A Scoring Matrix Method for Integrated Evaluation of Water-Related Ecosystem Services Provided by Urban Parks

A scoring matrix method for integrated evaluation of water-based ecosystem services provided by urban green spaces

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Abstract

Increasing urbanization, landscape conversion and resources consumption represent, probably, the most important, visible and irreversible human-induced actions on Earth. In the last decades, these action as well as climate change generate several pressures which impact on ecosystems. Urban ecosystem is particularly exposed to such pressures and it is therefore important to understand and asses how anthropic pressures are related to the provision of ecosystem services (ES). In particular we focus on green urban spaces at the local scale (i.e. urban parks), their connection to the hydrologic cycle and the provision of water-induced ecosystem services (WES). The approach is developed adopting a wide-minded holistic approach to comprehensively understand the links between anthropic pressures and WES production in two park located in Turin (Italy), the Arrivore Park and the Michelotti Park. A scoring matrix is created with the help of biological, chemical and physical indicators collected in public available databases provided by local authority. The matrices reveal that in the two parks anthropic pressures are marked despite the different park collocations within the city contest and the different conditions. The more damaged WES are habitat maintenance, recreational services, provision of drinkable and non-drinkable water and erosion preven-

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tion. In the Arrivore Park hydromorphological alterations and urbanization represent the most important pressures while in the Michelotti Park water intakes, point sources pollution as well as hydromorphological alterations must be considered. The matrix should provide an easy tool to support policy-makers, public administrations and private companies to undertake sustainability actions within urban planning.

Keywords: Urban ecosystem, Ecosystem services, Water-related Ecosystem Services, Anthropic influence, Scoring Matrix

1. Introduction

Ecosystems are large communities of interconnected living organisms that establish mutual relationships for the management of the environment where they live. They are generally classified into two types: natural and artificial. The former can reach their balance in almost complete autonomy, while the latter (i.e. urban, industrial, agricultural ecosystems) are deeply modified by human actions that change the environment assets to accomplish the needs of human beings. Anthropic activities modify the environment where people live and, in particular in the last decades, such activities have been more and more driven by climate change, population increase, increasing urbanization and the consequent conversion of large parts of natural landscape into artificial ones.

In this paper, we focus on the urban ecosystem as a mix of different biotypes: artificial, half-artificial and semi-natural (Beichler et al., 2017). Roughly speaking, in the first group we include buildings and infrastructures, in the second group we include private and public gardens, green spaces along streets and roads, cemeteries, parking lots, etc., while the last group consists of big parks, urban forests and protected areas (Wang, 2013).

One of the main characteristics of biotypes is their capacity to be a source of Ecosystem Services (ES). In the urban context, ES can be defined as the benefits that people obtain from urban biotypes (Millennium Ecosystem Assessment, 2003) or the elements of urban biotypes directly enjoyed, consumed, or used to yield human well-being (Boyd and Banzhaf, 2007). They generally improve people's well-being, the safeguard of a territory and the protection of its resources (Bolund and Hunhammar, 1999). Following a well-established categorization (Millennium Ecosystem Assessment, 2003), ES can be divided into four categories, i.e. provisioning, regulating, cultural and supporting, respectively. Provisioning ES is related to the supply of primary goods for direct or indirect human use (e.g. food, freshwater, fibers, timber, etc...). Regulating ES concerns the preservation of the ecosystem biophysical elements in order to guarantee the safeguard of natural functions and a good quality of life. (e.g. flood and erosion control, water purification, climate and disease regulation, etc...). Cultural ES includes all the recreational, educational, spiritual, aesthetic and intellectual inspirations provided by the ecosystem (i.e. related to mental and physical health, tourism, culture, art and design, spiritual experience, etc...) while supporting ES makes the existence of provisioning, regulating and cultural ES (e.g. nutrient cycling, habitat provision, enhancement of biodiversity, etc...)possible.

Although the definitions and classifications of ES are case-specific and purpose-driven, it is nowadays well recognized that "*an ecosystem services-based approach is a way of understanding the complex relationships between nature and humans to support decision-making, with the aim of reversing the declining status of ecosystems and ensuring the sustainable use/ management/conservation of resources*" (Martin-Ortega et al., 2015)

The generation, nature and characteristics of ES mainly depend on the features of the environment and, in the context of the present work, on its location and the presence of water. Water cycle is, in fact, deeply connected to the provision of ES because human well-being mostly depends on the state of natural capital and on flows in and between ecosystems that, in turn, depend on water behaviour (Martin-Ortega et al., 2015) Therefore, among the various ES, we identify the Water-related Ecosystem Services (WES) as the benefits obtained from all the services connected to water (Brauman, 2015). Consequently, all the ES which composition, function and structure are related to water supply in the WES category fall. WES constitute essential services for humans as sources for drinking or irrigation use. Freshwaters are related to hydroelectric energy production, wastewater auto-depuration, climate regulation, sediment management, flood protection, fishing or recreational activities (Martin-Ortega et al., 2015; Pham et al., 2019).A groundwater system provides water and geothermal energy; it stores water during flood events that is then supplied during period of drought (Griebler et al., 2014; Tuinstra and van Wensem, 2014). WES are also connected to water behaviour in the hyporheic zone that regulates the physical, chemical and biological characteristics of water in great part of the ecosystem (Boano et al., 2014).

Urbanization, cities expansion and increase in population generally mean an increment in impermeable surfaces, water pollution and hydro-morphological alterations (Grizzetti et al., 2016). As a consequence, there is a strong modification of the urban environment with a depletion of water resources, fragmentation of habitats and damaging of WES (Depietri et al., 2012). Therefore, in the target of more livable, sustainable and resilient cities, the knowledge of how human actions can influence the WES production plays a central role (Brauman, 2015; Schmalz et al., 2016)

Despite the fact that in the last years the quantification and evaluation of ES within urban areas have been vastly debated (Schneider et al., 2012;

Sabater and Tockner, 2010; Qiu and Turner, 2013; Montoya-Tangarife et al., 2017; Lyu et al., 2018), there is a lack of studies that deal with the influence of anthropic pressures on WES production especially on the smaller scales (Haase et al., 2014). Existing analysis and tools are often focused on large spatial scales (Qiu et al., 2017; Grizzetti et al., 2016; Zheng et al., 2016), and basin scale (Schmalz et al., 2016; Bai et al., 2011) and the WES are usually assessed through the evaluation of land cover as a proxy indicator (Sohel et al., 2015; Burkhard et al., 2014). Among various approaches we recall here the eco-hydrological approach SWAT (Soil and Water Assessment Tool) (Arnold et al., 1998; Karabulut et al., 2016)), the Integrated Valuation of Ecosystem Services and Tradeoffs model (InVEST) (Sand-Jensen, 2013; Keeler et al., 2012) or the conceptual framework Driver-Pressure-State-Impact-Response (DPSIR) developed by the European Environment Agency (EEA) (Lyu et al., 2018; Gregory et al., 2013).

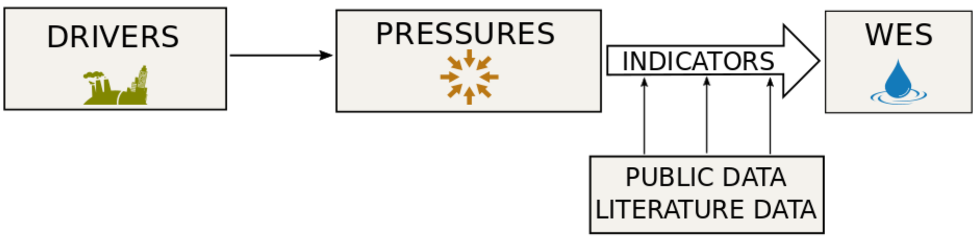

Figure 1: Conceptual model of the proposed analysis.

In the present paper, we propose a scoring method that, with a holistic approach and the use of easy available data, quantifies the influence of human impacts on the WES production on the local scale (i.e. on the urban park scale). To this extent, the method (see Fig. 1) conceptually identifies the drivers, i.e. the factor that lead the changes of chemical, morphological, hydrological and biological elements within the ecosystems (Peng et al., 2019). The drivers are successively related to the anthropic pressures that, in turn, are able to influence the WES production and that it is possible to quantify with the help of suitable indicators.

The matrix-based approach is definitely not a novelty in the assessment of ES and it has been successfully applied to ES quantification in several case studies (Kopperoinen et al., 2014; Montoya-Tangarife et al., 2017; Burkhard et al., 2009; Kroll et al., 2012; Nedkov and Burkhard, 2012). The positivity of the matrix approach is due to its feasibility and its capacity to integrate different data ranging from general to detailed information. The matrix-based approach can also be a valid alternative to GIS-based spatially modeling or hydro-ecological models especially when we need a first-level analysis for management purposes or the starting point for a decision making process. Frequently, in fact, the methods and tools for ES assessment are too complex and expensive or they require specialized knowledge that implies a long learning time (Olander et al., 2017).

Therefore this paper will develop, through the application of the proposed method, two real cases and the answer the following questions:

1. In urban context and with reference to urban green spaces on the local scale (i.e. urban parks), what are the anthropic pressures that influence the WES production?
2. Is it possible to identify some indicators that, with the help of existing and easily available data, are able to quantify such pressures?
3. Is it possible to obtain an easy-to-use, first level method, able to give useful information for the WES management in the urban green space?

2. Method

2.1. Framework for WES assessment

In the last years, the importance of ES safeguard as a core action for the improvement of people's well-being has been greatly increased and, consequently, WES are more and more being incorporated into environmental policies (Karabulut et al., 2016). For example, in 2012, the European Commission adopted the seminal EU Water Framework and Floods Directive (WFD) that acknowledges the services provided by water bodies (European Commission, 2012). In the light of WFD and the already mentioned Millennium Ecosystem Assessment (Millennium Ecosystem Assessment, 2003) framework, we have selected nine WES provided by urban green spaces: habitat maintenance, flood protection, erosion prevention, water purification, carbon sequestration, water production for drinkable and non drinkable use, food provisioning and, finally, recreational services (Table 1). The selected WES are clearly related to water in different ways, directly or indirectly: water can be categorised as a provisioning service but water also represents a reciprocal link between ecosystem functions and people's well-being. Water modifies the elements of the ecosystem and, at the same time, human actions and ecological processes change the attributes of water. (Sand-Jensen, 2013; Brauman et al., 2007)

The complexity embodied in the behaviour of water will also drive the indicators choice and it is therefore appropriate to adopt the hydrologic service framework proposed by Brauman (2015). The WES are categorized based on the benefits provided and it is easier to identify the ecological processes that mainly impact on the attribute of water. According to Brauman (2015) the hydrologic services have been organized in five broad categories (Table 1): (1) diverted water supply, i.e. the "extractive uses" including public, industrial

WES	MA (2003)	Brauman (2015) categories				
		Diverted water supply	In situ water supply	Water damage mitigation	Spiritual and aesthetic	Supporting
Habitat maintenance	Supporting					X
Flood protection	Regulation			X		
Erosion prevention				X		
Water purification				X		
Carbon sequestration			X[(a)]			
Drinkable use	Provision	X				
Non drinkable use		X	X			
Food provisioning			X	X		
Recreational	Cultural				X	

(a) Formally not present into Brauman (2015)

Table 1: WES framework

and thermoelectric uses; (2) improvement of in-situ water supply, including hydropower generation, transportation, water recreation and fish production; (3) water damage mitigation, which includes regulating services such as flood prevention and erosion protection; (4) provision of water-related cultural services such as spiritual uses, aesthetic appreciation and tourism; and finally, (5) water-related supporting services, e.g. the creation of habitats for aquatic organisms and plants growth. Finally, we note that the carbon sequestration as a WES is not formally present in Brauman (2015) categories. We link it to the capacity of aquatic ecosystems to provide the carbon sequestration benefit and, in this perspective, we indicate the in situ water supply as the most suitable for carbon sequestration (Melaku Canu et al., 2015).

2.2. Drivers and pressures

Forasmuch as a few ecosystem elements affect the characteristics of water that flows through it, a holistic approach is fundamental to understand the relationships between multiple human activities and ecosystems attributes.

In order to identify the drivers that are the most responsible for the ecosystem services changes, a definition from Millennium Ecosystem Assessment (2003) is adopted. A driver can be natural, such as climate variability, extreme weather event and solar radiation, or human-induced, like climate change, land use change, air and water pollution, soil erosion, fertility change, fertilizer use, irrigation, introduction of alien species and harvesting. Natural and/or human-induced factors can cause direct or indirect changes on ecosystems: a drivers is "direct" if its actions relapse on the entire ecosystem process, while, on the contrary, an "indirect" driver affects one or more direct drivers (Millennium Ecosystem Assessment, 2005). Therefore, to understand the relationship between the supply of WES and human pressures, the main Direct Drivers (DD) have been identified (Figure 2).

The DD include economic activities, land use, consumption and lifestyle patterns and climate change, which give rise to various pressures on the elements of the ecosystem. Figure 2 shows the eleven identified pressures that represent the ultimate results through which human activities act on WES production. The pressures can act directly on the characteristics of water (i.e. Nonpoint source (NPS) pollution or point source (PS) pollution, temperature), or can modify the balance of water (i.e. water intakes for drinkable or non drinkable use, urbanisation and occupation of flood plains, hydro-morphological alterations, sediment movements) or can indirectly act on water flow (e.g. introduction of alien species, intensive or illegal fishing, etc...).

2.3. Indicators

The definition of indicators able to quantify the influence of anthropic actions on WES production is the core of the proposed matrix method. The assessment and mapping of ES are highly complex because they are connected

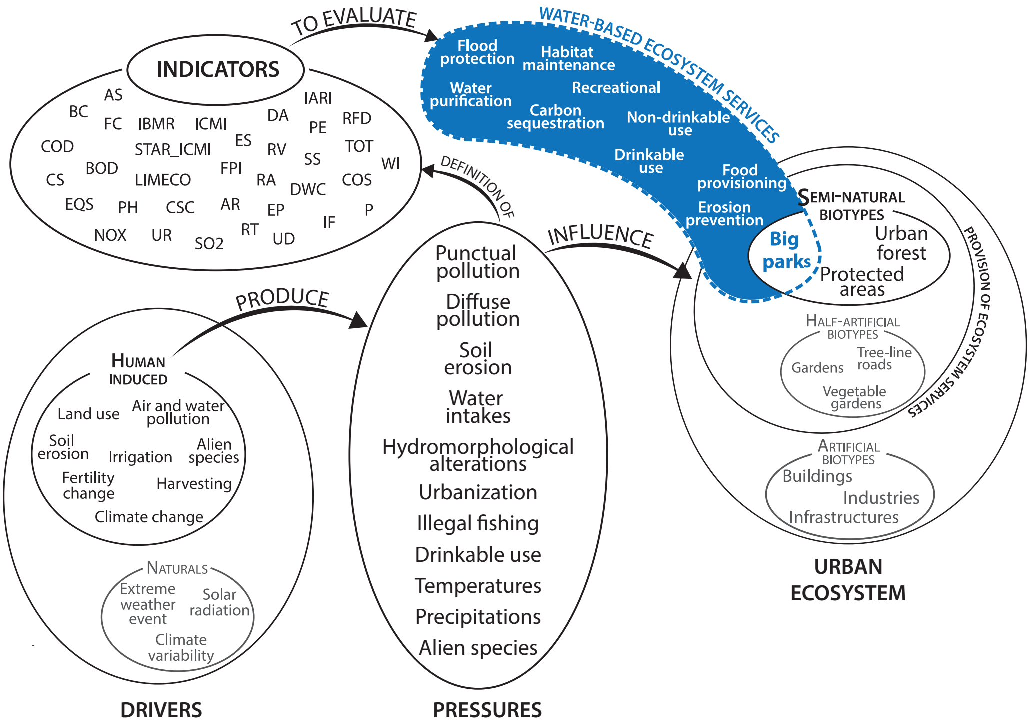

Figure 2: Holistic representation of the analysed processes. Anthropic actions and activities produce pressures that generate negative impacts within the urban ecosystem. The negative impacts turn into unfavourable influences on WES production. The degree of influences can be evaluated with the adoption of suitable indicators, which are then used to complete the scoring matrix

to each other and it is often not very easy to understand the impact of human interferences on ecosystems (Carpenter et al., 1998; Qiu and Turner, 2013; Bennett et al., 2009; Rall et al., 2017; Stürck et al., 2014). The ES assessment is generally based on the biophysical parameters that are used for monitoring, measuring and modelling the ecosystem functions (Shoyama et al., 2017) while the links among ES are often addressed through specific indicators that are able to detect the combined effects of different pressures. For instance, dissolved oxygen and ammonium concentrations can be used to characterize the combined effects of climate change and urbanization (Astaraie-Imani et al., 2012). Applications of manure and fertilizers, as well as agricultural and urban runoff, have been used to characterize the sources of water pollution (Carpenter et al., 1998). In the same way, biophysical and economic indicators that derive from organic waste from households, untreated domestic sewage and nitrogen and phosphorus sources can be used to describe the human impact on freshwater ecosystem (Sand-Jensen, 2013; Keeler et al., 2012).

Table 2 shows the list of the 35 selected indicators. First of all, they have been chosen as a natural consequence of the previous adopted analysis that, starting from WES and DD, is able to identify the pressures that anthropic actions carry on WES production in the context of an urban green space. The presence of the indicators in well-established directives (for example the Water Framework Directive) has been also considered a mandatory quality for the indicator itself. Finally, we preferred using indicators quantifiable with data provided by public and easily accessible datasets. This latter to avoid the direct use of experts' judgements and, as much as possible, to reduce the degree of subjectivity, that is often an obstacle for the comparison of different methods applied in different contexts. Table 2 reports the name and the acronym of each indicator as well as the main quantities measured or an indication of the physical quantity used to quantify the indicator itself. The table also shows the parameters ranges that are often provided by databases with non-numerical categories (e.g. good, poor, sufficient, significant, not significant, compromised, not compromised, etc...).

Table 2: Indicators classification. Type: Biological (B), Chemical (C), Hydromorphological (HM), Morphological (M), General (G). When not differently specified the ranges are: High (H), Good (G), Sufficient (S), Poor (P), Bad (B), not Good (nG), Elevated (E), Medium (M), Low (L), Significant (Si), not Significant (nSi),Compromised (C), not Compromised (nC). For datasets see Section 4.1

Acronym	Name	Type	Dataset	Measured quantities	Range	Reference
AS	Alien Species	B	APW	Presence	Si-nSi	Pejchar and Mooney (2009)
BC	Birds community	B	PRND	Biodiversity assessment	C-nC	-
FC	Fish community	B	PRND	Biodiversity assessment	C-nC	-
IBMR	Organic Macrophytic Index in River	B	APW	Macrophyte	H-G-S-P-B	Erba et al. (2009)
ICMI	Intercalibration Common Metric Index	B	APW	Diatomee	H-G-S-P-B	Giorgio et al. (2016)
STAR-ICMI	Standardisation of River Classification - Intercalibration Multimetric Index	B	APW	Macrobenthos	H-G-S-P-B	Spitale (2017)
ES	Ecological Status	B-HM	APW	Integrated index	H-G-S-P-B	Carballo et al. (2009)
DA	Dam Alterations	HM	APW	Anthropic impact	Si-nSi	Gabbud and Lane (2016)
IARI	Index of alteration of the hydrological regime	HM	APW	Regime deviation	H-G-nG	Rinaldi et al. (2017)
PE	Permeability	HM	APW	Hydraulic conductivity	$10^{-9} - 10^{-3} m/s$	Pisinaras et al. (2016)
RFD	Relative Flow-rate Deficit	HM	WPP	Water quantity	$+\% - -\%$	Smokorowski et al. (2011)
RV	Riparian vegetation	HM	APW	Modifications	Si-nSi	Weissteiner et al. (2014)
SS	Suspended Sediments	HM	APW	Sediment concentration	$\text{Mg/l}^{(a)}$	Vercruysse et al. (2017)
TOT	Time Of Travel	HM	GP	Time	1week-1year	Pisinaras et al. (2016)
WI	Water Intakes	HM	APW	Numerosity	Si-nSi	Gabbud and Lane (2016)
FPI	Flood Plain Intersection	M	GP	Urbanization in flood area	E-M-L	Morris et al. (2005)
RA	Riverbed alterations	M	APW	Anthropic impact	Si-nSi	Sabater and Tockner (2010)
COD	Chemical oxygen demand	C	APW	Organic biod. matter	$25\, mg/l^{(b)}$	Benedetti et al. (2008)
BOD	Biochemical oxygen demand	C	APW	Organic biod. matter	$125\, mg/l^{(b)}$	Benedetti et al. (2008)
CS	Chemical status	C	APW	Chemical quality	G-nG	Cesa et al. (2013)
EQS	Environmental Quality Standard	C	APW	Specific pollutants	H-G-S	Balsotti and Governa (2013)
LIMeco	Pollution Level by Macrodescribers for the ecological status	C	APW	Nutrients, oxygenation	H-G-S-P-B	Valeriani et al. (2015)
PH	Acidity/basicity index	C	APW	hydrogen ions concentration	0-14	Steinberger and Wohl (2003)
AR	Agricultural Runoff	G	APW	Anthropic impact	Si-nSi	Taboada-Castro et al. (2012)
COS	Contaminated sites	G	APW	Numerosity	Si-nSi	Caniani et al. (2015)
CSC	Carbon soil content	G	GP	Carbon topsoil	$\%^{(c)}$	Kuittinen et al. (2016)
DWC	Drinkable Water Consumption	G	WPP	Anthropic impact	$Si - nSi$	Li et al. (2016)
EP	Extreme Precipitations	G	APW	Rainfall intensity	Numerosity^{d}	Blasco et al. (2015)
IF	Illegal fishing	G	APW	Anthropic impact	Si-nSi	-
P	Precipitations	G	WPP	Historic of precipitation	%	Blasco et al. (2015)
RT	River Temperature	G	WPP	Temperature alteration	℃	Steinberger and Wohl (2003)
UD	Urban Wastewater	G	APW	Anthropic impact	Si-nSi	Hussain et al. (2015)
UR	Urban Runoff	G	APW	Anthropic impact	Si-nSi	Schneider et al. (2012)
NOx	Nitrogen Oxides	G	GP	Total emission	$\text{t/year}^{(e)}$	Driscoll et al. (2001)
SO2	Sulfur dioxide	G	GP	Total emission	$\text{t/year}^{(f)}$	Driscoll et al. (2001)

(a) from 200 mg/l maximum allowed according to the WFD

(b) maximum allowed according to the WFD

(c) classes: (1)0-1,0% (2)1,1-2,0% (3)2,1-4,0% (4)>4%

(d) An extreme event is an event with rainfall intensity greater than 10mm/20min

(e) classes: (0)0-115 (1)115-432 (2)432-1055 (3)1055-2321 (4) 2321 - 5252 (5)>5252

(f) classes: (0)0-62 (1)62-257 (2)257-654 (3)654-1846 (4)1846-9149 (5) >9149

The indicators are divided into three macro categories according to literature and directives analysis: i.e. biological, hydro-morphological and chemical parameters (in some cases the same parameter can be included in different categories). In a fourth group (G), we included the indicators that do not clearly belong to the other categories. The biological indicators are mostly related to the ecological status of the ecosystem and they can summarize the environmental stresses and their causes. The hydro-morphological indicators are, in particular, linked to the alteration of natural assets, the alterations of nutrient and hydrologic cycles and the decay of environmental biodiversity (Sand-Jensen, 2013). Chemical and Physical parameters are often linked to the presence of microorganisms and/or substances which could provoke environmental damages or endanger people's health. Finally, the general parameters refer to indicators that are not included in WFD; however, they constitute useful information to assess the anthropic pressure impacts on WES.

3. Matrix

The effects of anthropic pressures on WES production have been summarized in the matrix proposed in Table 3. The two matrix axis report the selected WES and the anthropic pressures (see Figure 2), respectively. In each intersection between rows and columns, we collocate the various indicators (see Table3). In this way, the matrix immediately gives some useful indications. First of all, it is possible for an indicator to be present in more than one intersection, or it is possible for an intersection to be void. In the first case, the presence of different indicators testifies the multiple links there are between the different pressures and their effect on WES and it leads into an integrated comprehension of the complex relationships. On the other hand, a void cell suggests no influence or a lack of information that could be filled in with the outcomes of a new measurement campaign and can indicate an indirect way for future investments.

Operatively, we rank the indicators on a scale from 0 to 5 where the values represent the classes "no influence (0)", "low influence (1)", "low-medium influence (2)", "medium influence (3)", "high influence (4)" and "very high influence (5)". Consequently, when in a cell there is a single indicator we use the value of the indicator itself. On the other hand, when in a cell there are more than one indicator, we calculate an average value and, in this case, a fractional value is possible. The values are also reported with a color-like scale ranging from white (0) to red (5) to give an immediate vision about the level of influence of the pressure on the WES. The cells with no-value are reported in blue color. The "no-relation" between WES and pressures are represented within the matrix with the violet color.

4. Study areas

The proposed scoring matrix method has been applied to two urban fluvial parks. They are located in Turin (Italy - N45°4′45″ E7°40′34″) that covers a surface of 13.010 ha and has a population of 878.074 inhabitants (Total Turin Metropolitan Area 682000 ha with 2278000 inhabitants). Turin is a city characterized by a moderate continental climate (Köppen-Geiger classification *Cfa* - humid subtropical climate (Oliver, 2005)) with mild winters, hot humid summers and quite abundant precipitations (average precipitation 981 mm per year; average precipitation days 80.9 per year). The topographical landscape is mostly flat and hilly and, from an urbanistic point of view, the Roman origin and the expansions as a consequence of Industrial Revolution (19th century) and Economic Boom (from the 1950s to the late 1960s)are well recognisable; the latter in particular was due to a big expansion of the automotive industry. Four rivers flow through Turin: Po, Dora

Table 3: Relationship between Indicators for anthropic pressure impact and WES. Gaps in this table identify intersections where there was actually no suitable indicators to assess the influence of anthropic pressures on WES production. Moreover, the recurrence of an indicator in one or more intersection is due to its relationships with the analysed WES.

Anthropic Pressures	Water-based Ecosystem services								
	Habitat maintenance	Flood protection	Erosion prevention	Water purification	Carbon sequestration	Drinkable use	Non drinkable use	Food provisioning	Recreational
PS pollution	COS-UD-CS-BOD-COD	-	-	BOD-COD	-	CS-COD-UD	CS	COS-CS	COS-CS
NPS pollution	ES-UR-LIMeco	-	-	ESQ-LIMeco-UR-AR-STAR-ICMI-ICMI	-	ESQ-UR-AR-LIMeco	ESQ	ES-STAR-ICMI-LIMeco-ESQ - PH	ESQ
Soil erosion	SS	-	SS	SS	-	SS	-	-	SS
Water intakes	WI	-	-	-	-	-	IARI-WI	-	-
Hydrom. alterations	IARI-RA-RV	RA-DA-RV	RA-RV	RV-IBMR	RV	IARI	-	RA-DA-IARI	RA-RV-IARI
Urbanisation	FPI-BC-NOX-SO2	FPI	FPI-SO2-NOX	-	CSC	PE-TOT	TOT	SO2-NOX	FPI
Illegal fishing	IF	-	-	-	-	-	-	-	-
Drinkable use	-	-	-	-	-	DWC	-	-	-
Temperature	T-RT	-	-	-	-	-	-	T-RT	T
Precipitations	P-RFD	EP-RFD	EP	RFD	-	P-RFD	RFD-P	-	RFD-P
Alien Species	AS-FC	-	AS	-	-	-	-	FC	AS

Riparia, Stura and Sangone. They represent important natural elements within the city context. Despite the increasing urbanization, the landscape transformation and the growing infrastructures, Turin offers a wide assortment of parks, historical gardens and green infrastructures and with its 21.7 square meters of green areas per inhabitant, it is one of the greenest cities in Italy (ISTAT, 2014; Treepedia, 2019) and several fluvial parks contribute to WES provision.

The two selected parks are located along two rivers and in different urban contexts. The first area is the *Arrivore Park* (hereinafter *Arrivore*) and it is located in District 6 (Figure 3). Agricultural and recreational activities were common activities inside the park but with the expansion of the city, the park was abandoned until 1983 when the city administration started a rehabilitation project. The park extends on 58 ha and it is located along the Stura right riverbank. The park is characterized by hydrogeological instability and water pollution due to the nearby presence of landfills, an incinerator and industrial activities. The park is also characterized by a great natural value, especially for the avifauna that finds a shelter and defense here during the migratory period. Within the *Arrivore* cycle paths, there are equipped rest and sport areas and a children playground. Furthermore, 170 allotment gardens were realized in the park during the rehabilitation project and their social importance for the safeguard of the territory is a core element for the urban development planning.

The second area is the *Michelotti Park* (hereinafter *Michelotti*), a long linear park (10,7 ha) located in District 7, between the Po right riverside and the Superga Hill (Figure 4). It is characterized by meadow grass footways, tree lined roads and a central parking space. Valuable trees like *Platanus*, *Gingko Biloba* and *Tilia cordata* characterize the entire park. The fluvial fauna is characterized by the presence of birds, bats and fish.

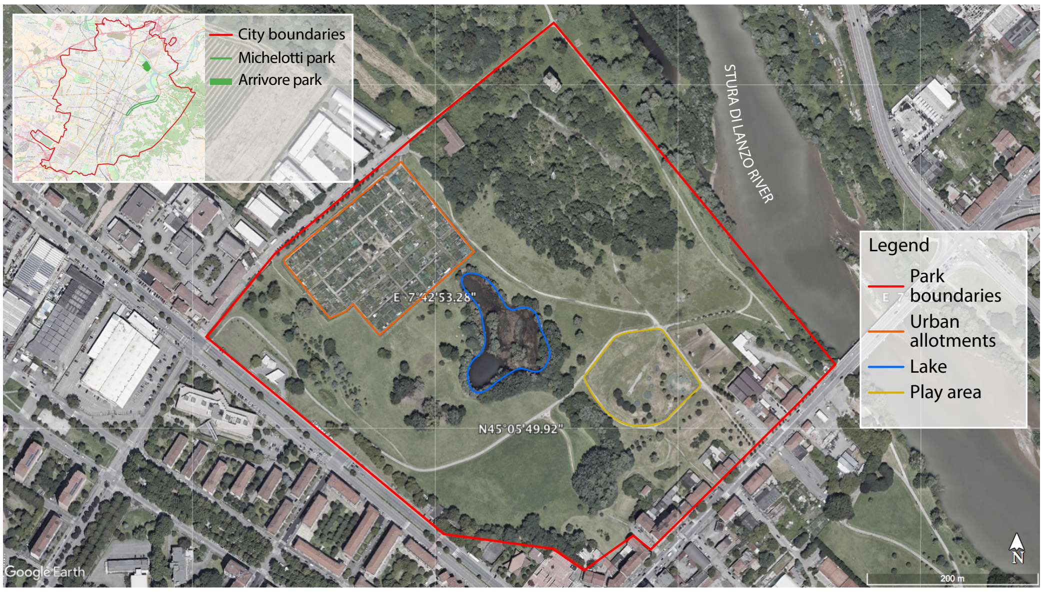

Figure 3: Arrivore park is composed of urban allotments, one small lake fed by groundwater, a play area for children and several pedestrian and bicycle paths.

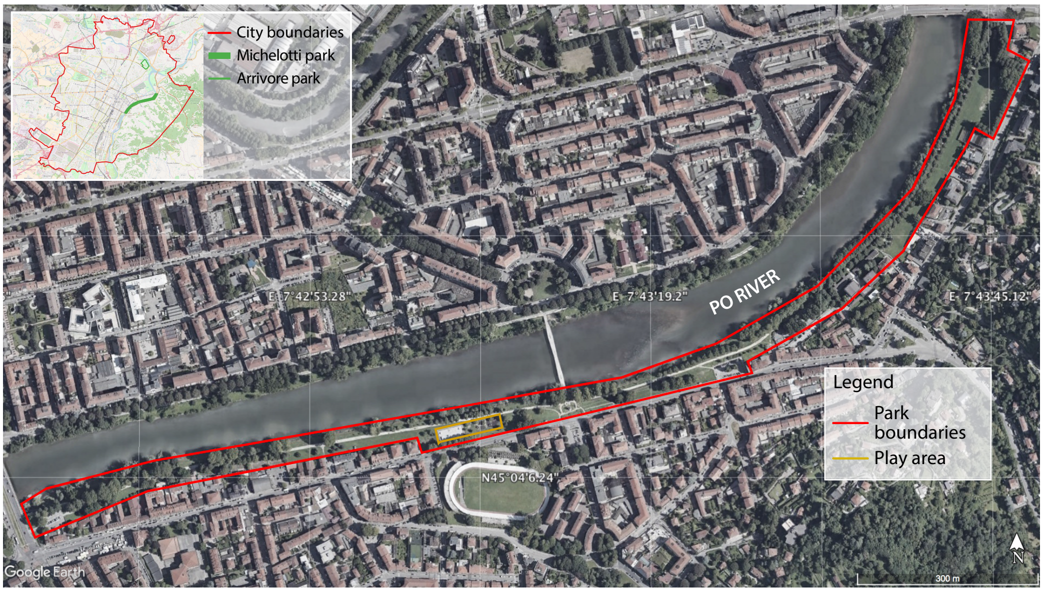

Figure 4: Michelotti Park is characterized by a long linear extension. It is mainly composed of meadow grass footways and a little play area can be found near the centre of the park.

4.1. Data sources

One of the scopes of this paper is the use of open access data already available in public databases.For this aim we collected data from several sources provided by local and national authorities. The datasets are easily accessible throughout web apps that make information straightforward and quick to consult. In particular, we used data provided by ARPA Piemonte Webgis (`webgis.arpa.piemonte.it`), Geoportale Piemonte (`www.geoportale.piemonte.it`), Piedmont Regional Naturalistic Database (`www.regione.piemonte.it/bdnol/RicercaAction.do`) and Water Protection Plan report (`www.regione.piemonte.it/web/temi/ambiente-territorio/ambiente/acqua/`). In Table 2 , the datasets are indicated with the acronyms APW, GP, PRND and WPP, respectively.

5. Results and discussion

Table 4 shows the results of the proposed matrix method for the quantification of anthropic influences on WES production. For the sake of comparison, the *Arrivore* results and the *Michelotti* results are reported in the top and bottom part of the table, respectively. The values are also reported in a color scale (the darker the red, the higher the influence). In the table, the blue cells refer to "no data" cases while the violet cells desribe the situation in which there is no direct link between the anthropic pressures and the WES.

As expected, the urbanization context causes a significant influence on WES production in the two considered parks. Despite the different collocation (the *Michelotti* is closer to the city center, while the *Arrivore* is located in a more industrialized area), the impacts of human presence and activities are marked. Moreover, there are similarities and differences between the two parks. The most harmful pressure for both parks is the "hydromorphological alterations" that show a medium-high (*Michelotti*) and a high level (*Arrivore*) of influence. The high anthropic influence on WES, for both parks, concerns also habitat maintenance and recreational, followed by food provisioning, erosion prevention, and drinkable use. Non-drinkable use, water purification, flood protection, and carbon sequestration result in a low-medium influence.

Table 4: *Arrivore* (top) and *Michelotti* (bottom) fluvial park matrices. Indicators are on a scale form 0 to 5 where the values represent the classes "no influence (0)", "low influence (1)", "low-medium influence (2)", "medium influence (3)", "high influence (4)" and "very high influence (5)"

	Water Ecosystem Services (WES)								
Pressures	Habitat maintenance	Flood Protection	Erosion prevention	Water purification	Carbon sequestration	Drinkable use	Non drinkable use	Food provisioning	Recreational
Arrivore									
PS pollution	2,2	-	-	1	-	3,25	3	3	3
NPS pollution	3	-	-	3	-	3	4	2,2	3
Soil erosion	0	-	0	0	-	0	-	-	0
Water intakes	2	-	2	-	-	-	3,5	-	-
Hydromorph. alterations	5	4	5	5	4	5	0	4	4,6
Urbanization	3,25	3	3	-	1	1	2	3	3
Illegal fishing	4	-	-	-	-	-	-	-	-
Drinkable use	-	-	-	-	-	3	-	-	-
Temperatures	1	-	-	-	-	-	-	2	1
Precipitations	1	1,5	3	1	-	1,5	1,5	-	1
Alien species	4	-	4	-	-	-	-	4,5	5
Michelotti									
PS pollution	3	-	-	2	-	3,75	4	4,5	4,5
NPS pollution	3,3	-	-	2,83	-	3	3	2,4	3
Soil erosion	1	-	1	1	-	1	-	-	1
Water intakes	5	-	5	-	-	-	5	-	-
Hydromorph. alterations	4	3	3,5	4	4	5	0	3	4
Urbanization	2,5	2	2,66	-	0	1	2	3	2
Illegal fishing	4	-	-	-	-	-	-	-	-
Drinkable use	-	-	-	-	-	4	-	-	-
Temperatures	2,5	-	-	-	-	-	-	2,5	1
Precipitations	2	1,5	3	2	-	2	2	-	2
Alien species	4	-	4	-	-	-	-	4,5	5

In the *Arrivore* (Table 4-top), it is clear that the highest influences are caused by morphological alterations related to morphodynamic changes in riverbed, riverbank works, weirs constructions and vegetation management. Moreover, the indicators show a medium-high influence exerted by urbanization, NPS pollution and PS pollution and the presence of alien species. The PS pollution especially damages the recreational and the provision services. Specifically, the medium influence of the PS pollution is due to the presence of contaminated sites, within the *Arrivore*, related to ex-industrial areas and ex-illegal occupation of the park during the last years (Regione Piemonte, 2019). The presence of contaminated sites within the *Arrivore* constitutes a risk for the safeguard of surface water and groundwater because meteoric water facilitates the erosive action, with the consequent transport and infiltration of contaminants into aquifers. Additionally, the *Arrivore* holds 170 urban allotments. The presence of contaminants into soil and water could also have a negative impact on people, who make use of cultivated vegetables. Information collected from the previously cited datasets show that groundwater, within the entire territory of Turin, present a strong presence of hydrocarbons pollution. Adopting a wide holistic perspective, it is clear that groundwater contamination implies multiple trickle-down impacts related to provision of drinkable and non-drinkable water with a consequent impact on people's health, conservation of aquatic environment and safeguard of biodiversity.

In the *Michelotti* (Table 4-bottom), the highest influences are caused, more or less, by the same pressures than the *Arrivore*, but the values are different. The PS pollution shows a medium and high level of influence, (range 3.75-4.5, higher than *Arrivore* values). The score difference is related to the higher presence of urban drains within the river Po , which influences negatively the services provision (left part of the matrix). On the other hand, in the *Michelotti*, the water intakes exert a very high influence on erosion prevention, habitat maintenance and drinkable use. Hydroelectric intakes alter the environmental flow of the river Po, inducing temperature increase, oxygen decrease and damaging of auto-depuration mechanisms. Consequently, the entire aquatic environment of *Michelotti* is subjected to negative influences which cause changes in fishing communities and alteration of aquatic flora (see PRND dataset). Notwithstanding the proximity of the *Michelotti* to the city centre the influence of urbanization is lower than in the *Arrivore*, (the range score is 1-2.66 corresponding to low-medium influence) and, analogously, the hydromorphological alterations result in a medium-high influence, concerning only the riparian vegetation alterations.

The two matrices also show that the pressures caused by anthropic activities, which mainly influence the provision of WES, are related partly to the position of the park with respect to the city centre and partly to the environmental management. For instance, both the riverbeds have experienced critical modifications, like the removal of natural elements and/or the channellisation with concrete embankments. The natural balance is therefore compromised with the consequent loss of the organisms reproductive ability and biodiversity. Furthermore, in the fluvial context an important role belongs to the riparian vegetation, which has the capacity to carry out important WES such as the regulation of water temperature, the retention and regulation of sediments, the filtration of pollutants from runoff, the flood and erosion protection and the infiltrations in the aquifer. (Nava-López et al., 2016; Caro-Borrero et al., 2015).

5.1. Critical analysis

The aim of the proposed method is to analyse the anthropic impact on a set of specific Ecosystem Services, the Water-related Ecosystem Services, in two fluvial urban parks. In literature, generally, the problem is being addressed focusing on what type of services and in what quantity they have been provided by an ecosystem. To overcome this limitation we propose a method that can produce useful indications for urban planners and partitioners (Kopperoinen et al., 2014; Montoya-Tangarife et al., 2017; Burkhard et al., 2009; Kroll et al., 2012; Nedkov and Burkhard, 2012). At the same time, the method has to be carefully applied bearing in mind some issues.

According to Schröter et al. (2014), for example, an important question concerns the matrix complexity and its ability to identify the capacity of ES provision over time. This is related, in particular, to ecosystem management actions that can change the ES production. Moreover, the choice of ES is not always clear because it can be tricky to cover the entire diversity of ES within a single framework or within macro categories (i.e. provision, supporting, regulating, cultural): in literature it is possible to find different frameworks and visions (see, for example, Robinson et al., 2013; Carpenter et al., 2009; Brauman, 2015).

In addition, the measurement and assessment of ES require the definition of suitable indicators, which are related to ES nature. For this purpose, it is fundamental to individuate data, which are often both descriptive and quantitative. According to Dick et al. (2014) the ES assessment on the local scale is often linked to stakeholders and/or experts consultation to better understand the needs of local communities. Differently, the results on a large scale are data-driven to capture the temporal and spatial changes. Therefore, as asserted by Burkhard et al. (2014), the relation between the object of interest and the indicators has to be significant for the particular ecosystem service examinated.

In this perspective, our method is partially helping to address the above mentioned problems. It provides an easily tool based only on public and easy available data. Moreover, multiple indicators have been used to estimate the anthropic influence on WES. Our method suggests that the use of a large number of indicators is useful because the indicators can have a direct or indirect relationship with to WES and, on the other hand, data availability is not always homogeneous in the same area.

Nevertheless, in the proposed matrix there are cells in which the "no value" has been assigned. At first glance, the absence of value could be considered an equivalent of "no influence". This may actually be due to a lack of available data that makes it difficult to define the appropriate indicators. For example, specific datasets regarding the "carbon storage" or the "erosion protection" for the two parks has not yet been developed by regional authorities resulting in the impossibility to define specific useful indicators. To evaluate the impact of anthropic pressures on these WES, a set of data related to alteration of riparian vegetation, numbers of extreme precipitations, occupation of the flood plains by urbanization, water intakes and presence of alien species (in particular mammals, which can increase the erosion bank) have been chosen. Specifically, the indicators are minimally directly correlated with the WES but they are greatly indirectly related to the erosion protection. This aspect could also be improved helping policymakers and environment institutions to individuate the environmental sectors which need more data collection.

6. Conclusions

Nowadays the climate change, the increase of urbanization and population, with the consequent artificial conversion of large parts of natural areas, have strongly modified the urban environment. Fragmentation of habitats and damaging of WES have occurred and it is consequently of seminal importance to know how much the human actions can influence the WES production. Additionally, there is a lack of studies that deal with the anthropic pressures in WES production especially on the local urban scale. To this extent, a new type of scoring method has been developed to quantify the human pressures impacts on WES production and provision on the local scale. Anthropic pressures have been linked to direct and indirect drivers to provide an assessment of anthropic influence on WES within two fluvial urban parks. Available data from authorities and literature have been used to identify the most suitable indicators for the evaluation process. The method therefore aims to provide a quick and easy tool for the quantitative evaluation of WES losses and damages and to evaluate how the anthropic pressures negatively influence the provision of such services. The method is also based only on public and available data, which make the results comparable, accessible and objective as much as possible.

The analyses and the method are strengthened by adopting a wide-minded holistic approach, in order to completely understand the numerous relationships between nature and humans inside a green urban space. The results obtained describe on one hand how much every pressure could affect one or more WES. On the other hand, the assessment through the matrix allows to understand which human activities have caused (or could cause) the worst damages to a fluvial urban ecosystem. The matrix could be useful to drive land policy-makers, public administrations and private companies to undertake sustainability actions within the urban planning. The proposed scoring matrix, in fact, could improve the decision process inside urban planning because the matrix allows to quickly identify (1) the elements to safeguard urban ecosystems, and (2) the aspects to enhance the citizens well-being. Finally, the method could be improved and applied in different urban contests and, in particular, before and during the decision-making process in order to develop a correct and sustainable city-plan. Moreover, we would like to compare larger datasets with a different temporal extension to obtain a more detailed analysis framework and a possible evolution of the parameters. In this perspective, the method allows to outline new environmental analyses able to collect more data to fill the lack of indicators and to improve the matrix efficiency.

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