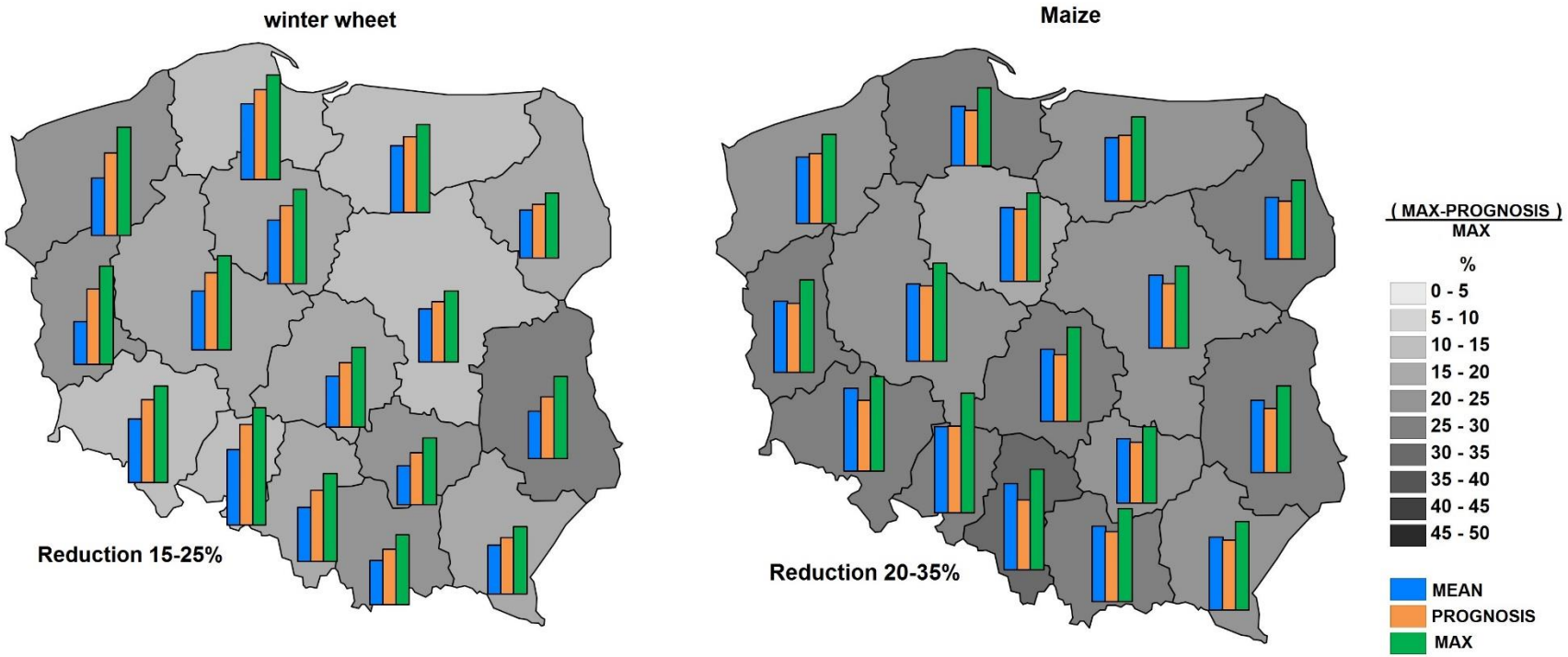




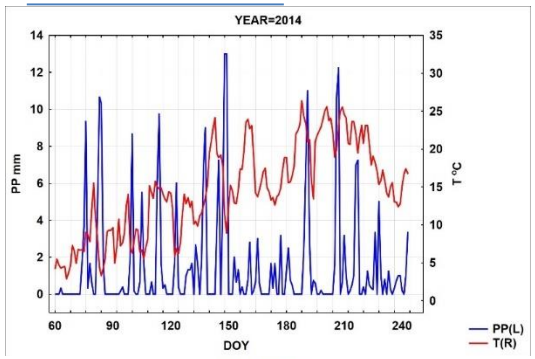


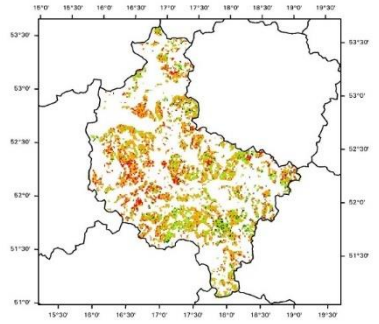
August 2015

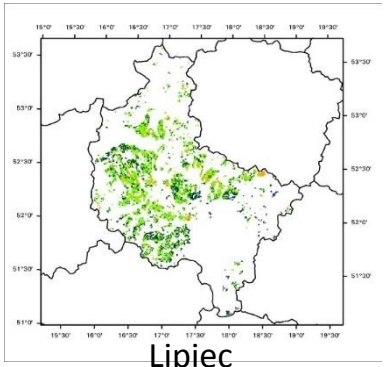
Crop prognosis -

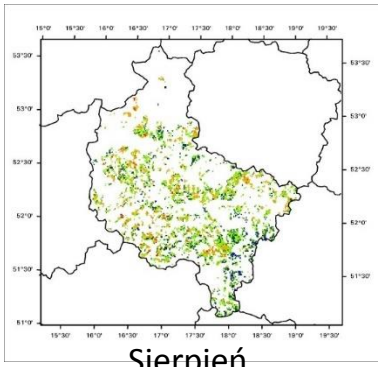


Temperatura – Opady – Susza – Plony





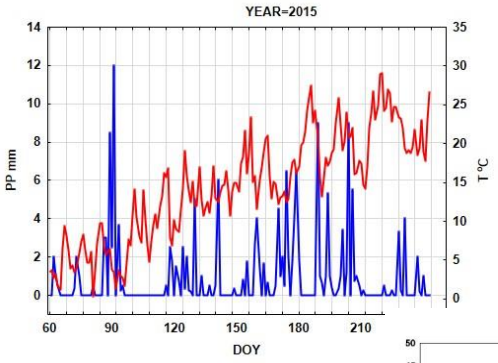


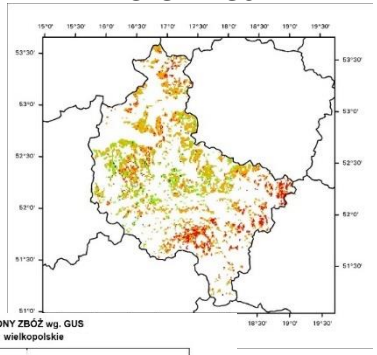


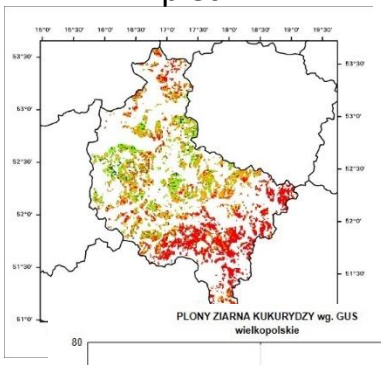
Czerwiec

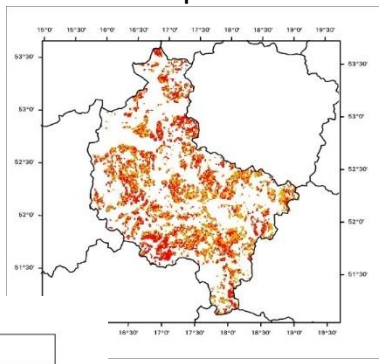
Lipiec

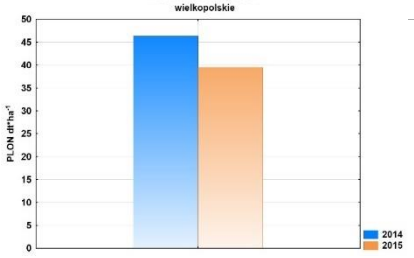
Sierpień

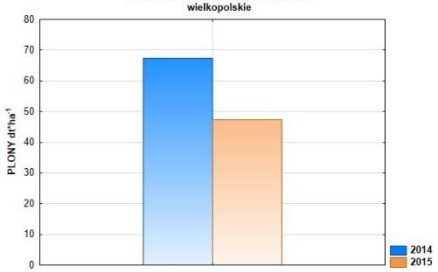




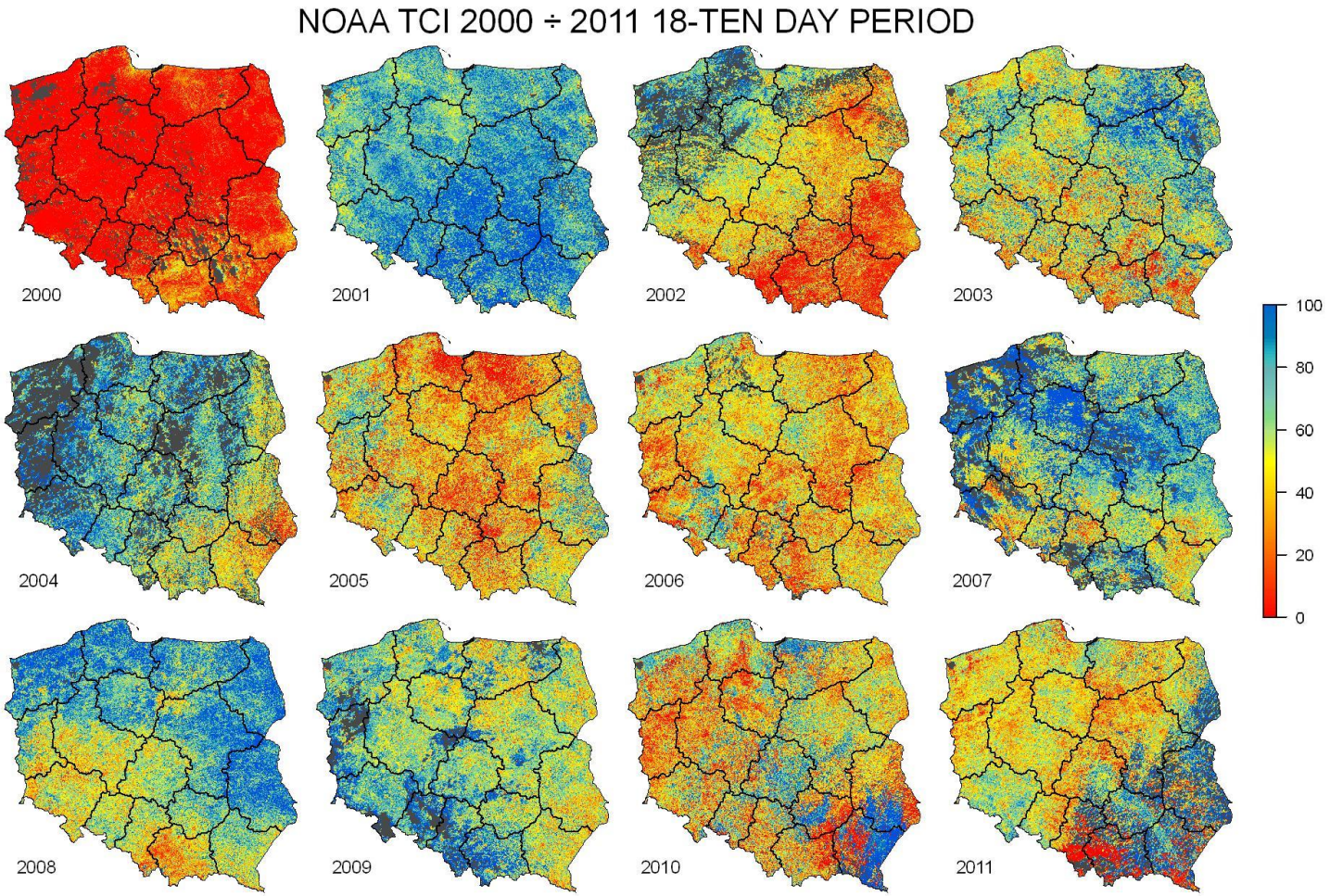




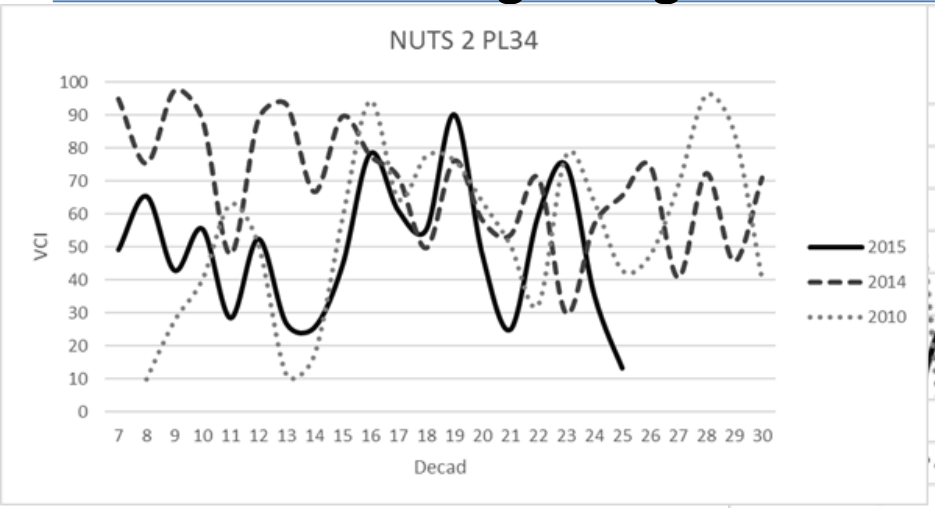


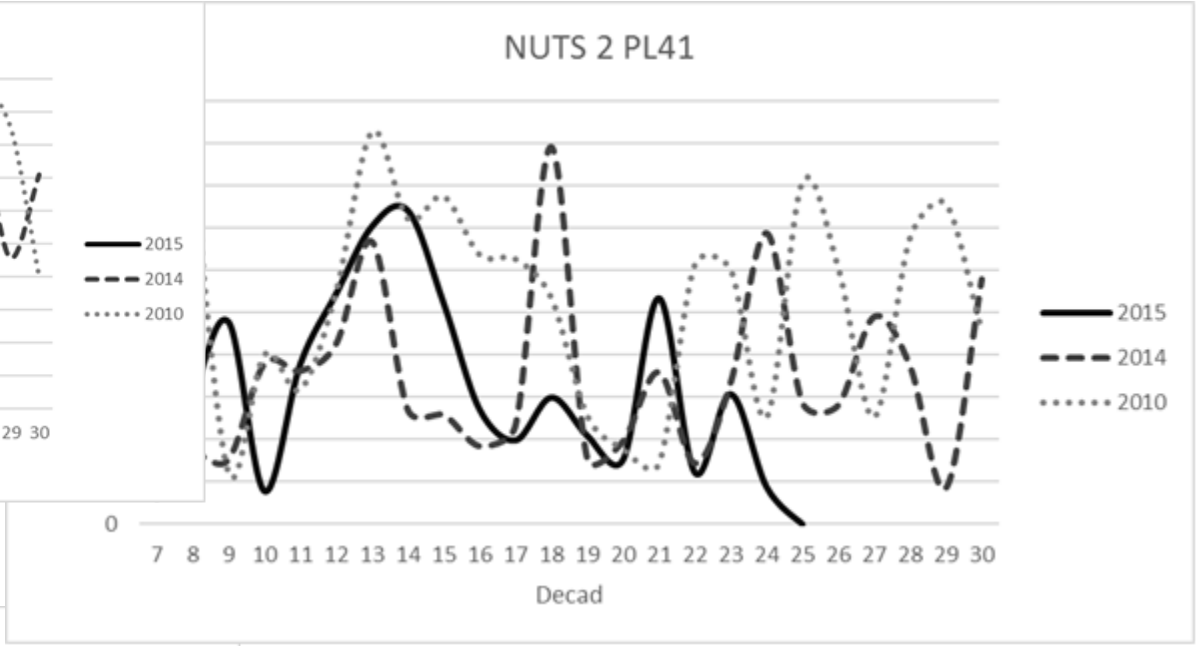


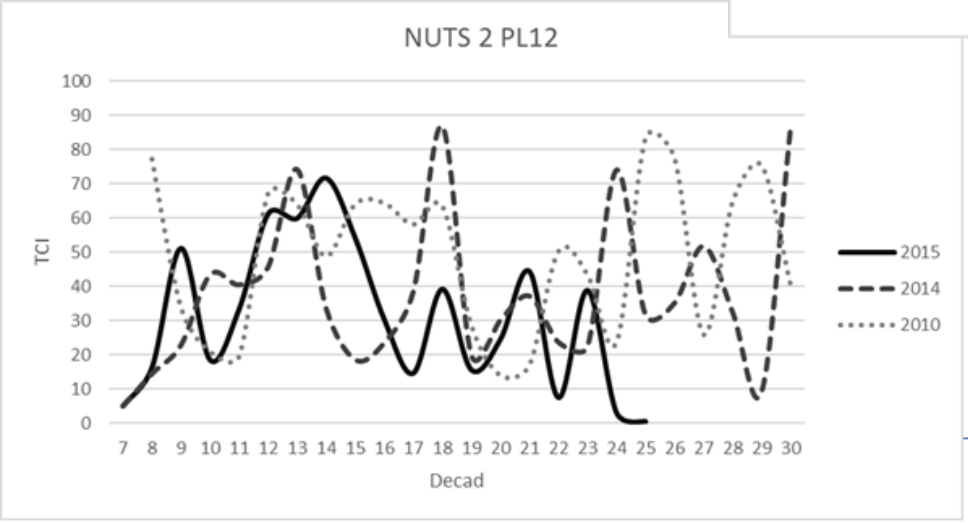
Drought Index TCI



TCI characterising drought effects

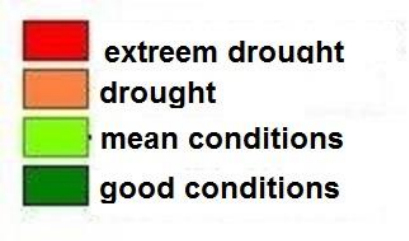


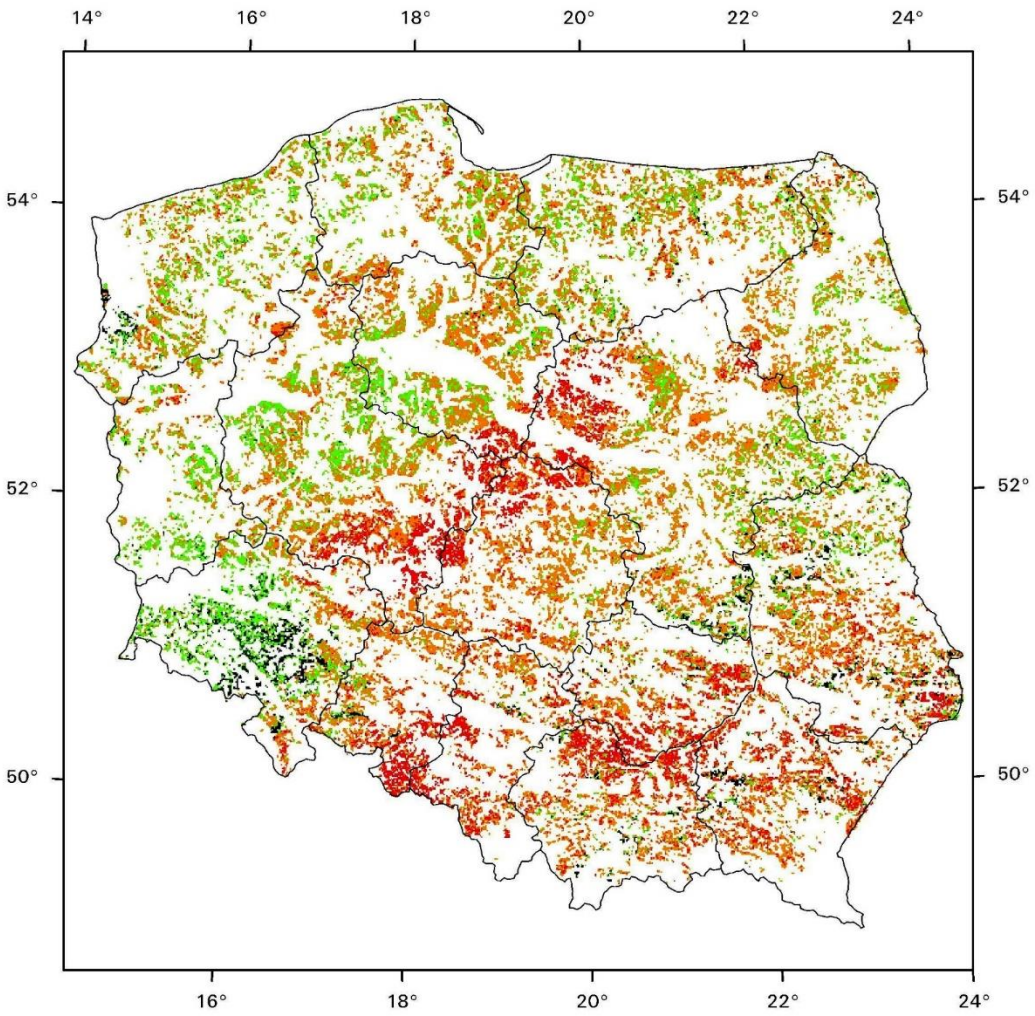




Drought in 2015

dekade 18

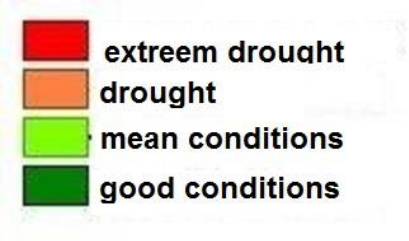


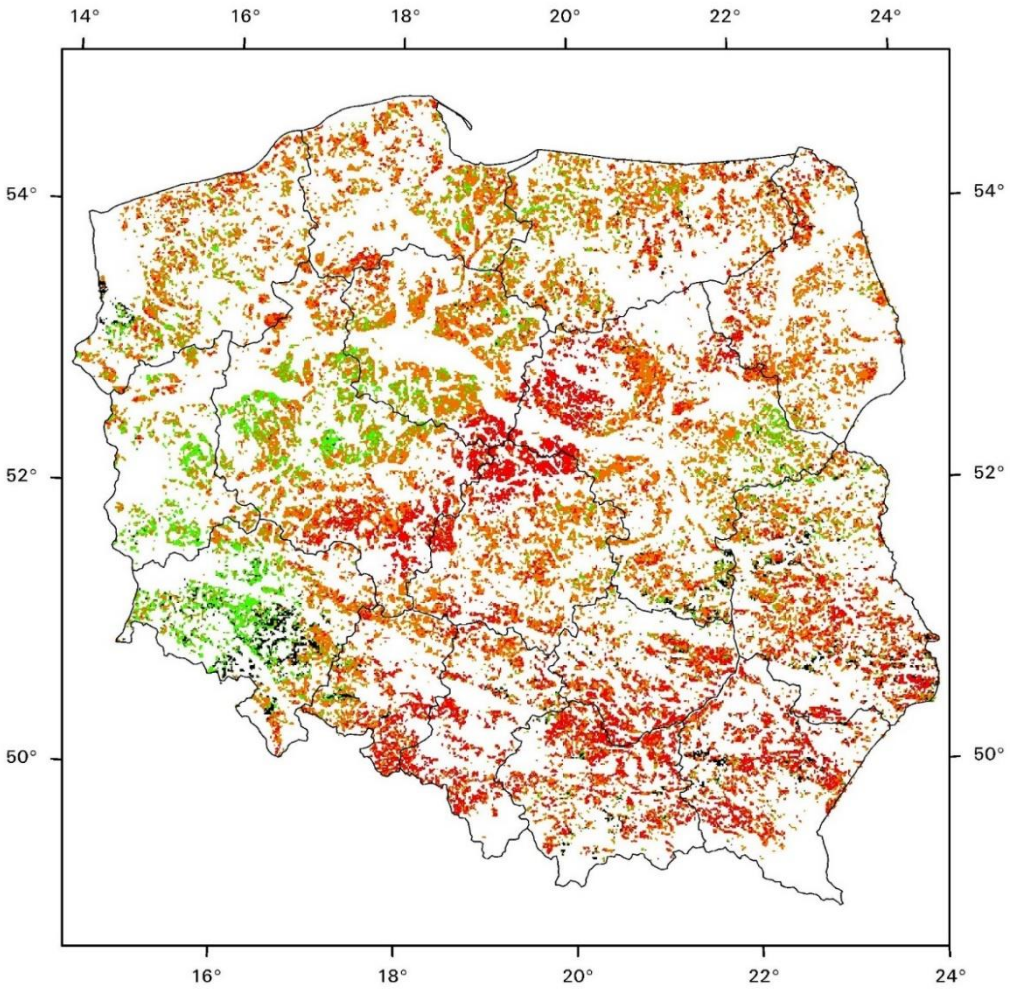


76 %

Drought 2015

dekada 19

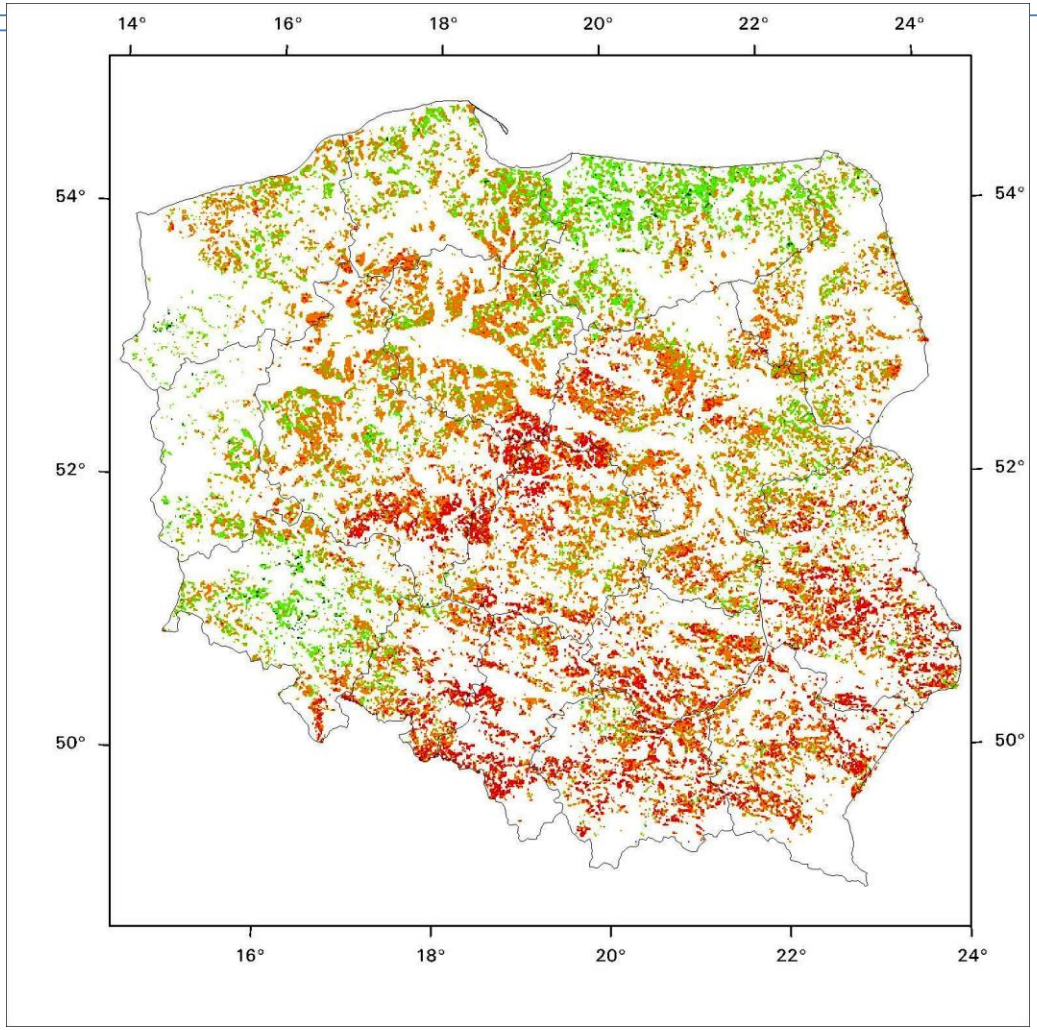




84 %

Drought 2015

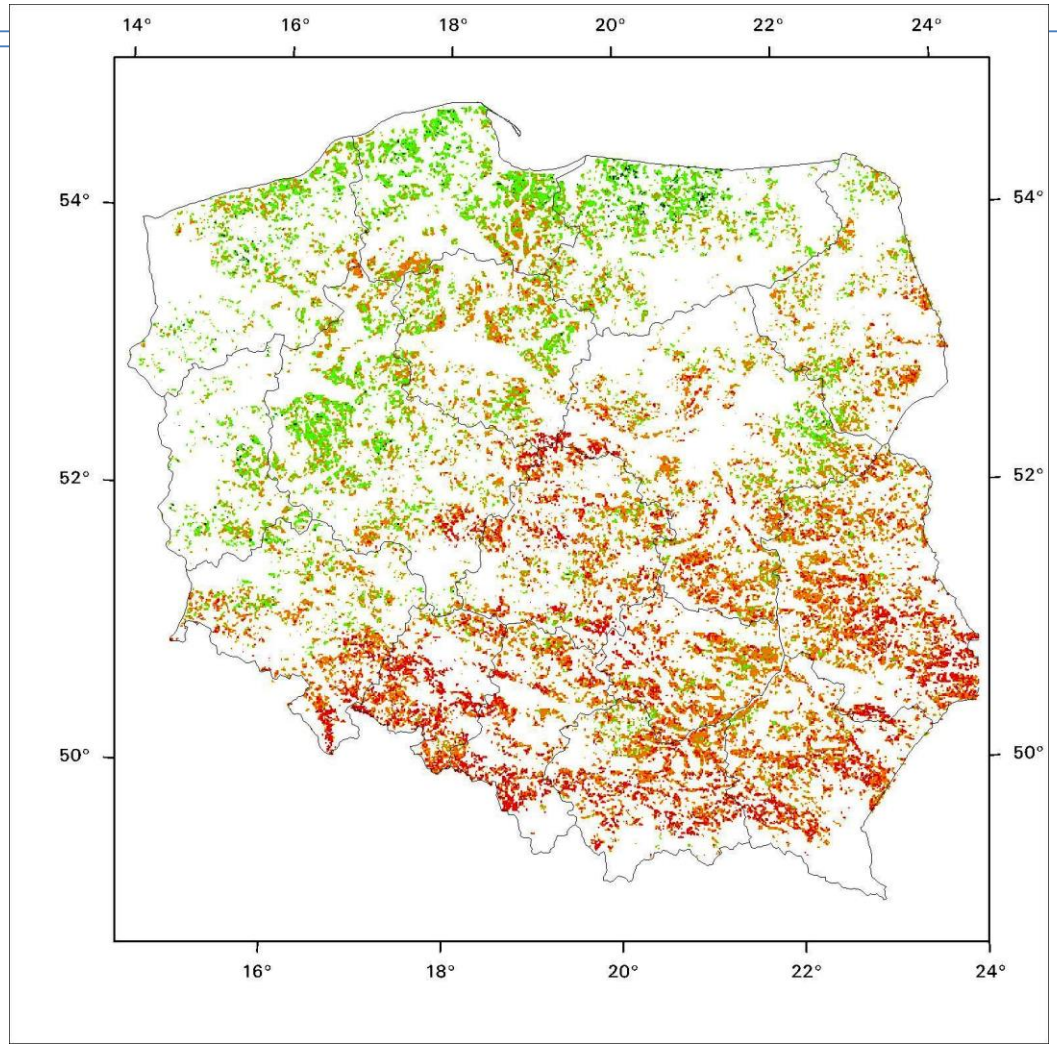
dekada 20



72 %

Drought 2015

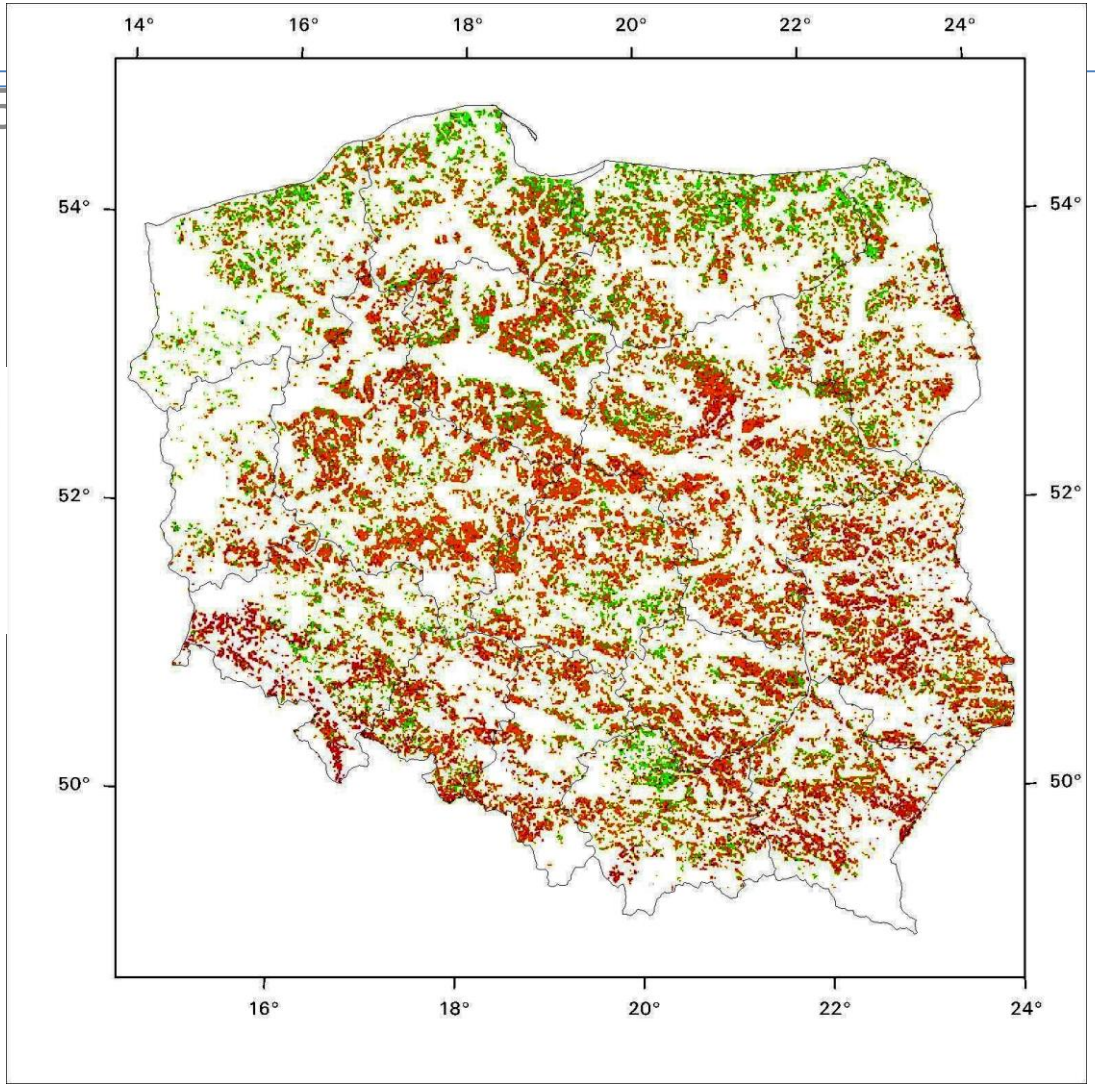
dekada 21



54 %

Drought 2015

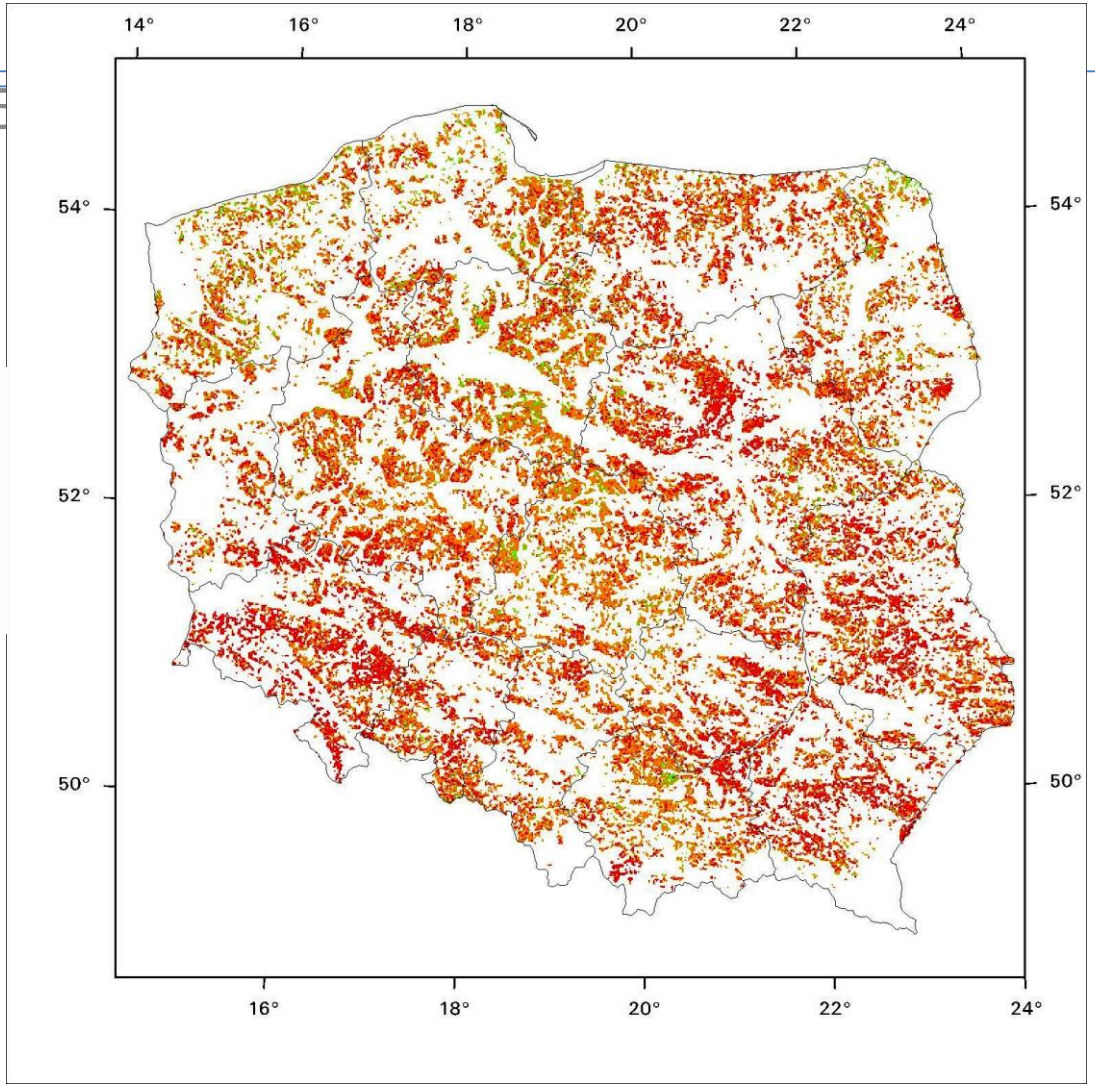
dekada 23



80 %

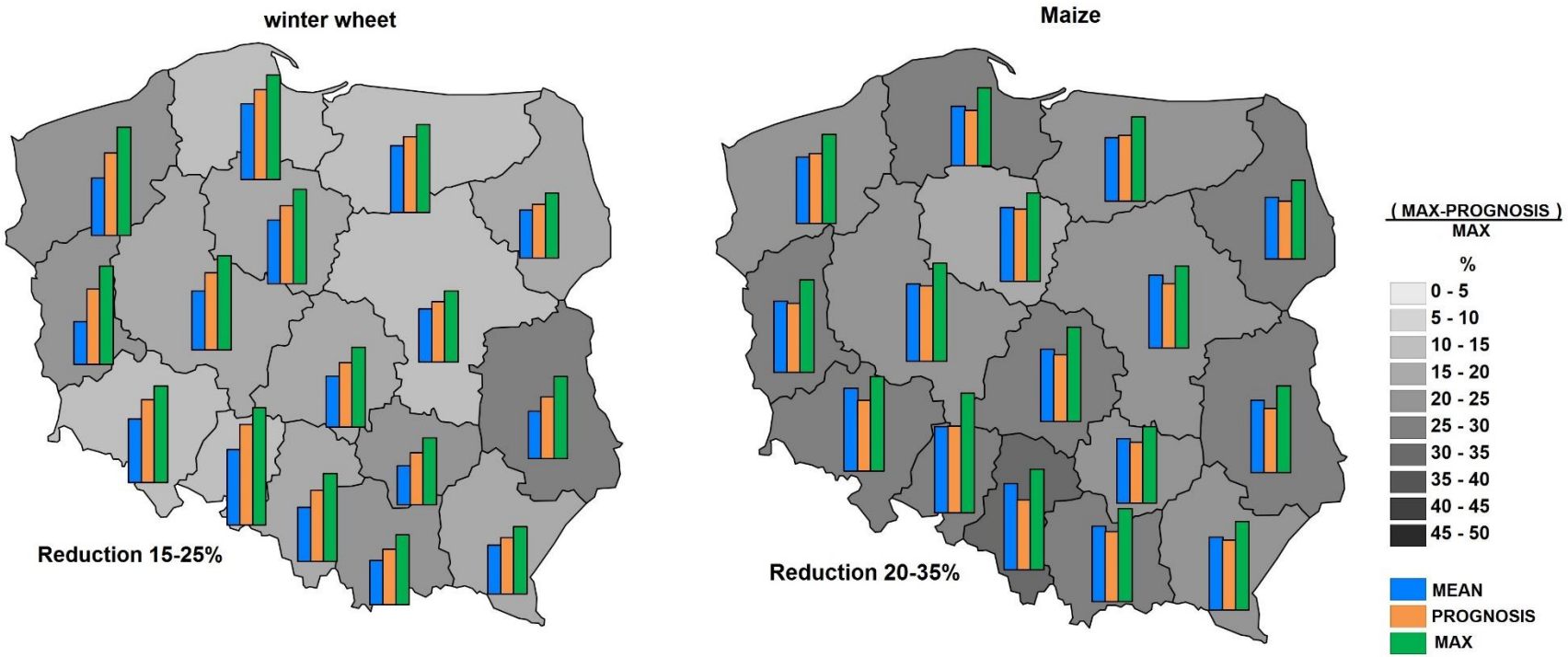
Drought 2015

dekada 24

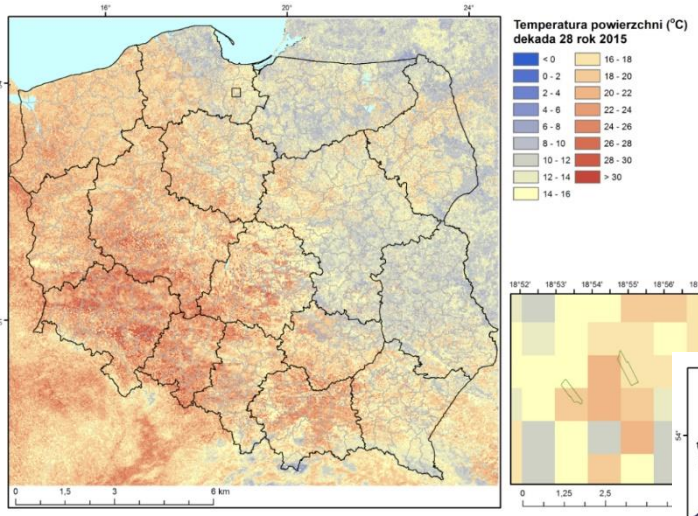


95 %

Crop prognosis -



Termiczny Wskaźniki Kondycji Roślin – TWKR
(Thermal Condition Index – TCI)



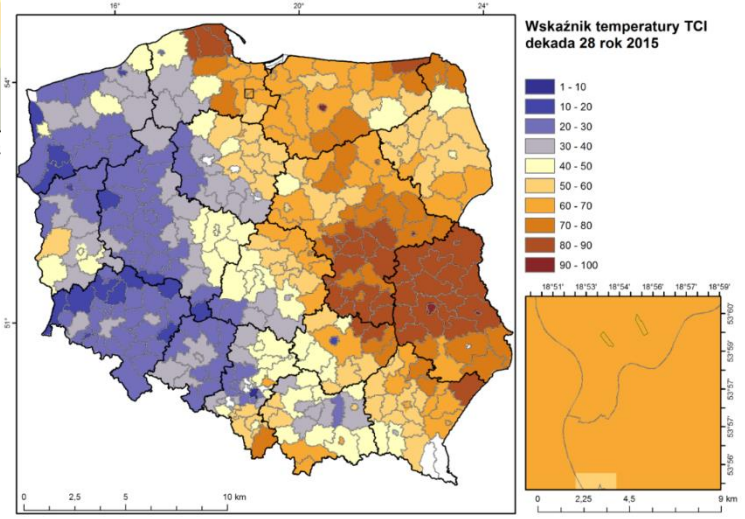
$$TCI = 100 \times \frac{T_{max} - T_{akt}}{T_{max} - T_{min}}$$

T_{akt} – temperatura roślin obliczona na podstawie aktualnie wykonanego zdjęcia.

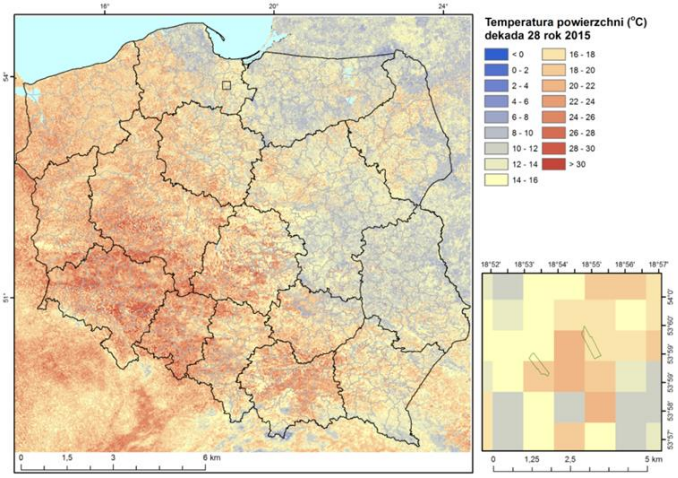
T_{max} – maksymalna temperatura roślin w danym w okresie

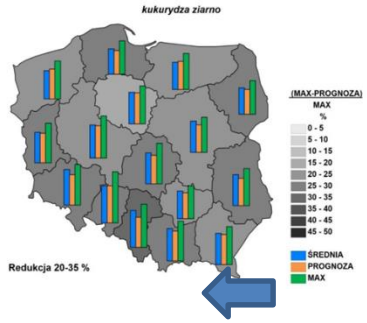
T_{min} – minimalna temperatura roślin w danym okresie

TCI dla powiatów (km²)



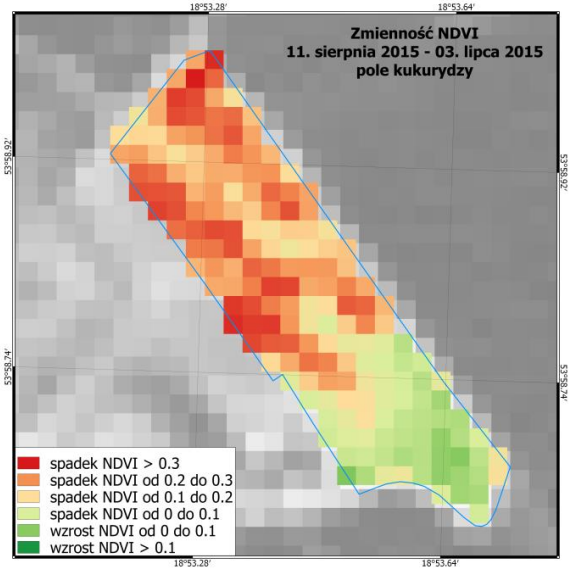
Analysis at field level

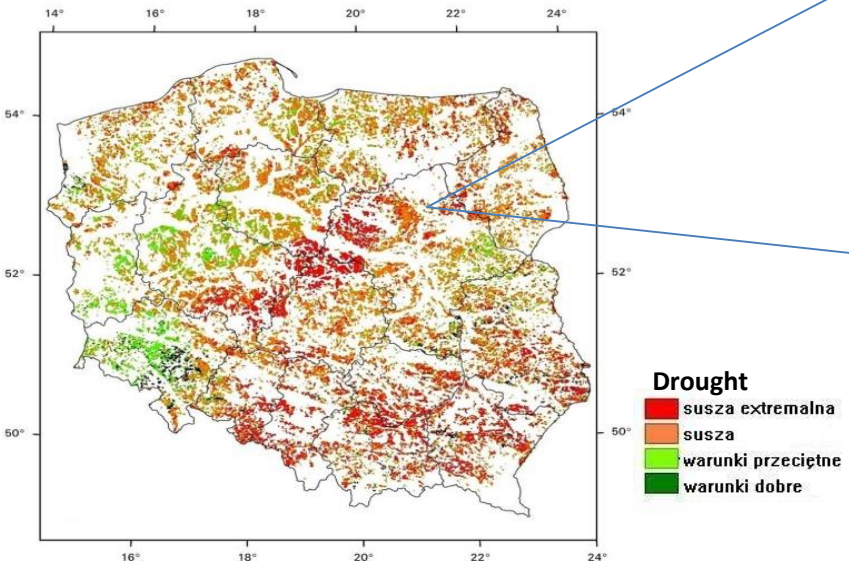




Surface

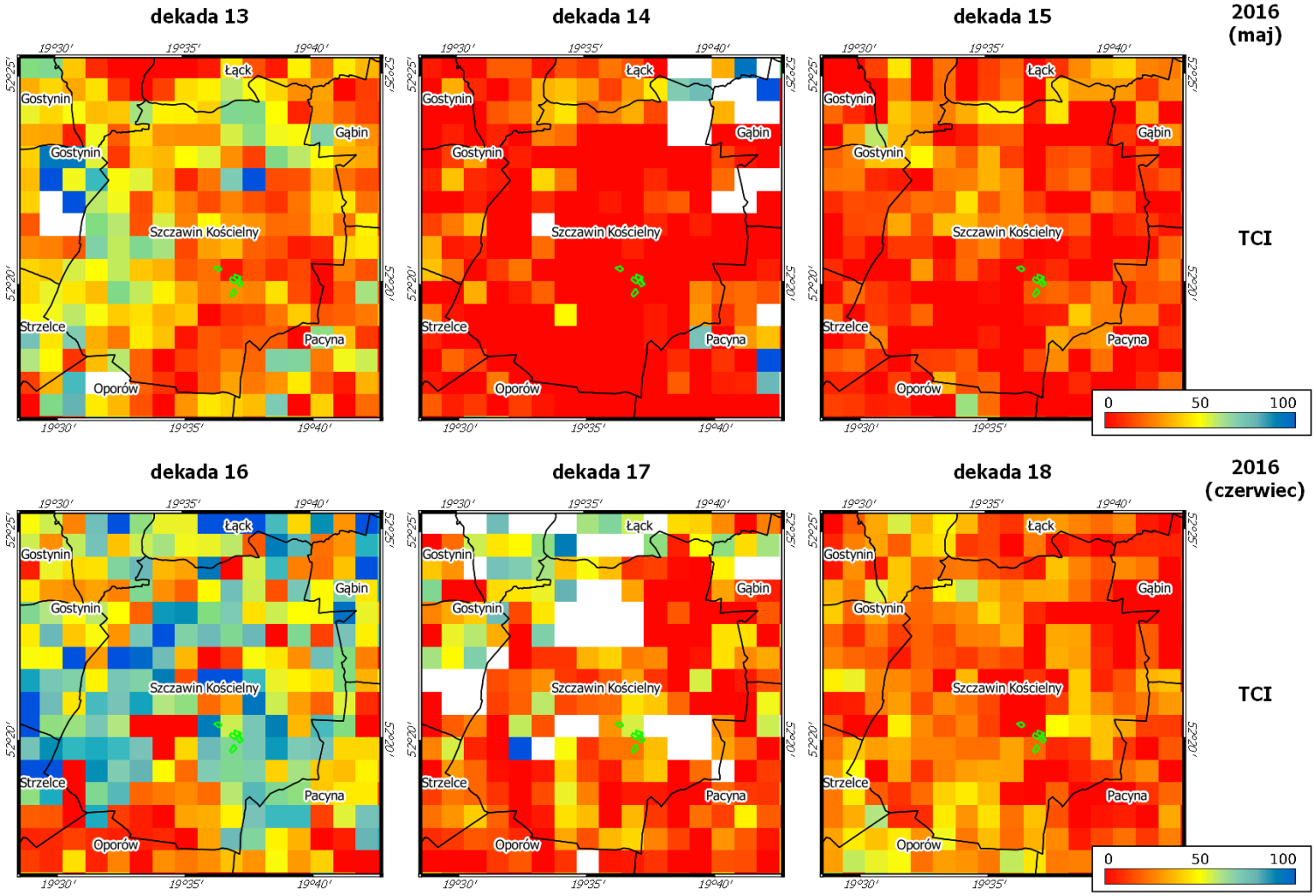
YIELD reduction



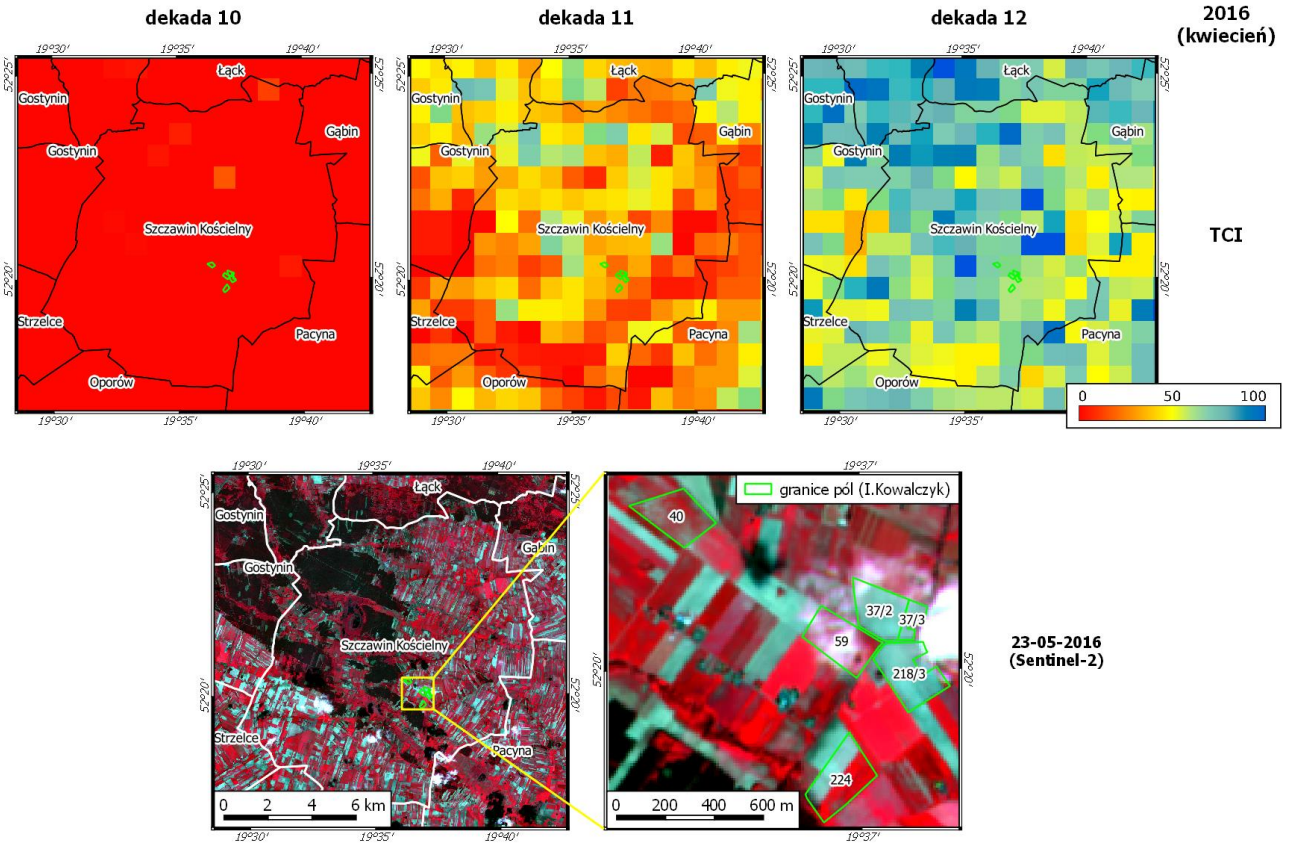


Yield reduction caused by drought in the Field

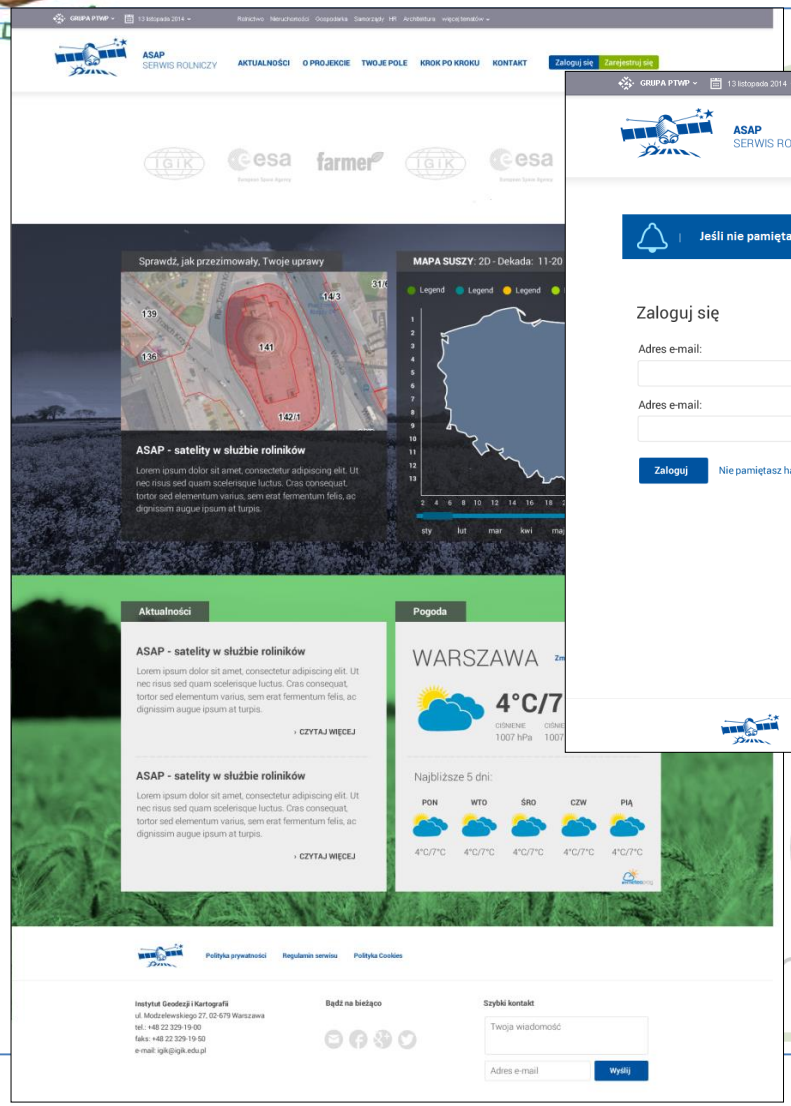
Changes in TCI during 2016 dekads 13-18

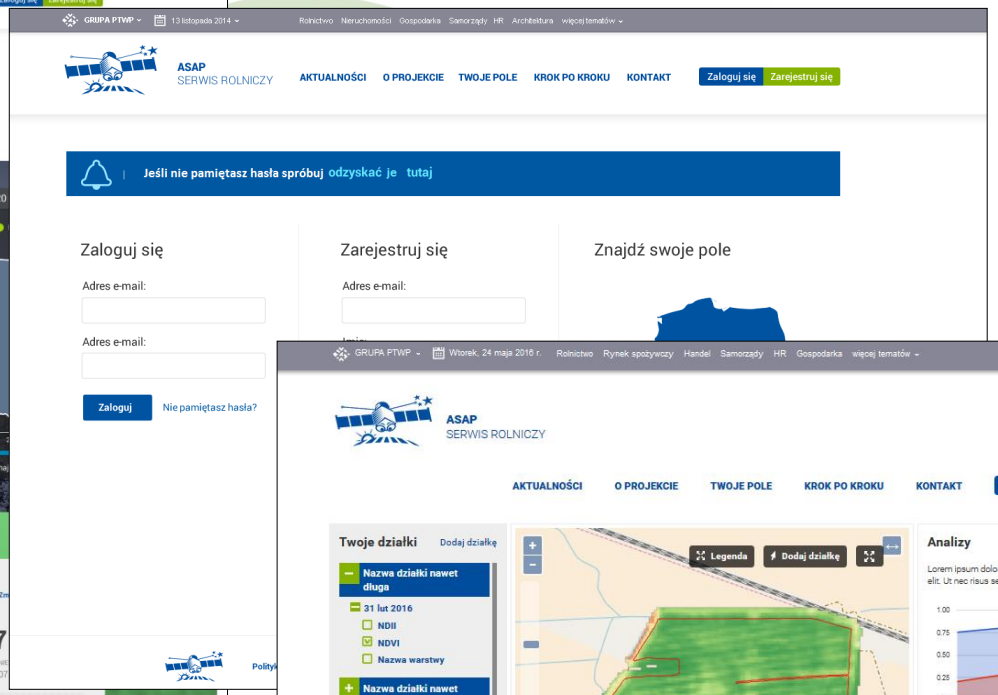


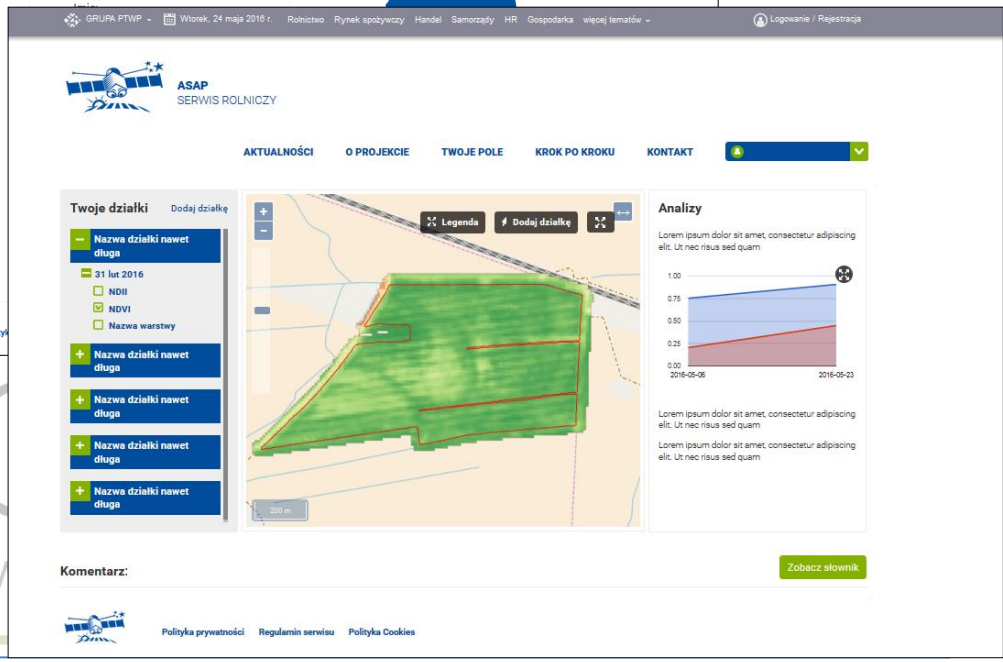
Susza 2016 – prywatne pole - skarga



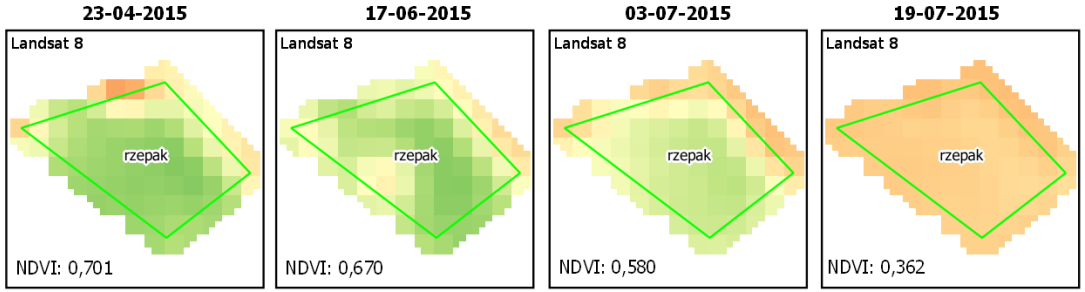
SERWIS ASAP – plaforma internetowa www.asap.farmer.pl

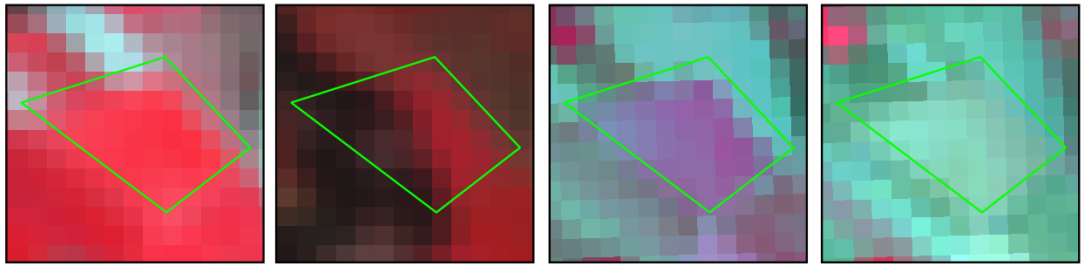


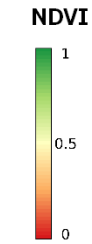




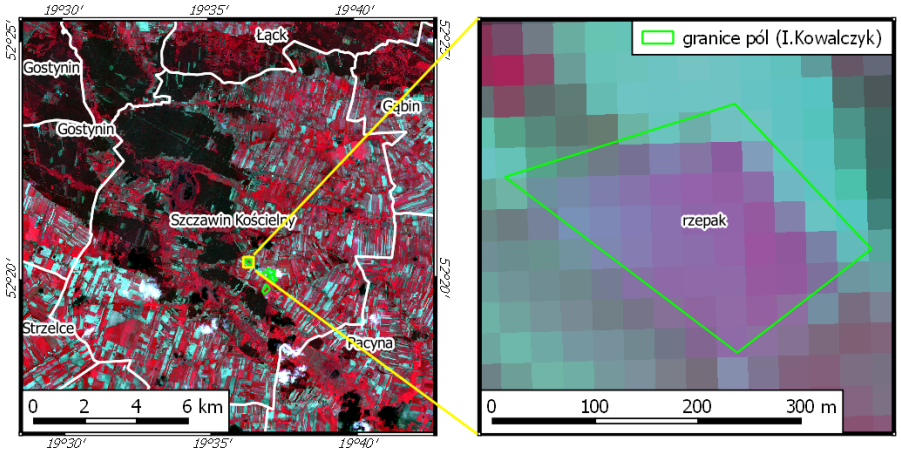
Monitoring changes at the field level







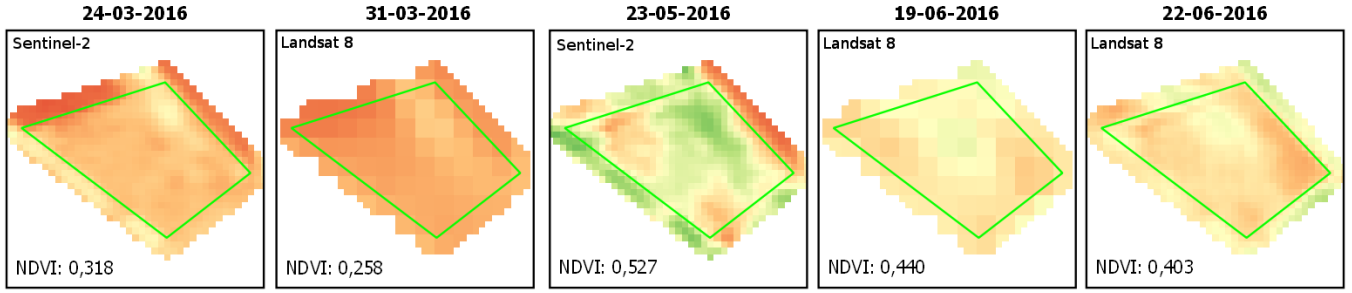
Landsat 8

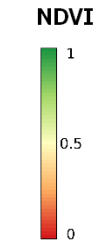


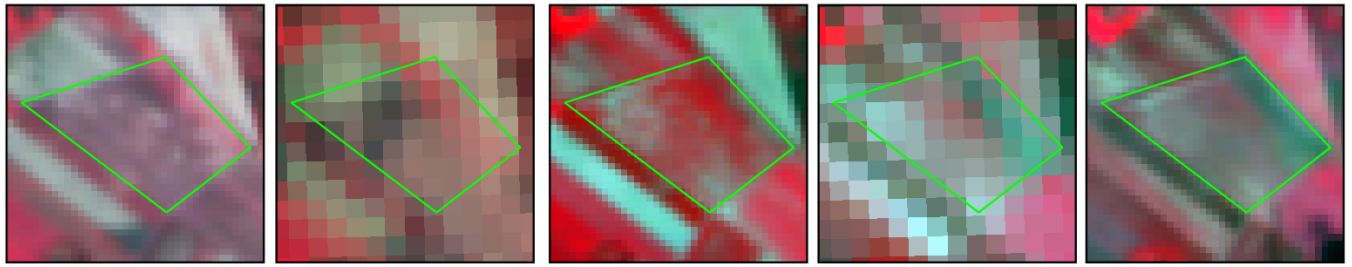
Pole numer:
140405_2.0035.40

uprawa 2015:
rzepak

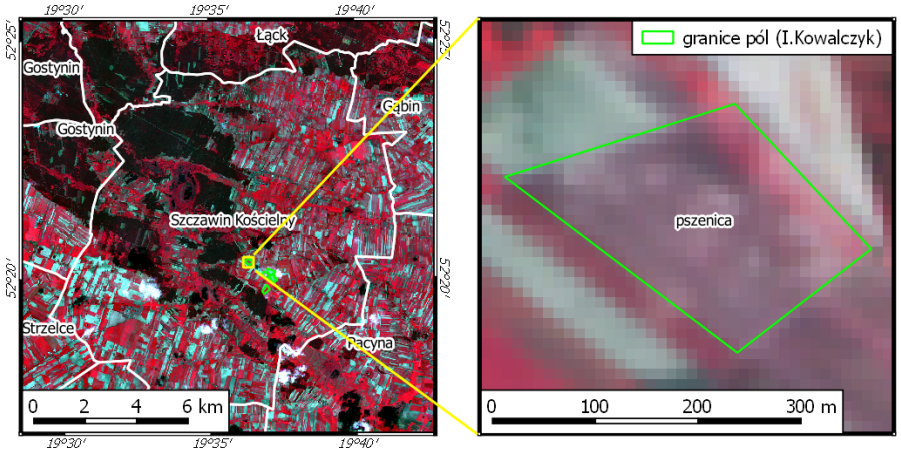
Monitoring Changes at the field level (2016)







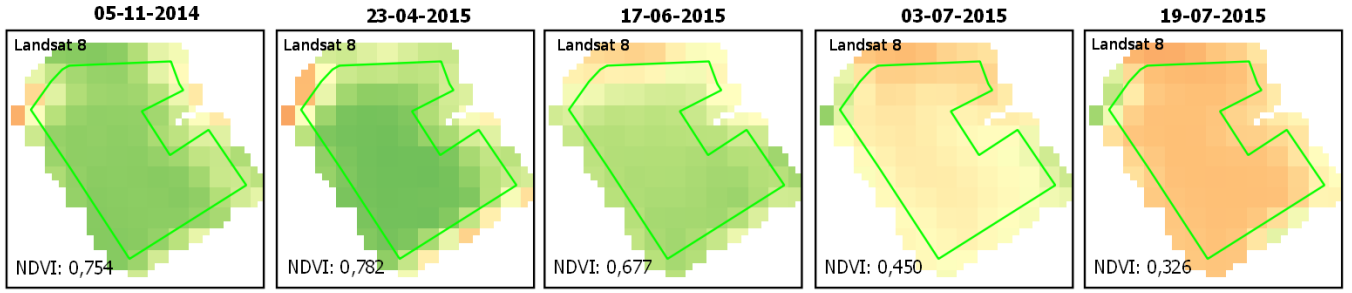
Sentinel-2 / Landsat 8

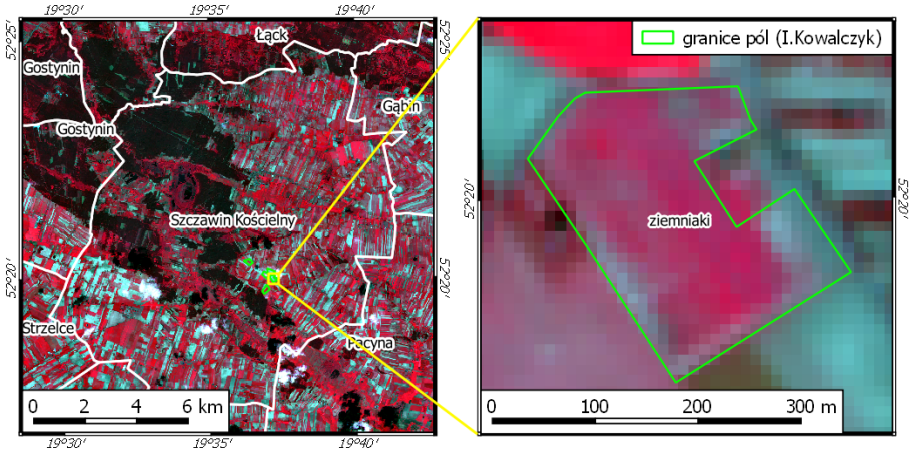


Pole numer:
140405_2.0035.40

uprawa 2016:
pszenica

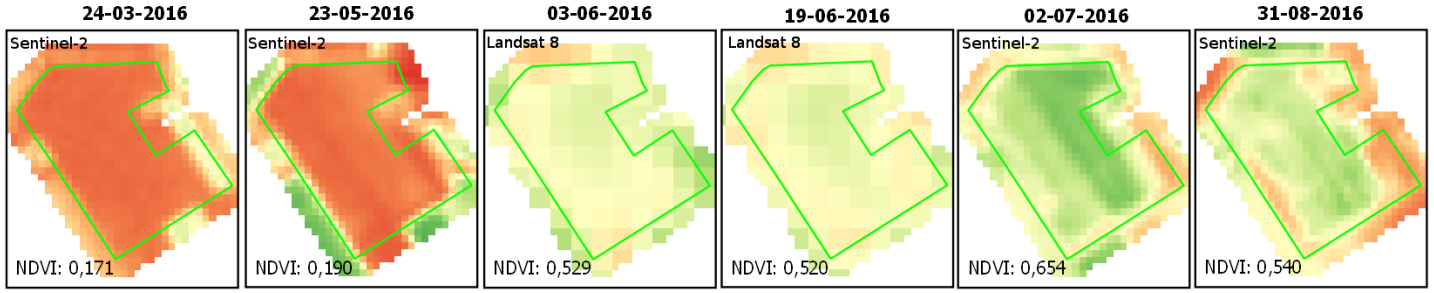
Monitoring Changes at the field level

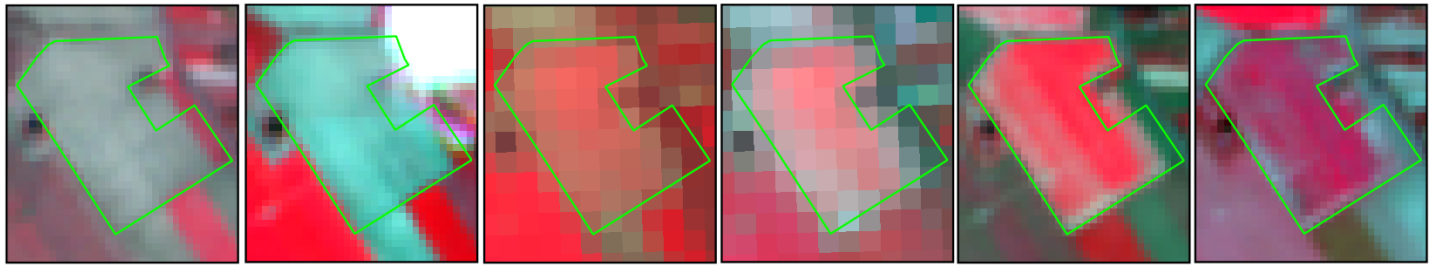




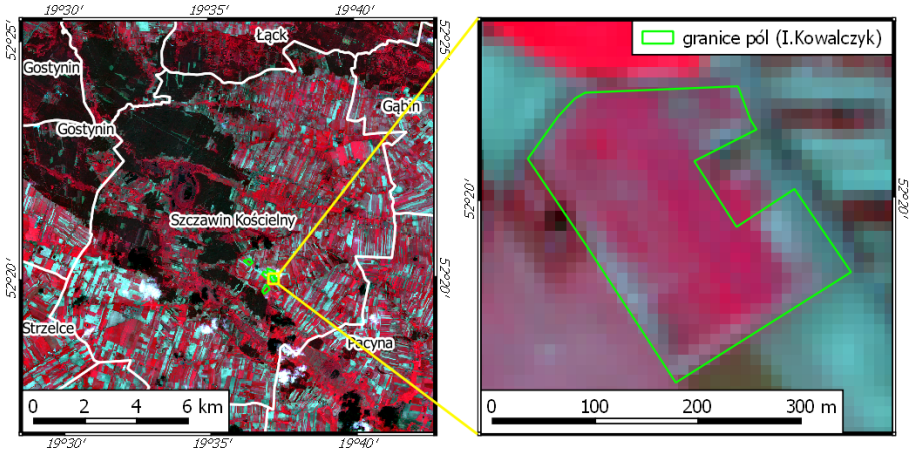
Pole numer:
140405_2.0035.218/3

uprawa 2014/2015:
pszenica ozima





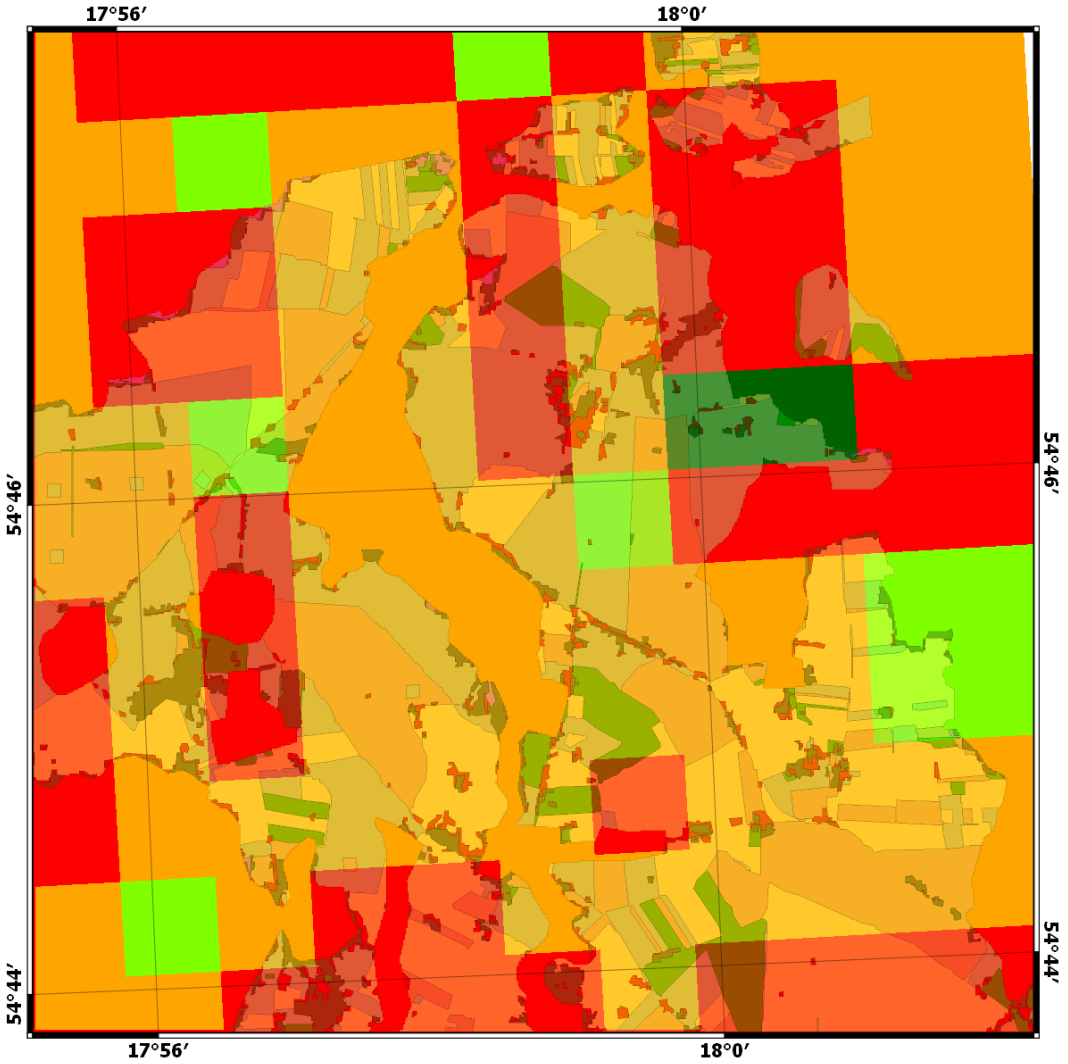
Sentinel-2 / Landsat 8



Pole numer:
140405_2.0035.218/3

uprawa 2016:
ziemniaki

Przykłady produktów:



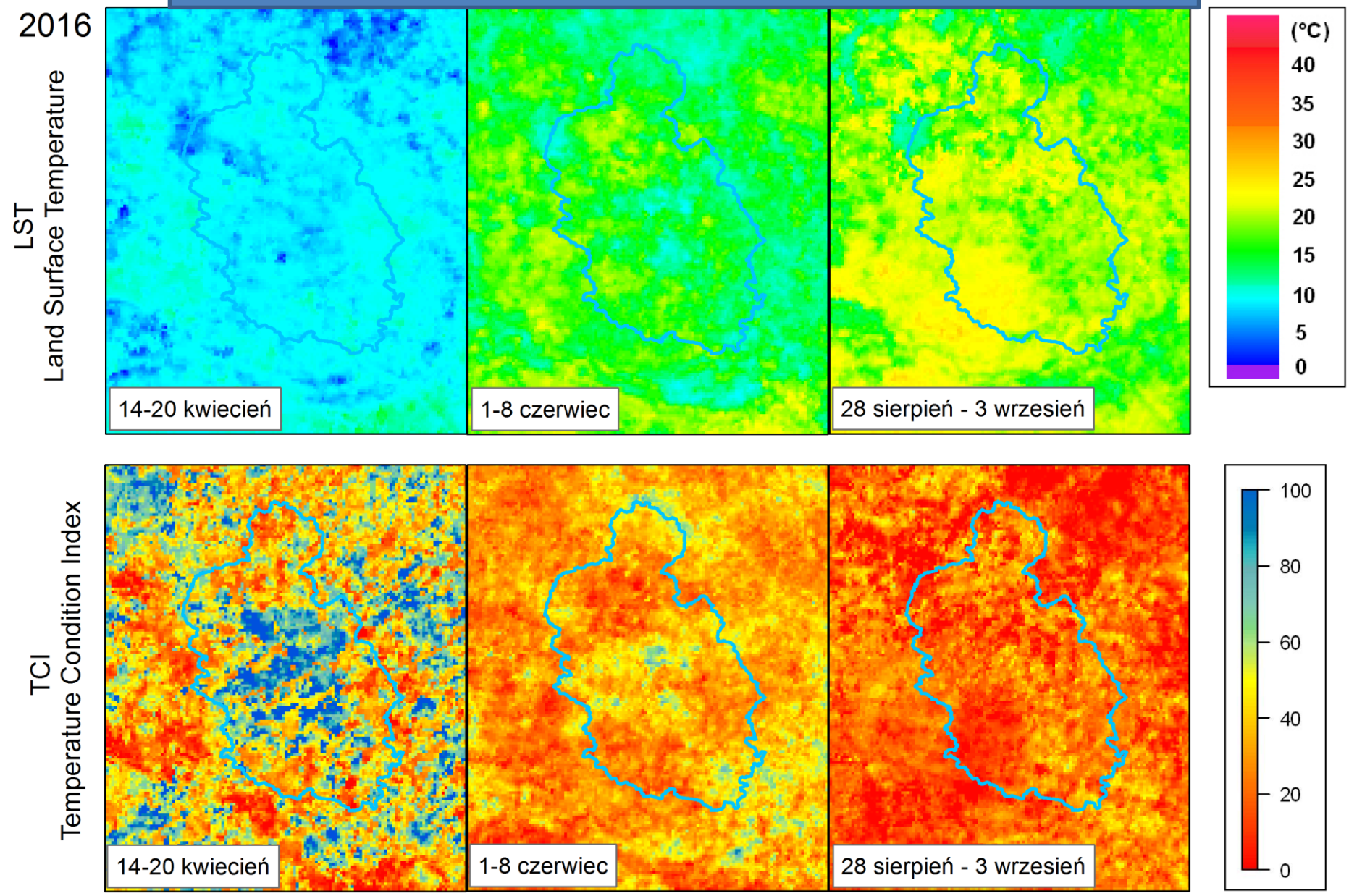
Klasyfikacja upraw na tle aktualnej mapy suszy rolniczej

06. maja 2016

- susza ekstremalna
- susza
- warunki przeciętne
- warunki dobre

0 0.5 1 1.5 2 2.5 km

Monitoring the Catchement Area



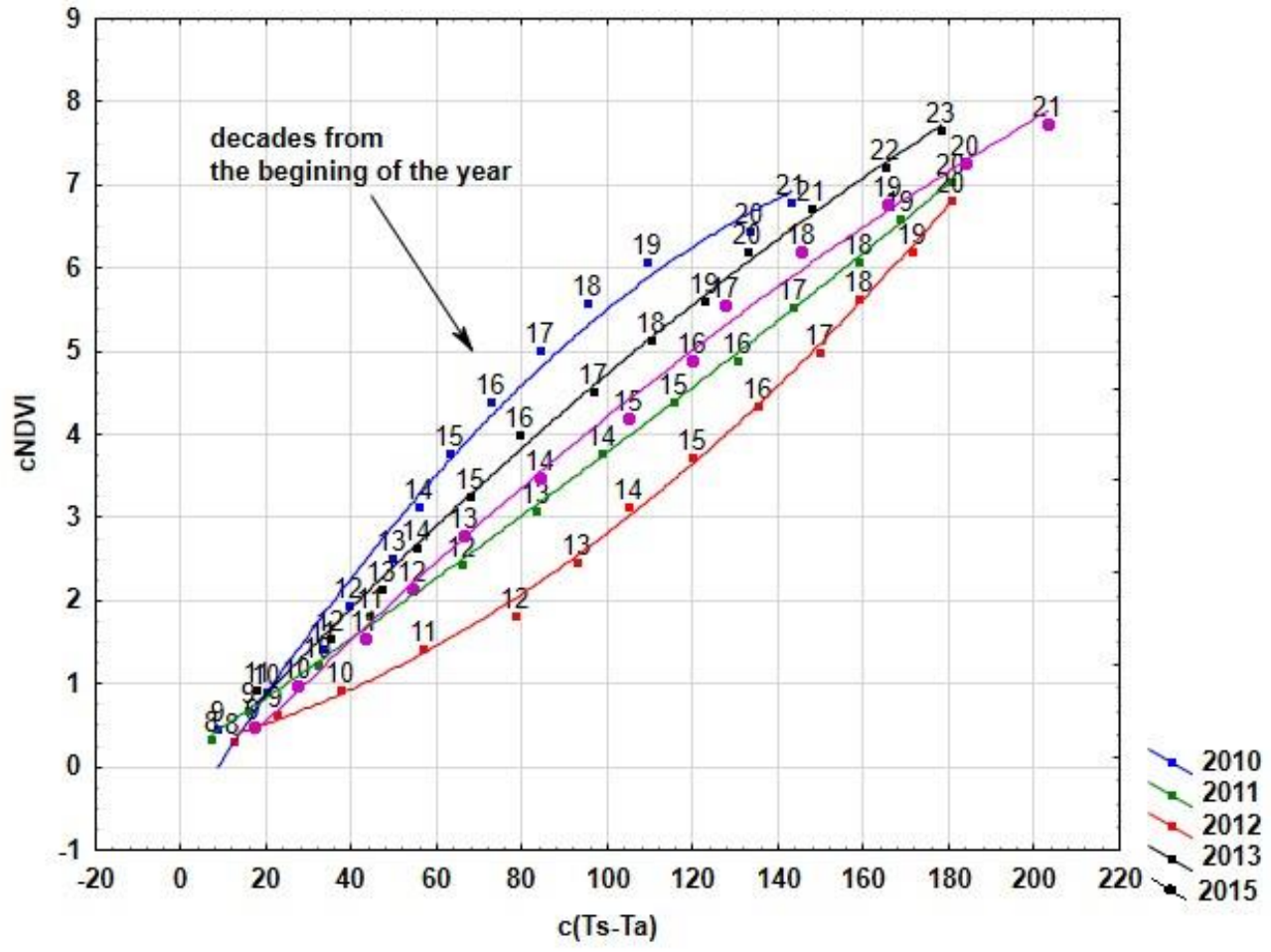
Effect of temperature on phenology

$$SDD_S = \sum_{Planting \cdot day}^{Day \cdot on \cdot which \cdot stage \cdot S \cdot is \cdot reached} \left(T_s - T_a \right)$$

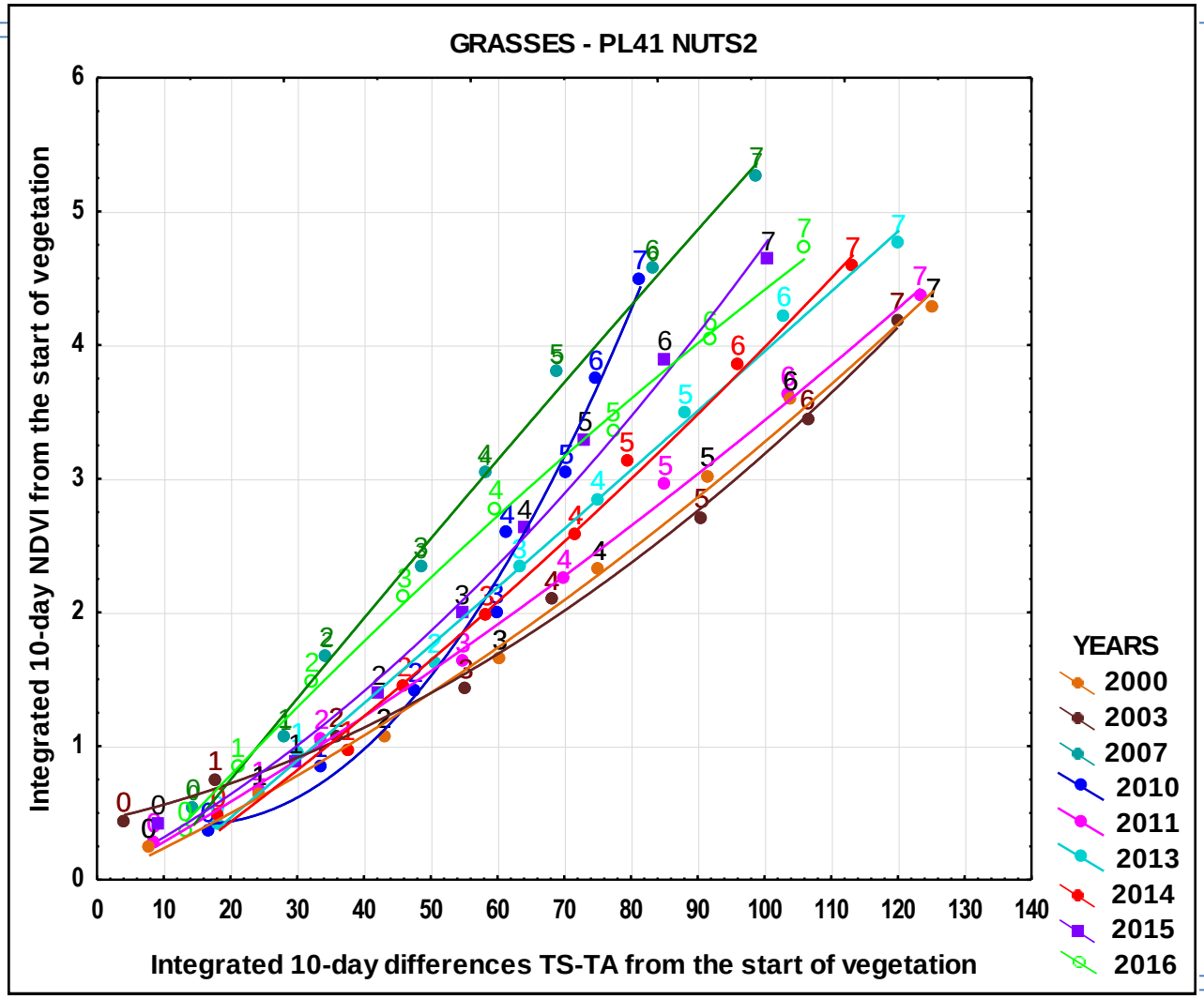
T_s – surface temperature

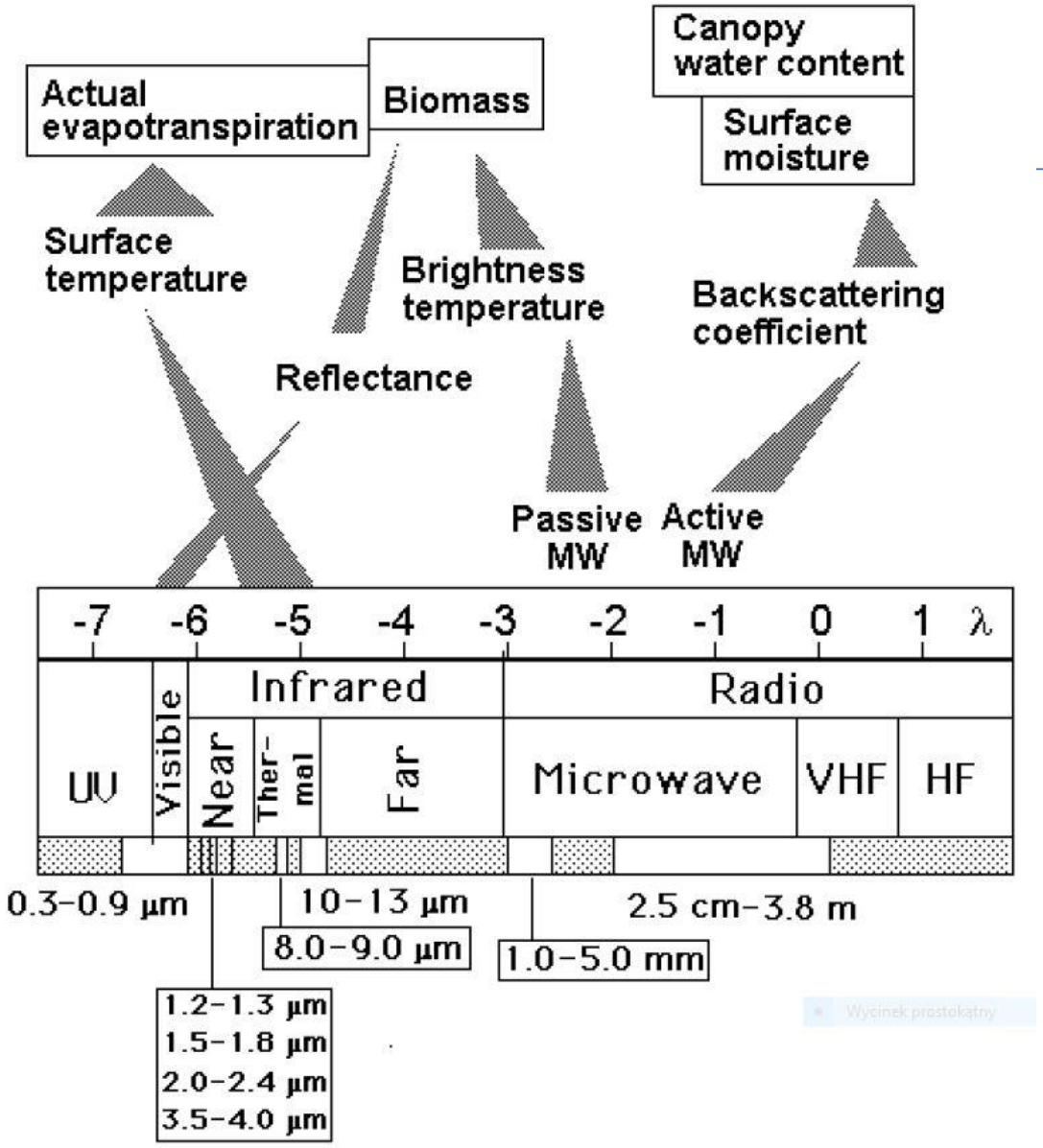
T_a – air temperature

Accumulated (Ts – Ta) Stress Degree Day versus accumulated NDVI



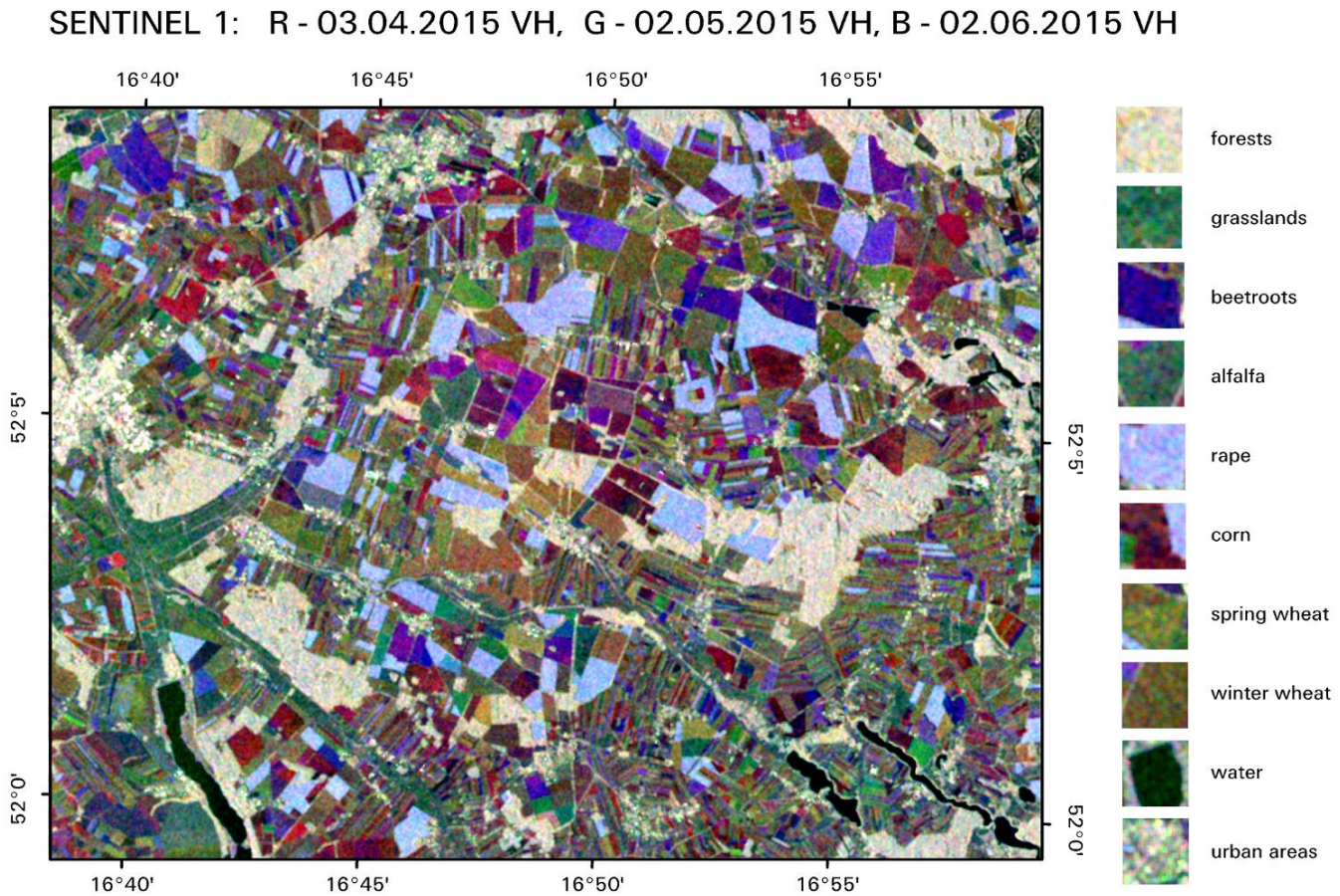
Ts-Ta versus NDVI



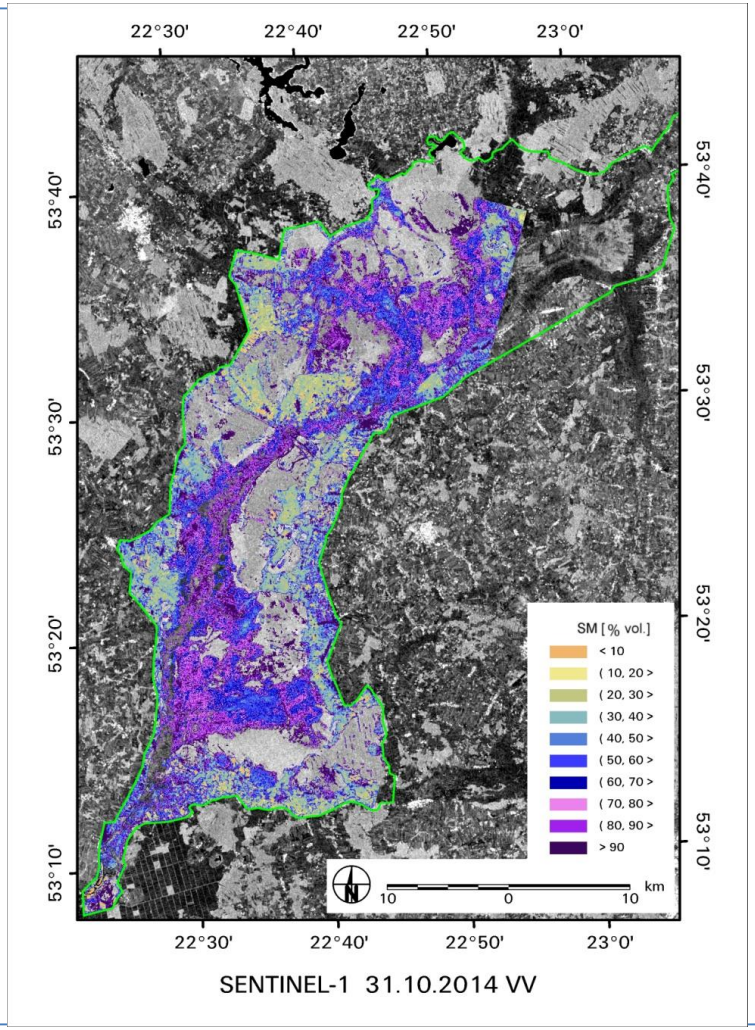


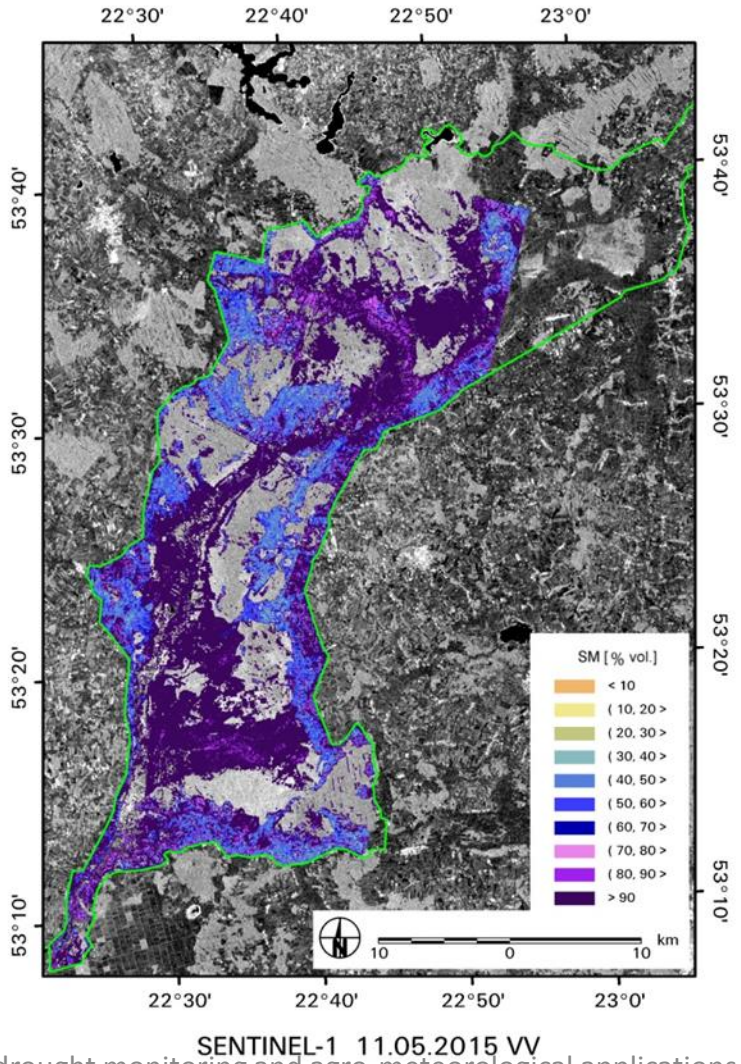
Remote sensing sources of crop weather modelling inputs. λ indicates the exponent of the wavelength in *m* (-6 corresponds to a *µm*, -2 to a *cm*, etc.).
The bottom line shows the main atmospheric windows, i.e. parts of the spectrum to which there is little absorption In the atmoshere.
The absorption is mainly due to CO_2 (thermal infrared) and water vapour.

Sentinel-1

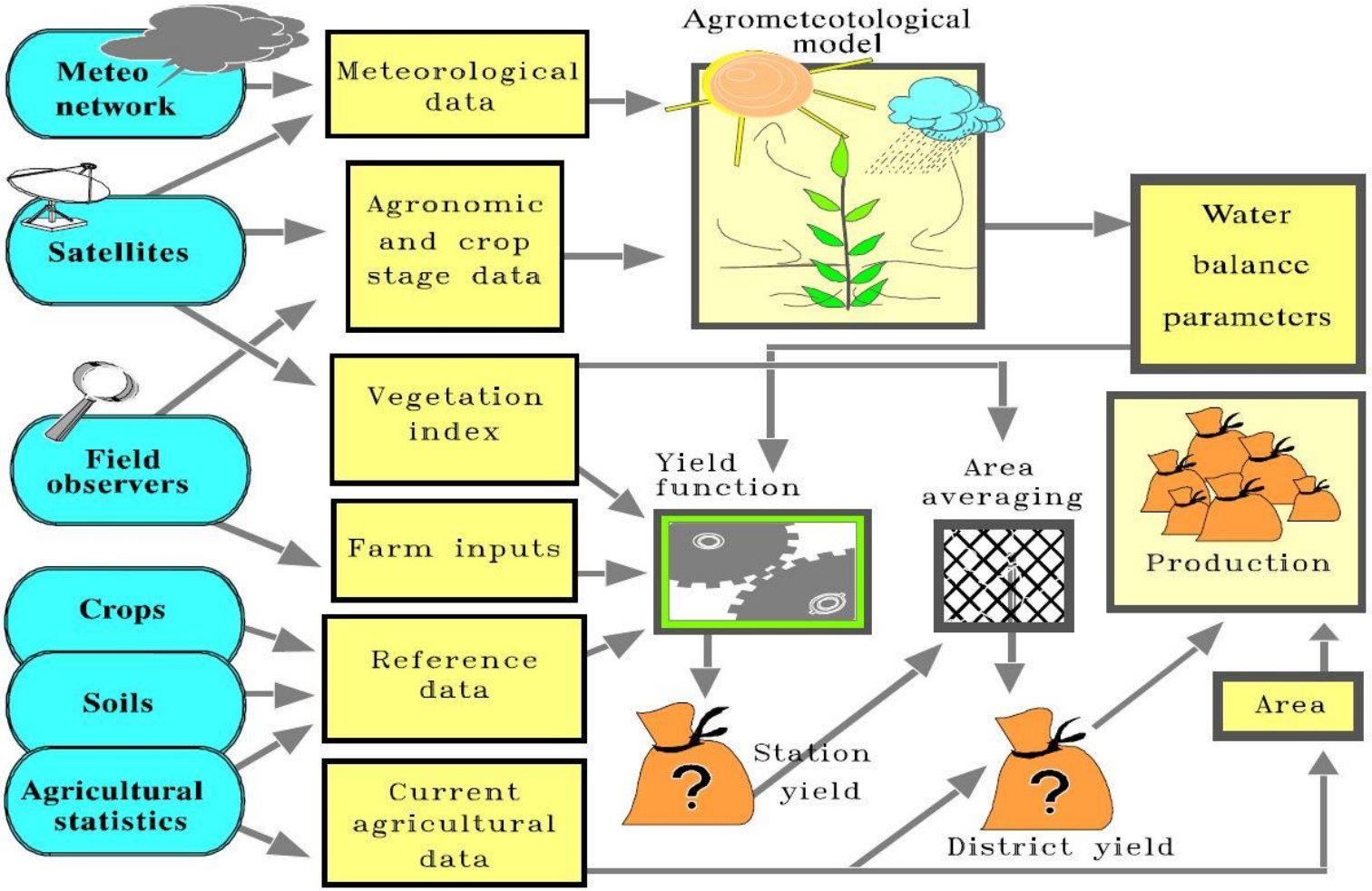

SENTINEL 1: R - 03.04.2015 VH, G - 02.05.2015 VH, B - 02.06.2015 VH
16°40'
16°45'
16°50'
16°55'
52°5'
52°0'
forests
grasslands
beetroots
alfalfa
rape
corn
spring wheat
winter wheat
water
urban areas

Sentinel1 – Soil Moisture





The flow of data
in FAO-promoted crop forecasting systems for food security



$$LE = R_n - G - H$$

LE – latent heat flux (Wm^{-2})
R_n – net radiation (Wm^{-2})
G – soil heat flux (Wm^{-2})
H – sensible heat flux (Wm^{-2})

$$H = \frac{\rho c_p \left(T_s - T_a\right)}{r_a}$$

ρc_p – volumetric heat capacity ($J\ m^{-3}K^{-1}$)
T_s – surface temperature (K) – Envisat ASAR, Sentinel 3, NOAA, ATSR, Terra Modis
T_a – air temperature (K)
r_a – stability corrected aerodynamic resistance (sm^{-1})

Crop Water Stress Index

$$CWSI = 1 - \frac{LE}{LE_p}$$

LE – actual potential evapotranspiration

LE_p – potential evapotranspiration

$$CWSI = \frac{T_a - T_{s\min}}{T_{s\max} - T_{s\min}}$$

T_a – air temperature

T_{smin}, T_{smax} – surface temperature minimum and maximum values

- Thank You for Your Attention