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UNIVERSITY OF LJUBLJANA
Faculty of Civil and Geodetic Engineering



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UNIVERSITY OF LJUBLJANA
Biotechnical Faculty

INTEGRATING ANNUAL SENTINEL-1/2 TIME SERIES AND FOREST INVENTORY DATA FOR MACHINE LEARNING-BASED TREE SPECIES CLASSIFICATION AT A NATIONAL SCALE

Joint SCERIN and MedRIN Workshop 16-19 July 2024

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Presentation

- Study area
- Reference dataset
- Input Sentinel-1/2 time series
- ML algorithm
- Tree species classification results
- Margin value
- Features importance



Study area

- Slovenia is one of the European countries with the highest percentage of forest cover

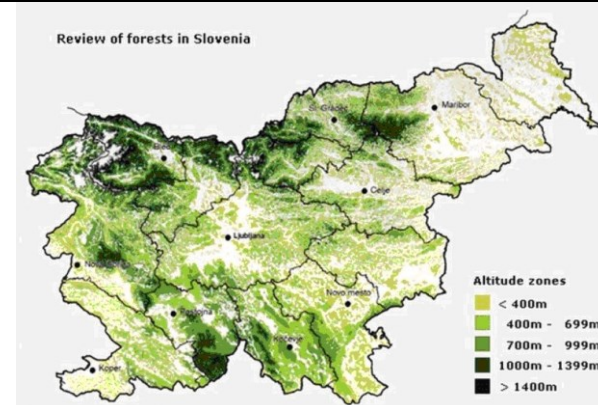
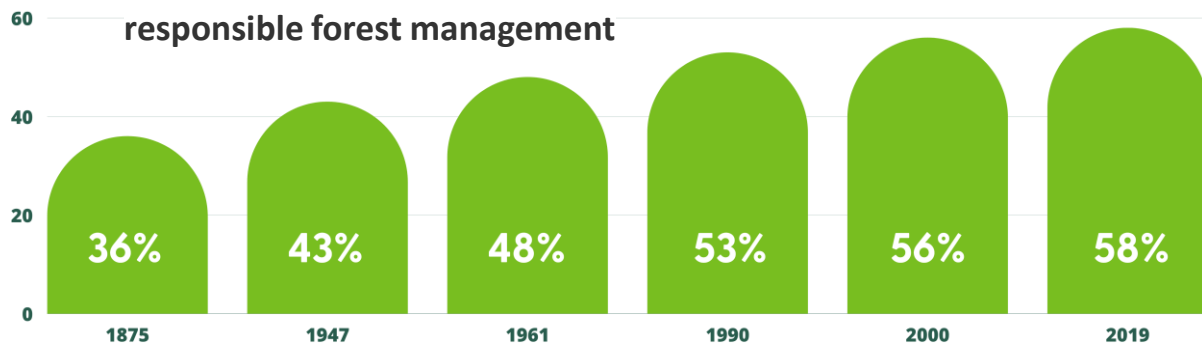


Total area of the Republic of Slovenia = 20 271 km²

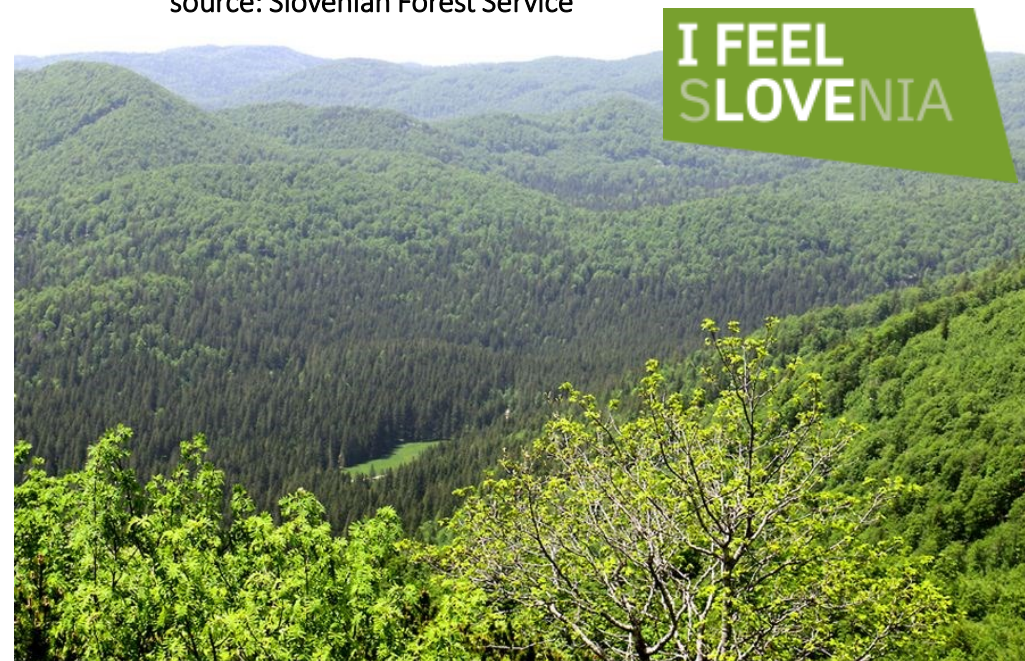


Total forest area in the Republic of Slovenia: 1 176 542 ha

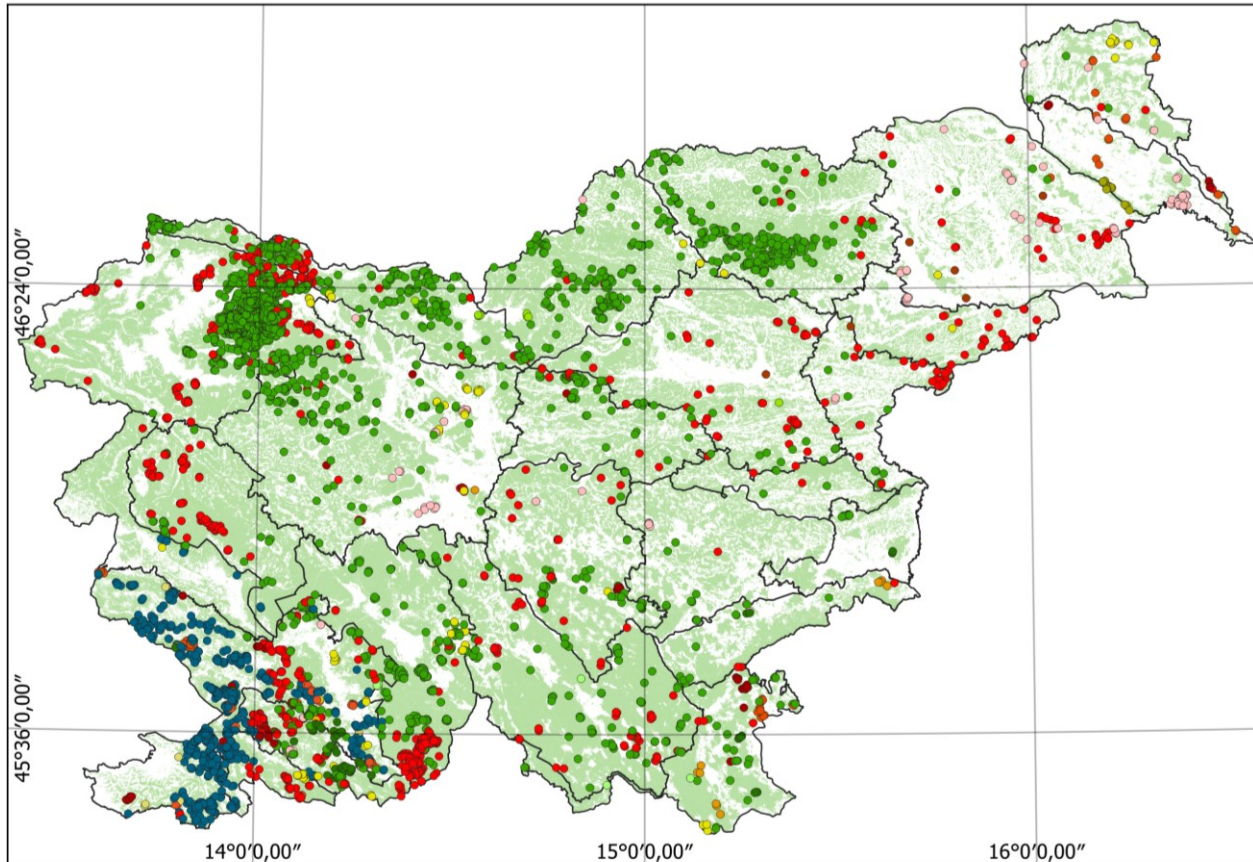
[source](#): Forest ecosystem, 2021



source: Slovenian Forest Service



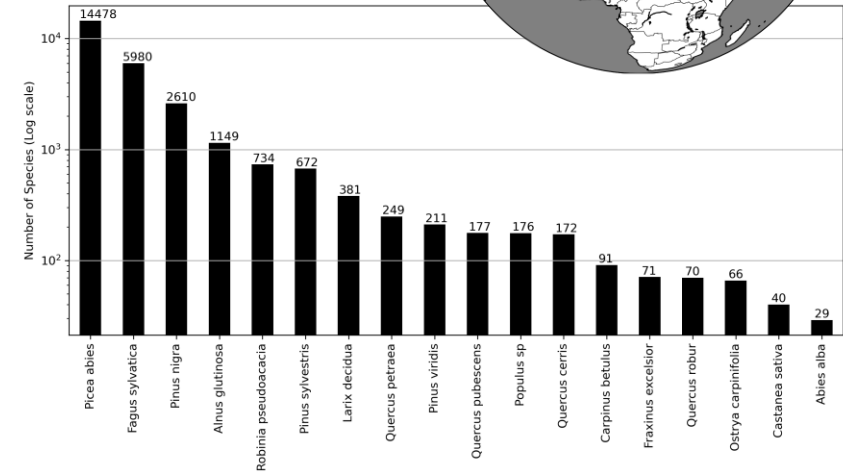
Reference dataset for tree species classification



- Drevesne vrste
- *Abies alba*
 - *Alnus glutinosa*
 - *Carpinus betulus*
 - *Castanea sativa*
 - *Fagus sylvatica*
 - *Fraxinus excelsior*
 - *Larix decidua*
 - *Picea abies*
 - *Pinus nigra*
 - *Pinus sylvestris*
 - *Pinus viridis*
 - *Populus sp*
 - *Quercus cerris*
 - *Quercus petraea*
 - *Quercus pubescens*
 - *Quercus robur*
 - *Robinia pseudoacacia*

Izdelava karte: Ana Potočnik Buhvald
Vir podatkov: GIS in ZGS (2021)
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0 25 50 km



Reference data for this study were derived from the Slovenian **stand map** for the reference year 2021 (author Slovenian Forest Service).

More than 27 000 points/pixels.

Forest inventory reference dataset for SP classification



- Sample points are made out of homogenous stands (centroid of stand) with 98 % SP1.

Map name	Tree Species	Number for Training	Number for Testing	Wood stock
		Samples	Samples	[%]
1	<i>Picea abies</i>	14,478	9,700	28,2
2	<i>Fagus sylvatica</i>	5,980	4,007	31,9
14	<i>Pinus nigra</i>	2,610	1,749	1,4
3	<i>Alnus glutinosa</i>	1,149	770	1,1
12	<i>Robinia pseudoacacia</i>	734	492	< 1
4	<i>Pinus sylvestris</i>	672	450	4,2
5	<i>Larix decidua</i>	381	255	1,6
6	<i>Quercus petraea</i>	249	167	5,1
13	<i>Pinus viridis</i>	211	141	< 1
16	<i>Quercus pubescens</i>	177	119	< 1
48	<i>Populus sp</i>	176	118	< 1
17	<i>Quercus cerris</i>	172	115	< 1
10	<i>Carpinus betulus</i>	91	61	2,7
8	<i>Fraxinus excelsior</i>	71	48	1,0
9	<i>Quercus robur</i>	70	47	1,2
15	<i>Ostrya carpinifolia</i>	66	44	1,3
11	<i>Castanea sativa</i>	40	27	1,5
7	<i>Abies alba</i>	29	19	7,9



Input feature for machine learning tree species classification




- Sentinel-1 coherence SITS (ASC_VV, _VH and DES_VV, _VH)
- Sentinel-2 spectral bands and indices (NDVI, IRECI)
- Combined Sentinel-1 and -2 SITS



Remote Sensing of Environment
Volume 280, October 2022, 113208

Sentinel-1 interferometric coherence as a vegetation index for agriculture

Arturo Villarroya-Carpio ^a, Juan M. Lopez-Sanchez ^a, , , Marcus E. Engdahl ^b

	P_ID	TIMESTAMP	B01	B02	B03	B04	B05	B06	B07	B08	B8A	B09	B11	B12	NDVI	IRECI	ASC_VV	ASC_VH	DES_VV	DES_VH
0	629195	2019-01-03	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	0.474342	0.462271	0.561583	0.597292
1	629195	2019-01-06	0.0025	0.0277	0.0542	0.0711	0.0944	0.1460	0.1653	0.1852	0.1862	0.2480	0.2044	0.1374	0.445181	0.145691	NaN	NaN	NaN	NaN
2	629195	2019-01-09	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	0.558348	0.393677	0.715511	0.570220
3	629195	2019-01-11	0.0112	0.0277	0.0462	0.0662	0.0966	0.1437	0.1603	0.1670	0.1867	0.2393	0.2050	0.1329	0.432247	0.139981	NaN	NaN	NaN	NaN
4	629195	2019-01-14	0.0205	0.0357	0.0623	0.0759	0.1045	0.1520	0.1689	0.1766	0.1917	0.2475	0.2162	0.1445	0.398812	0.135273	NaN	NaN	NaN	NaN
...
2228169	259918558	2019-12-14	0.0032	0.0125	0.0275	0.0310	0.0446	0.0635	0.0729	0.0873	0.0881	0.1125	0.1104	0.0710	0.475909	0.059656	NaN	NaN	NaN	NaN
2228170	259918558	2019-12-17	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	0.262350	0.273017	0.205720	0.259237
2228171	259918558	2019-12-23	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	0.221484	0.291191	0.296517	0.269125
2228172	259918558	2019-12-24	0.0002	0.0016	0.0205	0.0245	0.0441	0.0605	0.0685	0.0807	0.0837	0.1097	0.1347	0.0977	0.534221	0.060363	NaN	NaN	NaN	NaN
2228173	259918558	2019-12-29	0.0242	0.0572	0.0692	0.0912	0.1046	0.1398	0.1551	0.1910	0.1807	0.1590	0.2397	0.1761	0.353650	0.085404	0.532498	0.518855	0.210954	0.214235

2228174 rows × 20 columns

Machine learning for tree species classification

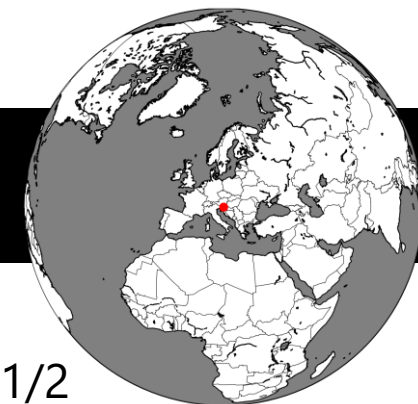


LightGBM:



- raw SITS (not interpolating time series gaps to consistent 5-day intervals, etc.);
- weighed classes (to make more consistent reference dataset);
- did not include *environmental and other additional data in classification analysis because we want to evaluate Sentinel-1 coherence, Sentinel-2 and combined SITS.*

Tree species classification results



Sentinel-2

Accuracy: 0.9031578947368422

Classification Report:

	precision	recall	f1-score	support
1	0.94	0.95	0.94	4756
2	0.89	0.90	0.89	1992
3	0.79	0.87	0.83	373
4	0.82	0.70	0.75	223
5	0.85	0.89	0.87	128
6	0.74	0.49	0.59	91
7	1.00	0.07	0.12	15
8	0.50	0.10	0.16	31
9	0.67	0.32	0.43	19
10	0.43	0.23	0.30	26
11	1.00	0.29	0.44	21
12	0.77	0.80	0.79	223
13	0.62	0.63	0.62	59
14	0.93	0.96	0.94	895
15	0.55	0.32	0.40	19
16	0.60	0.63	0.62	57
17	0.72	0.69	0.70	45
18	0.81	0.85	0.83	52
accuracy			0.90	9025
macro avg	0.76	0.59	0.62	9025
weighted avg	0.90	0.90	0.90	9025

F1-score: 0.8996436875516021

Sentinel-1

Accuracy: 0.8029916897506926

Classification Report:

	precision	recall	f1-score	support
1	0.88	0.89	0.88	4756
2	0.71	0.78	0.75	1992
3	0.60	0.69	0.64	373
4	0.65	0.35	0.46	223
5	0.76	0.59	0.67	128
6	0.56	0.11	0.18	91
7	0.00	0.00	0.00	15
8	0.00	0.00	0.00	31
9	0.67	0.11	0.18	19
10	1.00	0.04	0.07	26
11	0.00	0.00	0.00	21
12	0.56	0.55	0.56	223
13	0.38	0.24	0.29	59
14	0.86	0.95	0.90	895
15	1.00	0.21	0.35	19
16	0.58	0.26	0.36	57
17	0.56	0.42	0.48	45
18	0.57	0.54	0.55	52
accuracy			0.80	9025
macro avg	0.57	0.37	0.41	9025
weighted avg	0.79	0.80	0.79	9025

F1-score: 0.7922246059043783

combined Sentinel-1/2

Accuracy: 0.9042659279778393

Classification Report:

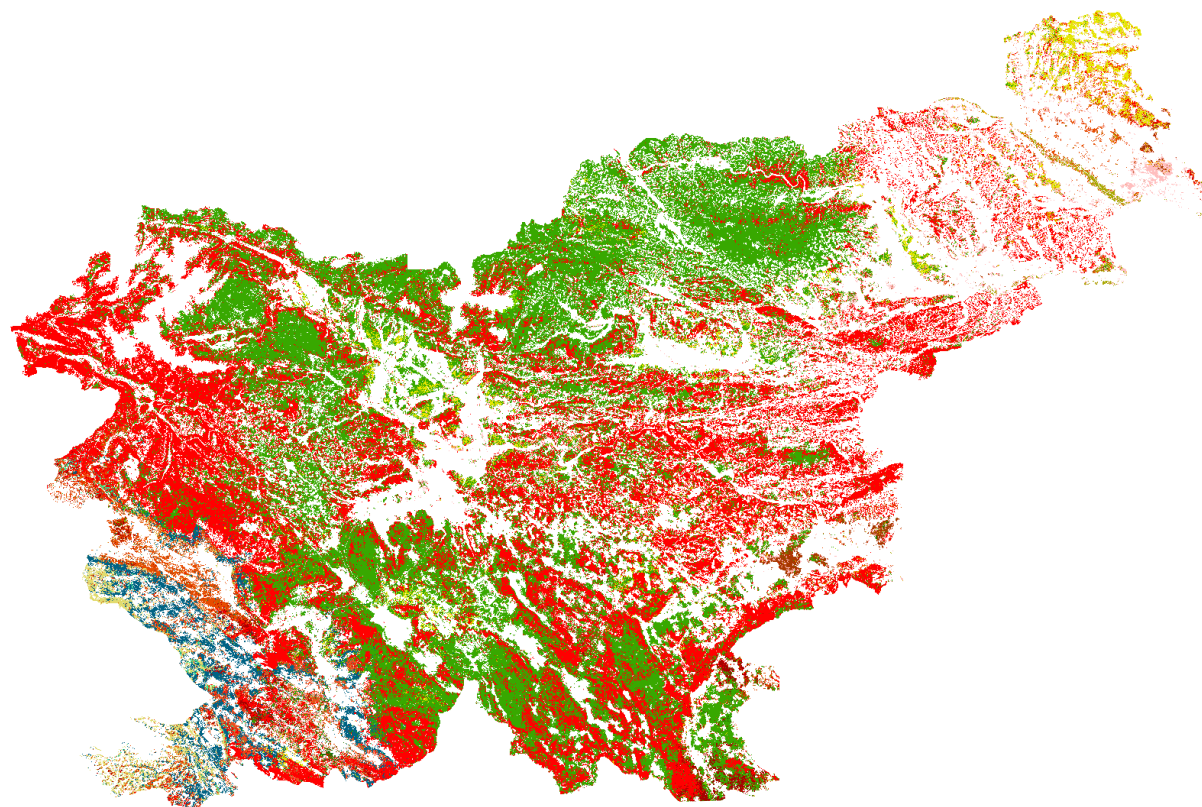
	precision	recall	f1-score	support
1	0.94	0.95	0.94	4756
2	0.88	0.91	0.90	1992
3	0.77	0.87	0.82	373
4	0.83	0.70	0.76	223
5	0.86	0.87	0.86	128
6	0.75	0.43	0.55	91
7	0.50	0.07	0.12	15
8	0.50	0.10	0.16	31
9	0.50	0.26	0.34	19
10	0.62	0.19	0.29	26
11	0.83	0.24	0.37	21
12	0.81	0.82	0.81	223
13	0.62	0.59	0.61	59
14	0.93	0.96	0.95	895
15	0.55	0.32	0.40	19
16	0.64	0.68	0.66	57
17	0.74	0.76	0.75	45
18	0.78	0.83	0.80	52
accuracy			0.90	9025
macro avg	0.73	0.59	0.62	9025
weighted avg	0.90	0.90	0.90	9025

F1-score: 0.9002568913826344

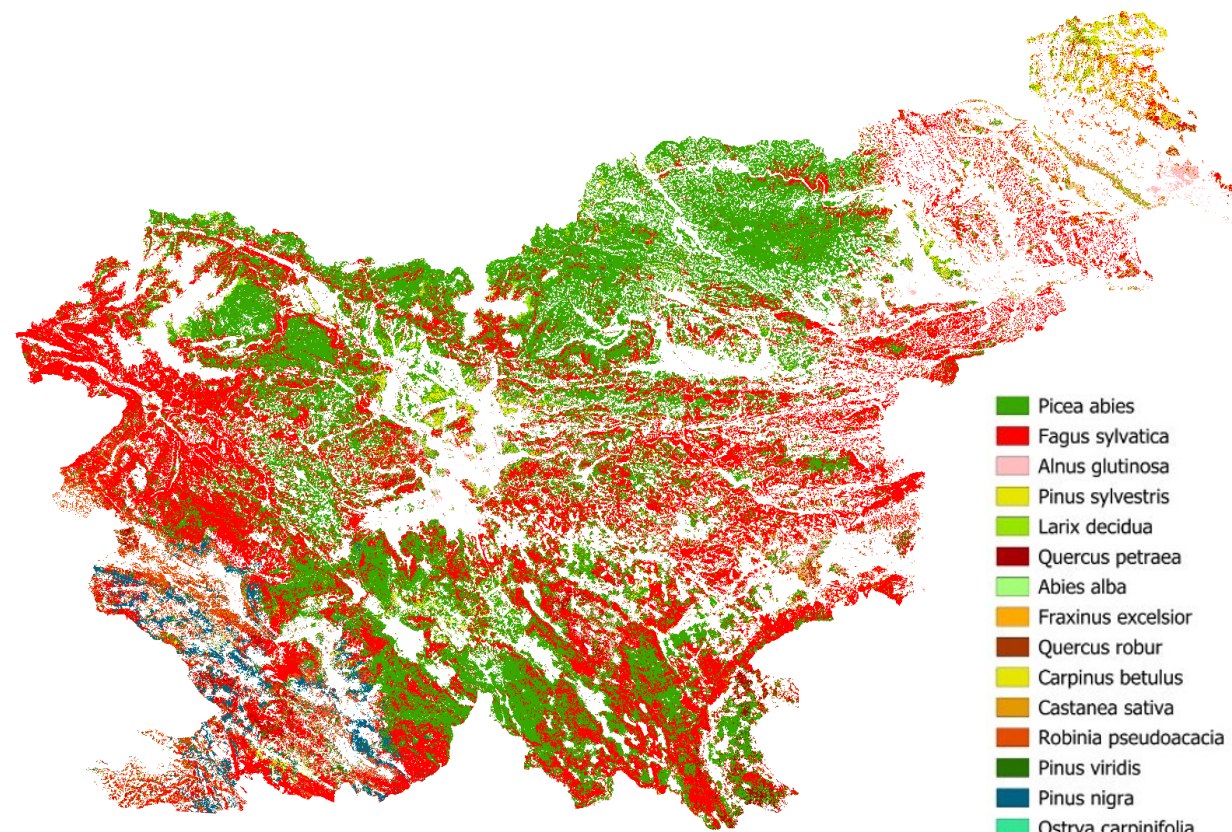
Tree species classification results (maps)



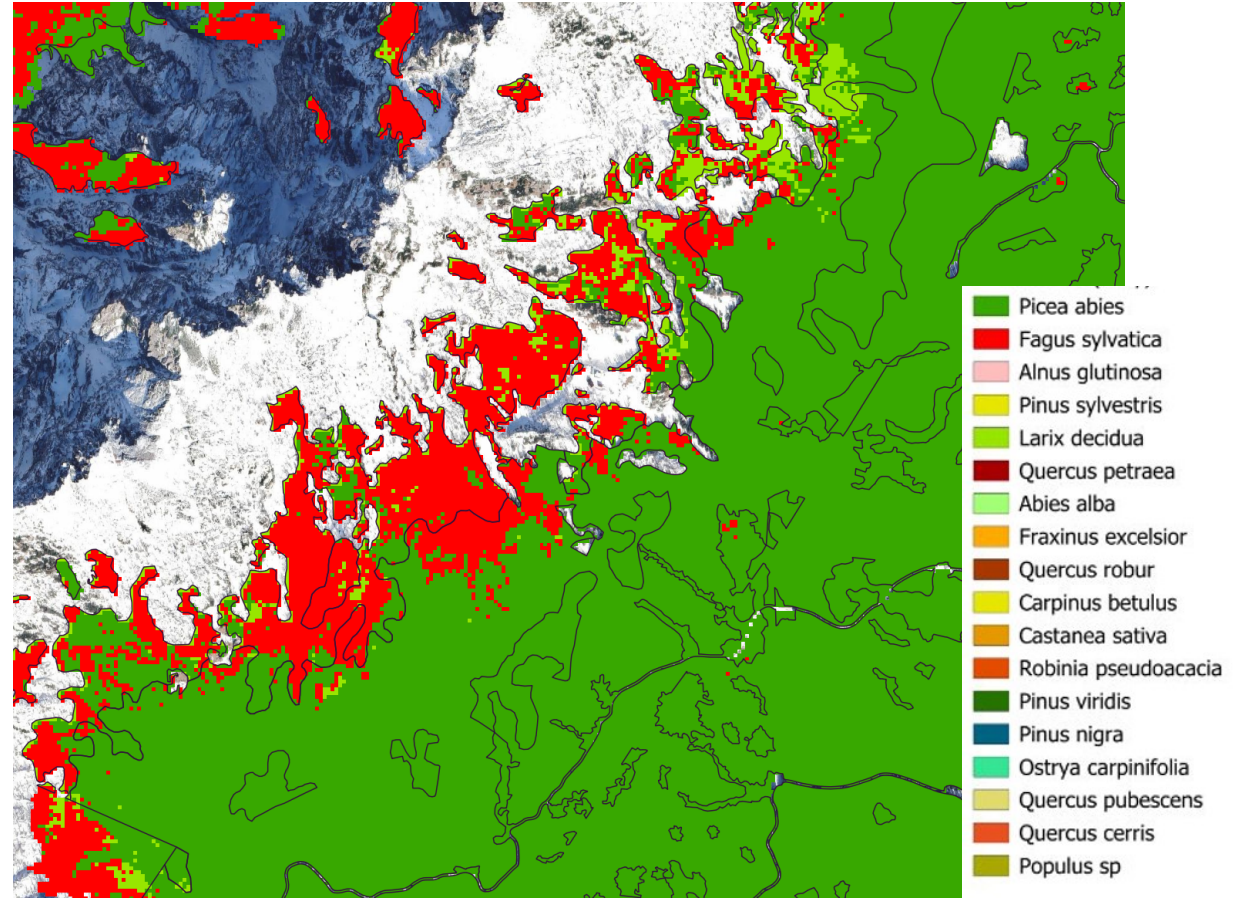
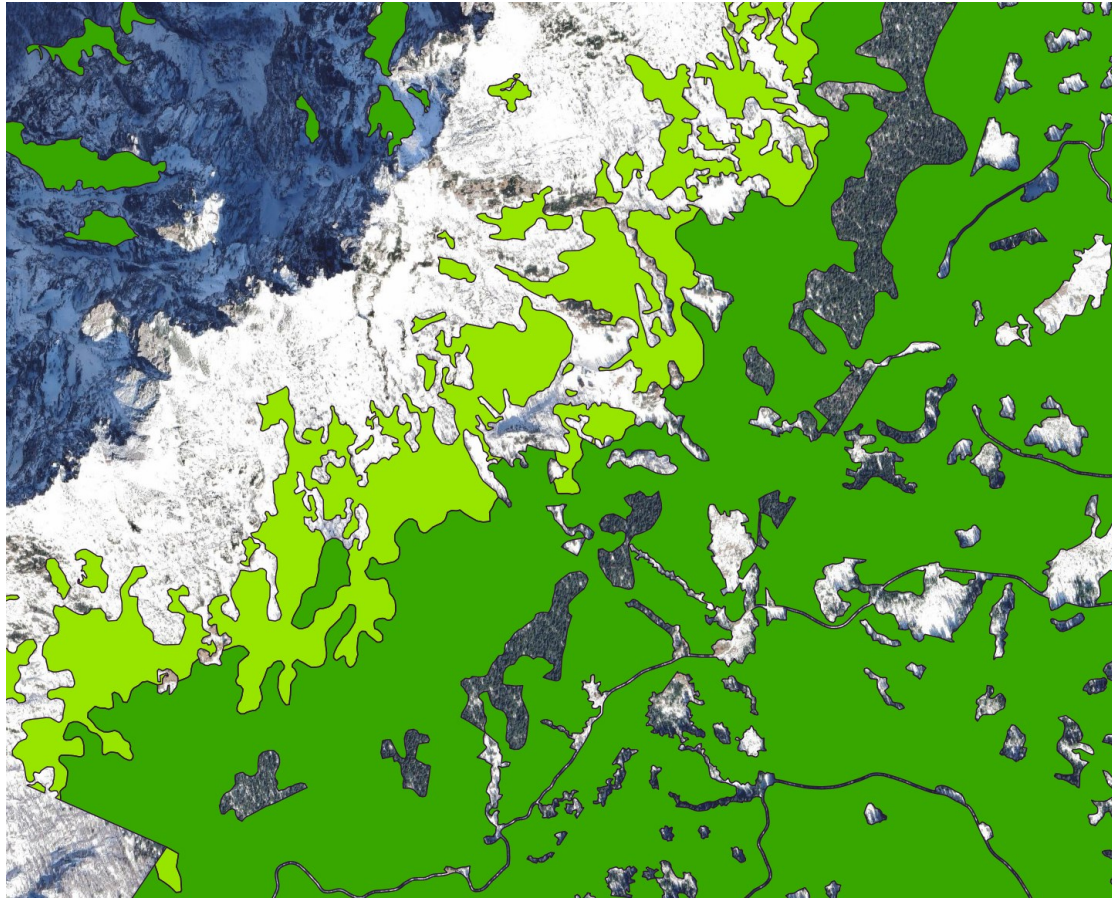
2019



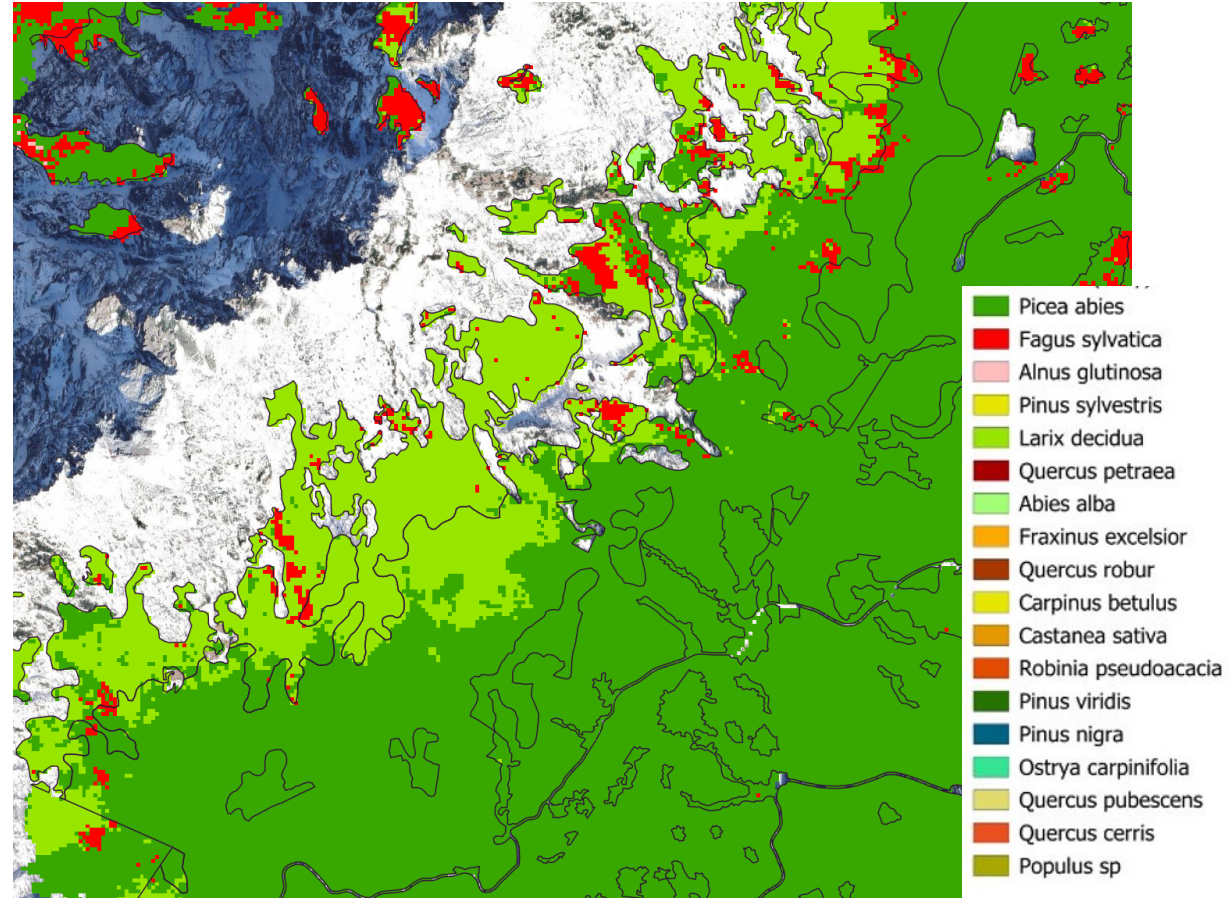
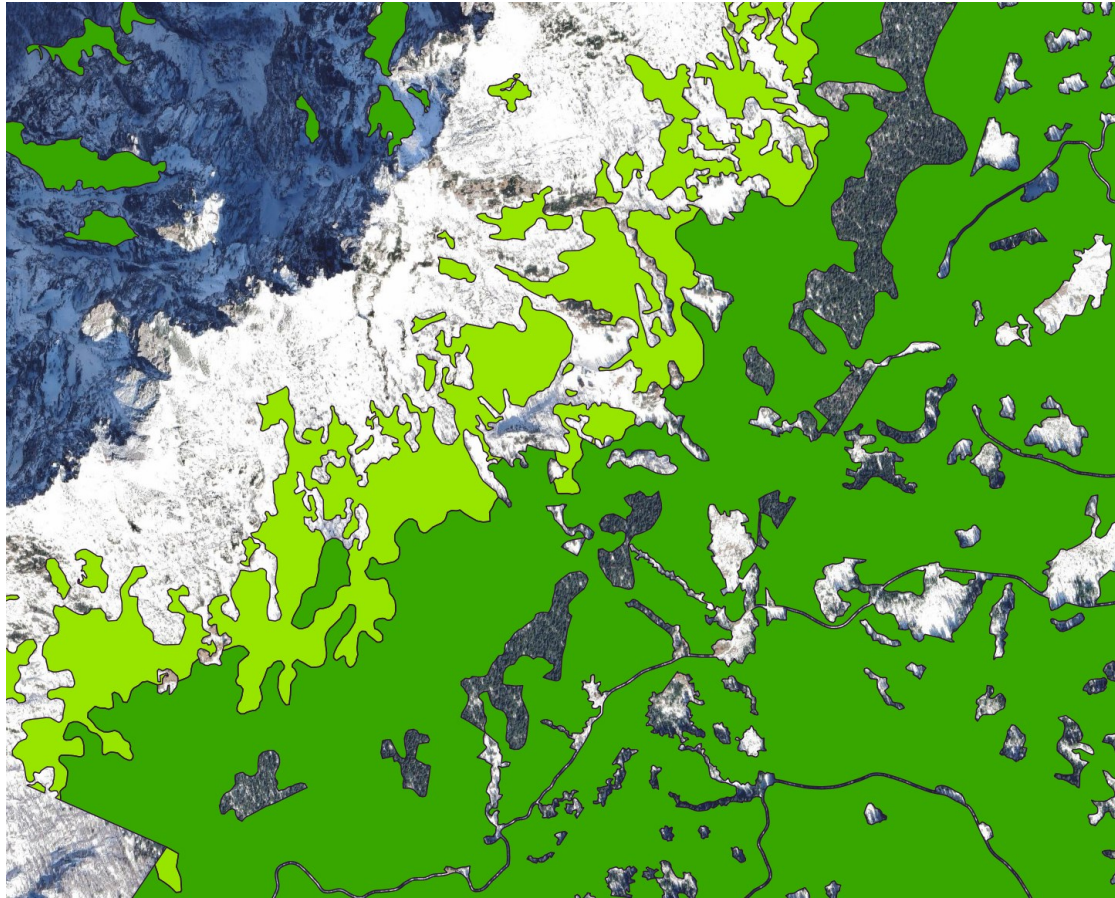
2020



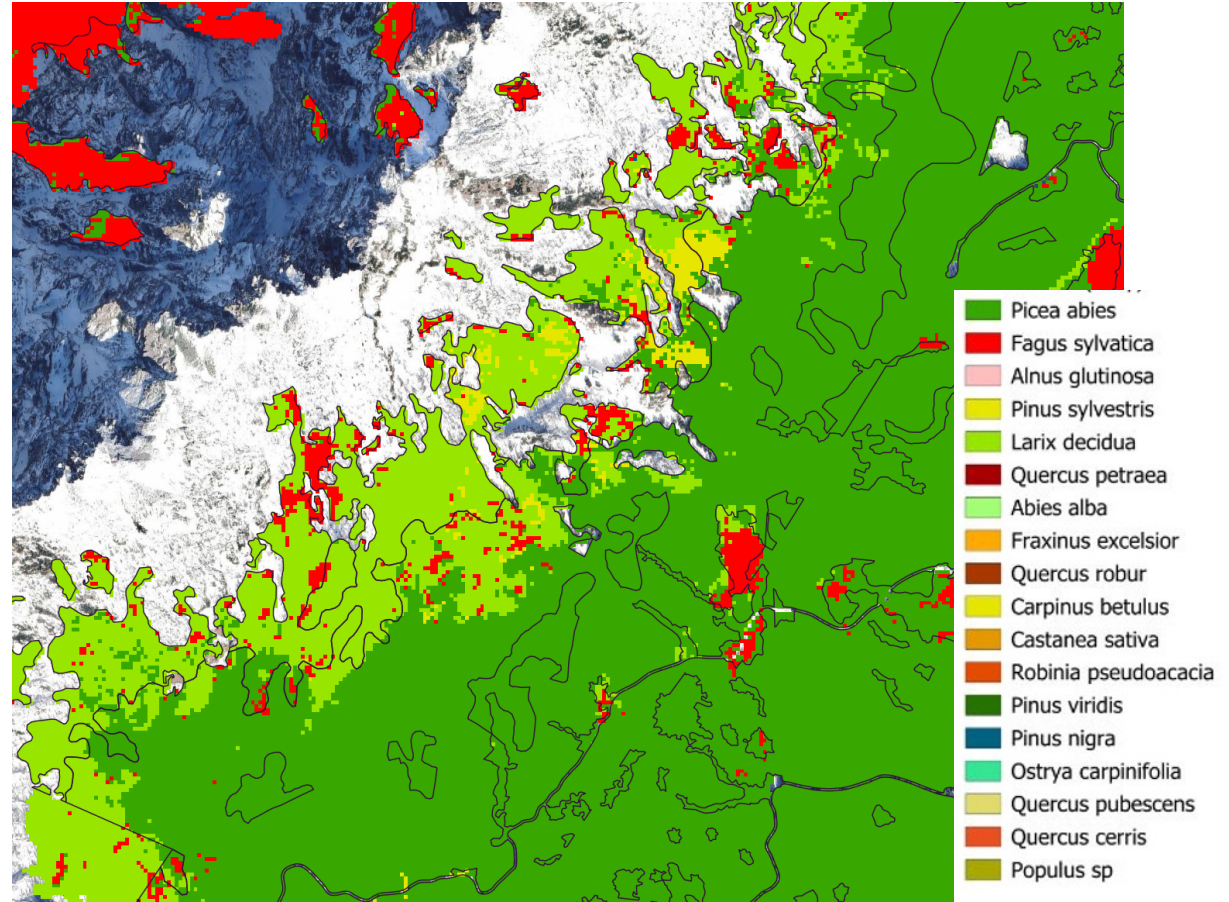
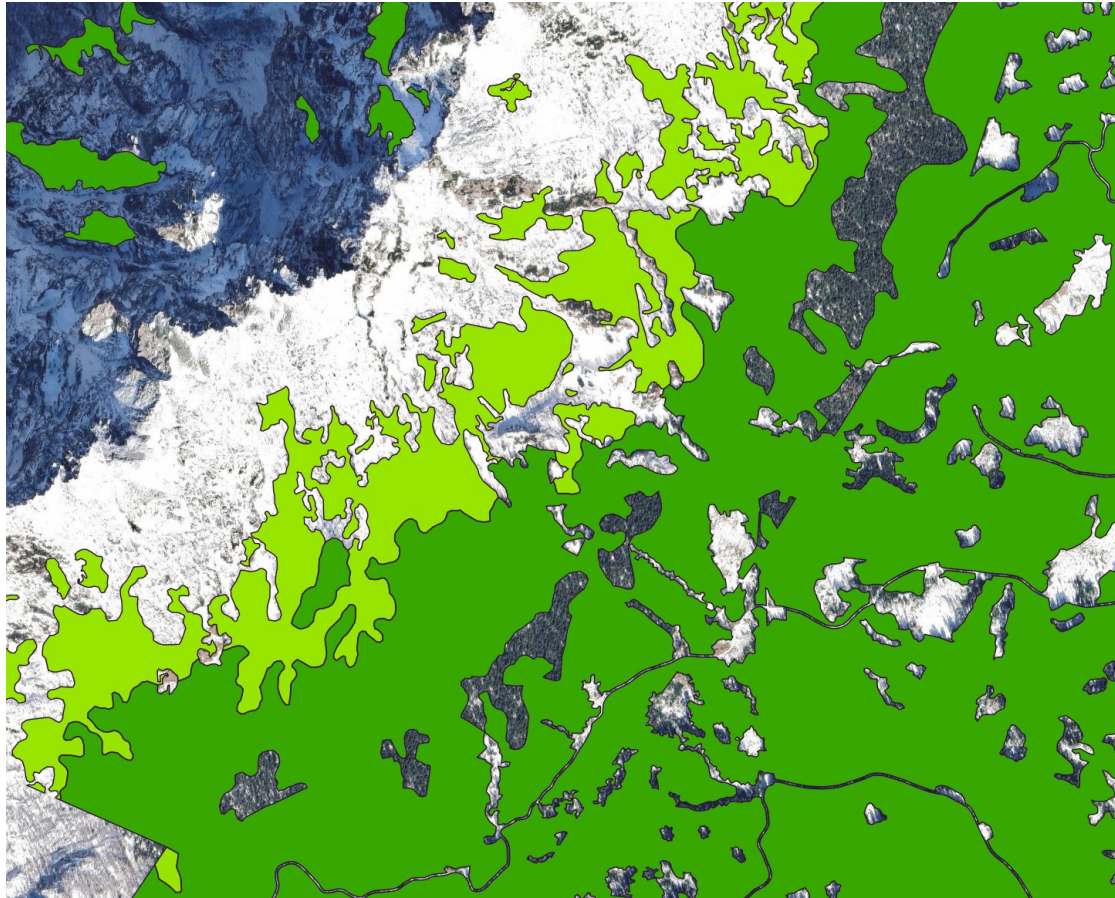
- Picea abies
- Fagus sylvatica
- Alnus glutinosa
- Pinus sylvestris
- Larix decidua
- Quercus petraea
- Abies alba
- Fraxinus excelsior
- Quercus robur
- Carpinus betulus
- Castanea sativa
- Robinia pseudoacacia
- Pinus viridis
- Pinus nigra
- Ostrya carpinifolia
- Quercus pubescens
- Quercus cerris
- Populus sp



2019

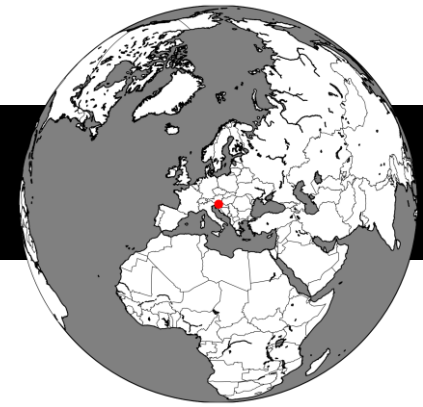


2020

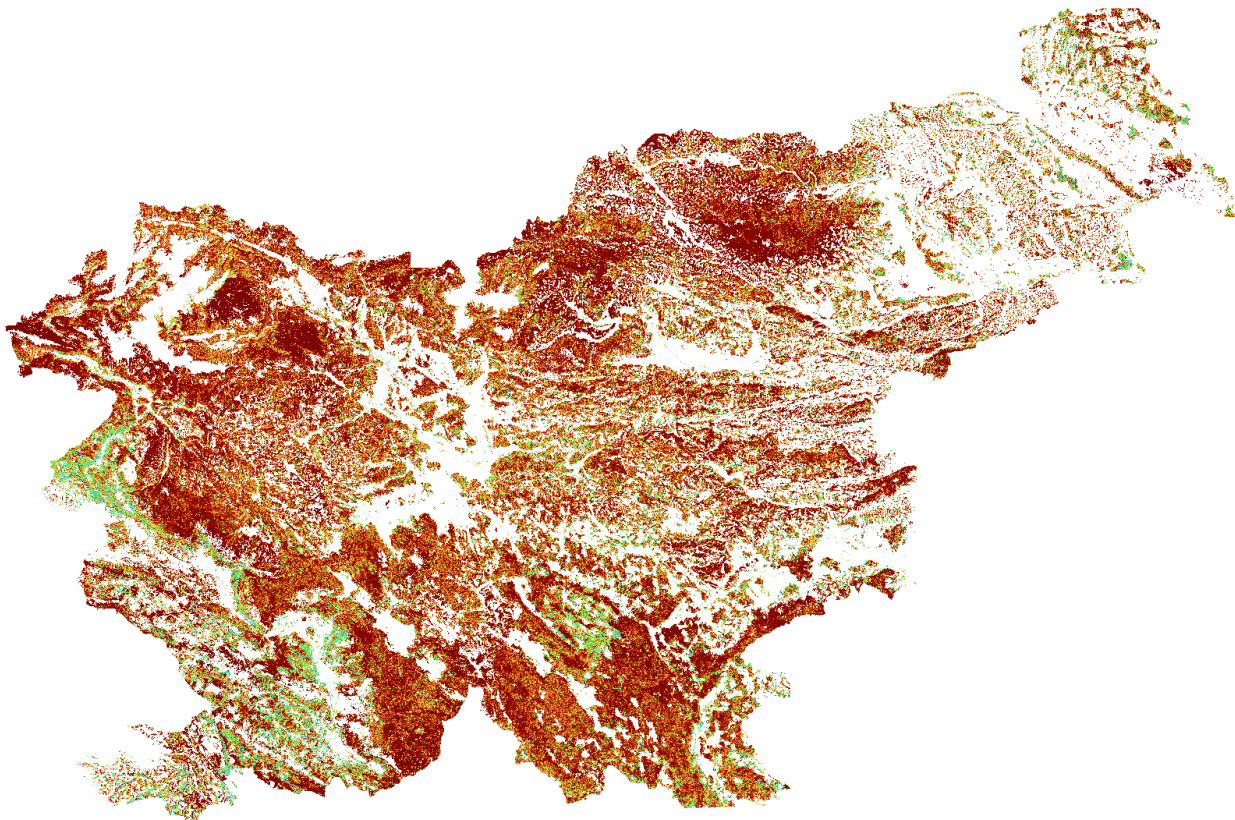


2021

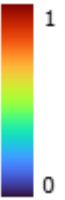
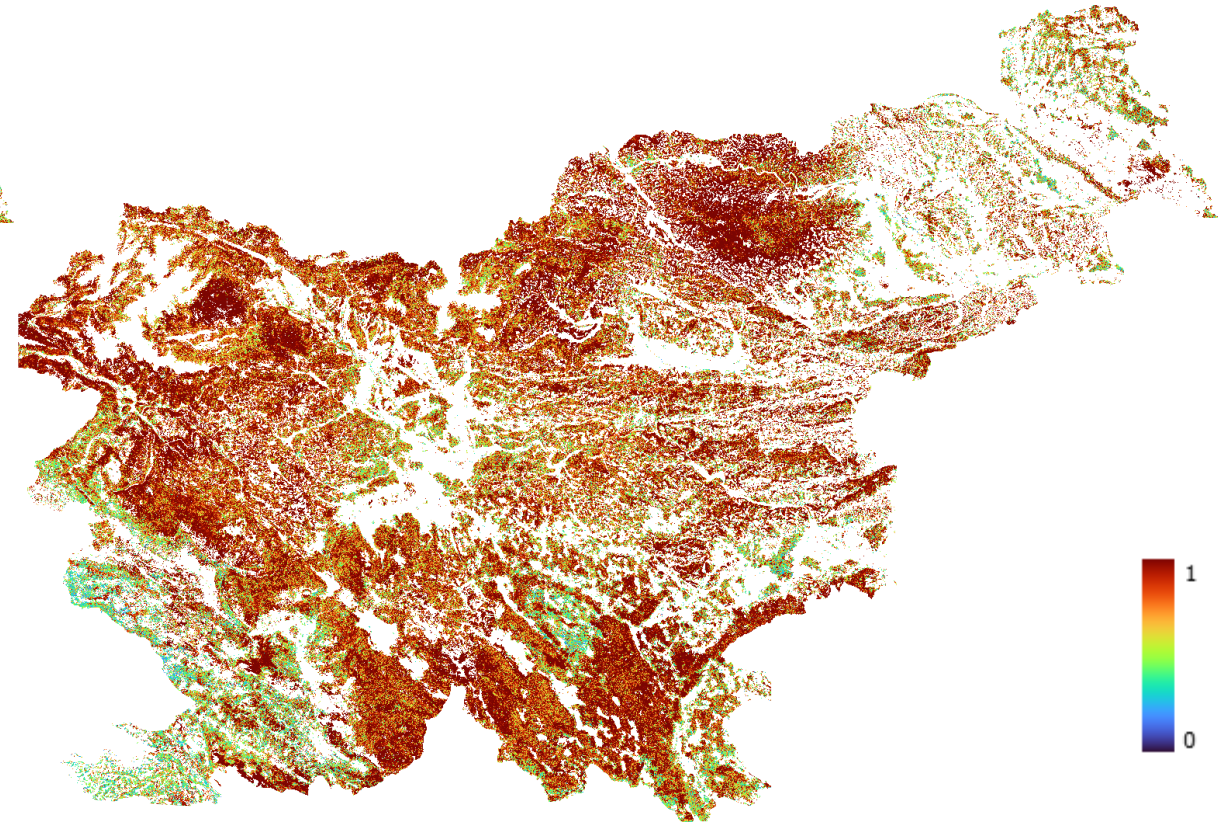
Tree species classification results (margin value)



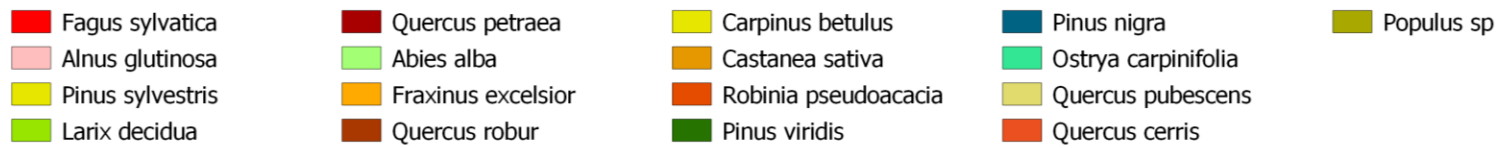
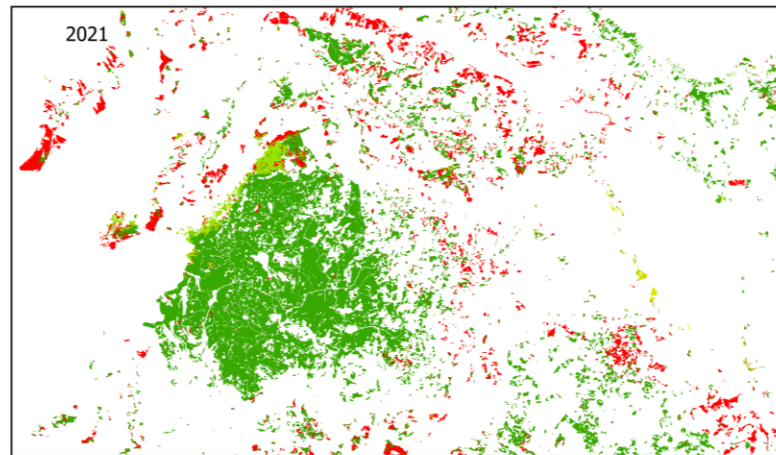
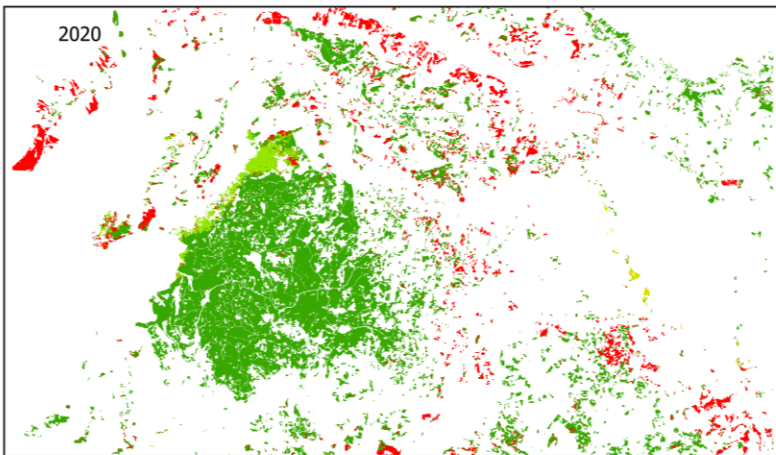
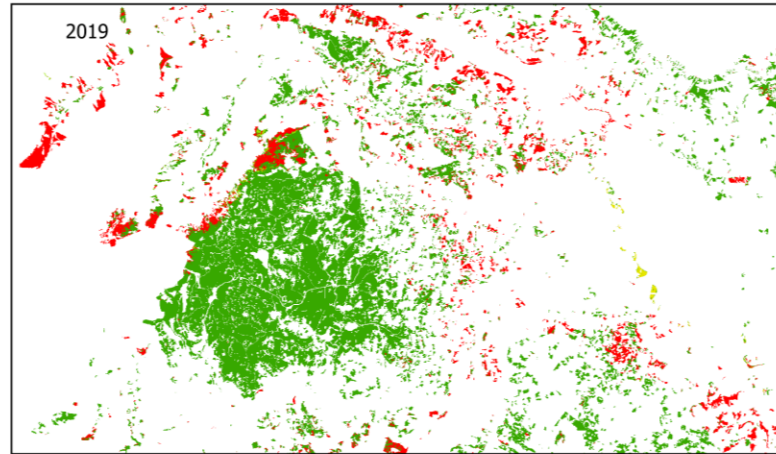
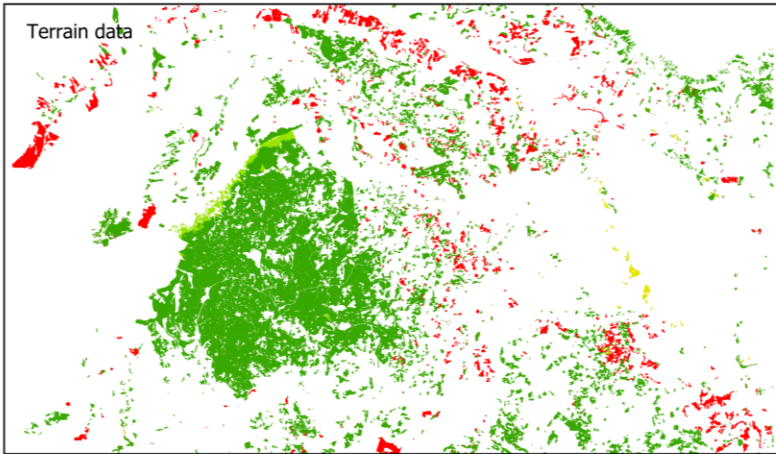
2019

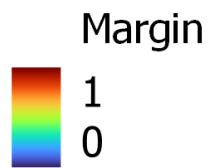
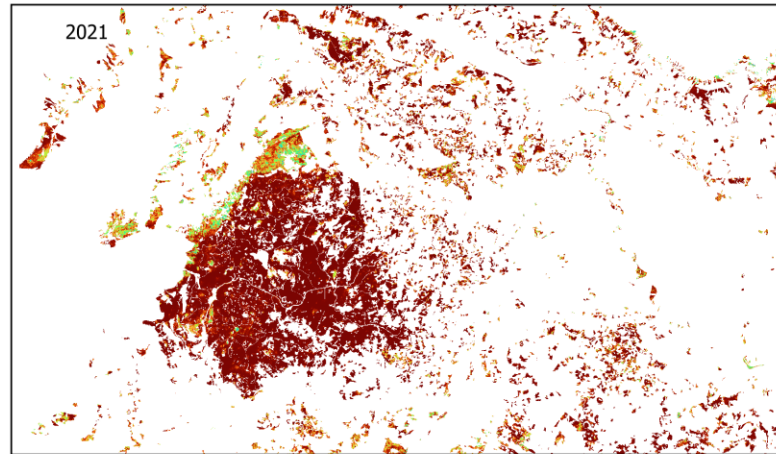
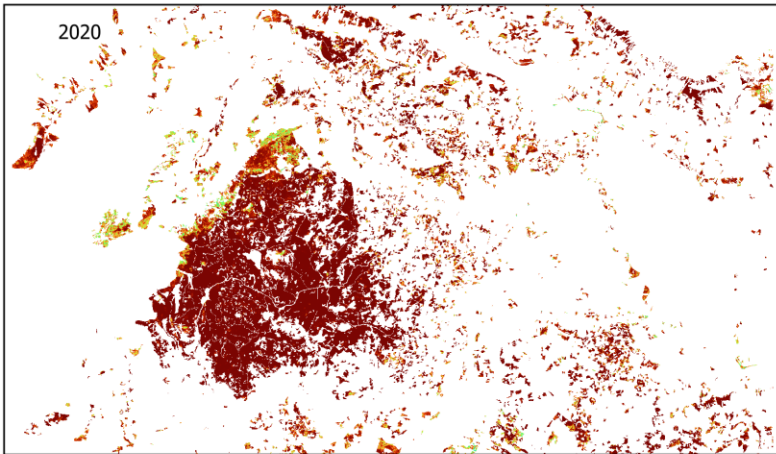
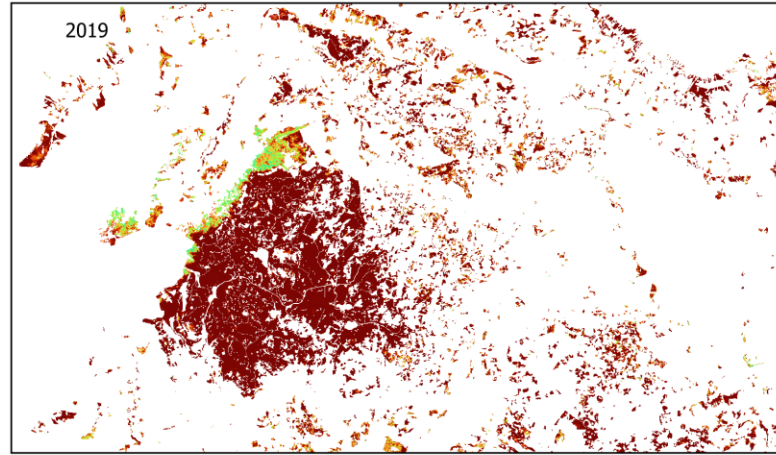
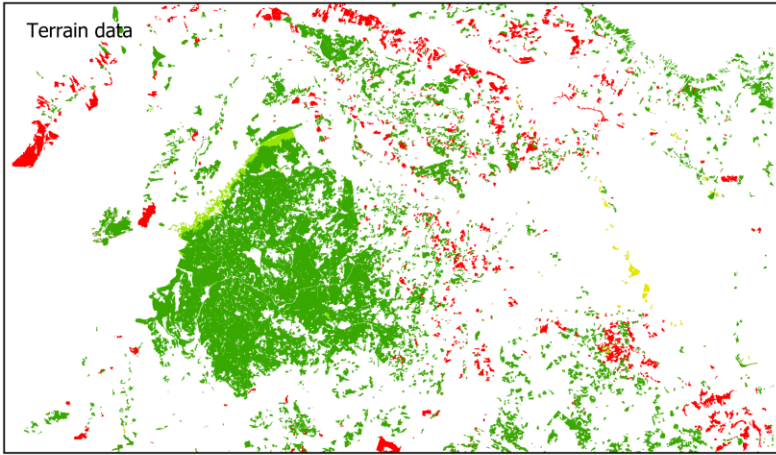


2020



The margin value is the output of the decision trees combined linearly, which represents the model's confidence in its predictions.



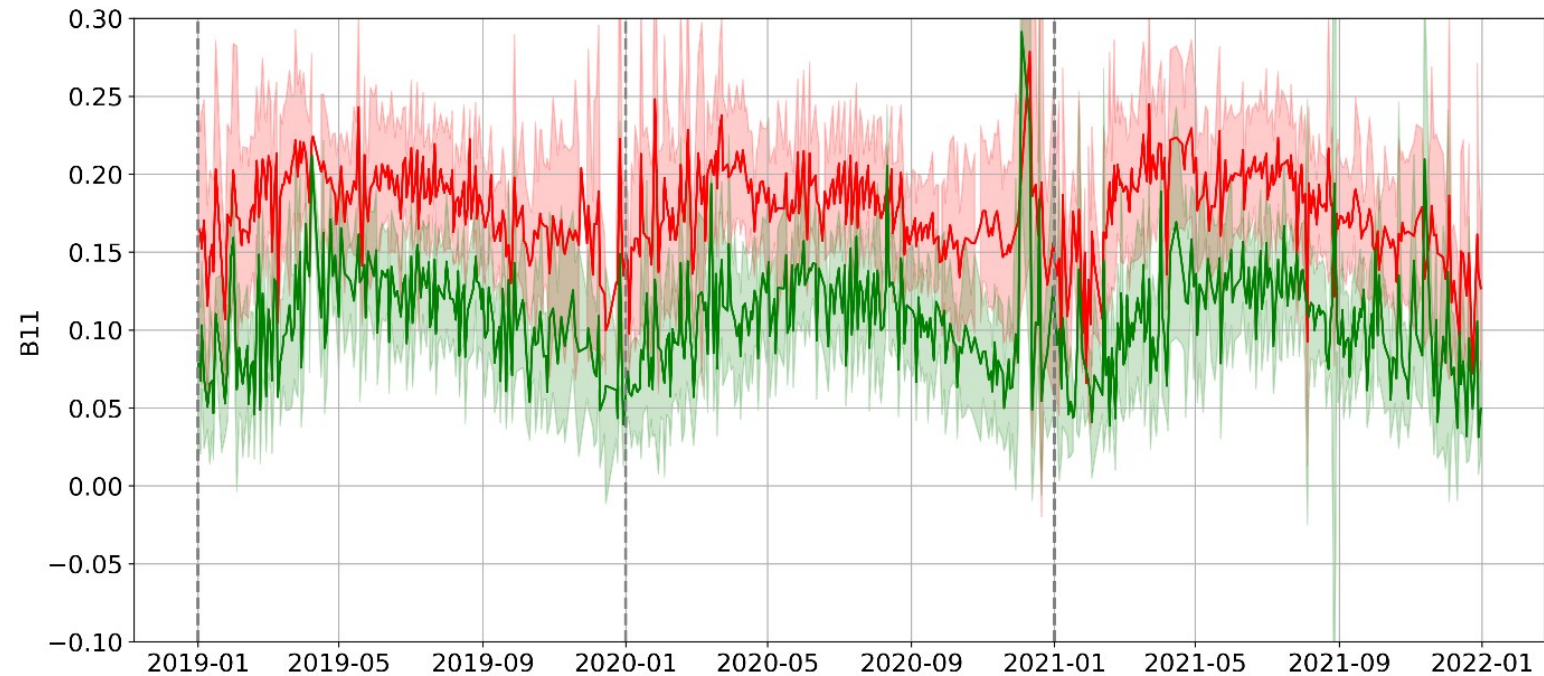


Feature importance (spectral information)

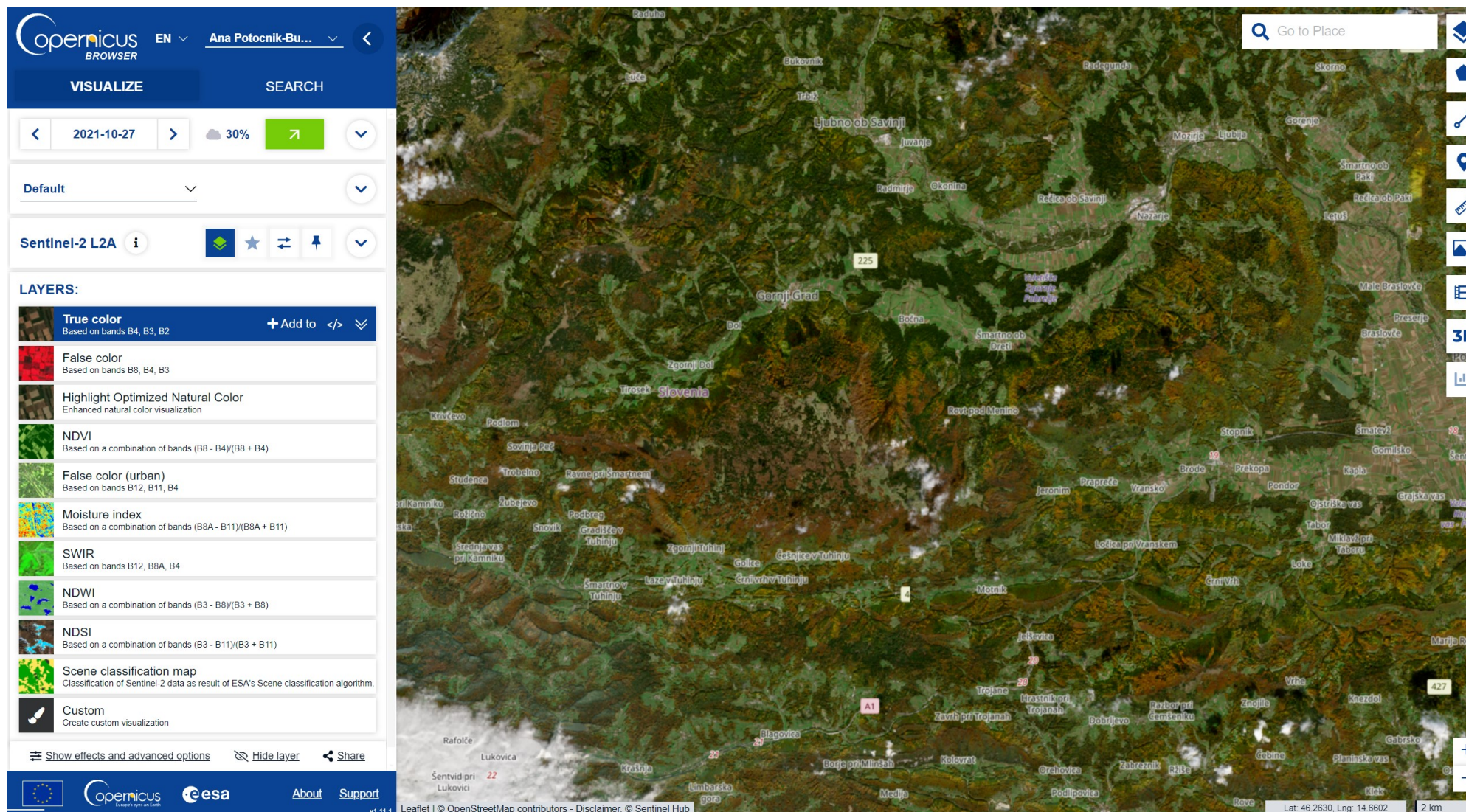


	#	Inf...ain
N B11		0.302
N B12		0.267
N IRECI		0.219
N B05		0.161
N B07		0.144
N B8A		0.135
N B08		0.135
N B06		0.132
N NDVI		0.130
N B09		0.119
N B04		0.090
N B03		0.084
N B01		0.067
N B02		0.056

coniferous / deciduous tree species



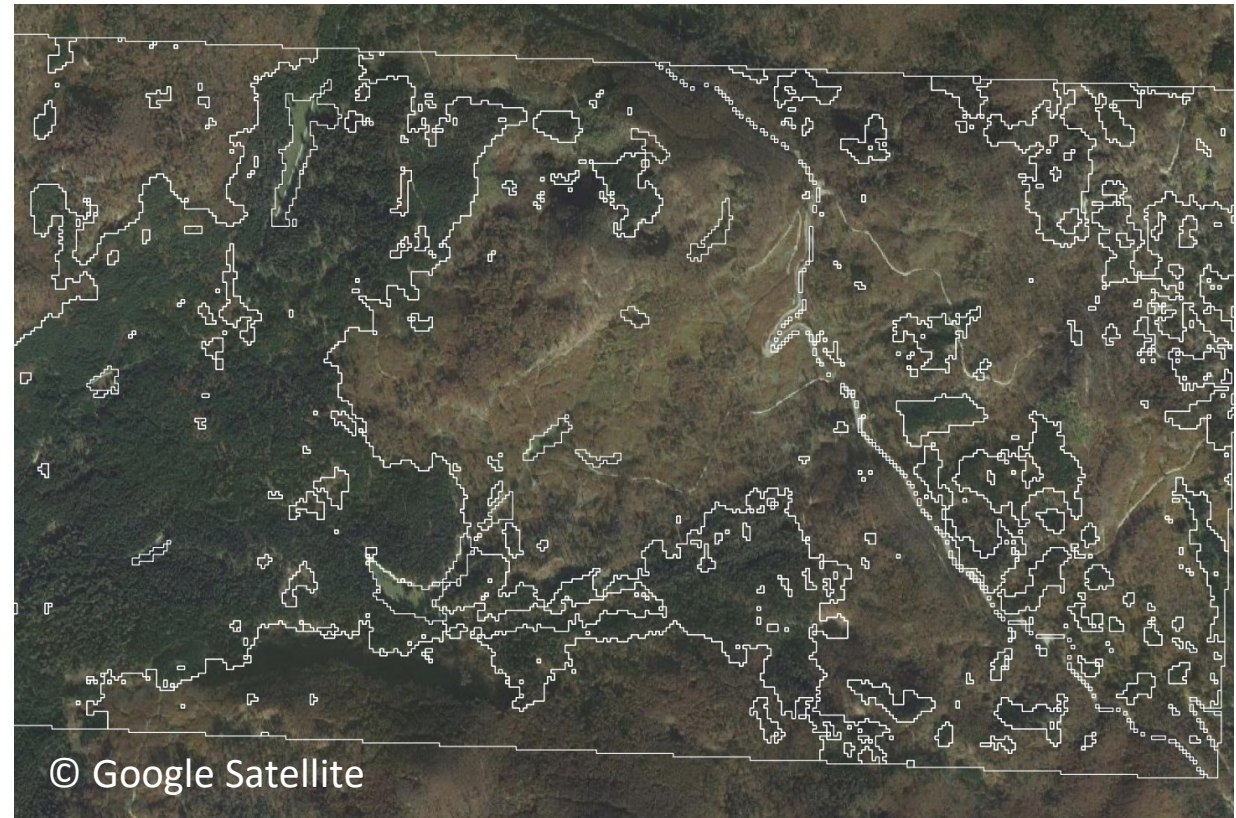
Feature importance (time information)



2021-10-27

coniferous / deciduous tree species

vectorized results out of Sentinel-2 classification (2019)





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THANK YOU FOR YOUR ATTENTION.

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