→ MAPPING URBAN AREAS FROM SPACE CONFERENCE

Automatic Generation of Updated Land Cover Maps at Decametric Spatial Resolution for the whole Italian Territory Using Satellite Data

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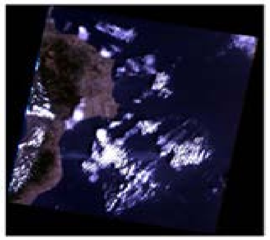
Purpose of this work

This study intends to address the following issues:

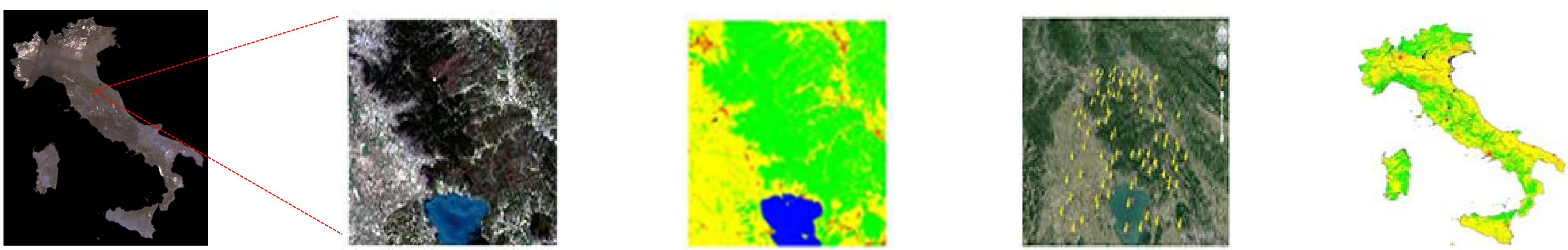
- Uniform land cover classification at a national level at high resolution (~30m)
- Determine territory morphology with high level of accuracy (>90%)
- Evaluate in a 6 month basis the change of land cover
- Create an automatic process

Methodology

Landsat Images



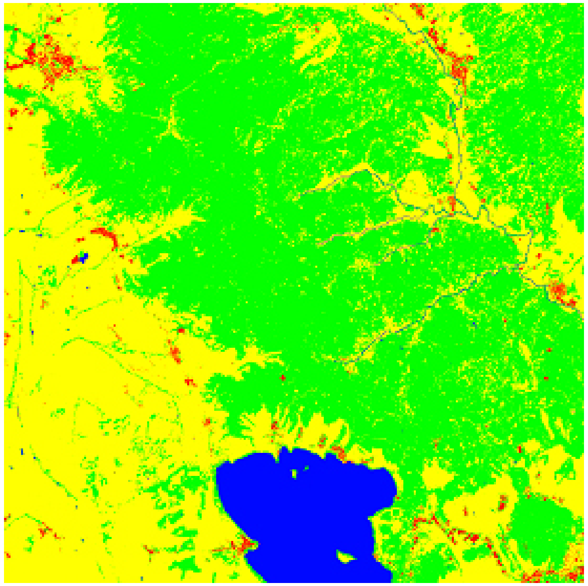
Pre-processing and mosaicing → Tiles creation 1500x1500 → Neural Network classification and manual correction → Validation → Output



Elaboration

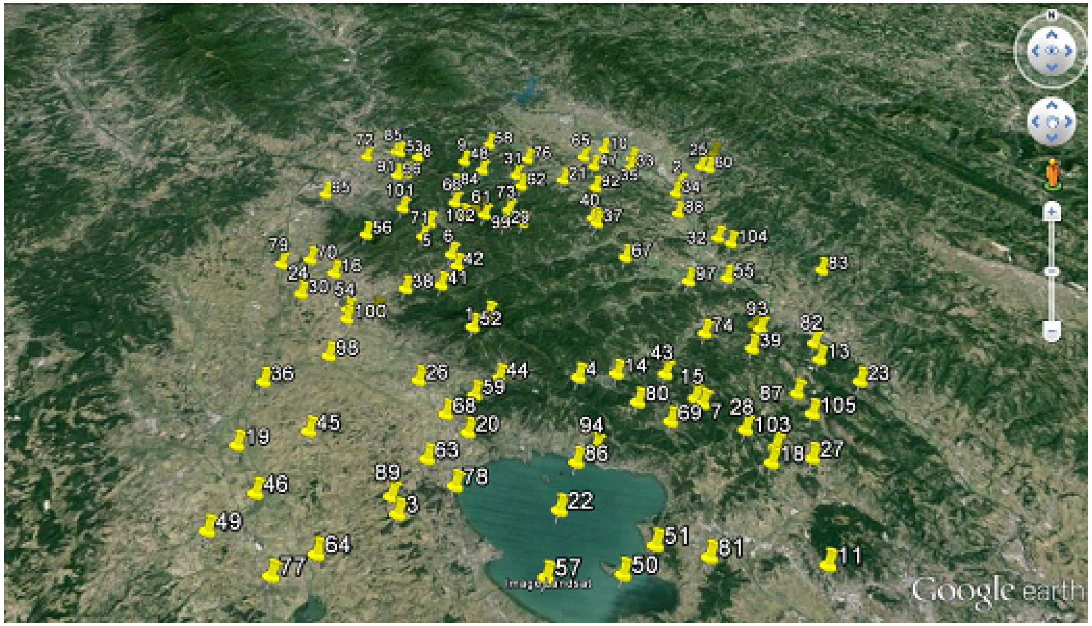
- The territory was divided in the following “thematic” classes: urban areas, woodlands, water surfaces, other natural areas (bare soil, rock ect)
- It was decided to limit the number of classes to 4 to simplify the automatic classification process making it more robust
- Each tile was classified using a MLP neural network algorithm plus manual correction

Red: urban areas
Green: woodlands
Blue: water surfaces
Yellow: other natural areas



Validation

- For data validation we used Google Earth
- After creating random check points we compare our classification in those points with high resolution images.
- This comparison determines the accuracy of the classification.

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Confusion Matrix
[[32  0  4  0]
 [ 0  0  0  0]
 [ 7  0 58  0]
 [ 3  0  0  1]]

Total Points Validated: 105
Classification Accuracy: 86.6666666667 %
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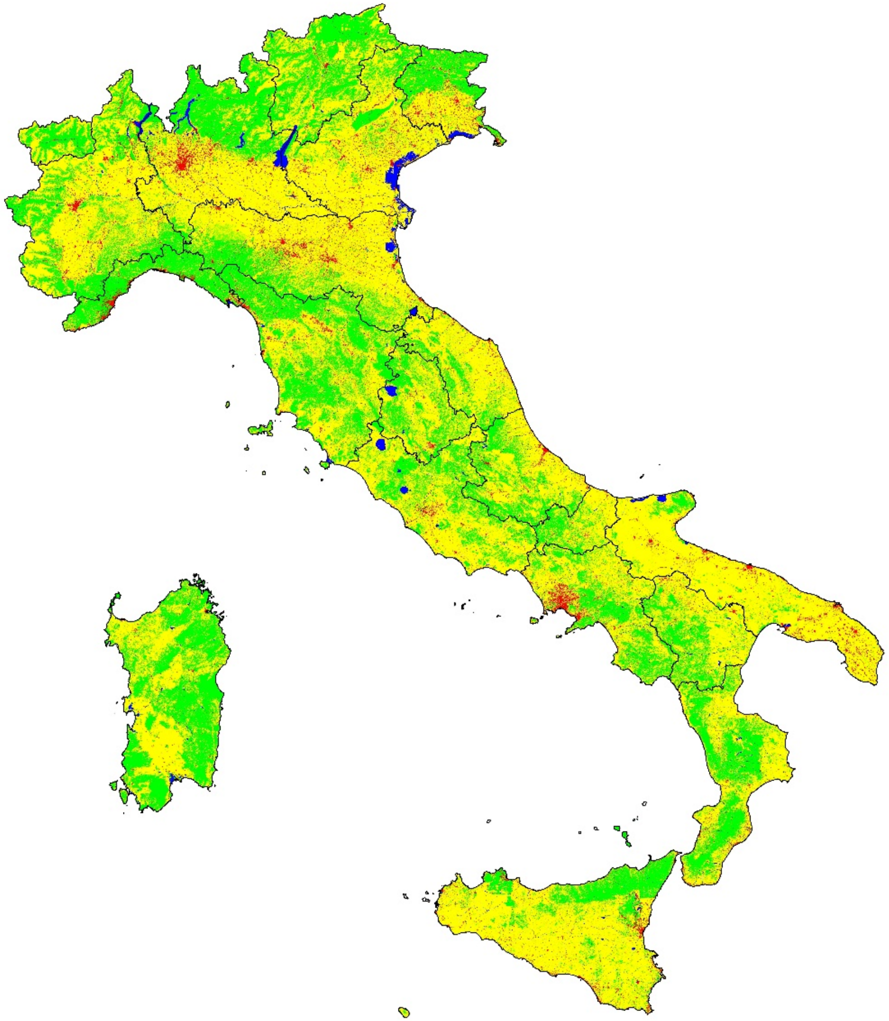
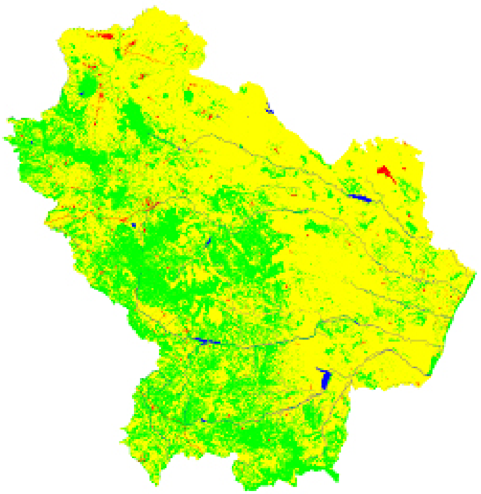
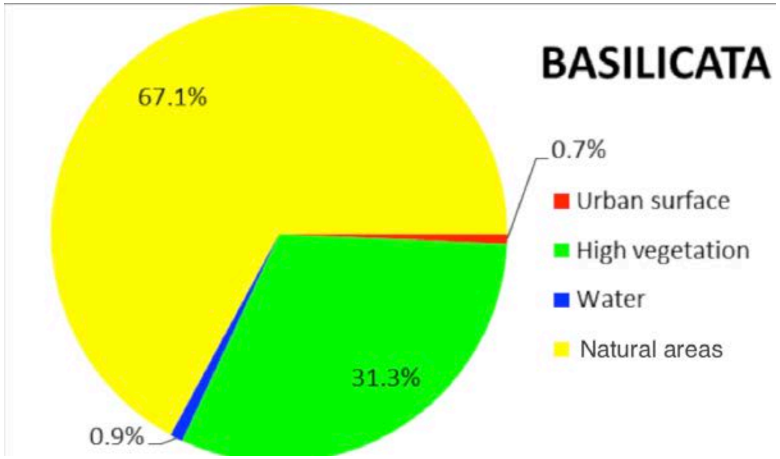
Results for Italy 2000



The overall estimated accuracy is of about 93%

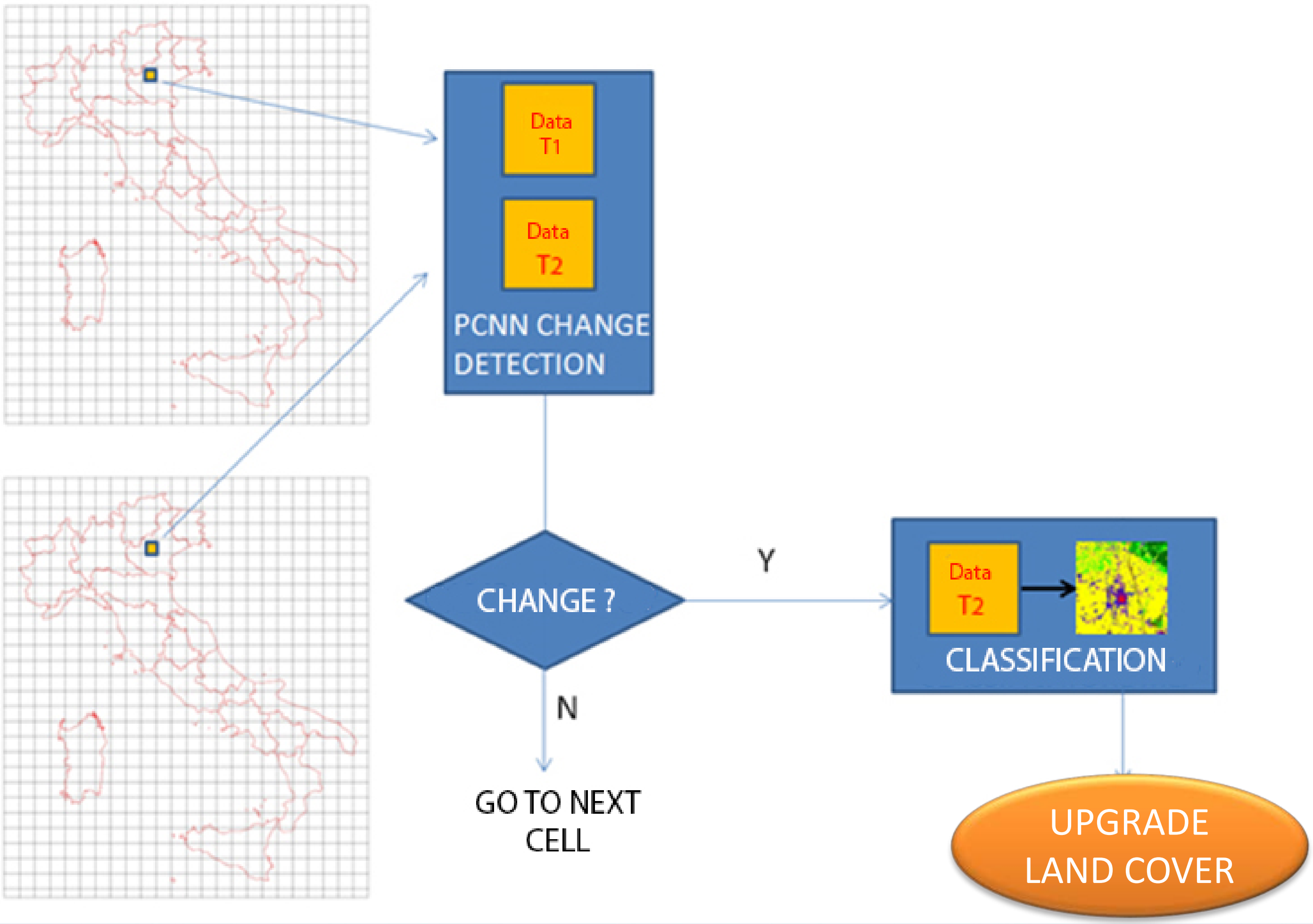
Basilicata





Basilicata		
Classes	Percentage	Km^2
Urban surface	0.7	69.94
High vegetation	31.3	3127.496
Water	0.9	89.93
Other natural areas	67.1	6704.632
Tot.	100	9992

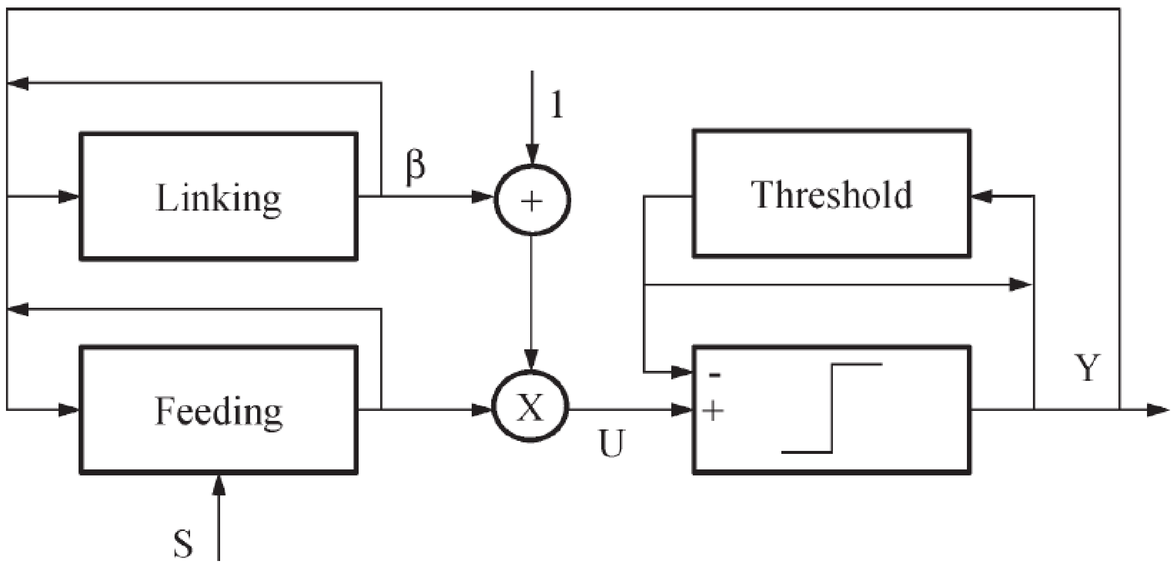
Updating classification



PCNN

Pulse-Coupled Neural Network (PCNN)

- Automatic detection algorithm
- Requires no training
- Unsupervised
- Very sensitive to image context

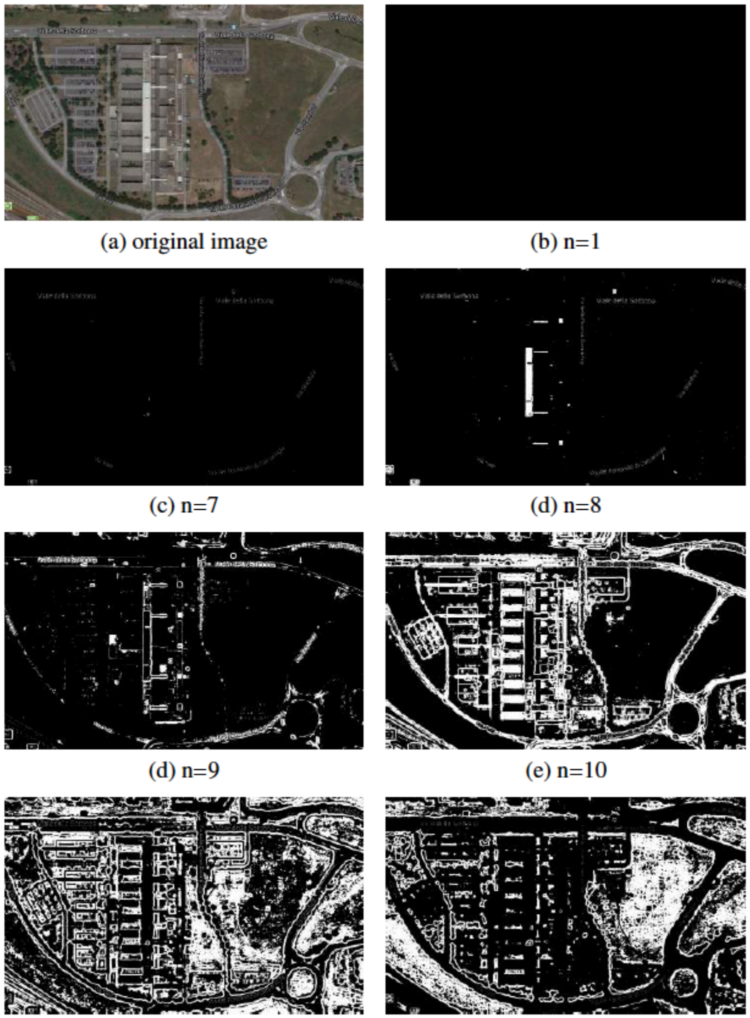


Schematic representation of a PCNN neuron

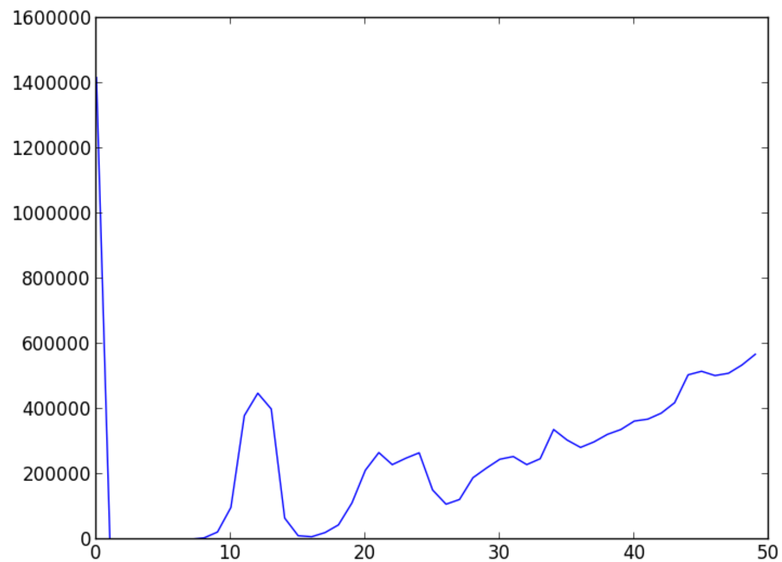
PCNN

- Feeding $F_{ij}[n] = e^{-\alpha_F} \cdot F_{ij}[n-1] + S_{ij} + V_F \sum_{kl} M_{ijkl} Y_{kl}[n-1]$
- Linking: $L_{ij}[n] = e^{-\alpha_L} \cdot L_{ij}[n-1] + V_L \sum_{kl} W_{ijkl} Y_{kl}[n-1]$
- Internal neuron state: $U_{ij}[n] = F_{ij}[n](1 + \beta L_{ij}[n])$
- Threshold: $\theta_{ij}[n] = e^{-\alpha_\theta} \cdot \theta_{ij}[n-1] + V_\theta Y_{kl}[n]$
- Output pulse: $Y_{ij}[n] = \begin{cases} 1, & \text{if } U_{ij}[n] > \theta_{ij}[n] \\ 0, & \text{otherwise.} \end{cases}$

Time signal



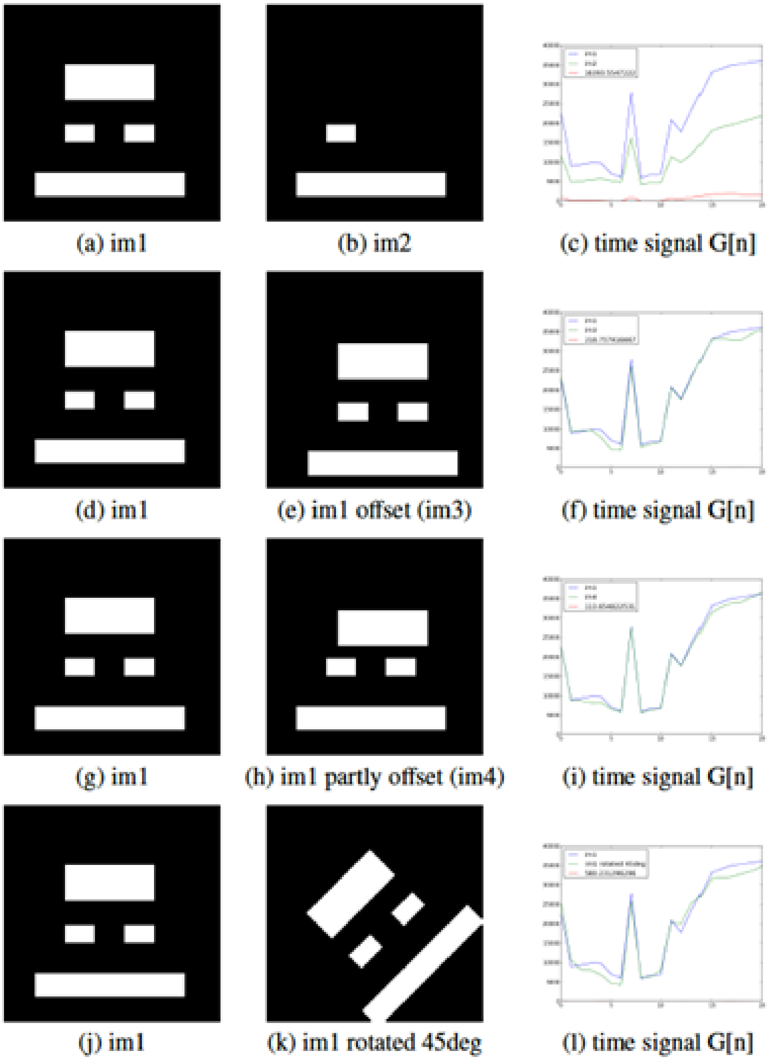
(a) original image (b) n=1
(c) n=7 (d) n=8
(d) n=9 (e) n=10
(c) n=11 (d) n=12



$$G[n] = \sum_{ij} Y_{ij}[n]$$

Number of neurons that pulsate during each iteration

Time signal

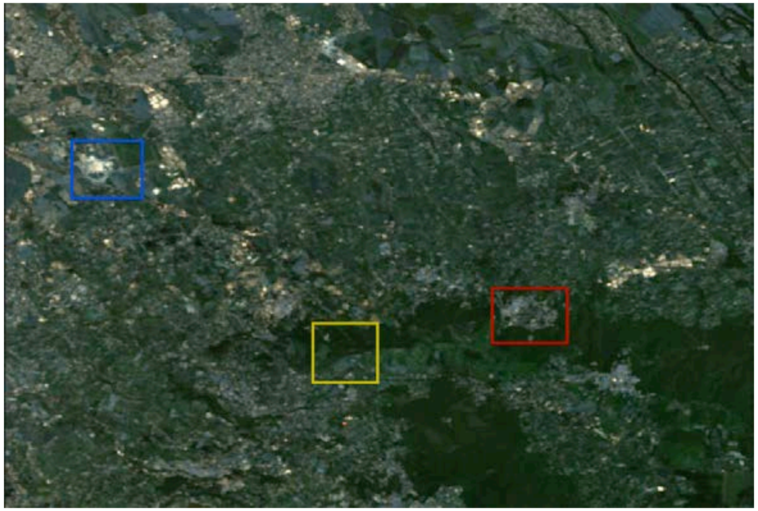


Important PCNN feature: **invariance** to changes in rotation, scale, shift, or skew of an object within the scene.

PCNN a powerful tool in change detection, where the view angle of the satellite can play an important role!

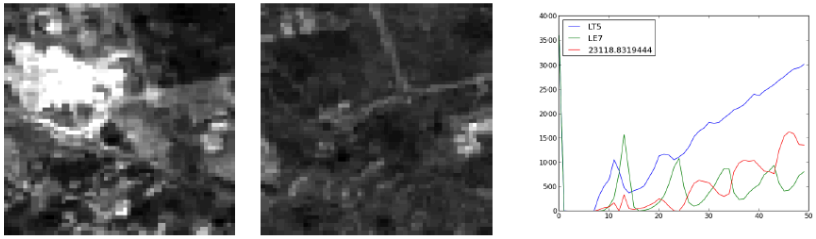
Change detection in Landsat data

Two Landsat 7 datasets: 5 bands in 2004 (17/02/04) and 2010 (01/06/10)

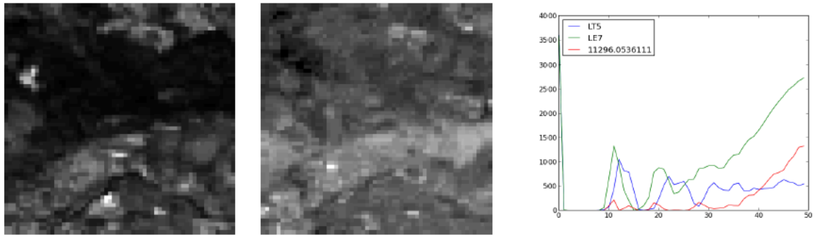


60x60 pixel boxes
30 pixel steps

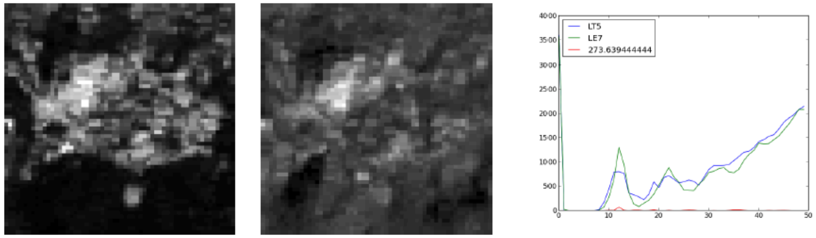
260 sub-areas



(a) region (1) - 2010 (b) region (1) - 2004 (c) G[n] vs. n



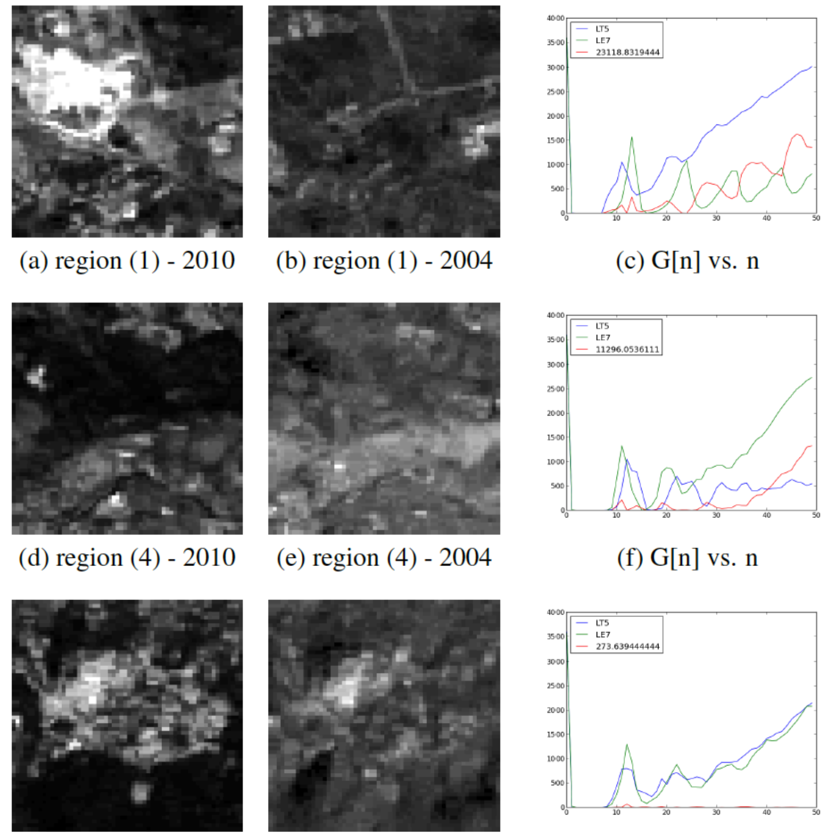
(d) region (4) - 2010 (e) region (4) - 2004 (f) G[n] vs. n



(g) region (6) - 2010 (h) region (6) - 2004 (i) G[n] vs. n

Change detection in Landsat data

Two Landsat 7 datasets: 5 bands in 2004 (17/02/04) and 2010 (01/06/10)



(a) region (1) - 2010 (b) region (1) - 2004 (c) G[n] vs. n

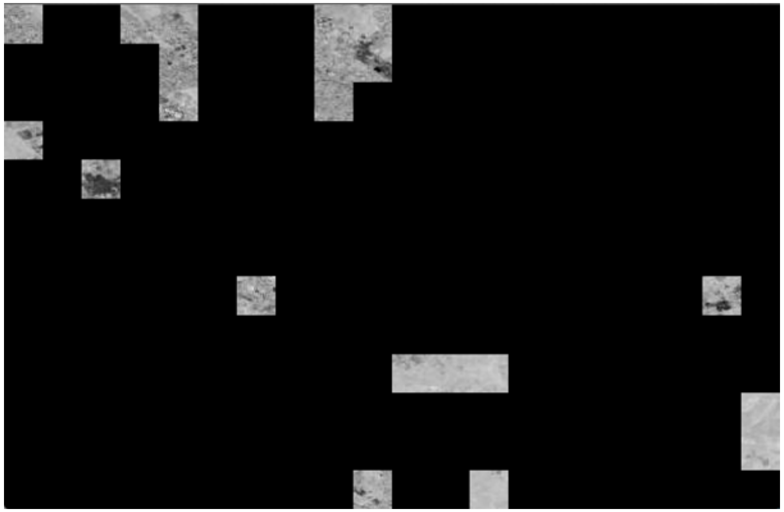
(d) region (4) - 2010 (e) region (4) - 2004 (f) G[n] vs. n

(g) region (6) - 2010 (h) region (6) - 2004 (i) G[n] vs. n

60x60 pixel boxes
30 pixel steps

260 sub-areas

Merging Landsat bands



Three bands combined

- **(band(3) AND band(4)) OR (band(3) and band(2))**

Spectral band	Wavelength (μm)	Resolution (m)
(1) Blue	0.45 - 0.52	30
(2) Green	0.52 - 0.60	30
(3) Red	0.63 - 0.69	30
(4) Near Infrared (NIR)	0.76 - 0.90	30
(5) Mid Infrared (MIR)	1.55 - 1.75	30

21 areas selected (8%)

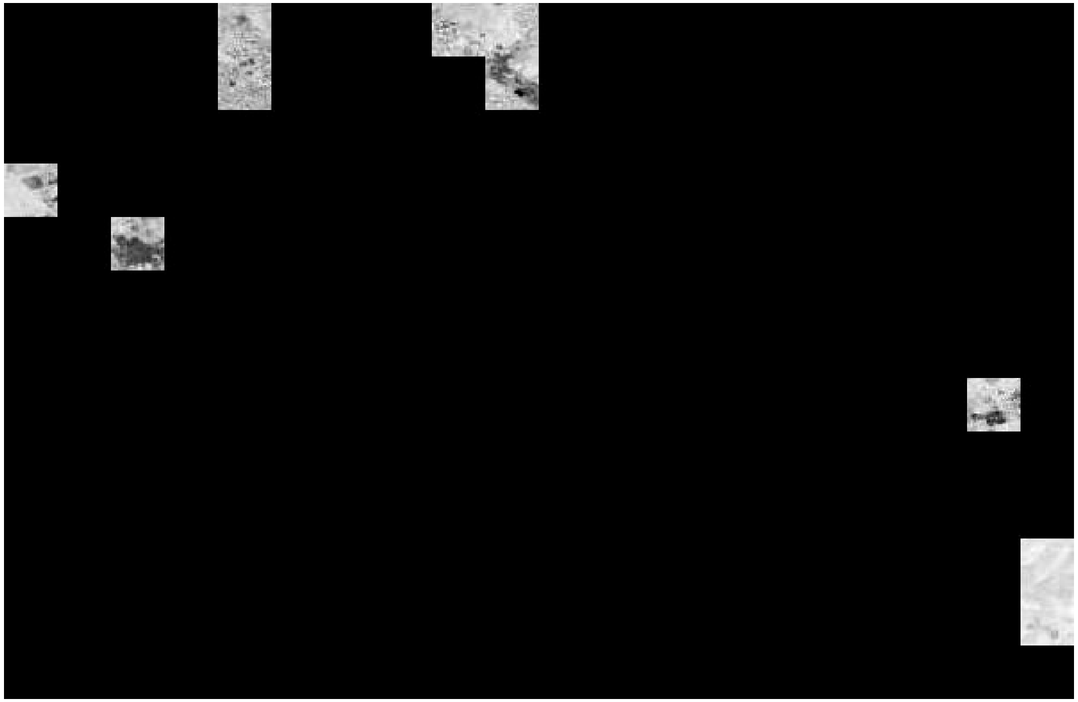
18 false positives

239 areas correctly purged

Desired map

Merging Landsat & ASAR

We combined the Landsat map with a similar map produced applying the PCNN to 2 ASAR Envisat images obtained in 2004 and 2010



Result: 10 areas selected – 7 false positives (before 18)

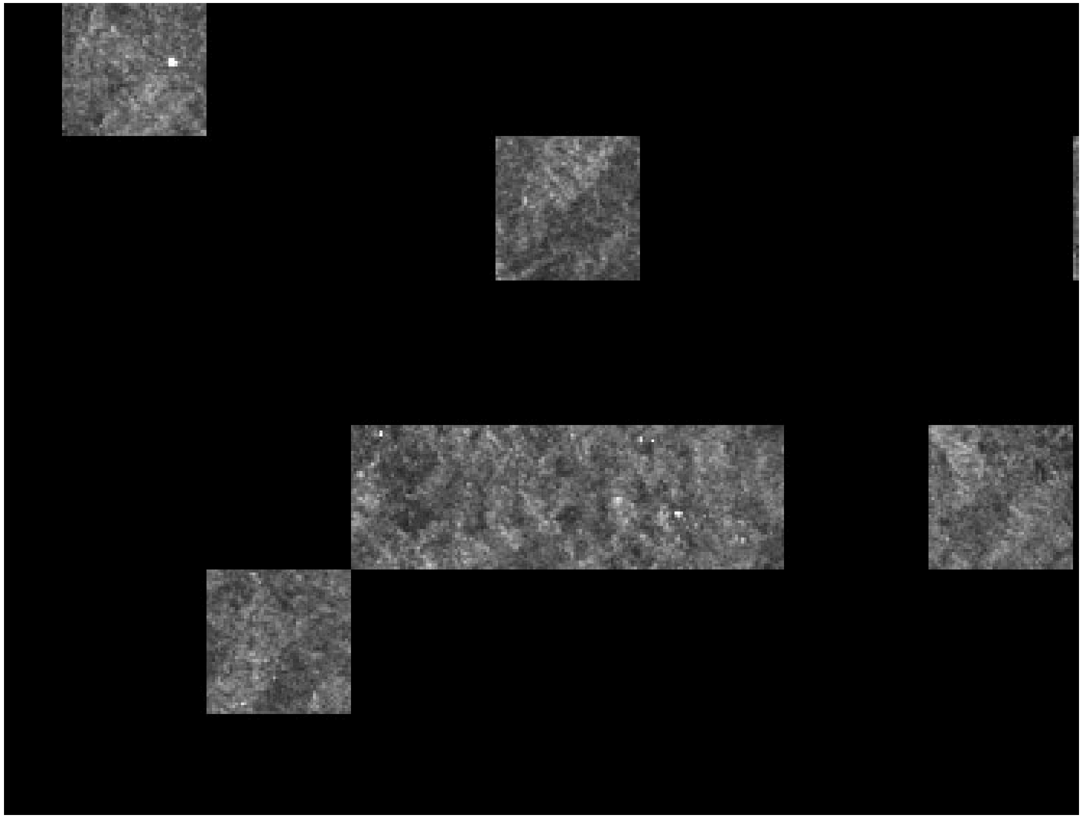
60% better performance

Sentinel-1 data

Result of 3 image combination in Feb. 2015 (29/01 – 10/2 – 22/2)

Result of 3 image combination in Sep. 2015 (02/09 – 14/09 – 26/09)

Sentinel-1 data



Zoom in a sample area with the mask superimposed

100x100 pixel boxes

50 pixel steps

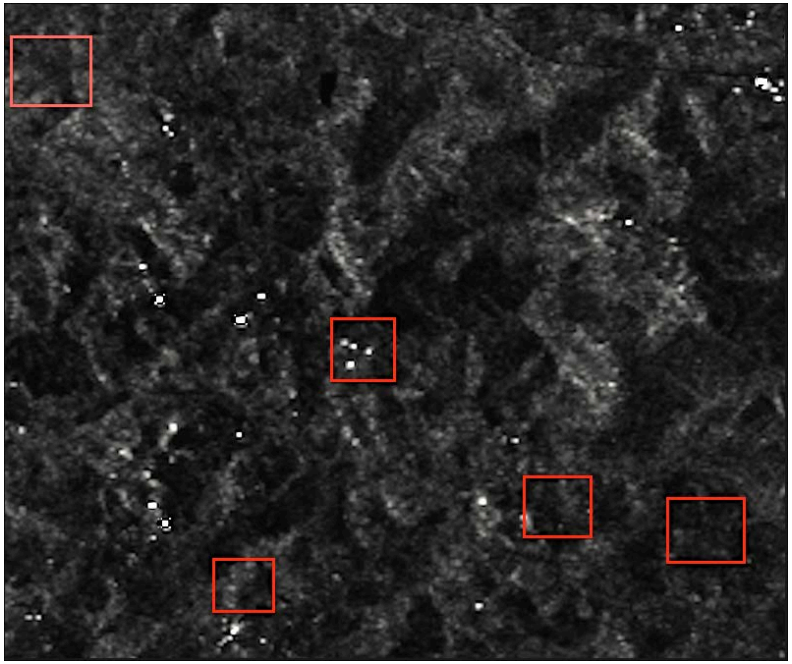
1521 sub-areas

413 selected as “changed” by the PCNN

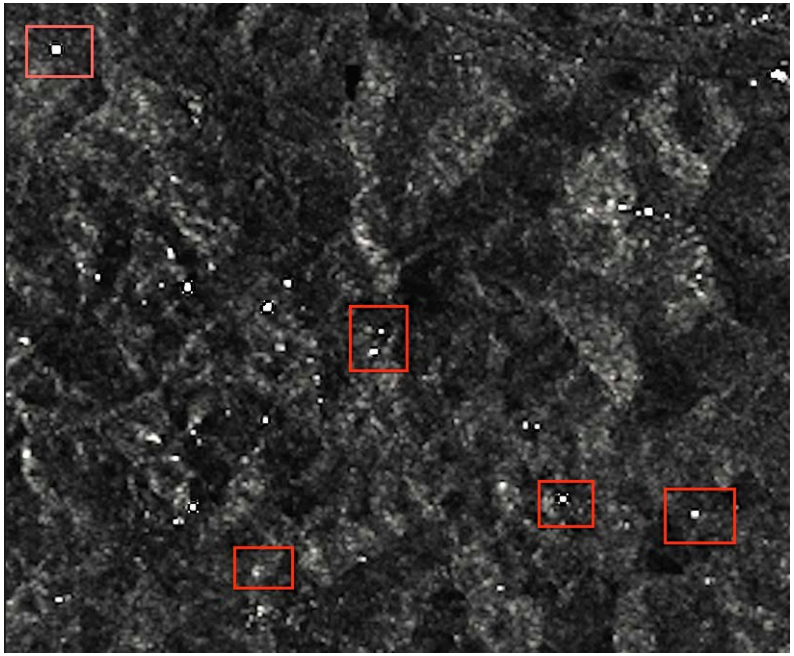
Thus only ~27% of the total area has shown significant change

Sentinel-1 data

Visual inspection of the selected areas



Feb. 2015



Sep. 2015

Summary

- A "Master" reference map with Landsat resolution has been created for the whole Italian territory
- Implemented validation procedures report an accuracy of about 93%
- PCNN is an effective algorithm to focus only on changes from the reference map
- Data fusion analysis has been performed to combine Optical and SAR results from PCNN
- Preliminary results with Sentinel-1 data

Future development

- Conclusion of the 2010 classification map using the PCNN method.
- Create a new map for 2015 using Landsat 8 and Sentinel-1 data
- Update the classification map every 6 months using the automatic PCNN procedure, preferably using SAR images that don't suffer from cloud coverage.
- When publicly available, start data fusion with Sentinel-2 images to improve performance

Thank you very much!