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High Resolution Land Cover of Italy

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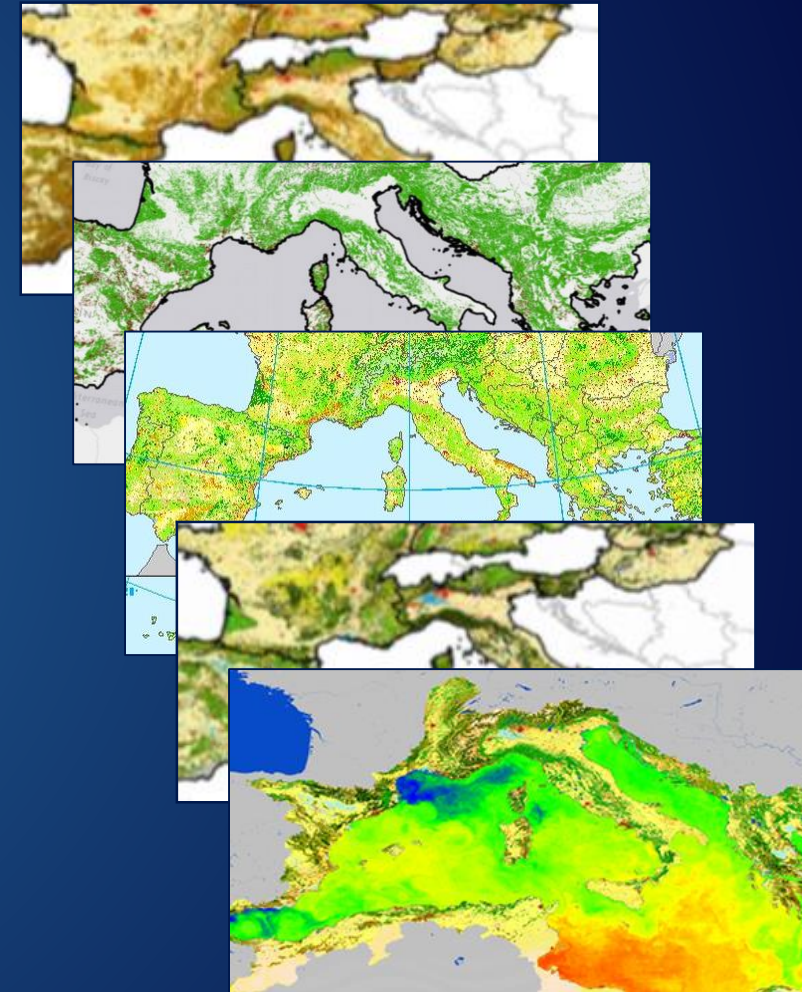
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Outline

- 1 Introduction and Background
- 2 Aim of the Work
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- 4 Experimental Results
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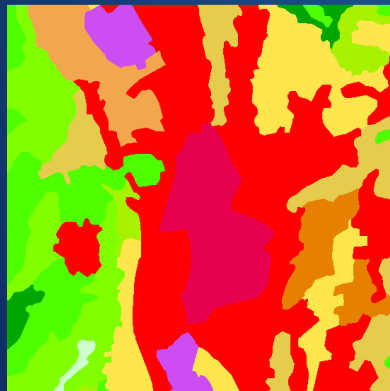
Introduction and Background

- ✓ Updating **land-cover maps** of the **Mediterranean sea Region** is fundamental to regularly monitor the **fragility** and **vulnerability** of the Mediterranean system.
- ✓ Many **thematic/cartographic maps** of the **Mediterranean area** have been produced in the past for a **wide range** of **applications** (e.g., climate change, monitoring of natural resources).
- ✓ **Remote sensing images** acquired by the last **generation** of **satellites** contain crucial information for producing updated land-cover maps at **high resolution**.
- ✓ **Time Series (TS)** of **Sentinel 2** multispectral images (eventually integrated with Sentinel 1 SAR data) are an **ideal information** source for producing **updated land-cover maps** up to **10 m resolution**.

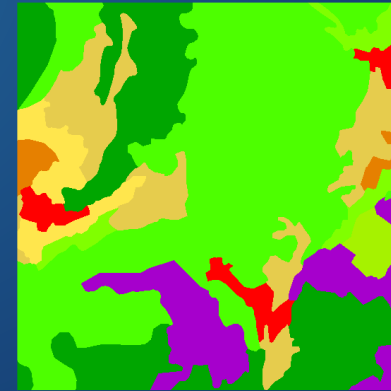


Introduction and Background

- ✓ **Problem:** It is difficult to collect **ground reference data at country scale** for training a classification system.
- ✓ **Possible solution:** Exploit the thematic maps of the Mediterranean area as an **information source for extracting weak labeled training samples**. This is not straightforward:
 - they are **not completely reliable** (outdated or not accurate);
 - they are typically **aggregated at polygon level** (polygon labels do not necessarily correspond to spectrally homogeneous areas);
 - there is a **semantic gap** between map **legends** and **RS data**.



Corine Land Cover 2012



Corine Land Cover 2012



Urban
Crops



Broadleaves
Conifers



Rocks
Snow



Grass
Water



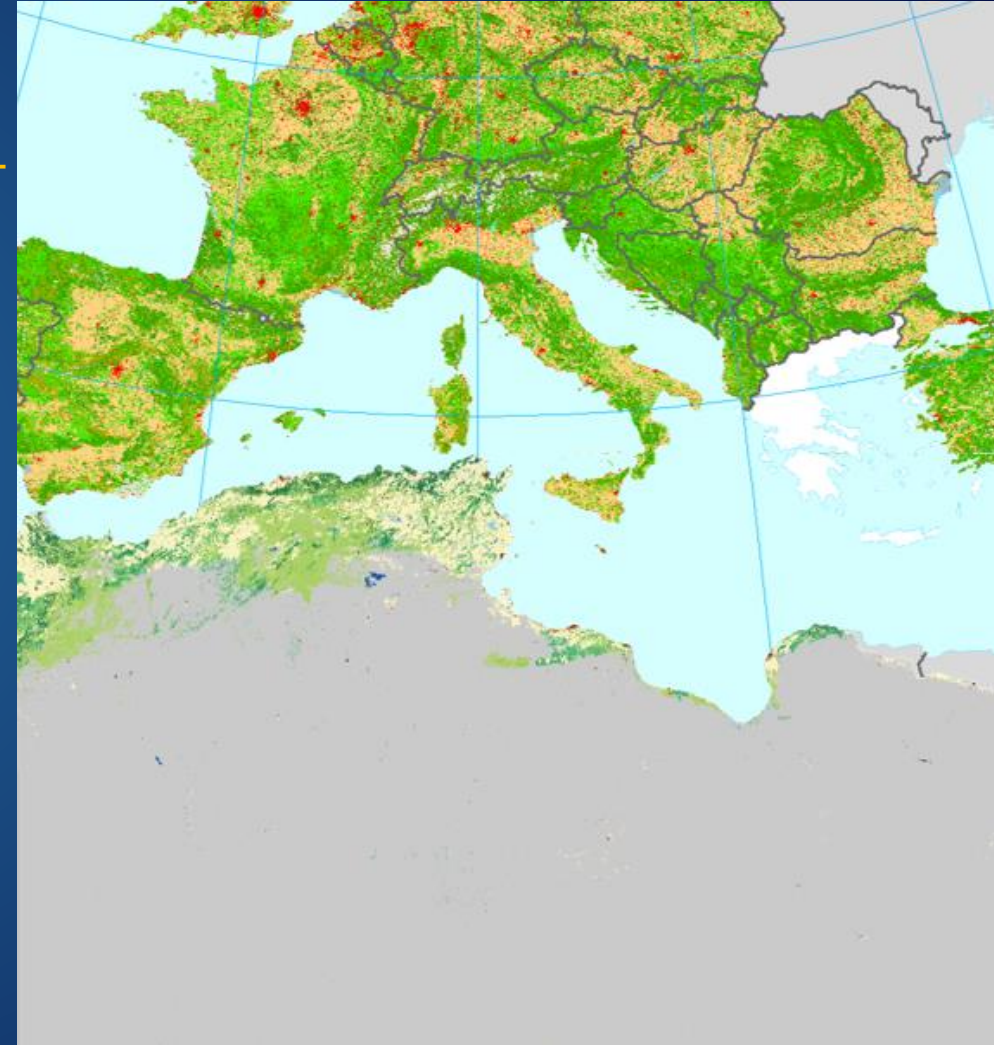
Shrub
Mineral Site

Mediterranean Land Cover Products

Maps Available	Year	Spatial Resolution	Coverage	RS data
GLC-SHARE 2014 (old GLC-2000)	2014	1 km	Global	SPOT VGT
MODIS GLC	2012	500 m	Global	MODIS
GlobCover	2010	300 m	Global	MERIS
GlobeLand30	2010	30 m	Global	LANDSAT
Corine Land Cover (CLC) Map	2012	100 m	Europe	IRS P6 LISS III RapidEye
ECOCLIMATE II	2007	1 km	Global	SPOT VGT

Corine Land
Cover Map

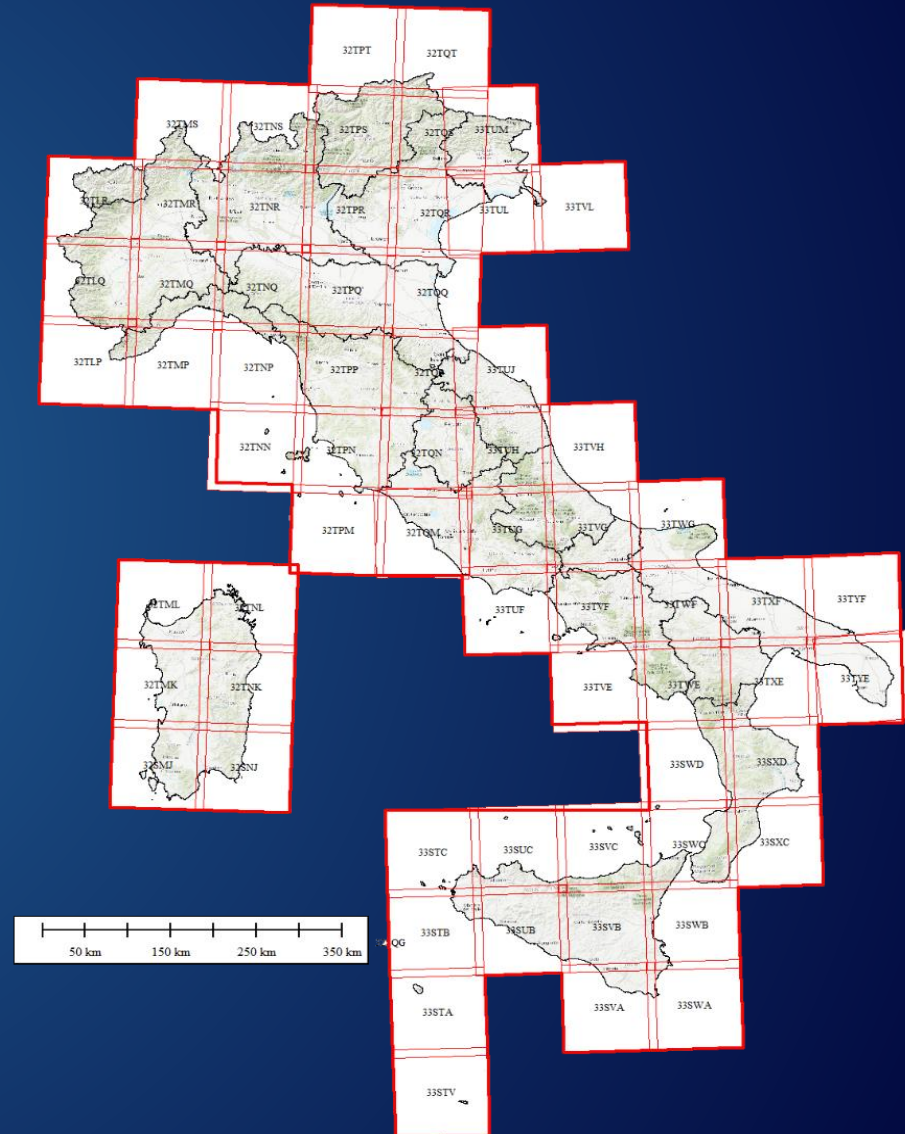
GlobeLand30



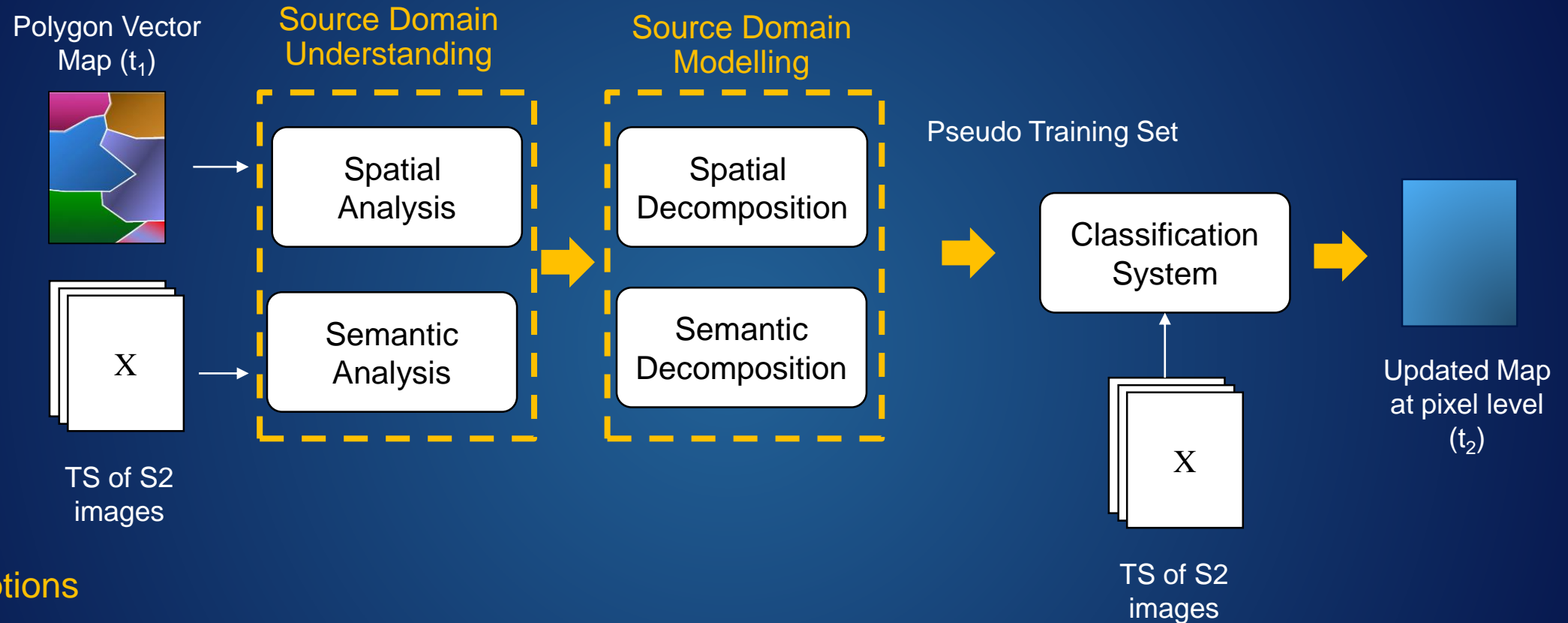
Aim of the Work

- ✓ Develop an **automatic system** based on Sentinel 2 image time series for updating land-cover maps.
- ✓ The proposed system has the following properties:
 - Automatically extracts a reliable **“pseudo” training set** from outdated maps to perform the unsupervised update of the thematic map;
 - Updates the thematic map by using **high resolution Sentinel 2 (S2)** time series (TS) to increase the spatial resolution of the map.
- ✓ Use the proposed system for generating **updated land-cover maps of Italy at 10 m resolution using S2 image time series.**

This work was supported by the European Space Agency (ESA) under project “S2-4Sci Land and Water – Multitemporal Analysis”.



Proposed Methodology: Conceptual Scheme



Assumptions

- ✓ **No new reference data** are available;
- ✓ The source map (which may be generated by sources different from remote sensing) presents a **set of classes discriminable** with the **S2 images**.

Proposed Methodology: Source Domain Understanding

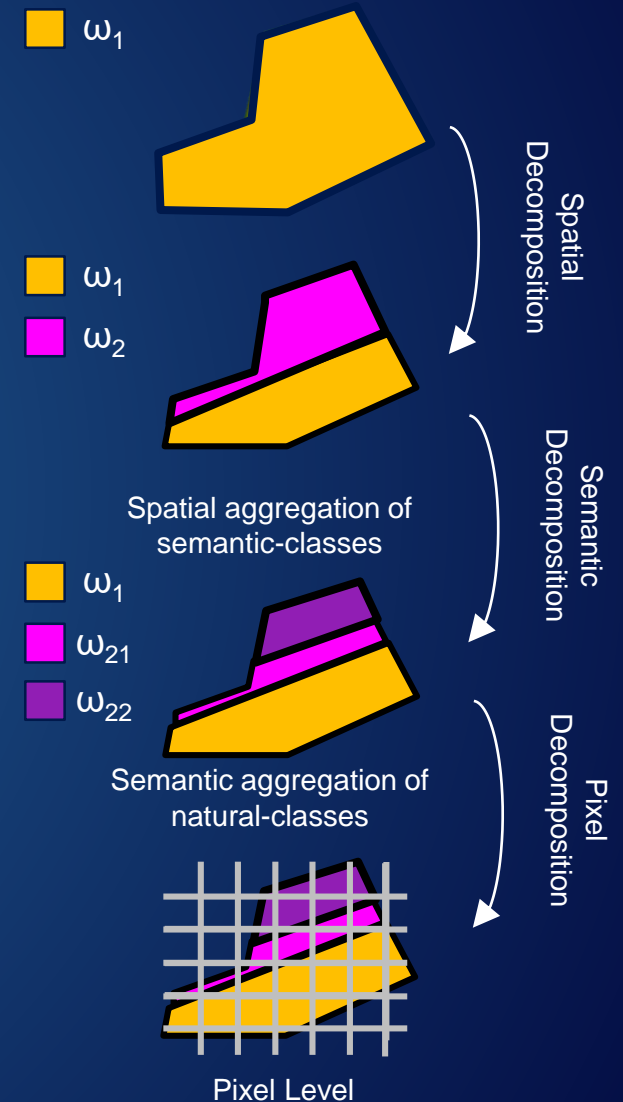
Goal: understand the properties of the **map domain** to identify its **discrepancy** with the **RS data domain** from the **spatial** and **semantic** view point.

✓ *Spatial Analysis*

- Thematic products are typically **aggregated** in **polygons** (include **contiguous parcels** associated to different labels);
- The **polygon boundaries** do not perfectly match the **pixel grid** of the RS data.

✓ *Semantic Analysis*

- Semantic aggregation due to **spatial aggregation** (e.g., “mixed forest”);
- Semantic aggregation is performed because of the **map legend definition** which does not include the **natural classes** (e.g., “crop” instead of singular cultivation).



Proposed Methodology: Source Domain Modelling

Goal: model the map from the **spectral** and **spatial** view point to **extract** a set of **samples** that has to be: i) **reliable**, ii) **informative**, and iii) **representative**.

✓ *Spatial Decomposition*

- Let $p_j = \{x_i^{ts}\}_i^{B_j}$ be the **j th polygon** of the map having B_j pixels, where x_i^{ts} is the **multitemporal spectral vector** of the i th pixel of the polygon. A **k -mean clustering** is applied to partition p_j into M_j clusters:

$$\operatorname{argmin}_{\{c_1, \dots, c_m\}} \sum_{k=1}^{M_j} \sum_{x_i^{ts} \in c_k} \|x_i^{ts} - \mu_k\|^2$$

cluster centroid of c_k

✓ *Semantic Decomposition*

- Identify the number of **natural classes** M_j present in the polygon, we used the Calinski Harabasz (CH) Index:

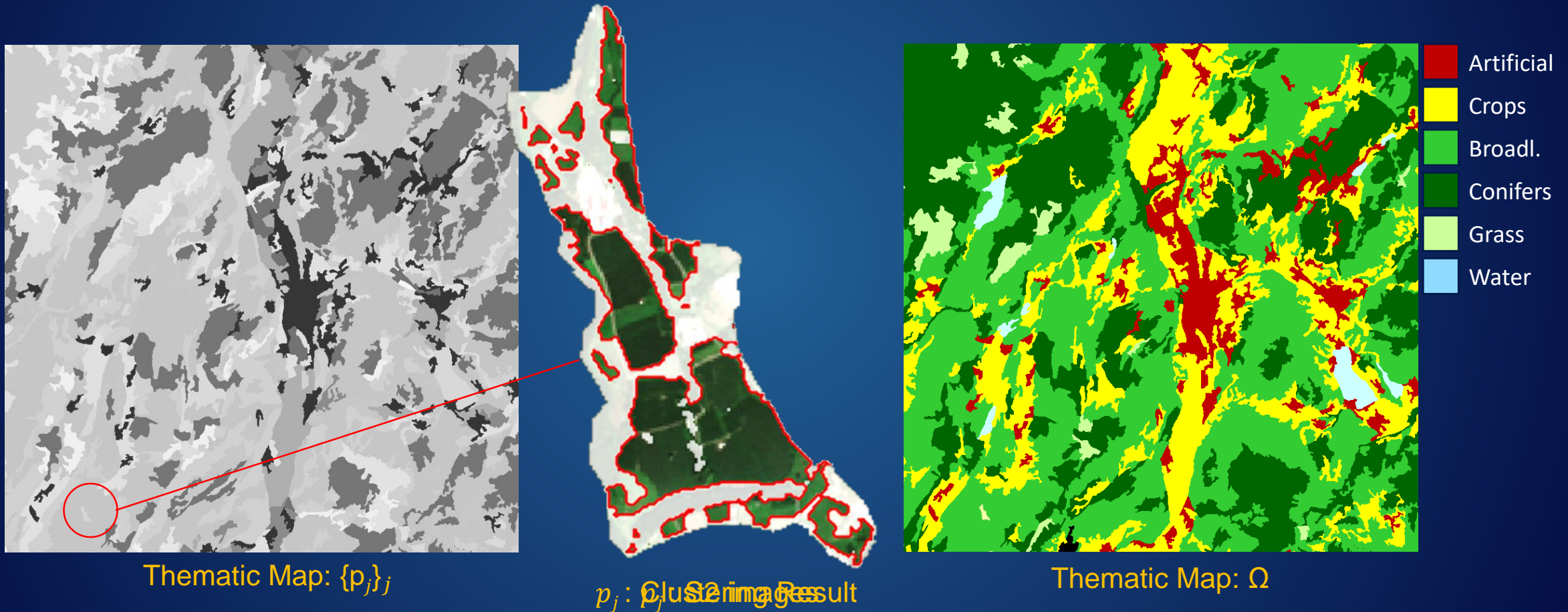
$$CH = \left[\frac{\sum_{k=1}^{M_j} N_j^k \|\mu_k - \mu\|^2}{M_j - 1} \right] / \left[\frac{\sum_{k=1}^{M_j} \sum_{b=1}^{B_j} \|x_b^{ts} - \mu_k\|^2}{B_j - M_j} \right]$$

pixels associated to c_k

centroid of p_j

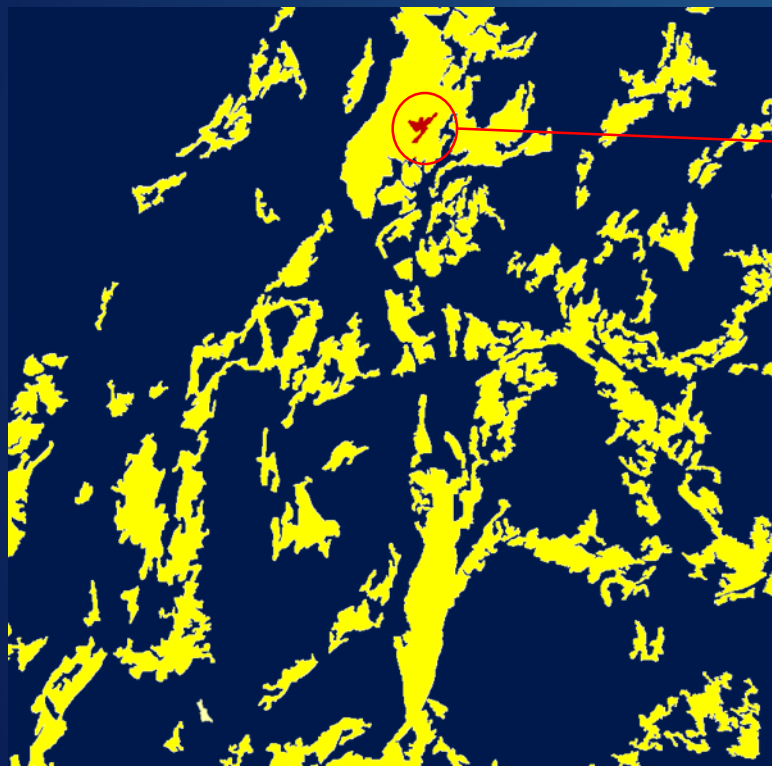
Automatic “Pseudo” Training Set Identification

The initial thematic map is characterized by a set of polygons $\{p_j\}_j$ and a set of land-cover classes Ω .

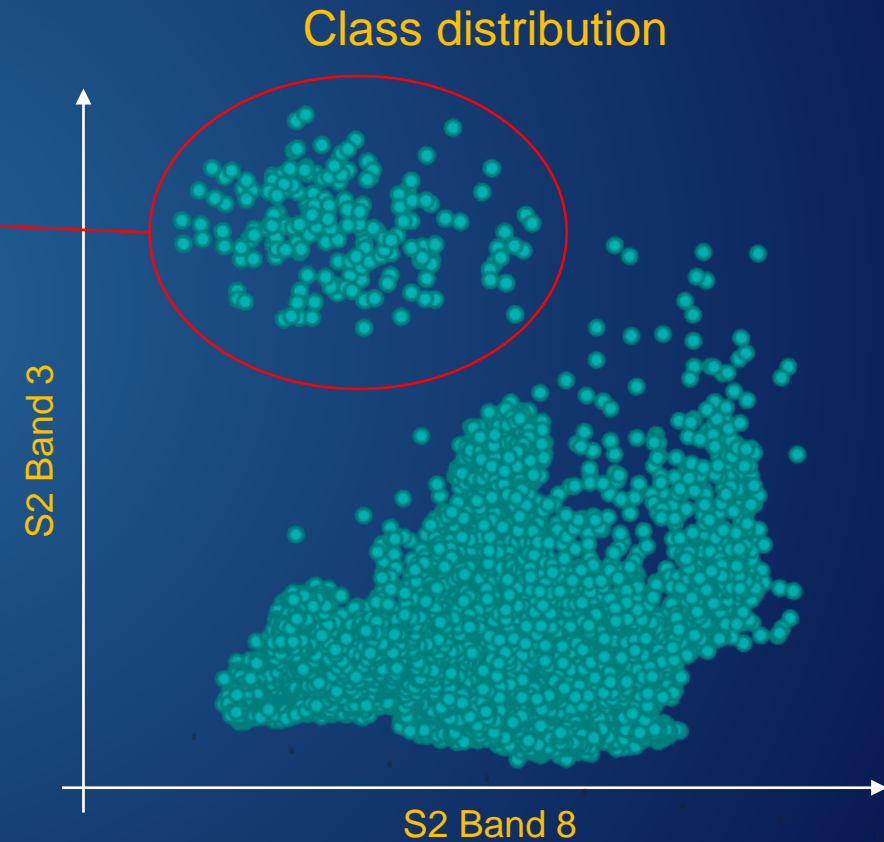


Automatic “Pseudo” Training Set Identification

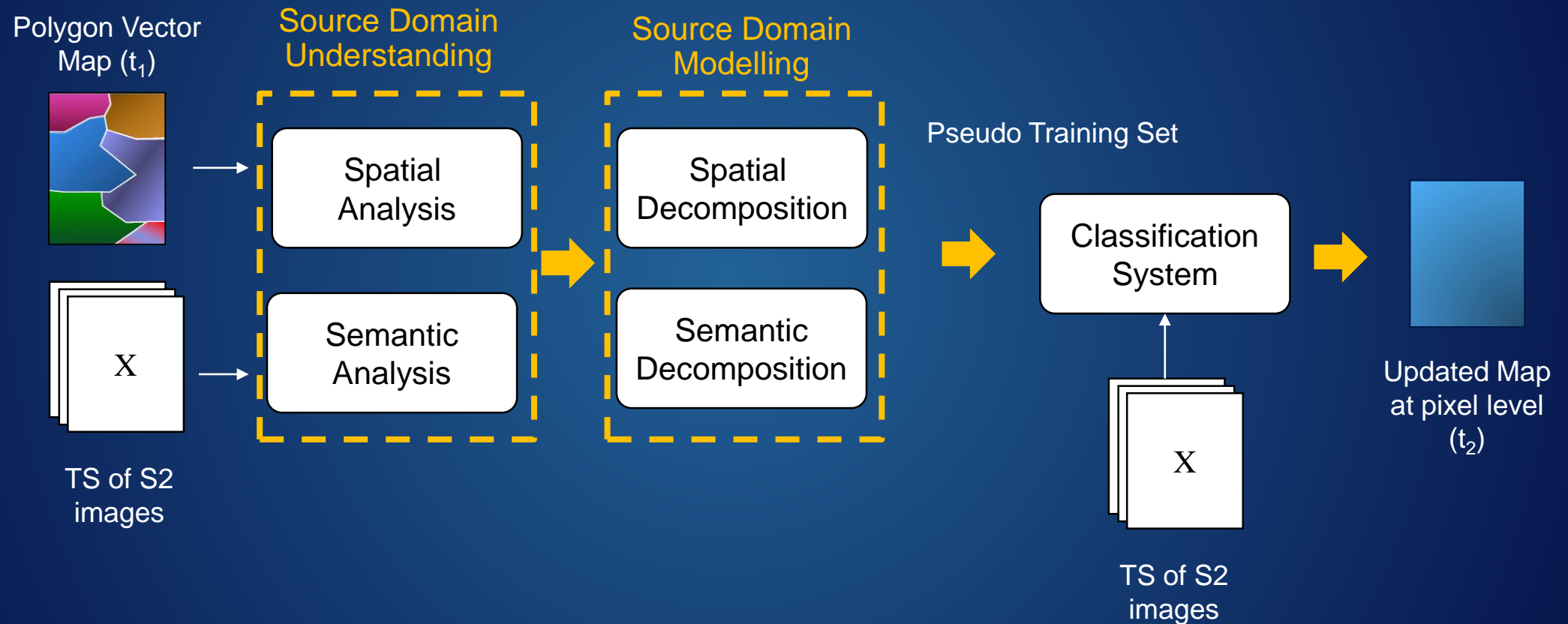
Class consistency analysis: Select the **most reliable samples** by comparing the distributions of the clusters belonging to the same class to remove the **outliers** (i.e., clusters farther from the overall class distribution).



Thematic Map: Class 0 Crop



Proposed Methodology: Conceptual Scheme

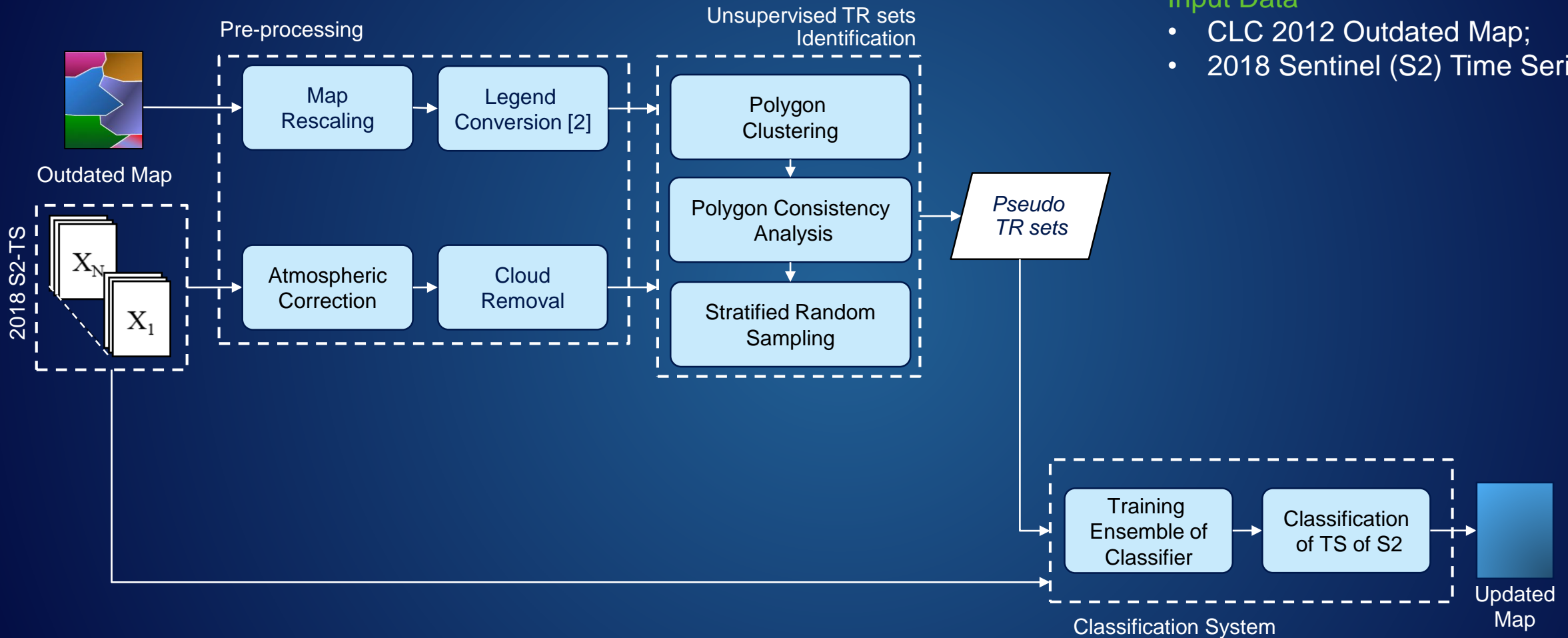


[1] C. Paris, L. Bruzzone, D. Fernández-Prieto, "A novel method based on source domain understanding and modeling to transfer labels from land-cover vector maps to classifiers for multispectral images," *IEEE International Geoscience and Remote Sensing Symposium (IGARSS '18)*, Valencia, Spain, 23-28 July 2018.

Proposed Methodology: System Architecture

Input Data

- CLC 2012 Outdated Map;
- 2018 Sentinel (S2) Time Series (TS).

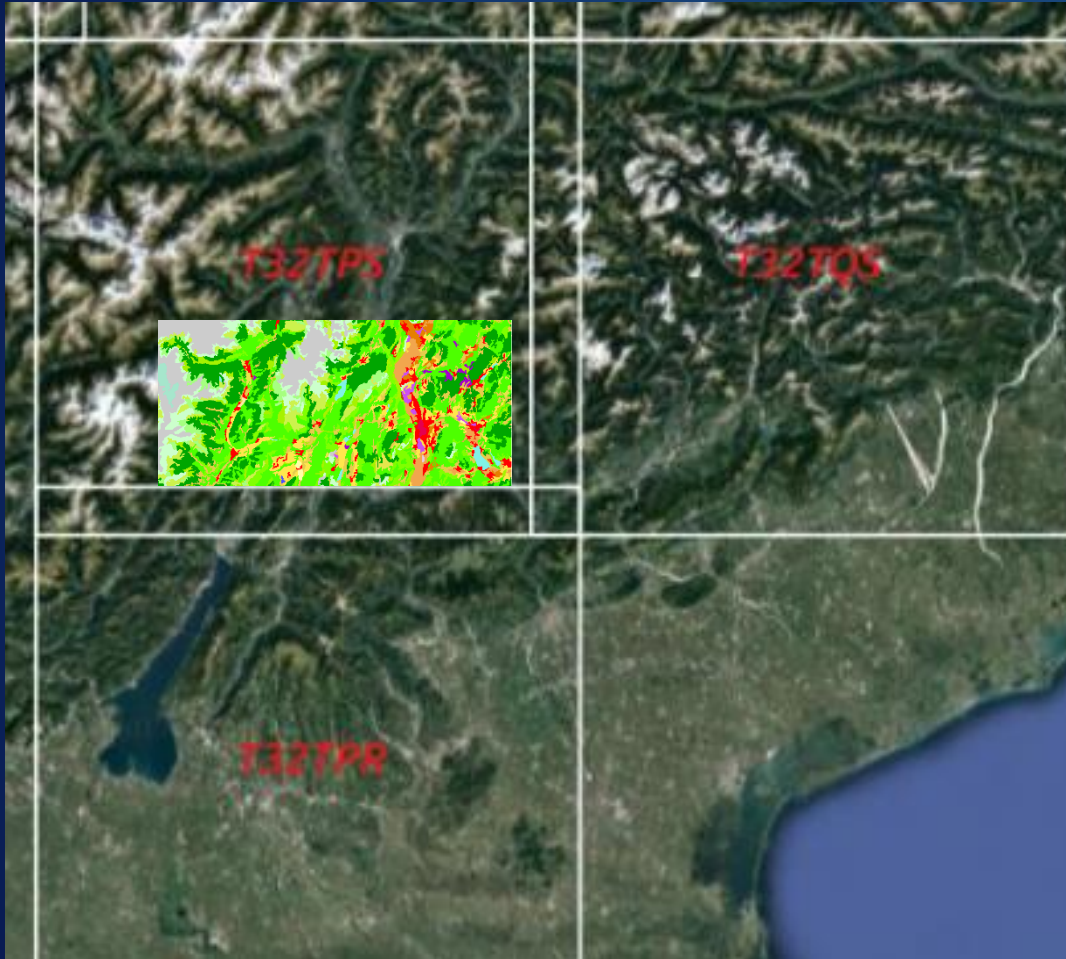


[2] Di Gregorio A., "Land cover classification system: classification concepts and user manual: LCCS", Number 8. Food & Agriculture Org., 2005.

Experimental Analysis

- ✓ The proposed method has been tested and **validated** at **regional/country level** on time series of Sentinel 2 images in the framework of the ESA the SEOM-S2-MTA project.
- ✓ Two main areas have been considered:
 - **Trentino Region, Italy** (land cover map update).
 - **Czech Republic** (update of crops labels at country level and detailed analysis of crops at regional level).
- ✓ The validated system is currently used for producing a **land-cover map of Italy**.

Experimental Results: Study Area



2012 Corine Land Cover (CLC) map

Study Area: Trentino Region (Italy)

- ✓ Extent: 1549 km²
- ✓ Validation data 2017 (35678 samples)

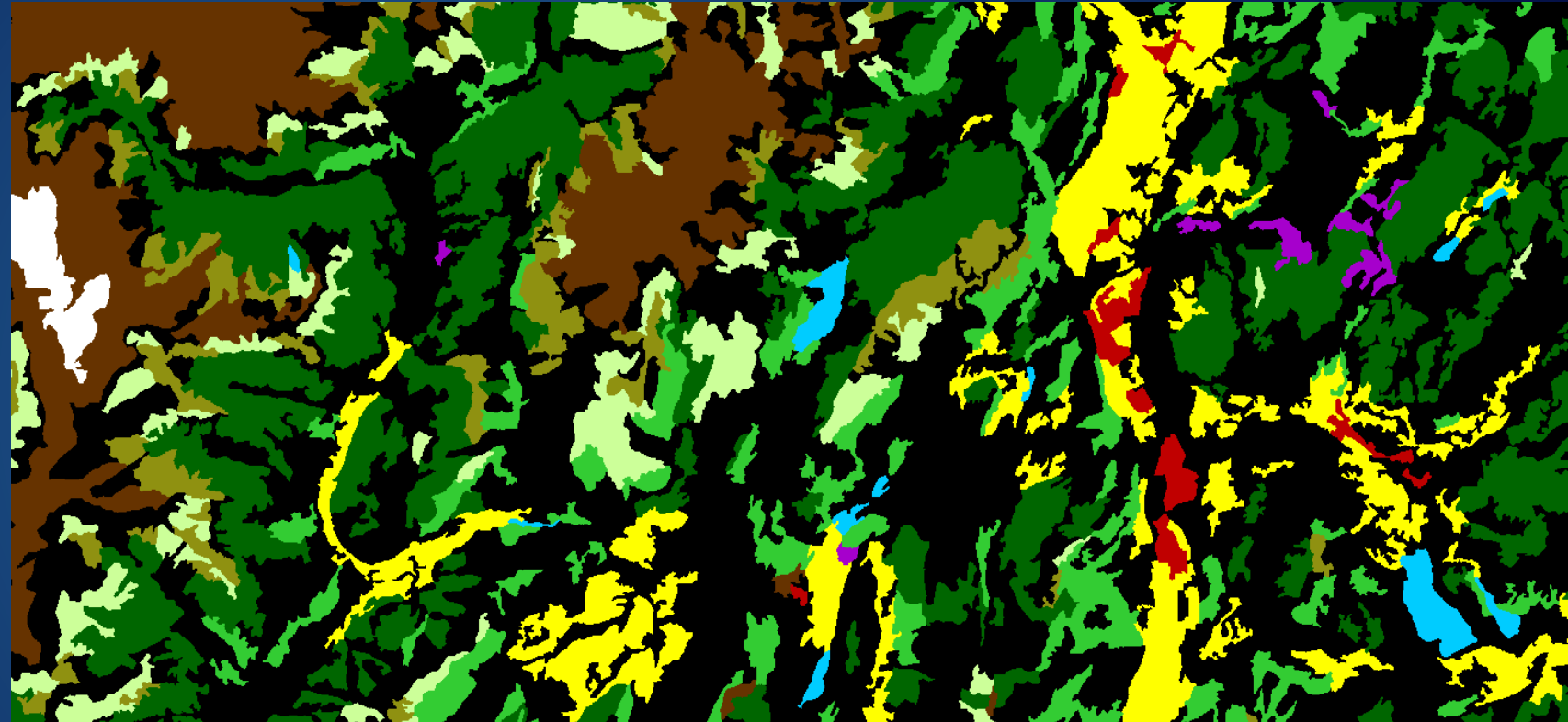
Map to be updated: 2012 Corine Land Cover (CLC)

- ✓ Source: visual interpretation
- ✓ Minimum Mapping Unit: 25 ha
- ✓ Spatial Resolution: 100m

RS data employed: S2 time series

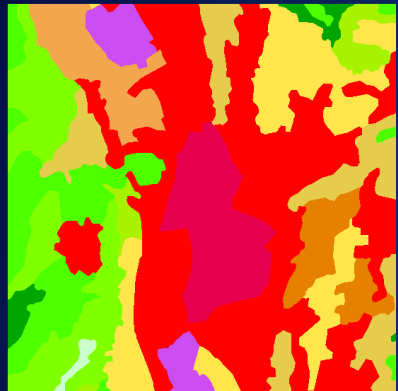
- ✓ Images acquired in:
 - 27/05/2017
 - 26/06/2017
 - 18/07/2017
 - 21/09/2017
- ✓ Spatial Resolution: [10m,20m]

Continuous urban	Urban
Discontinuous urban	-
Industrial units	Urban
Road and rail networks	Urban
Airports	Urban
Mineral Sites	Mineral Sites
Sport and leisure facilities	-
Non-irrigated arable land	Crop
Vineyards	Crop
Fruit trees	Crop
Annual crops	Crop
Complex cultivations	Crop
Broad-leaved	Broadleaves
Coniferous	Conifers
Mixed forest	-
Natural grasslands	Grass
Moors and heathland	Shrubland
Woodland-shrub	-
Bare rocks	Rocks
Sparsely vegetated areas	-
Glaciers/perpetual snow	Snow
Water courses	Water
Water bodies	Water

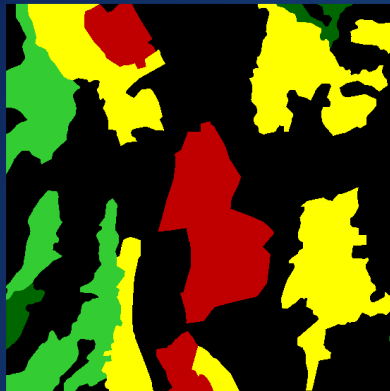


2012 Cover Creek Band Cave Map

Experimental Results: Land Cover Map Update



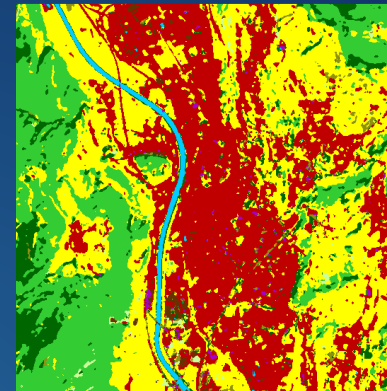
Corine Land Cover 2012



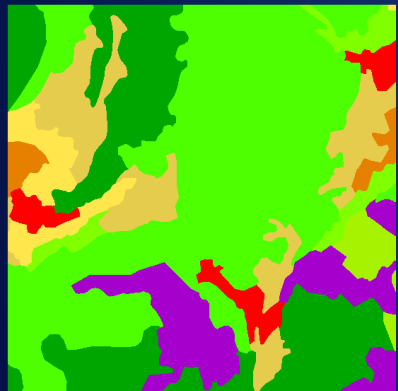
Corine Land Cover 2012
Converted



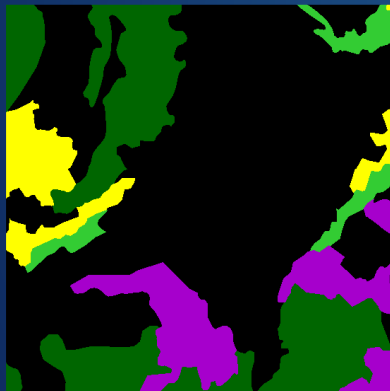
Sentinel-2 27/08/2016



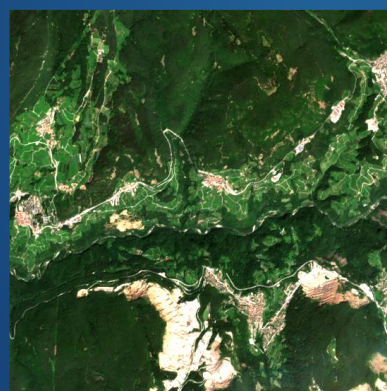
Updated Map (OA% 93.2)



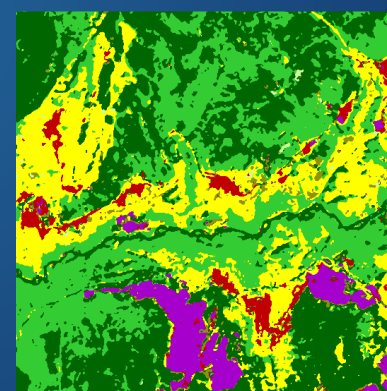
Corine Land Cover 2012



Corine Land Cover 2012
Converted



Sentinel-2 27/08/2016



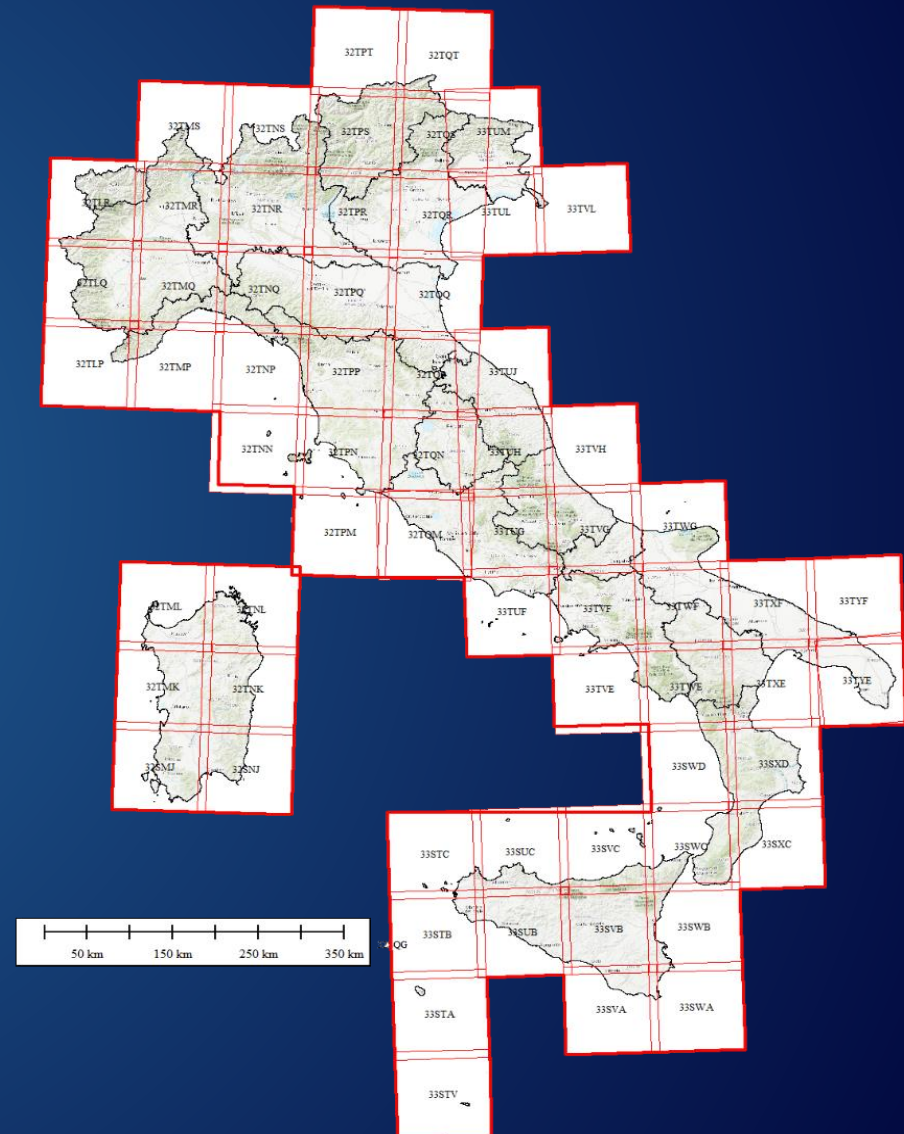
Updated Map (OA% 93.2)



	Accuracy	
	PA%	UA%
Urban	91.11	77.53
Crops	95.68	90.75
Broadleaves	99.33	89.87
Conifers	93.6	94.78
Grass	99.63	92.78
Water	99.91	99.93
Rocks	98.7	94.96
Snow	100	99.09
Shrubland	70.47	86.06
Mineral Site	75.96	99.14
OA%	93.16	

Production of Land Cover Map of Italy

- ✓ For the **production** of the updated maps at **country Italian scale** the developed processing chain has been run on the EO Innovative Platform Testbed Cloud Poland.
- ✓ The system works at granule level in a parallel architecture to fully take advantage from the **cloud computing environment** in order to run on **massive data** in **short time**.
- ✓ The final land-cover maps are expected to be produced within mid 2019.



Conclusion

- ✓ We have defined a methodology and the related processing chain for an **automatic updating of land-cover maps** at the resolution of Sentinel 2. The method:
 - Introduces the concept of **domain understanding and modeling** as crucial to characterize the properties of the map.
 - Exploits **outdated vector land-cover maps** for the classification of recent MS images.
 - Produces temporal consistent land-cover maps by using time series of seasonal images and **without requiring any updated reference training set**.
- ✓ Validation at **regional/country (Trentino region, Czech Republic)** level carried out in the framework of the ESA SEOM-S2-MTA project pointed out the effectiveness of the proposed method.
- ✓ The proposed method is very **promising** to be used for automatically generating updated land-cover maps at country scale.

This work was supported by the European Space Agency (ESA) under project “S2-4Sci Land and Water – Multitemporal Analysis”.