# Lessons learned while working with Sentinel data

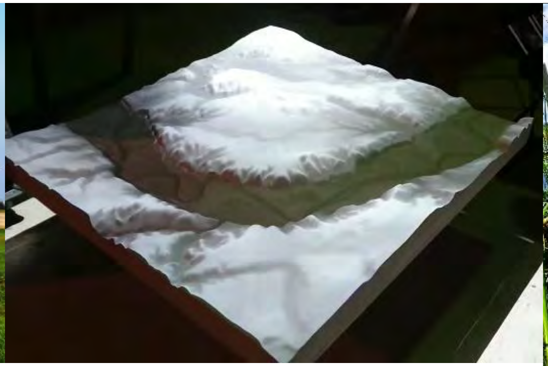
Institute for Environmental Solutions

Dainis Jakovels
Leading Researcher
E: dainis.jakovels@vri.lv

# Institute for Environmental Solutions - overview

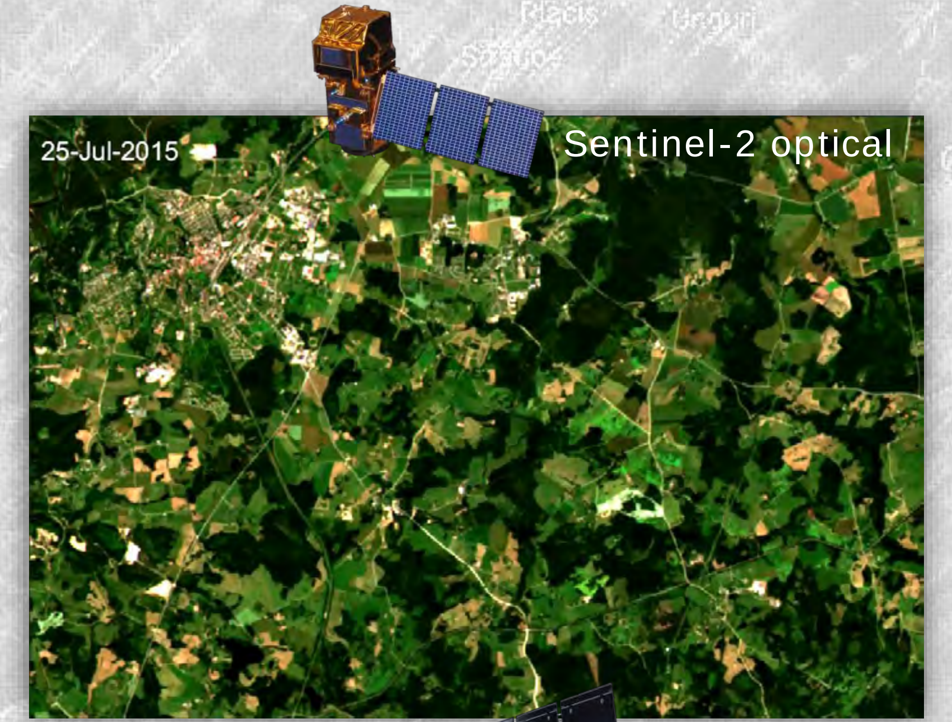
IES is a privately-established research and innovation institution.
We are a multi-disciplinary team of specialists in ecology, limnology, forestry, agriculture, chemistry, physics, technologies, and innovation management who apply EO and RS to develop data-based solutions in their particular fields of expertise.

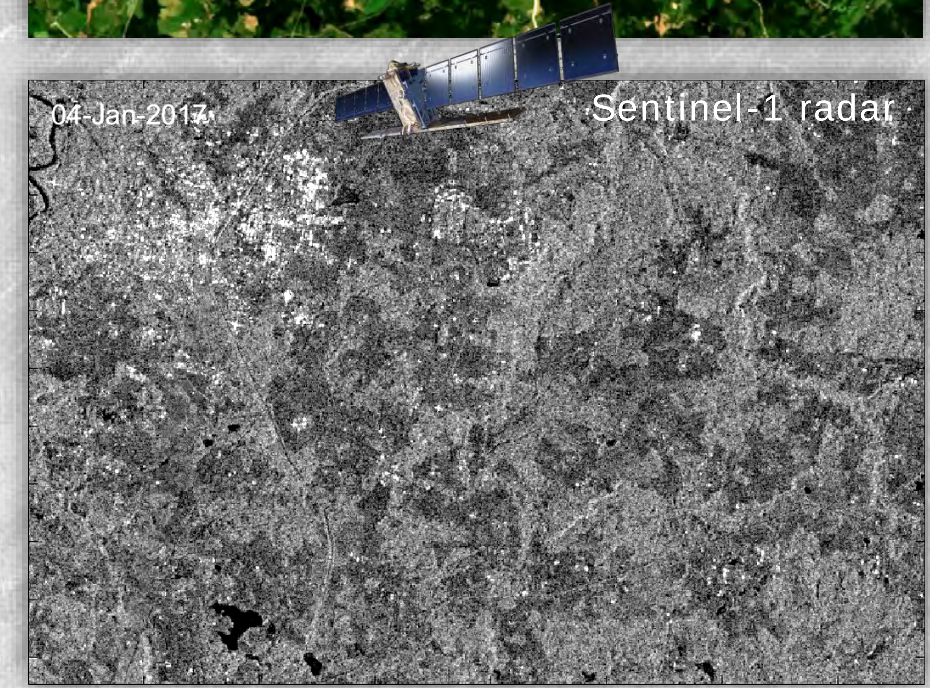
Key focus areas
- Data-based Environmental Solutions
- Earth Observation / Remote Sensing




# Sentinel satellites

Institute for Environmental Solutions

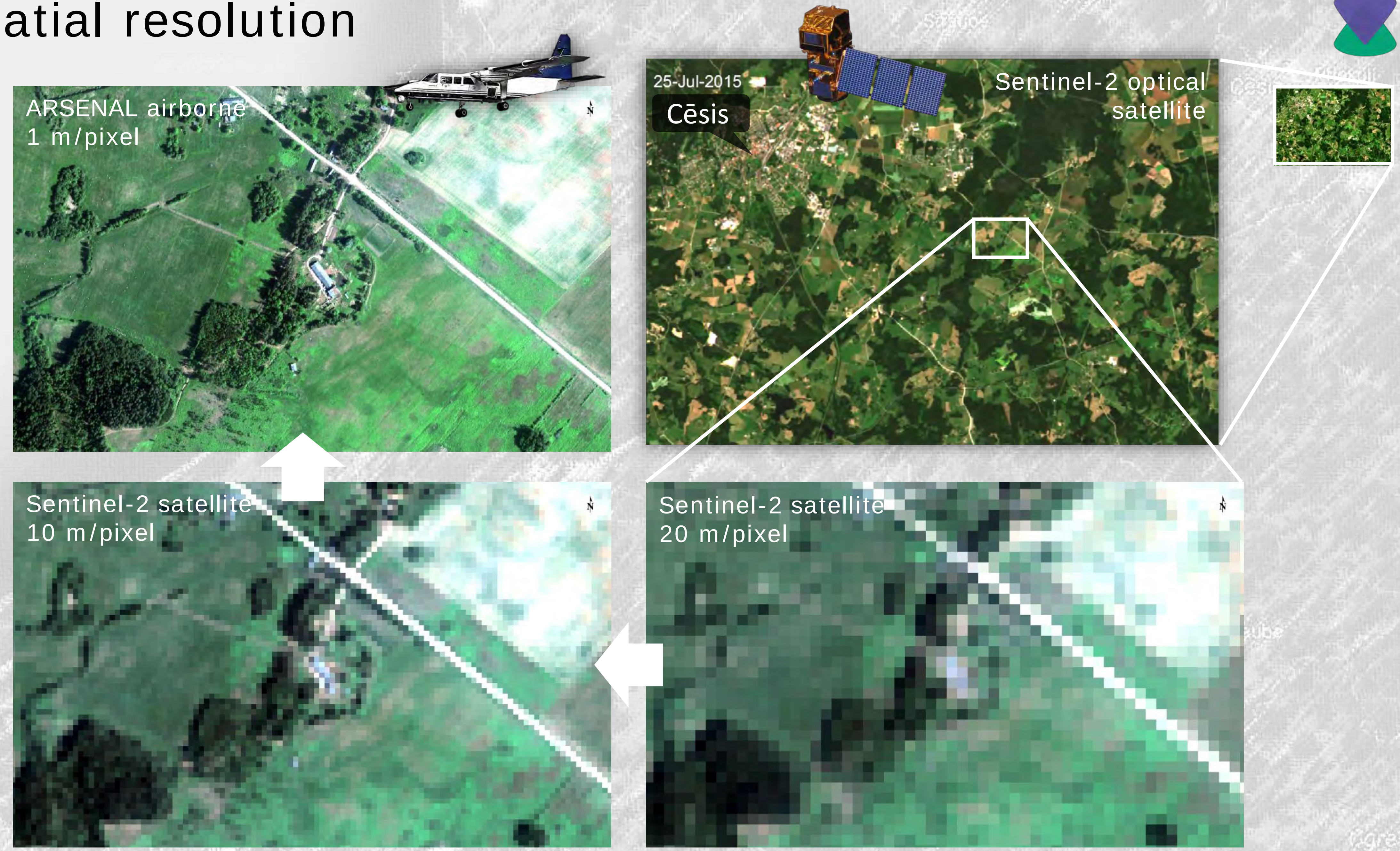



Frequency of data acquisition:
- Once every 5 days with Sentinel-2 optical
- Once every 6 days with Sentinel-1 radar

# Spatial resolution

Institute for Environmental Solutions

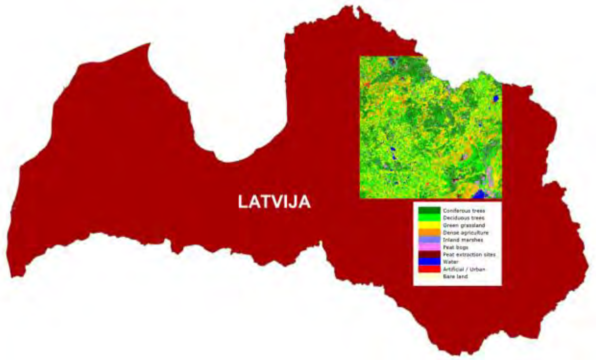



ARSENAL 1 m/pix vs 0,1 m/pix
Grass rolls
Hogweed
Grass rolls
Sheep
Institute for
Environmental
Solutions

# Drone data (< 1 cm/pix)

Institute for Environmental Solutions

# Case study: cross-check of agricultural land use




The pilot study in cooperation with the Rural Support service was performed in autumn 2017 covering 17% of the territory of Latvia. Its objective was cross-checking of declared agricultural land use types (including permanent and cultivated grasslands) using both Sentinel-2 optical and Sentinel-1 radar data.

Dominant agricultural land use/crop types

| Code | Land use / crop type | Sentinel-2 pixels | Percentage |
|---|---|---|---|
| | Total: | 3981250 | 100% |
| 710 | Permanent grasslands | 1701946 | 43% |
| 720 | Cultivated grasslands | 524363 | 13% |
| 112 | Wheat (winter) | 354247 | 9% |
| 111 | Wheat (summer) | 330254 | 8% |
| 131 | Barley (summer) | 144463 | 4% |
| 140 | Oats | 126212 | 3% |
| 610 | Fallow | 124261 | 3% |
| 121 | Rye | 109684 | 3% |
| 410 | Field beans | 77836 | 2% |
| 212 | Rapeseed (winter) | 77325 | 2% |
| 160 | Buckwheat | 76569 | 2% |
| 211 | Rapeseed (summer) | 71946 | 2% |
| 723 | Red clover | 32768 | 1% |
| 741 | Corn - other | 29541 | 1% |
| 791 | Corn for biofuel production | 17730 | 0% |
| 726 | Lucerne | 17002 | 0% |
| 445 | Mixture of cereals and peas or vetches | 15158 | 0% |
| 420 | Peas | 14691 | 0% |
| 141 | Oat with grasses | 13821 | 0% |
| 727 | Eastern galega | 12317 | 0% |
| 151 | Triticale (winter) | 10605 | 0% |
| 113 | Wheat with grasses | 6551 | 0% |
| 820 | Potatoes | 5784 | 0% |

# Case study: cross-check of agricultural land use

Institute for Environmental Solutions

Dominant agricultural land use/crop types

| Code | Land use / crop type | Sentinel-2 pixels | Percentage |
|---|---|---|---|
| | Total: | 3981250 | 100% |
| 710 | Permanent grasslands | 1701946 | 43% |
| 720 | Cultivated grasslands | 524363 | 13% |
| 112 | Wheat (winter) | 354247 | 9% |
| 111 | Wheat (summer) | 330254 | 8% |
| 131 | Barley (summer) | 144463 | 4% |
| 140 | Oats | 126212 | 3% |
| 610 | Fallow | 124261 | 3% |
| 121 | Rye | 109684 | 3% |
| 410 | Field beans | 77836 | 2% |
| 212 | Rapeseed (winter) | 77325 | 2% |
| 160 | Buckwheat | 76569 | 2% |
| 211 | Rapeseed (summer) | 71946 | 2% |
| 723 | Red clover | 32768 | 1% |
| 741 | Corn - other | 29541 | 1% |
| 791 | Corn for biofuel production | 17730 | 0% |
| 726 | Lucerne | 17002 | 0% |
| 445 | Mixture of cereals and peas or vetches | 15158 | 0% |
| 420 | Peas | 14691 | 0% |
| 141 | Oat with grasses | 13821 | 0% |
| 727 | Eastern galega | 12317 | 0% |
| 151 | Triticale (winter) | 10605 | 0% |
| 113 | Wheat with grasses | 6551 | 0% |
| 820 | Potatoes | 5784 | 0% |

Confusion matrix for dominant agricultural land use/crop types using S2 data (May 5 and Aug 30, 2017).

| | 111 | 112 | 121 | 131 | 140 | 151 | 160 | 211 | 212 | 410 | 420 | 710 | 720 | 820 | 740 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 111 | 49% | 1% | 1% | 23% | 12% | 0% | 3% | 1% | 0% | 2% | 3% | 2% | 2% | 1% | 0% |
| 112 | 4% | 66% | 11% | 4% | 1% | 7% | 0% | 0% | 3% | 0% | 2% | 0% | 0% | 0% | 0% |
| 121 | 2% | 21% | 57% | 2% | 2% | 8% | 1% | 0% | 4% | 1% | 2% | 1% | 1% | 1% | 0% |
| 131 | 22% | 1% | 1% | 53% | 7% | 1% | 2% | 0% | 0% | 1% | 4% | 3% | 3% | 1% | 0% |
| 140 | 23% | 0% | 0% | 16% | 38% | 0% | 7% | 1% | 0% | 3% | 3% | 4% | 4% | 2% | 0% |
| 151 | 1% | 32% | 15% | 2% | 0% | 44% | 1% | 0% | 1% | 0% | 2% | 1% | 2% | 0% | 0% |
| 160 | 1% | 0% | 0% | 1% | 4% | 0% | 71% | 1% | 0% | 1% | 1% | 9% | 9% | 2% | 0% |
| 211 | 5% | 0% | 0% | 3% | 4% | 0% | 7% | 75% | 0% | 1% | 1% | 1% | 2% | 0% | 0% |
| 212 | 1% | 16% | 10% | 1% | 0% | 1% | 0% | 0% | 69% | 0% | 1% | 0% | 0% | 0% | 0% |
| 410 | 3% | 0% | 0% | 3% | 8% | 0% | 2% | 0% | 0% | 76% | 2% | 0% | 2% | 2% | 1% |
| 420 | 5% | 0% | 0% | 14% | 3% | 0% | 2% | 0% | 0% | 1% | 62% | 3% | 5% | 3% | 0% |
| 710 | 0% | 0% | 0% | 0% | 0% | 0% | 1% | 0% | 0% | 0% | 0% | 58% | 38% | 0% | 0% |
| 720 | 0% | 0% | 0% | 1% | 1% | 0% | 2% | 0% | 1% | 1% | 1% | 38% | 52% | 2% | 1% |
| 820 | 2% | 1% | 0% | 4% | 1% | 1% | 2% | 0% | 0% | 3% | 8% | 3% | 5% | 69% | 1% |
| 740 | 0% | 0% | 0% | 0% | 1% | 0% | 1% | 0% | 0% | 3% | 0% | 2% | 8% | 1% | 83% |

# Case study: cross-check of agricultural land use

Institute for Environmental Solutions

Dominant agricultural land use/crop types

| Code | Land use / crop type | Sentinel-2 pixels | Percentage |
|---|---|---|---|
| | Total: | 3981250 | 100% |
| 710 | Permanent grasslands | 1701946 | 43% |
| 720 | Cultivated grasslands | 524363 | 13% |
| 112 | Wheat (winter) | 354247 | 9% |
| 111 | Wheat (summer) | 330254 | 8% |
| 131 | Barley (summer) | 144463 | 4% |
| 140 | Oats | 126212 | 3% |
| 610 | Fallow | 124261 | 3% |
| 121 | Rye | 109684 | 3% |
| 410 | Field beans | 77836 | 2% |
| 212 | Rapeseed (winter) | 77325 | 2% |
| 160 | Buckwheat | 76569 | 2% |
| 211 | Rapeseed (summer) | 71946 | 2% |
| 723 | Red clover | 32768 | 1% |
| 741 | Corn - other | 29541 | 1% |
| 791 | Corn for biofuel production | 17730 | 0% |
| 726 | Lucerne | 17002 | 0% |
| 445 | Mixture of cereals and peas or vetches | 15158 | 0% |
| 420 | Peas | 14691 | 0% |
| 141 | Oat with grasses | 13821 | 0% |
| 727 | Eastern galega | 12317 | 0% |
| 151 | Triticale (winter) | 10605 | 0% |
| 113 | Wheat with grasses | 6551 | 0% |
| 820 | Potatoes | 5784 | 0% |

Confusion matrix for dominant agricultural land use/crop types using S1 data (RON 160)

| | 111 | 112 | 121 | 131 | 140 | 151 | 160 | 211 | 212 | 410 | 420 | 710 | 720 | 820 | 740 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 111 | 39% | 3% | 0% | 34% | 19% | 0% | 2% | 0% | 0% | 0% | 0% | 0% | 1% | 0% | 0% |
| 112 | 3% | 62% | 5% | 17% | 3% | 2% | 2% | 0% | 0% | 0% | 0% | 1% | 4% | 0% | 0% |
| 121 | 1% | 5% | 71% | 14% | 1% | 2% | 2% | 0% | 0% | 0% | 0% | 1% | 2% | 1% | 0% |
| 131 | 3% | 1% | 0% | 90% | 2% | 0% | 2% | 0% | 0% | 0% | 0% | 0% | 1% | 0% | 0% |
| 140 | 14% | 2% | 0% | 34% | 42% | 0% | 3% | 0% | 0% | 0% | 0% | 1% | 3% | 1% | 0% |
| 151 | 1% | 12% | 10% | 7% | 1% | 62% | 2% | 0% | 0% | 0% | 0% | 1% | 3% | 0% | 0% |
| 160 | 1% | 3% | 1% | 23% | 1% | 0% | 61% | 0% | 0% | 0% | 0% | 1% | 3% | 4% | 1% |
| 211 | 0% | 0% | 0% | 10% | 0% | 0% | 1% | 87% | 0% | 1% | 0% | 0% | 0% | 1% | 0% |
| 212 | 0% | 0% | 1% | 4% | 0% | 0% | 1% | 0% | 93% | 0% | 0% | 0% | 0% | 0% | 0% |
| 410 | 1% | 1% | 0% | 15% | 1% | 0% | 3% | 1% | 0% | 65% | 4% | 0% | 0% | 7% | 1% |
| 420 | 1% | 0% | 0% | 11% | 1% | 0% | 3% | 1% | 0% | 5% | 75% | 0% | 0% | 2% | 0% |
| 710 | 1% | 2% | 1% | 6% | 1% | 1% | 3% | 0% | 0% | 0% | 0% | 27% | 58% | 0% | 0% |
| 720 | 2% | 3% | 1% | 14% | 2% | 1% | 3% | 0% | 0% | 0% | 0% | 13% | 60% | 0% | 0% |
| 820 | 1% | 1% | 0% | 9% | 1% | 0% | 3% | 0% | 0% | 1% | 0% | 1% | 2% | 81% | 1% |
| 740 | 1% | 1% | 0% | 29% | 1% | 0% | 10% | 0% | 0% | 1% | 0% | 0% | 1% | 10% | 46% |

# Case study: cross-check of agricultural land use

Institute for Environmental Solutions

Dominant agricultural land use/crop types

| Code | Land use / crop type | Sentinel-2 pixels | Percentage |
|---|---|---|---|
| | Total: | 3981250 | 100% |
| 710 | Permanent grasslands | 1701946 | 43% |
| 720 | Cultivated grasslands | 524363 | 13% |
| 112 | Wheat (winter) | 354247 | 9% |
| 111 | Wheat (summer) | 330254 | 8% |
| 131 | Barley (summer) | 144463 | 4% |
| 140 | Oats | 126212 | 3% |
| 610 | Fallow | 124261 | 3% |
| 121 | Rye | 109684 | 3% |
| 410 | Field beans | 77836 | 2% |
| 212 | Rapeseed (winter) | 77325 | 2% |
| 160 | Buckwheat | 76569 | 2% |
| 211 | Rapeseed (summer) | 71946 | 2% |
| 723 | Red clover | 32768 | 1% |
| 741 | Corn - other | 29541 | 1% |
| 791 | Corn for biofuel production | 17730 | 0% |
| 726 | Lucerne | 17002 | 0% |
| 445 | Mixture of cereals and peas or vetches | 15158 | 0% |
| 420 | Peas | 14691 | 0% |
| 141 | Oat with grasses | 13821 | 0% |
| 727 | Eastern galega | 12317 | 0% |
| 151 | Triticale (winter) | 10605 | 0% |
| 113 | Wheat with grasses | 6551 | 0% |
| 820 | Potatoes | 5784 | 0% |

Confusion matrix for dominant agricultural land use/crop types using combined S1&S2 approach.

| | 111 | 112 | 121 | 131 | 140 | 151 | 160 | 211 | 212 | 410 | 420 | 710 | 720 | 820 | 740 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **111** | 63% | 1% | 0% | 18% | 13% | 0% | 2% | 0% | 0% | 0% | 0% | 1% | 1% | 0% | 0% |
| **112** | 4% | **86%** | 3% | 3% | 1% | 1% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| **121** | 2% | 9% | 81% | 3% | 2% | 2% | 1% | 0% | 0% | 0% | 1% | 0% | 1% | 0% | 0% |
| **131** | 5% | 1% | 0% | 84% | 4% | 0% | 2% | 0% | 0% | 0% | 0% | 1% | 2% | 0% | 0% |
| **140** | 18% | 0% | 0% | 16% | 55% | 0% | 6% | 0% | 0% | 1% | 0% | 1% | 3% | 0% | 0% |
| **151** | 1% | 17% | 8% | 1% | 1% | 70% | 1% | 0% | 0% | 0% | 0% | 0% | 1% | 0% | 0% |
| **160** | 1% | 1% | 0% | 2% | 3% | 0% | **87%** | 0% | 0% | 0% | 0% | 2% | 3% | 1% | 0% |
| **211** | 1% | 0% | 0% | 3% | 1% | 0% | 4% | **89%** | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| **212** | 1% | 2% | 1% | 1% | 0% | 0% | 0% | 0% | **93%** | 0% | 0% | 0% | 0% | 0% | 0% |
| **410** | 1% | 0% | 0% | 2% | 4% | 0% | 2% | 0% | 0% | **88%** | 1% | 0% | 0% | 1% | 0% |
| **420** | 1% | 0% | 0% | 5% | 1% | 0% | 2% | 0% | 0% | 1% | **87%** | 0% | 1% | 1% | 0% |
| **710** | 0% | 0% | 0% | 1% | 0% | 0% | 1% | 0% | 0% | 0% | 0% | 41% | 57% | 0% | 0% |
| **720** | 1% | 1% | 0% | 4% | 2% | 0% | 2% | 0% | 0% | 0% | 0% | 16% | 72% | 1% | 0% |
| **820** | 1% | 0% | 0% | 2% | 1% | 0% | 2% | 0% | 0% | 1% | 1% | 1% | 3% | **88%** | 0% |
| **740** | 0% | 0% | 0% | 1% | 1% | 0% | 2% | 0% | 0% | 0% | 0% | 0% | 2% | 1% | **93%** |

# Case study: cross-check of agricultural land use

Institute for Environmental Solutions

Dominant agricultural land use/crop types

| Code | Land use / crop type | Sentinel-2 pixels | Percentage |
|---|---|---|---|
| | Total: | 3981250 | 100% |
| 710 | Permanent grasslands | 1701946 | 43% |
| 720 | Cultivated grasslands | 524363 | 13% |
| 112 | Wheat (winter) | 354247 | 9% |
| 111 | Wheat (summer) | 330254 | 8% |
| 131 | Barley (summer) | 144463 | 4% |
| 140 | Oats | 126212 | 3% |
| 610 | Fallow | 124261 | 3% |
| 121 | Rye | 109684 | 3% |
| 410 | Field beans | 77836 | 2% |
| 212 | Rapeseed (winter) | 77325 | 2% |
| 160 | Buckwheat | 76569 | 2% |
| 211 | Rapeseed (summer) | 71946 | 2% |
| 723 | Red clover | 32768 | 1% |
| 741 | Corn - other | 29541 | 1% |
| 791 | Corn for biofuel production | 17730 | 0% |
| 726 | Lucerne | 17002 | 0% |
| 445 | Mixture of cereals and peas or vetches | 15158 | 0% |
| 420 | Peas | 14691 | 0% |
| 141 | Oat with grasses | 13821 | 0% |
| 727 | Eastern galega | 12317 | 0% |
| 151 | Triticale (winter) | 10605 | 0% |
| 113 | Wheat with grasses | 6551 | 0% |
| 820 | Potatoes | 5784 | 0% |

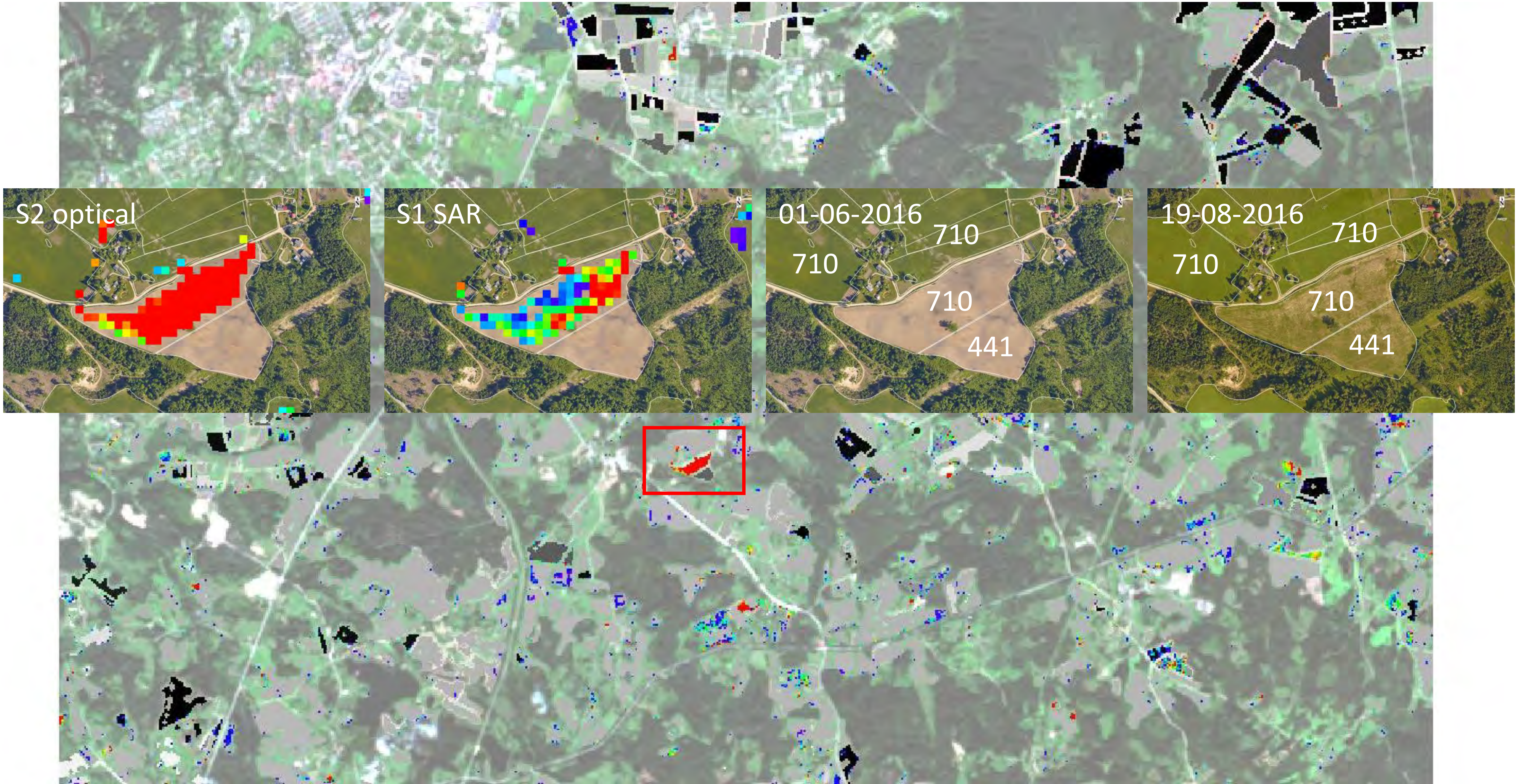
Confusion matrix for dominant agricultural land use/crop types using combined S1&S2 approach.

| | 111 | 112 | 121 | 131 | 140 | 151 | 160 | 211 | 212 | 410 | 420 | 710 | 720 | 820 | 740 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 111 | 63% | 1% | 0% | 18% | 13% | 0% | 2% | 0% | 0% | 0% | 0% | 1% | 1% | 0% | 0% |
| 112 | | | | | | | | | | | | | | | 0% |
| 121 | | | | | | | | | | | | | | | 0% |
| 131 | | | | | | | | | | | | | | | 0% |
| 140 | | | | | | | | | | | | | | | 0% |
| 151 | | | | | | | | | | | | | | | 0% |
| 160 | | | | | | | | | | | | | | | 0% |
| 211 | | | | | | | | | | | | | | | 0% |
| 212 | | | | | | | | | | | | | | | 0% |
| 410 | 1% | 0% | 0% | 2% | 4% | 0% | 2% | 0% | [illegible] | | | | 0% | 1% | 0% |
| 420 | 1% | 0% | 0% | 5% | 1% | 0% | 2% | 0% | 0% | 1% | | | 1% | 1% | 0% |
| 710 | 0% | 0% | 0% | 1% | 0% | 0% | 1% | 0% | 0% | 0% | 0% | [illegible] | 57% | 0% | 0% |
| 720 | 1% | 1% | 0% | 4% | 2% | 0% | 2% | 0% | 0% | 0% | 0% | 16% | 72% | 1% | 0% |
| 820 | 1% | 0% | 0% | 2% | 1% | 0% | 2% | 0% | 0% | 1% | 1% | 1% | 3% | 88% | 0% |
| 740 | 0% | 0% | 0% | 1% | 1% | 0% | 2% | 0% | 0% | 0% | 0% | 0% | 2% | 1% | 93% |

Producer's accuracy for classification of grasslands using different Sentinel data types.

| Sentinel data type | Producer's accuracy for grasslands |
|---|---|
| Sentinel-1 RON 80 | 89 % |
| Sentinel-1 RON 160 | 85 % |
| Sentinel-2 (2 scenes) | 96 % |
| Sentinel-1 + Sentinel-2 | 97 % |

# Case study: cross-check of agricultural land use

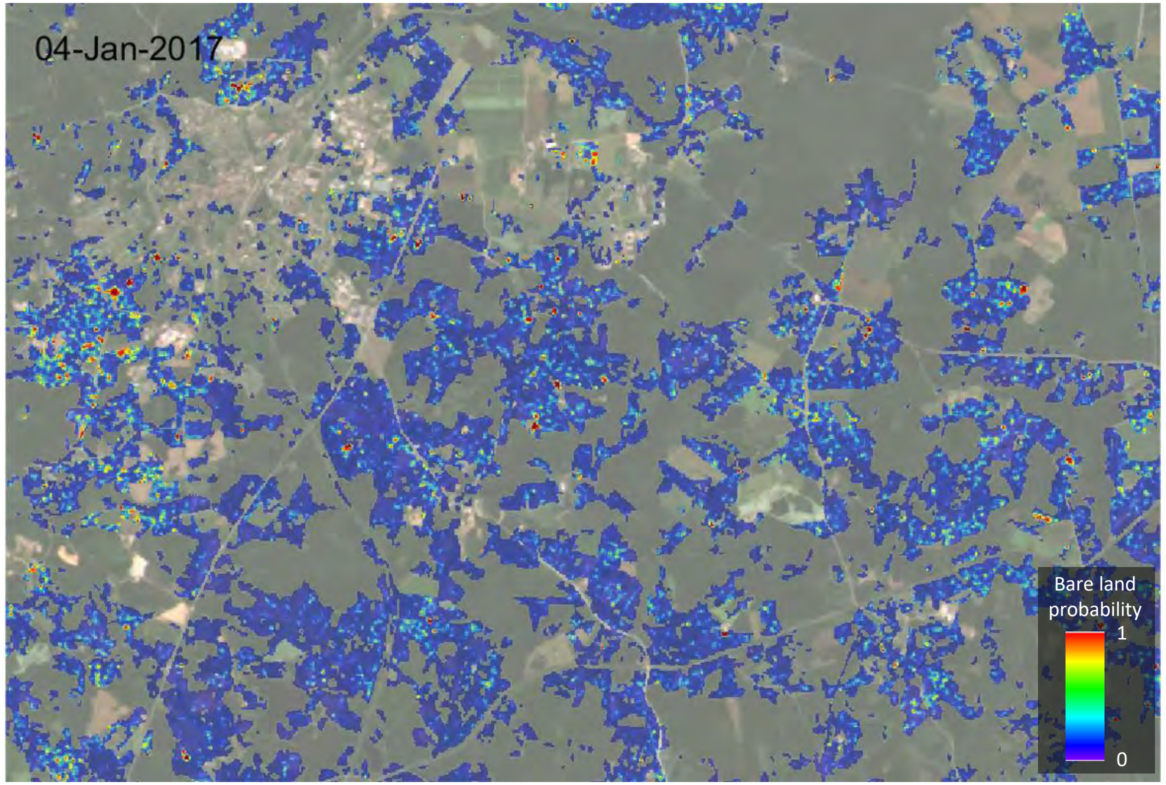


# Detection of management activities in grasslands (ploughing events)

Sentinel-1 backscatter based algorithm for detection of ploughing events

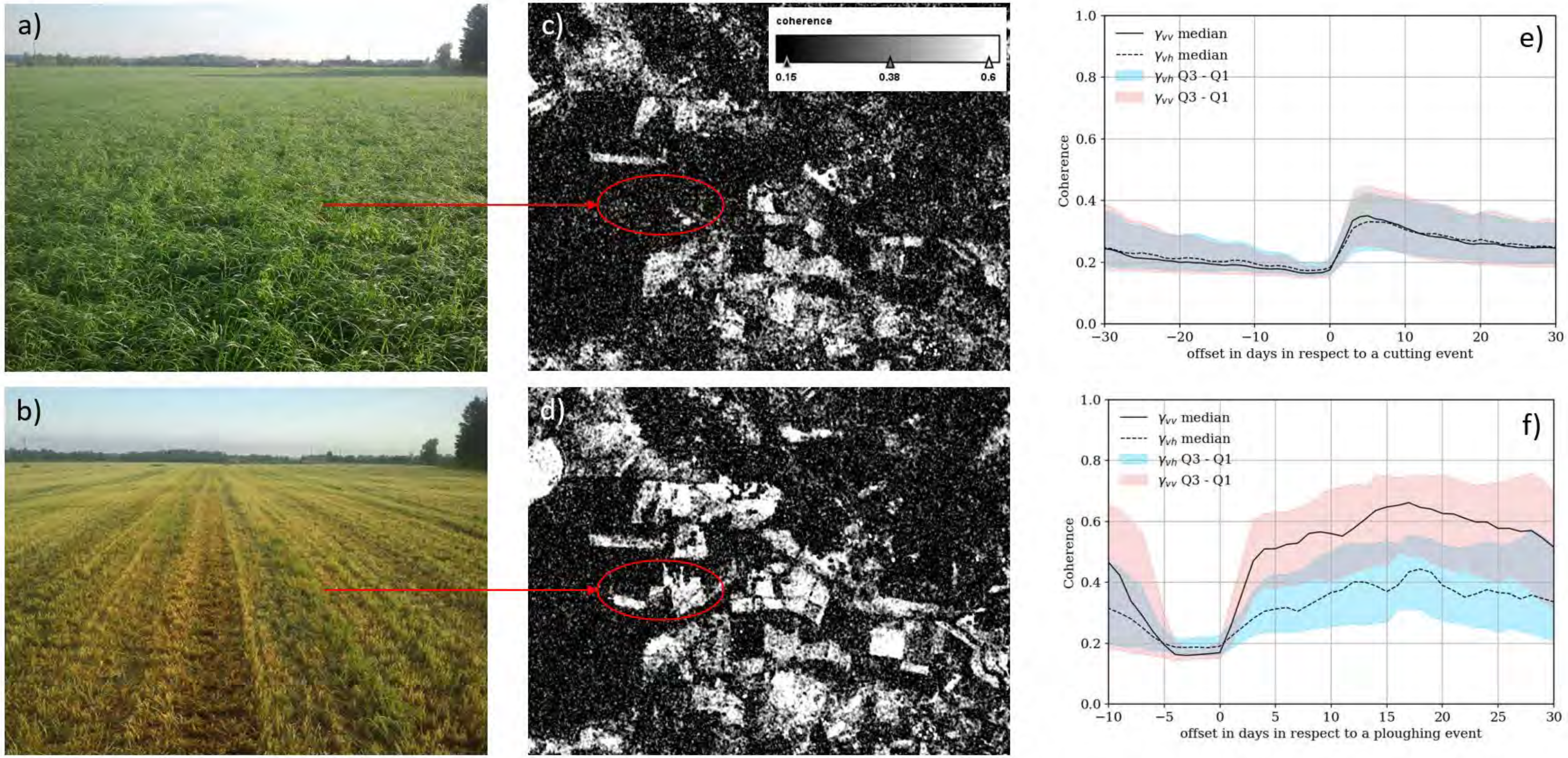
Cesis municipality: Sentinel-2 true colour

Monitoring of ploughing events




Ploughing events occur as sudden disturbance in grasslands.

# Detection of management activities in grasslands (moving and ploughing events)




Agricultural grassland before (a, c) and after mowing (b, d), red oval marks the area with coherence increase after mowing. The signatures of mowing (e) and ploughing (f) events.


Voormansik, K., Zalite, K., Sünter, I., Tamm, T., Koppel, K., Verro, T., Brauns, A., Jakovels, D. and Praks, J., 2020. Separability of mowing and ploughing events on short temporal baseline Sentinel-1 coherence time series. *Remote Sensing*, *12*(22), p.3784.

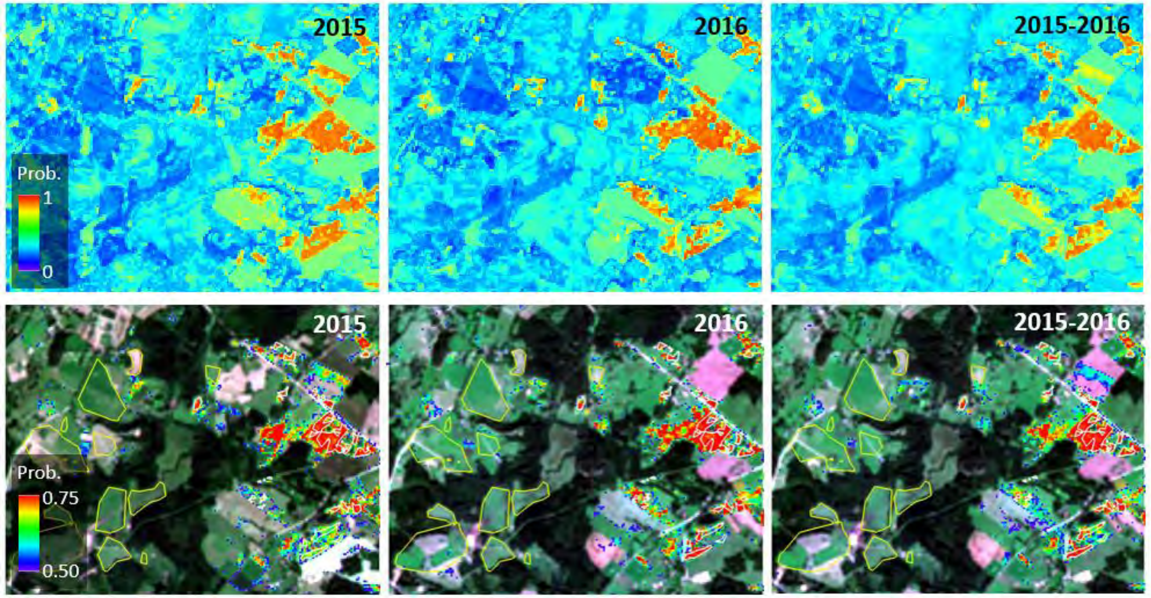
# Detection of invasive species Heraclum sosnowskyi

Institute for Environmental Solutions

Heracleum sosnowskyi in Cesis pilot territory

Heracleum sosnowskyi (Sosnowsky's hogweed) is an invasive species that should be regularly controlled in order to limit its further spread.
Detection of hogweed presence in open areas (e.g., grasslands) was demonstrated with **>90%** producer's accuracy using temporal Sentinel-2 spectral data and SVM-based classification model. Approach is limited to open areas and stand size comparable to pixel size (20x20 m).

Detection of Heracleum sosnowskyi in Cesis pilot territory using temporal Sentinel-2 spectral data




Combined result from 2015-2017 showing permanent Heracleum sosnowksyi areas

# Forest monitoring (yearly)

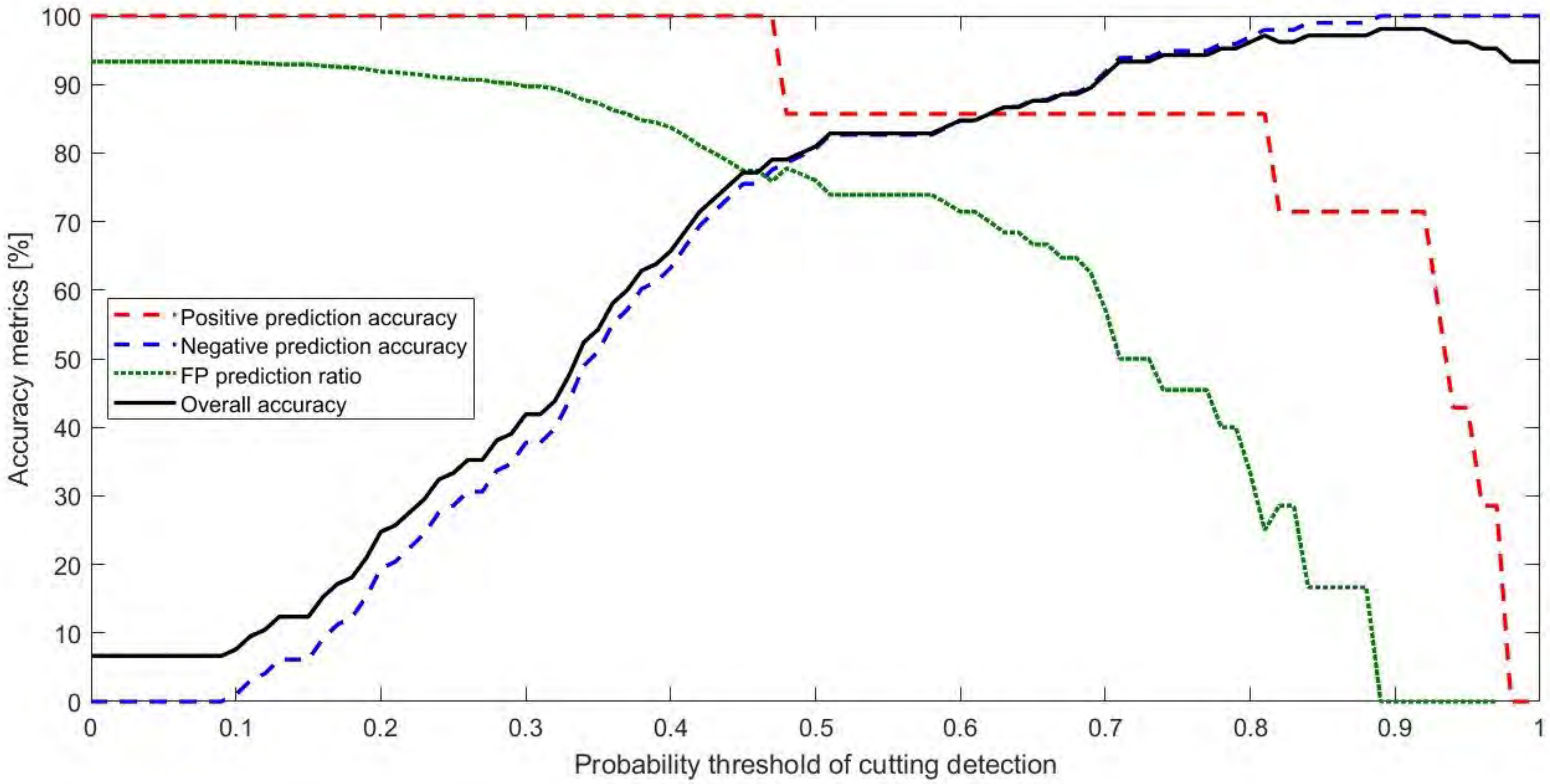
Institute for Environmental Solutions

# Forest monitoring (towards weekly)

# Forest monitoring (towards weekly)

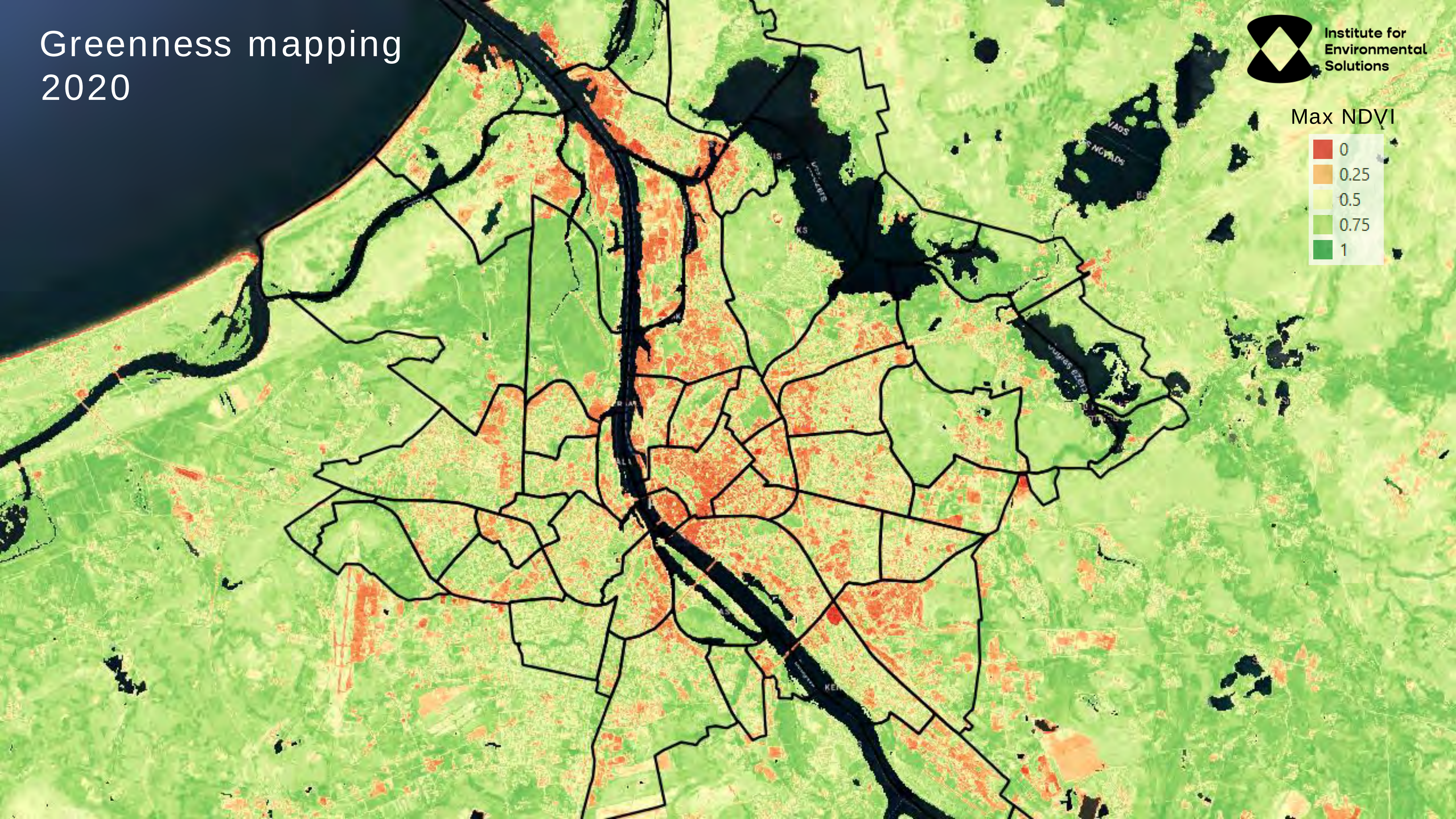
Zooming to Jauncelmi; 42900100008-1-3

# Forest monitoring (towards weekly) – the dilemma

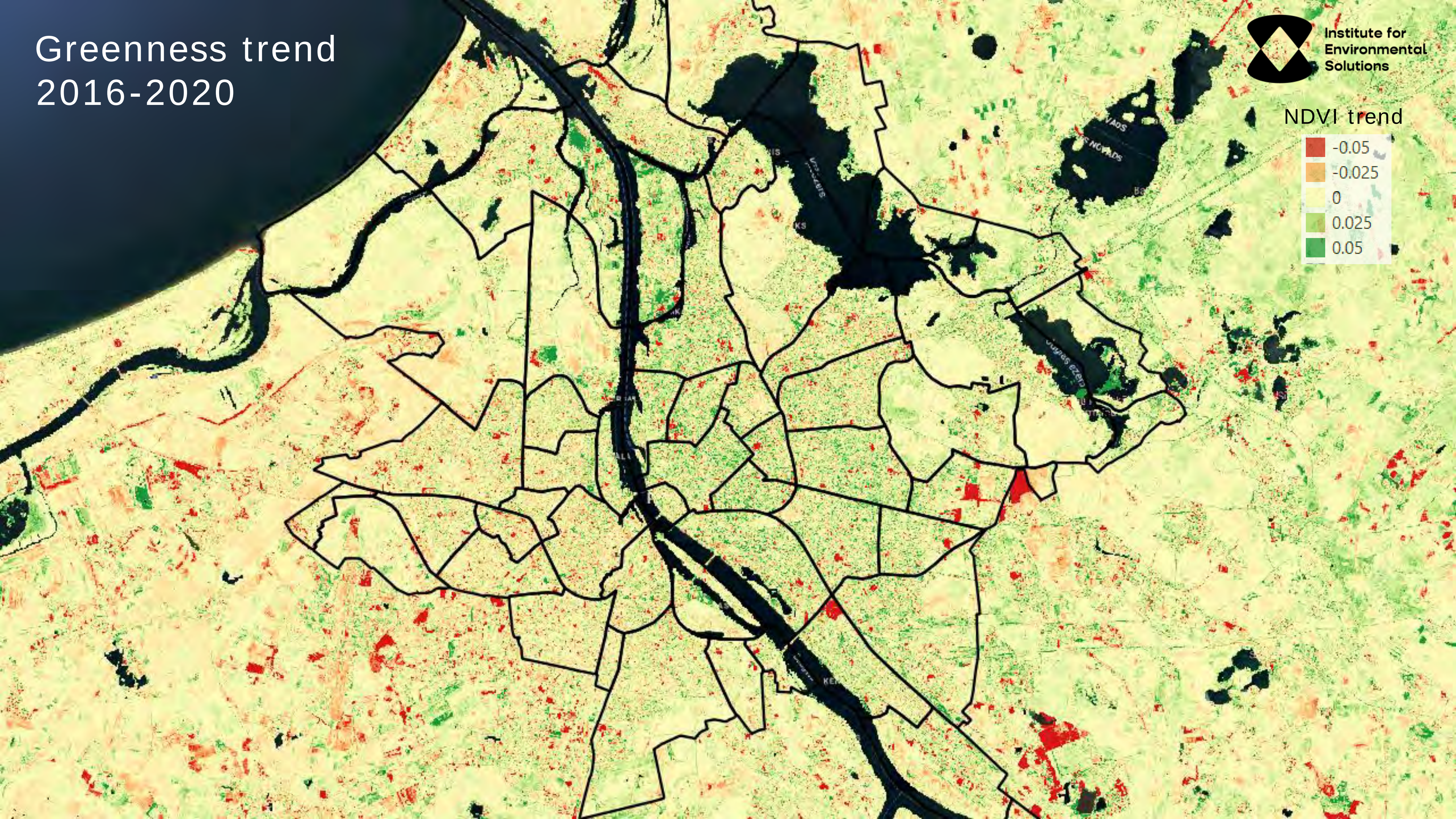


# Greenness mapping 2020

Institute for Environmental Solutions

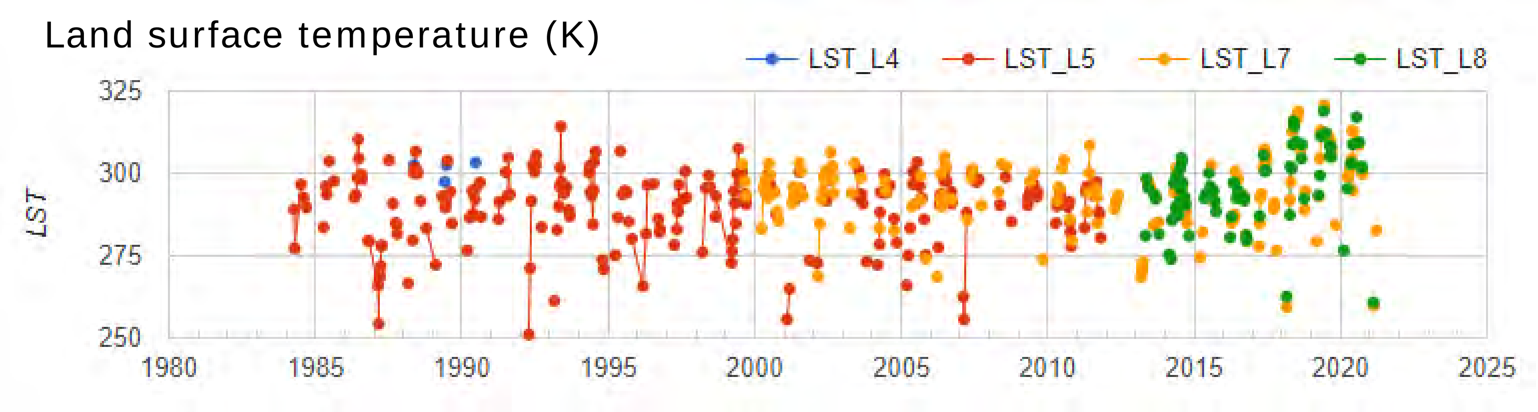


# Greenness trend 2016-2020

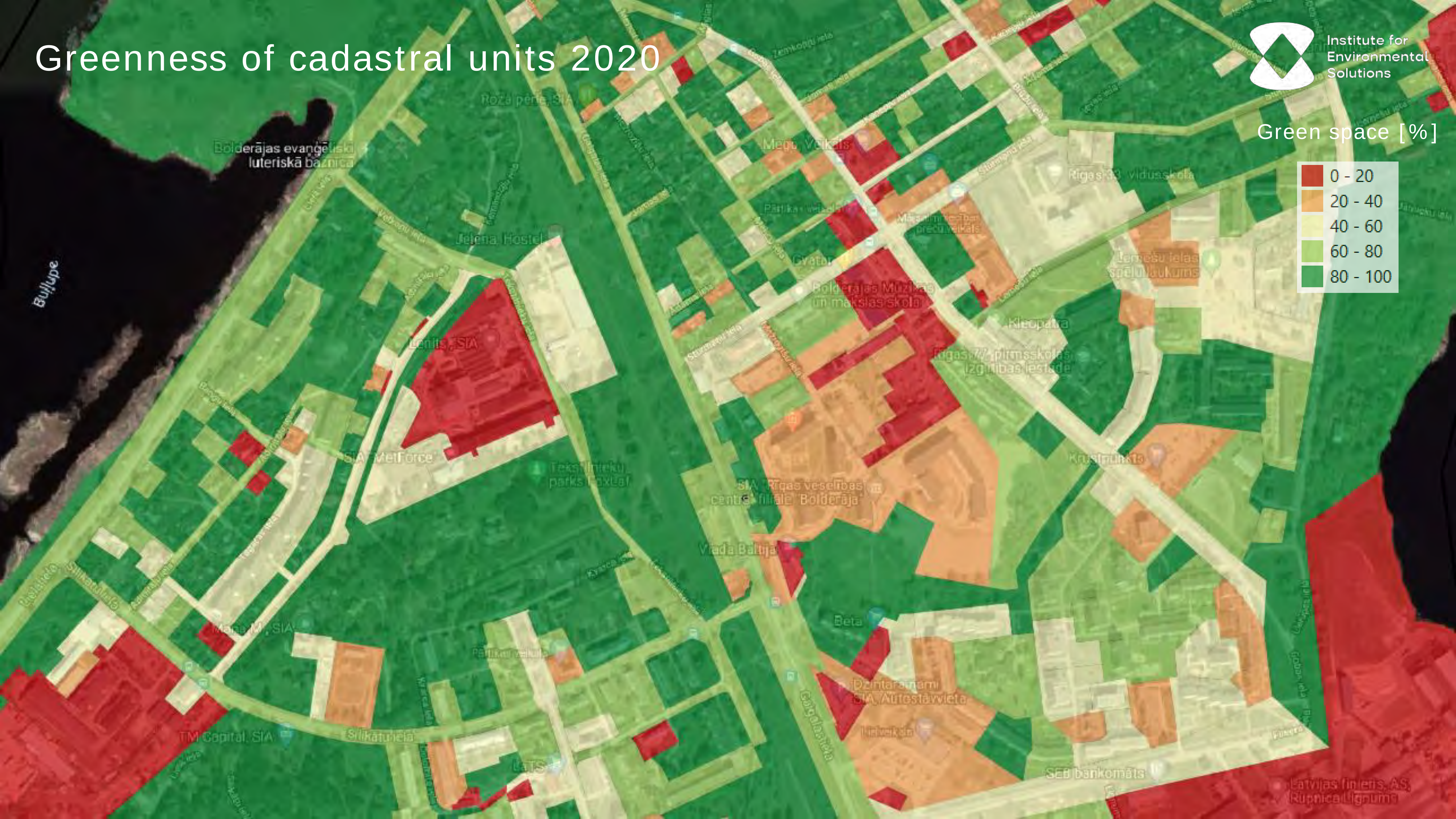


# Greenness trend 2016-2020

Institute for Environmental Solutions

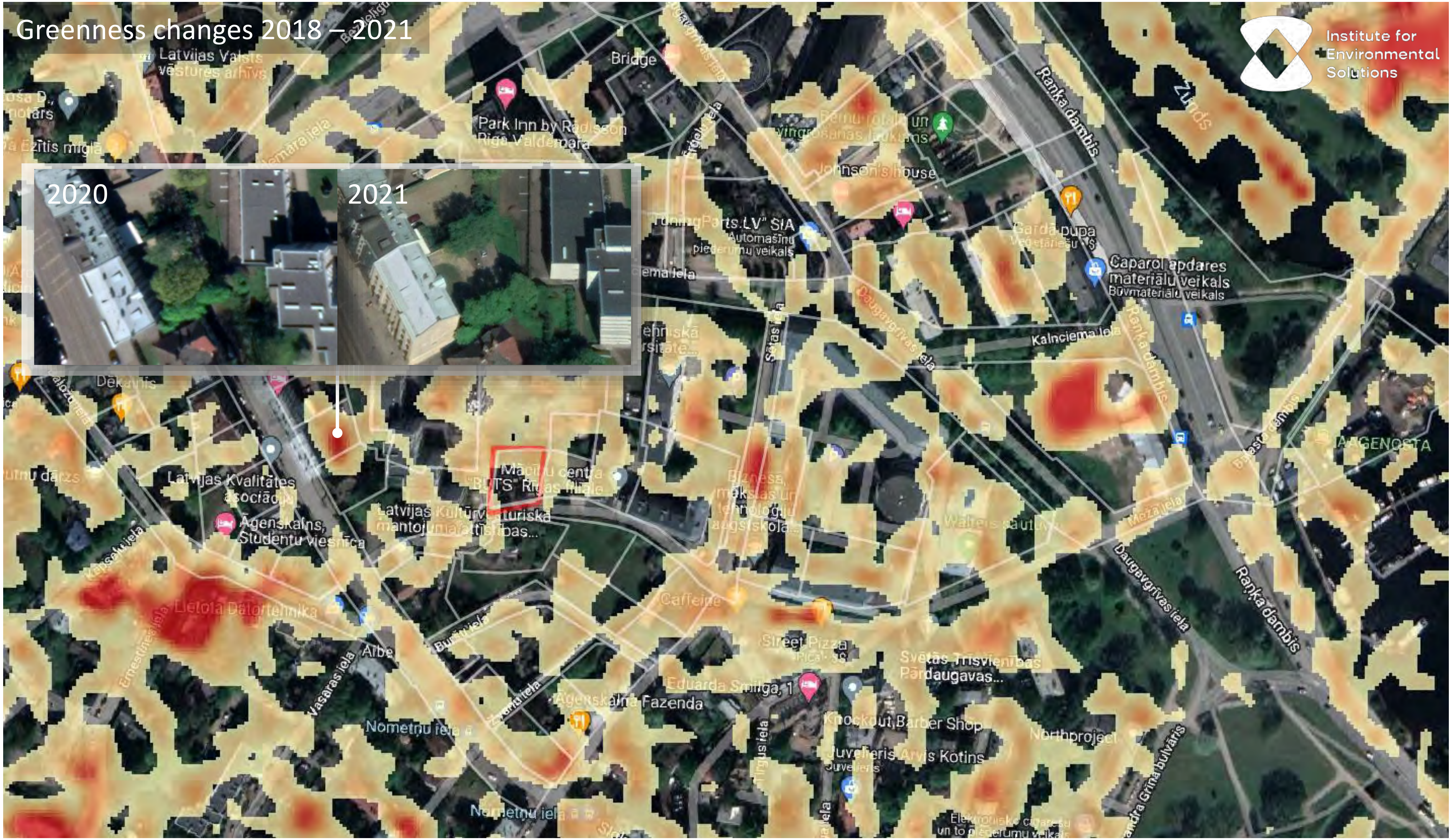

# Greenness of cadastral units 2020



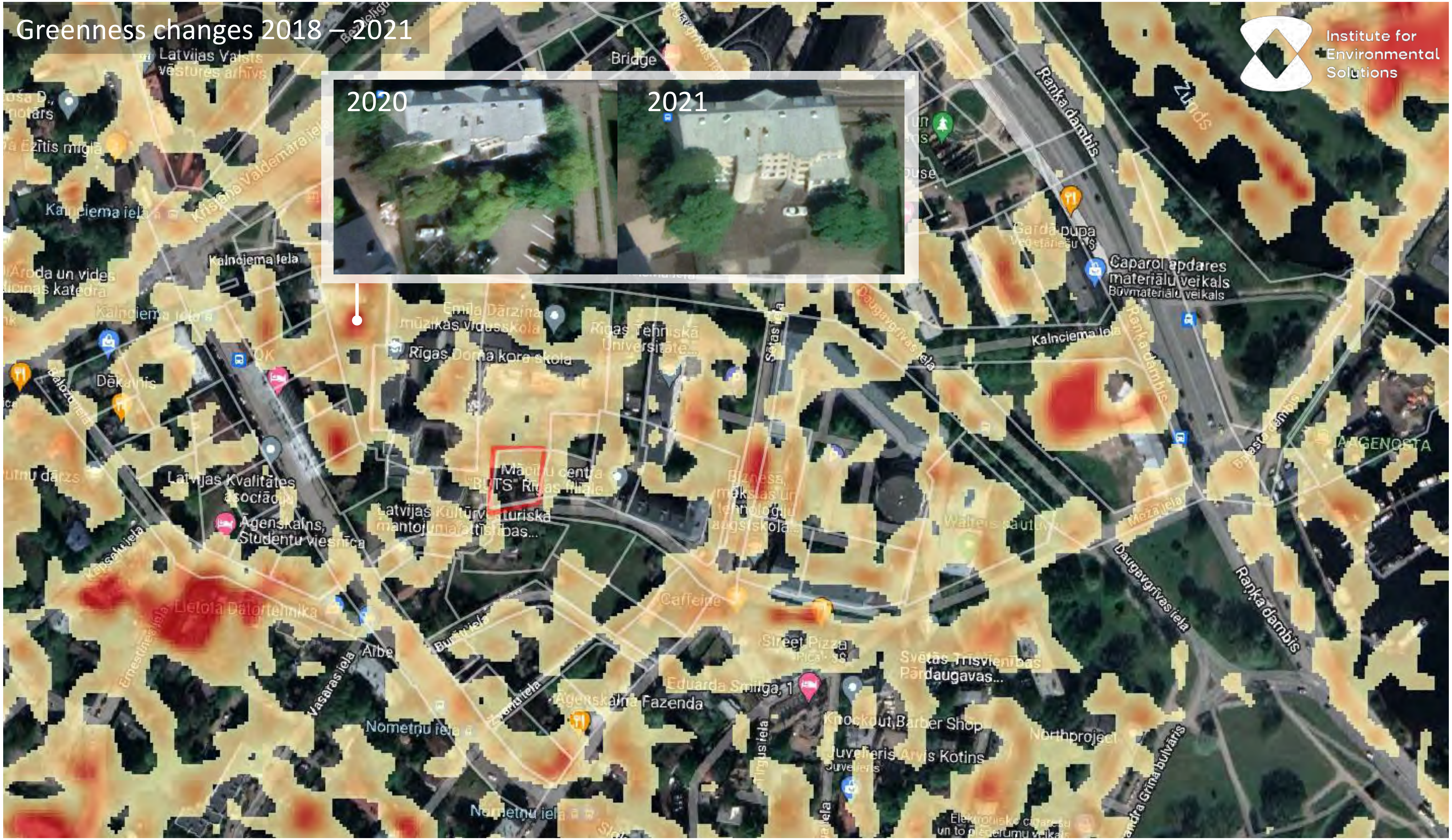
# Greenness changes within cadastral units 2016-2020

# Greenness changes 2018 – 2021

Institute for Environmental Solutions



# Greenness changes 2018 – 2021

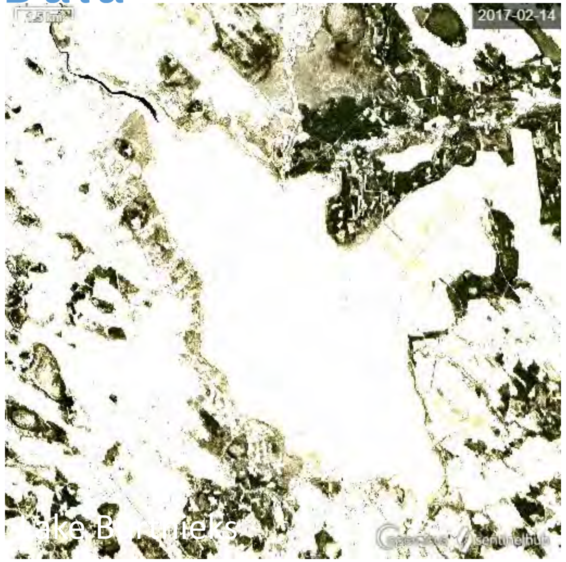


# SentiLake - Lake water quality monitoring

Institute for Environmental Solutions

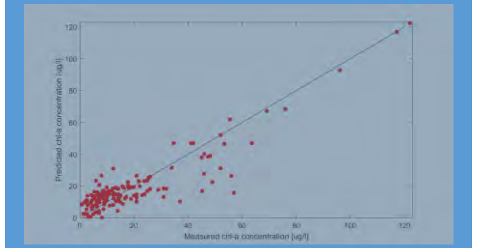
LVĢMC

## Data



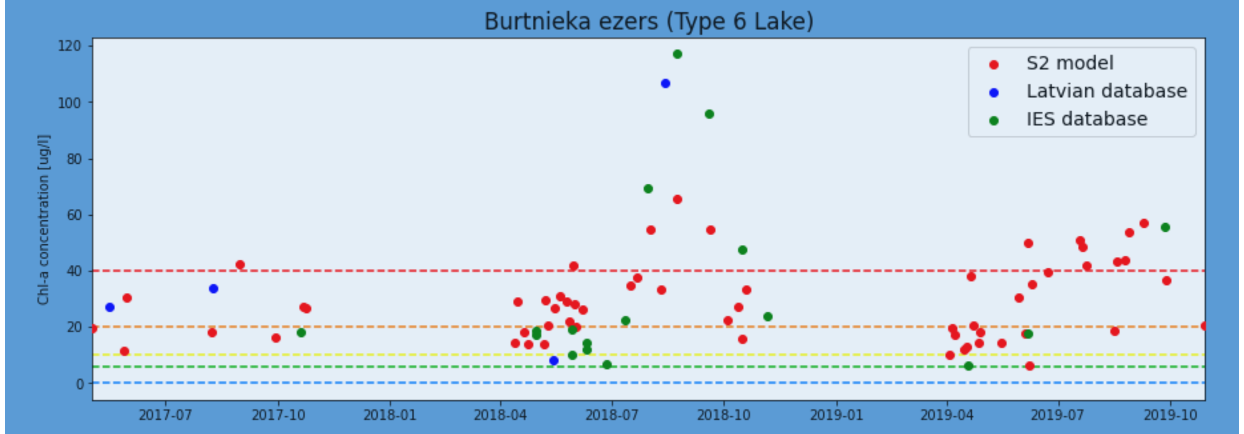

1...4 Sentinel-2 satellite data acquisitions per month

## Model



Chlorophyll-a concentration assessment from spectral data

## Result

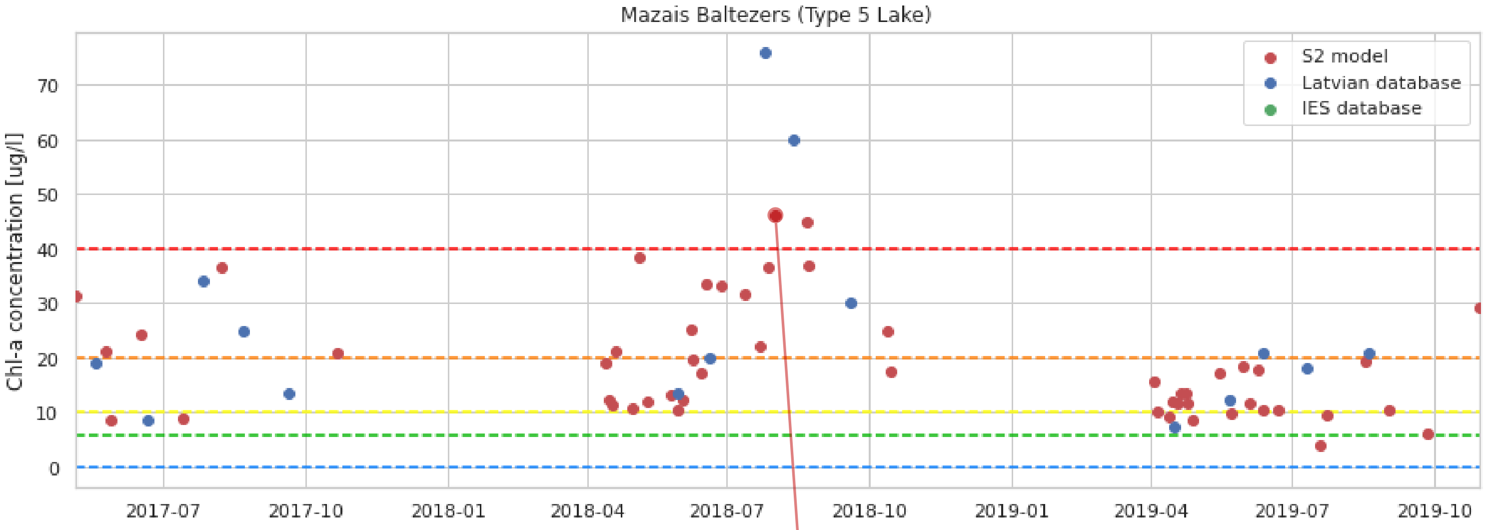



Chlorophyll-a concentration is used for assessment of lake water quality status

# SentiLake - lake water quality monitoring

Institute for Environmental Solutions

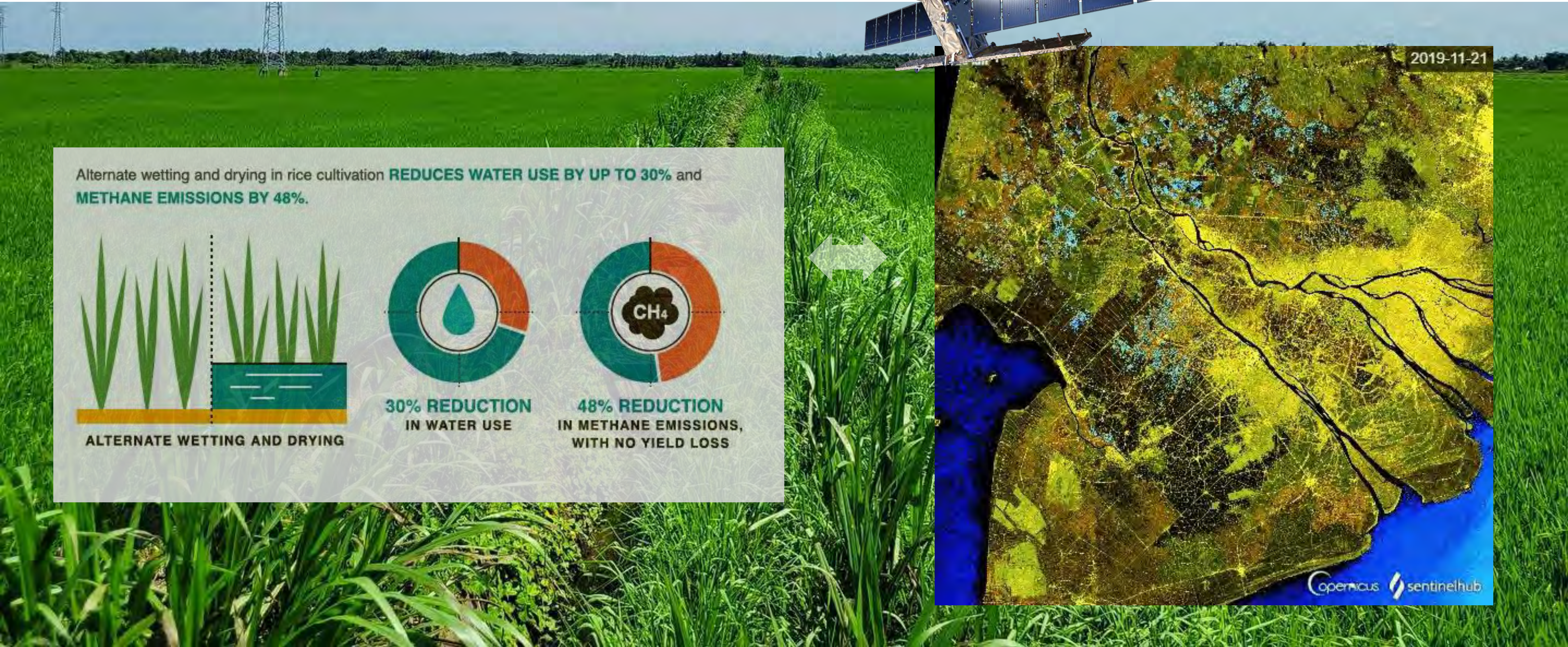
LVĢMC


# SentiRice – support tool for sustainability certification of rice fields

Institute for Environmental Solutions

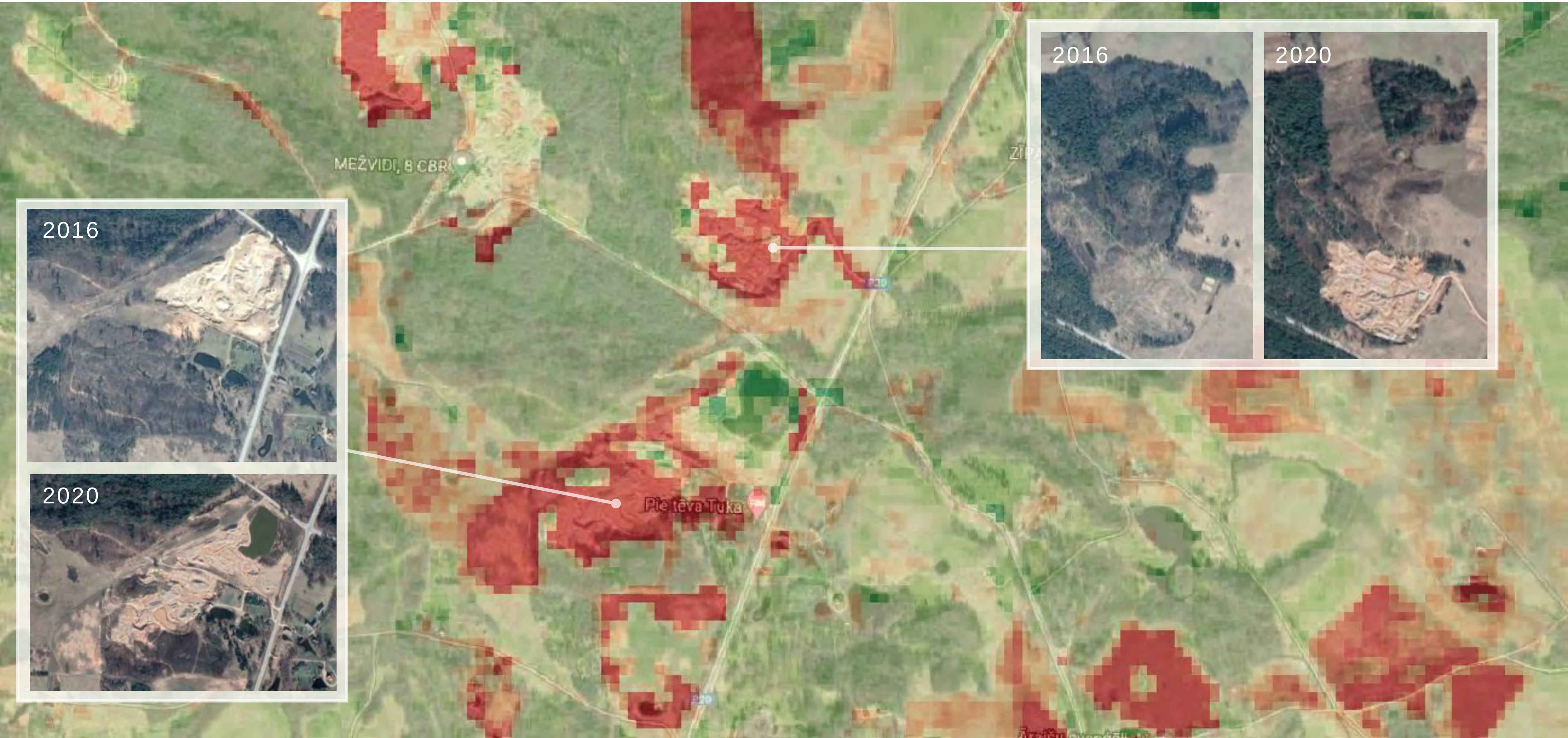
Preferred by Nature™
formerly NEPCon



# SentiCheck – monitoring of mining sites

Institute for Environmental Solutions

Valsts vides dienests



Institute for
Environmental
Solutions

Dainis Jakovels
Leading Researcher
E: dainis.jakovels@vri.lv