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Article

# The Role of Water Utilities in Implementing Urban Nature-Based Solutions: An Italian Perspective

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## Abstract

This study employed a comprehensive methodology to investigate the role of water utilities in the implementation of Nature-Based Solutions (NBS) for water management such as Sustainable Drainage Systems. The methodological approach involved analysing the Urban Nature Atlas database to evaluate European funding sources and stakeholders associated with NBS for water management in Europe. Focusing on the Italian context, the study then conducted semi-structured interviews with Italian experts and mapped exemplary cases where Italian water utilities actively participating in NBS implementation efforts. The results provide insight into the factors hindering and driving NBS development by water utilities in Italy. Using a SWOT analysis, the study proposes five distinct roles that water utilities could potentially adopt to advance NBS. The article offers valuable insights for policymakers, urban planners, and water utility stakeholders, emphasising the importance of multi-stakeholder collaboration to secure financing for NBS.

**Keywords:** water utilities; nature-based solutions; NBS; water management; Sustainable Drainage Systems; SuDS

## 1. Introduction

The early 2000s saw a substantial acceleration in urbanisation phenomena (OECD, 2020), which was often not supported by sustainable planning policies. This has led to intense land consumption for human purposes and the progressive waterproofing of the territory. This trend exacerbates the impacts of climate change, increasing vulnerability to environmental, social, and economic pressures, notably flood risks due to reduced rainwater interception and infiltration capacities. Italy experiences alternating periods of water scarcity and extreme rainfall, resulting in sewer overflow and flooding episodes. Inadequate management of rainwater runoff exacerbates sewer flooding and pollution, making coordinated rainwater management initiatives necessary. In addition to hydraulic challenges, there are also concerns about the impact of combined sewage on the quality of surface and underground water bodies. The absence of separation between sewage and grey water hinders proper purification, causing excess rainfall to transport pollutants into the sea, rivers, and land. A coordinated rainwater management project is therefore crucial for the effective handling of these issues (Teixidó et al., 2023).

In this context, Nature-Based Solutions (NBS) have emerged as a holistic approach to address water-related challenges while enhancing ecosystem services and community resilience. Particularly, Sustainable Drainage Systems (SuDS) represent a key component of NBS, are designed to manage urban rainwater by replicating natural drainage processes to mitigate flooding, pollution, and enhance urban amenity and biodiversity. SuDS encompass various interventions, including managed aquifer recharge schemes, rain gardens, green roofs (Maiolo et al., 2020), permeable pavements (Scholz and Grabowiecki, 2007), filter drains (Thomas et al., 2015), filter strips, vegetated swales (Flanagan et al., 2017), constructed wetlands (Boano et al., 2020; Rizzo et al., 2018), and bioretention systems (Quinn and Dussailant, 2014; Piacentini and Rossetto, 2020).

Several articles have examined infrastructures managing stormwater runoff and offering water-related services (Gimenez-Maranges et al., 2020; Fenner, 2017; Xia et al., 2017; Eger et al., 2017; Åstebøl et al., 2004), focusing on climate change mitigation by favouring infiltration and reducing runoff volumes providing reliable and efficient adaptation measures (Faivre et al., 2017), while also providing direct and indirect benefits to the whole community. These multi-objective infrastructures enable the creation of "sponge cities," blending blue, green, and grey elements within urban areas to absorb water and mitigate flood risks.

International recommendations endorse Sustainable Drainage Systems (SuDS), acknowledging their role in urban water management. Water-related policies, such as those in the European Union (Demuzere et al., 2014), Australia's water-sensitive cities (Ferguson et al., 2013, European Environment Agency, 2015), and China's Sponge City development, endorse and support the application of SuDS (Moore et al., 2016; Xiang et al., 2019; Qi et al., 2020).

Given their characteristics and potentialities, NBS emerge as solutions of strong interest to stakeholders involved in correct urban water management. Traditional strategies, such as sewerage improvements and detention basins construction, while effective as hydraulic solutions, have limitations due to the availability of accessible areas and their financial sustainability. This growing awareness underscores the need to redirect hydraulic defence toward alternative and sustainable approaches.

Specifically, the adoption of SuDS solutions offers several advantages for water utilities, including the reduction of water volumes discharged into the sewer system, thereby enhancing the efficiency of minor purification plants serving mixed sewers. An efficient stormwater management system significantly diminishes the operational costs of traditional networks and, notably, the costs associated with extreme events. Furthermore, it furnishes tools to address a comprehensive spectrum of water conditions, spanning from scarcity to excess water, from drought to floods, including both initial and subsequent rains.

Cases providing evidence regarding the involvement of water utilities in NBS planning and implementation are registered in the US (Cassin, 2021; Cousins and Hill, 2021; Shifflett et al., 2019; Travaline et al., 2015), Canada (Possantti and Marques, 2022) and in Europe, as in the cases of New Castle (O'Donnell et al., 2017) and Copenhagen (Tubridy, 2021; Fryd et al., 2012).

However, few studies have recently examined the preferences and behaviours of officials in water utilities and agencies regarding green and smart infrastructure for stormwater management. Meng et al. (2017) surveyed officials in Pennsylvania, revealing a preference for smart infrastructure and Meng and Hsu (2019), through a US national survey, found that officials are willing to invest in smart technologies for long-term cost reductions. Furlong et al. (2017) explored the water sector's contribution to greening in Melbourne, emphasizing collaborative efforts with local governments. Piacentini and Rossetto (2020) surveyed Mediterranean regions, indicating limited adoption of water-sensitive practices in Italy, mostly limited to individual local initiatives, and not included in the system logic (Sturiale and Scuderi, 2018).

Building upon the preceding background, this study aims to address existing knowledge gaps concerning the role of water utilities in the development of NBS in Italy. The decision to focus our analysis on a singular country is based on the distinctive contextual characteristics of this sector. In Italy, water utilities are defined as "hybrid" organizations, since they can be public, private or mixed-owned, and they provide a public-interest service, under a business-oriented approach (Micacchi and Lenzi, 2023). Notable legislative frameworks governing the water utilities sector in Italy include Law No. 142/90 and Law No. 36/1994. Water utilities could play a relevant role in NBS implementation, while mitigating the financing gap arising from the challenges faced by public resources in financing NBS-related expenditures, thus facilitating a sustainable transition within urban environments.

The paper is organized as follows. Firstly, Using the Urban Nature Atlas database, funding sources and stakeholders across Europe are examined. Secondly, semi-structured interviews with officials and experts from water utilities shed a light on the Italian context, by identifying the challenges and solutions involved in NBS implementation, as well as the role of water utilities.

Mapping cases of water utilities' involvement in NBS at the Italian level highlights promising practices that could be replicated and adopted more widely.

## 2. Materials and Methods

Data collection and analysis comprise three main steps, explained in the following. First, to understand the primary funding sources and mechanisms employed for NBS implementation in Europe and Italy, as well as identifying the actors involved, the Urban Nature Atlas database<sup>1</sup> (Naturvation, 2017) was analysed. This database is a comprehensive collection of around 1000 urban NBS cases across Europe. Building on Todorova (2023), we developed a two-tier approach. First, we searched for solutions aiming to address water challenges (n=406) across Europe analysing the whole sample. Then, for a more in-depth examination targeted at the country level, we refined our focus exclusively on Italian cases (n=90)<sup>2</sup> screening the individual cases to identify the involvement of water utilities in the implementation of NBS projects. Descriptive statistical methods were employed to present the results of the database analysis (Section 3.1).

Secondly, semi-structured interviews were conducted with key stakeholders in the Italian water utility sector and experts in related fields. Water utility employees were selected based on company size and economic and financial performance (REF, 2022, no. 217), while experts were chosen based on their subject expertise. Through snowball convenience sampling, and web-based searches, 18 interviewees were scheduled, comprising 14 from water utilities and 9 experts, totalling 23 respondents (Tables S1 in Supplementary materials). The questions used for guiding the interviews are reported in the Appendix A available in the Supplementary. Although geographic location was not set as a selection criterion, responses were gathered from water utilities operating in northern and central Italy, which constituted the context of the study. Interviews were “verbatim” transcribed using Word Online (McLellan et al., 2003). NVIVO12 software facilitated inductive qualitative coding, allowing emergent themes directly from the data, discovering variation, examining complexity, and minimising the impact of a priori assumptions (Glaser and Strauss, 1967).

In the results section (3.2) respondents were identified as “U#” for utility operators and “E#” for experts. Finally, interview findings were synthesized into a SWOT matrix, a commonly used tool for organizational analysis and strategic planning (Bartol and Martin, 1998; Dyson, 2004; Sorensen et al., 2004).

Third, the study addressed interviewees' need to map and disseminate best practice examples of NBS development involving Italian water utilities, without claiming to be exhaustive. A methodological approach for mapping was employed, including a brief analysis of scientific literature via SCOPUS database, interviews responses, snowball sampling approach, web searches, and scrutiny of about 46 databases (Table S2 in the Supplementary materials provides the list). A comprehensive overview of the projects identified is provided in the supplementary materials (Table S3 and in Figure S1 in the Supplementary Materials). Moreover, whenever relevant, reference to these projects is made within results - mainly when dealing with the “drivers” (section 3.2) - to underline their potentialities.

## 3. Results

In Section 3.1 we present the results from the analysis of the Urban Nature Atlas database, while in Section 3.2 we present the results of the semi-structured interviews obtained through qualitative coding.

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<sup>1</sup> The Urban Nature Atlas database (<https://una.city>) was developed during the course of the “Naturvation project”, functioning now as a stand-alone tool and including also NBS cases beyond Europe.

<sup>2</sup> The 90 Italian cases refer to the following cities and surroundings: Bari, Bologna, Catania, Genoa, Milan, Naples, Palermo, Rome and Venice.

3.1. Results from the Database Analysis

At the European level, the analysis of 406 NBS (selected as “water management” challenge) cases reveals that public budgets are the primary funding sources, dominated by local authorities (35%), followed by national budgets (13%), EU funds (13%), and regional budgets (11%). Corporate investments (10%) and contributions from Non-Governmental Organizations (NGO) (5%) also play a substantial role. Results for Italy are consistent with those observed at European level, with local (29%), regional (12%), national (9%), and EU funds (20%) being major contributors. On the contrary, in Italy major private contribution comes primarily from foundations (10%) and NGO(8%), whereas corporate investments only for 4%. Financing instruments predominantly consist of earmarked public budgets (about 43%) and direct funding or subsidies (about 44%) both at the European and Italian scale.

The initiating organisations at both levels are primarily public bodies, particularly local governments/municipalities (Europe: 37%, Italy: 44%). Followed by private sector/corporates (10%) and researchers/university (13%), regional governments (7%) and NGO/civil society (7%) in Europe, while regional governments (9%), NGO/civil society (12%) in Italy.

The results concerning stakeholders involved in implementation of NBS (Figure S2 and S3 in Supplementary materials) are also very similar between Italy and Europe, mainly local government (22%-24%) both in Europe and Italy, citizens and community groups (16%), private sector (14%), research and university (7%-10%), NGO (7%-9%).

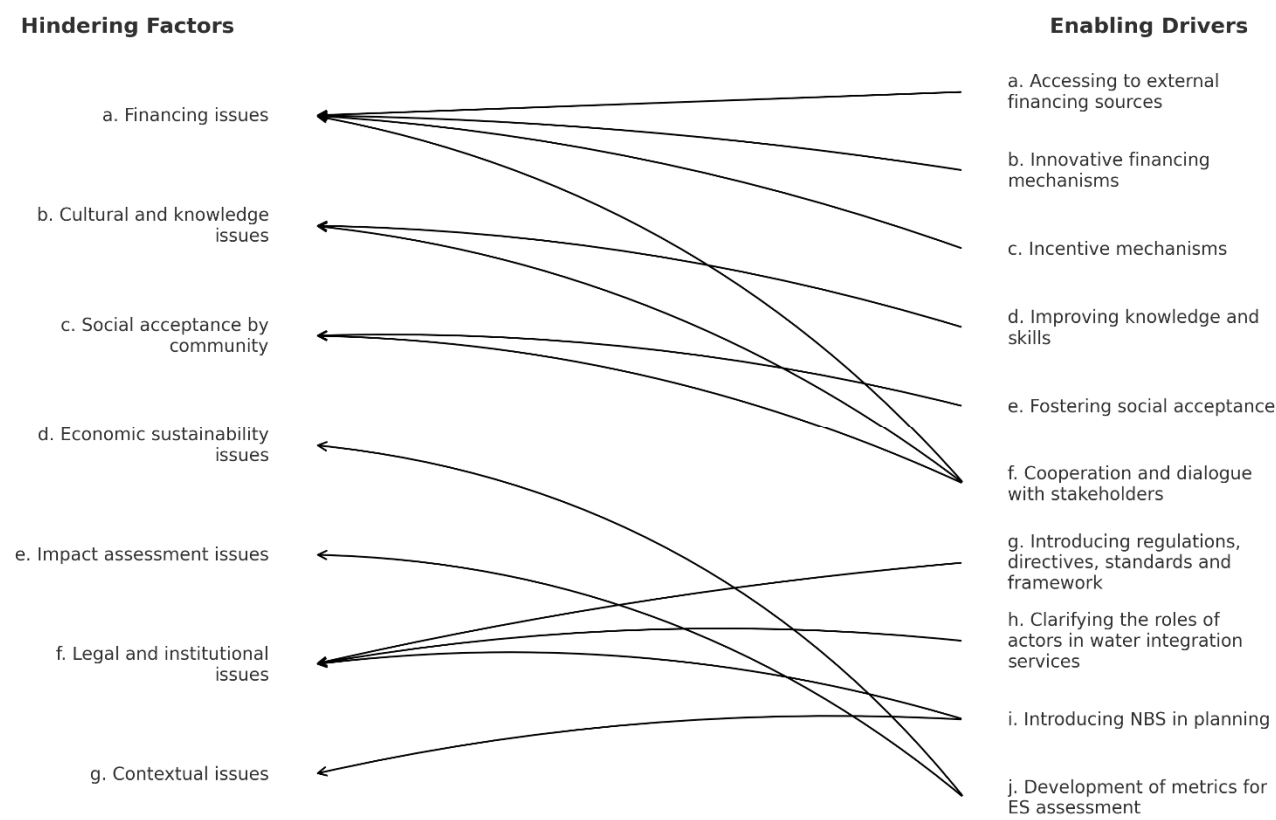
The 406 selected NBS are mainly classified as blue areas (229) and parks and (semi)natural urban green areas (213), followed by grey infrastructure with green features (186) and green areas for water management (170). NBS have been developed to mitigate mainly the following challenges in addition to water management (406), green space habitat, and biodiversity (374); health and well-being (245) and regeneration, land use, and urban development (210). In Italy, the 90 case studies are classified as parks and urban forests (semi natural green areas) (54), grey infrastructure featuring greens (urban green space connected to grey infrastructure) (26), blue areas (26), nature on buildings/external building greens of external buildings (13). NBS are aim at mitigating particularly: water management (24), climate action for adaptation, resilience and mitigation (19), coastal resilience (12), green space, habits, and biodiversity (80), environmental quality (28), regeneration, land use and urban development (38), social justice, cohesion, and equity (40), health and well-being (46), cultural heritage and cultural diversity (34), economic development and employment (23), sustainable consumption and production (18).

Upon scrutinizing the 90 Italian cases, it was found that only 3 cases<sup>3</sup> indicated the participation of multi-utilities, their role is not specified, but none of these were water utilities. Consequently, the analysis of the database revealed no substantive evidence regarding a significant involvement of water utilities in the development or financing of NBS at the Italian level. This collective examination underscores the critical reliance on public funding, the prevalent role of local governments, and the minimal engagement of utilities, particularly water utilities, in the advancement of NBS within Italian urban environments.

3.2. Results of Interviews

Semi-structured interviews have enabled the identification of factors that hinder the involvement of Italian water utilities in the development of NBS. At the same time, enabling drivers have been identified to encourage greater involvement from water utilities in this area. The results are presented on the following pages and summarised in **Figure 1**, where the rows represent the potential beneficial impacts of enabling drivers in mitigating the related hindering factors.

<sup>3</sup> ACTV for “Let’s open the walls” (Venice); Tirreno Power Spa for “PARC - Petromyzon And River Continuity” (Genoa); “RomaEnergia” Energy Agency for “Tree planting in Rome” (Rome).



**Figure 1.** Hindering factors and enabling drivers for water utilities in promoting NBS.

3.2.1. Hindering Factors

Seven hindering factors been identified as motivating Water Utilities' policies on the implementation of urban NBS.

**a. Financing issues**

*Issues related to water tariff.* Water utilities primarily rely on the water tariff paid by users to fund investments, determined by their strategic plans aligned with intervention priorities. Under regulated regime, tariff proposals are submitted to the Agency for Local Water Management (in Italian: *EGA - Ente di Governo d'Ambito*) representing all municipalities insisting in an Optimal Territorial Area (In Italian: *ATO - Ambito Territoriale Ottimale*)<sup>4</sup>, for approval, limiting autonomy in financing choices. Tariff-funded projects, legally defined by the Italian Regulatory Authority (in Italian: *ARERA – Autorità di Regolazione per Energia, Reti e Ambiente*), with limited water utility flexibility to include others, as well as yearly possible increase in the water tariff (maximum 8% per year).

Respondents highlight the difficulties in covering priority intervention costs, typically focused on existing infrastructures (e.g. by promoting investments to repair/improve pipelines to reduce water losses) rather than NBS. Small operators face greater difficulty due to limited resources and stagnant tariffs (U12<sup>5</sup>).

Lower water tariffs in Italy, compared to other European countries, limit resources for additional initiatives after covering priority interventions. Also, a strong reluctance to request even a modest

<sup>4</sup> It represents a territory on which integrated public services are organised, for example water by the Regions with a specific Regional Law (in the case of the integrated water service with reference to river basins), and the Agency for Local Water Management, structures with legal personality acts on them organizing, entrusting and controlling the management of the integrated service

<sup>5</sup> Respondents are identified with code "U#" if water utilities operators and "E#" if experts.

tariff increase from citizens is registered. Moreover, justifying NBS expenses within tariffs is complex, as existing approaches prioritize conventional "end of pipeline" approaches that do not explicitly encompass NBS. Generally, dialogue with regulatory authorities is necessary for NBS inclusion (E19). However, even if these practices are successfully integrated, they often receive minimal economic recognition due to their perceived lower value. Consequently, water utilities are discouraged, as they lack sufficient institutional support and exhibit reluctance to engage in dialogue with authorities out of concern for non-recognition, preferring conventional interventions instead (U6).

**Difficulty to access other financial sources.** Water utility stakeholders explore public funding sources from regional, national, and European entities for projects, facing challenges in accessing them. For instance, even when public funding is available, it is directed to regions or municipalities, that generally do not have the competence to realize this kind of interventions. In such a context, water utilities need to intervene on behalf of a third party (i.e. regional or municipal public authorities) and this, according to respondents, is not effective for a massive-scale promotion of NBS projects.

Funds are often directed to regions or municipalities lacking the expertise for such projects, necessitating water utilities to intervene on their behalf, hindering large-scale NBS promotion. Capitalization is crucial for transforming assets into tariff-included investments, especially for maintenance and co-financing (U3). Respondents suggest direct funding to ATOs for easier intervention by water utilities and greater flexibility in terms of projects to be funded. On the contrary, when accessing funding calls, the intervention is generally predetermined (U3). This involves primarily political choices, potentially achieved through lobbying (U3).

Despite EU initiatives like LIFE and HORIZON, challenges exist, including accessing and meeting short-term requirements for European funding calls. PNRR funds, although promising for sustainable projects, face obstacles due to complex requirements and tight timelines.

Contrary to attributing the financial constraint to a scarcity of resources, three interviewees emphasise its "political nature" (E23). Allocation decisions by entities like Agency for Local Water Management reflect political will, impacting water utilities as managers and not resources owner. The EU allocates resources for sustainability through initiatives like LIFE, HORIZON, and INTERREG, yet small-scale operators face hurdles accessing funds. However, small-scale operators encounter obstacles in accessing and meeting the short-term requirements of European funding calls (U3). Also, these projects often cover only design costs, excluding implementation expenses, with similar challenges in accessing PNRR resources (National Recovery and Resilience Plan). Limited participation of private actors and banks further complicates funding, exacerbated by a time mismatch between tariff payback periods and debt repayment timelines. Assistance is needed for small-scale actors due to limited capacity, despite institutions like the EIB (European Investment Bank) allocating resources for sustainability objectives (U4; EIB, E21).

**Maintenance costs.** The interviewees stressed the increased maintenance requirements of NBS compared to grey infrastructures, posing challenges in management despite similar implementation costs. Insufficient recognition and addressing of this aspect exacerbate the issue. However, this aspect is not consistently recognized or sufficiently addressed (U3). A lack of resources and skills to sustain long-term maintenance costs, particularly in public bodies, threatens NBS efficacy.

Municipalities struggle with competing priorities, lack of specialized knowledge, inadequate cooperation, and insufficient funds, leading to project abandonment. As expressed by one respondent, *"This aspect is crucial. Today, municipal projects are frequently abandoned due to neglect, stemming from insufficient funds to support ongoing costs, resulting in operational inefficacy"* (U2). Some regions consider transferring maintenance responsibilities from municipalities to tariff-operating entities, necessitating tariff increases (U2). A respondent suggested that implementers should also manage the NBS for an initial period, thus incentivising them to pay more attention during the planning phase, for example avoiding inappropriate plant selections solely for aesthetic purposes (U2). Post-implementation, NBS managers must protect and maintain ecosystem services, promoting biodiversity.

Furthermore, it's crucial to consider contextual factors during NBS planning, like urban tree root damage or access challenges in remote or protected areas with specific vehicles (U2). Post-implementation, ecosystem services, such as increasing biodiversity and possible new species need to be valorised and protected (U2, U3). Incorporating investments into the balance sheet is essential for covering operational expenses, but it's challenging for utilities (U3). Typically, they include in the tariff, the costs of interventions on owned assets or those under ATO concession. Developing NBS on municipal land requires costly land purchases, an option rarely used. Alternatively, utilities can obtain concessions by municipalities, but if municipalities demand maintenance, tariff coverage for operational expenses is impossible (E16).

### **b. Cultural and Knowledge Issues**

**Lack of internal skills.** The respondents emphasized a significant challenge concerning capacity building within water utilities for the development of NBS projects. Generally, smaller operators face a more pronounced "cultural divide" in multidisciplinary skills than larger operators (E23). The lack of NBS projects by water utilities is compounded by the difficulties in finding professionals with the required multidisciplinary and transversal background and skills (encompassing engineering, urban planning, ecology, and natural sciences) (E23; U3). This shortage is also attributed to the current absence of comprehensive courses in Italy, a situation that is expected to improve in the coming years (E18). Furthermore, the challenges of recruiting new colleagues are also exacerbated by the necessity to immerse them in complexities related to innovative technical aspects, administrative responsibilities, and tight deadlines (U12). Water utilities appear to be as key drivers in terms of excellent skills in water management and mentioned the growing interest in NBS solutions. However, this growing interest requires a corresponding growth in knowledge to avoid opportunistic entry into the business just to earn opportunities or greenwashing (E18).

**Path dependency and lack of innovation.** The development of innovative NBS in water utilities faces hurdles despite regulatory encouragement, as familiar projects are often favoured over innovative ones (E16). For many respondents the "engineering" background of projects managers in water utilities is identified as a priority issue also compared to financial constraints, with resistance to change being a significant barrier, *"Money is not the issue. There is enough money there. The issue is the human brain, the human capacity"* (E20) (U10).

Overcoming the lack of innovation requires a shift in skills, which is challenging due to entrenched mindsets and resistance by utilities (E20), but also for municipalities that need to think to a new concept of urban planning and the city (U13). Furthermore, some hesitations, are also dictated by the results not always clearly valuable since the planning stage (U3).

Overcoming this requires a shift in skills and mindset (E20), also from municipalities, municipalities that need to think to a new concept of urban planning and the city (U13). Furthermore, some hesitations, are also dictated by the results not always clearly valuable since the planning stage (U3). Younger employees show more interest in sustainability but face resistance and often technical staff facing challenges in managing existing infrastructures, exhibit limited availability and enthusiasm for overseeing new complex projects (E23). This engineering-centric perspective narrows the focus, overlooking broader considerations related to sustainability, ecosystem services, and potential trade-offs (U4) perpetuating a "path dependency" trend, that hinder the integration of innovative approaches in water utilities (U4). In relation to this a respondent said: *"I was trained to build a great infrastructure in old style kind of wastewater treatment, and that's my training. When somebody comes to me and says that what I have been learning 20 years ago is not relevant anymore, it's very difficult to change your mind and competence. Also, engineers are talking to politicians and politicians want to be able to show that they have built something for the community instead of showing that they have recreated a natural wetland"* (E20). The lack of innovation also stems from the nature of utilities as former public companies, lacking competitive market pressure to find innovative solutions (E19) (U3).

### **c. Social acceptance by community**

Cultural barriers have emerged as significant impediments hindering the ecological transition. Communities face knowledge gaps and lack awareness regarding the impacts of NBS, leading to

resistance and often unfounded prejudices (E22; U6; U7; U8). Citizens often express scepticism about the effectiveness of NBS, considering them a waste of money compared to more conventional approaches (E17). There is a prevailing belief that NBS projects are initiated and subsequently abandoned due to inadequate management, resulting in their ineffectiveness over a short period and fostering reluctance to support potential tariff increases (U11). In addition, citizens express concerns about perceived adverse impacts. Examples include worries about increased mosquito populations in wetlands or bioswales (U3). The "Sponge city" project, incorporating small-scale interventions (i.e., infiltrating vegetation, SuDS, flowerbeds and a parallel cycle path), faced complaints over perceived reductions in parking spaces, road width, and speed limits, reflecting a NIMBY (not in my backyard) tendency raised by many interviewees. While concerns about permeable pavements in parking lots include fears of vehicle substances percolating into the subsoil, despite advances in vehicle technology and the stormwater treatment provided by permeable surfaces. Finally, several respondents reported instances of "NO" signals displayed on project announcement panels as expressions of disappointment.

#### **d. Economic sustainability issues**

The interviewees present varied perspectives on the cost-effectiveness of NBS compared to traditional grey interventions. Engineers generally perceive NBS as more expensive, prioritizing financial aspects. A respondent said: *"If we had to look only at the economic side, we wouldn't even make an NBS. I am very transparent, I am an engineer, because the costs of these interventions are much more expensive than a traditional intervention"*. However, NBS integration is preferred in environmental enhancement contexts or where landscape constraints exist, such as the mentioned cases of phytopurification near a castle in Brescia and interventions for rural enhancement in Val Canonica (U1; U2).

Trade-offs often arise between environmental and financial priorities. Financially sustainable utilities may prioritise environmental aspects, while the majority prioritise business profitability over environmental considerations, creating a perception of conflicting priorities (U13). Some experts argue against generalizing NBS as more expensive, citing cases where NBS have lower maintenance costs compared to traditional solutions and the cost-effectiveness profile of NBS varies on a case-by-case basis, considering territorial needs and challenges (E15; E16). For instance, while, given the same investment cost, maintenance costs for certain NBS (e.g., constructed wetlands or urban drainage systems) could be higher than those for grey solutions, in some cases this is not true.

For example, the "Castelluccio da Norcia" project reported lower operational costs for the French Reed Bed compared to conventional methods (Rizzo et al., 2018). NBS also offer benefits like land redevelopment and simpler maintenance procedures, potentially offsetting initial costs. Maintenance is easier for exposed NBS compared to buried ones, reducing cleaning frequency. NBS also often introduce simpler maintenance procedures, potentially reducing costs in the long run. Despite potential savings, cost-effectiveness varies depending on factors like land preparation and ecosystem services provision (E16).

#### **e. Impact assessment issues**

Linked to the previous barrier, an acknowledged challenge to the adoption of NBS lies in the difficulty in measuring and monetising their impacts, to highlight their potential effectiveness and efficiency, particularly when compared to traditional grey solutions. The inability to integrate these benefits into financial statements limits their appeal to investors and discourages utilities from pursuing NBS. This challenge extends to the evaluation of ecosystem services, where the absence of standardized accounting methodologies hinders comprehensive communication of the benefits of NBS. Interviews reveal that generally, only medium-large projects undergo in-depth environmental impact analyses, to ensure proper environmental and social integration within the context, often outsourced to external professionals (U14). Specific evaluation methodologies for ecosystem services are rarely employed with limitations to the assessments required by regulations, such as the calculation of the indicators required by ARERA. While some European projects, like LIFE Metro ADAPT, deploy specialised methodologies such as the BEST methodology (U6; U7; U8).

## f. Legal and institutional issues

Some interviewees noted that utilities are also subject to a legislative and regulatory risk that can introduce uncertainties and hinder autonomy and operational efficiency, complicating short- and long-term planning strategies, also in relation to NBS. Bureaucratic slowness and authorisation hurdles create obstacles. An example of such hurdles mentioned by respondents was the problem in the past with hiring specialised profiles for innovative projects due to the need to use the slow public tender procedure for new assumptions. Generally, this reflects a misalignment between public bodies and private needs, impeding speed and flexibility for innovation strategies (U4). Additionally, respondents highlight the lack of regulatory space and political will for NBS. Finally, changes in municipal administration could also introduce challenges in terms of decision discontinuities.

The fragmentation of stakeholders within integrated water systems poses a significant obstacle, resulting in unclear responsibilities and hindering effective collaboration. While national legislation asserts that the management of rainwater falls under the responsibility of local administrations (i.e., municipalities), the practical implementation of this mandate lacks consistent definition. In certain cases, the management responsibility is transferred to water utilities through formal agreements, while in others, municipalities assume that water service utilities naturally handle this activity. This allocation of responsibility significantly influences the interest of water utilities in developing urban NBS (U11; U12; U3; E16).

## g. Contextual Issues

**Projects scale.** Interviewees highlight challenges in integrating urban NBS due to limited space, high land prices, authorization complexities, and increased maintenance costs. Italian cities' historical structures further complicate integration, requiring careful urban planning and re-evaluation (U13; U14). *The Italian urban structure, as a derivative of the Roman Empire, does not always allow an easy introduction of NBS or at least with simple methods of design, compatible with the times and needs of the city (i.e., construction sites that do not interrupt the urban flow, etc.)* (U13; U14).

Indeed, well-planned NBS should be aligned with territorial development priorities but rather be aligned with them, taking into account population growth and the evolving needs of the area (Rubini, E22). While some recognise the potential of peripheral and rural regions due to availability of space and lower costs (E20), most acknowledge the potential of both urban and peripheral areas (U3; E16; U11; U12). They stress the importance of assessing each NBS type and its objectives without generalizing to avoid deeming projects unfeasible from the beginning (E16). However, the potential role of water utilities in urban areas will increase if these entities gain more competence in the management of urban rainwater, aligning their responsibilities with integrated services (E15). Finally, the financial dimension is also impacted by the limited size or excessive fragmentation of projects, restricting the development of robust financial instruments and hindering access to funding from institutions, which often require substantial financial commitments (U4).

**Timing of the impacts.** Another issue mentioned by the respondents is the timing of the impacts, since generally NBSs require long-term to produce benefits (E20). This means that the need to intervene in an emergency or quickly, favouring post-intervention actions over preventive measures, results in a preference for interventions capable of delivering immediate impacts. Moreover, the long-term benefits also create a mismatch in the case of debt repayment, as previously mentioned, with respect to access to external sources of funding.

**Size and geographical location of the water utilities.** The size of water utility operators emerges as a determinant factor in the implementation and efficient management of NBS. Larger entities exhibit greater investment capacity, ability to attract skilled professionals, and research capabilities, all contributing to more effective NBS implementation (IREN, U9). Interviewees emphasize regional disparities, particularly between the North and South of Italy, in terms of resource distribution, skill levels, spending capacity, and priorities. The South faces challenges such as greater sector fragmentation and lack of planning, focussing on emergency-level interventions over advanced planning, including NBS (E21; U9). The difficulty of the South is also evident in the possibility of

accessing financing resources (E21). In this context, according to certain respondents the privatization of water services was deemed an ineffective strategy.

3.2.2. Enabling Drivers

Nine different categories of drivers have been found motivating the policies of Water Utilities in implementing urban NBS.

**a. Accessing to external financing sources**

Regarding the possibility of involving other financial sources, a couple of smaller operators express difficulties in perceiving current interest from entities other than municipalities: *‘I find it hard to think, at least for our interventions, that a municipality or, in any case, a public body that is not directly involved could finance it, certainly not a private individual, if not for aspects related to sustainability or which could constitute an appeal’* (U1). Conversely, the majority of interviewees see potential for the creation of collaboration and synergies by leveraging financial resources and involving stakeholders who stand to benefit from NBS projects. There is a particular focus on potential partnerships with investment funds and real estate, emphasising the increase of property value near NBS sites (U2).

Corporations are seen as having a significant future role in NBS projects (U13), driven by interests in biomonitoring, minimizing impacts, and addressing climate-related risks like flooding that can affect their operational zones and business, such as flooding (U11). Successful dialogues between managers, production companies, and business associations have been observed for example in the ‘working tables’ organised in the APUA project (U11), leading to collaborative solutions for local territories. NBS projects, developed in partnership with water utilities, can find a space on this.

For instance, tools like the Business Improvement District can generate synergies for the redevelopment of business areas, also in collaboration with or relying on water utilities as a technical partner (E23). Additionally, some utilities have contractual agreements with corporations to develop projects aiming to offset emissions through NBS as part of neutrality plans. Moreover, regional funds for urban regeneration are accessible. An illustrative instance is the tender initiated by Regional Agency for Agricultural and Forestry Services (in Italian: ERSAF - *Ente Regionale per i Servizi all’Agricoltura e alle Foreste*) in the Lombardy Region, facilitating collaboration between municipalities and utilities in urban regeneration endeavours, thereby enabling the recovery of costs linked with retrofitting interventions on car parks (U11; U12).

In addition to providing financial assistance, the National Recovery and Resilience Plan (PNRR) funds present opportunities, also to address various constraints, including bureaucratic, technical, administrative, and primarily, political hurdles. These resources have facilitated the development of projects such as the "Sponge City" initiative in the Metropolitan City of Milan, with significant involvement from CAP Holding and MM Spa (see Table S3 in Supplementary materials for more details).

However, the dynamics, time constraints, eligibility criteria, and terms mentioned above must be taken into account when applying for grants (U11; U12). Furthermore, regarding the engagement of financial institutions, respondents stress the necessity for tailored credit lines dedicated to water management, considering sector-specific characteristics and temporal mismatches between investment payback periods and the timeframes requested by banks (U11; U12; E17).

Interest from national and European banking institutions in the water sector has grown exponentially from 2018 to 2021, leading to the development of tailored financing models. An example is the EIB Italian Small Water Utilities Programme Loan, which provides financing to unlisted industrial operators. Loans have been granted to medium-sized water service operators<sup>6</sup>

<sup>6</sup> Since November 2017, companies such as Brianzacque (ATO Monza Brianza), Amap (ATO Palermo), Gaia (ATO 1 Toscana Nord), Acque Veronesi (ATO Veronese) and ASA (ATO 5 Toscana) have benefited from this dedicated funding channel.

(E19; E21). Also, European funds play a crucial role (i.e. LIFE, Horizon Europe, PRISMA, INTERREG calls) (E23; U3). NBS development may also expand the range of potential funds and funding programs to which utilities can apply. Indeed, since NBS may provide a broad range of benefits, extending beyond just water related ones, and if some of them are directly targeted by ad hoc funding opportunities (e.g. biodiversity aspects), this ultimately results in a potentially large set of funding opportunities for utilities (U3; U11).

Also, Public-Private Partnerships are highlighted as effective models for matching public and private resources, facilitating complex projects (E17). Private resources can also be mobilized through crowdfunding, sponsorship, payment for ecosystem services, (see for example the case of LIFE Brenta 2030 in Table S3) as well as through the establishment of facilities or funds (U7). The project "Bioclima" serve as examples of successful Public-Private Partnership (Table S3). Water utilities can allocate their own resources, often through corporate social responsibility (CSR) initiatives, to mitigate negative impacts of operations and demonstrate commitment to environmental and social protection. Hybrid interventions, such as planting to absorb pollution near incinerators, are documented in Sustainability Reports (U6).

### **b. Innovative financing mechanisms**

Water utilities have the potential to influence the development of the sustainable financial market due to their inherent commitment to essential services for sustainable development, benefiting from instruments like green bonds and sustainability bonds (Ref. 2019, n.114). These attract a growing number of diverse investors, including pension funds, infrastructure funds, standard asset management funds, debt funds and offer advantages like subsidized rates and achievement of predefined sustainability indicators, thereby ensuring transparency. However, small operators face challenges due to financial constraints and high transaction costs (E21).

To address this challenges, potential alternatives for small and medium-sized industrial companies include financial pooling, the aggregation of network contracts, or the establishment of ad hoc corporate vehicles that can be secured and placed in financial market capital (U4; E21). Models like "trait enhancement" and "Collaboration Agreement" enable responsibility and risk sharing. A winning example in this sense is the Viveracqua consortium succeeding in issuing Hydrobonds and pooling resources from 14 operators in the Veneto region for innovative projects. Other major operators have also had experience with issuing green bonds, including Hera and Iren. However, the challenge lies in adapting these instruments to include NBS interventions. Furthermore, integrating NBS into water tariffs is seen as a viable strategy by respondents for the potential development of NBS by water utilities (U3), exemplified by initiatives like the LIFE Brenta 2030 project, aiming to finance NBS through the water tariff, aligning with regulations and leveraging customer resources for NBS development.

### **c. Incentive mechanisms**

At the regulatory level, providing incentives for managers to prioritize the development of NBS projects over traditional ones could significantly accelerate the advancement of these solutions. Offering incentives to municipalities is also considered beneficial, allowing water utilities to assist them with technical interventions. The legislative framework for new constructions presents an opportunity for incentives or tax breaks, encouraging citizen involvement (E18). Incorporating NBS into urban planning is highlighted as essential for their effective valorisation. Another noteworthy aspect, acknowledged by some interviewees, involves incentivizing Responsible Project Managers (RUPs) within consulting firms and managing bodies to prioritize NBS projects. The existing bonus structure, often tied to yearly project completion numbers, may discourage the pursuit of complex or innovative projects. Introducing additional rewards or incentives for managers engaged in multi-

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Before the launch of the program, EIB loans over 50 million euros were obtained from SMAT (100 million), Cap Holding (70 million), Veritas (50 million), Publiacqua (50 million), MM (70 million), Brianzacque (50 million), Acquedotto Pugliese (200 million), Abbanoa (200 million).

objective projects offers a pathway to promote NBS adoption, actively involving water utilities in the process (E16; E18).

#### **d. Improving knowledge and skills**

Addressing the "cultural divide" and skill gaps that impede the testing and implementation of NBS involves disseminating knowledge through university and professional courses. Creating multidisciplinary teams is suggested to develop successful multi-objective projects since multi-skilled profiles are often challenging to find. However, effective management is crucial to facilitate discussions and reach agreements between experts (E16). In this sense, collaborations are highly effective, also to develop knowledge and 'standard' case studies to replicate (E16). Collaborations and the sharing of good practices play an essential role in disseminating expertise from academia to practitioners. The exchange of skills and successful pilot projects among utilities, fostering a network and collaborative approach, promote positive competition and a "nudge" for improvements and the testing of more innovative projects, including participation in European projects (E19; E23; U3). Successful interventions demonstrating the potential of NBS can influence political will, build confidence among the public sector and financiers, and overcome barriers to innovation.

#### **e. Fostering social acceptance**

Respondents note often citizens' limited awareness of NBS despite growing sustainability concerns. Most water utilities already promote education programs to highlight NBS benefits targeting citizens and students (E15). However, additional efforts are necessary, calling for systematic national campaigns (E17). Presenting NBS as tangible technological systems, emphasizing protection against vandalism and pollution, proves crucial for efficacy (U11; U12). Achieving citizen acceptance involves transparently presenting project objectives, using explanatory panels, and providing data-supported impact assessments (U10). Effective communication, facilitated by Communication Offices, demands accessible language comprehensible to all (U11, U12).

Participatory mechanisms like stakeholder participation facilitate discussions. For example, initiatives like 'water living laboratories' - territorial structures based on the concept of partnership, involving research, innovation, business, public administration and the environmental aspects – encourage inclusive decision-making, bottom-up approaches aligning solutions with territorial needs for social acceptance (U10; E22). However, fostering acceptance requires cultural shifts and behavioural changes, potentially impacting aspects like parking distance, speeds limits and travel comfort (U11; 12). Consumer guidance, influencing political and business decisions, assigns individuals a central role in societal-level leadership and transformational change (E22).

#### **f. Cooperation and dialogue with stakeholders**

Sustaining dialogue with stakeholders in the integrated water cycle, including regulatory bodies, area authorities, institutions, and municipalities, is essential for the up-scaling of NBS projects (U9). Collaborative efforts, especially with municipal support, can initiate pilot initiatives or develop more complex projects, although smaller entities face authority limitations. Partnerships and structured agreements minimize conflicts, combining experiences and resources. Encouraging research, internally and with the scientific community, ensures science-based targets and scalability evaluation.

For example, a respondent indicated that, through collaboration with reclamation consortia, a project initially focused solely on planting interventions was expanded to integrate wetlands (U10). Furthermore, partnerships and structured collaboration agreements can minimize possible conflicts in technical, legal and economic aspects, combining experiences and resources for successful results (U9; U12).

Given the innovative nature of these solutions, encouraging research is fundamental, both internally and by developing partnerships with the scientific community, universities, and research centres to test experimental projects, facilitate a science-based target, and evaluate their potential for scalability and replication (U1). Collaborating with nearby universities seems preferred by respondents, ensuring contextual knowledge crucial for project success. This synergic approach

results in economic resources, experience, and growth through participation in multidisciplinary projects (U1).

Also, networking among companies, sharing good practices and experiences are frequently emphasised (E15). Furthermore, once the monetary and community value of NBS is recognized, exploring partnerships across unconventional sectors becomes feasible. For example, before COVID, some discussions emerged regarding possible public-private partnerships for energy and water efficiency interventions in buildings. This possibility was emerging, with a first decree of subsidized financing, but changing spending priorities post-COVID have negatively impacted the trajectory of these discussions (E15).

#### **g. Introducing regulations, directives, standards and frameworks**

Water utilities, as service managers, are significantly influenced by political directives in advancing NBS. While current resource allocations prioritize traditional issues, political measures such as "command and control" are identified as crucial drivers for NBS adoption (E20). Water protection plans and regional regulatory bodies (ARERA) play crucial roles, but interviewees advocate for a more forward-thinking approach at both the Agency for Local Water Management and ARERA levels. ARERA could enhance its resolutions by explicitly explaining the standard NBS cases included in the tariff. This would remove ambiguity for local authorities and water utilities, encouraging them to explore also non-traditional interventions. However, the lack of clarity also provides flexibility for local bodies to explore NBS without preclusion (E15) (E19).

Finally, regarding the possibility of ARERA adopting incentive mechanisms for such solutions, it must be acknowledged that the regulatory body operates under a system of technological neutrality and cannot prefer one technology over another, even if it is more sustainable, without an upward policy direction (E19). However, ARERA's actions in extending the scope of environmental costs to the extent possible in tariffs, including recognizing costs associated with ecosystem services, indirectly facilitate the implementation of NBS and are considered one of the most significant drivers (E19).

Additionally, the European Taxonomy of investments directs financial resources toward sustainability projects, including NBS (REF, 2021, n.195), aligning with regional and European regulations' facilitation of NBS. *The role of the Taxonomy is central, because all these financial solutions would converge towards the schemes of the Taxonomy. If the entire financial world is equipped to evaluate projects according to taxonomic rules, when you are within those rules, you also see your financial support guaranteed* (U4). The Taxonomy's standardised approach to project evaluation is expected to guarantee financial support within its rules (U4). Nonetheless, regulations must strike a balance, as strict interpretations often stemming from inaccurate translations of Anglo-Saxon terms of the European directive, may hinder the adoption of sustainable alternatives, exemplified by the rejection of valuable circular solutions due to stringent interpretations European guidelines on the DNSH (Do Not Significant Harm) principle (U11; E19; U12).

#### **h. Clarifying the roles of different actors in water integration services**

Legislation should address the lack of clarity in roles and skills within the water cycle. Some managers suggest assigning greater responsibilities, such as rainwater management, to utilities through formal agreements. Water utilities possess valuable knowledge and expertise within their operating territories and can often handle these solutions more efficiently and expediently compared to municipalities, which often face resource and personnel constraints. *"Our experience with the region is that there are two regional reference departments, there is the municipality, there are us, there are the consortiums. Therefore, from this point of view, a request for simplification in operational terms would be optimal"* remarked a manager.

This shift of responsibilities from municipalities to water utilities is actively pursued in regions like Lombardy, where managers express interest in assuming these services (U1; U2).

#### **i. Introducing NBS in planning**

To overcome context and scale challenges associated with the adoption of NBS, NBS should be introduced broadly from project origin, encompassing aspects related to building characteristics, as

well as general structure and components, and not limited to spot interventions. Adopting a holistic and globally integrated approach to urban planning is essential for reimagining cities in a more harmonious and sustainable manner.

Also, many smaller NBS scale interventions can be inserted quite easily into the urban environments, such for example on the edges of the streets, in which case it is not a question of using “new” space but of redesigning that existence in a more sustainable way. For example, in Lombardy, significant market growth has been observed following the review of regulations pertaining to rainwater. A similar trend occurred with phytopurification, which gained momentum after its introduction in the water law in 1999. The Italian market experienced a notable surge from around 10 units in the 1990s to approximately 8.000 systems nowadays (E16).

1. Development of metrics for ES assessment

Interviewees underscore the relevance of developing accessible and standardized methodologies and metrics to evaluate and quantify the ecosystem services provided by NBS. This necessity is deemed critical across all sectors involved in NBS development. Standardised metrics play a pivotal role in facilitating effective communication, enhancing the credibility of NBS among stakeholders and expediting their integration into intervention planning with local authorities. Moreover, these metrics serve as vital tools in securing financial support for NBS initiatives. Furthermore, the adoption of effective metrics enables the demonstration of how NBS are inherently more sustainable, resilient, and efficient when compared to traditional “grey” solutions (E15).

4. Discussion

The results of the analysis allow to highlight the current and potential role of water utilities in developing NBS in Italy. Examination of aggregated data from the Naturvation database indicates that water utilities have not been involved in developing NBS in Italy, with public bodies acting as the main organisation and main source of funding. However, with a more comprehensive analysis encompassing different databases, we have identified relevant Italian case studies (Table S3 in Supplementary materials). The interviews shed light on the underlying factors influencing this trend in Italy. Some of these are specific to the water utilities sector, while others can be considered “transversal”, impacting multiple stakeholder classes involved in NBS development.

**Table 1** summarises the relevant answers from respondents in the form of a SWOT matrix. This has given us a clearer picture of the internal and external pressures and opportunities for the water utilities sector in implementing NBS. This summary overview helps to identify potential problem areas and encourage policy developments (Dyson, 2004).

Table 1. SWOT matrix.

|                                                                                                                                                                                                                                                                                       |                                                                                                                                                                                                                                                                                                                                                                                                                                                            |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <p><b>INTERNAL STRENGTHS</b></p> <p>(S1) Technical skills</p> <p>(S2) Knowledge of the territory and local needs</p> <p>(S3) Greater speed of adaptation to innovations/market demands compared to the public sector</p> <p>(S4) Skills in monitoring and maintenance of projects</p> | <p><b>INTERNAL WEAKNESSES</b></p> <p>(W1) (Potential) Lack of knowledge about NBS and lack of multidisciplinary profile (“silos” experts)</p> <p>(W2) “Engineering” oriented approach</p> <p>(W3) Path dependency: tendency to replicate the same “well known” projects</p> <p>(W4) Lack of financial resources</p> <p>(W5) Lack of organizational and financial dimension (for smaller operators)</p> <p>(W6) Lack of autonomy in investments choices</p> |
| <p><b>EXTERNAL OPPORTUNITIES</b></p> <p>(O1) Policy regulations and public incentives (comprising ARERA role)</p>                                                                                                                                                                     | <p><b>EXTERNAL THREATS</b></p> <p>(T1) No administrative clarity related to responsibilities</p>                                                                                                                                                                                                                                                                                                                                                           |

|                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                                                                                                                                                                                                                                                                                                                                              |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| (O2) Partnership with other sectors/stakeholders<br>(O3) Dedicated funding resources<br>(O4) Accessing to European call for funds for project aims also at “climate”, “biodiversity” etc.<br>(O5) Growth in demand for green investments from investors and the corporate sector<br>(O6) Development of directives and regulations that favour these investments (EU Taxonomy)<br>(O7) Increasing sensibilization of community in sustainability transition | (T2) Bureaucratic slowness of public sector<br>(T3) Political orientations not in line with the acceptance and encouragement of these solutions<br>(T4) Lack of social acceptance by communities and municipalities<br>(T5) No competitive markets for water utilities<br>(T6) No recognition of NBS value in comparison with grey solutions |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|

Historically, Italy embraced stormwater collection until the 19th century (Chocat et al., 2001), yet there is still a lack of integration of adaptive stormwater management systems and the adoption of Sustainable Drainage Systems (SuDS) in policy and practice (Gimenez et al., 2020). Despite this, respondents, particularly from larger utilities, express interest in exploring sustainability-aligned solutions, including NBS. However, utilities encounter challenges such as limited decision-making autonomy, engineering-centric approaches favouring traditional systems, and inadequate internal skills for NBS multifunctionality. Confusion persists regarding NBS definitions and categorization. Additionally, some projects involving structural interventions at the source, such as those aimed at controlling water losses or depuration, which do not always involve the use of natural elements but, as they are aimed at efficiency improvements also in terms of sustainability, are incorrectly reported as NBS. Another contributing factor is the tendency of professionals to use specific and technical terminology for interventions, often failing to recognize them under the broader term of "NBS," since the concept of NBS emerged relatively recently in 2015 (EC, 2015). The literature extensively documents the prevalent confusion regarding the precise definition of NBS (Nesshöver et al., 2017).

Further compounded by the absence of widespread standards and metrics (Kabisch et al., 2017). Additionally, fostering social participation through information sharing and a participatory approach can promote community acceptance and minimise critics (Gimenez et. al, 2020).

Additionally, stakeholder fragmentation and administrative ambiguities hinder effective decision-making and regulatory integration of rainwater management. The complexity is also evident in stakeholder fragmentation within water management, resulting in ambiguous competencies, responsibilities, and slow decision-making processes due to administrative ambiguities, as confirmed by (Piacentini and Rossetto, 2020). The site-specific nature of NBS and urban space constraints necessitate comprehensive urban planning revisions and cultural shifts toward NBS integration. A cultural shift is imperative, both formally through regulatory measures and informally through changes in culture and discourse, as confirmed by (Coxon et al., 2021). Supportive policies, financial incentives, and European funds are deemed essential for fostering NBS implementation by water utilities as affirmed by (Piacentini and Rossetto, 2020), with the pivotal role of the ARERA regulator. Moreover, leveraging resources from citizens through water tariffs and innovative financing mechanisms from financial institutions with dedicated credit lines, considering the growing interest in sustainable markets, are paramount is emphasized.

Strategically integrating NBS across the water cycle aligns with specific objectives and solutions, emphasizing the regulatory, community, and national levels' importance. European Regulation 2020/852, which outlines a framework for sustainable investments, underscores that water service is not merely a component of the 'Green Deal' but constitutes its fundamental cornerstone. advocating for integrated policies ensuring soil conservation, water quality protection, and quantitative management. Although some Italian utilities have initiated pilot NBS projects, systematic planning remains limited, highlighting the need for broader adoption and scaling up initiatives.

Water utilities should adopt an integrated and multiscale policy aimed at guaranteeing soil conservation, qualitative protection, and quantitative management of water, aligned with multi-

objective principles that yield benefits across multiple levels. Some utilities in Italy have already demonstrated a strong sensitivity to this issue and have initiated pilot projects. However, such cases remain limited, largely due to the absence of systematic planning.

Considering our focus on a sector rather than a specific organization, proposing specific development strategies based solely on the SWOT analysis would pose challenges and may be ineffective. Instead, by utilizing insights gleaned from the SWOT matrix regarding potentialities and internal and external pressures and acknowledging the role of water utilities as management entities, we have delineated five proactive roles that water utilities can adopt to promote the advancement of NBS, as detailed below. In addressing our research question, we stress that the role of water utilities transcends merely providing funding; rather, it encompasses a broader spectrum of functions. For each identified role discussed subsequently, we highlight the strengths and opportunities to capitalize on (S, O) as well as the obstacles and threats to address (W, T). A visual representation is provided in Table S4 in the Supplementary materials.

#### **Role 1: Experts (Exploiting: S1, S2, S3, S4; targeting: W1, T2)**

Water utilities possess technical expertise in water management and treatment (S1), coupled with agility in adapting to market demands (S3), a trait lacking in public entities (T2). Although there is a skills gap in NBS-specific areas, training can address this gap, enabling utilities to swiftly adapt to new technologies or trends (W1).

Their knowledge of local territories needs and priorities allows them to develop tailored intervention solutions, maximizing community benefits effectively. They serve as standard-bearers and pioneers in developing impactful strategies for community development (S2). As said by a respondent: *„Since we provide a service for citizens, it also means trying to develop new solutions that are effective and also bring advantages to local stakeholders. We are very rooted in the territory and for the territory, so it becomes truly essential to be standard-bearers, spokespersons, even pioneers in so-called design areas, perhaps not yet consolidated and fully developed”* (U13). Additionally, water utilities excel in monitoring NBS project performance over time, minimizing maintenance issues. By collecting data on water quality, biodiversity, and community resilience, they can assess solution effectiveness and enhance future projects (S4).

#### **Role 2: Innovators (Exploiting: S3, O2, O3, O5, O7; targeting: W4, T4, T6)**

Water utilities can take a relevant part in promoting innovative projects (S3), also developing partnerships with universities, research centres, and other experts who can integrate their expertise for the testing and development of pioneering and innovative projects (O2). Compared to public administrations, water utilities have a greater drive for innovation (U10). Starting from their base of skills and infrastructure, they can start to integrate natural elements into existing infrastructures and solutions, testing mixed green-grey solutions to facilitate the transition to more sustainable interventions. This may include, for instance, incorporating green roofs, permeable pavements, or constructed wetlands into stormwater management systems, enhancing the overall efficiency of water utilities' operations. By establishing pilot projects and demonstration sites, water utilities can showcase the effectiveness of NBS to the community and other stakeholders (T4, T6), as well as potential funders and donors (W4, O3, O5). These projects serve as practical examples and may inspire similar initiatives (O7).

#### **Role 3: Knowledge sharing (Exploiting: O7, targeting: W1, W2, W3, T4, T6)**

Water utilities can provide training and capacity building programs for their staff, as well as for local contractors and community members (W1, W2, W3). Building local expertise in designing, implementing, and maintaining NBS ensures the sustainability of these solutions. Their role in knowledge sharing is not limited to industry professionals; water utilities can and should also serve as advocates for significant community education and awareness campaigns aimed at citizens and educational institutions (T4). Through educational programmes, workshops, and community engagement initiatives, they can inform residents about the benefits of green infrastructure, conservation practices, and sustainable water management. Many utilities are already involved in these efforts. Furthermore, they can advocate for the dissemination and sharing of best practices

(through platforms, articles, etc.) and collaborate with other operators and organisations (not limited to public entities) to develop integrated projects within the community (O7). These initiatives aim to maximise benefits for the community and have the potential for scalability and replication, thus contributing significantly to closing the knowledge gap regarding NBS (T6).

**Role 4: Funder (Exploiting: O2, O3, O5, O6; targeting: W4, W5)**

Water utilities play a crucial role in supporting Nature-Based Solutions (NBS) by allocating funds to green infrastructure projects, enhancing water management systems' resilience and sustainability. Collaborative networks enable them to develop alternative financial instruments, such as hydrobonds, to address challenges related to fragmented stakeholders and urban-scale interventions (O2, W4, W5). Also, water utilities can promote or participate in innovative financing mechanisms, such as payment for ecosystem services, that can allow mutual learning between stakeholder groups with different perspectives (Golladay et al., 2021), payment for watershed services (Jones et al., 2023) and pay for success instruments such as environmental impact bonds (Appel et al., 2017) (O3, O5, O6).

Incorporating NBS costs into water tariffs, regulated by agencies like ARERA, represents a viable approach, as demonstrated by the LIFE Brenta 2030 project in Italy. Internationally, Peru has emerged as a leader in progressive NBS policy for water management (Coxon et al., 2021). Furthermore, water utilities can act as competent partners within partnerships to apply for European projects, national and regional tenders, and therefore to access sources that they would traditionally not be able to easily access. Projects integrating various aspects such as biodiversity, climate adaptation, and mitigation, are increasingly attracting European funding. Some examples include LIFE REWAT, Trigea EAU, LIFE Brenta, Interreg Alpine Space are reported in Table S3 in Supplementary materials (O2, O4). Investments in NBS can enhance utilities' reputation and social acceptance, especially when coupled with awareness campaigns. Moreover, given the significant influence of the public sector on utilities, preference for NBS over alternative solutions could manifest through green procurement policies (W4). Finally, while NBS could, in principle, be framed within the urban infrastructure domain that traditionally falls within public investments, rapid urbanization and a lack of public funding for urban NBSs may render the involvement of private investors attractive, and sometimes even necessary.

**Role 5: Partner (Exploiting O1, O2, O3, O7; targeting: T1, T3)**

Water utilities can collaborate with local communities, environmental organisations, government agencies, and businesses to jointly develop and implement NBS projects. Collaboration fosters knowledge exchange, leverages resources, and ensures the success of NBS initiatives. Additionally, collaboration with the agriculture sector is becoming increasingly important, for example for the reuse of water for agricultural irrigation (Canning and Stillwell, 2018) like in "Req pro" project (see Table S3 in Supplementary materials) (O2).

Water utilities can advocate for policies that support the implementation of NBS. They can collaborate with policymakers (also through actively participating in organisations such as Utilitalia) to create regulations and incentives that encourage the adoption of green infrastructure and nature-based approaches in urban planning and development. Networking opportunities enhance their ability to effectively convey their needs and proposals, fostering dialogues and discussions with diverse stakeholders, thus mitigating the fragmentation associated with integrated water services (T1). By positioning themselves as promoters of these solutions and fostering active dialogue with regulatory bodies like Agency for Local Water Management and ARERA, water utilities can exert influence over pertinent political decisions (O7, O1, O3, T3).

## 5. Conclusions

The study examined the role of water utilities in the implementation of nature-based solutions for water management in Italy. Regarding the financing sources and instruments used for NBS implementation, our analysis of the Urban Nature Atlas database revealed that, despite water

utilities' current limited engagement in developing urban and peri-urban NBS in Italy, there is a positive trend towards recognising the value of these solutions.

Semi-structured interviews with Italian industry professionals and experts in the field revealed the obstacles and motivations that influence water utilities' engagement in NBS development. Although current interest appears sporadic and lacks a systematic approach, there is an interest and potential for water utilities to play an active role, particularly among managers responsible for rainwater investments in urban areas. NBS offer advantages over traditional interventions for water utilities and communities, yet financial constraints, limited autonomy in investment decisions, and cultural barriers impede their widespread adoption.

To address these challenges, it is necessary to create innovative financial instruments, promote stakeholder collaboration, and enhance regulatory incentives. Tailored credit lines for the water utilities sector, coupled with professional training and community engagement initiatives are deemed crucial. Furthermore, alongside professional training and community engagement initiatives. Moreover, administrative clarity and the role of ARERA authority in regulating water utilities are pivotal in incentivising them to consider NBS.

Based on findings of the interviews, a SWOT matrix was developed to highlight the internal and external pressures and opportunities facing water utilities. This analysis enabled us to identify five potential roles that water utilities could adopt to realise their potential: expert, innovator, knowledge-sharing entity, funder, and partner. However, realising these roles requires addressing barriers while leveraging facilitating factors.

Additionally, the study collected 20 case studies of Italian water utilities involved in NBS projects. While this preliminary and exploratory analysis acknowledges its limitations, it also highlights the need for further investigation. Integrating the data with other databases and sources could improve its reliability and comprehensiveness. Future research should also aim to broaden the scope of interviewees and involve additional stakeholders such as consortia, EGA, municipalities. Furthermore, it would be interesting to prioritise consideration of specific NBS and their potential for water utilities.

**Supplementary Materials:** The following supporting information can be downloaded at the website of this paper posted on Preprints.org, Table S1. Roles of respondents; Table S2. Overview of projects analysis for case studies mapping; Table S3. Mapping of best practices; Figure S1. Location of best practices; Figure S2. NBS basic descriptors - European overview ; Figure S3. NBS basic descriptors - Italian overview; Table S4. Roles details (i.e. S and O exploited and W and T targeted) in relation to SWOT; Appendix A. Guiding questions for the semi-structured interview

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## Appendix A. Guiding questions for the semi-structured interview

Note that the interviews were conducted in Italian (except one) and that the main questions that served as guides for the interview are provided here. These have been adapted whether the interviewer was a water utilities operator or an expert

#### *Section 1: General Information*

- What is your role in the organization? / What are your role and expertise related to the water utility sector?
- How long have you been working for the organization?

#### *Section 2: Actors and funding for NBS*

- Are there any cases among your investments/projects that can be classified as NBS?
- If yes, how many? Can you indicate which ones?
- If yes, what type of funding sources and financial instruments were used?
- If yes, were other parties also involved as co-financiers? Which ones?
- Is there currently and in the future an interest by your company in evaluating the potential of these solutions, also as an alternative to the more traditional ones?
- Do you think that the water utilities sector has significant potential for encouraging this type of solution, and if so, how?

#### *Section 3: Evaluation of NBS projects*

- What evaluations were made before choosing to finance these projects? (Alternatively, what assessments/documentation did you have to prepare to request financing for these solutions? Who made these financing choices?)
- What type of evaluation was the basis for your investment? (Financial assessment of environmental, social and economic impact in the short and long term? Indicators used?)
- Is there a business model behind your investment?

#### *Section 4: Barriers and opportunities for NBS investing*

- In your opinion, what are the main barriers and hindering factors for the development/financing of NbS for your organization/as a representative of the water utilities sector?
- What are the possible strategies/drivers that could enable your organization to overcome these barriers? (and, in general, for the water utilities sector?)
- Are you aware of regulations that require or incentivize investment in NBS for your industry?
- Are you aware of any policies that hinder the financing of NBS?

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