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# Relations between green infrastructures and surface water management. A study concerning two towns in Sardinia, Italy.

Federica Isola, Federica Leone
*University of Cagliari, DICAAR - Dipartimento di Ingegneria Civile, Ambientale e Architettura, IT*

## Highlights

- In all the world, cities have facing challenges connected with extreme weather phenomena.
- The main causes concerning flood events in urban areas are: soil waterproofing, climate change, limited capacity of water courses to receive rainwater and poor awareness within the planning system.
- Urban green infrastructures and Sustainable urban drainage may represent a possible approach to deal with critical situations deriving from extreme weather phenomena.
- The analysis of the two case studies highlights the total lack of issues concerning Urban green infrastructures and Sustainable urban drainage systems within local planning.

## Abstract

In all the world, cities have facing challenges connected with extreme weather phenomena. The complexity, which characterizes urban areas, requires an integrated and interdisciplinary approach to define policies and strategies to manage this kind of problems. Urban green infrastructure, and in general, green infrastructure, may represent a concrete and sustainable approach to face problems concerning surface water management, entailing economic and environmental benefits. Sustainable urban drainage concerns techniques and technologies, considered more sustainable than conventional solutions, used to drain superficial water deriving from meteorological events. Despite the numerous advantages of sustainable urban drainage systems and urban green infrastructure, their use is still limited within urban areas and local plans pay little attention to these unconventional approaches. From this context, the study aims at analyzing the implementation of sustainable urban drainage systems and urban green infrastructure within municipal masterplans in order to understand if and to what extent these approaches are included within spatial planning at the local level. In particular, the study analyses the municipal masterplans of two Sardinian municipalities that have recently approved their plan.

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Email: federica.isola@unica.it, federicaleone@unica.it
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## 1. Introduction

In all the world, cities have facing challenges connected with extreme weather phenomena and worsened by excessive waterproofing of soils due to, sometimes uncontrolled, urban expansions that may affect the functioning of urban drainage systems (Ferguson et al., 2013; Zhou, 2014). However, the complexity, which characterizes urban areas, requires an integrated and interdisciplinary approach to define policies and strategies to manage this kind of problems (Lawson et al., 2014). Green infrastructures (GIs) may represent a possible approach to deal with these critical situations (Pappalardo et al., 2017).
Although the concept of GI arose at the end of the twentieth century as an approach to landscape planning (Mell, 2016), several disciplines, including management and planning of water resources, have analyzed and interpreted this concept (Ahern, 2007a). Despite its numerous interpretations (Benedict & McMahon, 2006; Wright, 2011; Weber et al., 2006; Commissione Europea, 2013), one of the most well-known definition of Gi was provided by the European Commission (2013), where GI are conceived as "*... a strategically planned network of natural and semi-natural areas with other environmental features designed and managed to deliver a wide range of ecosystem services*" (p. 3).
The population growth, in particular in urban areas, and the challenges due to climate change have entailed the definition of a specific policy agenda for cities where the concept of GI is a key issue (Davies & Lafortezza, 2017). In fact, according to the United Nations (2016) a new urban agenda oriented towards environmental sustainability is necessary in order to address the relationships between environment, urban planning and governance.
From this perspective, the concept of Urban green infrastructure (UGI) has emerged in the international debate as a specific part of the GI. UGIs focus on the development and management of green areas networks in urban areas through the implementation of specific processes, approaches and themes (Pauleit et al., 2011, Davies et al., 2015; Davies & Lafortezza, 2017). UGIs show different benefits such as improving citizens wellbeing in terms of health and social cohesion, supporting local economy, protecting biodiversity and helping cities adapt to climate change (Pauleit et al., 2017). UGIs represent, on the one hand, multifunctional networks of blue and green spaces and, on the other hand, processes that govern their development (Ahern, 2007b; Benedict & McMahon 2006, Mell, 2016).
In particular, some studies (Elmqvist et al., 2015; Jayasooriya & Ng, 2014) have emphasized the economic saving and the collateral benefits provided by UGIs. In fact, they may represent an alternative approach to grey infrastructures in relation to the management and mitigation of effects caused by floods. On the other hand, the use of UGI is still limited due to different reasons such as, physical constraints of cities, poor attention that UGIs have within the planning and normative system and limited awareness of their importance (Pauleit et al., in press). Therefore, UGIs represent a key aspect of the ecosystem approach used to deal with problems connected with hydrogeological instability (Ellis, 2013).
From this perspective, UGIs, and in general, green infrastructure, may represent a concrete and sustainable approach to face problems concerning surface water management, entailing economic


**Figure 1:** The study area. *Source: authors' elaboration*

**Table 1:** List of the most significant flood events in Sardinia from 1999 to 2017

| Event Period | Province | Damages on buildings | Housing evacuation orders | Loss of human lives (number) | Resources needed for restoration |
|---|---|---|---|---|---|
| 13 November 1999 | CA | NA | NA | 2 | 20,66 million |
| 6-9 December 2004 | CA; NU; SS | yes | yes | 3 | 40 million |
| 30-31 January 2006 | NU; CA; OG | NA | NA | 0 | NA |
| 22-23 October 2008 | CA; OG | yes | yes | 5 | 73,50 million |
| 12 October 2010 | CA | yes | NA | NA | NA |
| 18-20 November 2013 | OT; NU | yes | yes | 16 + 1 missing people | 500 million |
| 15-18 June 2014 | OT; SS | no | yes | 0 | 1 million |
| 30 September-1 October 2015 | SS | yes | no | 0 | 52.265.191 euros |

*Source: authors' elaboration.*

and environmental benefits. According to Fletcher et al. (2014) sustainable urban drainage (SUD) concerns techniques and technologies, considered more sustainable than conventional solutions, used to drain superficial water deriving from meteorological events. In fact, SUD systems simulate the natural hydrological processes of the site before being urbanized and are based on sustainable development principles and objectives (Pappalardo et al., 2017). SUD systems differ from conventional solutions in relation to principles that address the problem. In fact, conventional approaches collect rainwaters through systems, such as channels and pipelines, that transport surface waters as quick as possible to the drainage area. SUD systems try to keep rainwater onsite as much as possible through landscape elements and natural processes that characterized the specific area (Ahaiblame et al., 2012).

Despite the numerous advantages of SUD systems and UGIs, their use is still limited within urban areas and local plans pay little attention to these unconventional approaches. From this context, our study aims at analyzing the implementation of SUD systems and UGIs within municipal masterplans in order to understand if and to what extent these approaches are included within spatial planning at local level. In particular, the study analyses the municipal masterplans of two Sardinian municipalities that have recently approved their plan. Conciliating objectives of economic development and objectives of environmental protection entails the necessity to have flexible and multidisciplinary planning tools that integrate issues concerning human-induced phenomena with ecosystem protection measures.

The study is composed of four sections. The second section describes the case studies and the methodological approach used. Results of our analyses are presented in the third section while implications, limits and suggestions for further research are discussed in the concluding section.

## 2. Case studies and methodological approach

The study aims at analyzing the integration of SUD systems and UGIs within the spatial plans at the local level, focusing on two Sardinian towns, Assemini and Capoterra, located in South-West Sardinia. The choice of Sardinia Region is not casual because in the last years different extreme flood events have occurred in this territory, representing an important natural hazard responsible for deaths and economic losses (Legambiente, 2013). Table 1 reports the main flood events in Sardinia from 1992 to 2017.

The choice of Assemini and Capoterra, therefore, reflects the combination of two facts. Firstly, both towns have been frequently interested by extreme

**Figure 2:** Green roof at Fundação Cásper Líbero in San Paolo. *Source: Joalpe [CC BY-SA 4.0]. Retrieved form Wikimedia Commons.*

flood events; in particular, the 1999 and 2008 floods caused significant damages in the two analyzed towns. Secondly, both municipalities have recently approved their masterplan in compliance with the Sardinia Hydrogeological Management Plan (HMP) and the Sardinian Regional Landscape Plan (RLP).

Assemini has a population of 26,901 inhabitants with municipal area of 118.17 km$^2$ (ISTAT, January 2018). The municipal masterplans was approved by the Sardinian regional administration in 2015. Capoterra has a population of 23,583 inhabitants with municipal area of 68,49 km$^2$ (ISTAT, January 2018). The municipal masterplan was approved by the Sardinian regional administration in 2016.

The study analyses all the documents included in the municipal masterplans in order to understand if, and to what extent they address the issues of UGIs and SUD systems. In particular, a content analysis was carried out and it was structured into two main phases as following:

- phase 1: different key words in relation to the subjects of UGI and SUD were identified based on the analysis of literature. For each key word, we assessed if it was contained by the documents of the two MMPs;
- phase 2: all the documents were analysed in order to understand how each MMP face the problems of surface water drainage.

Although in literature different definition of content analysis are provided, in this study we refer to the Krippendorff's definition (1989; 2013), according to which content analysis is one of the most important research techniques in the field of social science. In particular, content analysis "*...views data as representations not of physical events but of texts, images, and expressions that are created to be seen, read, interpreted, and acted on for their meanings, and must therefore be analyzed with such uses in mind*" (Krippendorff, 2013, p. xiii). In other words, the key aspect of this kind of analysis is represented by the assessment carried out by the analyst.

The key words, identified as more representative of UGI and SUD, are:

- green infrastructure/s;
- nature-based engineering;
- nature-based solutions;
- nature-based actions;
- urban drainage;
- urban sustainable drainage;
- runoff garden;
- draining floors.

## 3. Results

The contribution proposed refers to a study concerning the municipalities of Assemini and Capoterra in relation to how their MMPs address the surface water management with particular attention to UGIs and SUDs.

In the first phase, for each MMP the following documents were analysed:

- planning implementation code (PIC);
- building regulation (BR);
- general report (GR);
- environmental report (ER).

In relation to the municipality of Assemini, the inclusion of the key words is quite marginal within the PIC and the GR, and null in the ER and the BR. In relation to BR, this result is not surprising because it is a technical document that aims at regulating specific aspects, such as floor-area ratio and building coverage ratio, and, therefore, it does not address this kind of issues. On the other hand, the absence of these terms within the ER and the GR is quite critical. In fact, the ER is a document that should define and explain how the plan integrates environmental issues in terms of sustainable-oriented objectives that the MMP should address (Annex to Resolution No. 44/51 of December 14th 2010 "*Approval of Guidelines for the Strategic Environmental Assessment of Municipal Urban Plans")*. The PIC includes only two out of the eight key words, that is "green infrastructure" and "nature-based engineering", and both the key words are included in a specific part of the PIC "Zoning classification". In particular, the word green infrastructure occurs only once in relation to planning of a specific zone located in the North-western part of the municipal territory adjacent to the trunk road no. 130 and with the railway line that connect Assemini to Cagliari, the capital city of Sardinia. The PIC states that this area must be connected with the adjacent areas through a road connection and a green infrastructure. The word "nature-based engineering" occurs six times within the document, five out of six refer to allowed uses within specific zone type and one out of six concerns the urban green plan that must regulate the implementation of nature-based engineering interventions. In relation to the GR, the word "nature-based engineering" occurs only once and it refers to allowed uses within a specific zone type.

As regards the second phase of our analyses, despite damages caused by flooding within the municipal territory, the analyzed document does not mention nature-based solutions and the drainage of surface water is manage through a traditional approach. One exception is represented by the BR where an index of soil permeability is defined as a percentage of the land surface that must remain permeable. In case of non-compliance with this percentage, collection tanks for rainwater must be realized. The second exception concerns the ER where two indicators are defined, "Areas affected by flood events" and "Number of flood events".

As regards to the MMP of Capoterra, in relation to the first phase, the word "green infrastructure" is not mentioned in all the analyzed documents and the concept is distorted in the BR where green areas are planned for infrastructures. On the other

**Figure 3:** Retention basin of Grange Avenue in Greendale, Wisconsin. *Source: Aaron Volkening, [CC BY 2.0]. Retrieved form Sgobbo, 2018.*

**Figure 4:** Runoff garden in High Point, Seattle, Washington 2010. *Source: Brett VA, [CC BY 2.0]. Retrieved from Wikimedia Commons.*

hand, although all documents face the issue concerning green areas, a holistic vision is missing. The key words “nature-based interventions” and “nature-based engineering” are mentioned only by the BR and the ER and always in relation to landslide risk areas and water course arrangement. Moreover, all documents deal with the topic of urban drainage. In fact, in the municipal territory of Capoterra some water courses, such as the stream “Santa Lucia”, are protected. This situation entails different benefits such as improving the ecological functionality of water courses, protecting the surface hydrographic system through the regeneration of the riparian vegetation and regulating water regime in order to recharge groundwater aquifers. On the other hand, the BR and the GR do not define objectives and strategies in relation to these themes.
In relation to the second phase, the problems concerning flooding are faced in all document due to significant damages that these events have caused. For example, the PIC states that new interventions must defines objectives aimed at slowing down water flows, increasing the soil permeability, increase surface of naturally flooded areas and contrasting erosion processes. In particular, the principal systems concern the outflow water regulation through the consolidation of rocky walls and by maintaining natural vegetation. Moreover, article no. 19 of the PIC states that pedestrian paths must be constructed using permeable surface, such as reinforced lawn, gravel, stabilized earth, ecological asphalts. In relation to new settlements, the PIC defines measures aimed at reducing waterproofing and increasing green areas that must be minimum 25 percent of the land surface.
In conclusion, both case studies analyses the issues concerning UGIs and urban drainage systems in a descriptive and traditional way without suggesting solutions based on natural elements. These problems affect all the Sardinian regional territory, although the characteristics of its landscape are particularly relevant for the development of an integrated ecological network (Acierno, 2015).

## 4. Discussion and conclusions

In Italy, flood events in urban areas are becoming more common, and above all, more intense. According to data provided by ISPRA (the Italian Institute for Environmental Protection and Research) (2015) in 2011 the population at risk of flooding in Sardinia amounted to 1,639,362 inhabitants of which 3.4 percent, 5.9 percent and 15.9 percent live in areas classified as “high danger zones”, “medium danger zones” and “low danger zones”, respectively. The percentage of “high danger zone” and “low danger zones” are higher than the national averages (3.2 percent and 15.2 percent respectively).
The main causes concerning flood events in urban areas are: soil waterproofing, climate change, limited capacity of water courses to receive rainwater and poor awareness within the planning system

(a) (b)

**Figure 5:** Infiltration trench (a) and Phyto-purification basin (b). *Source: Aaron Volkening, [CC BY 2.0]. Retrieved from Flickr.com.*

that entails a poor attention to the concept of "limit" within policies that address urban transformations (Gibelli et al., 2015).

Italian regions have dealt with these problems in different ways. For example, in 2015 Lombardy Region elaborated a handbook of urban drainage (Gibelli et al., 2015) that defines ten objectives concerning the sustainable water management. Emilia-Romagna Region has defined a sort of guide for the design of public spaces through solutions based on nature within the European project REPUBLIC-MED (Dessì et al., 2016). Sardinia Region elaborated guidelines for the implementation of mitigation interventions with naturalistic engineering techniques as a part of the Flood risk management plan, approved in 2016.

However, the results of this study highlight the total lack of issues concerning UGIs and SUD systems within the analyzed plans. Due to the extent of damages caused by flood events in many Italian regions and, especially in the two case studies areas, water management need more attention within planning tools. Moreover, although on the one hand some choices can only be taken at national and regional scale due to management and normative issues, some choices at the local level may make water management more sustainable.

From this perspective three kinds of problems arise. The first is connected with the implementation of financing programs that aims at protecting environment and promoting ecosystem services. The second concern the lack of planning regulations on UGI and SUD at the local level and finally, the third, refers to the inability of local administrations to implement EU funding programmes (Angrilli, 2015).

In relation to the second problem, according to ISPRA (2013) UGI may represent an effective tool to implement SUD systems. In particular, four aspects should be taken into account: water flow control, transport, filtering and infiltration and storage of rainwaters.

In terms of water flow control, the design should start from the individual buildings through the

**Figure 6:** Green roof in Ørestad, Copenhagen, Denmark. *Source: Sgobbo, 2018.*

use of green roofs and walls, connected to a local drainage network, characterized by multiple paths within the entire area.
With regards to transport, excessive water should be conveyed to infiltration basins, which can be planned as multifunctional areas that during the flood event become areas of temporary flooding.
Infiltration and filtration should be guaranteed by draining trenches, rain gardens, green buffer zones placed on the sides of the roads to reduce surface water contamination and phyto-purification basins.
Excessive water could be channeled into basins so as to allow temporary storage and use of the same water for other purposes, such as irrigation.
In conclusion, two main strategies should be pursued: minimizing the flooding probability by increasing infiltration surfaces and minimizing the effects of flooding by using appropriate materials.
This study represents a starting point of a wider analyses where different MMPs are analyzed in order to define a clear and precise framework on how Sardinian local administration deal with the surface water management

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