

# A New Large-Scale Sentinel-2 Benchmark Archive and A Three-Branch CNN

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# Outline

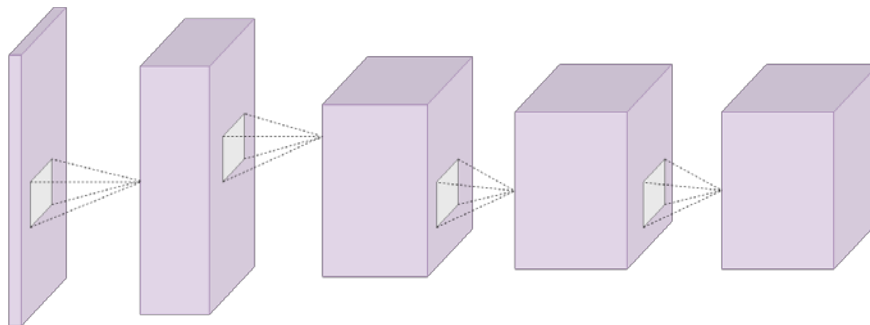
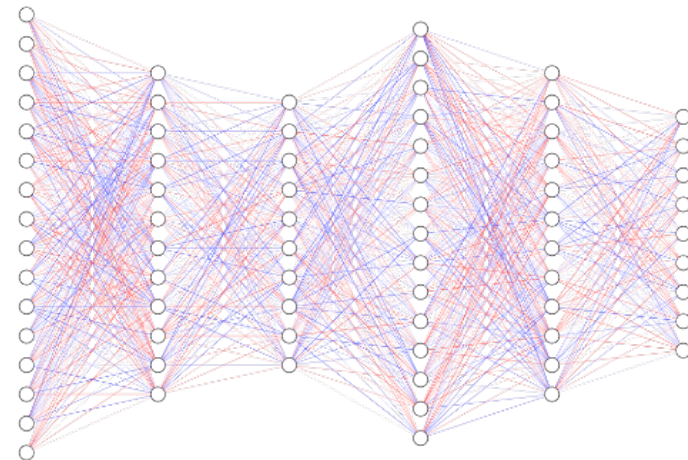


- 1 Introduction
- 2 Existing Benchmark Archives in Remote Sensing
- 3 BigEarthNet: Large-Scale Sentinel-2 Benchmark Archive
- 4 Three-Branch CNN
- 5 Experimental Results
- 6 Conclusion and Future Developments

# Introduction

- ✓ One of the most challenging and emerging applications in remote sensing (RS) is related to the accurate **description** of RS images present in the archives.
- ✓ Recent advances in deep learning have attracted great attention RS due to high capability of deep networks, e.g.,

- Convolutional Neural Network;
- Recurrent Neural Networks;
- Generative Adversarial Networks.



- ✓ To train such networks, very **large training sets** are needed with a high number of annotated images.

# Existing Benchmark Archives in RS

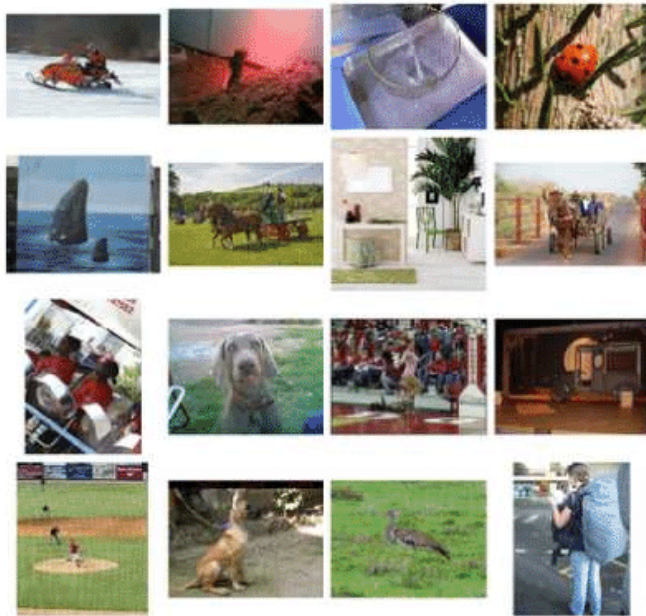


Archive Name	Image Type	Annotation Type	Number of Images
UC Merced	Aerial RGB	Single Label	2100
		Multi-Label	2100
WHU-RS19	Aerial RGB	Single Label	1,005
RSSCN7	Aerial RGB	Single Label	2,800
SIRI-WHU	Aerial RGB	Single Label	2,400
AID	Aerial RGB	Single Label	10,000
NWPU-RESISC45	Aerial RGB	Single Label	31,500
RSI-CB	Aerial RGB	Single Label	36,707
EuroSat	Satellite Multispectral	Single Label	27,000
PatternNet	Aerial RGB	Single Label	30,400

**Problem:** Publicly available RS image archives contain only a small number of annotated images and a large-scale benchmark archive does not yet exist.

# State of the Art Solutions

- ✓ Use of deep learning models pre-trained on large scale computer vision archives (e.g., ImageNet)



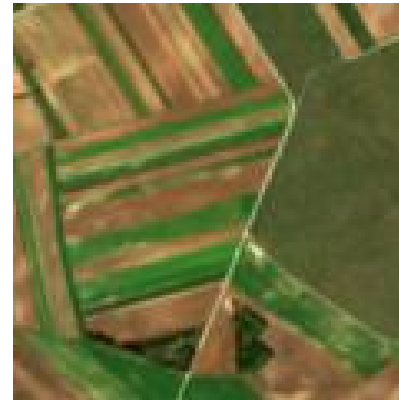
**Problem:** Differences on the characteristics of images between computer vision and RS.

# Limitations on Existing Archives in RS

- ✓ Existing RS archives contain images annotated by **single high-level category labels**.



farmland



non-irrigated arable land, vineyards, pastures, land principally occupied by agriculture

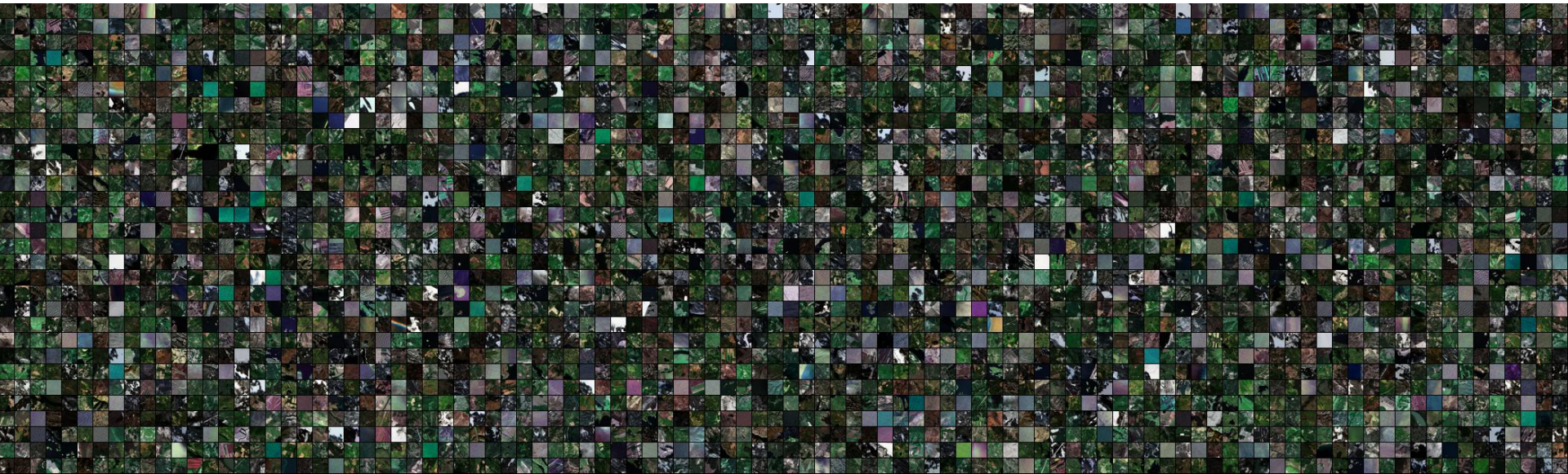
**Problem:** RS images generally contain **multiple classes** associated to different land-cover class labels (i.e., multi-labels).

- ✓ Most of the benchmark archives contain **Aerial images** that include only RGB image bands.

# BigEarthNet: A Large-Scale Benchmark Archive

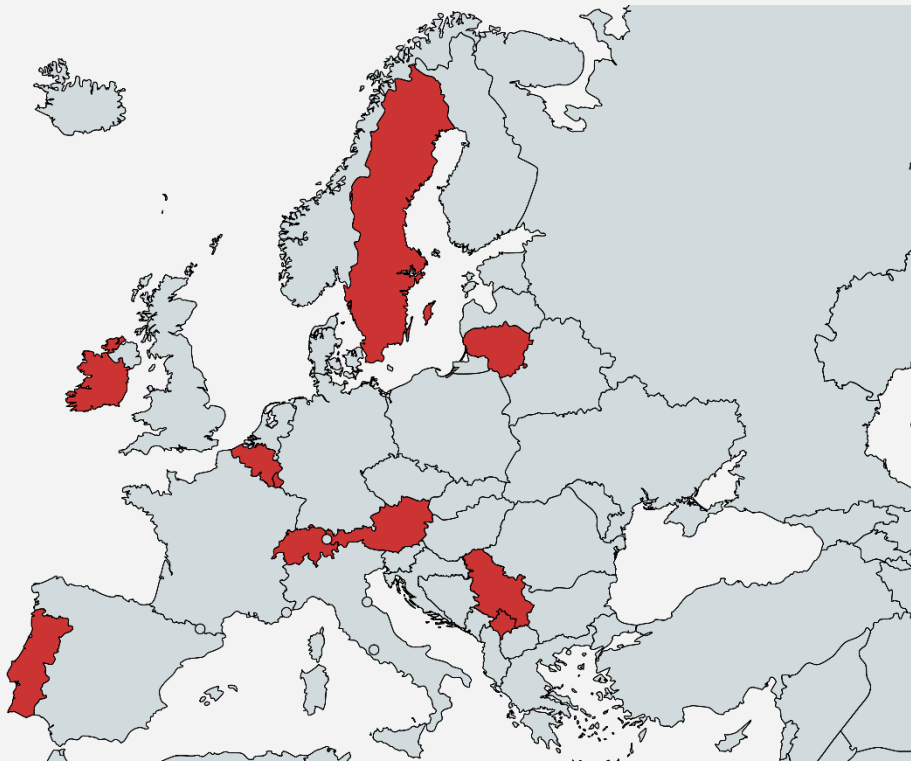


- ✓ The BigEarthNet is a new large-scale Sentinel-2 benchmark archive, consisting of 590,326 Sentinel-2 image patches.



# BigEarthNet: A Large-Scale Benchmark Archive

- ✓ To construct the BigEarthNet, 125 Sentinel-2 tiles (associated to cloud cover percentage less than 1%) acquired between June 2017 and May 2018 were selected.

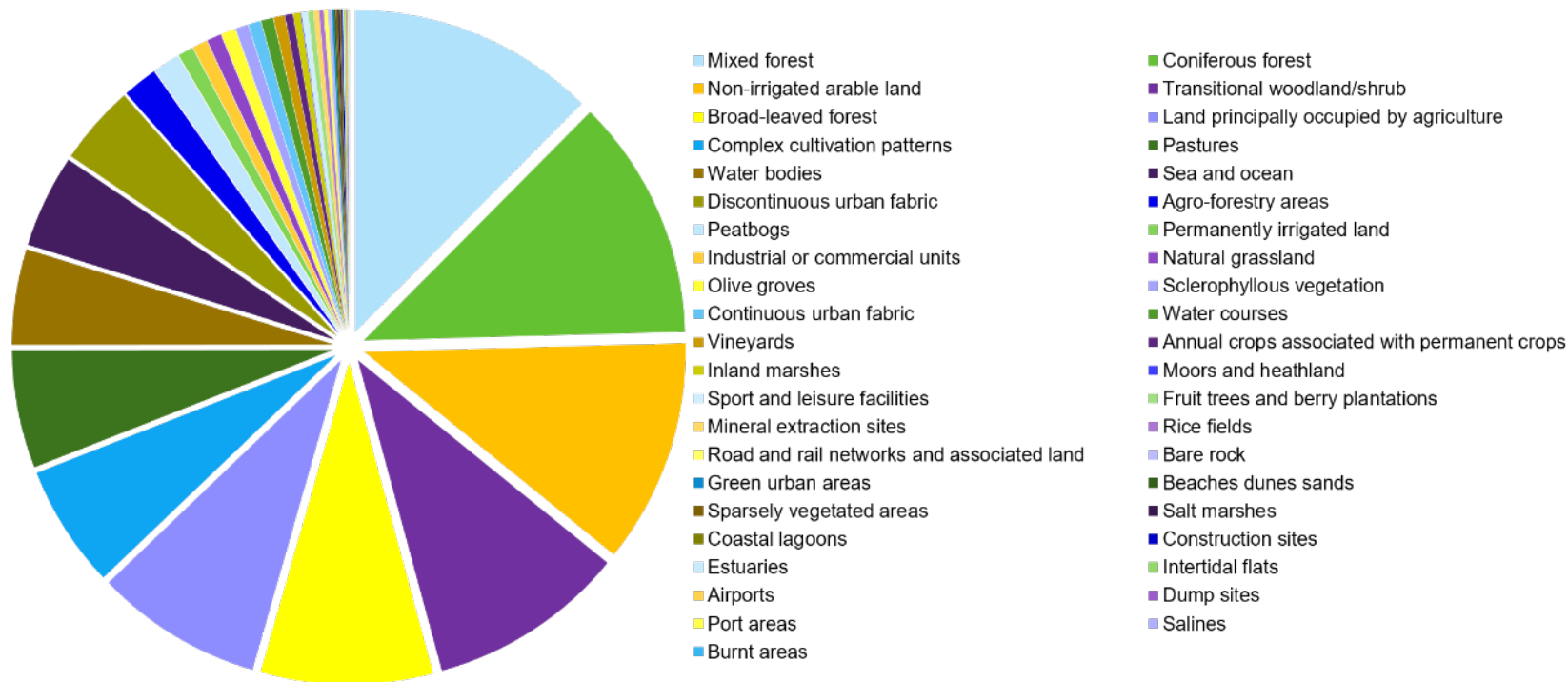


- ✓ Considered tiles are distributed over the 10 countries of Europe:
  - Austria
  - Belgium
  - Finland
  - Ireland
  - Kosovo
  - Lithuania
  - Luxembourg
  - Portugal
  - Serbia
  - Switzerland
- ✓ All the tiles were atmospherically corrected.



# BigEarthNet: A Large-Scale Benchmark Archive

- ✓ Selected tiles were divided into 590,326 non-overlapping image patches, each of which has size of 120x120 pixels in 10 meter resolution.
- ✓ Each image patch is associated with one or more land-cover class labels provided from the CORINE Land Cover (CLC) database of the year 2018 (CLC 2018).
- ✓ It is produced with assistance from the European Environment Agency's Eionet network.



# BigEarthNet: A Large-Scale Benchmark Archive

- ✓ The number of labels associated with each image patch varies between 1 and 12, whereas 95% of patches have at most 5 multi-labels.



Continuous urban fabric,  
Green urban areas



Non-irrigated arable land,  
Fruit trees and berry  
plantations,  
Pastures



Coniferous forest,  
Mixed forest,  
Water bodies,  
Transitional woodland/shrub.



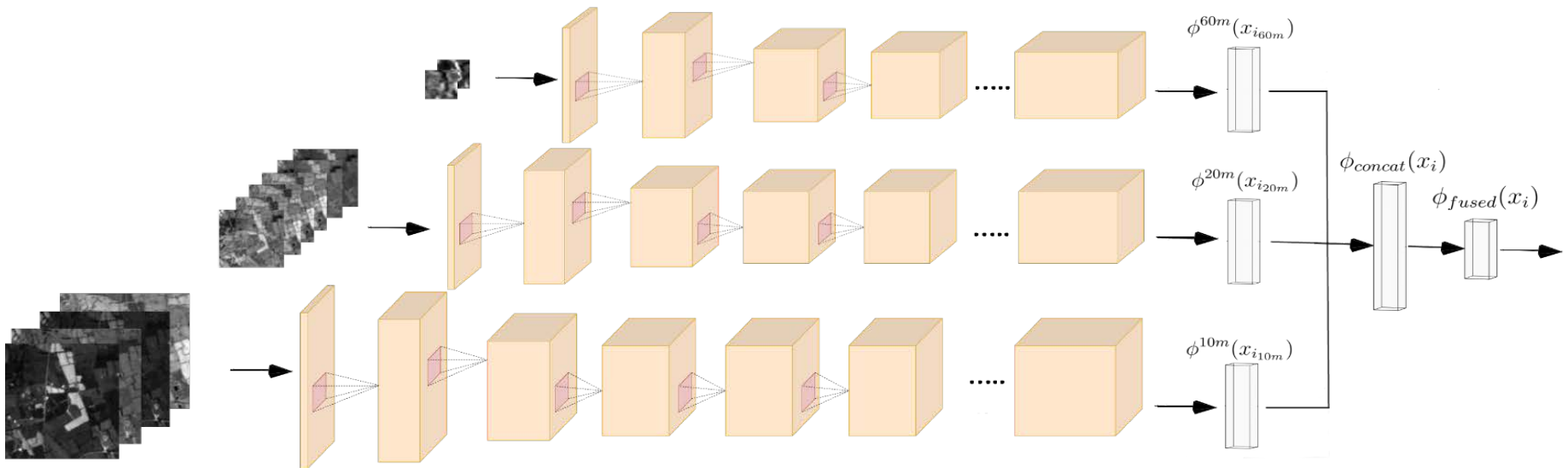
Discontinuous urban fabric,  
Construction sites,  
Green urban areas

- ✓ Images acquired in different seasons are considered.

Seasons	Number of Image Patches
Autumn	154,943
Winter	117,156
Spring	189,276
Summer	128,951

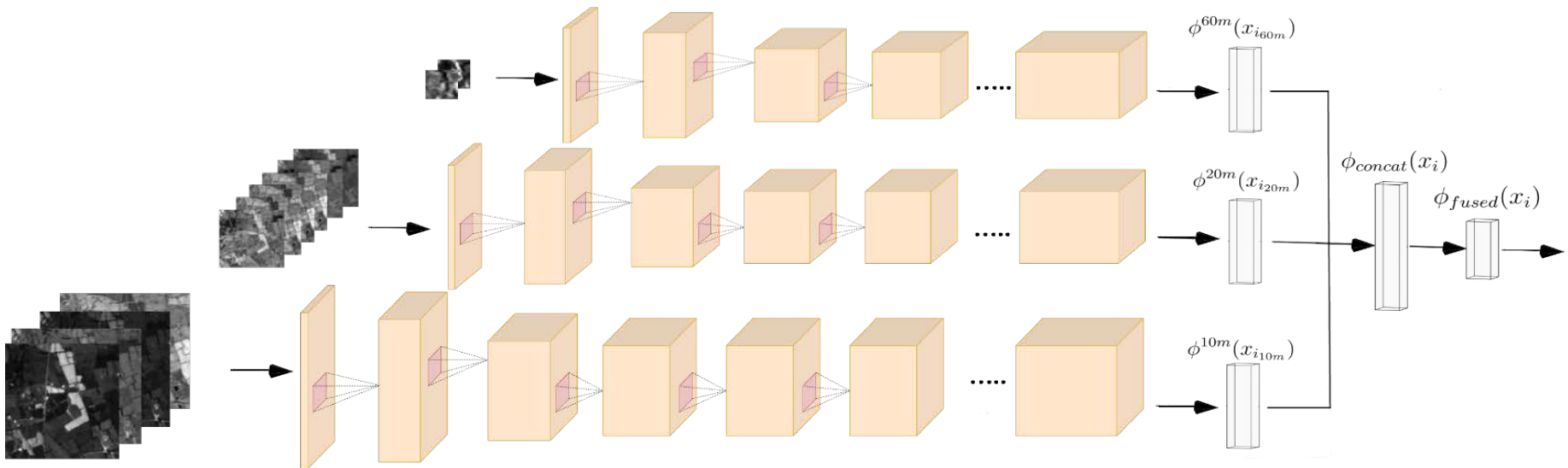
# Three Branch CNN (TB-CNN)

- ✓ TB-CNN includes three different convolutional branches specifically designed for different spatial resolutions of Sentinel-2 bands.
- ✓ Each branch acts as a feature extractor for different resolutions



# Three Branch CNN (TB-CNN)

- ✓ For the first and second branches developed for 60m and 20m resolutions, 2x2 filters and 3x3 filters are used, respectively, throughout the layers.
- ✓ 5x5 filters for initial layers and 3x3 filters for deeper layers are used for the last branch, which accepts 10m resolution bands.



# Applications on BigEarthNet

Multi-Label Scene Classification

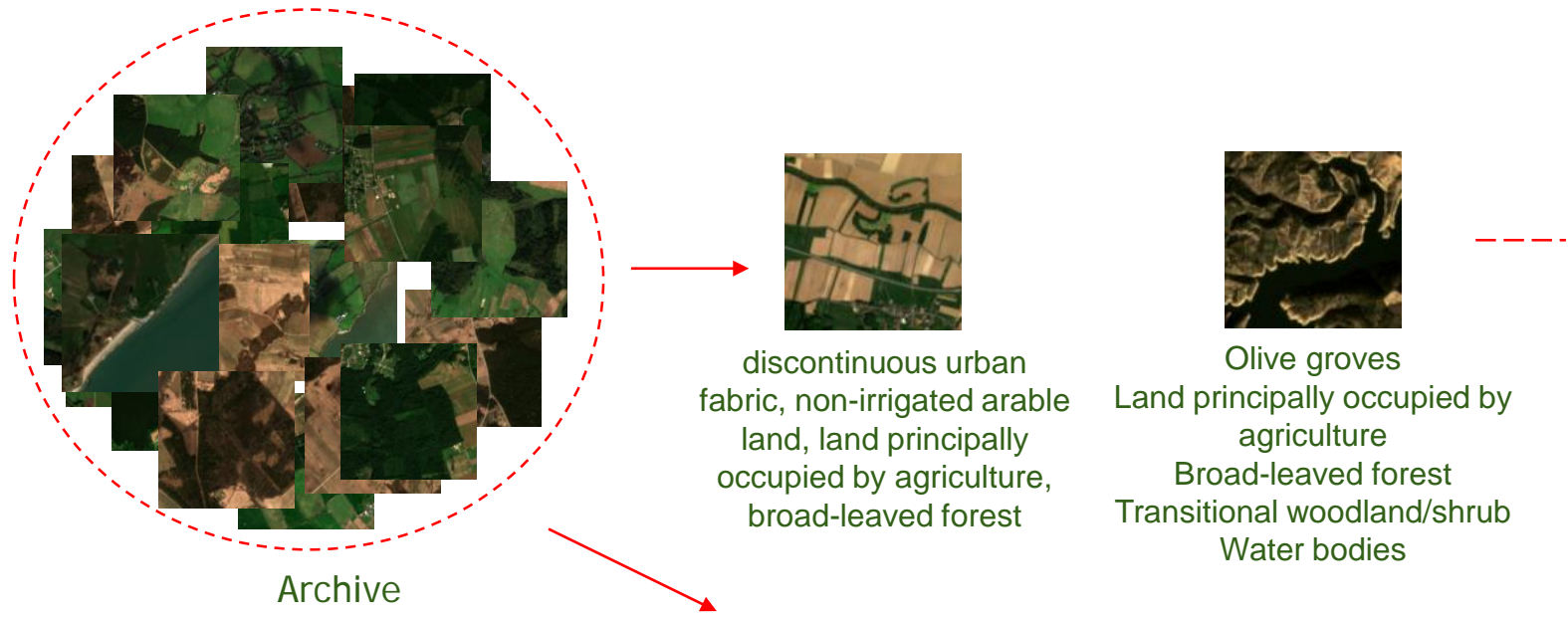
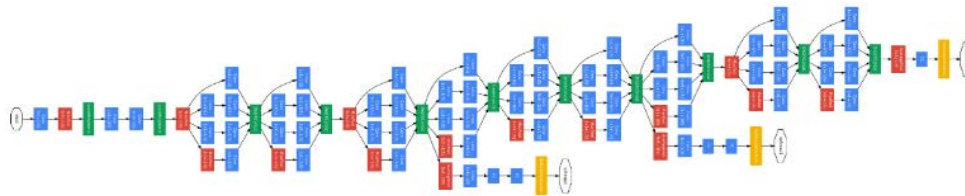


Image Retrieval

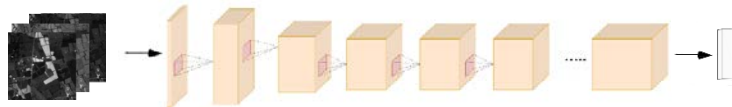


# Design of Experiments

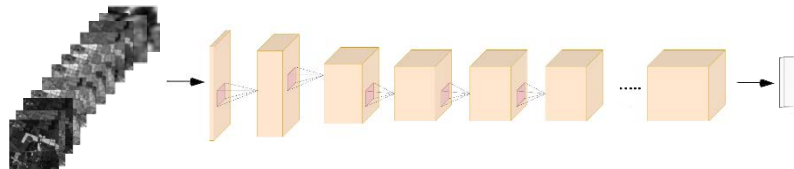
- ✓ We have compared the results with those obtained by:
  - Fine-tuning the last layer of Inception-v2 pre-trained on ImageNet.



- Standard CNN architecture trained on only RGB bands



- Standard CNN architecture trained on all spectral bands



# Results of Scene Classification



Methods	Recall	F <sub>1</sub> Score	F <sub>2</sub> Score
Pre-trained CNN on ImageNet*	40.75 %	0.4171	0.4085
RGB Bands in Standard CNN	54.72 %	0.5543	0.5451
All Bands in Standard CNN	57.20 %	0.6083	0.5812
All Bands in Three Branch CNN	<b>70.62 %</b>	<b>0.6519</b>	<b>0.6763</b>

\* We apply fine-tuning to the pre-trained Inception-v2 architecture.

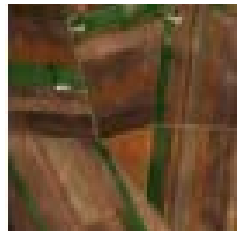
# Results of Content Based Image Retrieval

1<sup>st</sup>

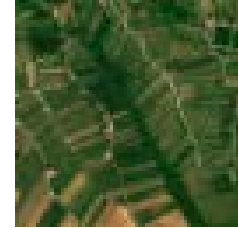
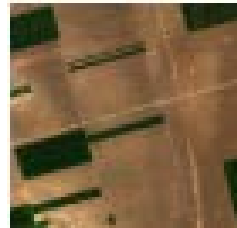
3<sup>rd</sup>

7<sup>th</sup>

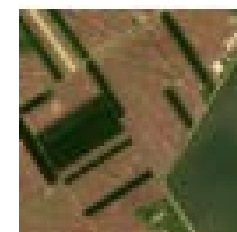
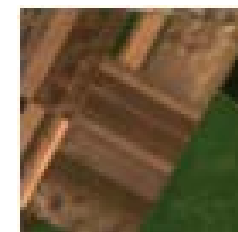
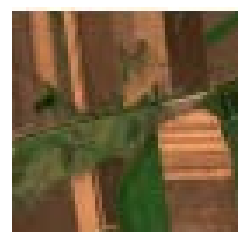
13<sup>th</sup>



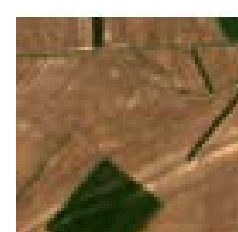
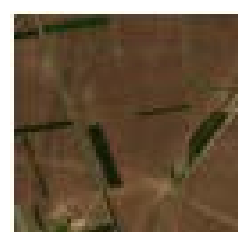
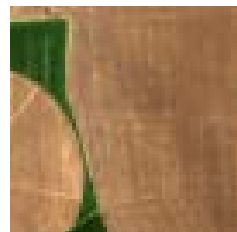
Query Image



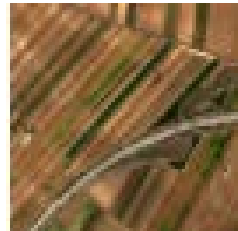
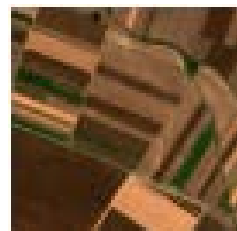
Pre-trained CNN on ImageNet



RGB Bands in Standard CNN



All Bands in Standard CNN

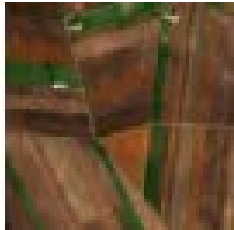


All Bands in Three Branch CNN



# Results of Content Based Image Retrieval

Query Image



Non-irrigated arable land

Pre-trained CNN on ImageNet



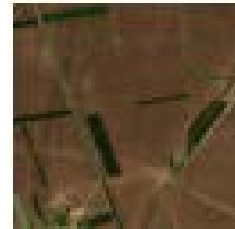
Industrial or commercial units, Non-irrigated arable land

RGB Bands in Standard CNN



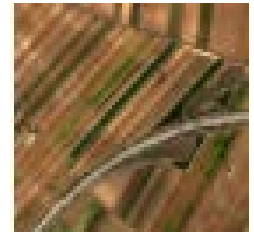
Non-irrigated arable land, Pastures, Water bodies

All Bands in Standard CNN



Discontinuous urban fabric, Non-irrigated arable land

All Bands in Three Branch CNN



Non-irrigated arable land

# Conclusion and Future Developments



- ✓ We have introduced a large-scale benchmark archive that consists of 590,326 Sentinel-2 image patches annotated by **multi-labels**, for RS image understanding.
- ✓ BigEarthNet will make a **significant advancement** for the use of **deep learning** in RS by overcoming current limitations of the existing archives.
- ✓ We plan to regularly enrich the BigEarthNet by increasing the number of **annotated Sentinel-2 images**.
- ✓ We are currently working on designing and implementing a **scalable architecture** for massive processing and analysis of images in the BigEarthNet.



<http://bigearth.net/>

We would like to thank to all RSiM and DIMA group members!