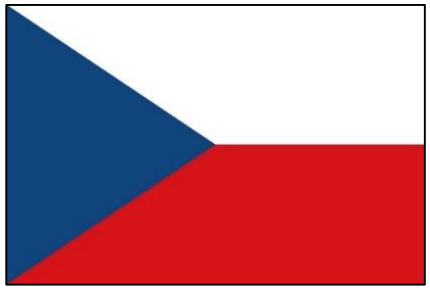


CZECH UNIVERSITY OF LIFE SCIENCES PRAGUE

INTRODUCTION TO CROP GROWTH MONITORING

Dr. Jitka Kumhálová

CUPAGIS

NICOPA

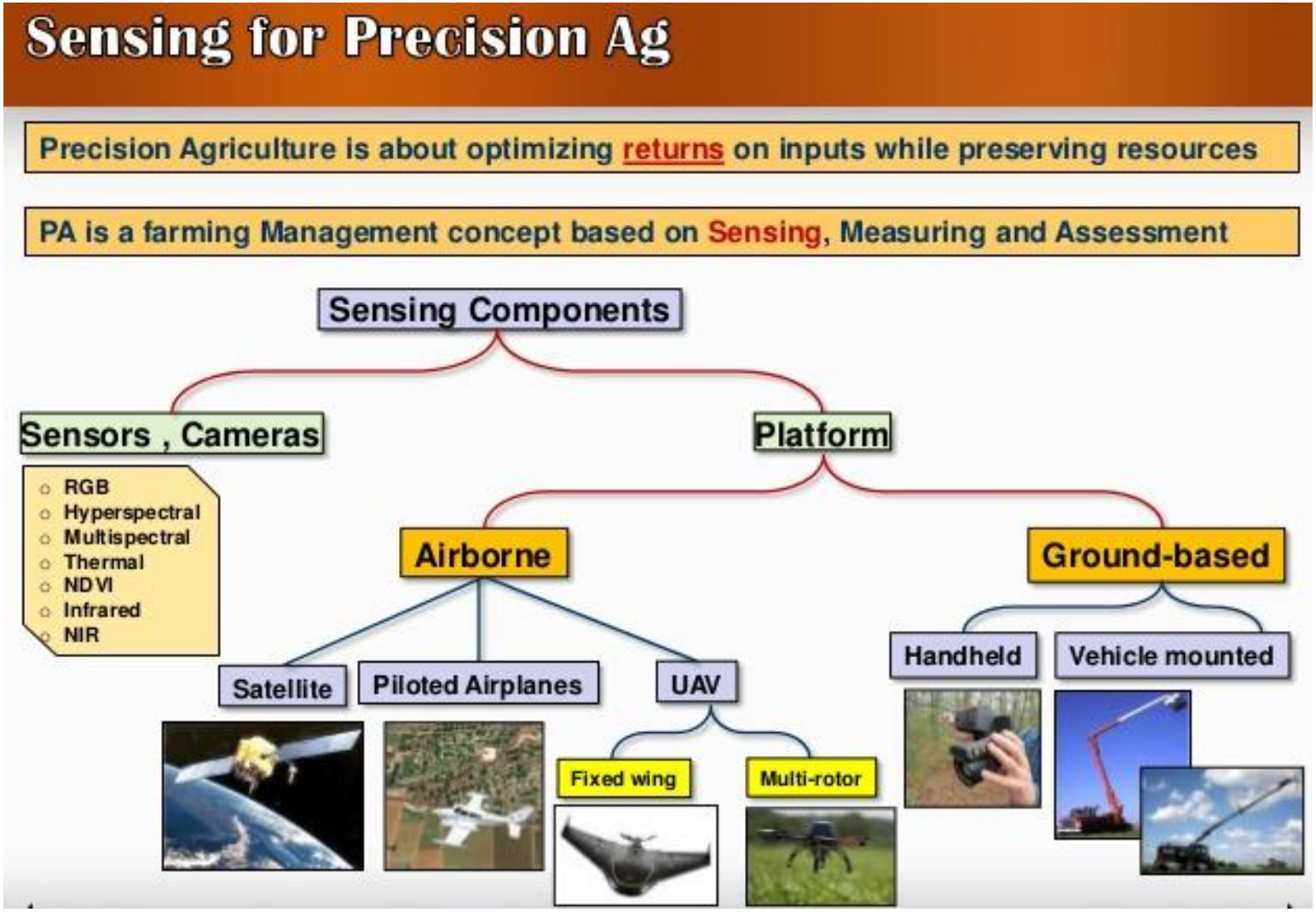
Co-funded by the Erasmus+ Programme of the European Union

Joint Project: Capacity Building in the Field of Higher Education ERASMUS+ 2018

Introduction

- Crop yields play a vital role in agriculture development in the world, so it is necessary to accurately estimate crop yields before harvest to allow crop yield management decision-making.
- In the past several decades, increasing demand for agricultural products and a desire for a higher rate of profit have led to tremendous changes in traditional agriculture.
- Pesticides, machinery, irrigation technology, new high-yielding varieties, and new field crop management methods have been proposed to meet agricultural production needs in different countries and regions.
- To ensure optimum crop yields, many scholars have begun to study the relationship between crop growth and growth environment and to propose crop models to simulate crop growth status.

Solution – Precision Agriculture



Source: Sonka and Coaldrake 1996

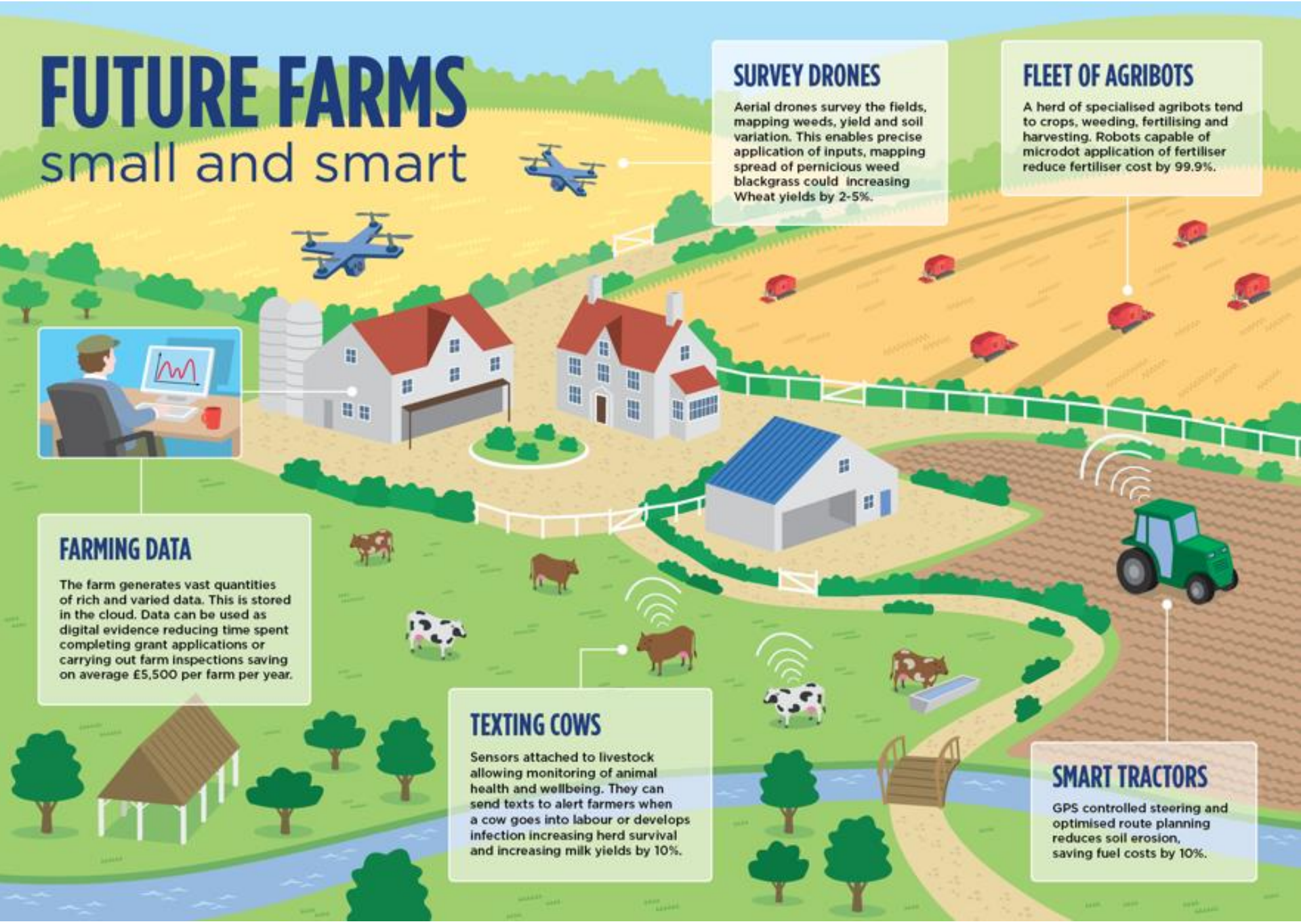
Geoinformatics - an essential tool for precision agriculture

- **Geoinformatics** – has been described as "the science and technology dealing with the structure and character of spatial information, its capture, its classification and qualification, its storage, processing, portrayal and dissemination, including the infrastructure necessary to secure optimal use of this information" or "the art, science or technology dealing with the acquisition, storage, processing production, presentation and dissemination of geoinformation".

- **Geographic Information Systems (GIS)** – is a system designed to capture, store, manipulate, analyze, manage, and present spatial or geographic data.

- **Remote sensing (RS)** - Is the way of following up the information about land cover with using images from bird´s perspective. It uses electromagnetic waves in one or more intervals of electromagnetic spectrum. This radiance is reflected or emitted from land cover (Cambell 1996).

FUTURE FARMS
small and smart



SURVEY DRONES

Aerial drones survey the fields, mapping weeds, yield and soil variation. This enables precise application of inputs, mapping spread of pernicious weed blackgrass could increasing Wheat yields by 2-5%.

FLEET OF AGRIBOTS

A herd of specialised agribots tend to crops, weeding, fertilising and harvesting. Robots capable of microdot application of fertiliser reduce fertiliser cost by 99.9%.

FARMING DATA

The farm generates vast quantities of rich and varied data. This is stored in the cloud. Data can be used as digital evidence reducing time spent completing grant applications or carrying out farm inspections saving on average £5,500 per farm per year.

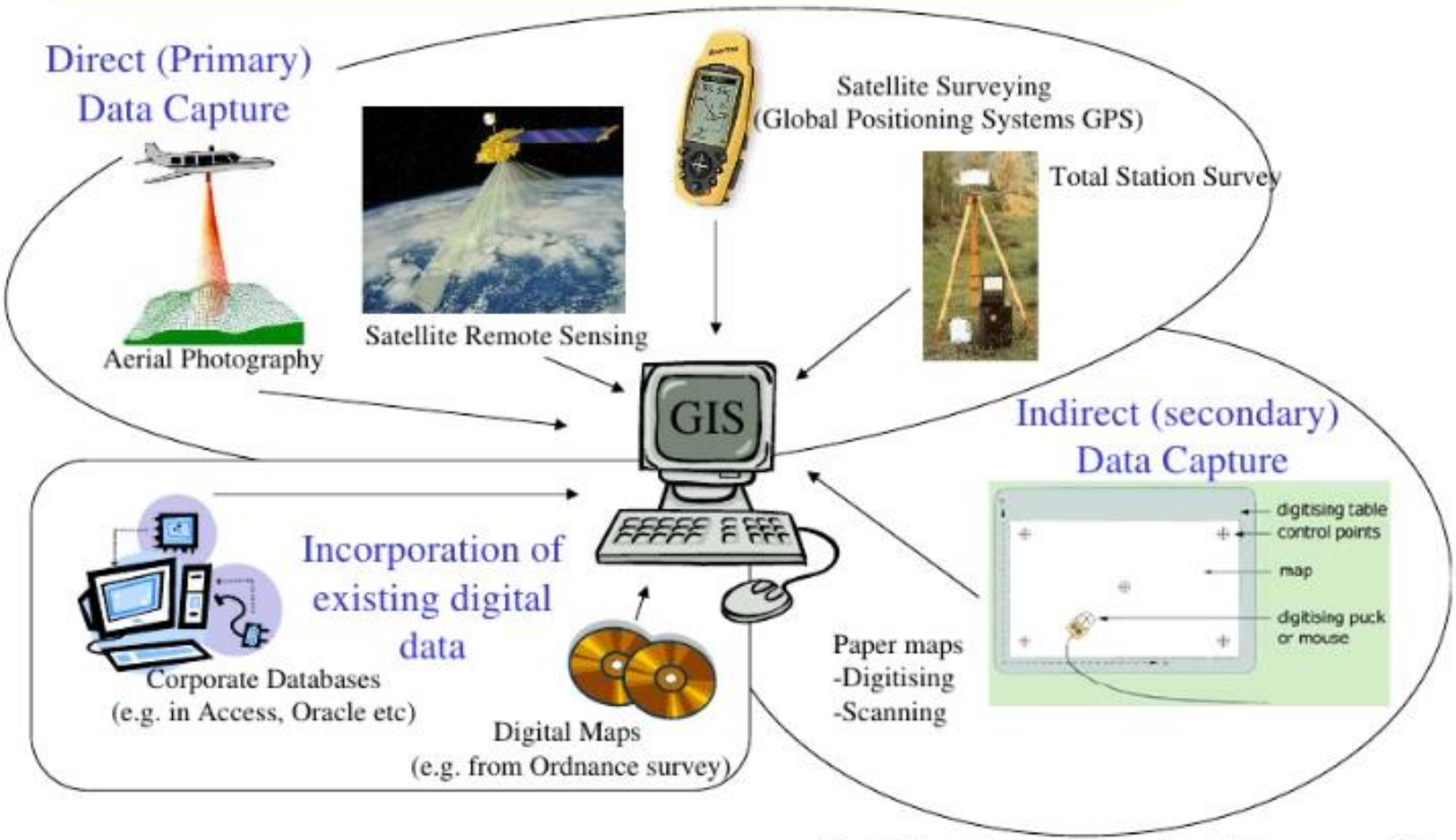
TEXTING COWS

Sensors attached to livestock allowing monitoring of animal health and wellbeing. They can send texts to alert farmers when a cow goes into labour or develops infection increasing herd survival and increasing milk yields by 10%.

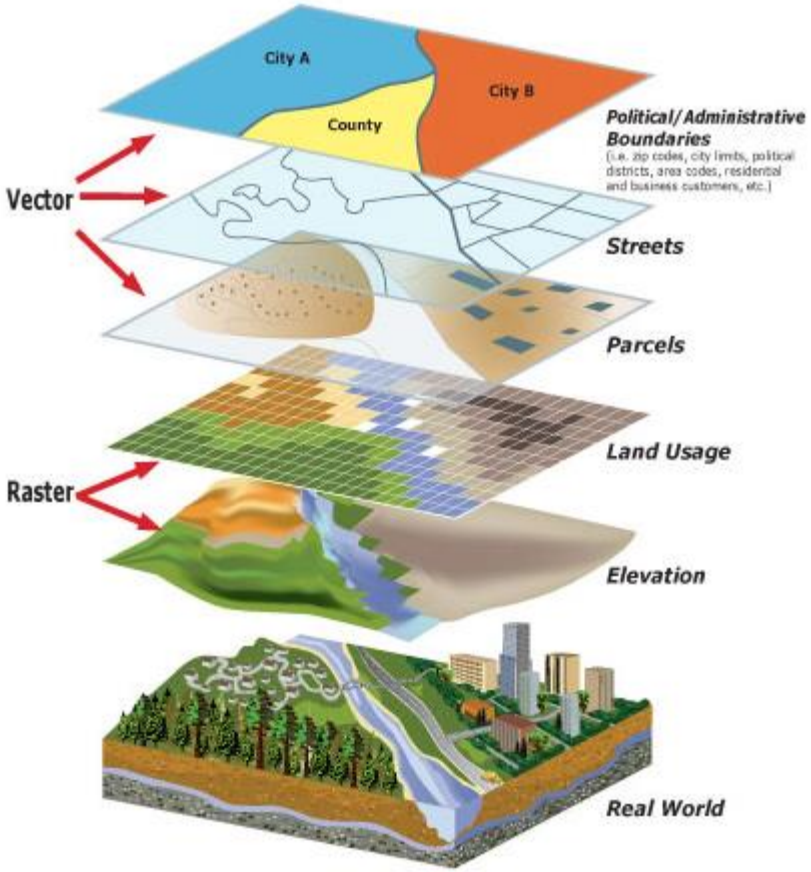
SMART TRACTORS

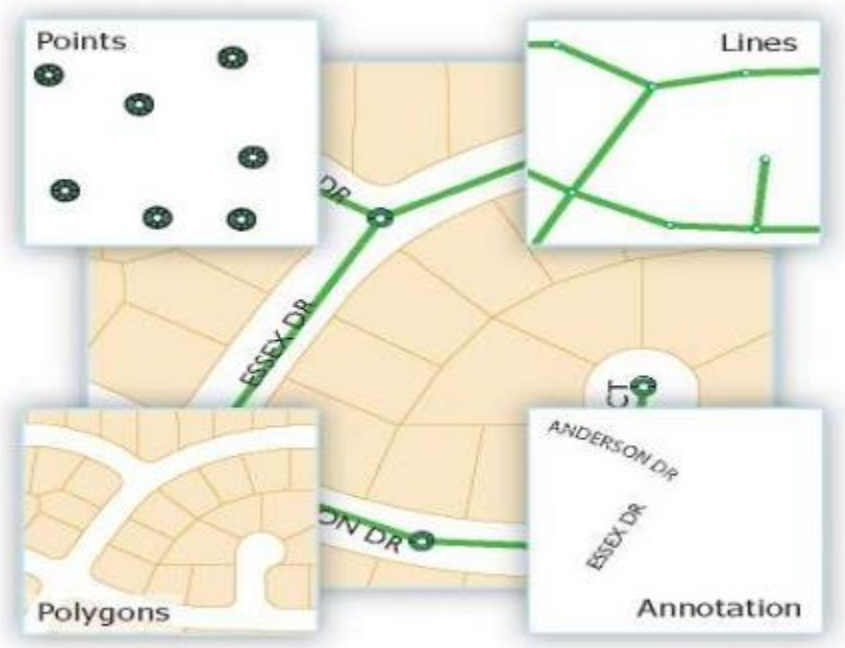
GPS controlled steering and optimised route planning reduces soil erosion, saving fuel costs by 10%.

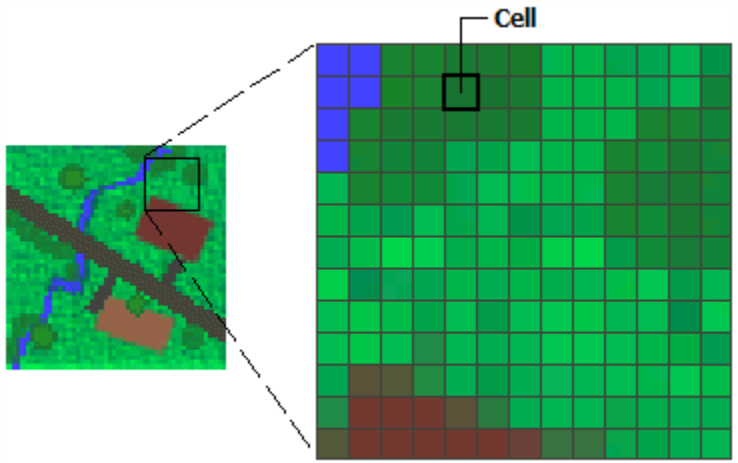
Sources of Data



Raster vs. vector data

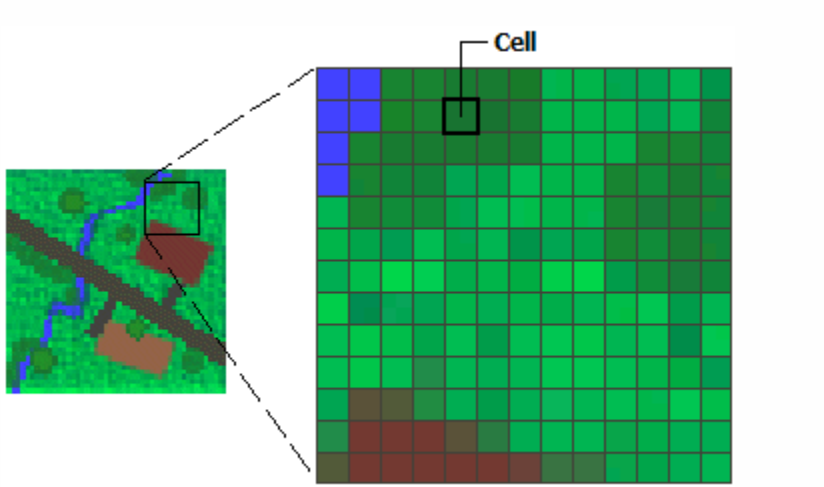






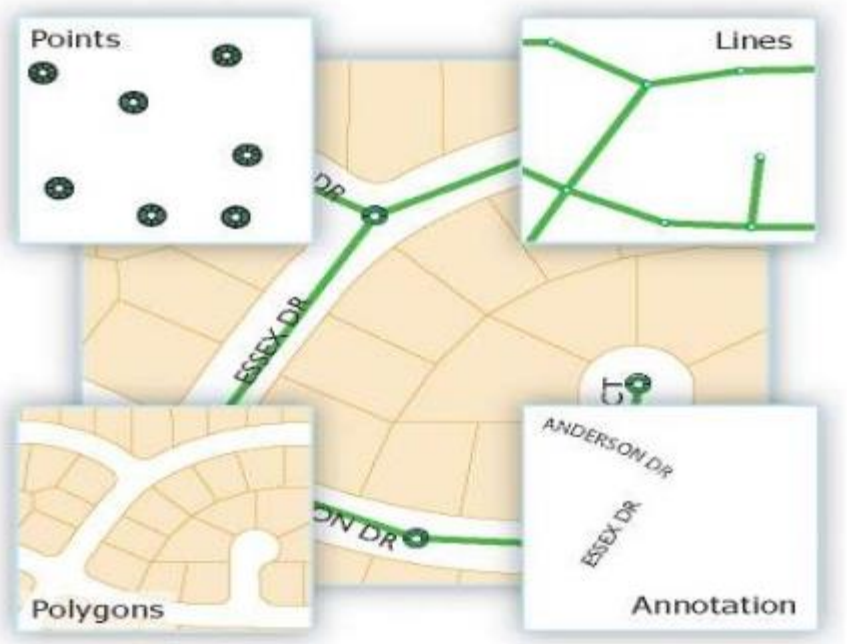
What is raster data?

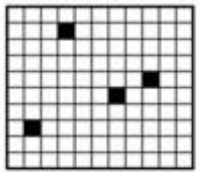
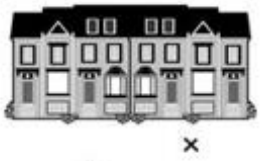
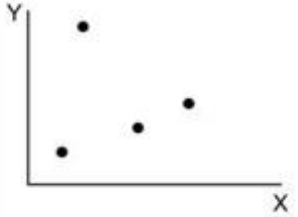
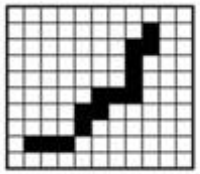
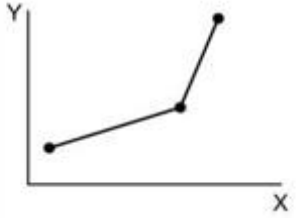
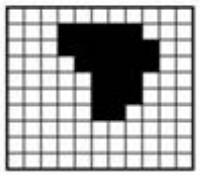
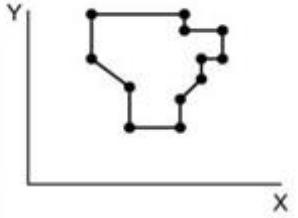
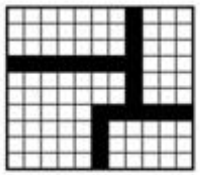
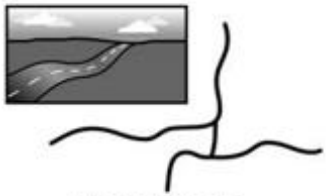
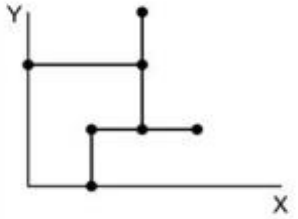
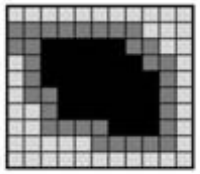
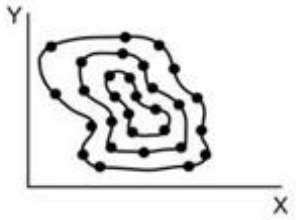
Raster consists of a matrix of cells (or pixels) organized into rows and columns (or a grid) where each cell contains a value representing information, such as temperature. Rasters are digital aerial photographs, imagery from satellites, digital pictures, or even scanned maps.

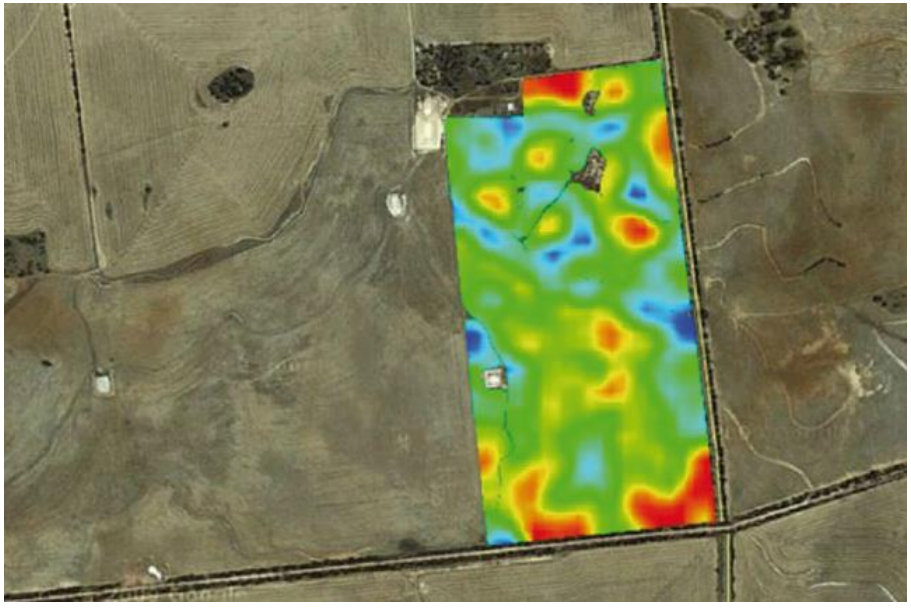


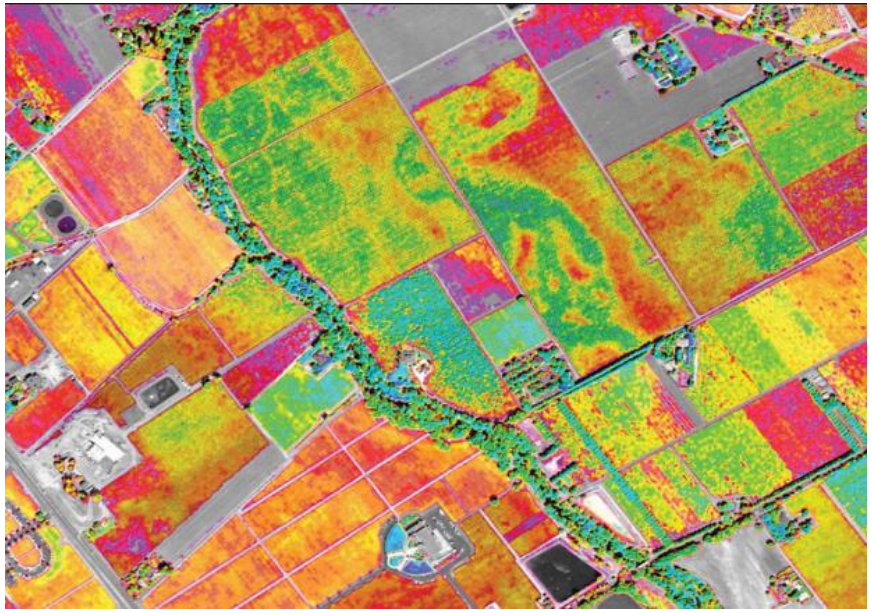
What is vector data?

A representation of the world using points, lines, and polygons. Vector models are useful for storing data that has discrete boundaries, such as country borders, land parcels, and streets.

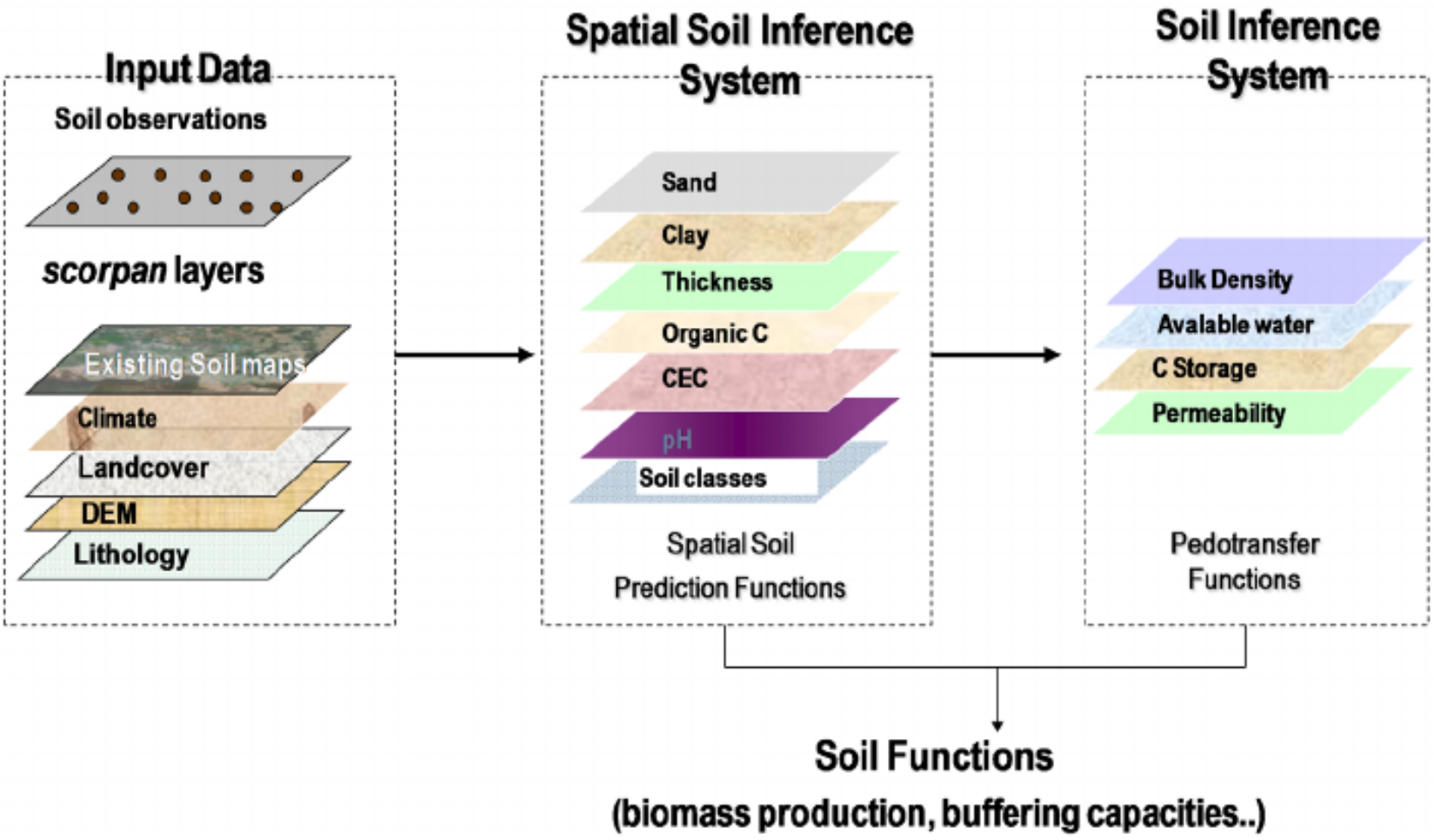


The raster view of the world	Happy Valley spatial entities	The vector view of the world
	 Points: hotels	
	 Lines: ski lifts	
	 Areas: forest	
	 Network: roads	
	 Surface: elevation	





Spatial Soil Information System



APPLICATION OF GEOINFORMATICS

examples of practical usage in crop growth monitoring

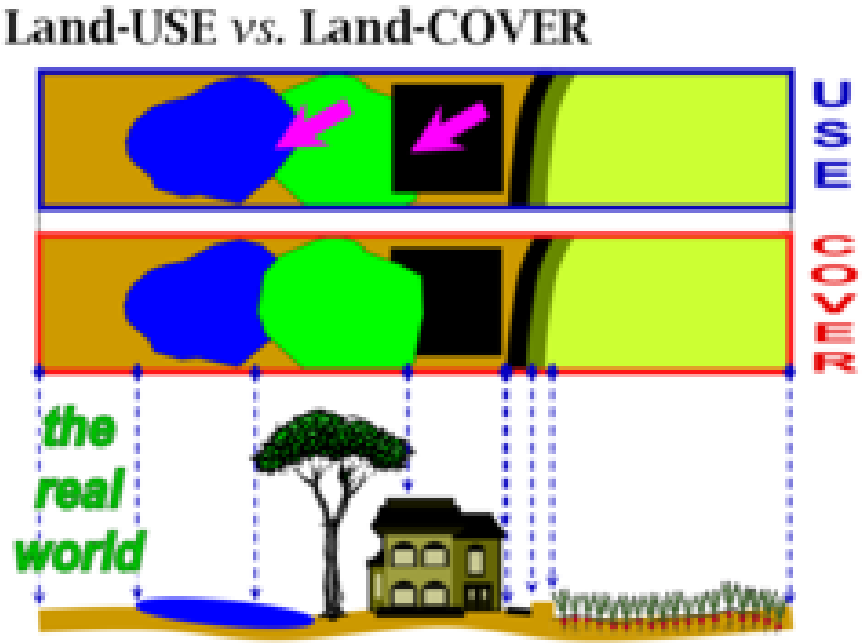
1. AGRICULTURE

- Classification of croplands, validation of vegetation´s health
- Estimations of yield
- Improvement of crop yield production and its quality
- Quality and degradation of soil, soil erosion
- Validation of agriculture management
- Validation of pastoral farming and irrigational systems
- Influence of dryness on crop
- Crop models
- **Precision agriculture**

2. LAND COVER, LAND USE MAPPING

LAND COVER – everything what sensors are able to detect

LAND USE – the purpose of soil what it serves – in farm management



Geoinformatics in agriculture

Basic trends in the use of geoinformatics in agriculture
Generally divided to:

1. Monitoring of production conditions (navigation, agriculture machines - row data and their conversion/processing)
2. Site-specific zones modelling (crop models, topography attributes)
3. Remote Sensing in Agriculture (satellite images, UAV…)

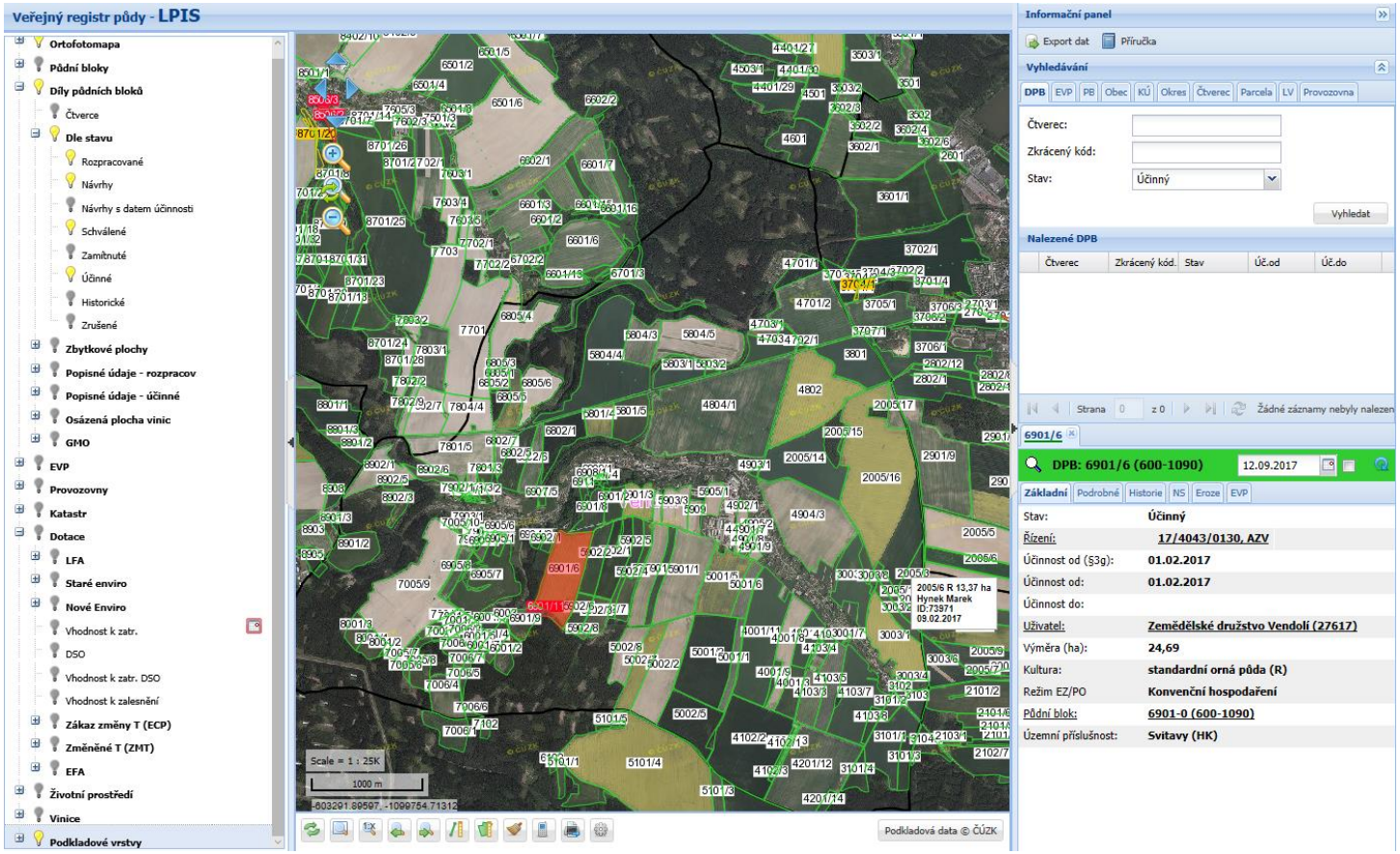
1. Monitoring of production conditions

SWs and APPLICATIONS USED FOR DATA COLLECTING and PROCESSING

- Access data - downloading
- Editing possibility /Export and Manage data
- Viewer only

LPIS – Public Land Register - eAGRI – Ministry of Agriculture of the Czech Republic

http://eagri.cz/public/app/lpisext/lpis/verejny2/plpis/



Free Data Sources

Open access data

http://www.uhul.cz/mapy-a-data/katalog-mapovych-informaci/

Geoportal UHUL
Forest management institute

Water in Landscape

http://www.vodavkrajine.cz/

Example from the Czech Republic

APLIKACE

Půda v mapách

Mapy vlastností zemědělské půdy, ohrožení vodní a větrnou erozí, ochranných opatření, evidence erozních událostí.

Limity využití půdy

Nástroj sloužící k ochraně nejkvalitnější zemědělské půdy.

Protierozní kalkulačka

Výpočet erozní ohroženosti půdy a tvorba návrhu jejího omezení.

Kalkulačka vláhové potřeby

Určení vláhové potřeby a závlahového množství zemědělských plodin.

eKatalog BPEJ

Základní informace a půdní charakteristiky pomocí kódu BPEJ.

WAKPP

Webový archiv Kompletního průzkumu půd obsahuje záznamy z prvního moderního průzkumu půd na území bývalé ČSSR.

KPP

Mapová část WAKPP zobrazuje kolem 400 000 sond na území ČR.

Monitoring eroze

Hlášení evidence a vyhodnocování erozních událostí.

Půda v číslech

Statistiky a mapy o zemědělské půdě a ohrožení půdy.

IS meliorační staveb

Přehled zaznamenaných meliorační opatření v ČR.

Geoportal VUMOP
Research Institute for Soil and Water Conservation

http://geoportal.vumop.cz/

Example from the Czech Republic

Navigation systems

GNSS = Global Navigation Satellite System

- GPS NAVSTAR (created by USA)
- GLONASS (Russian Federation)
- Galileo (EU – European GNSS Agency – headquartered in Prague)

The GPS project was launched by the U.S. Department of Defense in 1973 for use by the United States military and became fully operational in 1995.

It was allowed for civilian use in the 1980s.

GPS quality was degraded by the United States government, this was discontinued in May 2000 by a law.

Information from agricultural machines

- Machines must be equipped with navigation.
- Data conversion – several brands – non-uniform system – SWs for the managements of agriculture companies - Spatial Management System - SMS SW (AgLeader, AgrarOffice (FarmFacts solution, Germany), PLM Viewer (Trimble Ag Business Solution, Netherlands)
- Telematics - the technology of sending, receiving and storing information using telecommunication devices to control remote objects.

Telematics

Information from agricultural machines

- Data affected by machine track (movement). Data accuracy are affected:
  - Field size
  - System calibration
  - Slope
  - Data errors affected by driver (service)
- Data processing / map deriving – geostatistics
- Cartography – instrument for visualisation

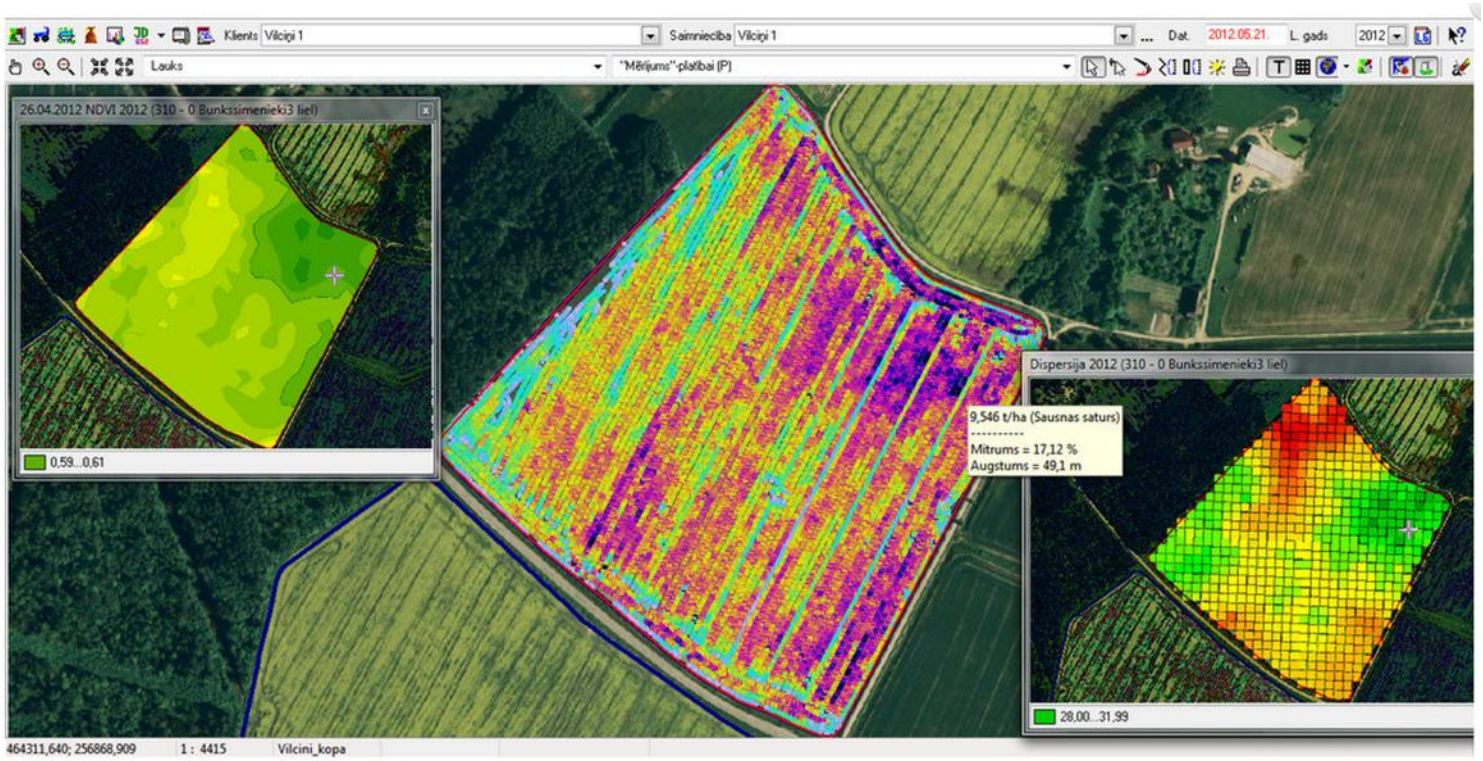
Agrar Office (AO)

- Software for the management of agricultural companies
- Farm Facts GmBH Solution

- Planning, control and analysis
- Field history and crop rotation
- Development of fertilisation plans
- Background and boundary maps of the field of all types
- Management of equipment, personnel and finance

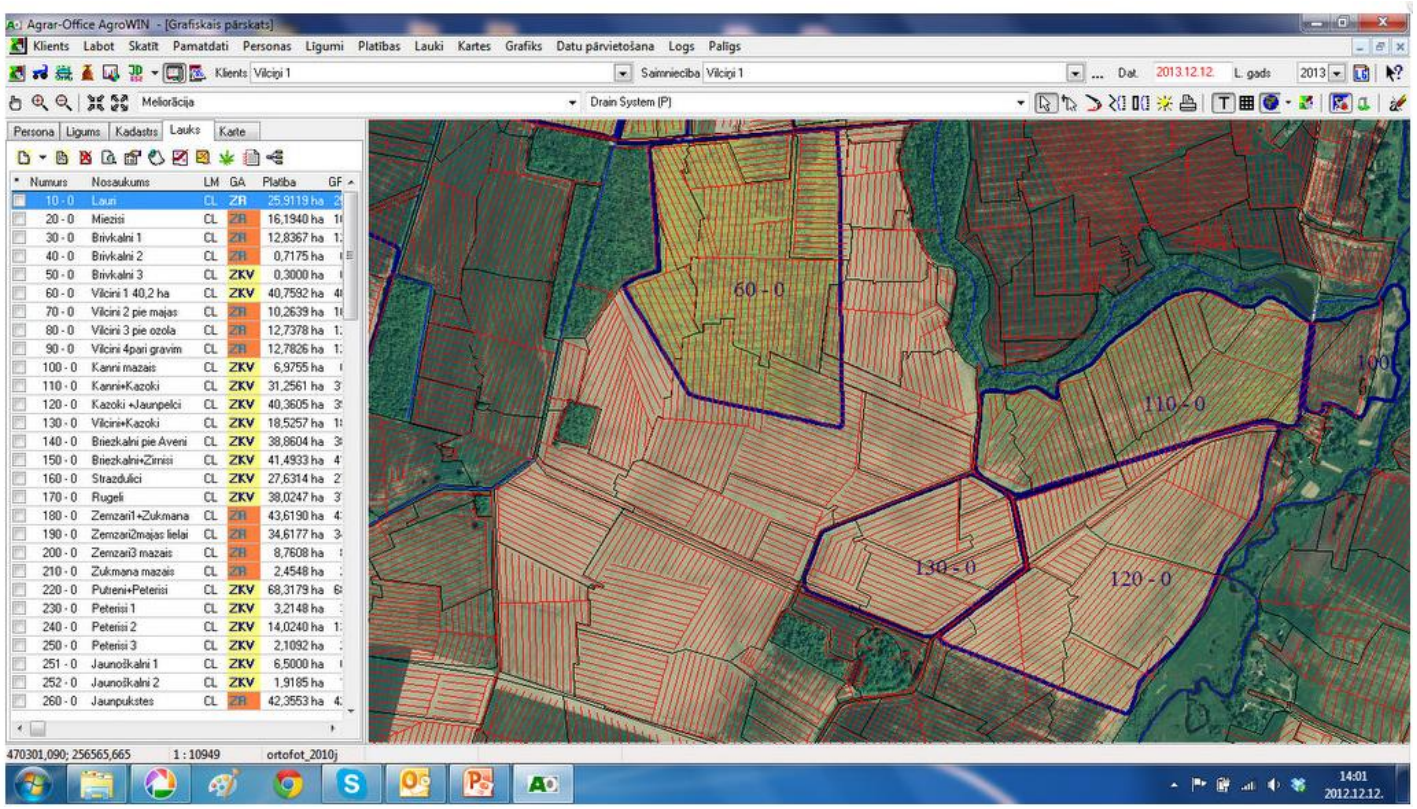
http://www.farmfact.de


Datu pārvietošana
Logs
Palīgs
Saimnieciba
Vilciņi 1
Dat.
2012.05.21.
L. gads
2012
"Mērījums":plašībai (P)
Dispersija 2012 (310 - 0 Bunkssimenieki3 liel)
ts 2013 (Vilciņi 1)
202
203
204
205
206
207
208
310 - 0
592
594
Augsnes paraugu kartes
Kartes
Detaļas
Makro/Mikro-Paraugu karte
Skats
Poligoni
Paraugi
Drukāt
Dispersijas parametri
Elements
Fosfors (Makro)
Palete
Fosfors 2
Paletes = PS
P205
Makro/Mikro
Paraugi:7
Vērtība
PS
Rekomendācija
Paraugu datums
5,00mg A 0,0kg/ha 2012.09.27.
10,30mg C 52,8kg/ha 2012.09.27.
13,20mg E 0,0kg/ha 2012.09.27.
13,00mg B 52,8kg/ha 2012.09.27.
8,30mg B 57,6kg/ha 2012.09.27.
8,30mg C 57,6kg/ha 2012.09.27.
8,00mg C 0,0kg/ha 2012.09.27.



Vector/raster maps – geostatistical analysis of the data sets

Tracking the field in a different angle of direction – technogenic compaction of the soil – yield decrease (especially on headlands due to heavy machinery).



New trends – to suggest (to design with the help of GIS tools) a fixed routes for the machines (Control Traffic Farming) in order to save the land and fuel costs.

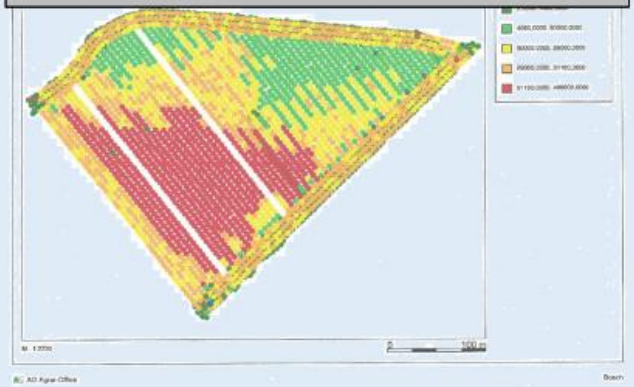
Agrar-Office → NEXT Farming OFFICE

TF Base Map

Persistent Relative Fertility

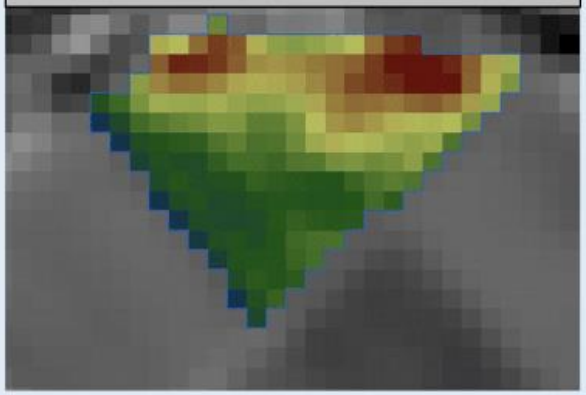
-40% Average +40%

Sowing Map 2016



Higher TF Basemap values
⇒ Higher sowing density

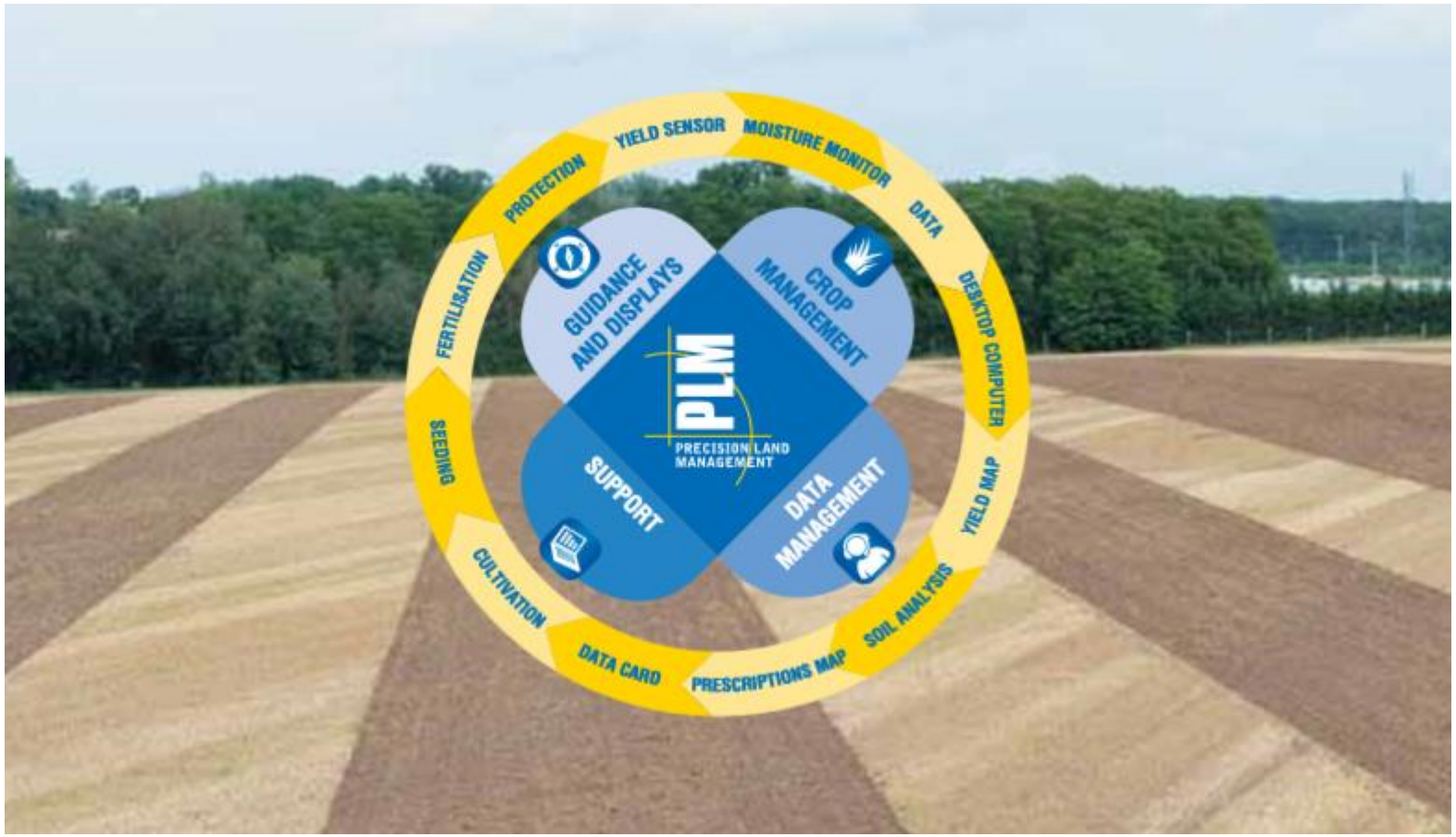
TF Yield Map2016



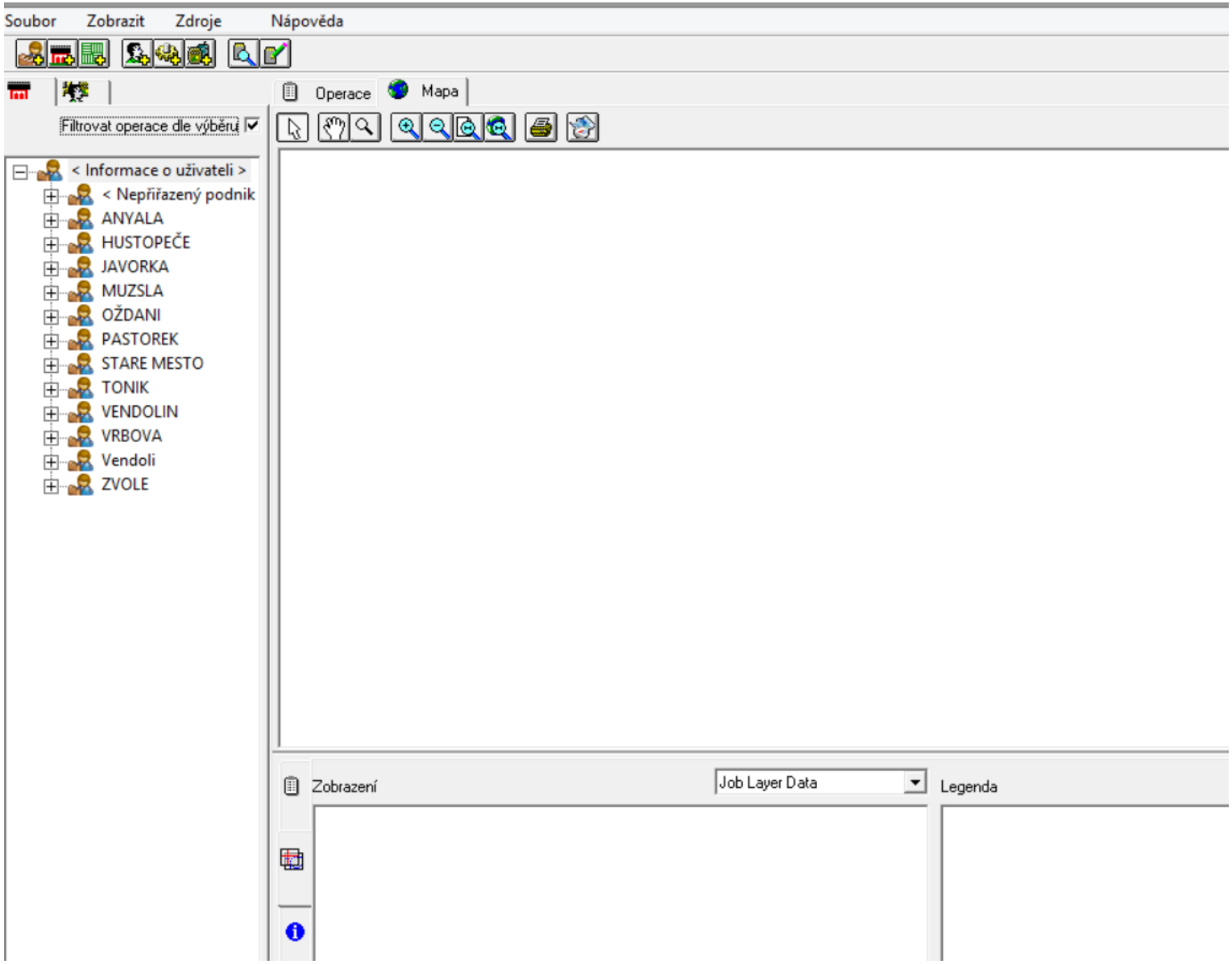
Yield Maize 2016 [t/ha]

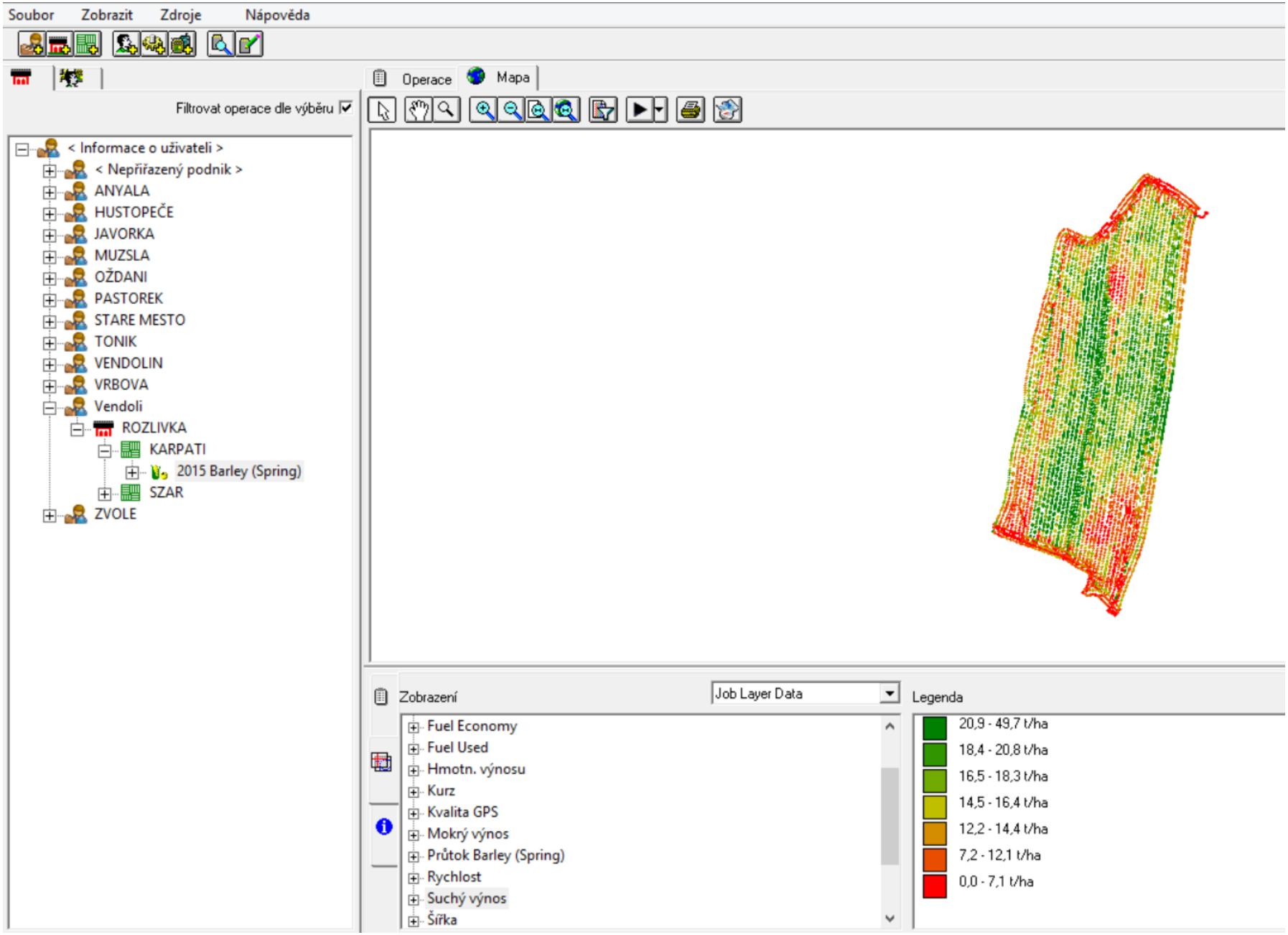
PLM Viewer (Trimble Ag Business Solution)

- Software for the management of agricultural companies.



http://www.newhollandplm.com/


Soubor
Zobrazit
Zdroje
Nápověda
Operace
Mapa
Filtrovat operace dle výběru
< Informace o uživateli >
< Nepřiřazený podnik
ANYALA
HUSTOPEČE
JAVORKA
MUZSLA
OŽDANI
PASTOREK
STARE MESTO
TONIK
VENDOLIN
VRBOVA
Vendoli
ZVOLE
Zobrazení
Job Layer Data
Legenda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Filtrovat operace dle výběru
< Informace o uživateli >
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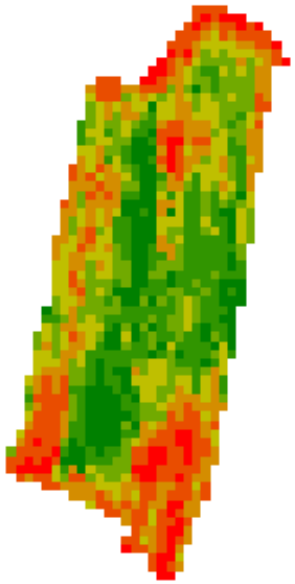
OŽDANI
PASTOREK
STARE MESTO
TONIK
VENDOLIN
VRBOVA
Vendoli
ROZLIVKA
KARPATI
2015 Barley (Spring)
SZAR
ZVOLE
Zobrazení
Job Layer Data
Legenda
Fuel Economy
Fuel Used
Hmotn. výnosu
Kurz
Kvalita GPS
Mokrý výnos
Průtok Barley (Spring)
Rychlost
Suchý výnos
Šířka
20,9 - 49,7 t/ha
18,4 - 20,8 t/ha
16,5 - 18,3 t/ha
14,5 - 16,4 t/ha
12,2 - 14,4 t/ha
7,2 - 12,1 t/ha
0,0 - 7,1 t/ha



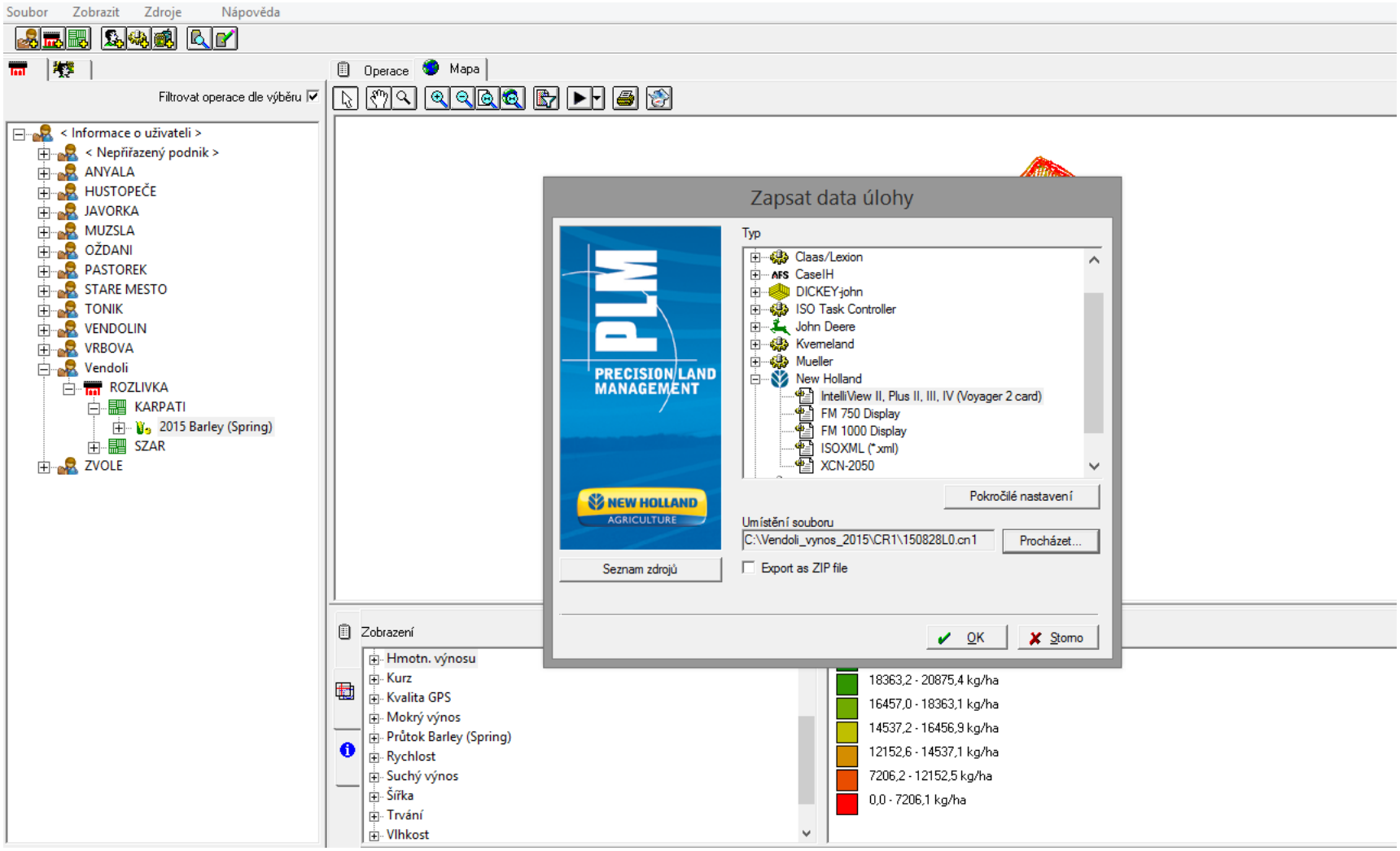
Zobrazení

Job Layer Data

- Elevation
- Engine Load
- Engine Power
- Fuel Economy
- Fuel Used
- Hmotn. výnosu
- Kurz
- Kvalita GPS
- Mokrý výnos
- Průtok Barley (Spring)
- Rychlost
- Suchý výnos
- Šířka
- Trvání
- Vlhkost
- Vzdálenost

Legenda

- 20,9 - 49,7 t/ha
- 18,4 - 20,8 t/ha
- 16,5 - 18,3 t/ha
- 14,5 - 16,4 t/ha
- 12,2 - 14,4 t/ha
- 7,2 - 12,1 t/ha
- 0,0 - 7,1 t/ha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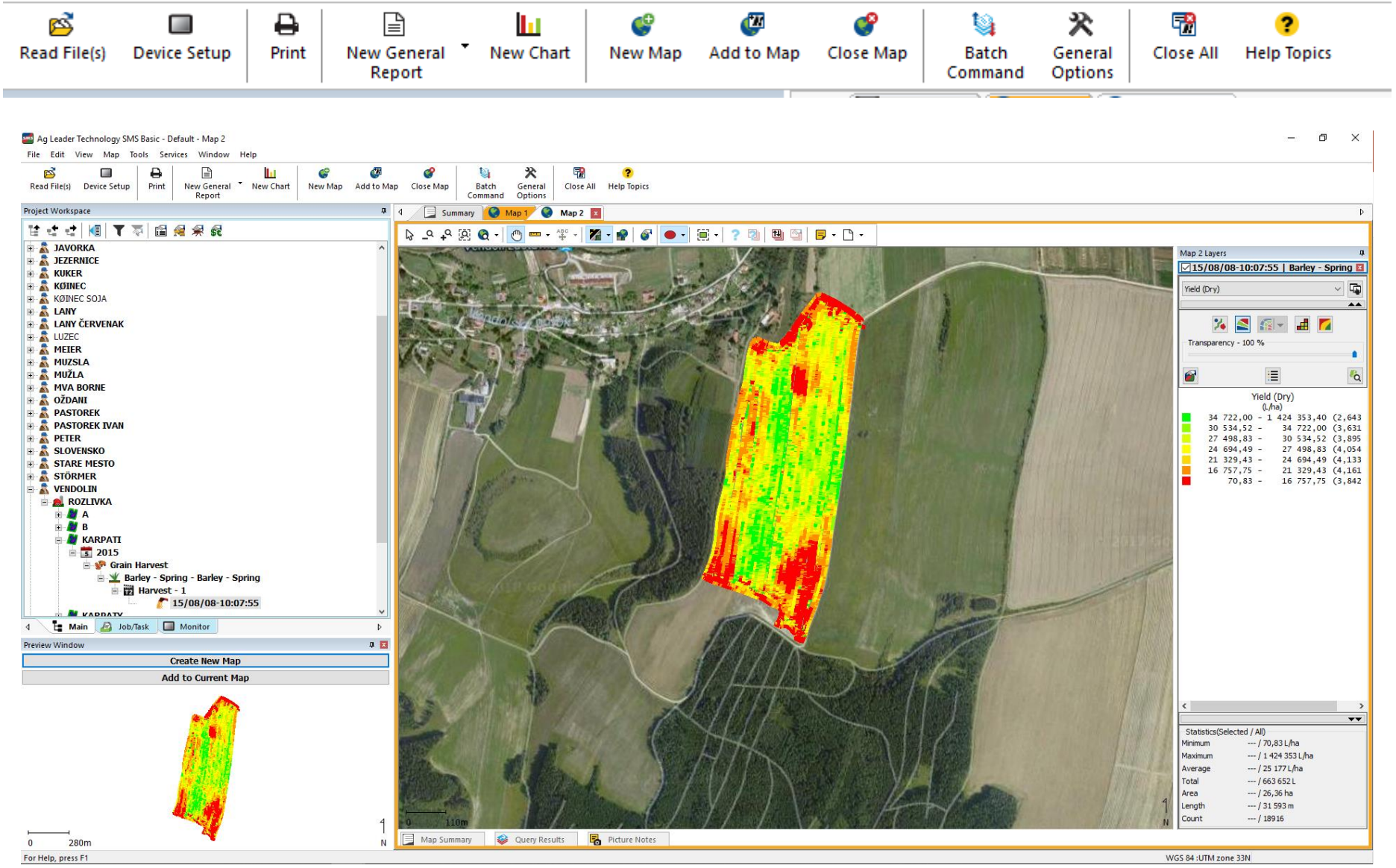
ROZLIVKA
KARPATI
2015 Barley (Spring)
SZAR
ZVOLE
Zapsat data úlohy
PLM
PRECISION LAND MANAGEMENT
NEW HOLLAND
AGRICULTURE
Typ
Claas/Lexion
CaseIH
DICKEY-john
ISO Task Controller
John Deere
Kverneland
Mueller
New Holland
IntelliView II, Plus II, III, IV (Voyager 2 card)
FM 750 Display
FM 1000 Display
ISOXML (*.xml)
XCN-2050
Pokročilé nastavení
Umístění souboru
C:\Vendoli_vynos_2015\CR1\150828L0.cn1
Procházet...
Seznam zdrojů
Export as ZIP file
OK
Storno
Zobrazení
Hmotn. výnosu
Kurz
Kvalita GPS
Mokrý výnos
Průtok Barley (Spring)
Rychlost
Suchý výnos
Šířka
Trvání
Vlhkost
18363,2 - 20875,4 kg/ha
16457,0 - 18363,1 kg/ha
14537,2 - 16456,9 kg/ha
12152,6 - 14537,1 kg/ha
7206,2 - 12152,5 kg/ha
0,0 - 7206,1 kg/ha

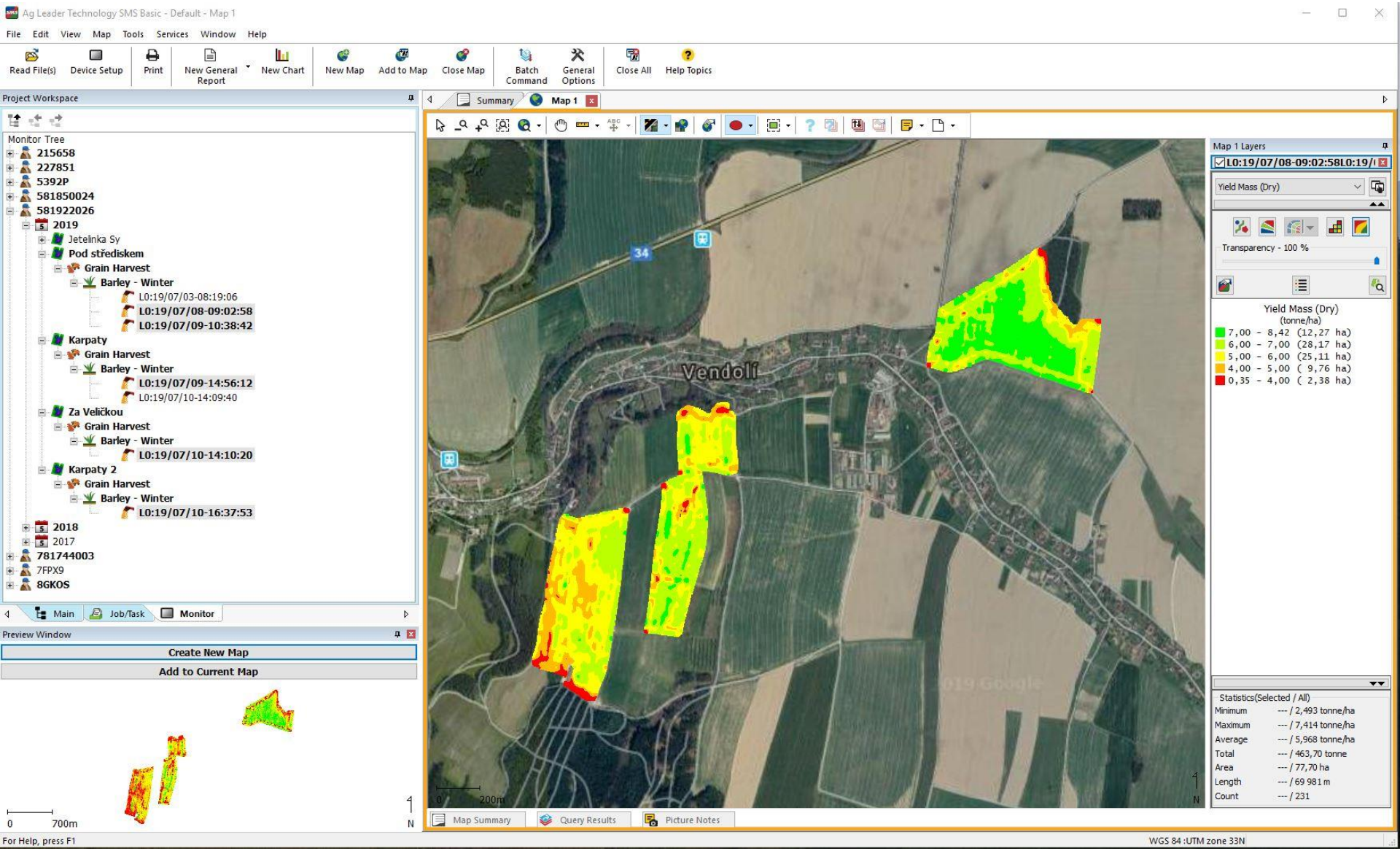
Spatial Management System (SMS)

- Software for the management of agricultural companies.
- Ag Leader Technology
- Basic / Advanced / Mobile

http://www.agleader.com/



SW interface



SW interface

Ag Leader Technology SMS Basic - Default - Summary

File Edit View Tools Services Window Help

Read File(s) | Device Setup | Print | New General Report | New Chart | New Map | Add to Map | Close Map | Batch Command | General Options | Close All | Help Topics

Project Workspace

Monitor Tree

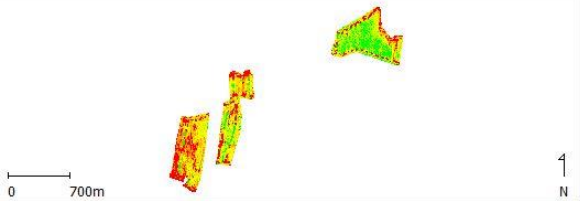
- 215658
- 227851
- 5392P
- 581850024
- 581922026
  - 2019
    - Jetelinka Sy
    - Pod střediskem
      - Grain Harvest
        - Barley - Winter
          - L0:19/07/03-08:19:06
          - **L0:19/07/08-09:02:58**
          - **L0:19/07/09-10:38:42**
    - Karpaty
      - Grain Harvest
        - Barley - Winter
          - **L0:19/07/09-14:56:12**
          - L0:19/07/10-14:09:40
    - Za Veličkou
      - Grain Harvest
        - Barley - Winter
          - **L0:19/07/10-14:10:20**
    - Karpaty 2
      - Grain Harvest
        - Barley - Winter
          - **L0:19/07/10-16:37:53**
  - 2018
  - 2017
- 781744003
- 7FPX9
- 8GKOS

Main | Job/Task | Monitor

Preview Window

Create New Map

Add to Current Map



Summary | Map 1

Summary of Selected General Management Information

Summary Type: User Defined

Monitor	581922026
Year	2019
Physical Field	Pod střediskem
Operation	Grain Harvest
Physical Product	Barley - Winter
Dataset	L0:19/07/08-09:02:58

Area	Avg. Moisture	Est. Weight (Wet)	Est. Yield Mass (Dry)	GPS Count	Marks Count	Date Logged	Cal File	GPS File
19,66 ha	12,78 %	128,09 tonne	6,515 tonne/ha	23335	0	08.07.2019		190711o7.cn1

Monitor	581922026
Year	2019
Physical Field	Pod střediskem
Operation	Grain Harvest
Physical Product	Barley - Winter
Dataset	L0:19/07/09-10:38:42

Area	Avg. Moisture	Est. Weight (Wet)	Est. Yield Mass (Dry)	GPS Count	Marks Count	Date Logged	Cal File	GPS File
8,857 ha	13,23 %	59,42 tonne	6,708 tonne/ha	9856	0	09.07.2019		190711o7.cn1

Monitor	581922026
Year	2019
Physical Field	Karpaty
Operation	Grain Harvest
Physical Product	Barley - Winter
Dataset	L0:19/07/09-14:56:12

Area	Avg. Moisture	Est. Weight (Wet)	Est. Yield Mass (Dry)	GPS Count	Marks Count	Date Logged	Cal File	GPS File
24,63 ha	12,46 %	132,77 tonne	5,391 tonne/ha	23272	0	09.07.2019		190711o7.cn1

Monitor	581922026
Year	2019
Physical Field	Za Veličkou
Operation	Grain Harvest
Physical Product	Barley - Winter
Dataset	L0:19/07/10-14:10:20

Area	Avg. Moisture	Est. Weight (Wet)	Est. Yield Mass (Dry)	GPS Count	Marks Count	Date Logged	Cal File	GPS File
7,554 ha	12,35 %	41,85 tonne	5,540 tonne/ha	6854	0	10.07.2019		190711o7.cn1

Monitor	581922026
Year	2019
Physical Field	Karpaty 2
Operation	Grain Harvest
Physical Product	Barley - Winter
Dataset	L0:19/07/10-16:37:53

Area	Avg. Moisture	Est. Weight (Wet)	Est. Yield Mass (Dry)	GPS Count	Marks Count	Date Logged	Cal File	GPS File
13,95 ha	13,13 %	85,09 tonne	6,102 tonne/ha	14971	0	10.07.2019		190711o7.cn1

General | Properties | Linked Items | Associated | Dataset Values

For Help, press F1

WGS 84 :UTM zone 33N

SW interface

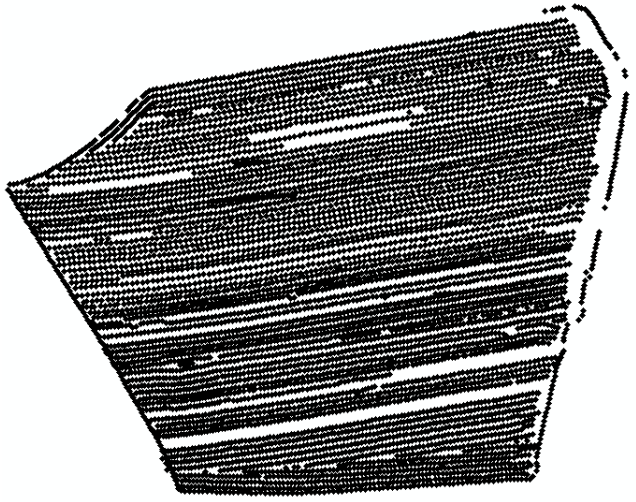
Supposted formats

Ag Leader Technology® Ag Leader Integra/Versa/Compass/ InCommand (*.agdata) Ag Leader Integra/Versa/Compass/ InCommand (*.agsetup) Ag Leader® Integra/InSight/Edge Boundary (*.iby) Ag Leader Integra/InSight/Edge Guidance (*.pat) Ag Leader Integra/InSight/Edge Log (*.ilf) Ag Leader Integra/InSight/Edge Prescription (*.irx) EZ-Guide 250/500 (*.shp) EZ-Guide Plus (*.fld) PF 3000/PFAdvantage/YM 2000 (*.yld) PF Boundary (*.bdy) PF Navigation (*.pfn) PFL – Cotton (*.pfl) TGT Prescription (*.tgt) AGCO FieldStar II/Falcon VT/Task Controller (TaskData.xml) Falcon Log (*.rpt) Falcon Prescription (*.tif) » Fieldstar » AutoFarm A5 System (*.sqlite) A5 System (*dbmain.db) Ag Leader Integra/Edge Boundary (*.iby) Ag Leader Integra/Edge Guidance Pattern (*.pat) Ag Leader Integra/Edge Log (*.ilf) Ag Leader Integra /Edge Prescription (*.irx) Ag Leader Integra/Versa (*.agdata) Ag Leader Integra/Versa (*.agsetup) Case IH AFS Harvest (*.yld) AFS Planting and Seeding (*.ens) Agri Check ADX Air System (*.log) EZ-Guide Plus (*.fld) FM-750/FM-1000/FMD/EZ-Guide 250/500 (*.shp) Remote Data Logger (*.shp) Universal Display/UD Plus (*.vyg) AFS200/AFS300/AFS Pro600/AFS Pro700 (*.vy1) CLAAS CEBIS (*.dat) CEBIS II/Task Controller (TaskData.xml) Evrard Evrard Integra/Versa (*.agdata) Evrard Integra/Versa (*.agsetup) Flexi-Coil FlexControl System (*.log) Gradient Gradient Intellislope File (*.xml) HARDI HC 9500 Boundary (*.iby)

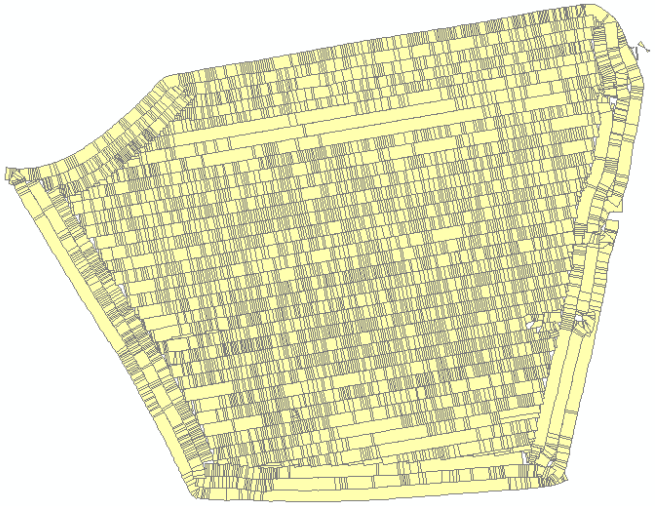
(HARDI continued)… HC 9500 Guidance Pattern (*.pat) HC 9500 Log (*.ilf) HC 9500 Prescription (*.irx) HC 9600/9500/8600/8500 (*.agdata) HC 9600/9500/8600/8500 (*.agsetup) Hemisphere GPS Air M3 & Outback 360/STS/S3 (*.log) Air M3 & Outback 360/STS/S3 Template (*.tmp) ISO11783 Displays ISO11783 Task Controller (TaskData.xml) ISO11783 Display- Type 1 (TaskData.xml) » ISO11783 Display- Type 2 (TaskData.xml) » Kverneland Tellus (TaskData.xml) » Mueller ISO Displays (TaskData.xml) » John Deere Greenstar GSD (*.gsd) › Greenstar GSY (*.gsy) › John Deere Greenstar 2 (*.ver) John Deere Greenstar 3 (*.ver) Kinze Vision Boundary (*.iby) Vision Guidance Pattern (*.pat) Vision Prescription (*.irx) Vision/Cobalt Log (*.ilf) Mid-Tech Mid-Tech Boundary (*.bnd) Mid-Tech General Mapping (*.gmf) Mid-Tech Guideline (*.gln) Mid-Tech Record (*.rcd) Mid-Tech Prescription (*.arm) » Miscellaneous Agri Check/FlexControl Tag (*.tag) New Holland EZ-Guide Plus (*.fld) FM-750/FM-1000/FMD/EZ-Guide 250/500 (*.shp) FlexControl System (*.log) Harvest Log (*.log) Remote Data Logger (*.shp) SP Planter (*.ens) Infoview/Intelliview (*.vyg) Intelliview II/Plus II/III/IV (*.vy1) YLD (*.yld) Precision Planting 20/20 Seed Sense (*.dat) Raven Viper/Viper Pro Log (*.RBIN) Viper Pro Prescriptions (*.shp) » Envizio Pro Prescriptions (*.shp) » RDS Boundary (*.B??) Ceres 2/Hermes (*.0??) Pro Series/8000i/34i (*.x??) AgGPS 160 (*.shp) AgGPS 170 (*.shp)

Supported formats

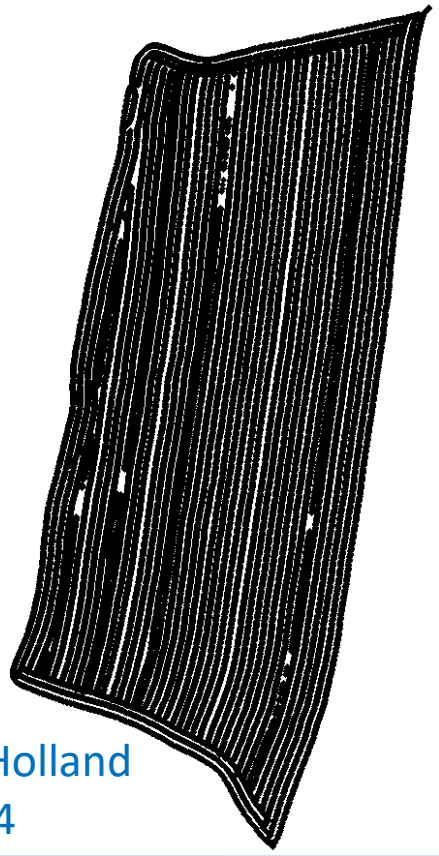
Trimble AgGPS 70 RDL (*.shp) AgGPS EZ-Map (*.shp) EZ-Guide Plus (*.fld) CFX-750/FMX/FMD/EZ Guide 250/500 (*.shp) Trimble Yield Data (TaskData.xml) Internet Download Options Internet Imagery Soil Survey Data (U.S. Only) 3D Surface Files (Advanced Only) Digital Elevation Model (*.dem) LIDAR Files (*.las) NED Elevation Model (*.bil) SDTS Elevation Model (*.ddf) Images Graphic Interchange Format (*.gif) JPEG (*.jpg,*.jpeg) JPEG 2000 (*.jpg2) MrSID (*.sid) Portable Network Graphics (*.png) Tagged Image Format (*.tiff; *.tif) Windows Bitmap (*.bmp) Windows Metafile (*.wmf) Google Spatial Files KML – Keyhole Markup (*.kml) » KMZ – Compressed KML (*.kmz) » Management Item Files (Product Lists) Comma delimited text (*.csv) Dbase (*.dbf) Management Setup File (*.msf) Tab delimited text (*.txt) MapInfo MID/MIF File MapInfo (*.mif) Non-Spatial Files (Lab Results) CSV – Comma delimited (*.csv) Dbase File (*.dbf) Text – Tab delimited (*.txt) Shapefiles Shapefile (*.shp) Text File CSV – Comma delimited (*.csv) Dbase File (*.dbf) Text – Tab delimited (*.txt) TIGER Files Tiger Line (*.rt1) Tiger Line County Subdivisions (*.rt7)



Sampo 2075 – 2007



John Deere – 2016



New Holland - 2014

Point / polygon shapefile

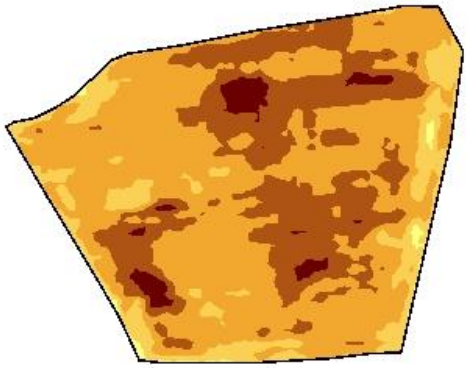
Attribute table

Table

14_08_31-11_09_47

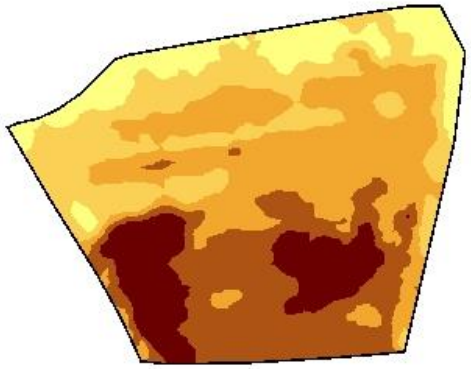
FID	Shape	Region	Elevation	Distance	Duration	Width	Heading	Timestamp	GPS_Qualit	Engine_Loa	Engine_Pow	Fuel_Econo	Fuel_Used	Moisture	Flow_Wheat	Engaged	Speed	Mass_Yield	Wet_Yield	Dry_Yield
0	Point	14/08/31-11:09:47	553.37	0.67	1	0	256	1409478084	1	43	0	0	46.8	13.5	0.2	1	2.4	0	0	0
1	Point	14/08/31-11:09:47	553.28	0.52	1	8.9	256	1409478085	1	44	0	21.4	36	13.5	1	1	1.9	2160.8	2.2	2.2
2	Point	14/08/31-11:09:47	553.3	0.44	1	8.9	259	1409478086	1	43	0	25.3	36	13.5	2.4	1	1.6	6128.7	6.1	6.1
3	Point	14/08/31-11:09:47	553.39	0.5	1	8.9	260	1409478087	1	45	0	22.4	36	13.5	3.3	1	1.8	7415.7	7.4	7.4
4	Point	14/08/31-11:09:47	553.51	0.53	1	8.9	260	1409478088	1	45	0	21.3	36	13.5	3.3	1	1.9	6996	7	7
5	Point	14/08/31-11:09:47	553.59	0.47	1	8.9	235	1409478089	1	45	0	26.1	39.6	13.5	3	1	1.7	7171.9	7.2	7.2
6	Point	14/08/31-11:09:47	553.77	0.5	1	8.9	226	1409478090	1	45	0	24.7	39.6	13.5	2.3	1	1.8	5168.5	5.2	5.2
7	Point	14/08/31-11:09:47	553.88	0.5	1	8.9	251	1409478091	1	46	0	24.7	39.6	13.5	1.4	1	1.8	3146.1	3.1	3.1
8	Point	14/08/31-11:09:47	553.77	0.44	1	8.9	241	1409478092	1	46	0	27.8	39.6	13.5	1	1	1.6	2553.6	2.6	2.6
9	Point	14/08/31-11:09:47	553.76	0.33	1	8.9	241	1409478093	1	63	0	40.5	43.2	13.5	1	1	1.2	3404.8	3.4	3.4
10	Point	14/08/31-11:09:47	553.8	0.17	1	8.9	230	1409478094	1	57	0	108.3	57.6	13.5	1	1	0.6	6609.4	6.6	6.6
11	Point	14/08/31-11:09:47	553.8	0.11	1	8.9	230	1409478095	1	59	0	151.8	54	13.5	1.3	1	0.4	13278.9	13.3	13.3
12	Point	14/08/31-11:09:47	553.89	0.25	1	8.9	235	1409478096	1	62	0	67.1	54	13.5	1.5	1	0.9	6741.6	6.7	6.7
13	Point	14/08/31-11:09:47	553.89	0.06	1	8.9	235	1409478097	1	52	0	306.4	54	13.5	1.9	1	0.2	35580.5	35.6	35.6
14	Point	14/08/31-11:09:47	553.88	0.22	1	8.9	235	1409478098	1	54	0	65.5	46.8	13.5	3.1	1	0.8	15832.5	15.8	15.8
15	Point	14/08/31-11:09:47	554	0.55	1	8.9	224	1409478099	1	52	0	26.5	46.8	13.5	4.8	1	2	9805.9	9.8	9.8
16	Point	14/08/31-11:09:47	554.12	0.47	1	8.9	242	1409478100	1	54	0	30.9	46.8	13.5	6.1	1	1.7	14582.8	14.6	14.6
17	Point	14/08/31-11:09:47	554.26	0.36	1	8.9	213	1409478101	1	50	0	40.2	46.8	13.5	6.1	1	1.3	19038.7	19	19
18	Point	14/08/31-11:09:47	554.34	0.39	1	8.9	230	1409478102	1	50	0	37.6	46.8	13.5	5.8	1	1.4	16709.9	16.7	16.7
19	Point	14/08/31-11:09:47	554.44	0.36	1	8.9	245	1409478103	1	51	0	37.3	43.2	13.5	6	1	1.3	18726.6	18.7	18.7
20	Point	14/08/31-11:09:47	554.54	0.53	1	8.9	266	1409478104	1	54	0	27.7	46.8	13.5	6.5	1	1.9	13779.9	13.8	13.8

Yield maps – visualisation - information



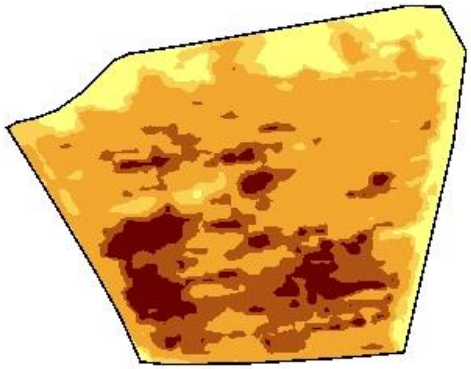
Yield 2004 (t/ha), winter rape

0.3 2 3 4 5 7.1



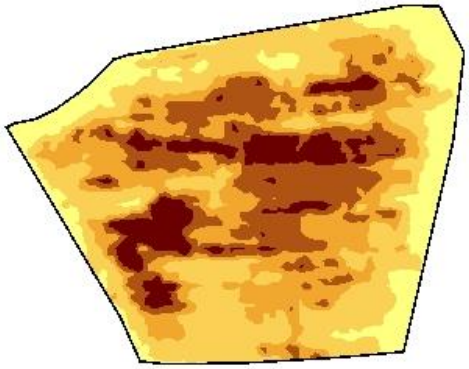
Yield 2007 (t/ha), winter barley

1.1 4 5 6 7 10.1



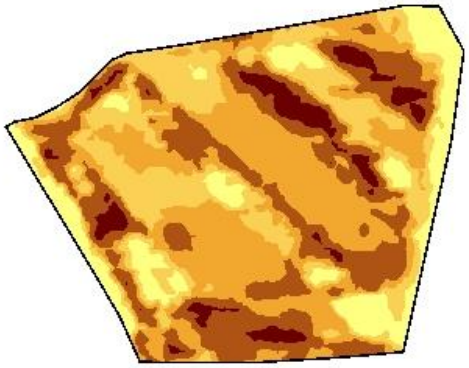
Yield 2011 (t/ha), winter wheat

0.5 5 6 8 9 13.5



Yield 2012 (t/ha), winter rape

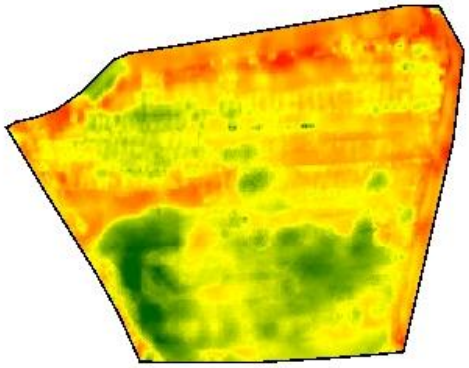
0.1 2 3 3,5 4 6.6



other track direction

Yield 2014 (t/ha), winter wheat

0.1 3 4 5 7 8.9



Yield frequency map for cereals (%)

High : 160.05

Low : 43.57

N

0 50 100 m

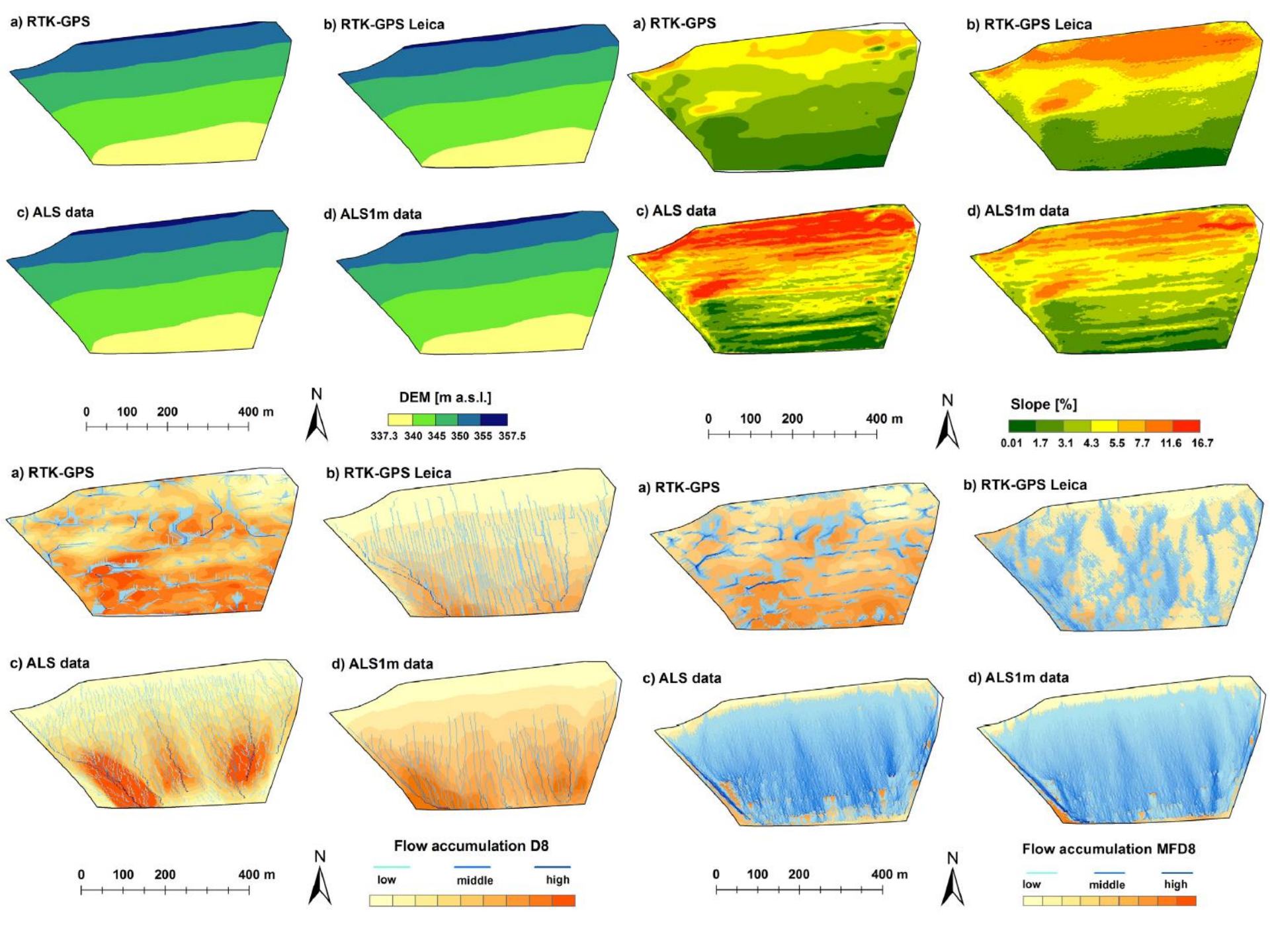
2. Site-specific zones modelling

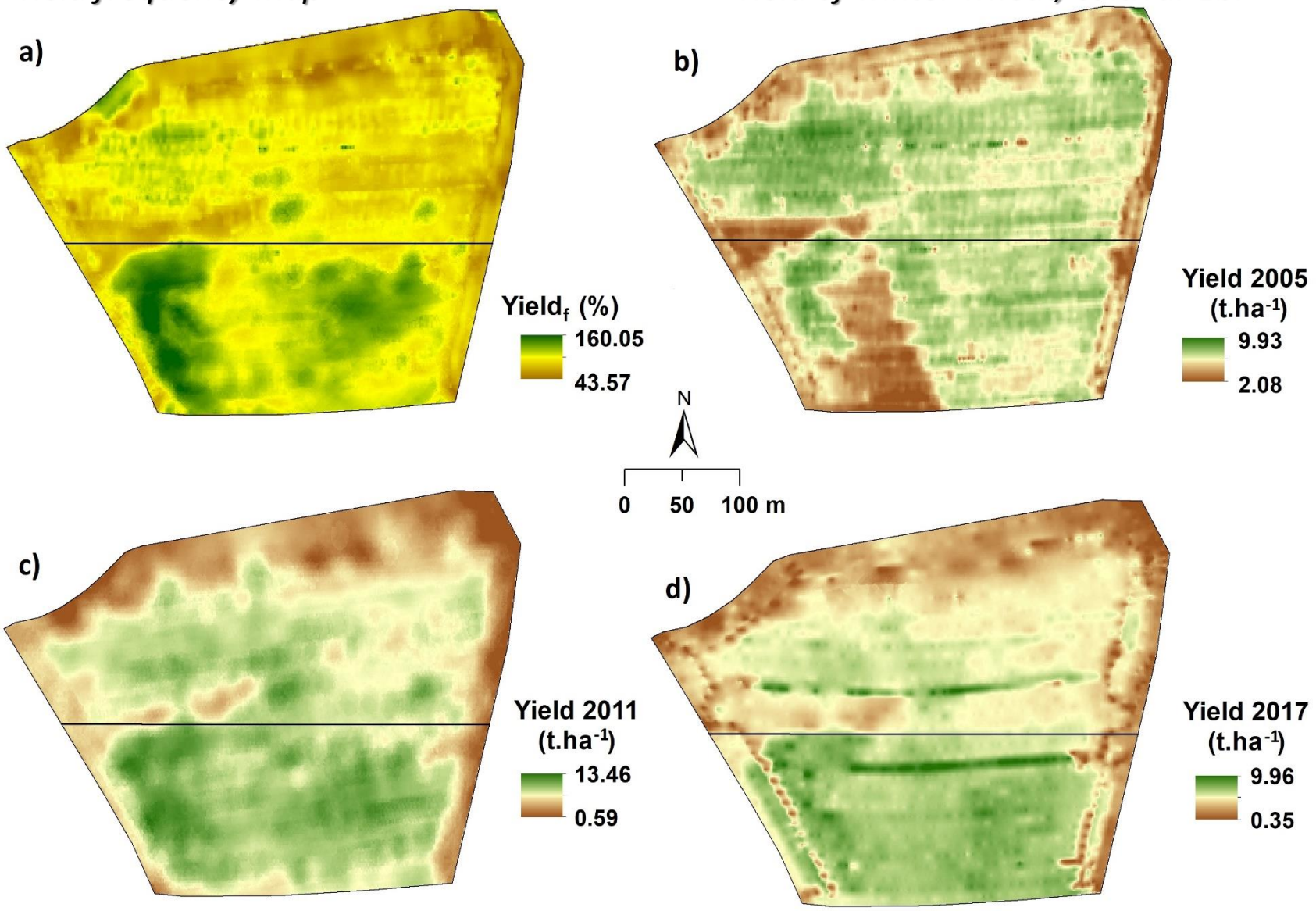
Topografic attributes

- Digital elevation model, digital surface model, slope model, flow acumulation model (D8 a MFD8 algorithm, TWI), curvature and aspect
- Model accuracy depending on accuracy and number of input data

Data sources:

- Storages (USGS, national storages, cadastre offices…)
- Web-services – ArcGIS, QGIS
- Data from machines (elevation)
- Own data – UAV, GPS, RTK-GPS, Laser Scanning
- Useful combination with meteodata (especially precipitation)

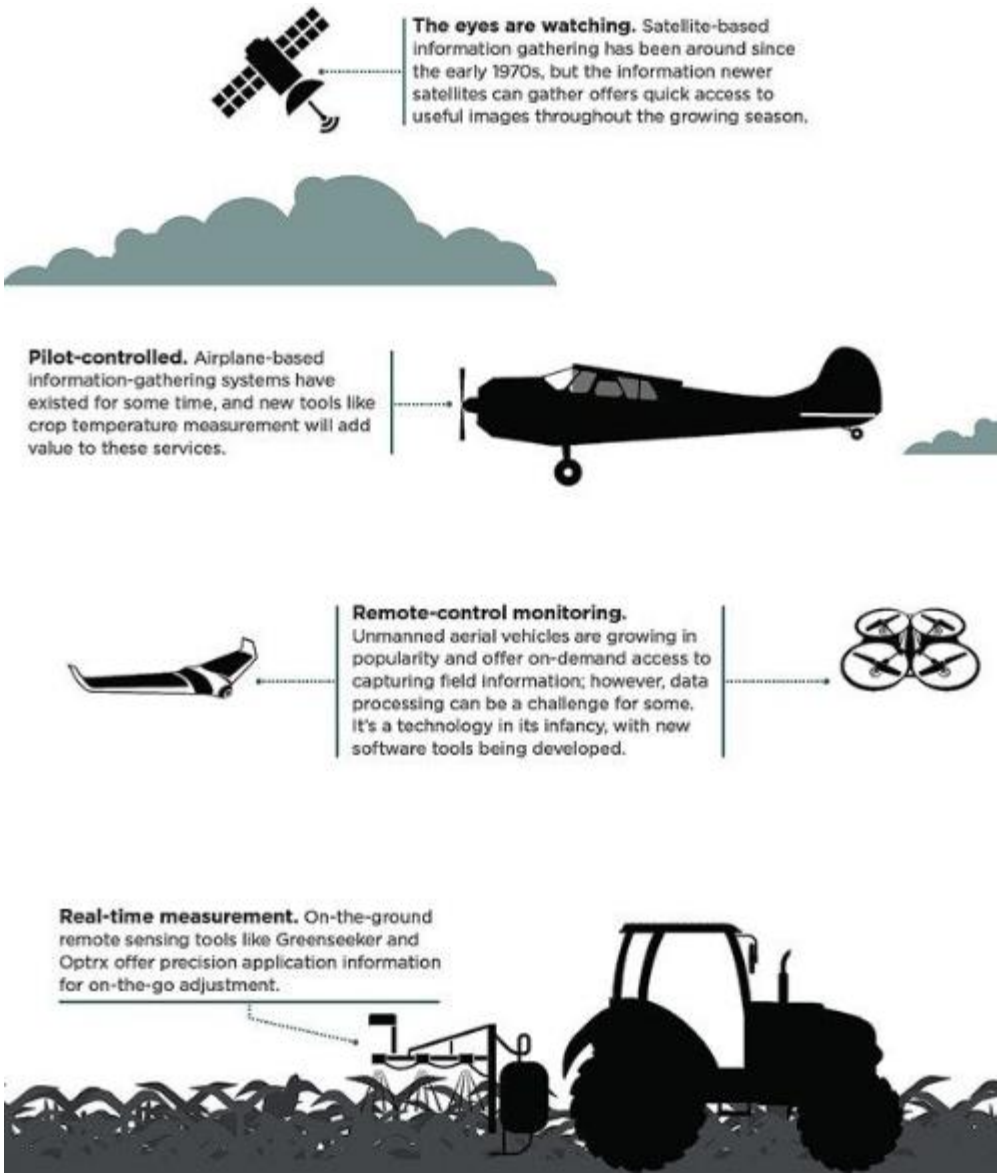

a) RTK-GPS
b) RTK-GPS Leica
c) ALS data
d) ALS1m data
0 100 200 400 m
N
DEM [m a.s.l.]
337.3 340 345 350 355 357.5
a) RTK-GPS
b) RTK-GPS Leica
c) ALS data
d) ALS1m data
0 100 200 400 m
N
Slope [%]
0.01 1.7 3.1 4.3 5.5 7.7 11.6 16.7
a) RTK-GPS
b) RTK-GPS Leica
c) ALS data
d) ALS1m data
0 100 200 400 m
N
Flow accumulation D8
low
middle
high
a) RTK-GPS
b) RTK-GPS Leica
c) ALS data
d) ALS1m data
0 100 200 400 m
N
Flow accumulation MFD8
low
middle
high

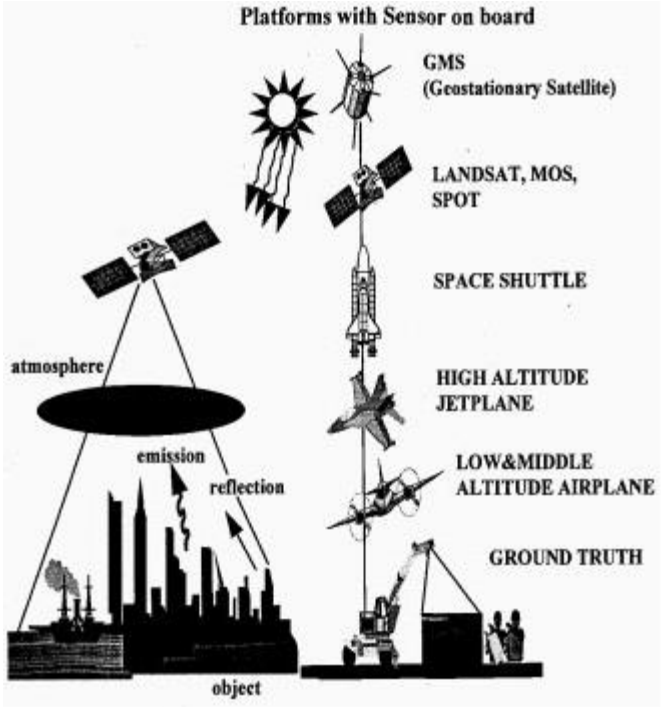

Yield frequency map
Yield of winter wheat, cultivar Ebi
a)
b)
Yield$_f$ (%)
160.05
43.57
Yield 2005
(t.ha^{-1})
9.93
2.08
N
0
50
100 m
c)
d)
Yield 2011
(t.ha^{-1})
13.46
0.59
Yield 2017
(t.ha^{-1})
9.96
0.35
Yield of winter wheat, cultivar Baletka
Yield of spring wheat – two cultivars
- Seance in the upper part
- Astrid in the lower part

3. Remote Sensing

- Satellite images, airborne images (or UAV), handheld sensors (GreenSeeker…), sensors on machines (on the go - Yara N-Sensor…)
- Free data (Landsat, Sentinel)
- Commercial data (QuickBird, WorldView, SPOT, …)
- Image processing (geometric, atmospheric correction), „big data“ – mosaicking
- Spectral indices (usability, purposes)
- Spatial, spectral, temporal resolution

Platform – Sensor Combination





EMR detectors according to their data acquisition characteristics:

Active vs passive

- Radar
- X-ray
- Sonar
- Lidar

Optical/electronic vs optical/photo-chemical
(digital) (analog)

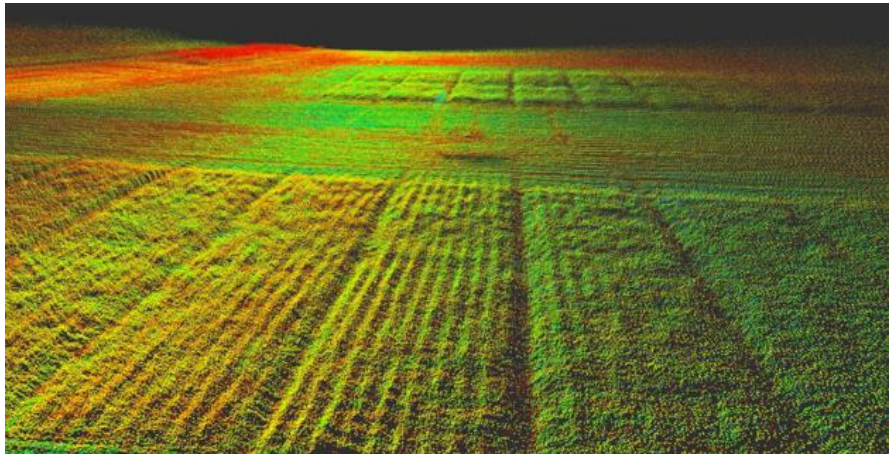
- Multispectral scanner, Hyperspectral scanner
- radiometer

Continnous vs intermittent

- Strip camera

- Multispectral vs single

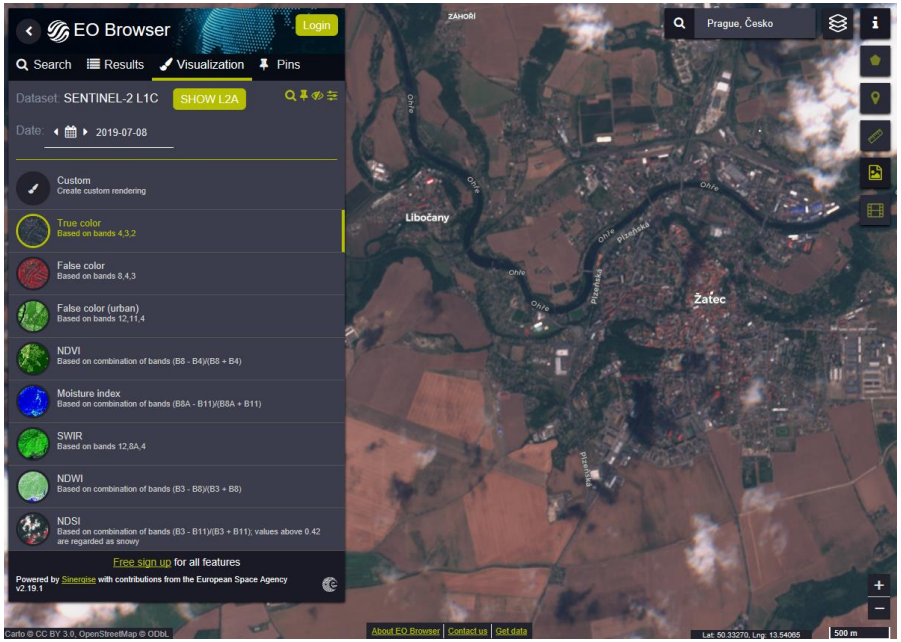
- camera array
- multi-lens system



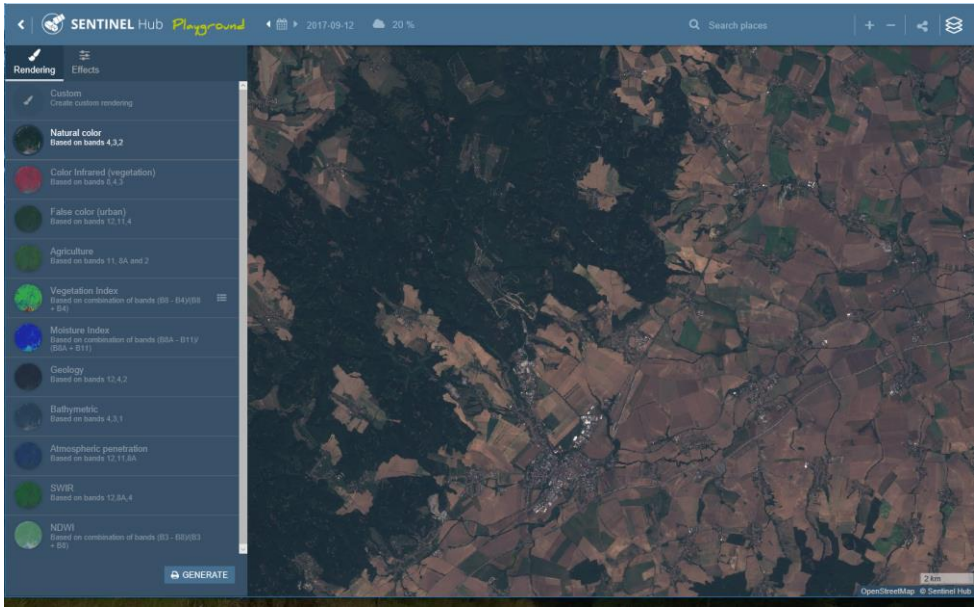
Data access - Quick look

EO Browser

https://apps.sentinel-hub.com/eo-browser/



Sentinel Playground

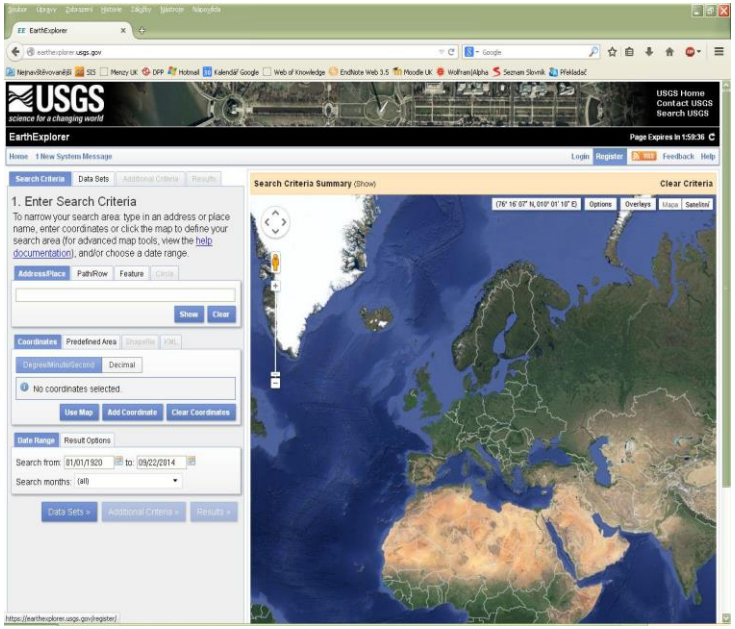


http://apps.sentinel-hub.com/sentinel-playground/

Free sources

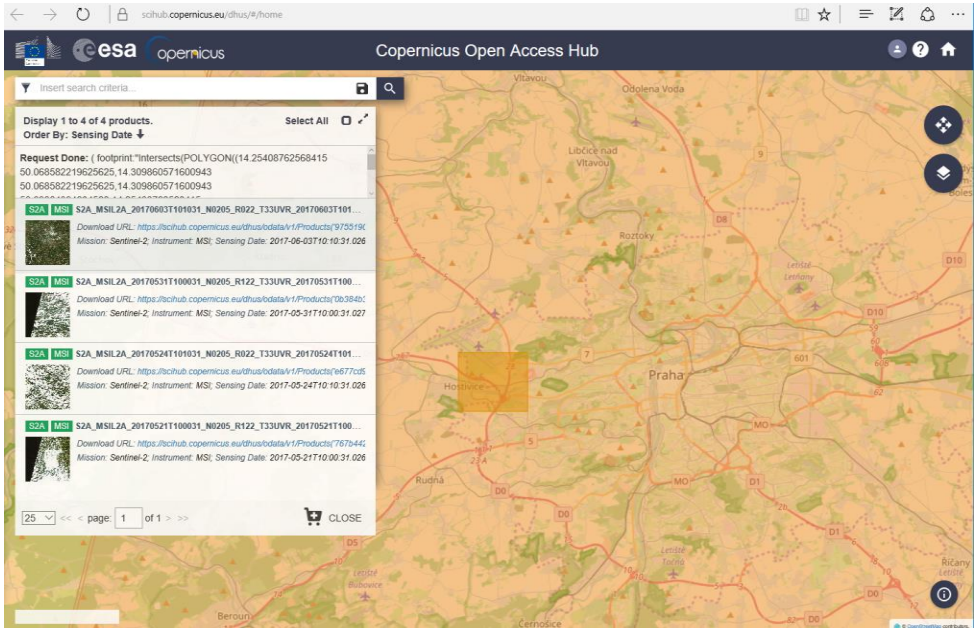
USGS – Earth Explorer

http://earthexplorer.usgs.gov



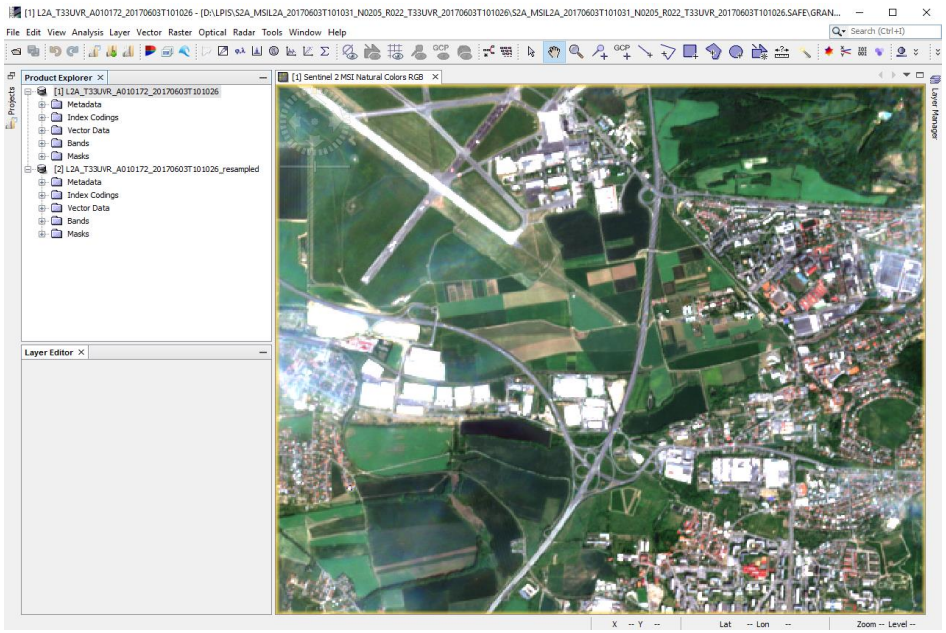
Copernicus Open Access Hub

https://scihub.copernicus.eu/dhus/#/home



Know How – Free vs. comercial SWs for data processing

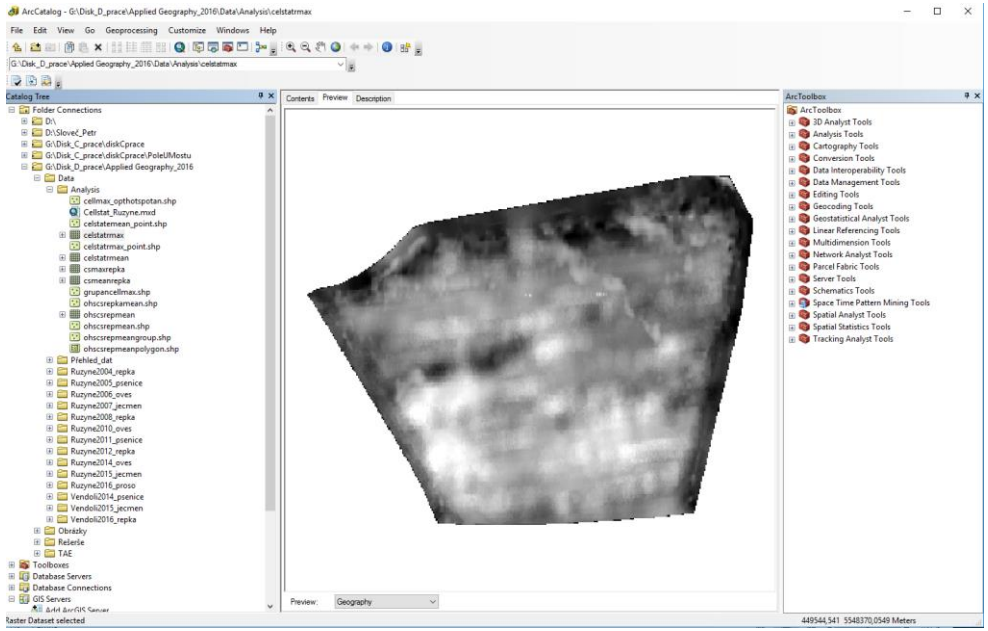
- **SW SNAP (ESA)**
- **Comercial SW (ENVI, Idrisi, Agisoft Metashape, Pix4Dmapper…)**



- Sentinel 2 and Landsat images processing
- Basic editing tool for vector data
- Data conversion to GIS SW formats

Data processing in GIS SW

- **SW ArcGIS (ESRI)**
- **SW QGIS (open source)**

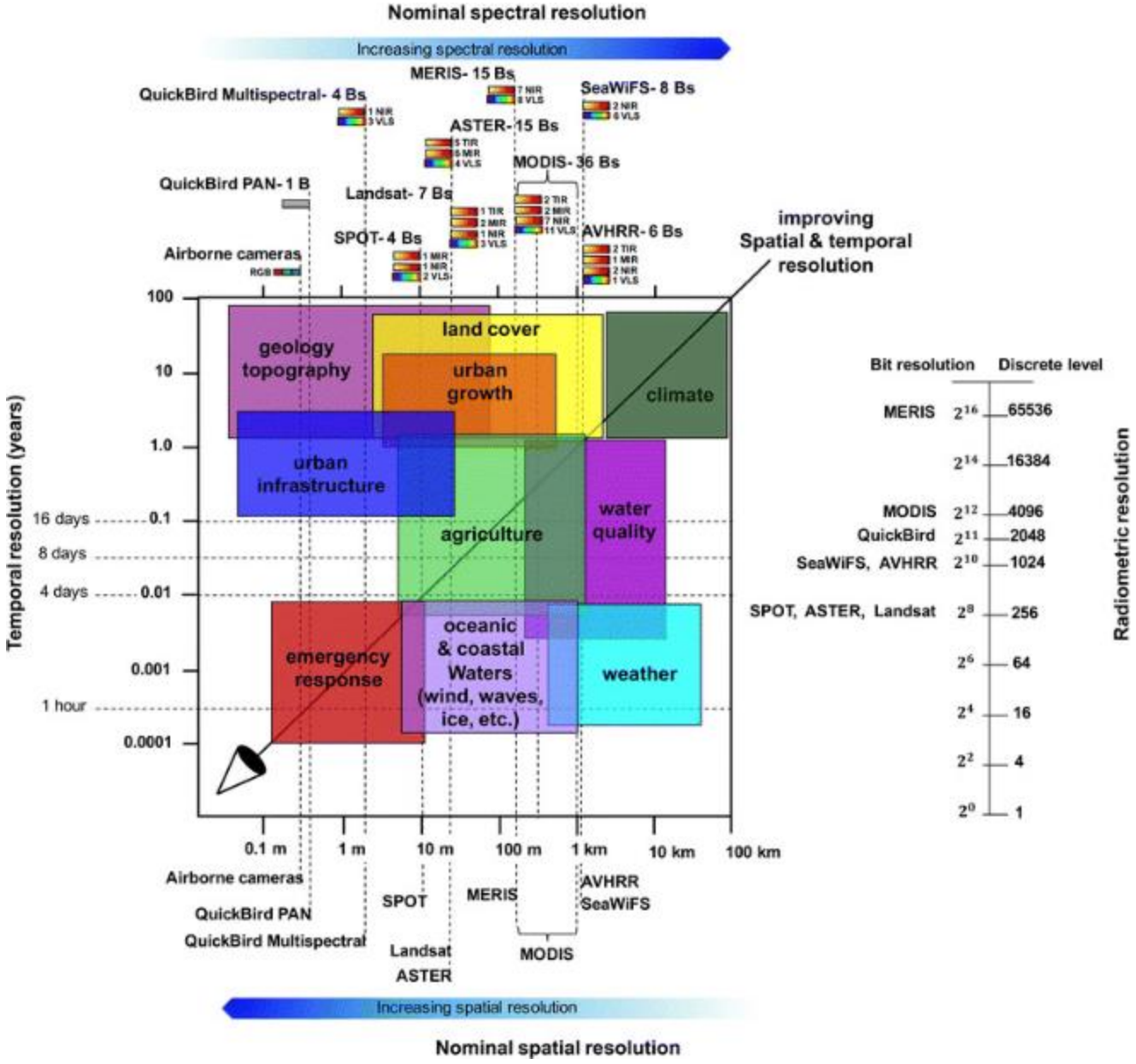


- Raster and vector data processing
- Data visualisation
- Yield maps deriving
- Vector data editing – boundaries, application maps…

Properties of images (raster data)

The quality of remote sensing data consists of its resolution:

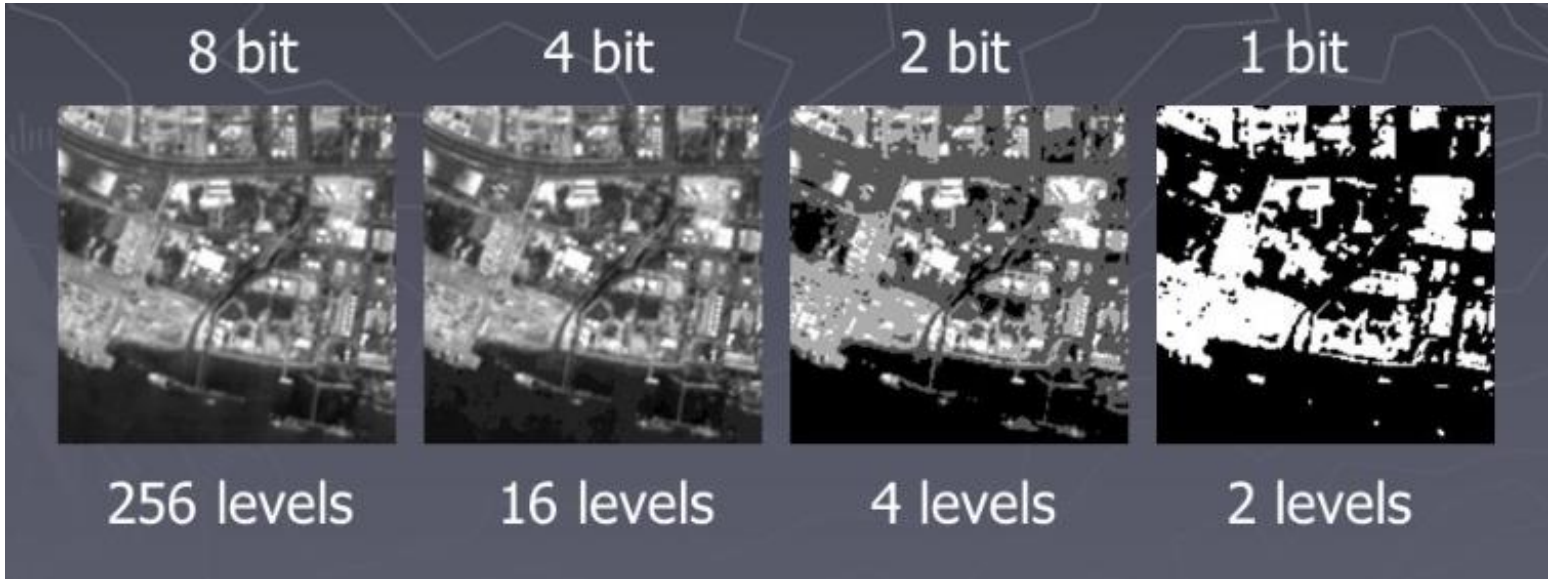
1. **Radiometric resolution**
2. **Spectral resolution**
3. **Spatial resolution**
4. **Temporal resolution**


Nominal spectral resolution
Increasing spectral resolution
MERIS- 15 Bs
QuickBird Multispectral- 4 Bs
SeaWiFS- 8 Bs
ASTER- 15 Bs
MODIS- 36 Bs
QuickBird PAN- 1 B
Landsat- 7 Bs
AVHRR- 6 Bs
SPOT- 4 Bs
Airborne cameras
improving
Spatial & temporal
resolution
geology
topography
land cover
urban
growth
climate
urban
infrastructure
water
quality
agriculture
emergency
response
oceanic
& coastal
Waters
(wind, waves,
ice, etc.)
weather
Temporal resolution (years)
100
10
1.0
0.1
0.01
0.001
0.0001
16 days
8 days
4 days
1 hour
0.1 m
1 m
10 m
100 m
1 km
10 km
100 km
Airborne cameras
QuickBird PAN
QuickBird Multispectral
SPOT
Landsat
ASTER
MERIS
MODIS
AVHRR
SeaWiFS
Increasing spatial resolution
Nominal spatial resolution
Bit resolution
Discrete level
MERIS
MODIS
QuickBird
SeaWiFS, AVHRR
SPOT, ASTER, Landsat
Radiometric resolution

Radiometric resolution

- Is a measure of the sensor´s ability to distinguish between two objects of similar reflectance.
- It can be thought of as defining the sensitivity of a sensor to fine or subtle differences in captured EMR.
- Is given by the number of „just discriminable“ signal levels. For digital imagery, it is indicated by the bit-range.

Radiometric resolution



Indicates number of levels in which the image is recorded.

Spectral resolution

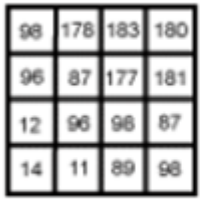
- Is a measure of the specific wavelength intervals that a sensor can record.
- For digital imagery, it corresponds to the number of spectral bands and the range of sensitivity within each band.
- Spectral resolution affects separability and identifiability of the targets.

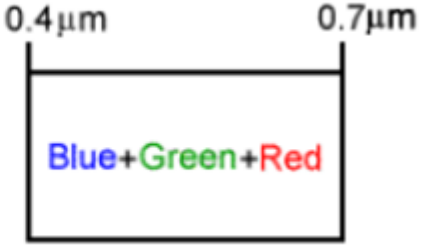
Spectral resolution

- **The number of images created in MS mode**
- **The width of the interval of recorded wavelength**

Panchromatic image

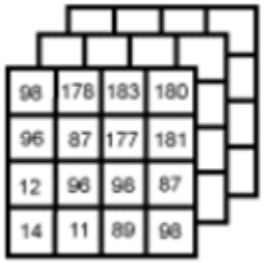
Visible spectrum

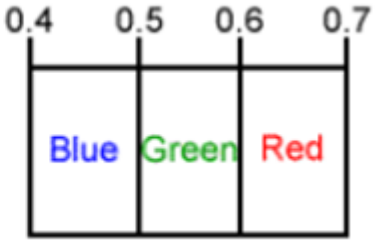




Multispectral image

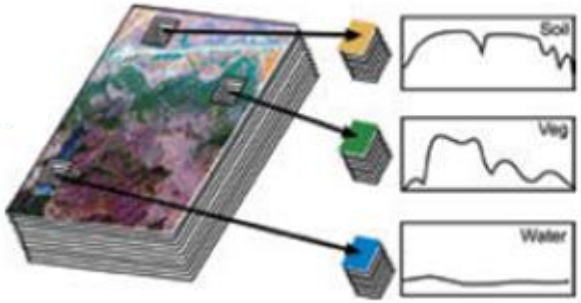
e.g. Landsat TM better spectral res.(7 bands) thanSPOT (3 bands)

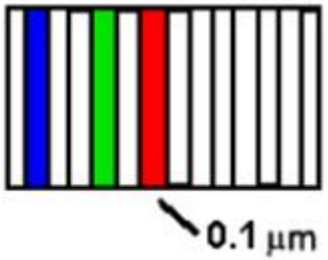




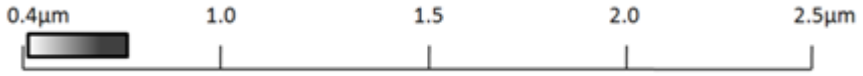
Hyperspektrální snímky

Narrow bands



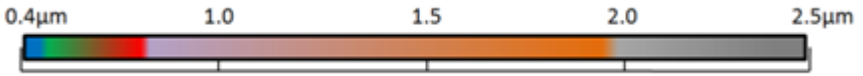


Panchromatic image

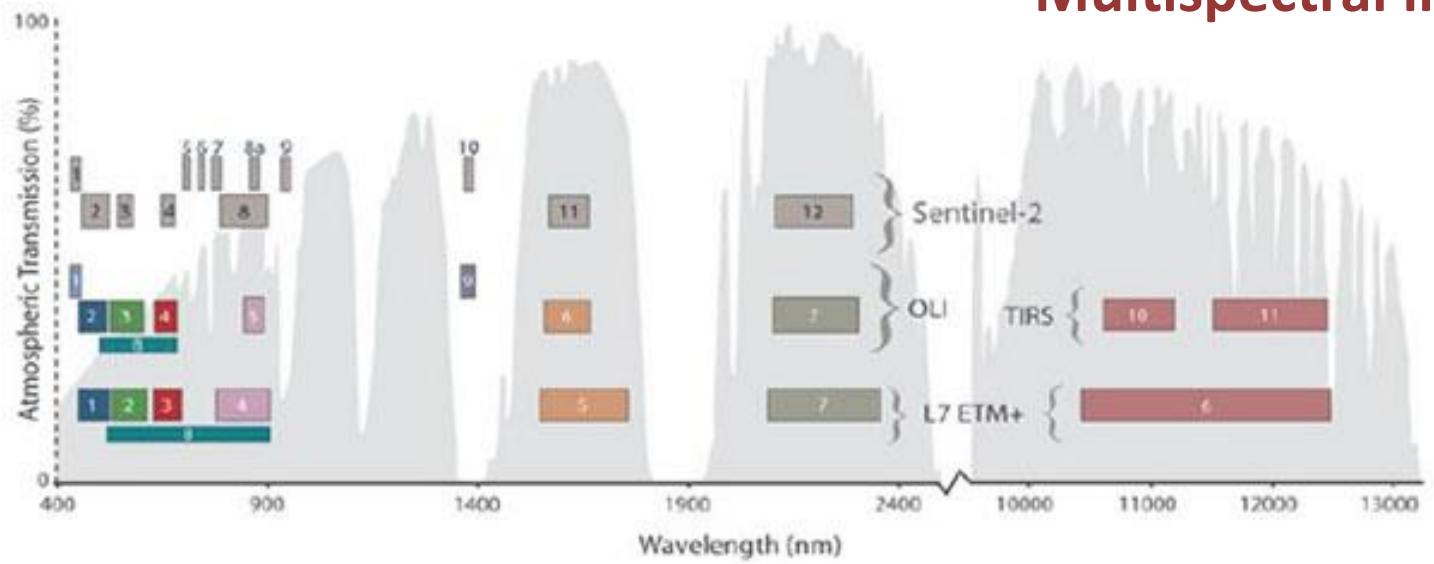


Multispectral image

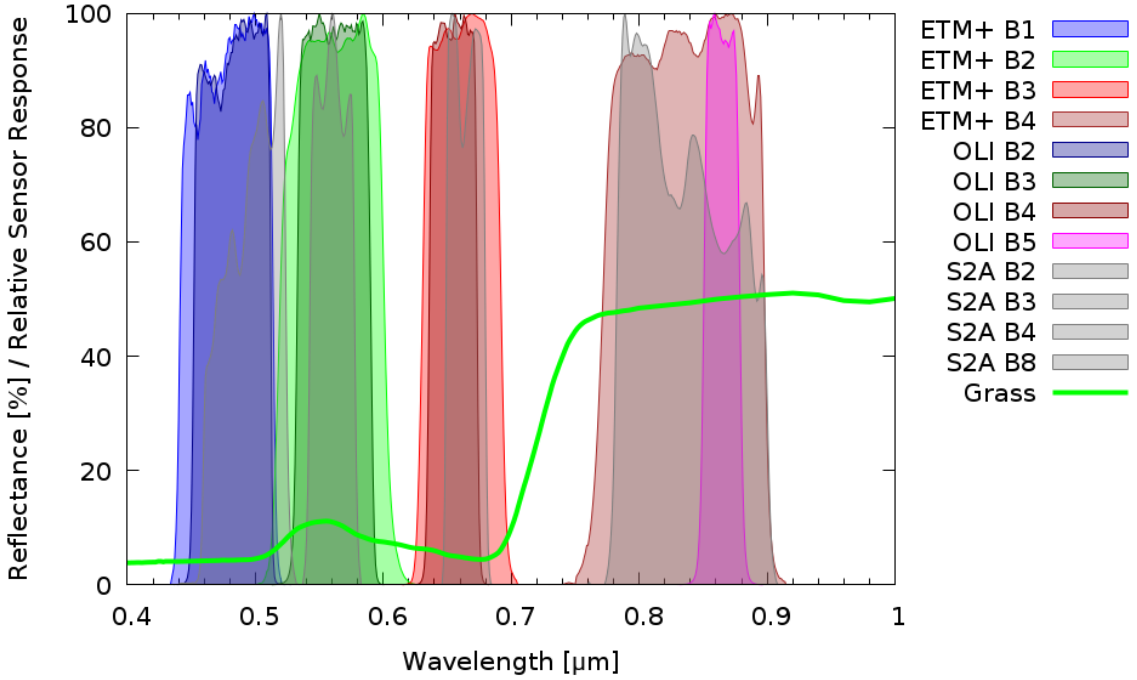
Hyperspectral image



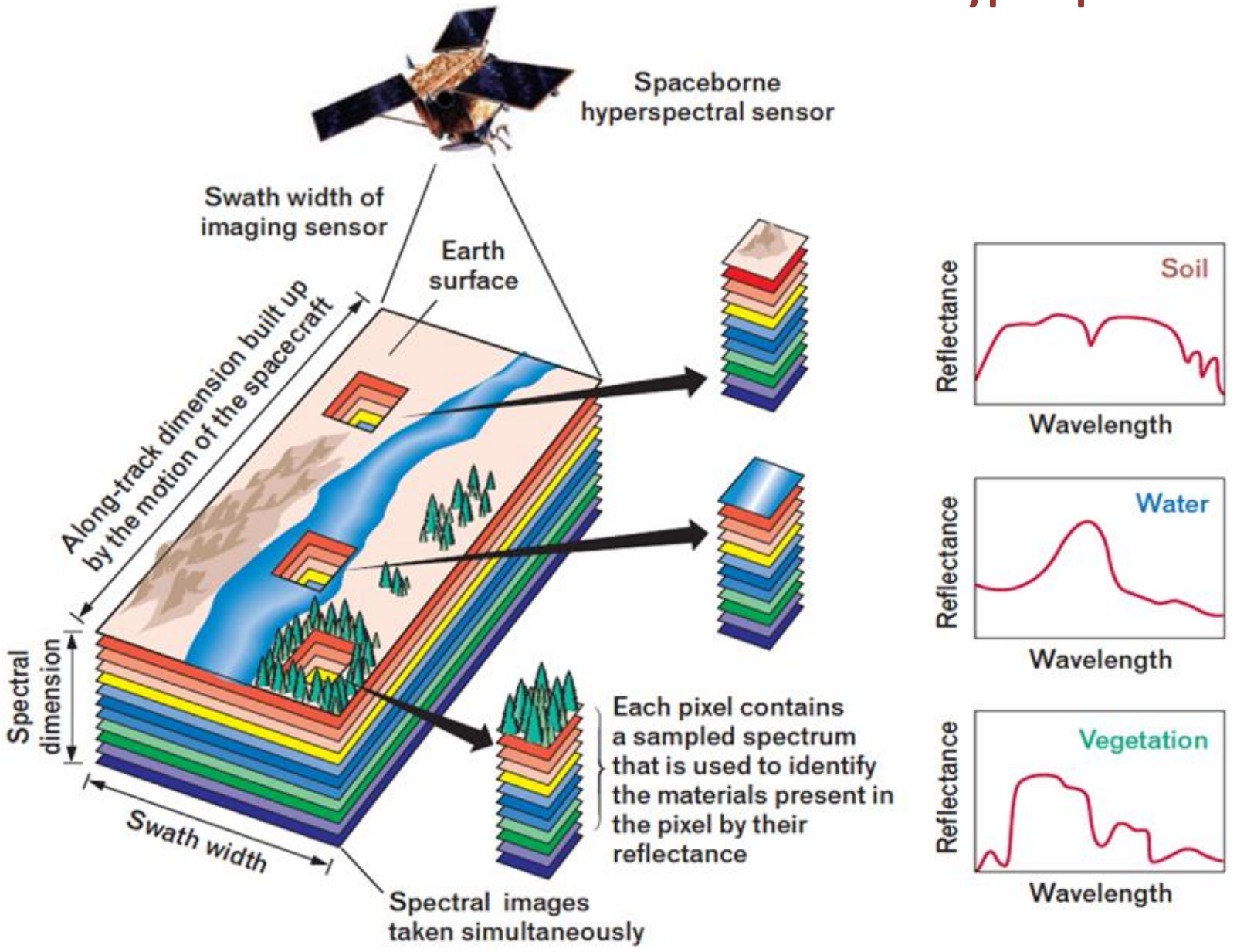
Multispectral image



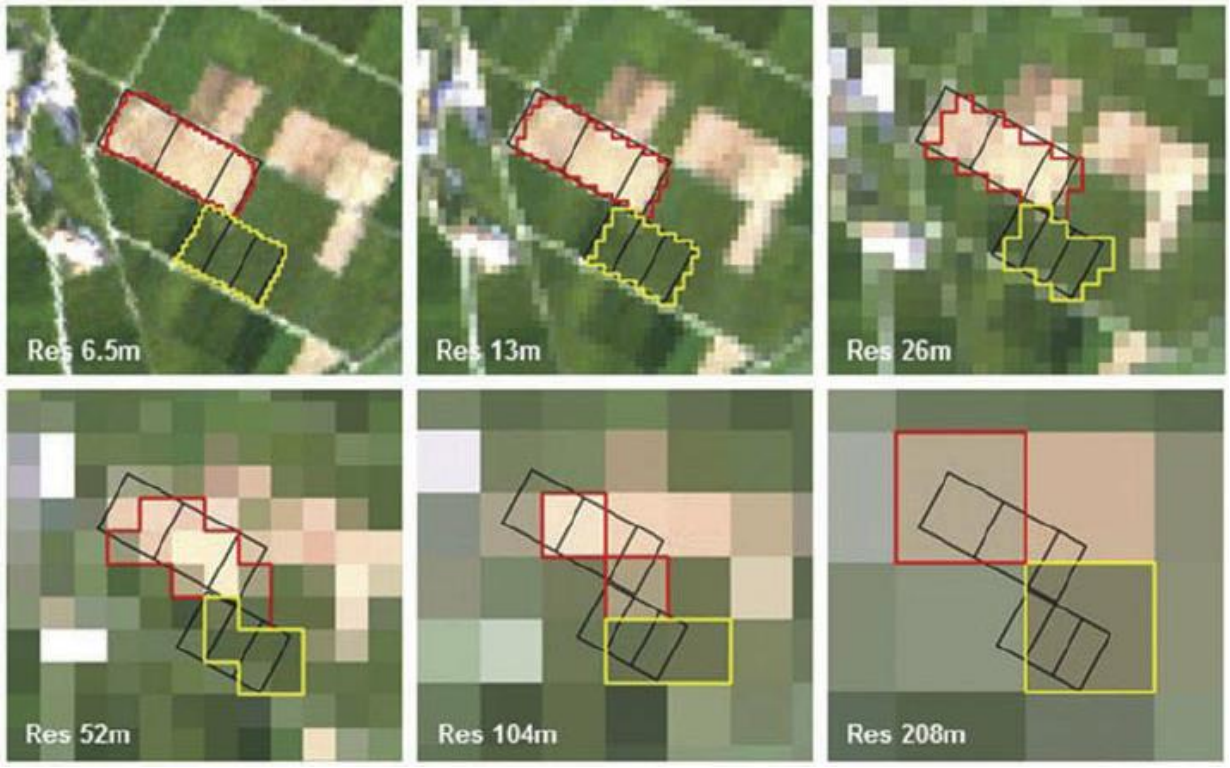
ETM+, OLI, Sentinel 2A relative spectral response / spectral signature of grass



Hyperspectral image



Spatial resolution

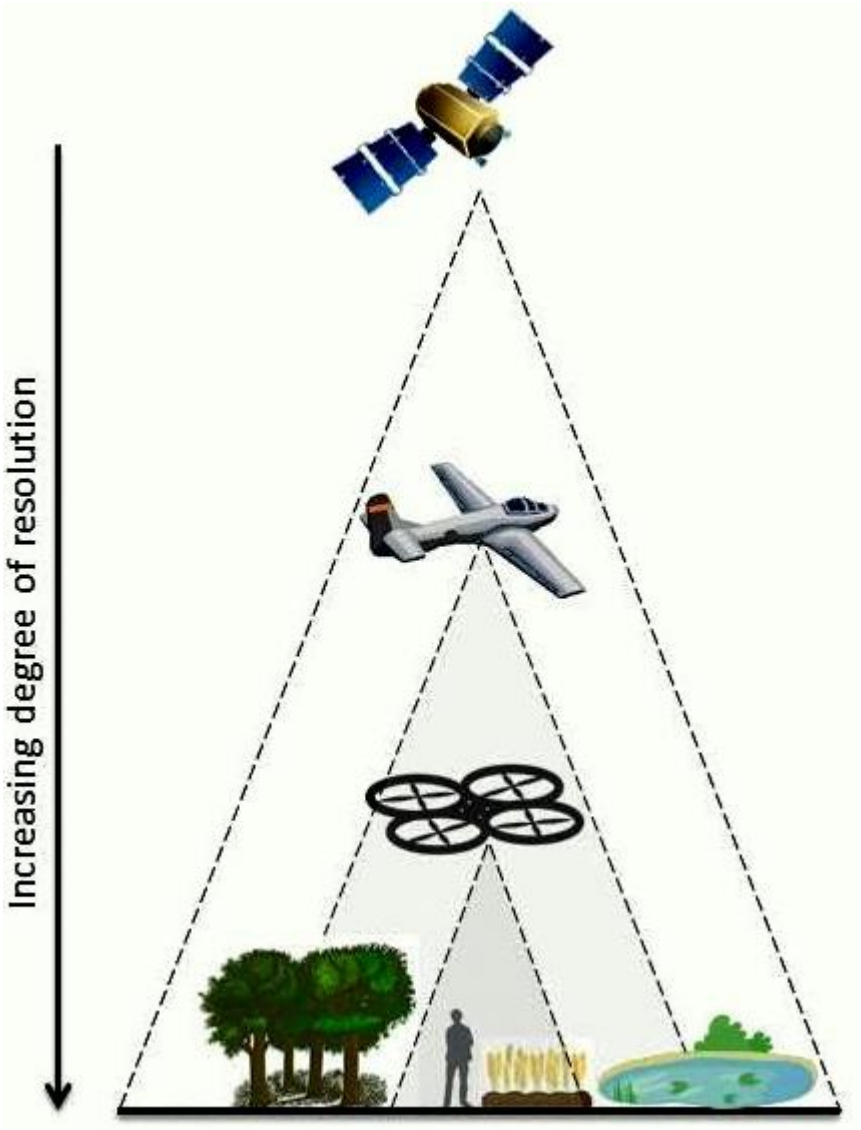


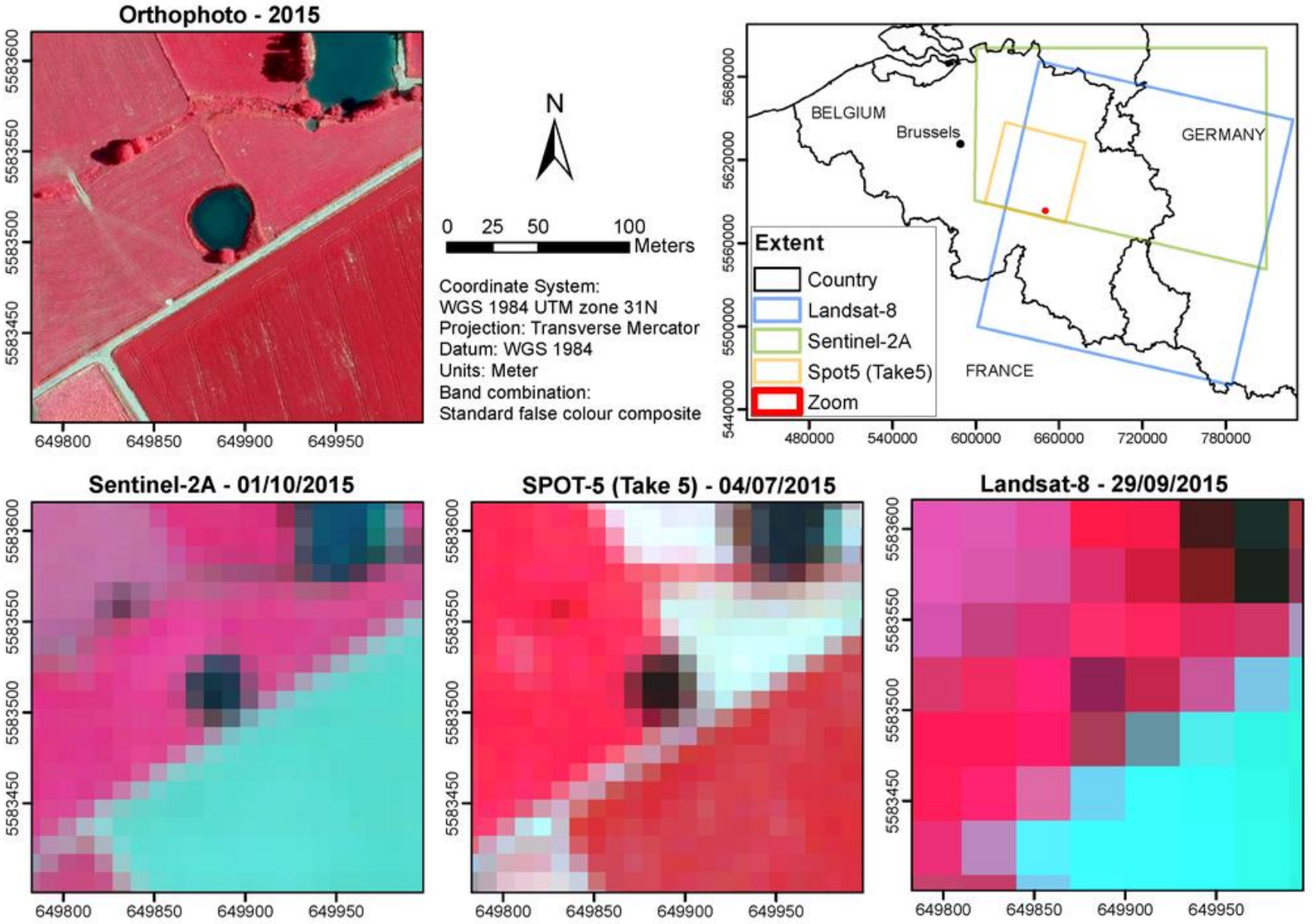
The size of a pixel that is recorded in a raster image.

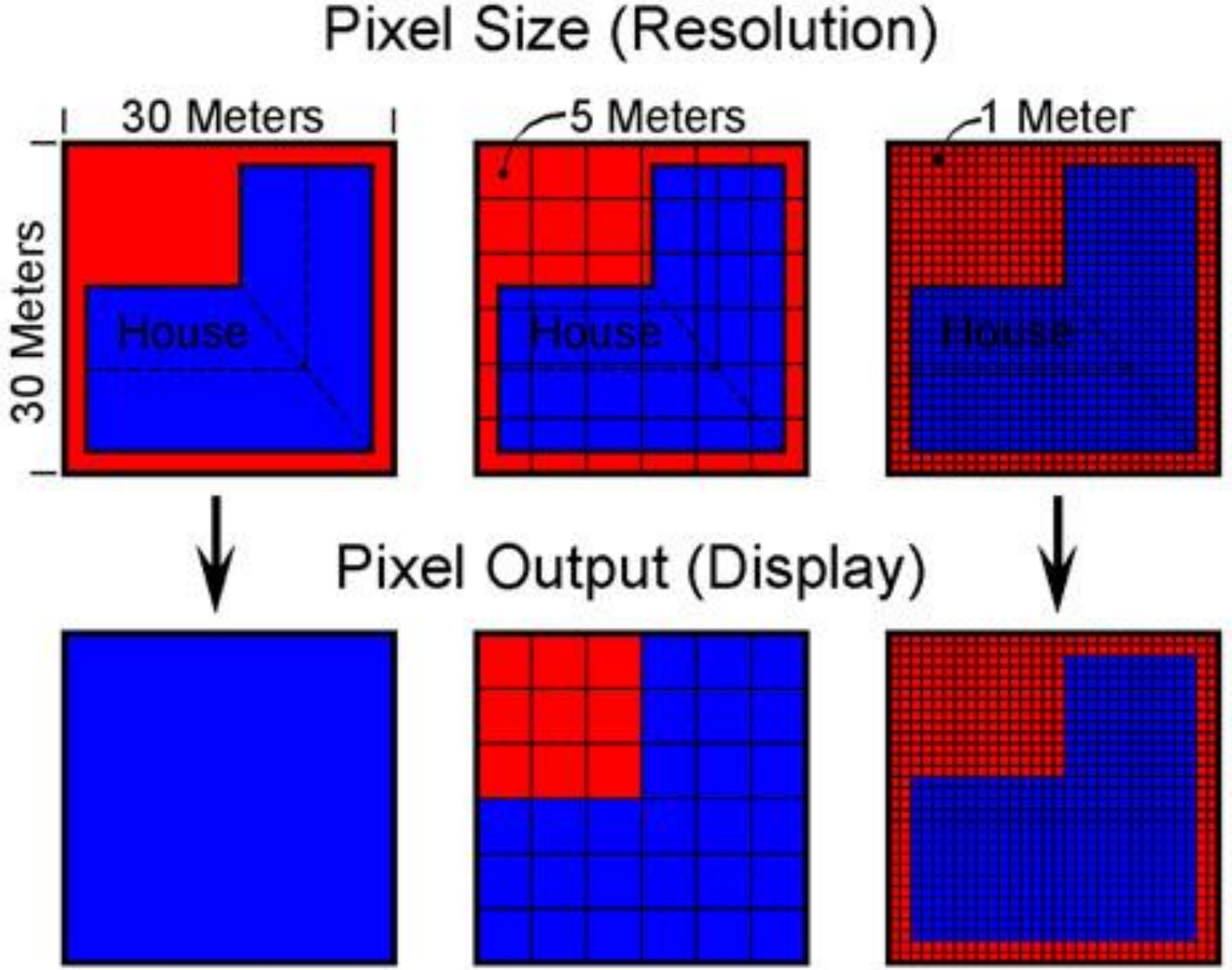
Examples:

Satellite	Pixel
METEOSAT 7	2,5-5 km
NOAA 17	1,1 km
QuickBird 2	0,65 m
LANDSAT 8	30 (15) m
SPOT 5	2,5 (10) m
Sentinel 2	10/20/60m

Platform – Sensor Combination

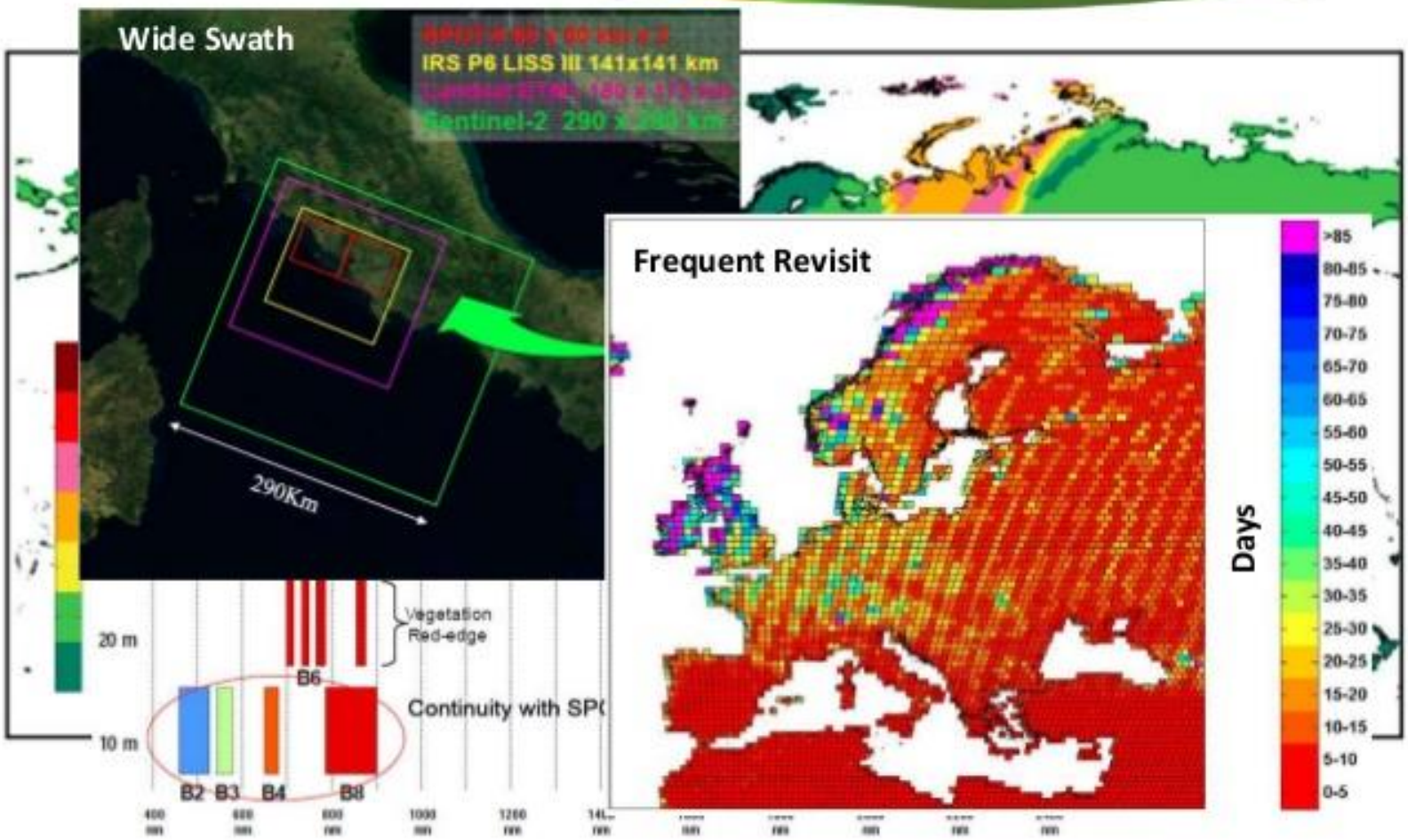



Orthophoto - 2015
5583600
5583550
5583500
5583450
649800
649850
649900
649950
N
0 25 50 100
Meters
Coordinate System:
WGS 1984 UTM zone 31N
Projection: Transverse Mercator
Datum: WGS 1984
Units: Meter
Band combination:
Standard false colour composite
BELGIUM
Brussels
GERMANY
FRANCE
Extent
Country
Landsat-8
Sentinel-2A
Spot5 (Take5)
Zoom
5680000
5620000
5560000
5500000
5440000
480000
540000
600000
660000
720000
780000
Sentinel-2A - 01/10/2015
SPOT-5 (Take 5) - 04/07/2015
Landsat-8 - 29/09/2015


Pixel Size (Resolution)
30 Meters
30 Meters
House
5 Meters
House
1 Meter
House
Pixel Output (Display)

Large Scale Assessment: Sentinel 2

@ 10/20/60-m spatial resolution



Source: ESA/ESTEC

Band	Band	Central wavelength (nm)	Bandwith (nm)	Spatial resolution (m)	Objective
B1	VNIR	443	20	60	Aerosol Correction
B2		490	65	10	Aerosol Correction, Land Measurement Band
B3		560	35	10	Land Measurement Band
B4		665	30	10	Land Measurement Band
B5		705	15	20	Land Measurement Band
B6		740	15	20	Land Measurement Band
B7		783	20	20	Land Measurement Band
B8		842	115	10	Water Vapor Correction, Land Measurement Band
B8a		865	20	20	Water Vapor Correction, Land Measurement Band
B9		945	20	60	Water Vapor Correction
B10	SWIR	1380	20	60	Cirrus Detection
B11		1610	90	20	Land Measurement Band
B12		2190	180	20	Aerosol Correction, Land Measurement Band

Sentinel 2

Temporal resolution

- Is a measure of how often an area on the earth´s surface is visited by the sensor.
- In other word, it describes the periodicity (respective character) of the sensor´s data acquisition capabilities over a fixed target.
- It is represented in terms of the amount of time (e.g. In hours, days, etc.) between sensor visits to the same area.

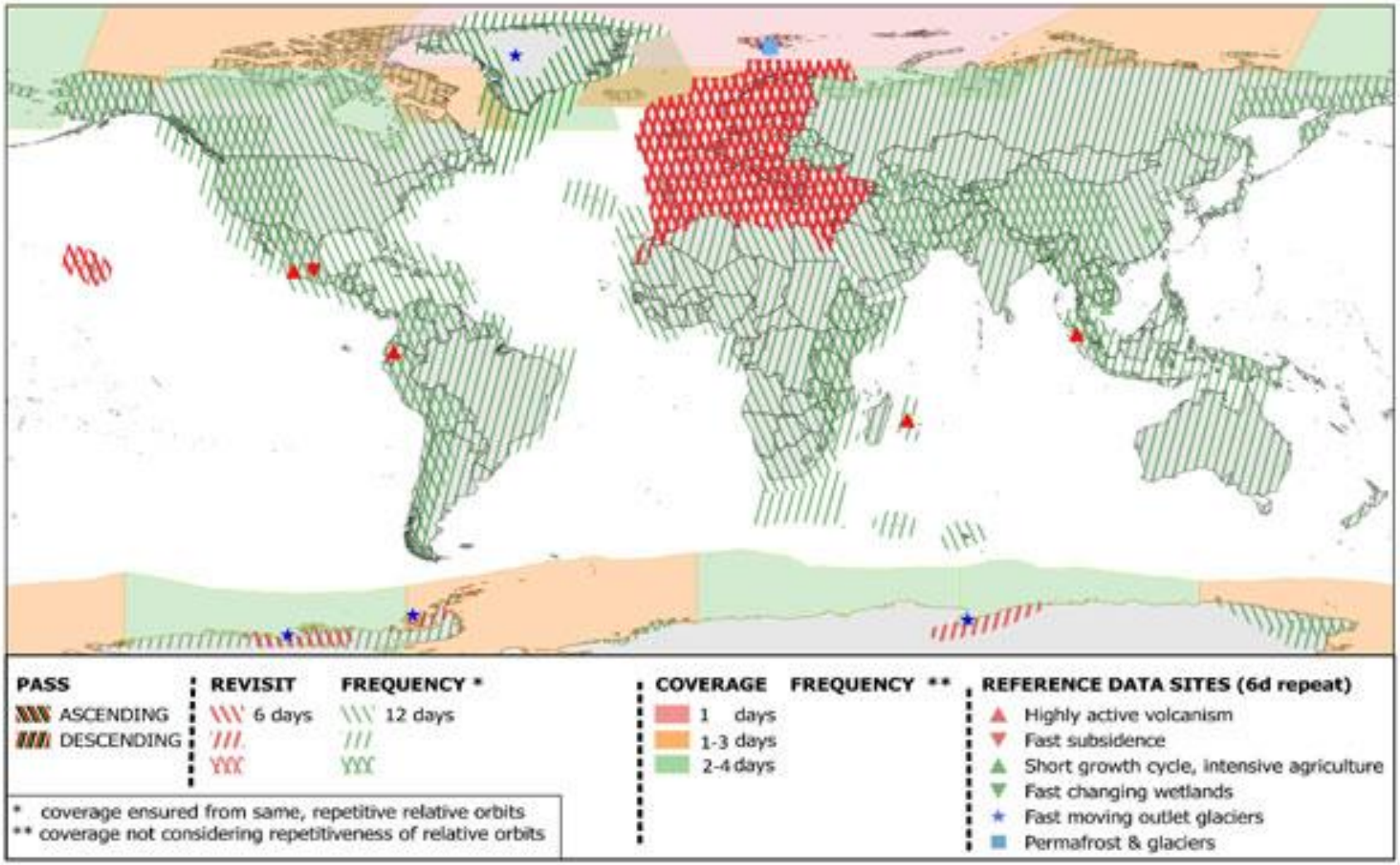
Temporal resolution– the frequency with which the system produces images of the same area :

Satellite	Temp.res.	Width of scene	Pixel
METEOSAT 7	30 minutes	polokoule	2,5-5 km
NOAA 17	12 hours	2600 km	1,1 km
QuickBird 2	2 – 4 days	11 km	0,65 m
LANDSAT 7	16 days	185 km	30 (15) m
SPOT 5	26 days	60 km	2,5 (10) m
Sentinel 2	5 days	270 km	10/20/60 m

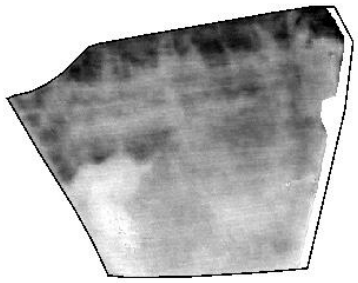
Sentinel-1 Constellation Observation Scenario: Revisit & Coverage Frequency

sentinel-1

validity start: 05/2017



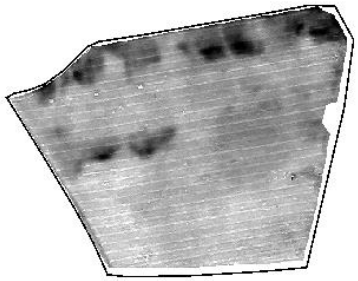
Satellite images – last image from vegetation season vs. yield data



NDVI QB, 22.5.2007 (BBCH 59)
winter barley

High : 0.79

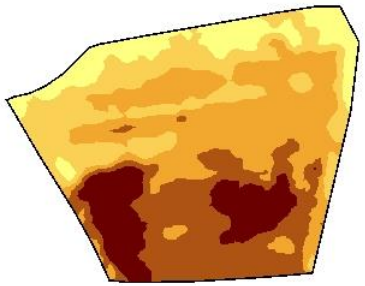
Low : 0.47



NDVI Landsat 5, 31.5.2011 (BBCH 62)
winter wheat

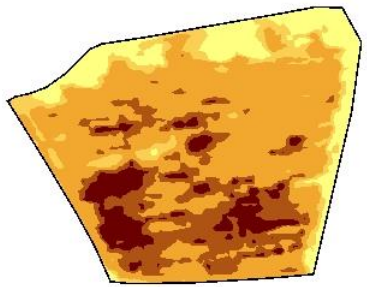
High : 0.85

Low : 0.55



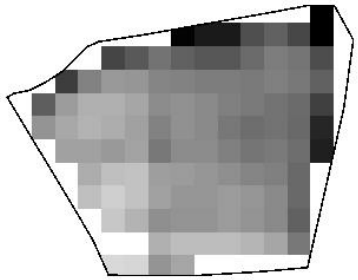
Yield 2007 (t/ha), winter barley

1.1 4 5 6 7 10.1



Yield 2011 (t/ha), winter wheat

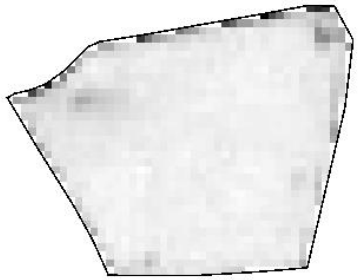
0.5 5 6 8 9 13.5



NDVI Landsat 8, 28.6.2014 (BBCH 82)
oats

High : 0.96

Low : 0.53



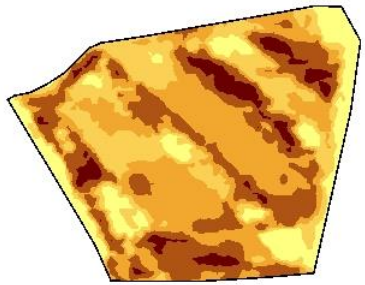
NDVI Sentinel 2, 18.7.2016 (BBCH 84)
millet

High : 0.91

Low : 0.70

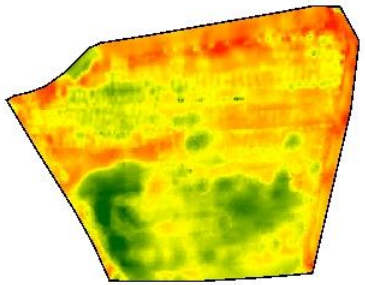
N

0 50 100 m



Yield 2014 (t/ha), winter wheat

0.1 3 4 5 7 8.9



Yield frequency map for cereals (%)

High : 160.05

Low : 43.57

N

0 50 100 m

Unmanned Aerial Vehicles (UAV) DATA and THEIR APPLICATION

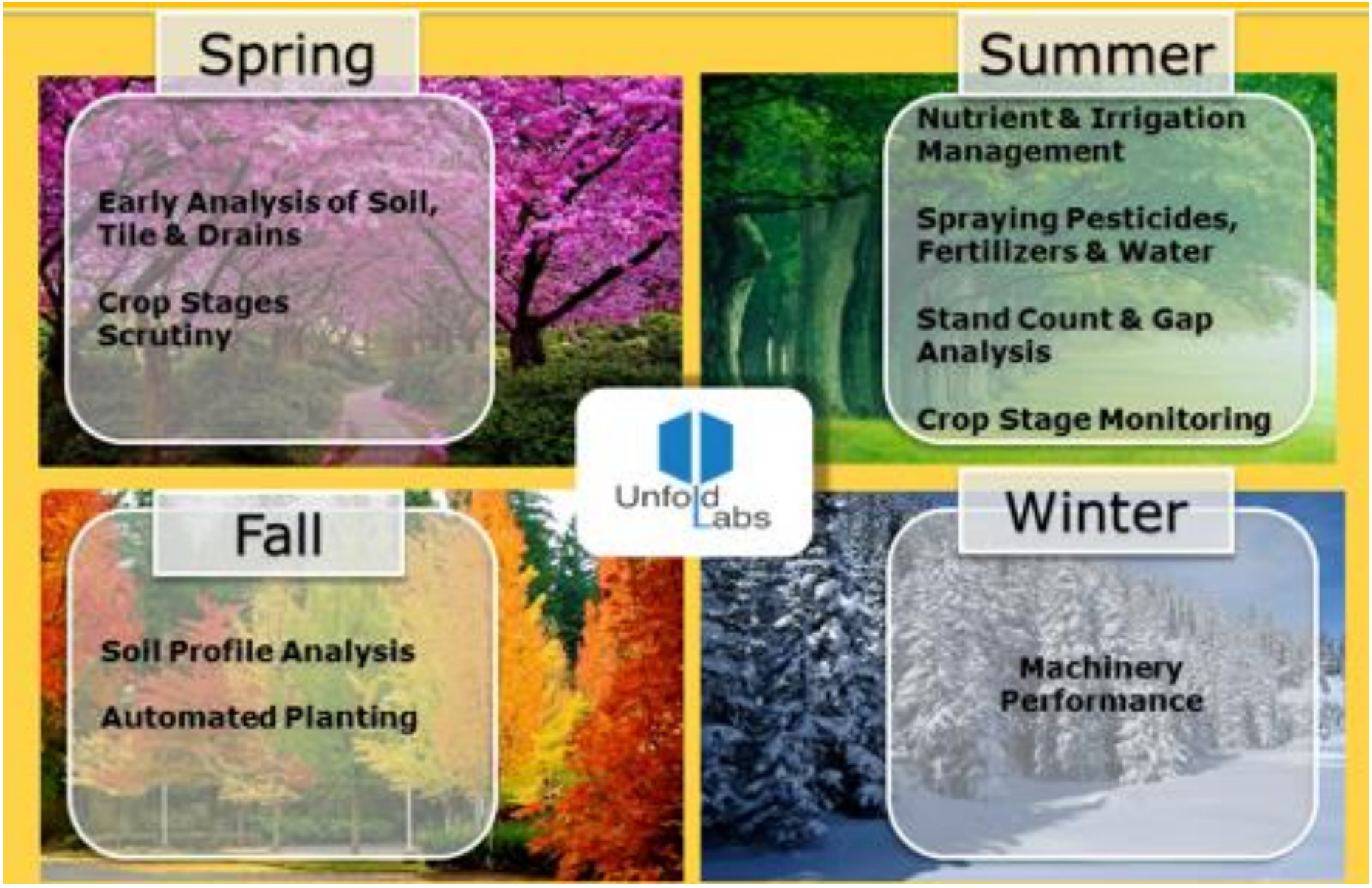
Definition:

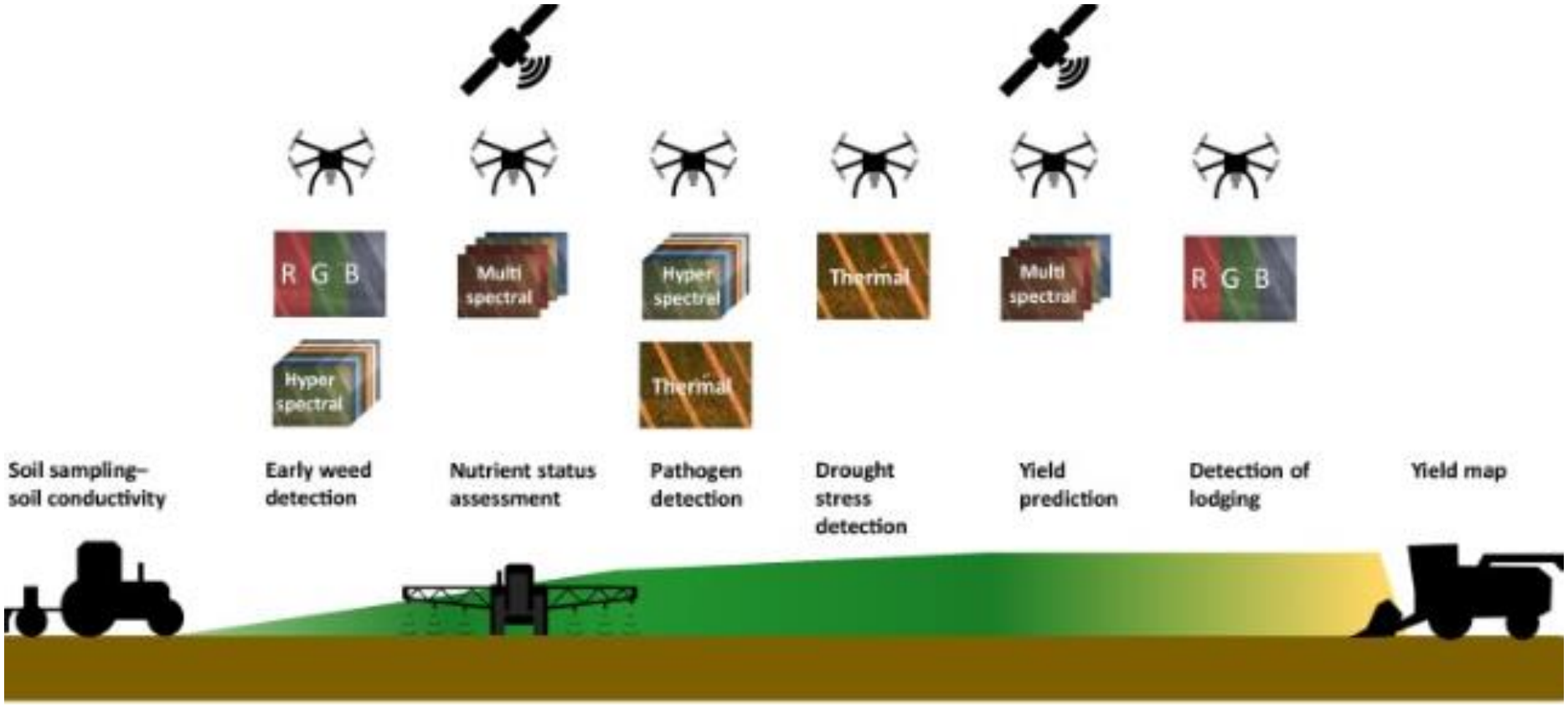
A UAV is an aircraft which can flight without a human pilot and controlled by the radio channel.
Multi rotors are the one type of UAVs, further which are classified into number of rotors in their platform.

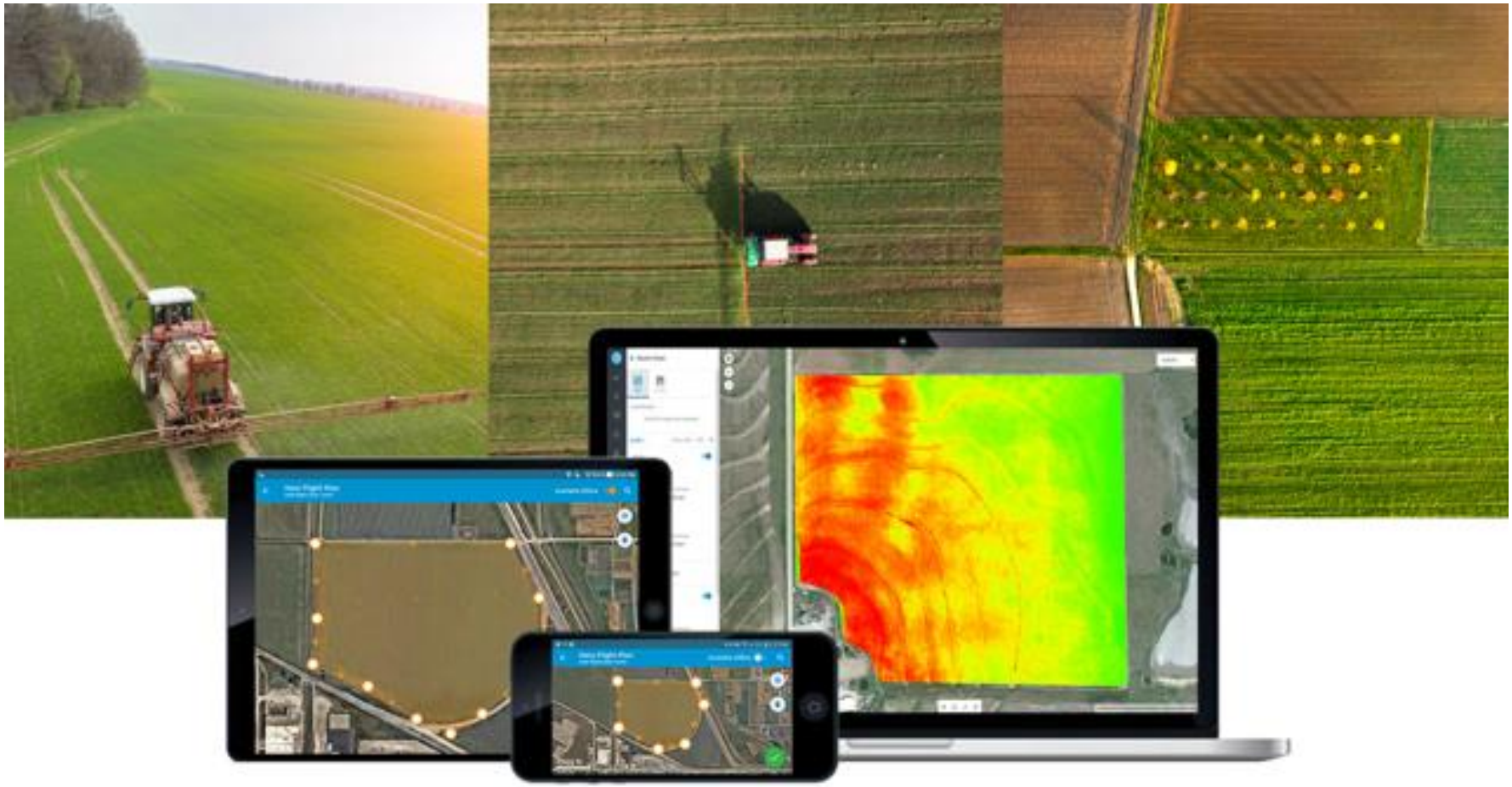
Different types of UAV models are (according to Mogili and Deepak, 2018):

- **Fixed wing** - are entirely different in their design compare to multi rotors and aerodynamic shape of two wings are gives an easy glide of UAV.
- **Single rotor helicopter** - is a model has just one big sized rotor on top and one small sized on the tail of the UAV.
- **Quad copter**
- **Hexa copter**
- **Octo copters** - are multi-rotors that is lifted and propelled by four, six, eight rotors.


ParrotDiscoPro AG
RF70 UAV
3DR Aero-M 915
AgDrone UAS
Ag-wing
Trimble UX5
eBee
Phoenix 2
DT26X surveillance
E384 Mapping Drone
PrecisionHawk Lancaster
Xinhengjia
ProHawk® UAV
Xena Observer
Xena Thermo
Quad Indigo
AEE Tech AP10 Pro
DJI Phantom 4 PRO
DJI Agras
EZ|MANTA
JMR-V1000
AG-6A
AgStar X8
ZJ-6N-10L
DJI AGRAS MG-1 Pro
Hercules HL10
EnRoute Zion AC 1500
ROA Parkour 280
Polie UAV Drone UA-8 Series
US8-Mini Series
UAV UC6 Series
Skytech TK110HW
Yuneec H520 Hexacopter
Agr drone AK-61
Yamaha FAZER R G2
YM-6160
X810 Drone Crop Sprayer
Shenzhen Micromulticopter
iMK-8
Ace X88-J2
AG550

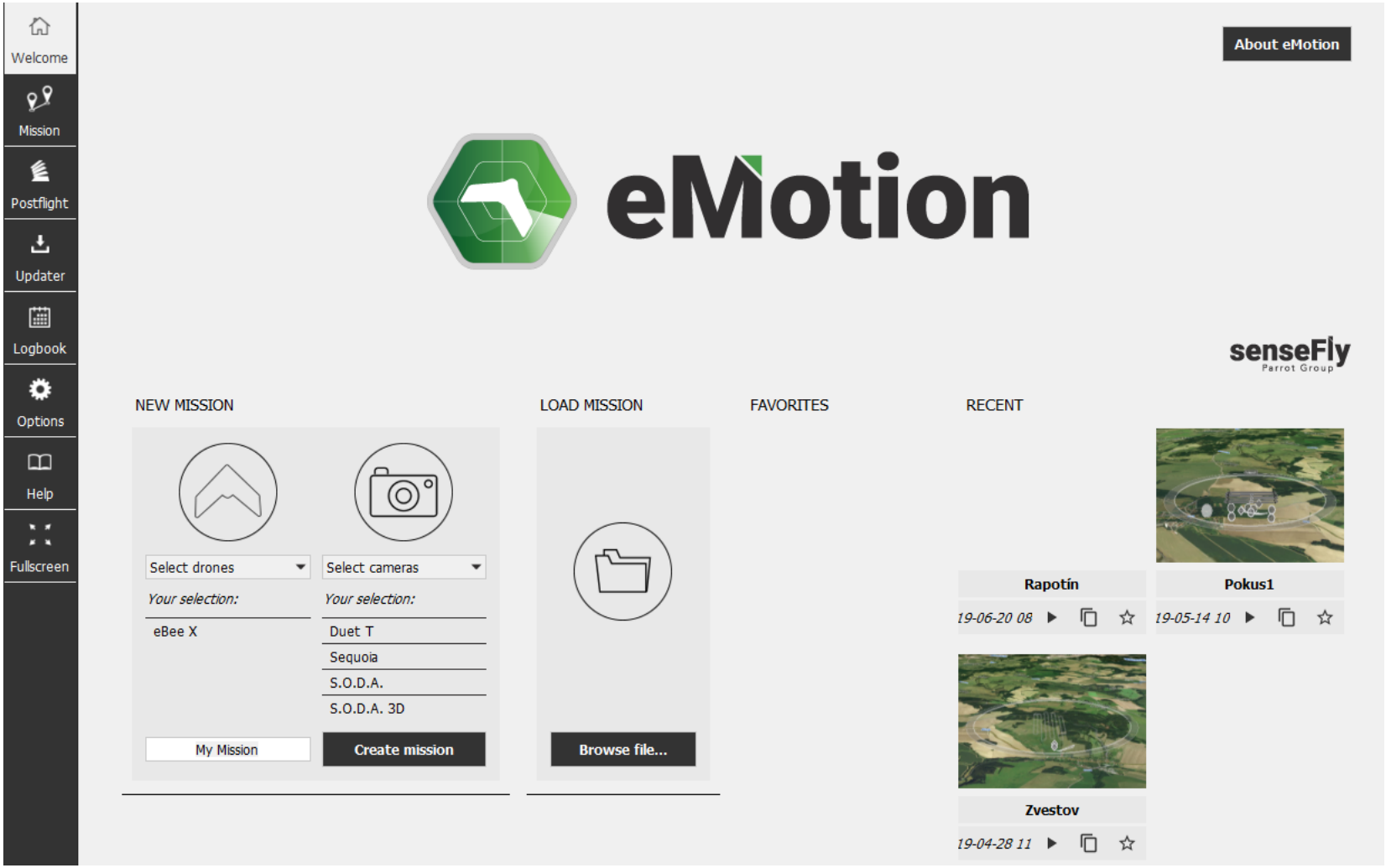

Spring
Early Analysis of Soil, Tile & Drains
Crop Stages Scrutiny
Summer
Nutrient & Irrigation Management
Spraying Pesticides, Fertilizers & Water
Stand Count & Gap Analysis
Crop Stage Monitoring
Unfold Labs
Fall
Soil Profile Analysis
Automated Planting
Winter
Machinery Performance


R G B
Hyper spectral
Multi spectral
Hyper spectral
Thermal
Thermal
Multi spectral
R G B
Soil sampling–
soil conductivity
Early weed
detection
Nutrient status
assessment
Pathogen
detection
Drought
stress
detection
Yield
prediction
Detection of
lodging
Yield map

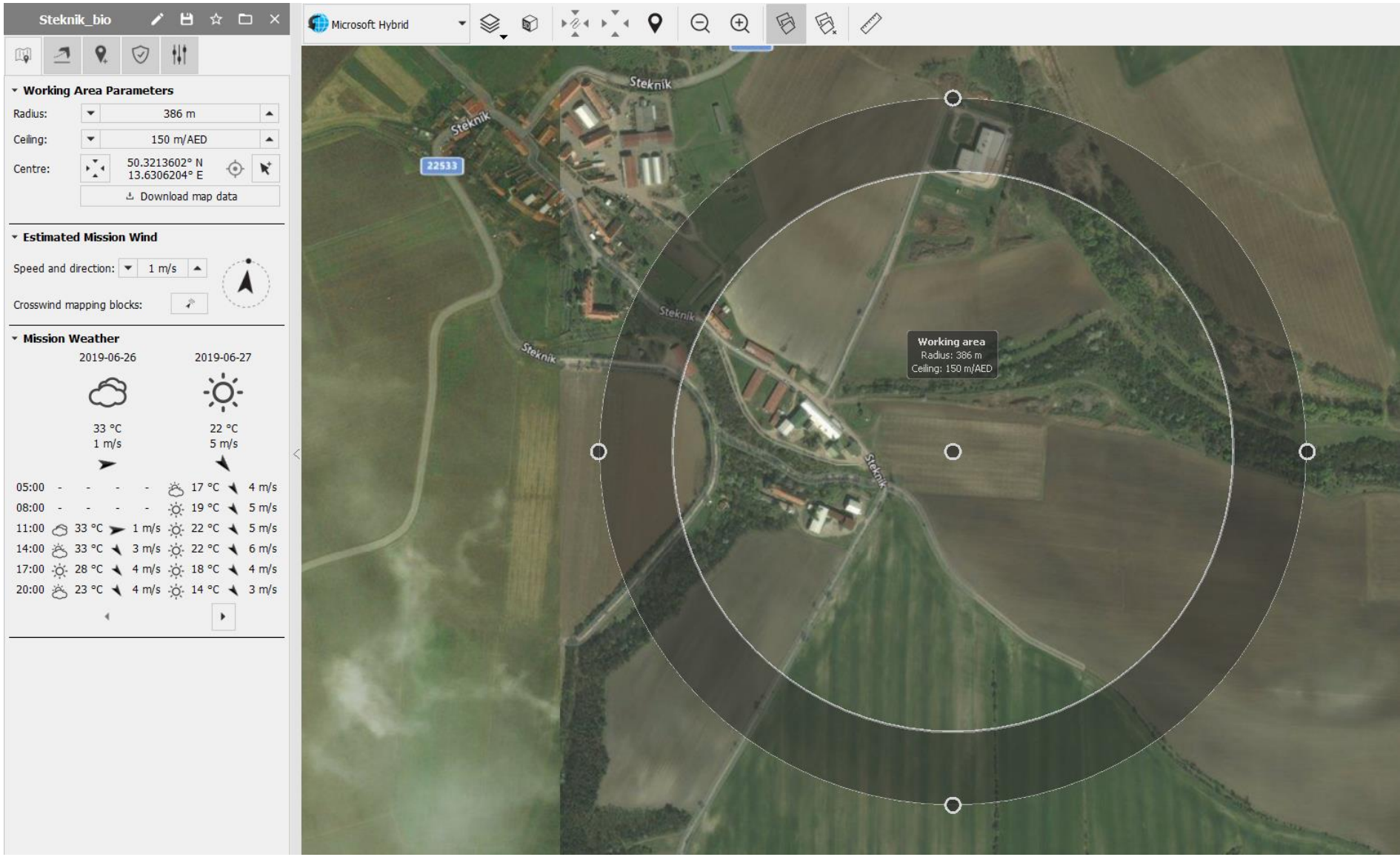


Set the parameters of UAV flight – many possibilities

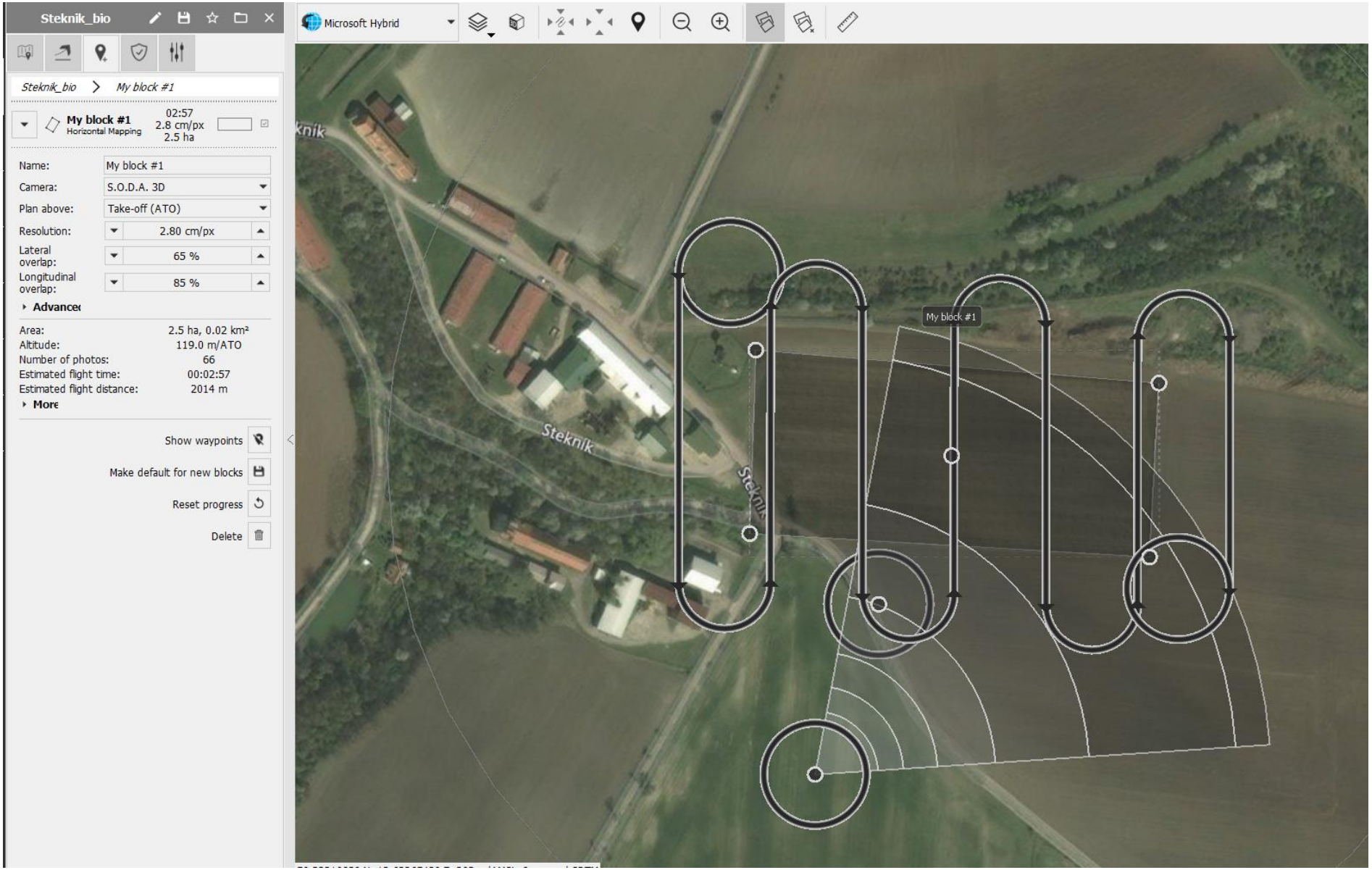
An example of set a mission in eMotion SW:



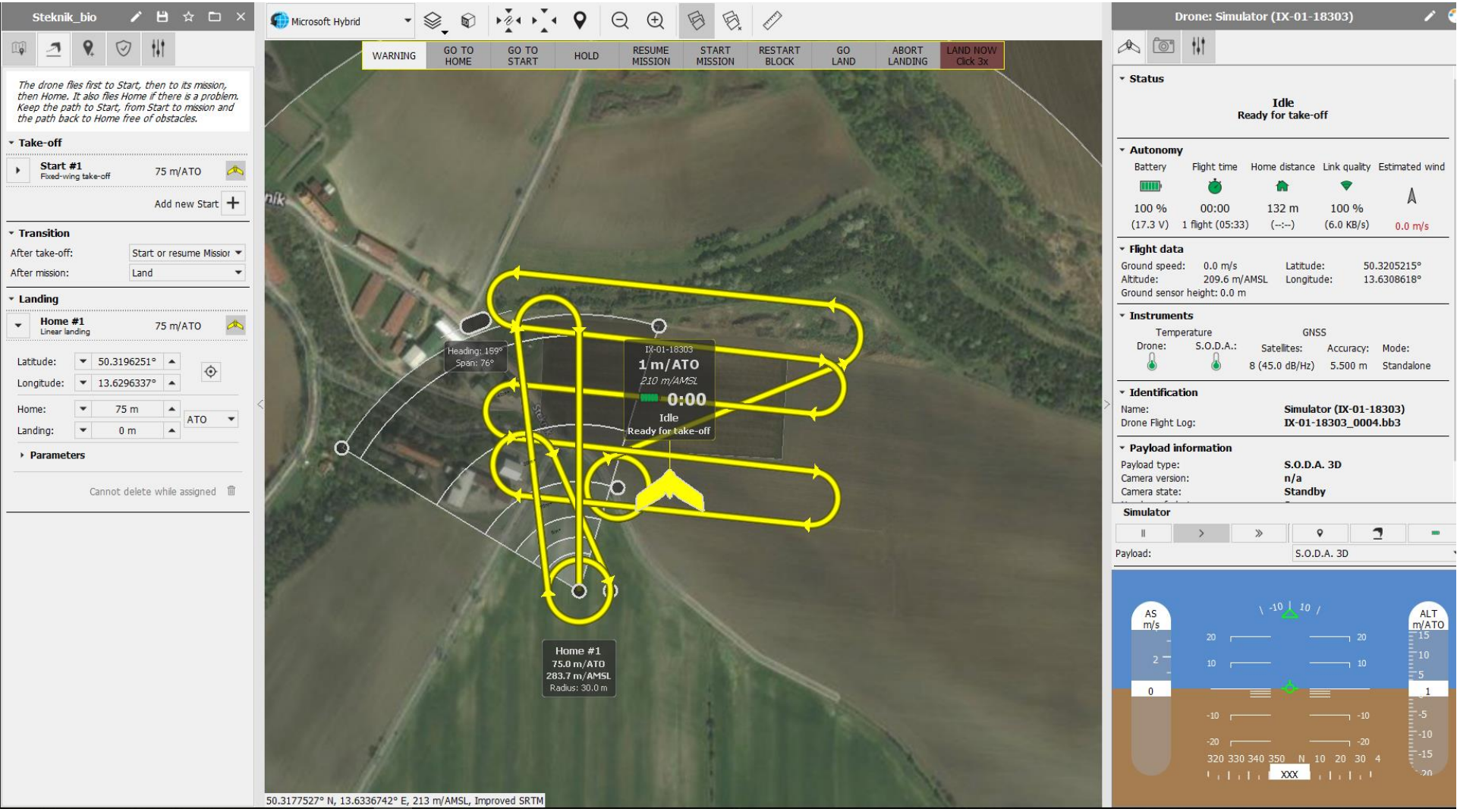
- **Set working area parameters**



- **Set mission block, take-off and landing parameters**

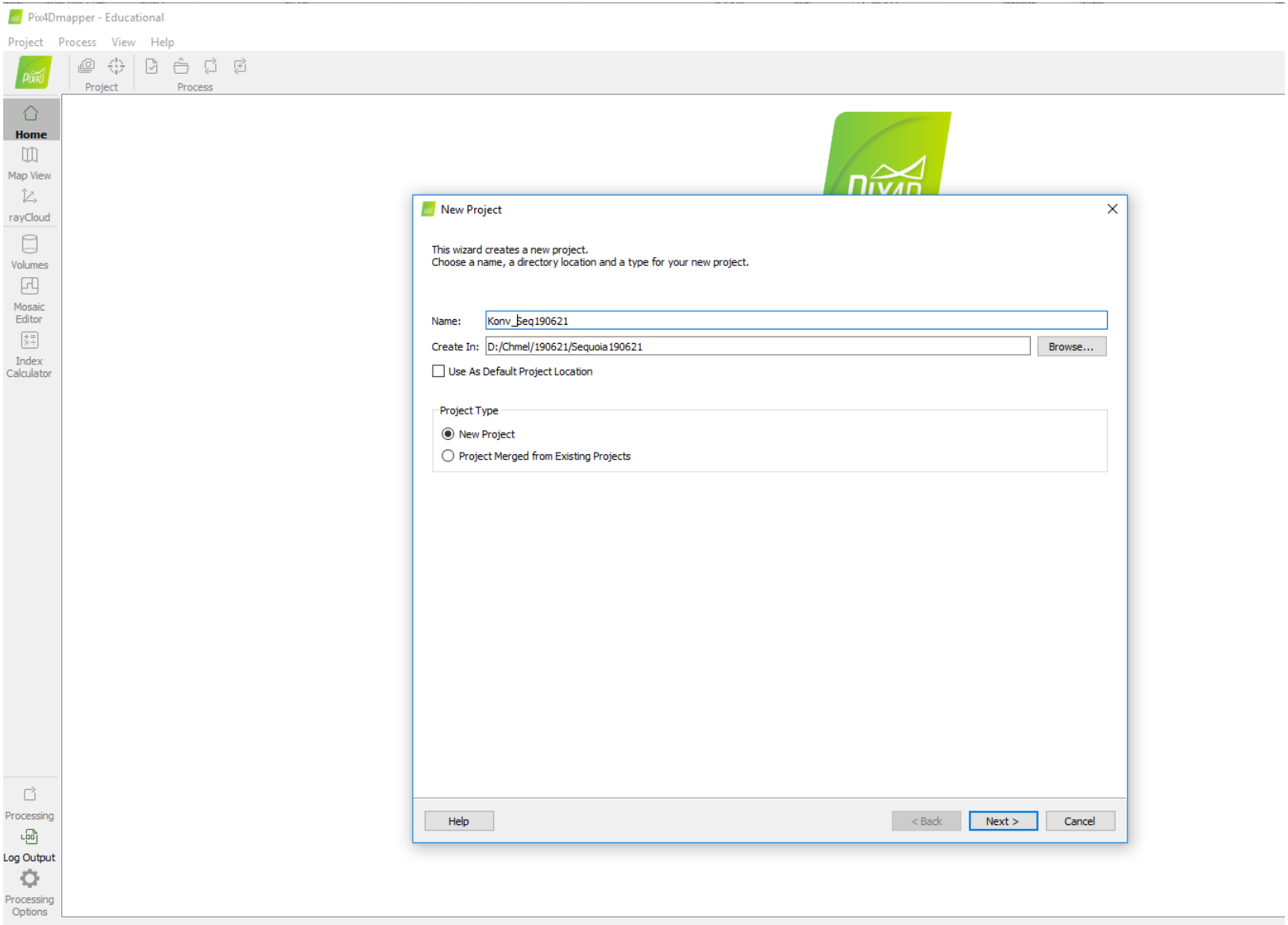


- **Drone simulator**

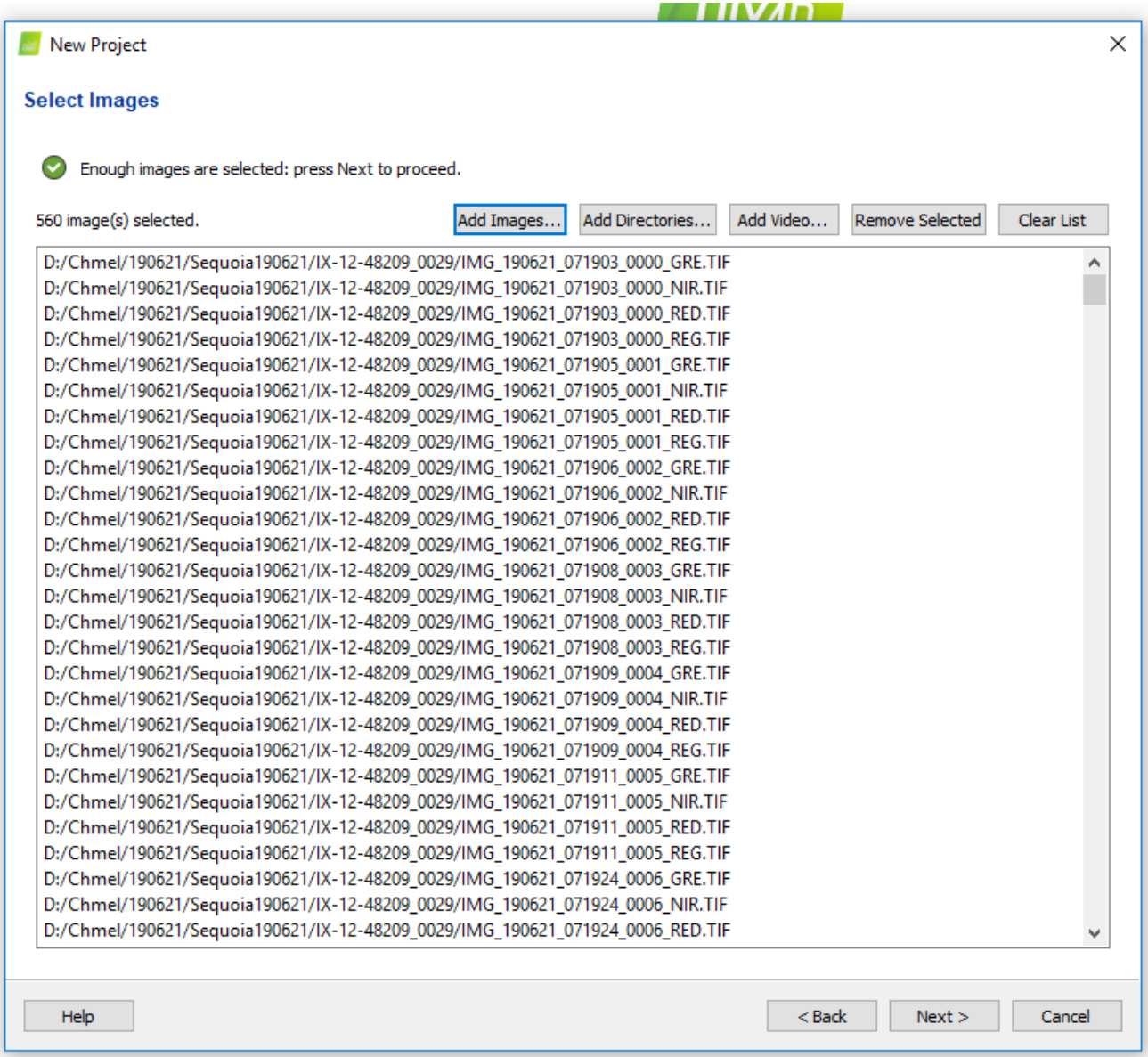


An example of data processing in Pix4D SW

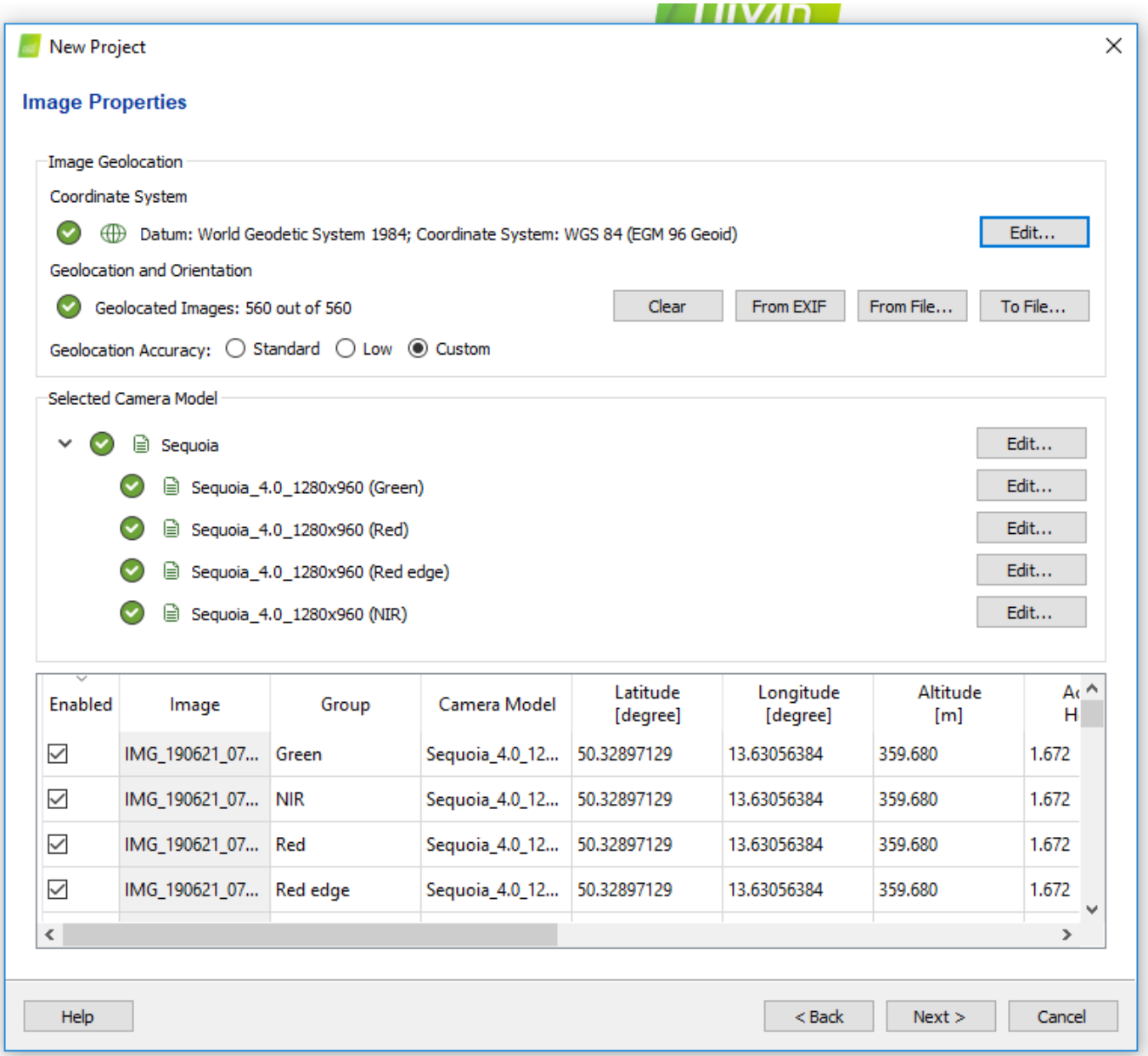
- **Create a new project**



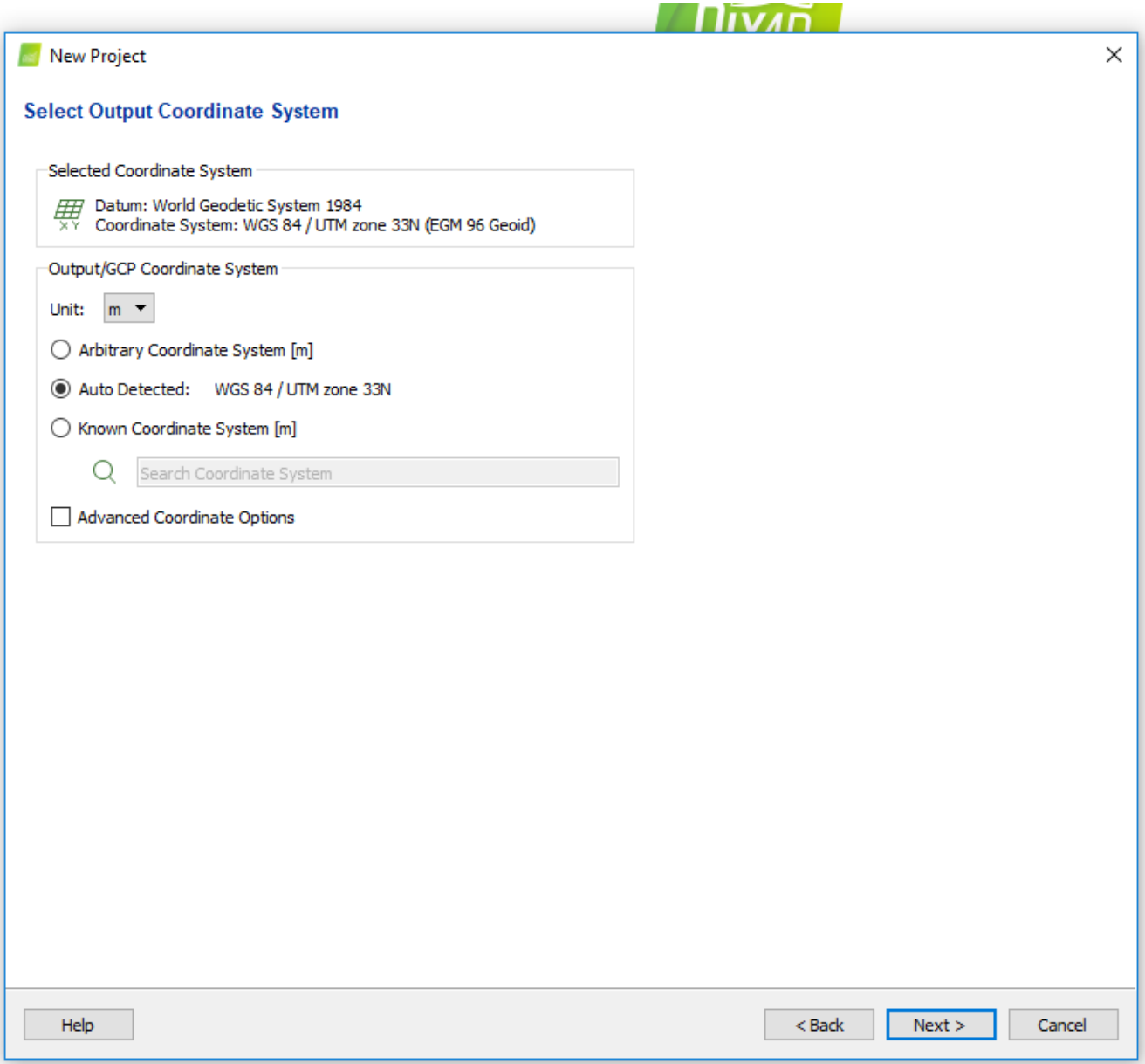
- **Select images**



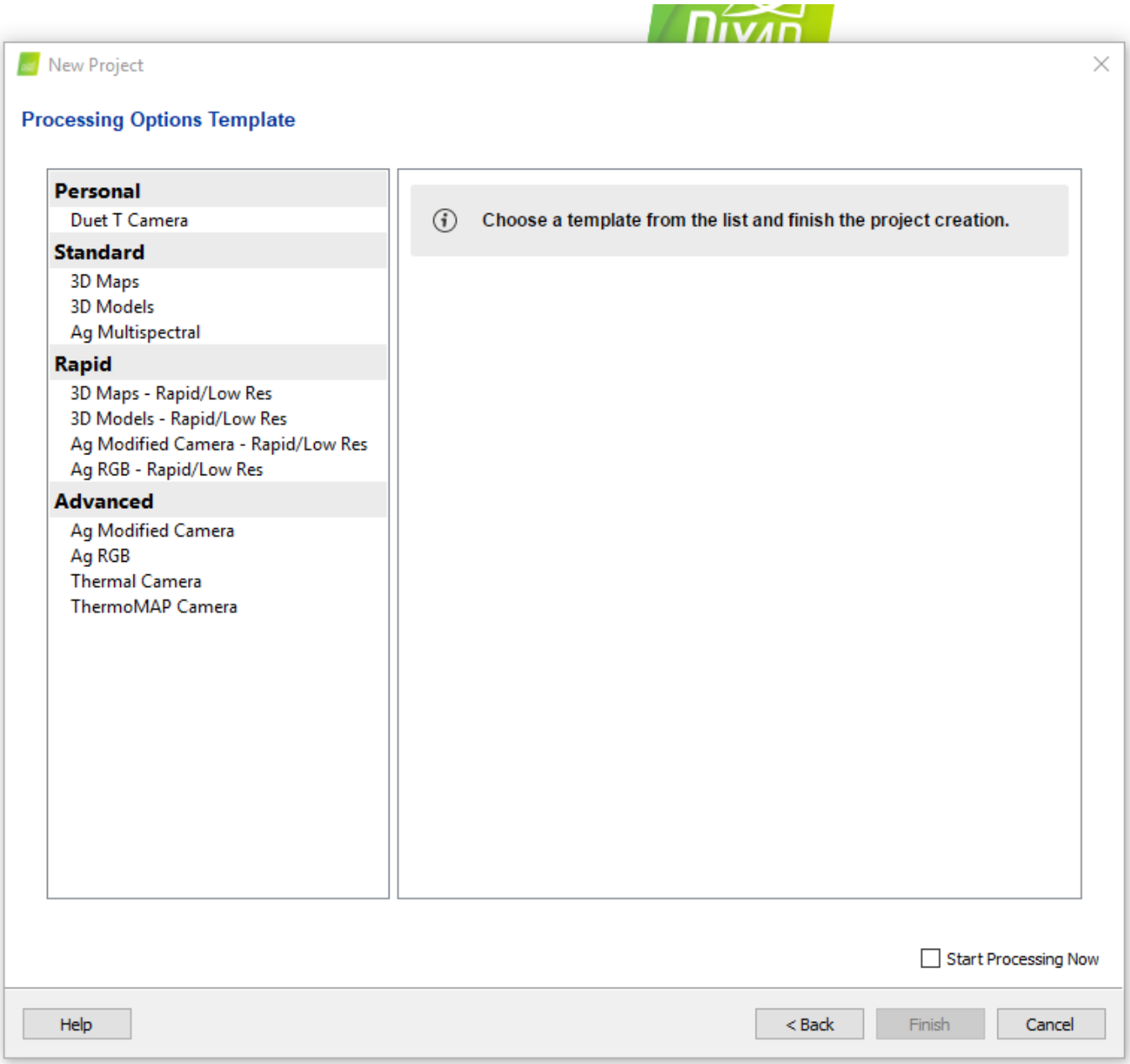
- **Set image properties**



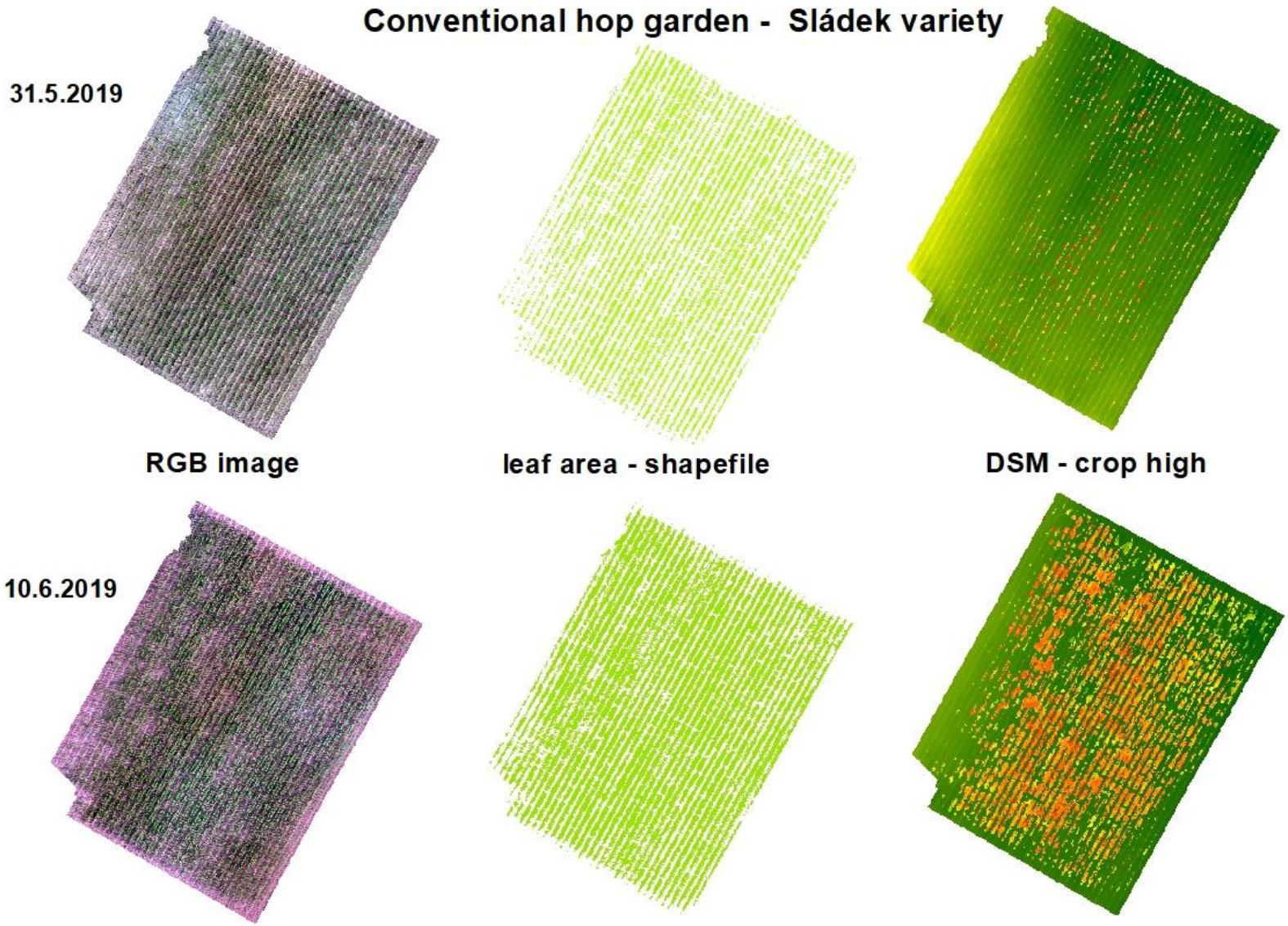
- **Select output coorditate system**



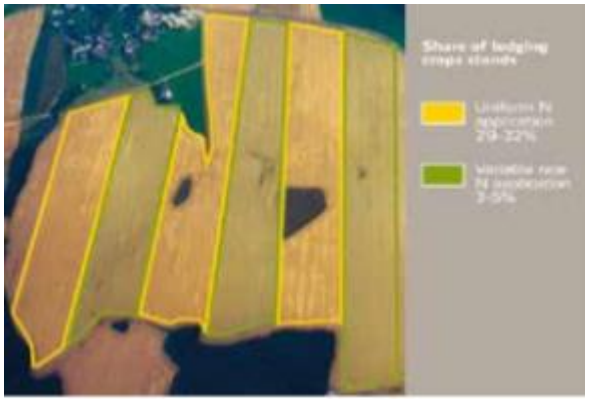
- **Select processing options template**



- **Result - example**



On the base of RGB ExGreen index



Thanks for your attention!