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Nature-Based Solutions modeling and Cost-Benefit Analysis to face climate change risks in an urban area: the case of Turin (Italy)

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IAERE Annual Conference
23rd-24th February 2023, Naples

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Outline

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- Material and Methods
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  - Protection from flood risk
  - Costs-Benefits comparison
- Discussion and conclusion

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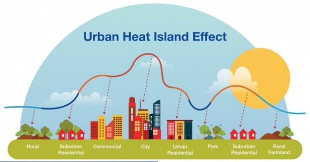
Introduction (1/3)

The **quality of life** in **cities** is endangered by interlinked pressures:

- **population concentration:** up to 84% in European cities by 2050 *(UN DESA, 2019)*
- **climate change** *(Kabisch et al., 2017; Rosenzweig et al., 2018)*:
  - **urban heat island** (UHI) effect due to increase in temperature
  - **flood hazards** due to soil sealing



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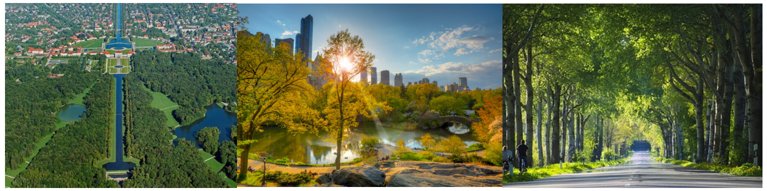
Introduction (2/3)



Nature-Based Solutions (NBS)

"Living solutions inspired by, supported by or copied from **nature** and which aim to help societies addressed a variety of **environmental, social and economic challenges** in **sustainable** ways" (*EC, 2015*) to achieve more **resilient** cities *(Cohen-Shacham, 2016)* and **wellbeing**

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Introduction (3/3)

Pollution removal & CO_2 sequestration
(Abhijith *et al.*, 2017)

Temperature mitigation
(Koc et *al*., 2018; Aram et al., 2019, Stewart and Oke, 2021)

Water security and treatment
(Nika *et al*., 2020; Boano *et al*., 2020; Song *et al.,* 2019)

Disaster risk reduction
(Naumann *et al*., 2014; Potschin *et al*., 2014; Terton, 2017 (Ozment *et al.* 2019)

Habitat and biodiversity protection
(Griscom *et al*., 2017; Parker *et al.,* 2020, Lavorel *et al*., 2020; Maes and Jacobs, 2017; Chausson *et al*., 2020, MG Hutchins *et al*., 2021)

Mental and physical health and wellbeing
(Bratman et al., 2015; Park et al., 2007, Cervinka et al., 2014; Lee at al., 2017; O'Brien et al., 2018; Gidlow *et al*., 2016, Milligan and Bingley, 2007; Jane, 2009; Corraliza *et al*., 2012; Gill, 2014; Lubans *et al*., 2016; McCracken *et al*., 2016; McCormick, 2017; (Furuyashiki *et al*., 2019; Kotera, 2020; Doimo *et al*., 2021, Faccioli and Bateman, 2018

Increase sociability and active lifestyle
(Pretty *et al*., 2007, 2010, White *et al*., 2019, Roe and Aspirall, 2011…)

Aesthetic improvement

Energy saving

Economic growth and development
(Kabish et al., 2017, Cook et al., 2020)

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Research objective

The aim of the study is to analyze the contribution of **selected NBS** in improving urban resilience for two selected climate change risks: **UHI (Urban heat island) effect** and **urban floods** in **Turin Municipality**

- Identify the most **vulnerable areas** in Turin
- identify a **set of NBS** to face the selected climate risks
- define **4 intervention scenarios** of NBS and **test** their **effectiveness**
- analyze and compare **costs** and **benefits** related to the scenarios (for each NBS)
- draw **conclusions** for **policy making** to support climate-proof urban planning

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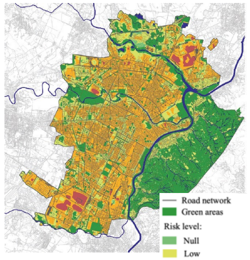
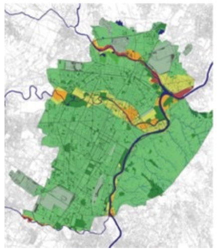
Material and Methods (1/4)

1. Selection of area under climate risk

- Consultation of Climate Resilience Plan of Turin municipality
- Reference to: (a) areas under **moderate to high UHI effect** risk (46% of the area) (b) **medium to high flood-prone areas** (40%) (Directive 2007/60/EC)
- Area mapped using **Q-GIS** 3.16



Urban Heat Island (UHI) risk



Flooding from heavy rainfall

Roads subject to flooding

Fonte: Piano di resilienza climatica, Comune TO, 2020

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Material and Methods (2/4)

2. Identification and selection of NBS

- Development of a 25 NBS interventions list (from literature & DBs)
- Final **list of 15 NBS** (screening criteria: financial viability, presence of a prevalent green component, direct effects on climate risks)
- For each, in depth analysis adapting **NWRM** (Natural Water Retention Measures) scoring

Code	Name	Effectiveness against Flood Risk	Heat Island Effect Reduction	Environmental Co-Benefits	Total Score
1	Forested green areas	1.9	3	2.3	7.2
2	Rain gardens	1.6	1.5	1.7	4.8
3	Urban gardens	1.2	2	1.6	4.8
4	Green roofs	1	1.5	1	3.5
5	Green facades	0.1	1	0.7	1.8
6	Roadside trees and green paths	1.6	3	2.2	6.8
7	Green rails	1	2	1	4
8	Green urban furniture	1	2	1	4
9	Permeable surfaces	0.7	0	0.7	1.4
10	Rainwater harvesting	0.1	0	0.5	0.6
11	Infiltration basins	1.6	1.5	2	5.1
12	Infiltration trenches	1	0	1.2	2.2
13	Retention ponds	1.6	1.5	2.1	5.2
14	Restoration of rivers for the control of infiltrations	1.2	0	1.6	2.8
15	Creation of floodplains and riparian forests	2.8	2	3	7.8

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Material and Methods (3/4)

3. NBS scenario building

- ***Complete scenario (S1):*** the most effective NBS with reference to both targeted **climate risks** and **co-benefits**. Both **alternative** and **complementary** solutions are considered with respect to the current land use.
- ***Integrative scenario (S2):*** the most effective NBS as before. **Only complementary** solutions are considered with respect to the current land use.
- ***Flood scenario (S3):*** the most effective NBS with reference to **flood risks**. Both **alternative** and **complementary** solutions are considered
- ***UHI scenario (S4):*** the most effective NBS with reference to the **UHI effect risks**. Both **alternative** and **complementary** solutions are considered

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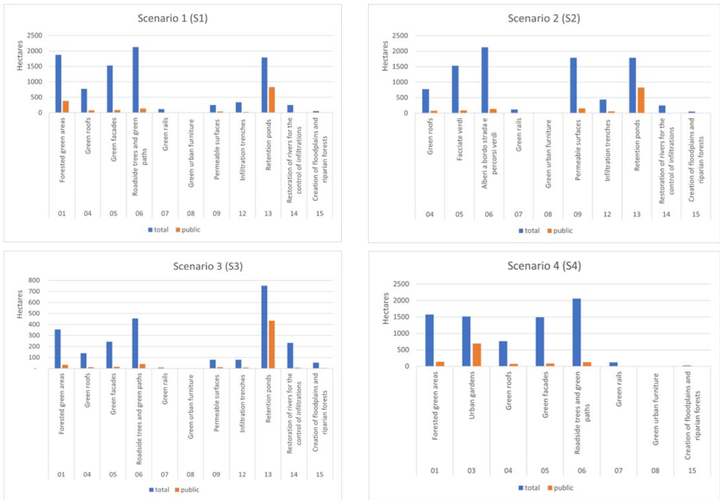

- **S1 shows the largest area** where NBS are expected to be implemented (about **27%** of the total municipal area potentially devoted to the development of identified NBS), followed by **S2 (26%), S4 (22%)** and **S3 (7%).**
- Scenario are developed considering **total area** (public + private) and **only public area**

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Material and Methods (4/4)

4. NBS scenario modeling and analysis

- **InVEST** (Integrated Valuation of Ecosystem Services and Tradeoffs) software models: "Urban cooling" and "Urban Flood Risk Mitigation"
- **Comparing** the 4 NBS intervention scenarios with the baseline scenario
- Economic benefits compared with the NBS installation and maintenance costs (up to year 2030) considering 3% and 5% discounted rate*

Code	Name	Costs			
		Installation (EUR/m²)	Maintenance (EUR/m²)	Average Annual Cost by 2030 (EUR/m²) r = 3%	Average Annual Cost by 2030 (EUR/m²) r = 5%
1	Forested green areas	1.32	2.49	0.47	0.49
2	Rain gardens	1.08	0.3	0.43	0.44
3	Urban gardens	3.85	3.85	4.3	4.35
4	Green roofs	77.5	55	64.09	65.04
5	Green facades	100	3.5	15.22	16.45
6	Roadside trees and green paths	33.78	34.22	10.57	10.41
7	Green rails	210	2.4	27.05	29.63
8	Green urban furniture	80	(n/a)	9.38	10.36
9	Permeable surfaces	65	3	10.62	11.42
10	Rainwater harvesting	32.5	0.63	4.44	4.84
11	Infiltration basins	26.25	2.83	5.9	6.22
12	Infiltration trenches	80	2.12	11.5	12.48
13	Retention ponds	14	3	4.64	4.81
14	Restoration of rivers for the control of infiltrations	3.8	1.7	2.16	2.19
15	Creation of floodplains and riparian forests	0.75	0.05	0.14	0.15

*Following the EU Commission indications on Cost-Benefits Analysis of Investment Projects (2014)

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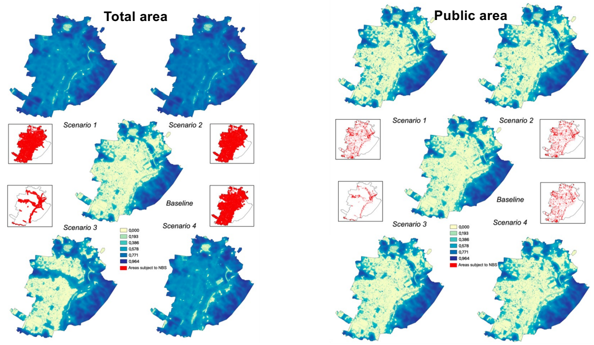
Results (1/5)

Temperature regulation

In all scenarios the **HMI** (heat mitigation index, 0-1) increases due to NBS: higher in the case of NBS in total areas compared to interventions applied only to public areas.



- The highest relative increase of the average HMI values is observed for **S1** and S2, followed by S4.
- The increase of the HMI for S3 is significantly lower (+27%).
- Forested green areas play a major role under S1 and S4 in determining HMI peaks
- Where only public areas are considered, the variations of HMI are much less pronounced: **S1**, S2 (+9%), S4 (+6%) S3 (+3%).
- However, when focusing on the **public areas** hosting NBS, a **significant increase is observed both in terms of the range and average of values**

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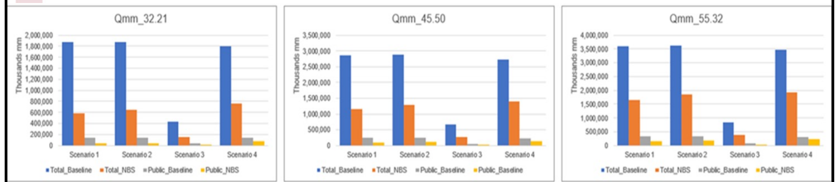
Results (2/5)

Protection from flood risk

Consideration of **3 values** of the rainfall depth parameter (i.e., the amount of rain (mm) fallen in a time (t) equal to one hour): a) **lower** (32.21 mm), b) **intermediate** (45.50 mm) c) **upper** (55.32 mm).

- **Run-off reduction:** S1 and S3 (53-69%) comparing to baseline, followed by S2 (49-65%) and S4 (44-58%): both for total and public area



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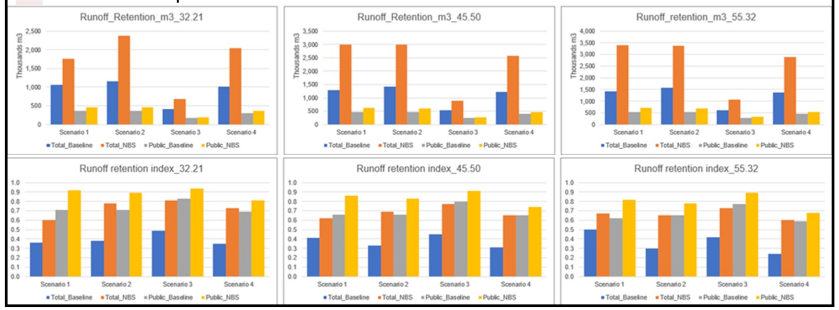
Results (3/5)

Protection from flood risk

- The highest **retained runoff** values observed for S2, S1 and S4, and rain amounts equal to 45.50 mm and 55.32 mm, lower values for S3 considering all the rain depths
- However, when considering the **retention runoff index** (i.e., retained runoff relative to rainfall depth), **S3 has higher values**, particularly for a 32.21 mm rainfall depth



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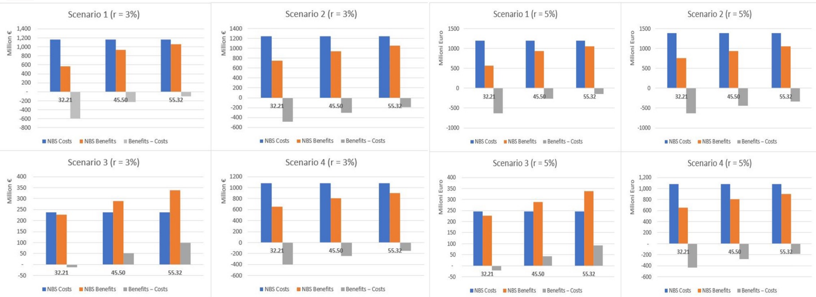
Results (4/5)

Total area

Comparative analysis of the costs and benefits, (for both 3% and 5% discounted rate) associated to the development of the NBS scenarios has highlighted **positive results only for S3**, thanks to the impact of the protection from flood risks



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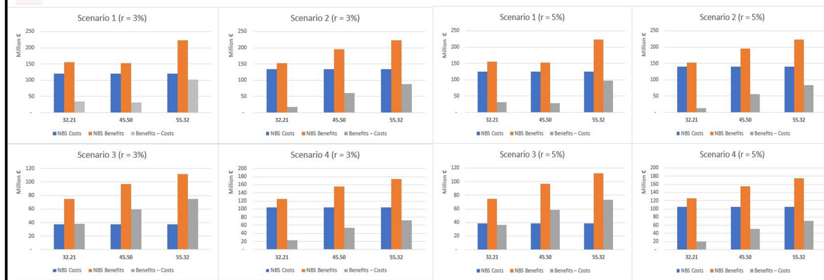
Results (5/5)

Public area

Positive results for all scenario, thanks to the impact of protection from flood mitigation risk and in particular when limited scale interventions are selected



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Discussion (1/2)

- Difference in unit value between scenarios ← **different purposes**.
  - S3 and S4 maximizes the benefits in terms of protection from flood risks and temperature regulation → difference in value is indicative of possible **trade-offs** between the ecosystem service values in the hypothesis of making choices that maximize one of the two ecosystem services separately rather than opting for **synergy** between them (S1 and S2).

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Discussion (2/2)

- Different **economic performances** were observed for **single NBS:**
  - Net benefits mainly observed for retention ponds, creation of floodplains and riparian woods, urban gardens, forested green areas, roadside trees, green paths, and green urban furniture.
  - Green roofs and green facades show costs exceeding benefits systematically
- Positive results for **protection against flood risks** (particularly when **limited-scale interventions** are considered) drive those linked to temperature regulation, suggesting possible **synergies** and **trade-offs** when NBS are **jointly implemented**.

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Conclusions (1/2)

- Even if there are some limitations, as we only considered two specific ecosystem services, our results can provide suggestions for elaboration of general guidelines for future climate proofing strategies:

  - The hypothesis of **extensive interventions** on public and private areas appears to be practically **unrealistic** and **economically unviable**.

  - **Better site-specific interventions** and setting **priorities** for areas with higher climate risks.

  - Integrated solutions should also be considered whenever possible:

  a) Existing + new NBS

  b) Gray + green NBS

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Conclusions (2/2)

- NBS should probably rely on a **policy mix** combining (i) **regulatory**, (ii) **financial** (or economic) and (iii) **soft** (or supportive) instruments
- Due to **lower transaction costs**, the development of NBS over public areas is likely to be **easier** and **cheaper** for **public authorities**.
- Rapid urban development coupled with increasing climate risks and limited public budget render the **involvement of private sector** necessary and even attractive.
- Needed creation and testing of new **public-private partnership collaborations** for the co-design and co-financing of NBS

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Thanks for your attention!

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Article

Nature-Based Solutions Modeling and Cost-Benefit Analysis to Face Climate Change Risks in an Urban Area: The Case of Turin (Italy)

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Abstract: Increasing urbanization and climate change challenges are leading to relevant environmental, economic and social pressures on European cities. These include increasing flood hazards and the urban heat island (UHI) effect. Nature-Based Solutions (NBS) are increasingly recognized within strategies to provide multiple ecosystem services to mitigate existing risks and pressures, as well as to make cities more resilient and livable. Although being increasingly addressed within the literature, NBS implementation on the ground still faces many technical and financial barriers. This paper aims to test the potential of selected NBS in mitigating the effects of identified climate change risks, i.e., the UHI effect and urban floods, in the Turin urban area (north-western Italy). Four different intervention NBS-based scenarios are developed. The supply of ecosystem services by NBS in each scenario is assessed using InVEST models and the effectiveness of NBS investments is analyzed by calculating and comparing the associated costs and benefits. Different results in terms of effectiveness and economic viability are observed for each scenario and each NBS. Flood risk mitigation oriented NBS seem to have the most impact, in particular forested green areas and retention ponds. The results are relevant to suggest policy mix strategies to embed NBS in city planning.

Keywords: Nature-Based Solutions (NBS); ecosystem services; economic valuation; green infrastructures; urban heat island (UHI) effect; urban flooding; sustainable cities; urban green

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Citation: Biasin, A.; Masiero, M.; Amato, G.; Pettenella, D. Nature-Based Solutions Modeling

Land **2023**, *12*(2), 280; https://doi.org/10.3390/land12020280