FLOODPLAIN FORESTS MAPPING USING EARTH OBSERVATIONS AND ARTIFICIAL INTELLIGENCE

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Technical objectives

- to tailor and prototype **suitable Artificial Intelligence (AI) systems** of the rapid high-resolution mapping of the Natura2000 floodplain forest habitats based **on the Copernicus EO information**; to demonstrate the capabilities of EO-based AI approaches as a powerful alternative to traditional and widely used field survey methods.
- to provide validation of the concept in terms of the **transferability of the EO-based AI approaches** to the country scale habitat mapping

AI - the effort to automate intellectual tasks normally performed by humans

- *Classification of the natural systems based on EO*

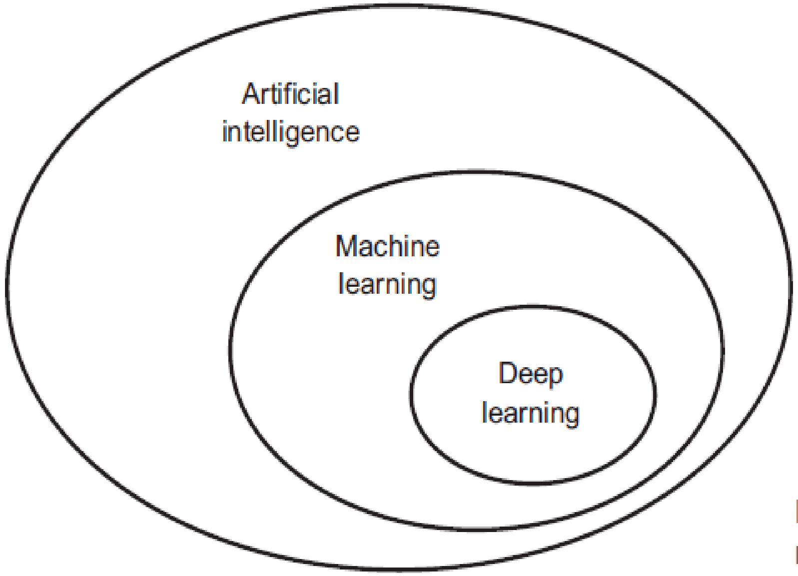
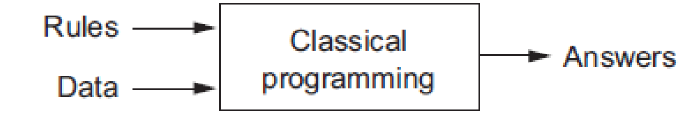
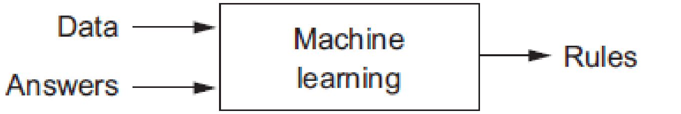


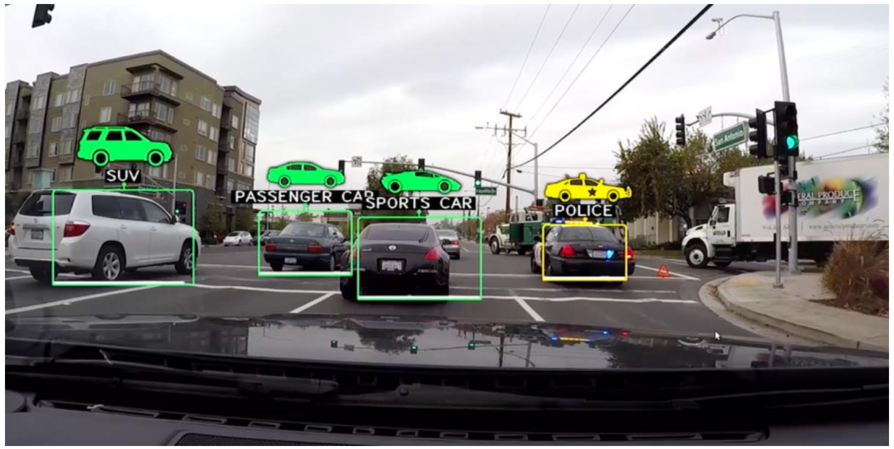
Figure 1.1 Artificial intelligence, machine learning, and deep learning

EXPERT SYSTEM



MACHINE LEARNING





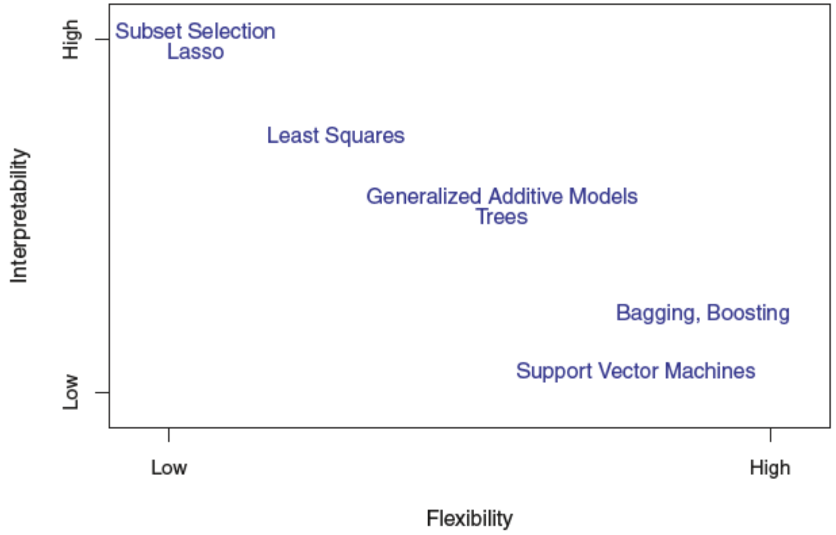
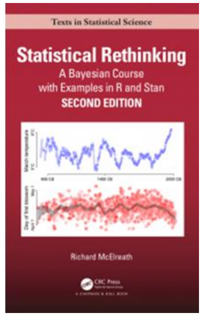
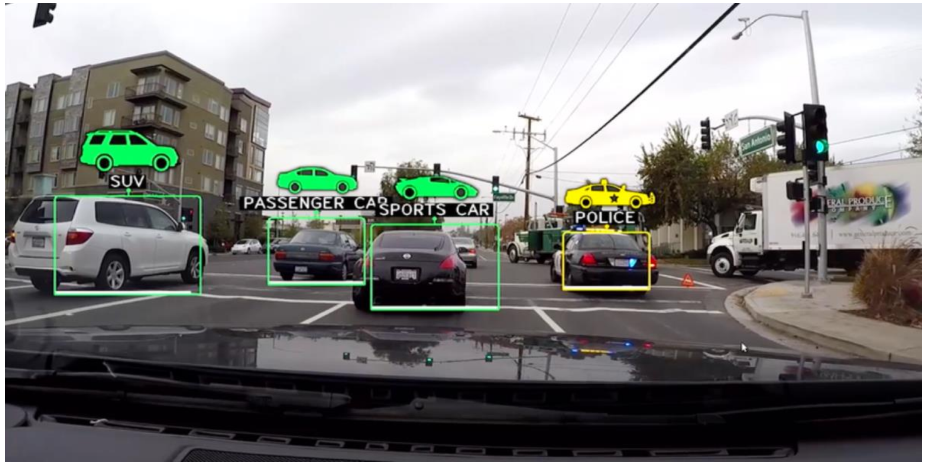


FIGURE 2.7. *A representation of the tradeoff between flexibility and interpretability, using different statistical learning methods. In general, as the flexibility of a method increases, its interpretability decreases.*

- MACHINE LEARNING, GEOBIA – Random Forest, Gradient Boosting, Support vector machines, Lasso,…
- DEEP LEARNING – Deep (Convolutional) Neural Networks
- BAYES INFERENCE – prior knowledge

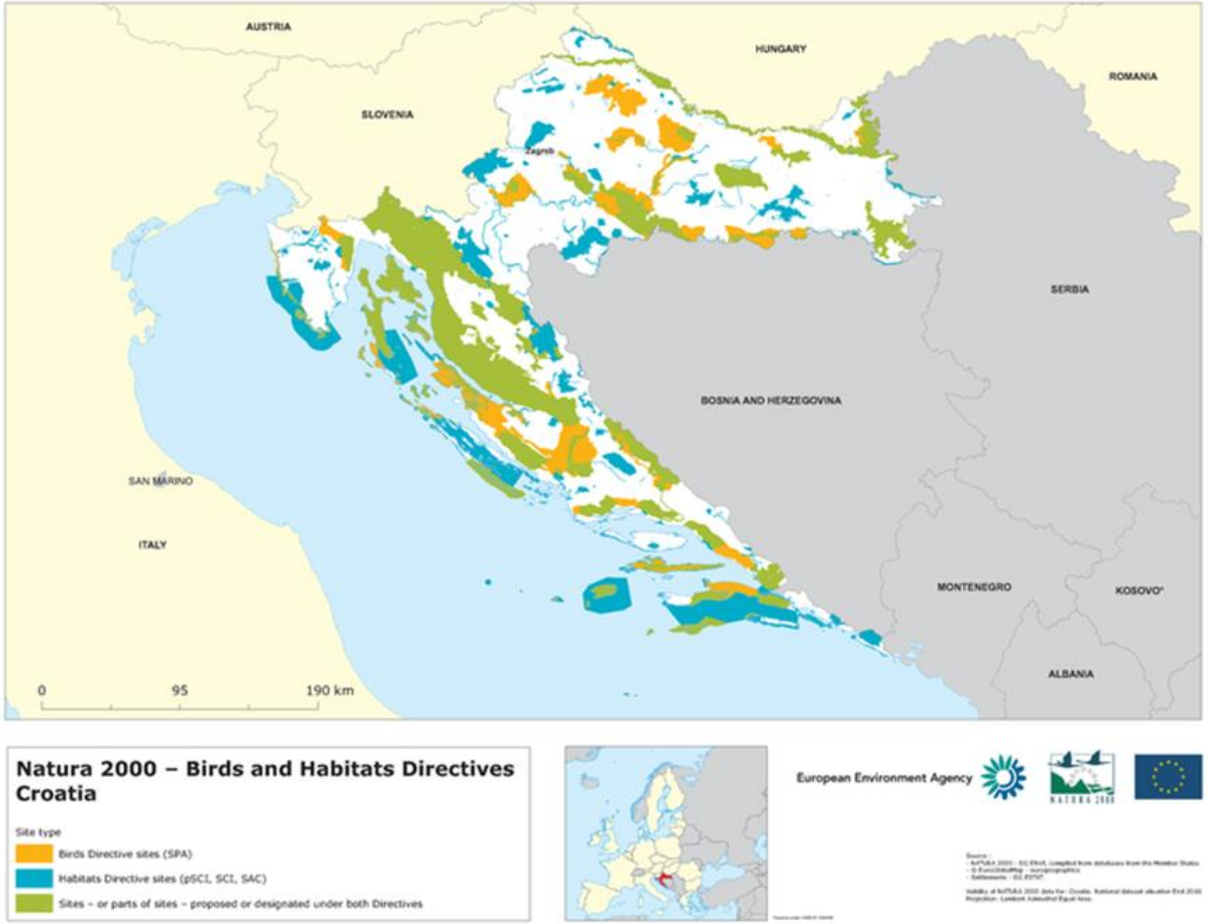


LET'S BUILD A
ML MODEL
WITH CARET

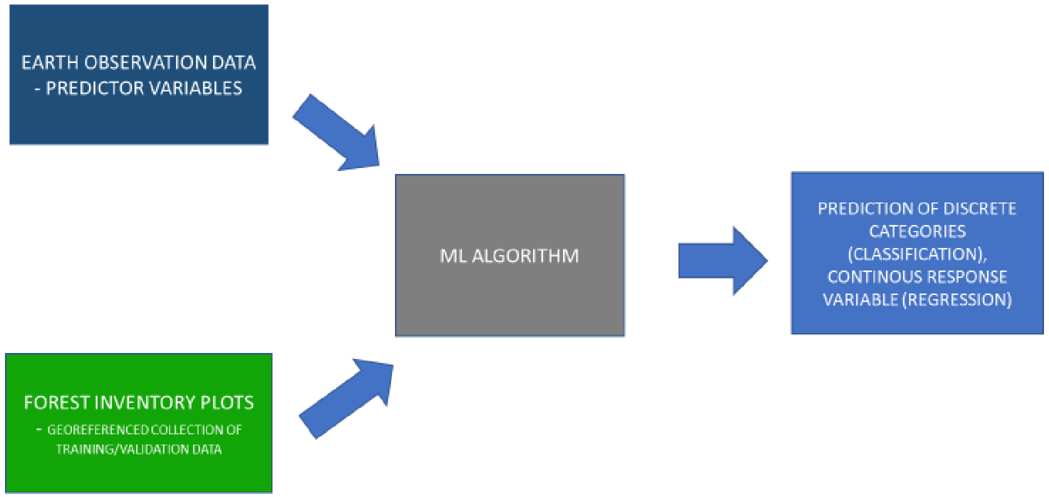


Natura 2000

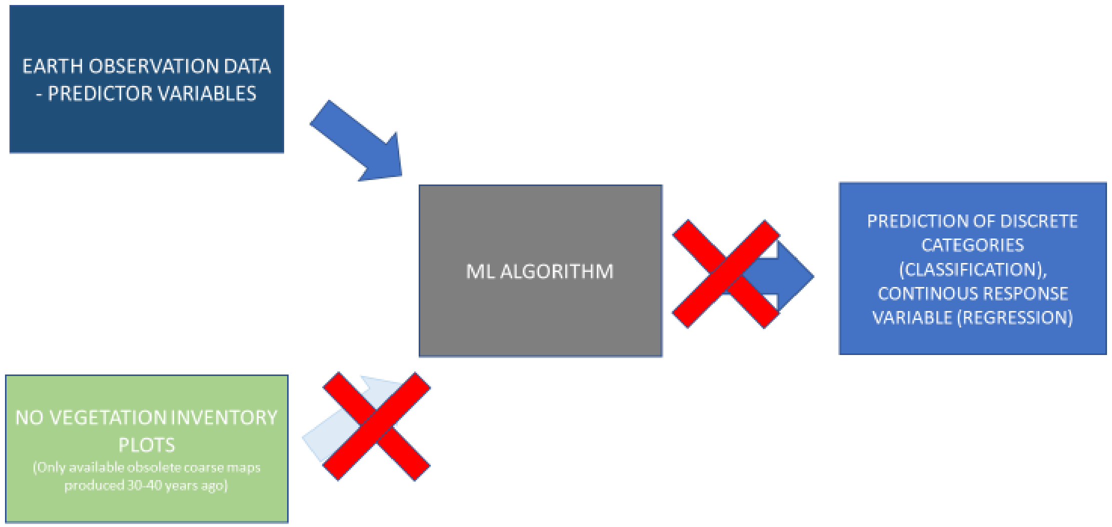
- The Habitats Directive presented the foundation for the Natura 2000, the network of protected areas stretching over 18% of the EU's land area and more than 8% of marine territory.
- The key requirements for EU countries defined by Natura 2000 are **(I) mapping of habitat types** within designated Natura 2000 areas and **(II) monitoring of changes** in habitats, i.e. changes in their distribution over **a period of six years**.

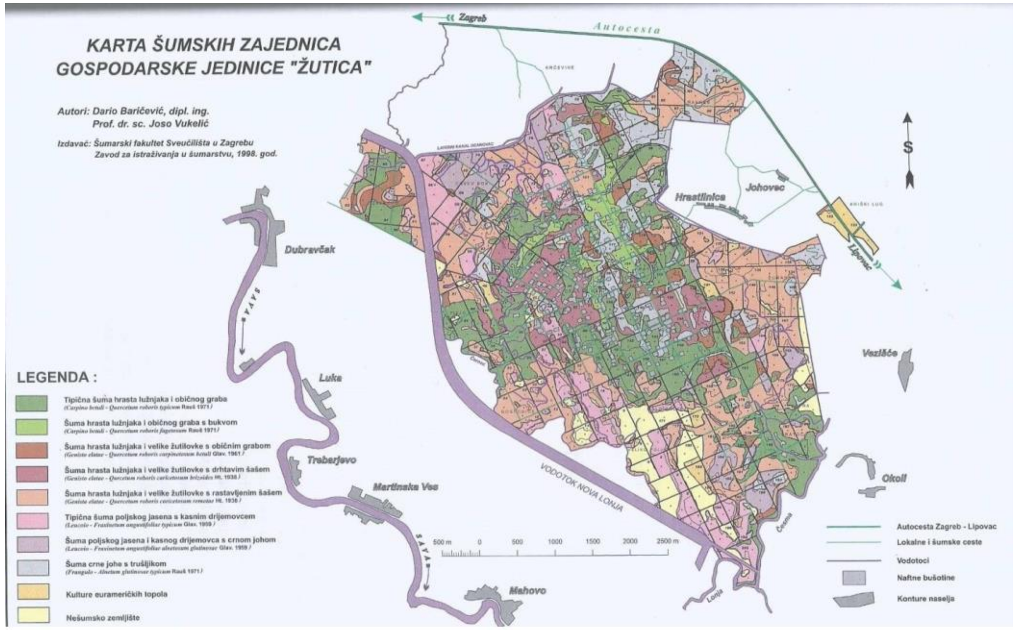


STANDARD SUPERVISED LEARNING FRAMEWORK



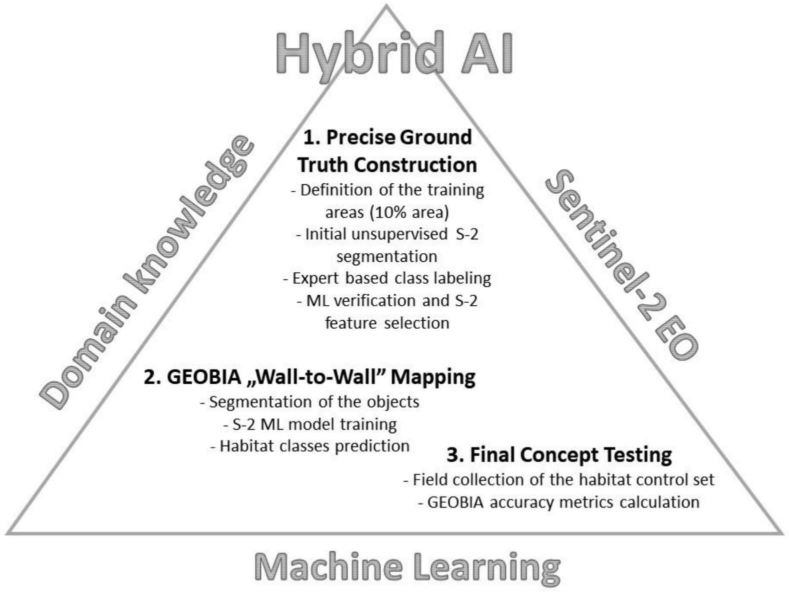
TYPICAL INCOMPLETE FRAMEWORK IN FOREST HABITATS CLASSIFICATION

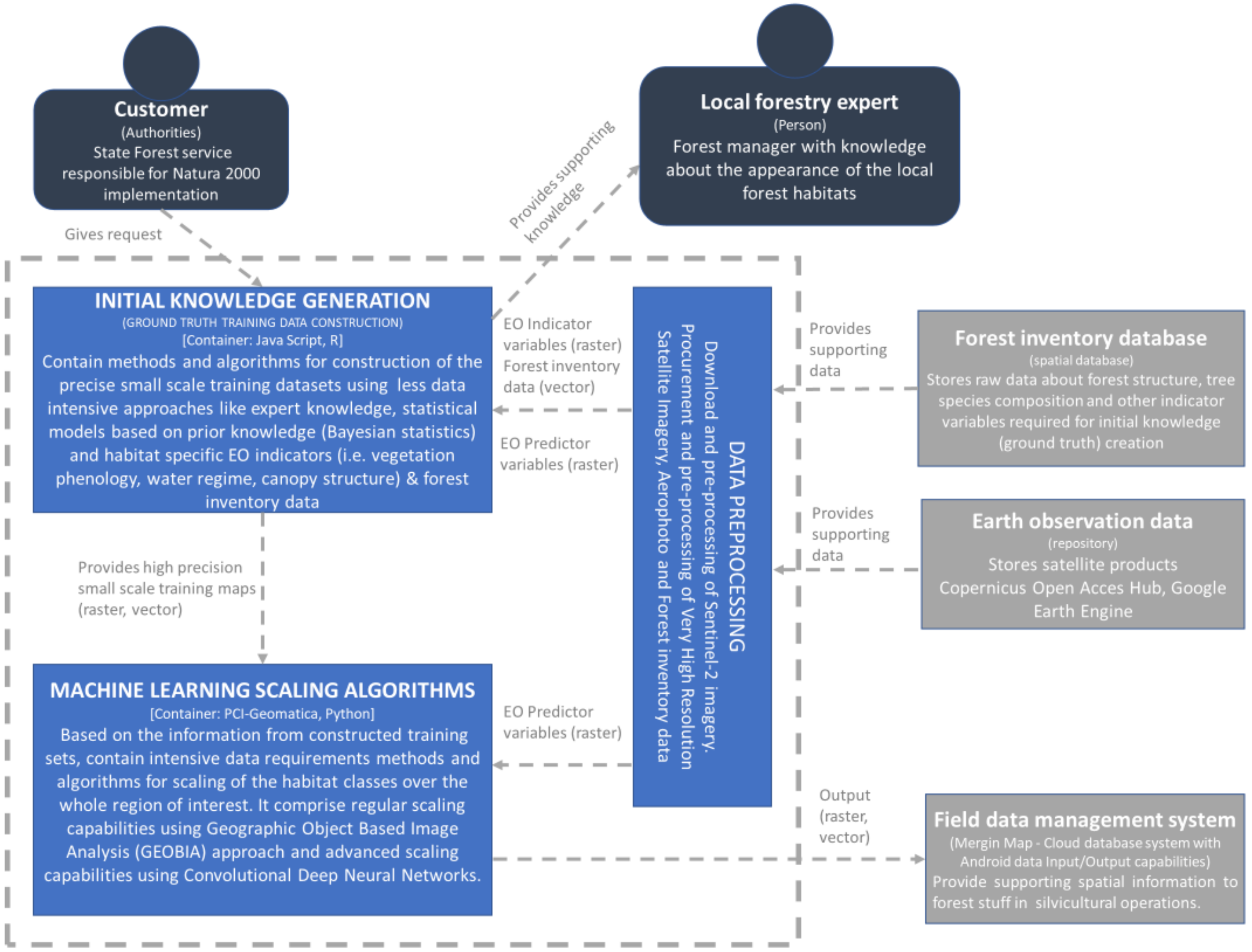




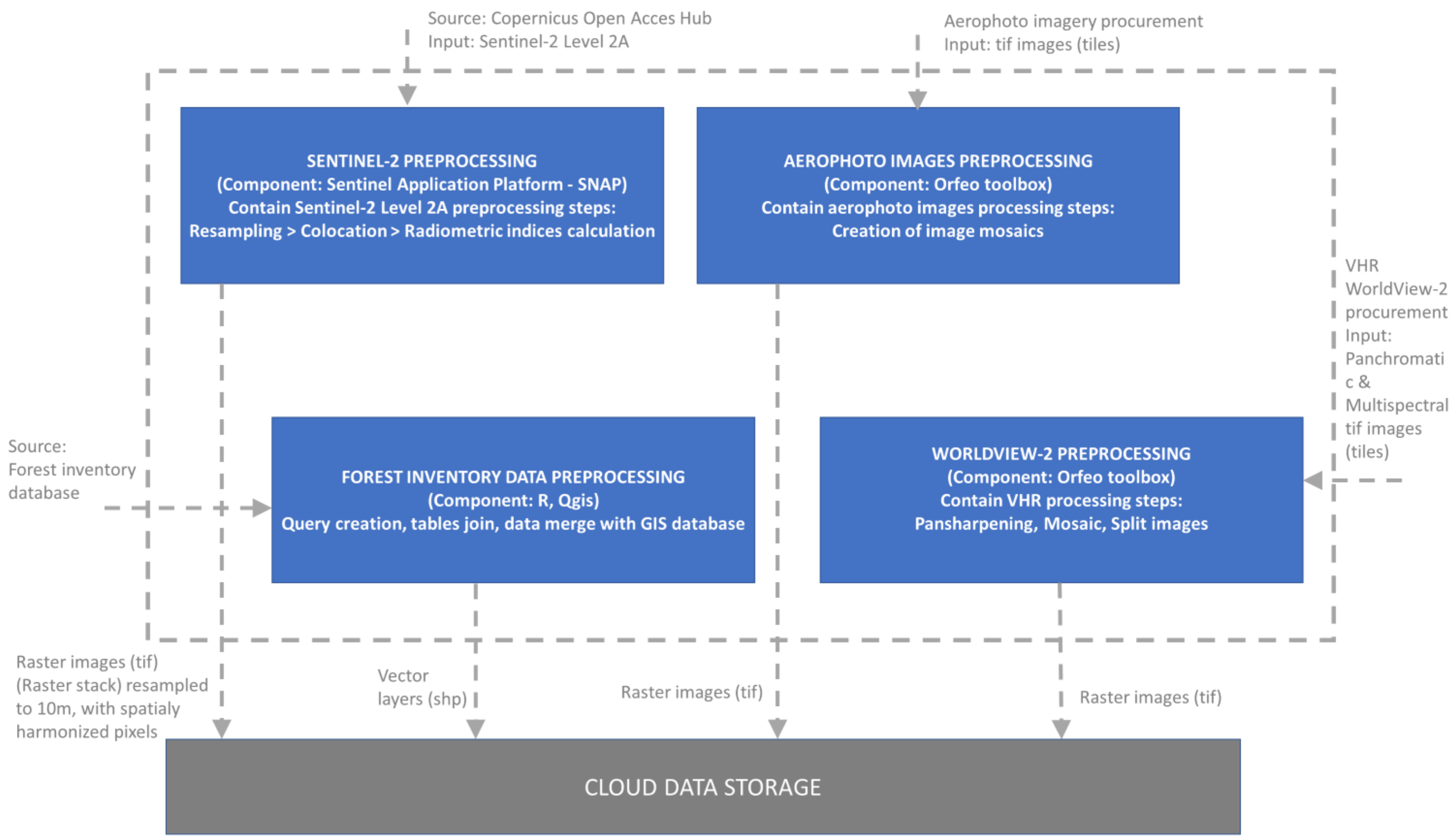
Field sampling by relevés, a list of species observed in a quadrant together with estimates of their abundance/dominance or cover

AI Habitats Mapping System





Data pre-processing sub-system

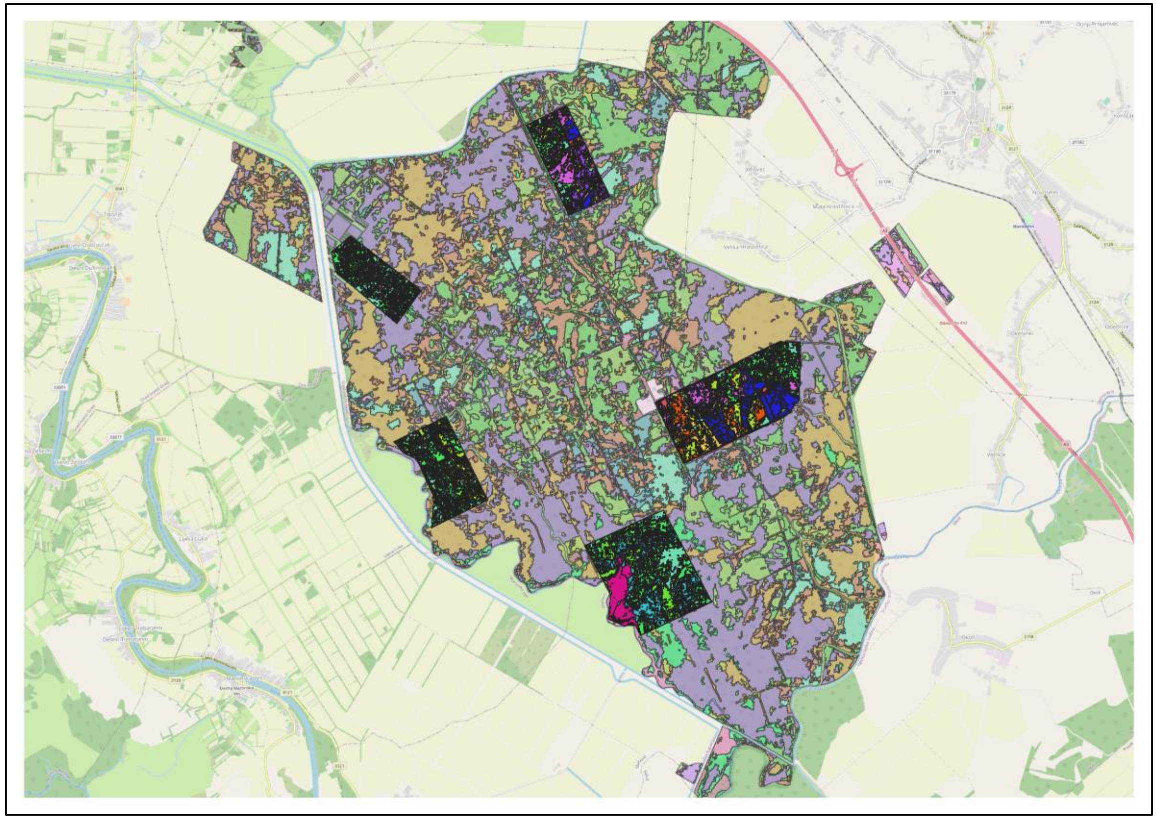


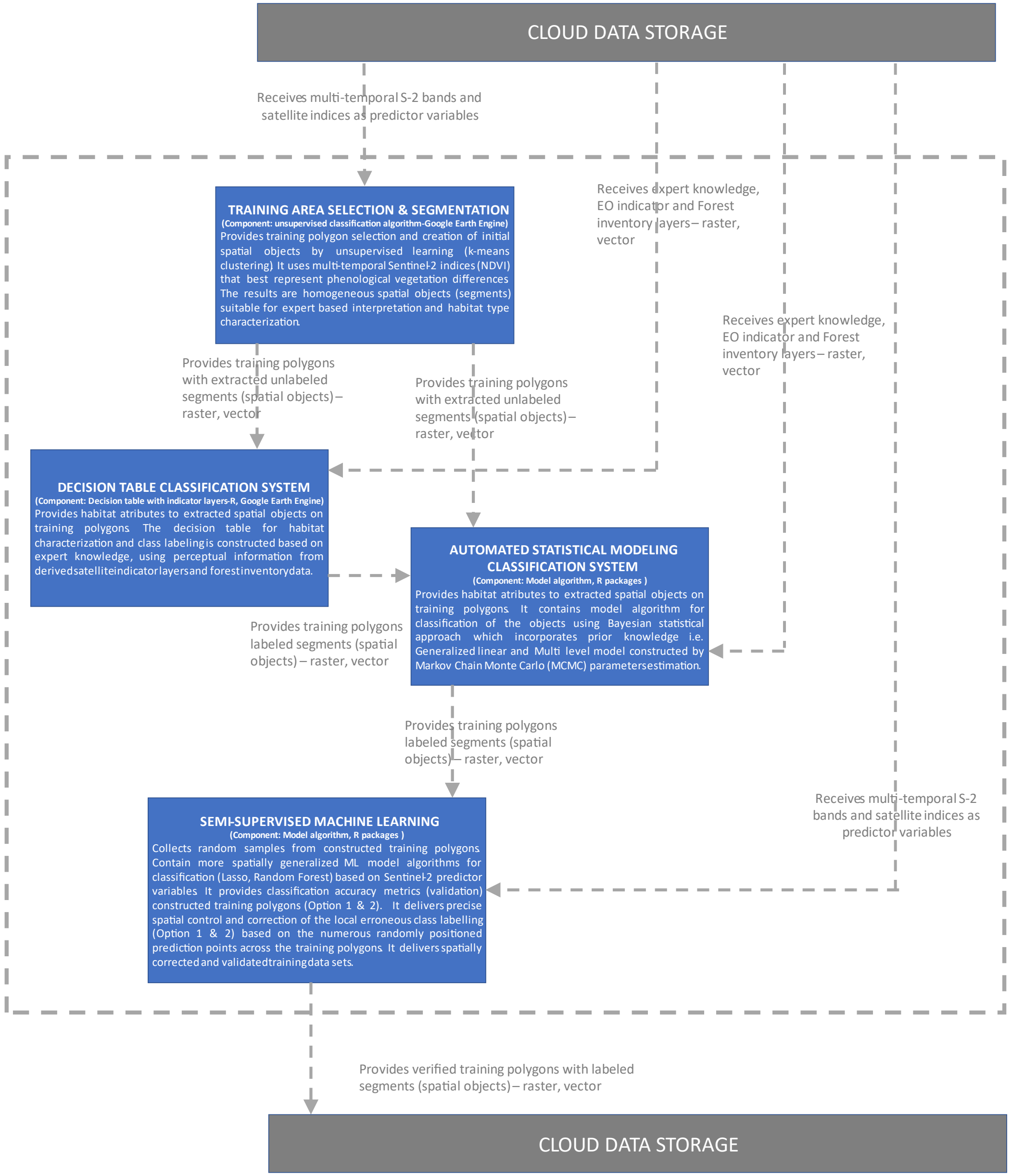
Mission ID	Product level	Sensing date	Sensing time	Relative Orbit number	Tile number
S2A	Level-2A	3.1.2020	9:54:01 AM	079	33TXL
S2A	Level-2A	2.4.2020	9:50:31 AM	079	33TXL
S2B	Level-2A	7.4.2020	9:50:29 AM	079	33TXL
S2B	Level-2A	17.4.2020	9:50:29 AM	079	33TXL
S2B	Level-2A	26.6.2020	9:50:29 AM	079	33TXL
S2A	Level-2A	21.7.2020	9:50:41 AM	079	33TXL
S2A	Level-2A	20.8.2020	9:50:41 AM	079	33TXL
S2A	Level-2A	9.9.2020	9:50:31 AM	079	33TXL
S2B	Level-2A	14.9.2020	9:50:29 AM	079	33TXL
S2A	Level-2A	19.10.2020	9:50:41 AM	079	33TXL

No	S-2 Band	Description	Central wavelength (μm)
1	B01	Coastal aerosol	0.443
2	B02	Blue	0.49
3	B03	Green	0.56
4	B04	Red	0.665
5	B05	Red edge 1	0.705
6	B06	Red edge 2	0.74
7	B07	Red edge 3	0.783
8	B08	Near infrared (NIR) 1	0.842
9	B8A	Red edge 4	0.865
10	B09	Water vapour	0.945
11	B11	Short-wave infrared (SWIR) 1	1.61
12	B12	SWIR 2	2.19

No	S-2 Index	Description	Formula
13	BI	The Brightnes Index	sqrt $(Red^2 / Green^2)/2$
14	BI2	The Second Brightnes Index	sqrt $(Red^2 + Green^2 + NIR\ 1^2)/3$
15	CI	The Colour Index	(Red - Green) / (Red + Green)
16	RI	The Redness Index	(Red2 / Green2)
17	NDVI	The Normalized Difference Vegetation Index	(NIR 1 - Red)/(NIR 1 + Red)
18	ARVI	The Atmospherically Resistant Vegetation Indeks	(NIR - (Red - (Blue - Red)) / (NIR + (Red - (Blue - Red))
19	GNDVI	The Green Normalized Difference Vegetation Index	(NIR 1 - Green) / (NIR 1 + Green)
20	SAVI	The Soil Adjusted Vegetation Index	(1 + L) (NIR 1 - Red) / (NIR 1 + Red + L) L = (0,1)
21	MCARI	The Modified Chlorophill Absorption Ratio Index	((Red edge - Red) - 0.2 * (Red edge - Green)) * (Red edge / Red)
22	NDWI	The Normalized Difference Water Index	(NIR 1 - SWIR 1) / (NIR 1 + SWIR 1)
23	MNDWI	The Modified Normalized Difference Water Index	(Green - SWIR 1) / (Green + SWIR 1)
24	NDPI	The Normalized Difference Pond Index	(SWIR 1 - Green) / (SWIR 1 + Green)
25	LAI	Leaf Area Indeks	
26	FAPAR	Fraction of Absorbed Photosynthetically Active Radiation	
27	FCOVER	Fraction of vegetation cover	
28	CAB	Chlorophyll content in the leaf	
29	CW	Canopy Water Content	

THE SUB-SYSTEM FOR INITIAL TRAINING DATA (GROUND TRUTH) GENERATION





Decision table for class labeling

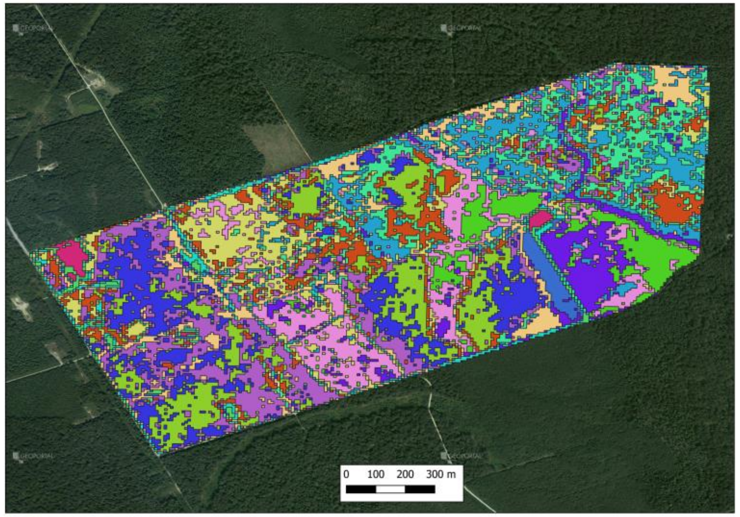
	Frangulo-Alnetum glutinosae	Leucojo-Fraxinetum angustifoliae	Genisto elatae-Quercetum roboris caricetosum remotae	Genisto elatae-Quercetum roboris caricetosum brizoides	Genisto elatae-Quercetum roboris caricetosum betuli	Carpino betuli-Quercetum roboris typicum	Carpino betuli-Quercetum roboris fagetosum	Nitrophilous pastures	Schrubbery of Amorpha fruticosa	Plantations of domestic willows	Plantations of foreign poplars
Orthophoto – visually discrenible tree canopy morphology	X										
Orthophoto – visually discernible absence of trees								X			
Orthophoto – forest infrastructure											
The presence of flooding (Landsat-8 flood mask)	X	X	X					X	X	X	X
The presence of surface ice core (Sentinel-2 RGB, 3.1.2020)	X	X	X					X	X	X	X
Excessive surface moisture (Sentinel-2 NDWI, 3.1.2020)	X	X						X	X	X	X
Start of vegetation greening (Sentinel-2 RGB, 2.4.2020)							X				
Start of vegetation greening (Sentinel-2 RGB, 17.4.2020)					X	X					
Start of vegetation greening (Sentinel-2 RGB, 27.4.2020)			X	X							
Start of vegetation greening (Sentinel-2 RGB, 30.5.2020)	X	X									
Canopy discoloration caused by oak lace bug (Sentinel-2 RGB, 14.9.2020)			X	X	X	X	X				
Dominant basal area percentage (forest inventory)	X	X	X	X	X	X	X	X	X	X	X

Phenology model from literature

Timeline	January, February	April			May	September	October
Flooded area	Narrow leaved ash Pedunculate oak (flooded association)						
Leaves unfolding		Willow Beech	Common Hornbeam	Pedunculate oak	Narrow leaved ash Black Alder		
Crown discoloration by pest attack						Pedunculate oak (Oak lace bug)	
Date of Sentinel-2 acquisition	3-Jan-2020	2-Apr-2020	17-Apr-2020	27-Apr-2020	30-May-2020	14-Sep-2020	4-Oct-2020

SYNTHETIC GROUND TRUTH CONSTRUCTION

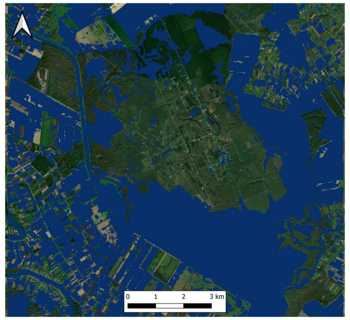
SEGMENTATION OF THE TRAINING POLYGONS
(K-MEANS CLUSTERING) - MULTITEMPORAL S-2 NDVI



LABELLING CLASSES USING PRIOR SINECOLOGICAL KNOWLEDGE

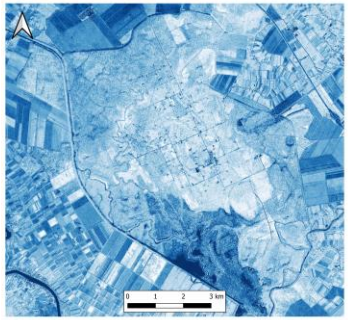
EO DATA

FLOOD TOLERANCE L8

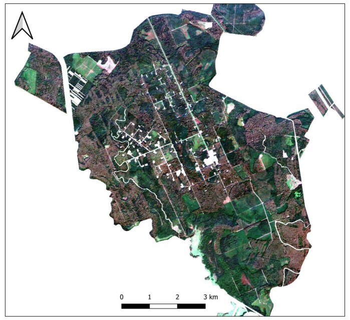


SURFACE ICE S2

MOISTURE NDWI S2

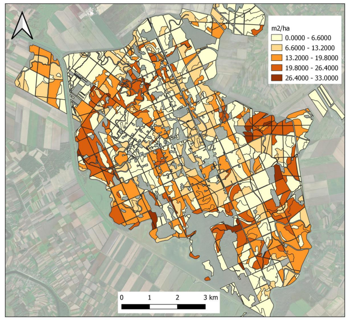


OAK DISCOLORATION PEST ATTACK S2

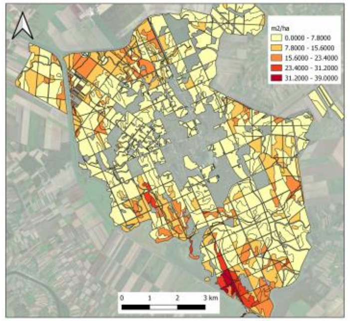


FOREST INVENTORY

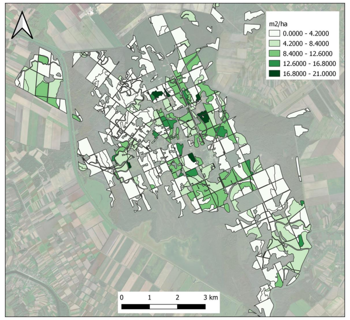
QUERCUS



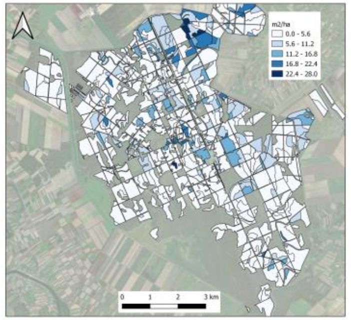
FRAXINUS



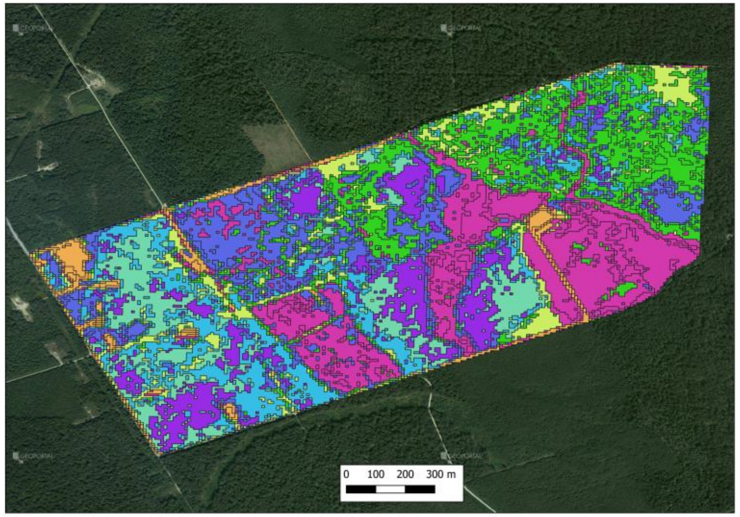
CARPINUS



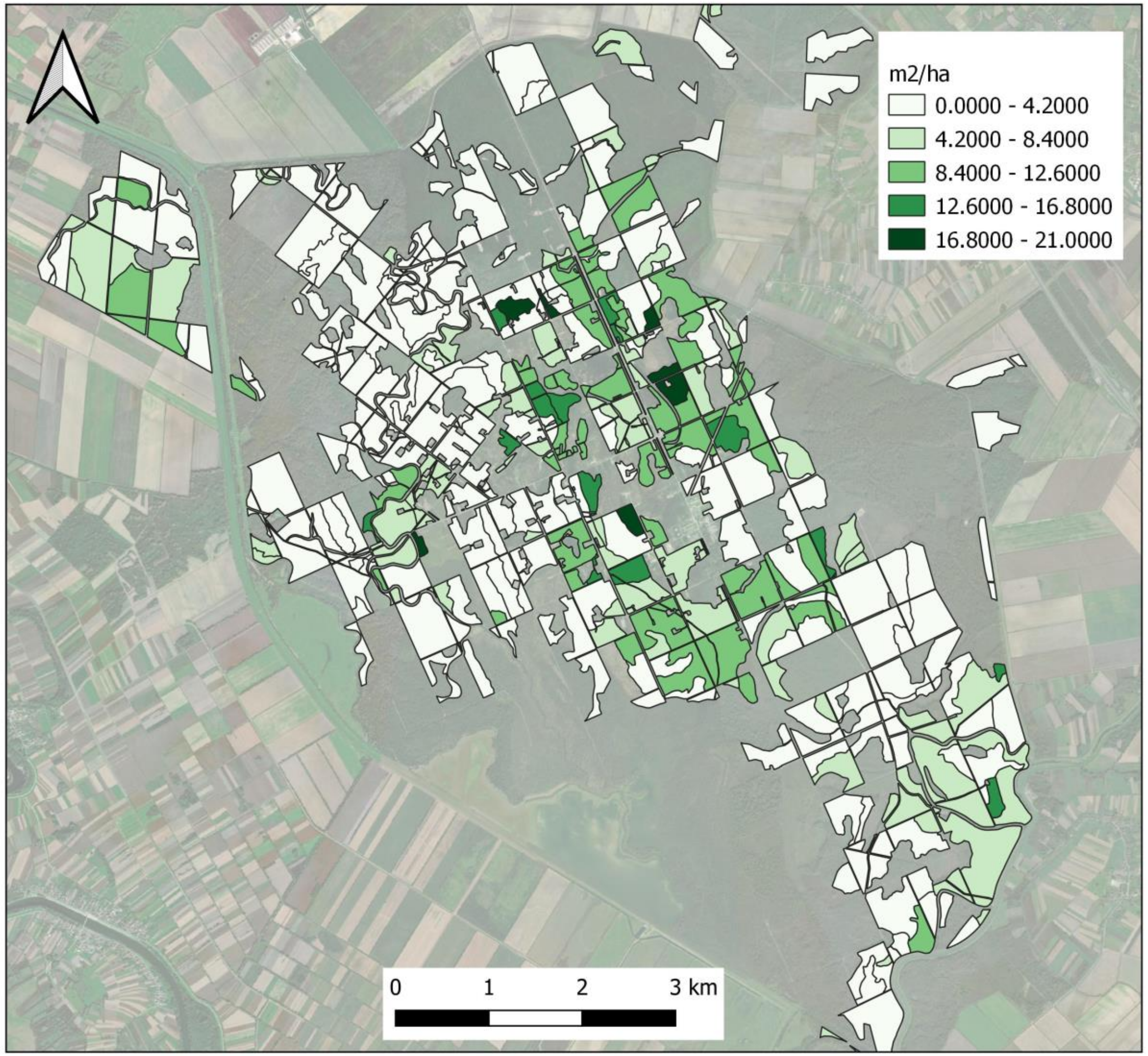
ALDER

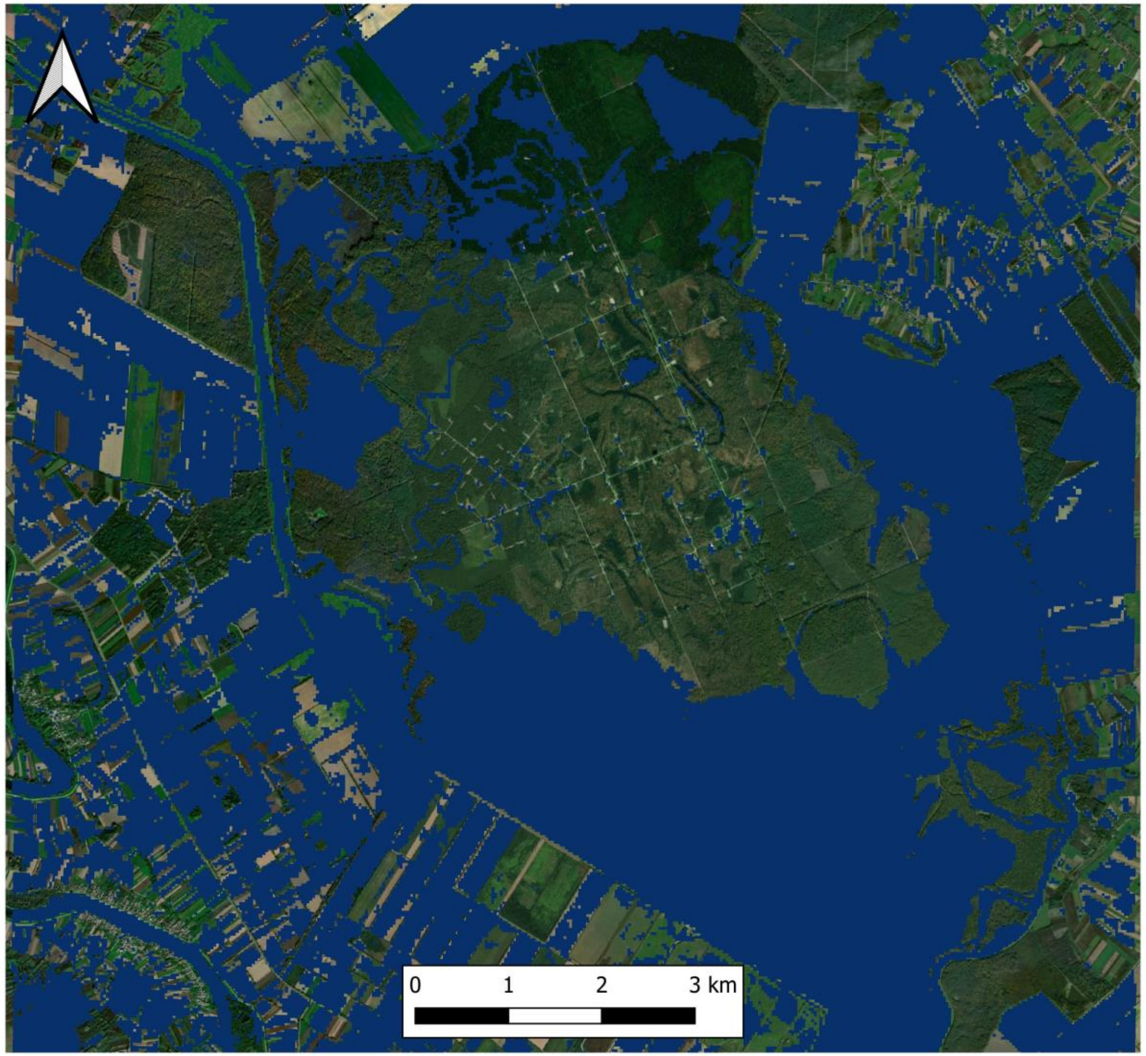


DEFINED HABITAT TYPES

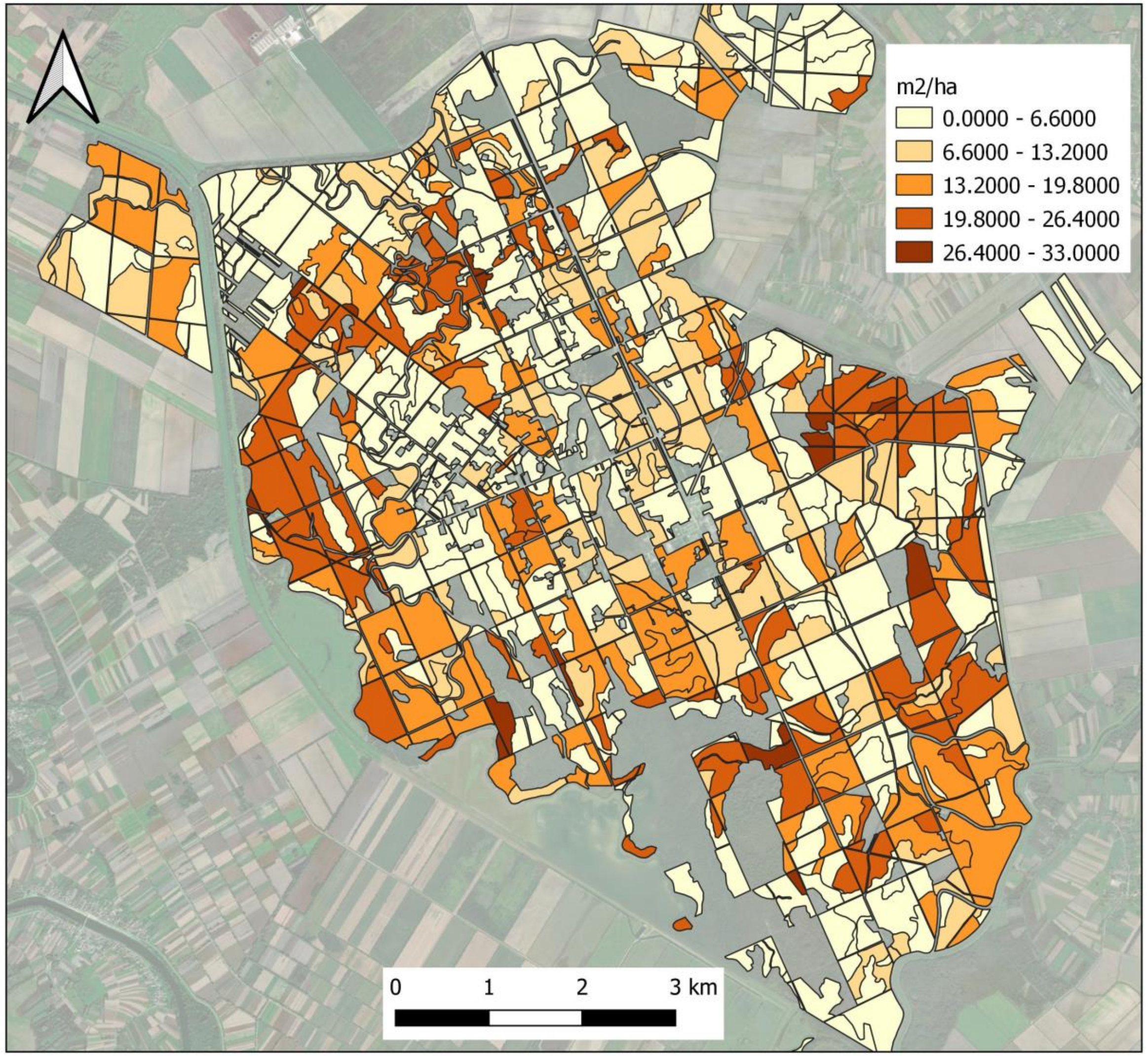


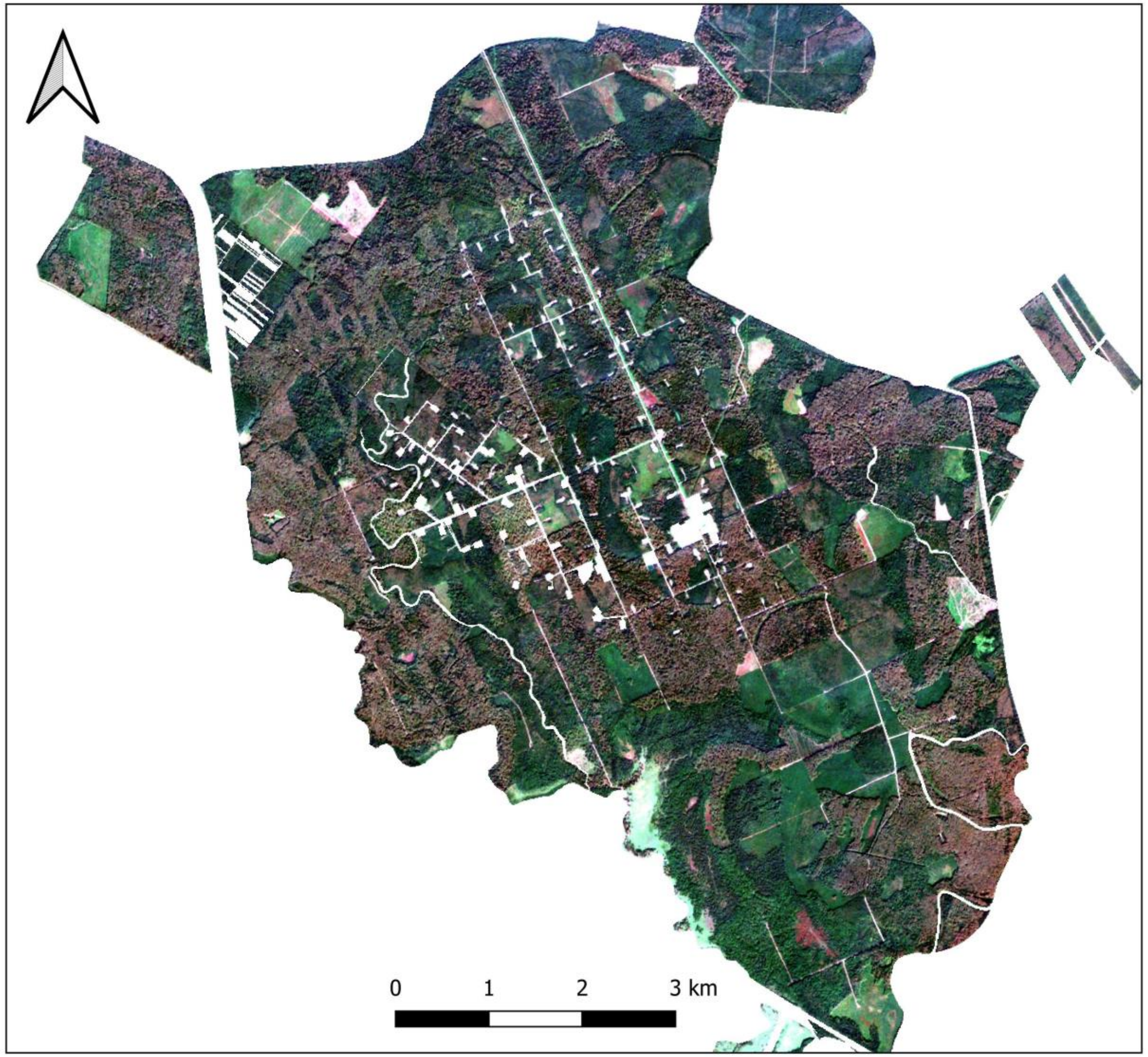
Flood tolerance (Carpinus betulus)





Discoloration - S-2 image 15.9.2020 (Quercus robur - Oak lace bug (Corythucha arcuata))





Random forest

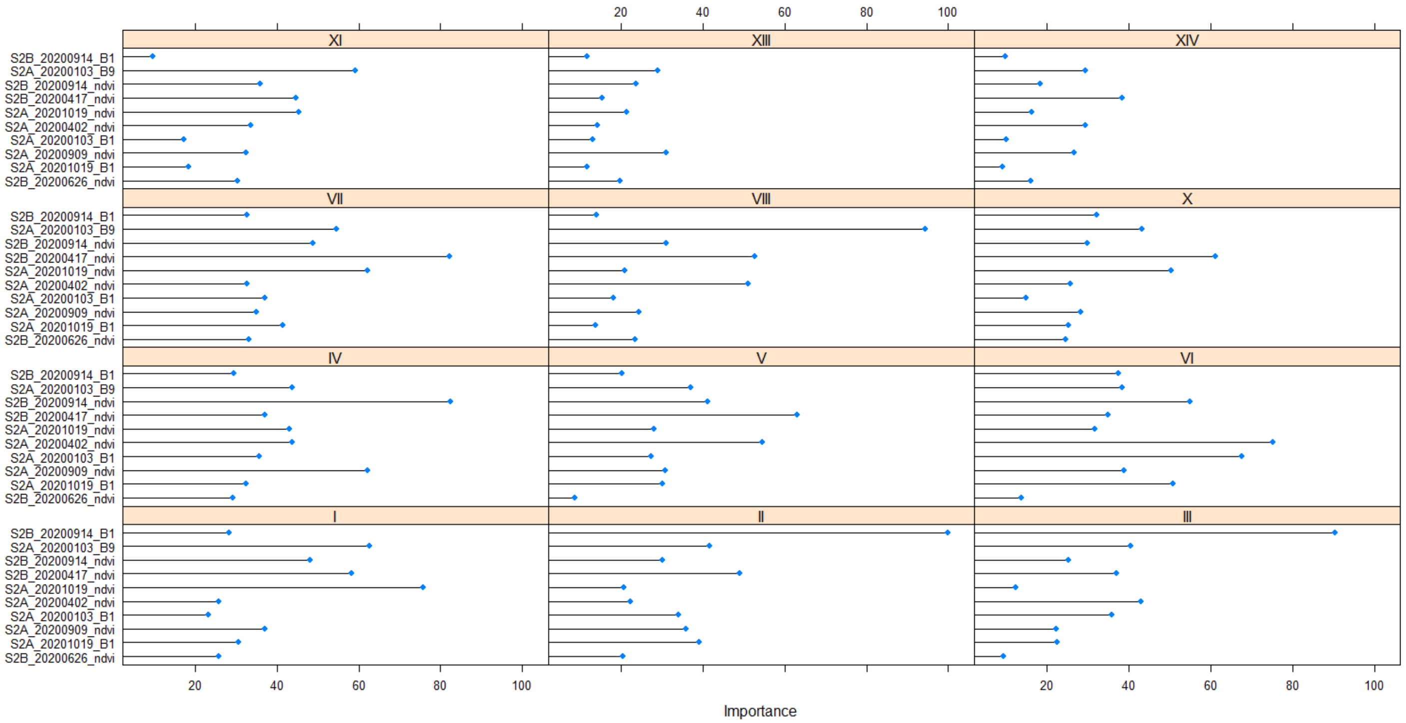
Overall Statistics:

Accuracy : 0.863

95% CI : (0.8582, 0.8677)

Kappa : 0.8393

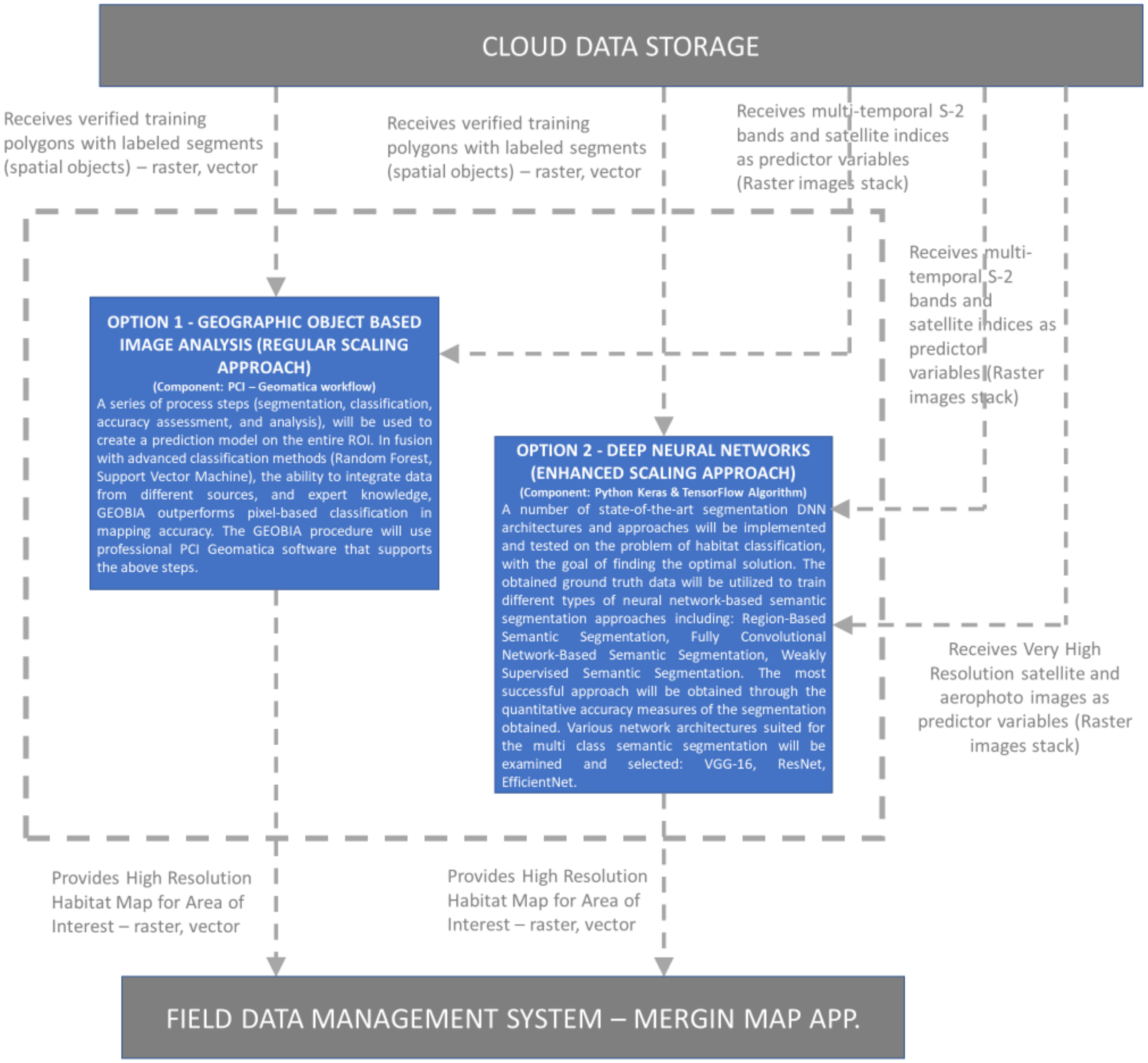
RF Variable importance



Between class separability – Lasso model

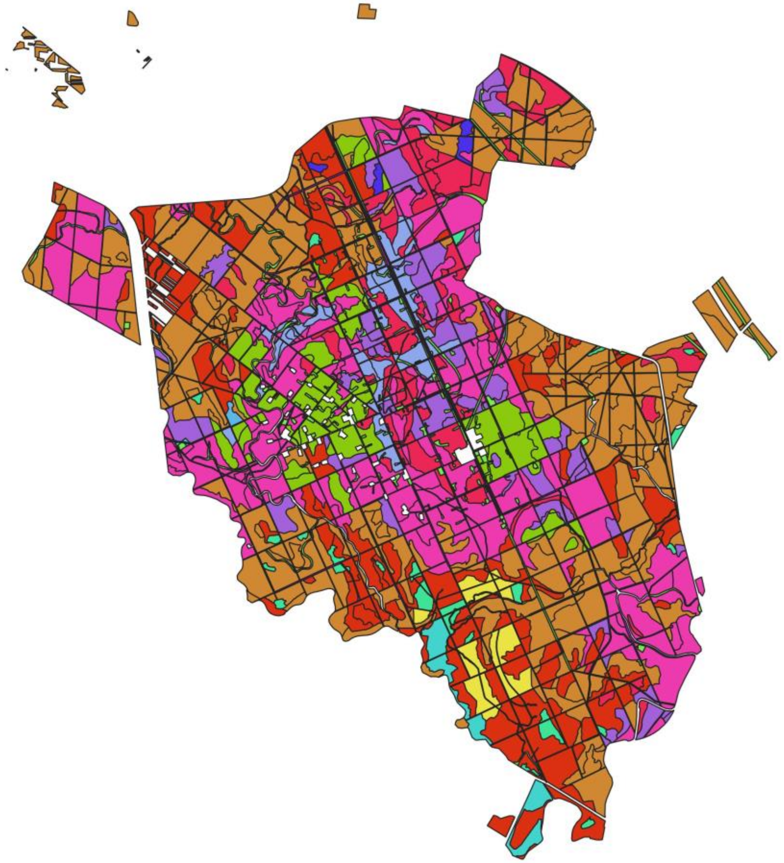
	I	II	III	IV	V	VI	VII	VIII	X	XI	XIII	XIV
I	1.00											
II	0.97	1.00										
III	1.00	0.95	1.00									
IV	0.99	0.92	1.00	1.00								
V	0.99	0.96	1.00	0.97	1.00							
VI	0.97	0.80	0.96	0.98	0.92	1.00						
VII	0.89	0.96	1.00	0.93	0.99	0.99	1.00					
VIII	1.00	1.00	1.00	0.96	1.00	1.00	0.98	1.00				
X	0.93	0.99	1.00	0.99	0.99	0.99	0.97	1.00	1.00			
XI	1.00	1.00	1.00	0.96	1.00	1.00	0.97	0.98	0.99	1.00		
XIII	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.98	1.00	0.98	1.00	
XIV	1.00	1.00	1.00	0.99	1.00	1.00	0.99	1.00	0.95	0.98	1.00	1.00

Scaling using GEOBIA or Deep Neural Networks

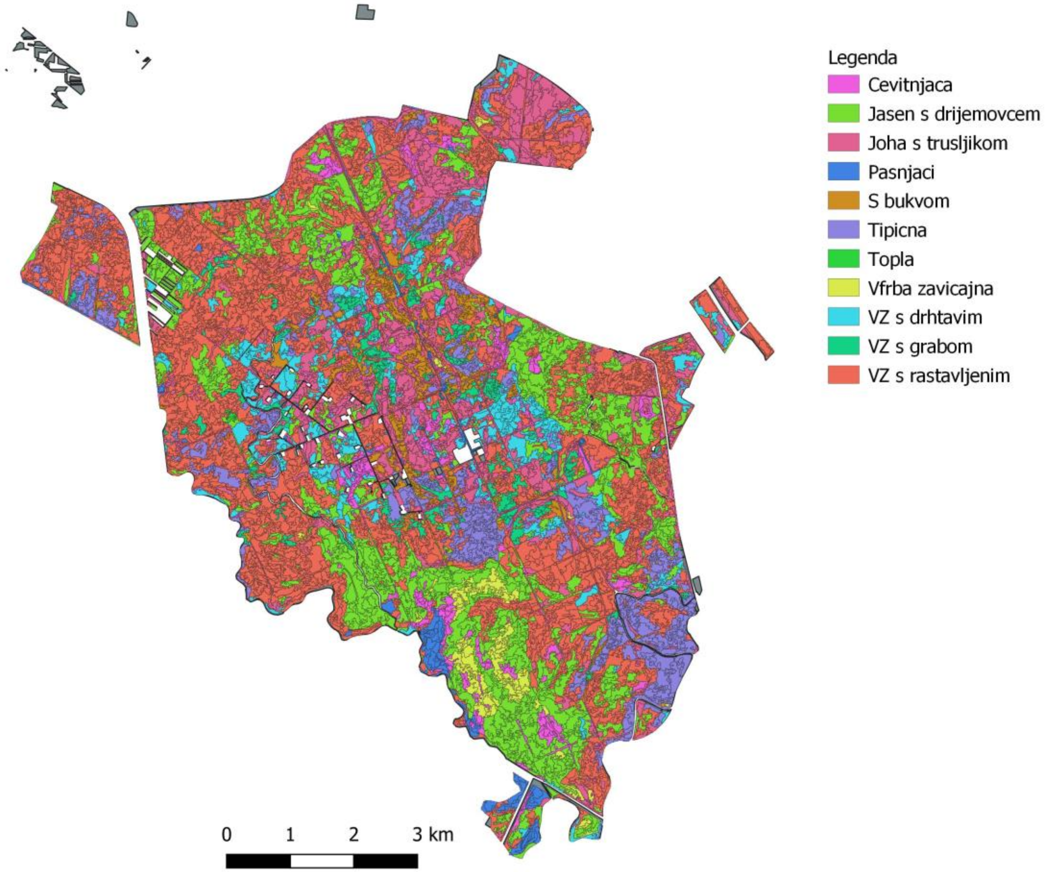


PRODUCTION OF THE FOREST HABITAT MAP FOR THE ROI OF WESTERN POSAVINA BY APLYING GEOGRAFIC OBJECT-BASED IMAGE ANALYSIS (RANDOM FOREST, SVM) ON THE CONSTRUCTED TRAINING POLYGONS (GROUND TRUTH)

OFFICIAL HABITAT MAP OF ŽUTICA FOREST



PRODUCED HABITAT MAP OF ŽUTICA FOREST USING SYNTHETIC GROUND TRUTH AND GEOBIA ON SENTINEL-2 MULTITEMPORAL IMAGERY



Key personnel

Prime contractor

Croatian Forest Research Institute

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Faculty of Geodesy, University of Zagreb

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University of Zagreb, Faculty of Electrical Engineering and Computing

Institute for Environment and Nature (IEN)

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Thank you!