Giovanni Giacco

Empowering Sustainability through Artificial Intelligence and Earth Observation: Learning from the Past, Monitoring the Present, Building the Future

Tutor: Prof. Carlo Sansone

Cycle: XXXVI

Year: Third

Background information

- **Master Degree:** *Computer Engineering* at University of Naples Federico II
  - Thesis: "*Deep Learning for Land Cover classification using Multispectral Sentinel-2 Satellite Imagery*"

- **Research laboratory**
  - PATTERN ANALYSIS AND INTELLIGENT COMPUTATION FOR MULTIMEDIA SYSTEMS (PICUS LAB)

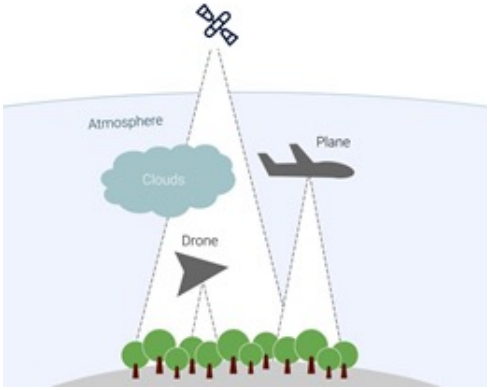
- **PhD start date**: 01/11/2020

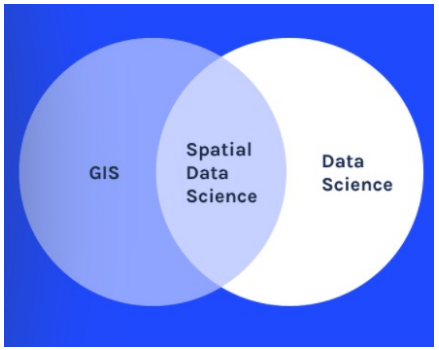
- **Period abroad**: Universidad Politécnica de Madrid 12/09/2022 – 22/12/2022
- **Scholarship type**: no scholarship
- Currently working for LATITUDO 40® (no company funded scholarship)

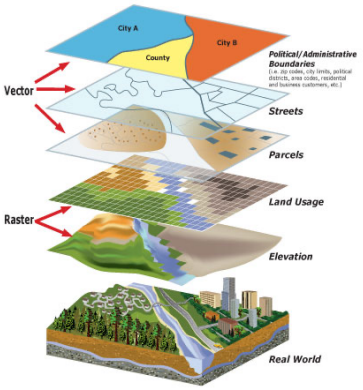
Summary of study activities

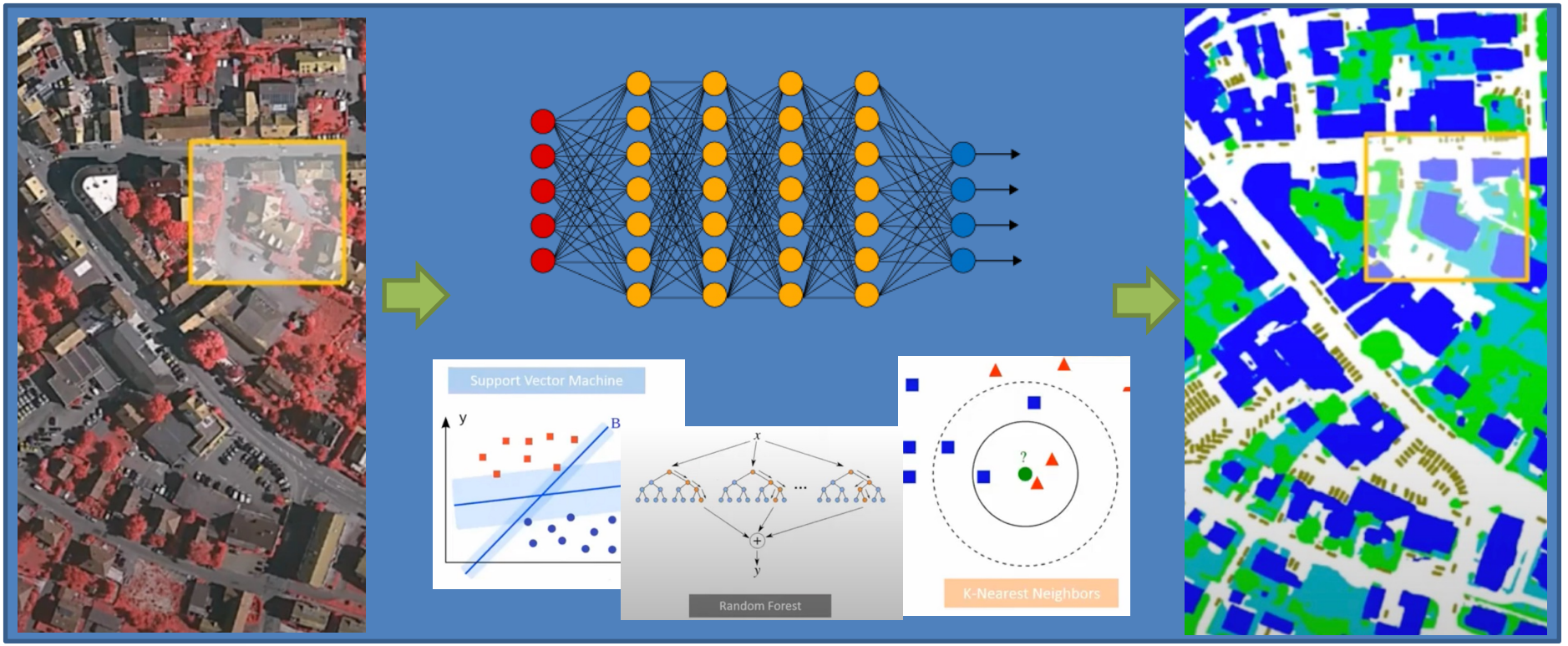
- **8 Courses.** The latest include:
  - Using Deep Learning properly
  - Satellite and aerial images: automatic processing and analysis in GIS
- **33 Seminars** with the aim of acquiring knowledge on AI, Deep Learning, Earth Observation and Remote Sensing.
- Latest attended **Conferences**:
  - "European Climate Change Adaptation (ECCA) Conference 2023", Dublin, Ireland, 19-21 June 2023. Poster presentation.
  - "AI Ecosystem Forum 2023", Athens, Greece, 29-30 June 2023. Oral Presentation.
  - "EBDVF 2023 European Big Data Value Forum 2023", Valencia, Spain, 25-27 October 2023. Oral Presentation.
  - "CANADA-ITALY FORUM ON AI", Montreal, Canada, 6-9 November 2023. Panel Presentation.
  - "GEOAI 2023", Torino, Italy. Oral Presentation.

Research area(s)









Research results

- Implementation of DL approaches for:
  Impervious Maps Extraction, Aboveground Biomass Estimation (AGB)

- Active Learning for Model Transfer of AGB estimation with few ground-truth sample data

- Proposed a methodology for Nature-based Solution Installation planning in a urban context
  - Experimentation in the city of Turin and Asti

- Proposed a methodology for *Scenario Thinking* applied to Earth Observation (EO) through synthetic EO data

- Construction of 1 datasets, shared on Zenodo.

PhD thesis overview

Objective

Develop solutions for User-centric Earth-Observation applications powered by Artificial Intelligence (AI), with a focus on Sustainability.

Main Challenges

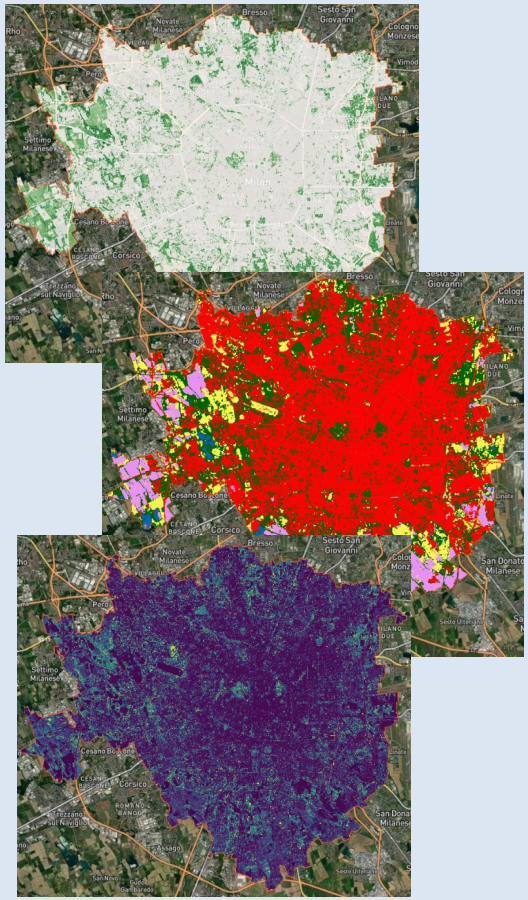
- Lack of generalization of DL approaches for different areas and time period
- Lack of ground-truth dataset for supervised learning
- Lack of frequently updated data. Existing Earth-Observation solutions based on data updated every 2-3 years.

Opportunities

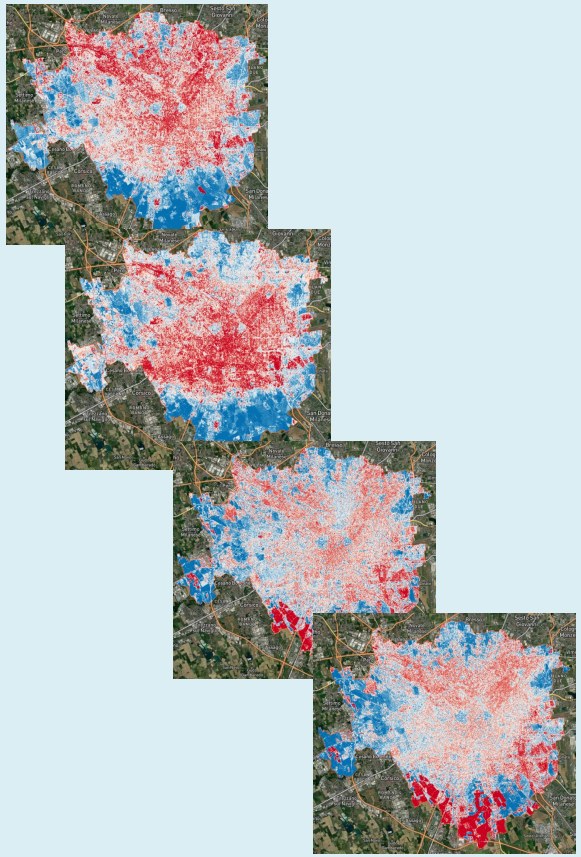
- Support the creation of up-to-date maps with free-of-charge satellite imagery.
- Propose solutions that helps the final user to get informed decisions from Remote Sensing data.

PhD thesis

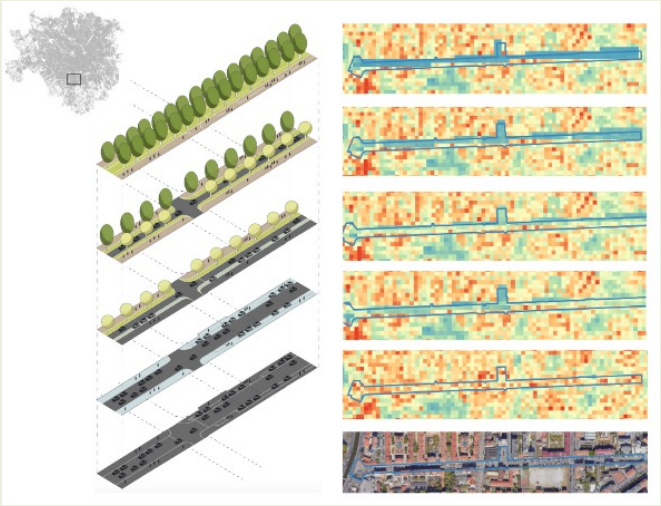
Learning from
PAST



Monitoring the
PRESENT

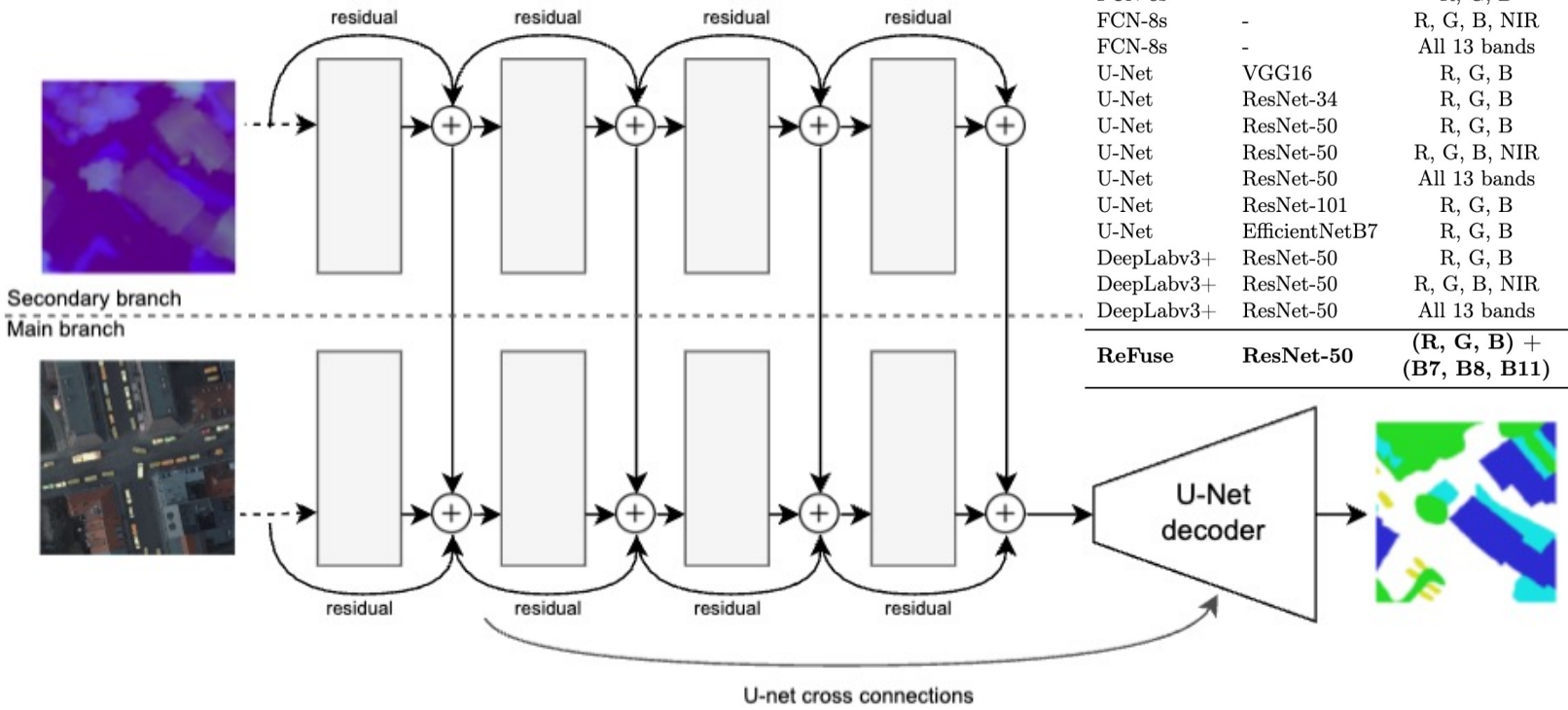


Building the
FUTURE



Learning from Past

Land Consumption Assessment



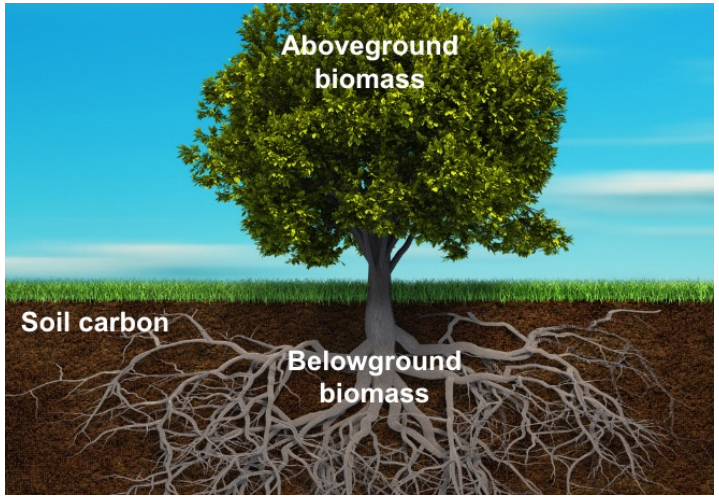
Network	Encoder	Bands	Accuracy	IoU
FCN-8s	-	R, G, B	89.54%	69.76%
FCN-8s	-	R, G, B, NIR	88.25%	69.55%
FCN-8s	-	All 13 bands	84.80%	60.35%
U-Net	VGG16	R, G, B	87.45%	70.03%
U-Net	ResNet-34	R, G, B	90.13%	70.54%
U-Net	ResNet-50	R, G, B	92.39%	73.50%
U-Net	ResNet-50	R, G, B, NIR	92.07%	71.37%
U-Net	ResNet-50	All 13 bands	89.37%	70.32%
U-Net	ResNet-101	R, G, B	90.39%	70.57%
U-Net	EfficientNetB7	R, G, B	94.48%	74.61%
DeepLabv3+	ResNet-50	R, G, B	92.19%	71.35%
DeepLabv3+	ResNet-50	R, G, B, NIR	91.32%	71.29%
DeepLabv3+	ResNet-50	All 13 bands	88.25%	68.50%
ReFuse	**ResNet-50**	**(R, G, B) + (B7, B8, B11)**	**95.72%**	**75.85%**

(a) (b) (c) (d)

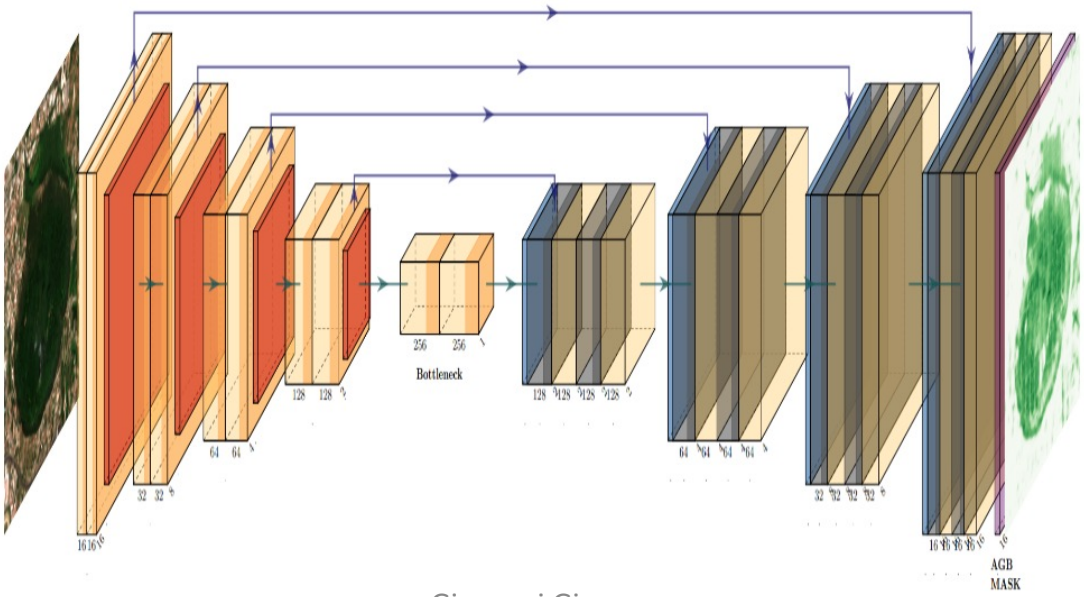
(a) Aerial image
(b) Sentinel-2
(c) ISPRA Ground-truth
(d) Predicted

Learning from Past

Aboveground Biomass Estimation (1)

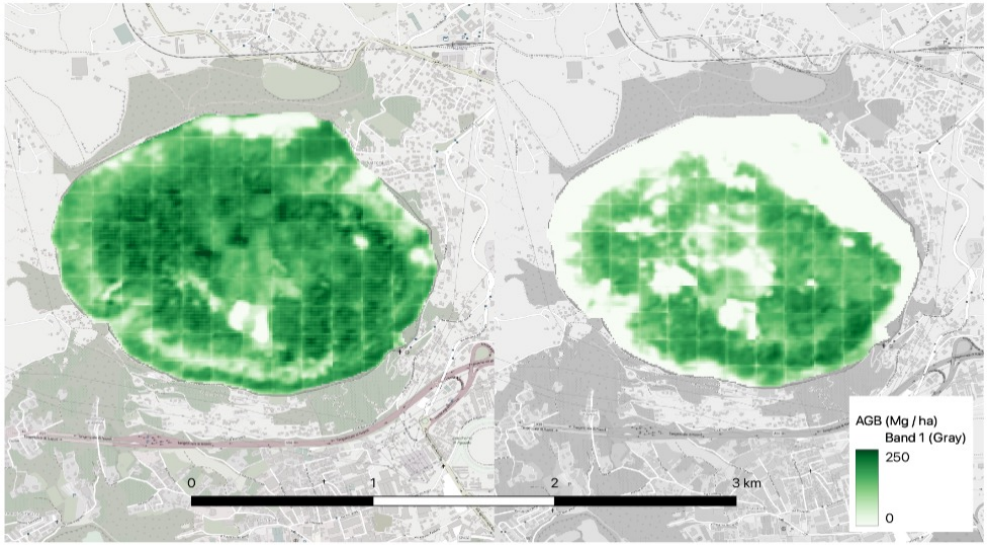


ReUse: Regressive U-Net



Learning from Past
Aboveground Biomass Estimation (2)

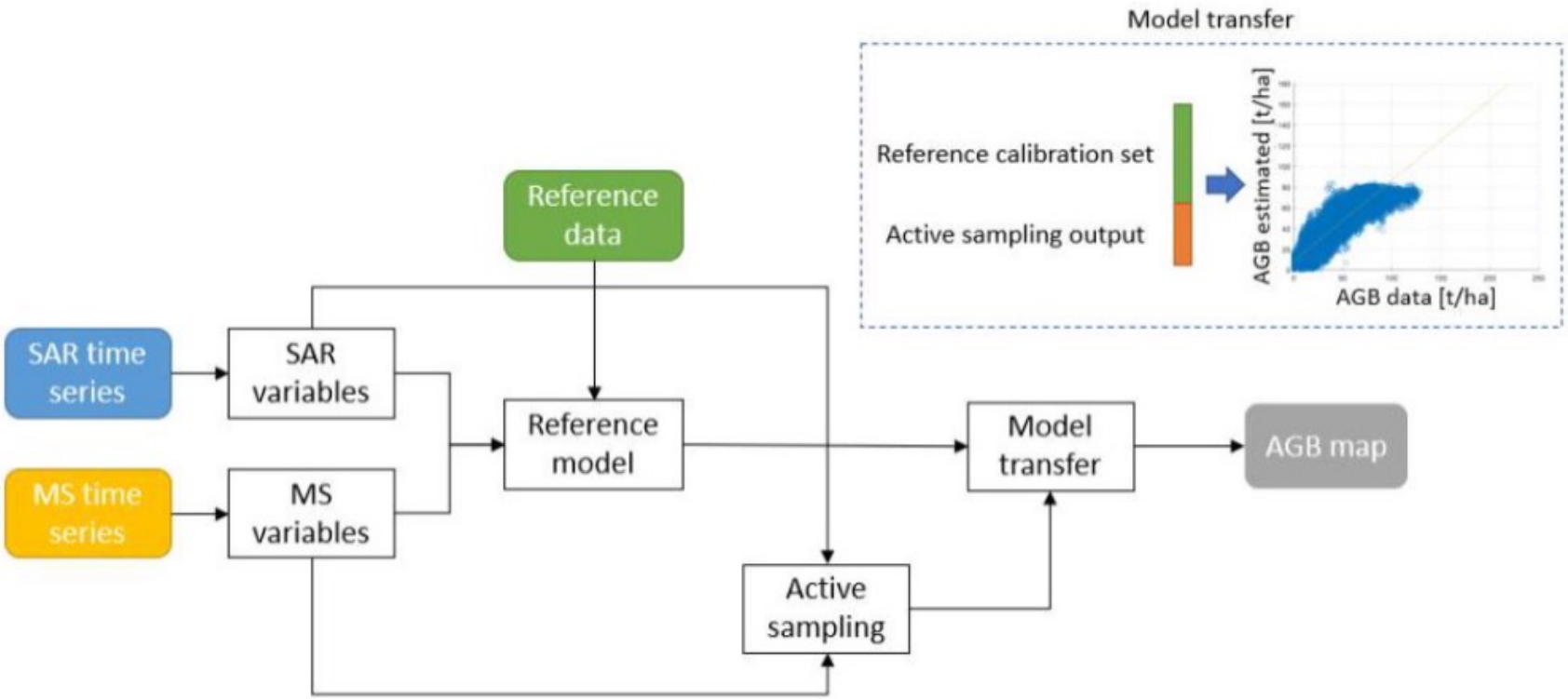
Area	Model	MAE	RMSE	R^2
Vietnam	ReUse raw bands	**42.0 ±6.6**	**57.7 ±7.3**	**0.4 ±0.2**
	ReUse feature extraction	44.4 ±6.0	59.5 ±4.7	**0.4 ±0.2**
	Competitor 1 [2]	60.1 ±8.3	73.0 ±9.4	0.2 ±0.2
	Competitor 2 [3]	58.9 ±8.6	72.0 ±9.7	0.2 ±0.2
Myanmar	ReUse raw bands	10.8 ±2.0	15.0 ±2.4	**0.7 ±0.1**
	ReUse feature extraction	**10.7 ±2.2**	**14.9 ±2.6**	**0.7 ±0.1**
	Competitor 1 [2]	15.7 ±1.9	20.2 ±2.3	0.4 ±0.1
	Competitor 2 [3]	15.5 ±1.5	20.1 ±1.8	0.4 ±0.1
Europe	ReUse raw bands	24.5 ±3.3	**46.6 ±5.2**	**0.6 ±0.1**
	ReUse feature extraction	**24.1 ±3.4**	46.9 ±4.2	**0.6 ±0.1**
	Competitor 1 [2]	32.5 ±3.1	48.0 ±4.4	0.5 ±0.5
	Competitor 2 [3]	34.8 ±3.1	51.1 ±3.9	0.5 ±0.5



On the left is the predicted aboveground biomass raster of the Astroni nature reserve before the July 2017 fire; on the right is the predicted aboveground biomass raster after a major fire event for the same area.

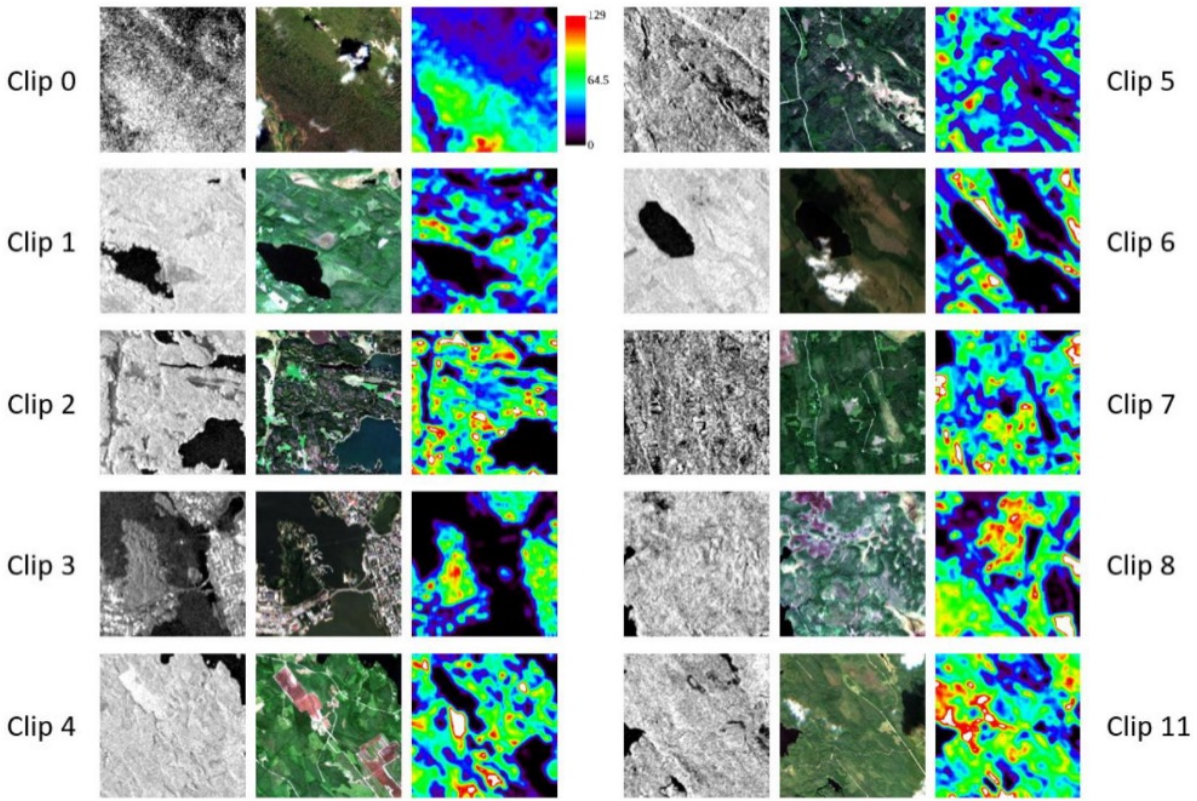
Learning from Past

Active Learning Strategies for Model Transfer and Field Sampling Reduction (1)



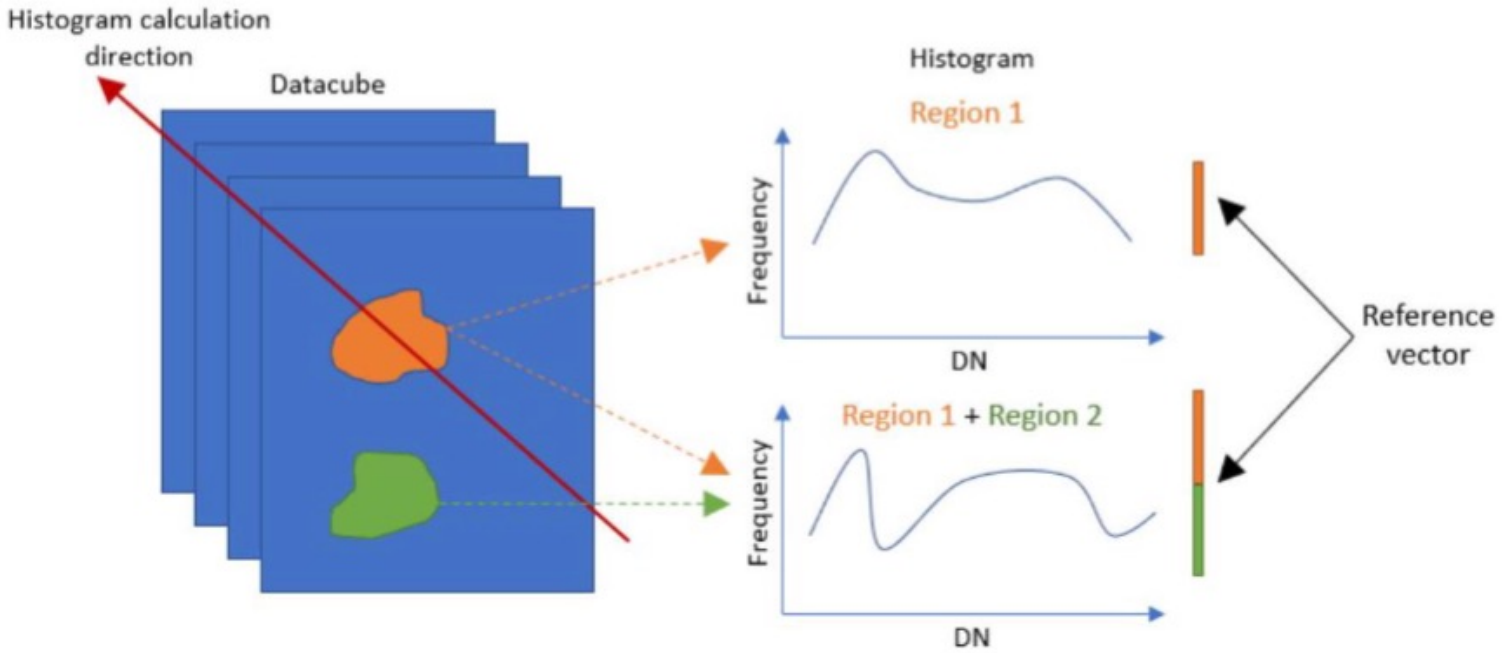
Active Learning Strategies for Model Transfer and Field Sampling Reduction (2)

Composition of the exploited dataset for some sample clips. From left to right, S1 SAR image, natural color Sentinel-2 image and AGB map. The size of each clip is 256 × 256 pixels. The pixel spacing of the maps is 10 m.



Active Learning Strategies for Model Transfer and Field Sampling Reduction (3)

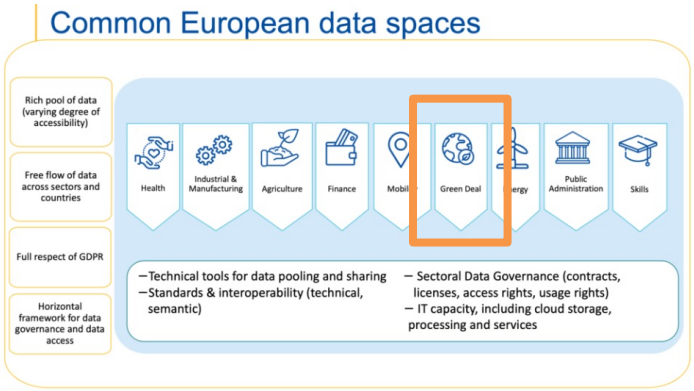
Cluster selection through Entropy:



	Proposed						Benchmark		
	PLSR		GB		Ensemble		Bootstrap		NN
Samples	RMSE		RMSE		RMSE		RMSE *	RMSE	
	Area	Inc	Area	Inc	Area	Inc			
All	28.8	31.3	33.7	36.3	28.8	30.6	26.2	46.8	
$k = 10$	30.7	32.1	34.2	36.7	30.0	31.5	27.7	47.7	30.4
$k = 5$	31.6	32.2	34.0	37.9	30.7	32.3	28.5	49.7	

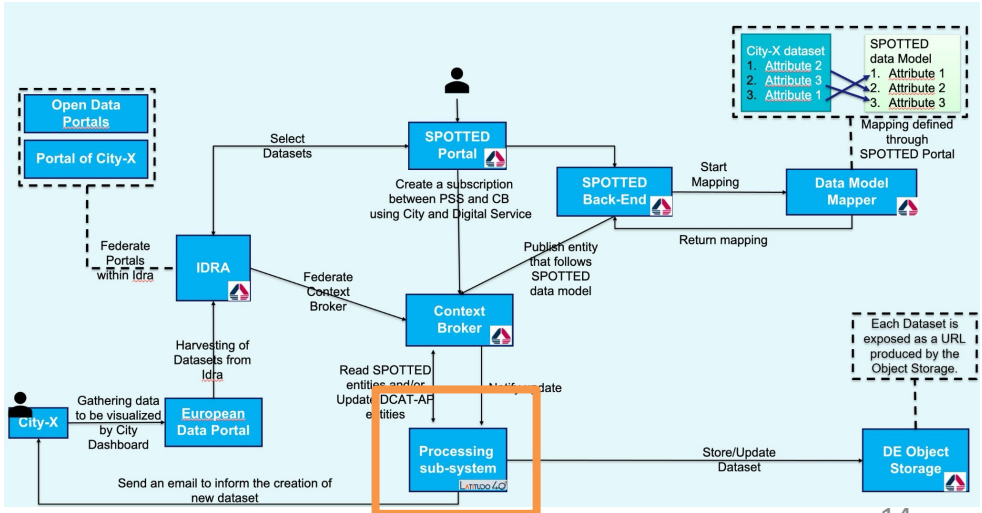
Monitoring the Present

- Machine Learning based Map Generation enable **up-to-date data availability**
- How can we enhance the availability of data across various sectors to enable continuous monitoring for end users?



Proposed Approach: ***AI Processing Sub-system module*** *

- Serverless: scalable, *near-to-zero* cost for idle, pay-as-you-go
- Ready for «code to data» paradigm (code can run «anywhere»)
- Data Spaces Integration ready via FIWARE



* Research activity made in collaboration with Latitudo 40 and Engineering Ingegneria Informatica S.p.A. for the European Research Project:

SPOTTED: Satellite Open Data for Smart City Services Development

Supports Public Administrations in the field of green areas management

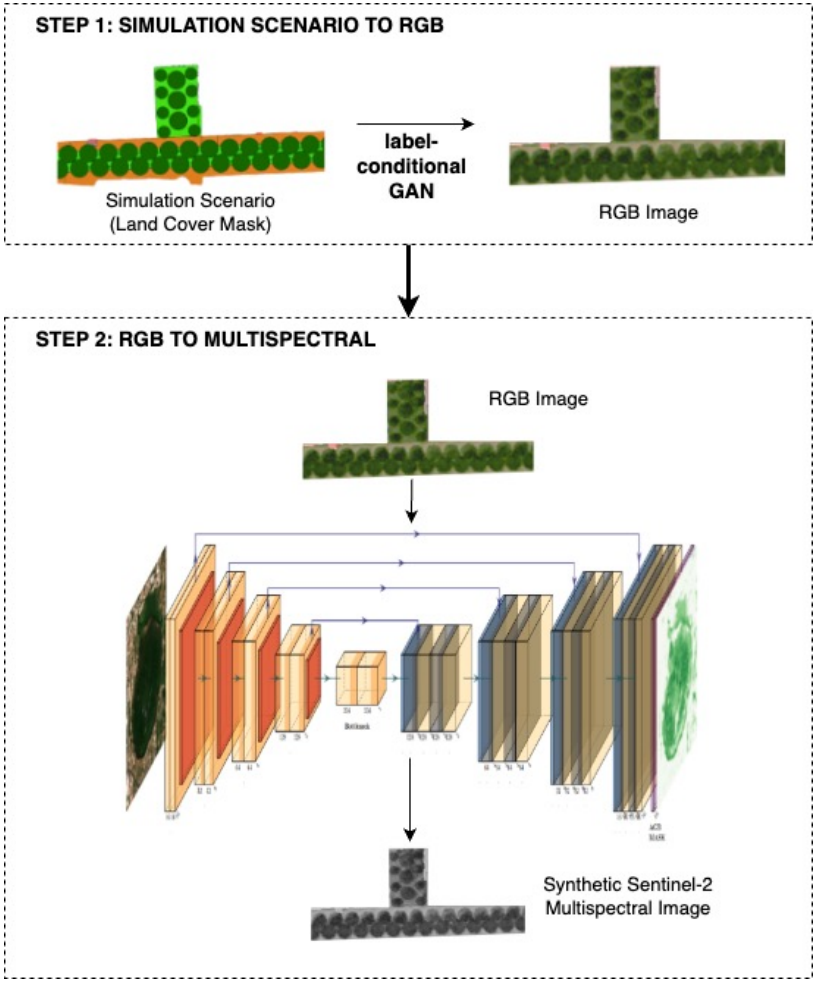
https://cef-spotted.eu

Scenario Thinking for Earth Observation (1)

Could we know the effect of an intervention **before** it is implemented?

Multi-step Approach:

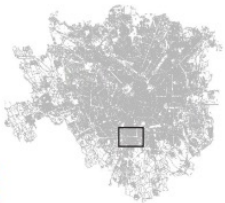
1. Simulation Scenario To RGB Image with *label-conditional GAN*
2. RGB Image To Synthetic Multispectral with a *Regressive U-Net*

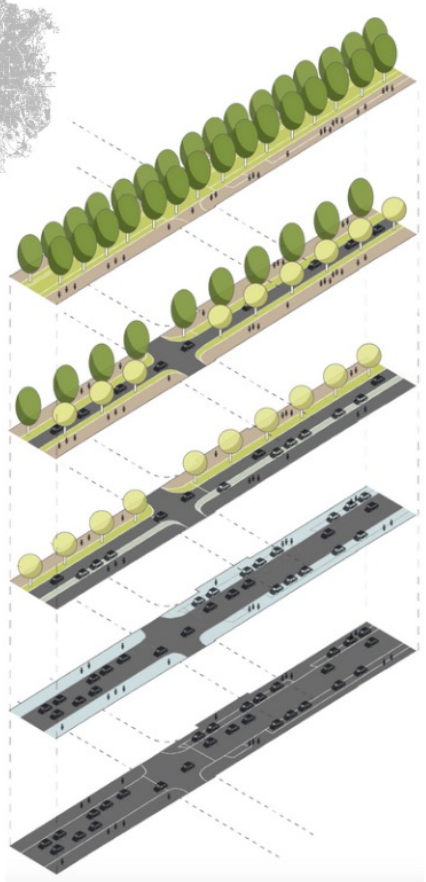


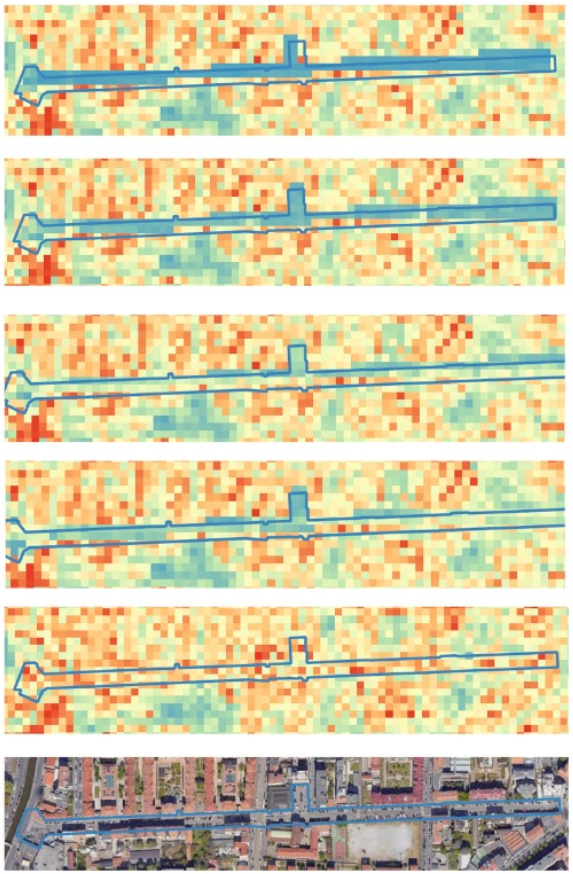
Scenario Thinking for Earth Observation (2)

① **NbS Design**

② **Synthetic Multispectral Data by Generative AI**







Scenario **4**
Average: **41,13 °C**

Scenario **3**
Average: **43 °C**

Scenario **2**
Average: **44,29 °C**

Scenario **1**
Average: **44,60 °C**

Scenario **0**
Average: **45,60 °C**

Research products [1/2]

[P1]	Giacco, G., S. Marrone, G Langella, and C. Sansone, *ReFuse: Generating Imperviousness Maps from Multi-Spectral Sentinel-2 Satellite Imagery,* **Future Internet** 14, no. 10 (2022): 278., DOI: https://doi.org/10.3390/fi14100278	Learning from Past
[P2]	Pascarella, A. E., *G. Giacco*, M. Rigiroli, S. Marrone, and C. Sansone, *ReUse: REgressive Unet for Carbon Storage and Above-Ground Biomass Estimation,* **Journal of Imaging** 9, no. 3 (2023): 61, DOI: https://doi.org/10.3390/jimaging9030061	Learning from Past
[P3]	D. Amitrano, G, Giacco, S. Marrone, A. E. Pascarella, M. Rigiroli, C. Sansone, *Forest Aboveground Biomass Estimation Using Machine Learning Ensembles:* *Active Learning Strategies for Model Transfer and Field Sampling Reduction,* **Remote Sensing** 15, no. 21 (2023): 5138., DOI: https://doi.org/10.3390/rs15215138	Learning from Past
[P4]	L. Battisti, G. Giacco, M. Moraca, G. Pettenati, E. Dansero, F. Larcher, *Spatializing Urban Forests as Nature-based Solutions: a methodological proposal* **Cities**, 144 (2024): 104629., DOI: https://doi.org/10.1016/j.cities.2023.104629	Learning from Past Building the Future
[P5]	Battisti, L., F Aimar, G. Giacco, and M. Devecchi, *Urban Green Development and Resilient Cities: A First Insight into Urban Forest Planning in Italy,* **Sustainability**, 15(15), 12085., DOI: https://doi.org/10.3390/su151512085	Learning from Past Building the Future
[C1]	G. Giacco, G. Mariniello, S. Marrone, D. Asprone, C. Sansone Toward a system for post-earthquake safety evaluation of masonry buildings **International Conference on Image Analysis and Processing**, Lecce, Italy, May 17 (pp. 312-323), Springer International Publishing, DOI: https://doi.org/10.1007/978-3031-06430-2_26	Monitoring the present

Research products [2/2]

[C2]	A. Filograna, G. Giacco; G. Di Caprio *Leveraging cloud-based geospatial data to enhance public services. A case study of the SPOTTED project 2023* **3rd International Conference on Electrical, Computer, Communications and Mechatronics Engineering (ICECCME)** Tenerife, Spain, July 19, IEEE, DOI: https://doi.org/10.1109/ICECCME57830.2023.10252358
[C3]	Pascarella, A. E, G. Giacco, M. Rigiroli, B. Vento, S. Marrone, G. Langella, A. Coppola, R. Chirone, P. Salatino, and C. Sansone, *AI and Sustainability: Territorial Monitoring and Waste Valorization,* Proc. of the Ital-IA 2023 Thematic Workshops co-located with the 3rd CINI National Lab AIIS **Conference on Artificial Intelligence (Ital IA 2023)**, Pisa, Italy, May 29-30, 2023, CEUR-WS.org, online https://ceur-ws.org/Vol-3486/143.pdf
[C4]	L. Battisti, G. Giacco, M. Moraca, F. Cuomo, G. Pettenati, E. Dansero *Servizi Ecosistemici, Aree verdi urbane e dati spaziali: una formula vincente per città resilienti ed ecologicamente attente,* **Memorie Geografiche Vol. XXII "Geografia e Tecnologia",** 2023, Firenze, Società di studi geografici, 2023, pp. 779 – 784
[D]	G. Giacco, *Generating Imperviousness Maps from Multispectral Sentinel-2 Satellite Imagery Dataset, Dataset*, Zenodo, 2022. DOI: 10.5281/zenodo.7058859

Monitoring the present

Learning from Past

Learning from Past

Building the Future

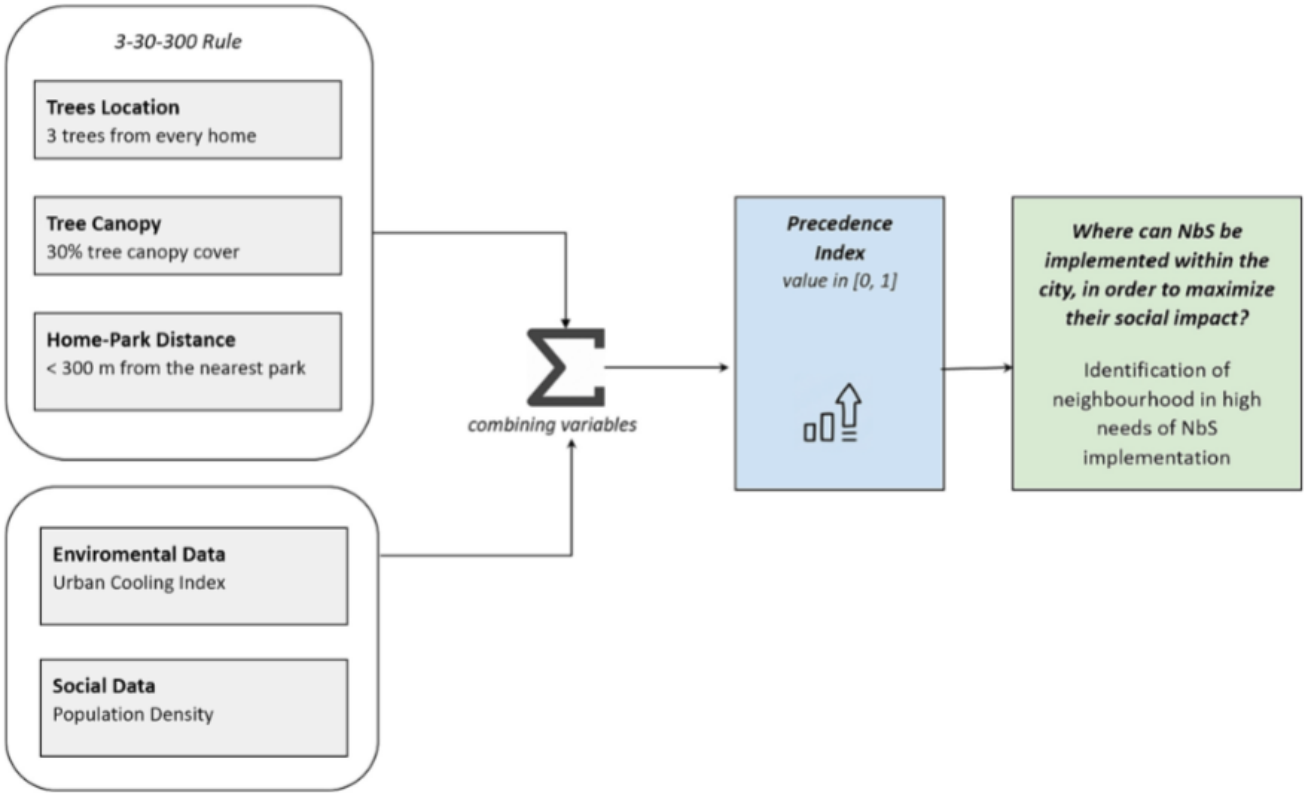
Learning from Past

THANK YOU

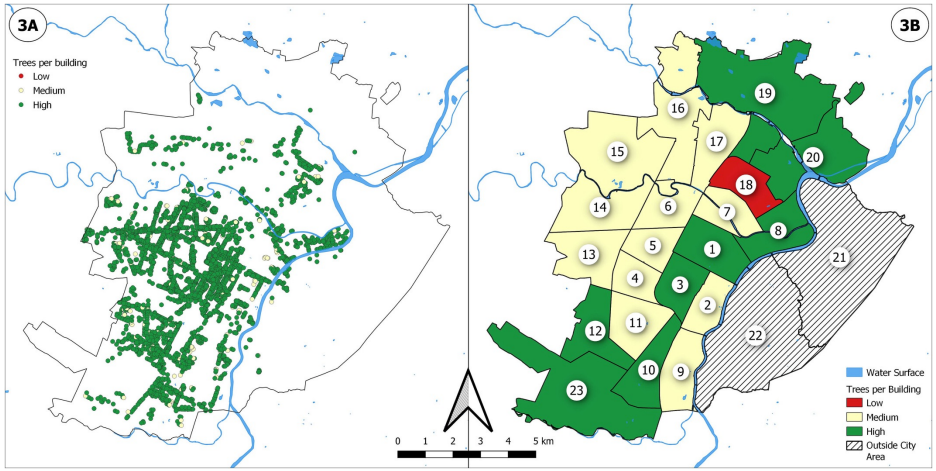
FOR YOUR ATTENTION

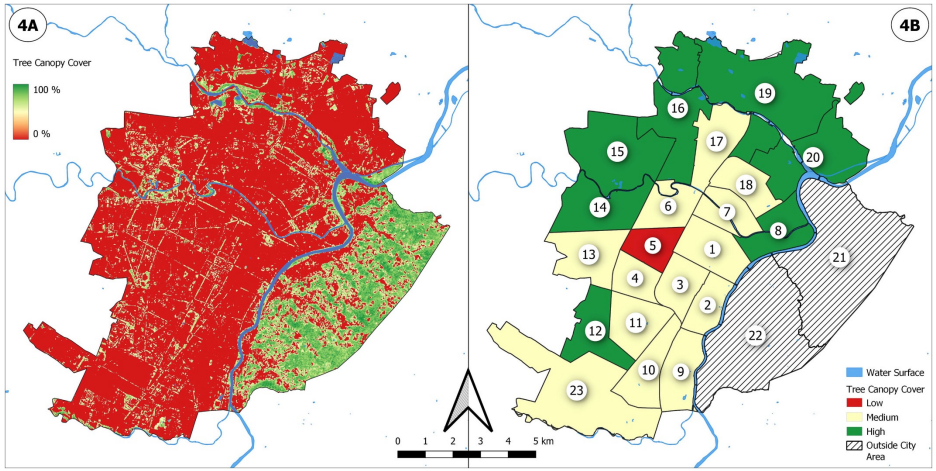
Backup (1) - Learning from Past
Planning Urban Forest as Nature-based Solutions (1)

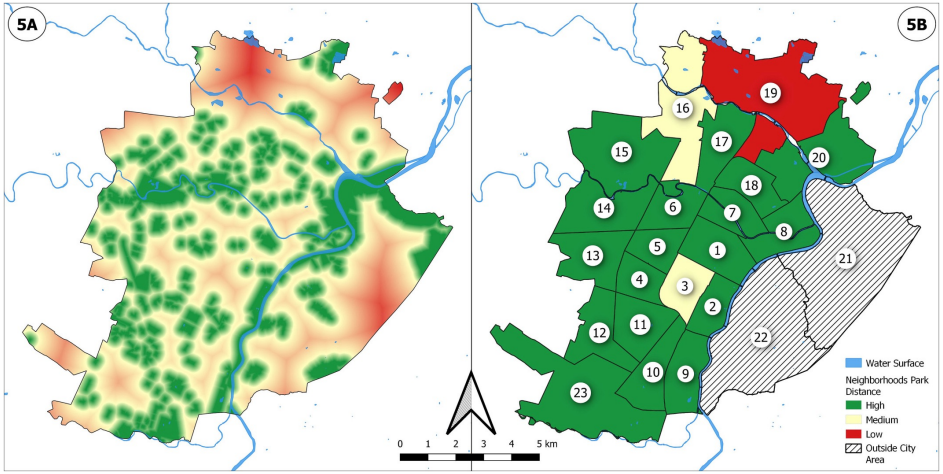
Where can Nature-based Solution be implemented within the city in order to maximize its social impact?

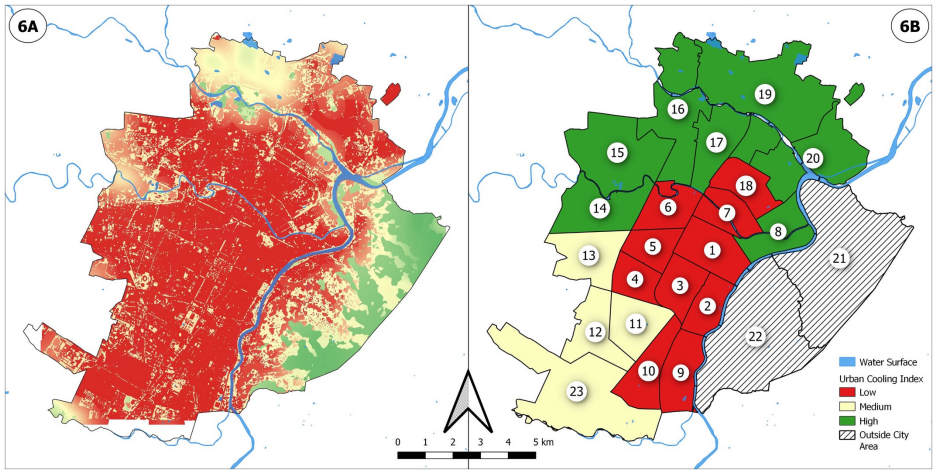


Backup (2) - Learning from Past
Planning Urban Forest as Nature-based Solutions (2)









Backup (3) - Learning from Past
Planning Urban Forest as Nature-based Solutions (3)