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Original

A Scoring Matrix Method for Integrated Evaluation of Water-Related Ecosystem Services Provided by Urban Parks / Rosini, Caterina; Revelli, Roberto. - In: ENVIRONMENTAL MANAGEMENT. - ISSN 0364-152X. - 66:(2020), pp. 756-769. [10.1007/s00267-020-01369-3]

Availability:

This version is available at: 11583/2848224 since: 2021-05-20T09:44:17Z

Publisher:

Springer-Verlag

Published

DOI:10.1007/s00267-020-01369-3

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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 actions 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 assess 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 parks 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).

19 One of the main characteristics of biotypes is their capacity to be a source
20 of Ecosystem Services (ES). In the urban context, ES can be defined as
21 the benefits that people obtain from urban biotypes (Millennium Ecosys-
22 tem Assessment, 2003) or the elements of urban biotypes directly enjoyed,
23 consumed, or used to yield human well-being (Boyd and Banzhaf, 2007).
24 They generally improve people’s well-being, the safeguard of a territory and
25 the protection of its resources (Bolund and Hunhammar, 1999). Following
26 a well-established categorization (Millennium Ecosystem Assessment, 2003),
27 ES can be divided into four categories, i.e. provisioning, regulating, cultural
28 and supporting, respectively. Provisioning ES is related to the supply of pri-
29 mary goods for direct or indirect human use (e.g. food, freshwater, fibers,
30 timber, etc...). Regulating ES concerns the preservation of the ecosystem bio-
31 physical elements in order to guarantee the safeguard of natural functions and
32 a good quality of life. (e.g. flood and erosion control, water purification, cli-
33 mate and disease regulation, etc...). Cultural ES includes all the recreational,
34 educational, spiritual, aesthetic and intellectual inspirations provided by the
35 ecosystem (i.e. related to mental and physical health, tourism, culture, art
36 and design, spiritual experience, etc...) while supporting ES makes the ex-
37 istence of provisioning, regulating and cultural ES (e.g. nutrient cycling,
38 habitat provision, enhancement of biodiversity, etc...) possible.

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

45 The generation, nature and characteristics of ES mainly depend on the
46 features of the environment and, in the context of the present work, on its

47 location and the presence of water. Water cycle is, in fact, deeply connected
48 to the provision of ES because human well-being mostly depends on the state
49 of natural capital and on flows in and between ecosystems that, in turn, de-
50 pend on water behaviour (Martin-Ortega et al., 2015) Therefore, among the
51 various ES, we identify the Water-related Ecosystem Services (WES) as the
52 benefits obtained from all the services connected to water (Brauman, 2015).
53 Consequently, all the ES which composition, function and structure are re-
54 lated to water supply in the WES category fall. WES constitute essential
55 services for humans as sources for drinking or irrigation use. Freshwaters
56 are related to hydroelectric energy production, wastewater auto-depuration,
57 climate regulation, sediment management, flood protection, fishing or recre-
58 ational activities (Martin-Ortega et al., 2015; Pham et al., 2019).A ground-
59 water system provides water and geothermal energy; it stores water during
60 flood events that is then supplied during period of drought (Griebler et al.,
61 2014; Tuinstra and van Wensem, 2014). WES are also connected to water
62 behaviour in the hyporheic zone that regulates the physical, chemical and bi-
63 ological characteristics of water in great part of the ecosystem (Boano et al.,
64 2014).

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

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

75 Sabater and Tockner, 2010; Qiu and Turner, 2013; Montoya-Tangarife et al.,
76 2017; Lyu et al., 2018), there is a lack of studies that deal with the influence
77 of anthropic pressures on WES production especially on the smaller scales
78 (Haase et al., 2014). Existing analysis and tools are often focused on large
79 spatial scales (Qiu et al., 2017; Grizzetti et al., 2016; Zheng et al., 2016), and
80 basin scale (Schmalz et al., 2016; Bai et al., 2011) and the WES are usually as-
81 sessed through the evaluation of land cover as a proxy indicator (Sohel et al.,
82 2015; Burkhard et al., 2014). Among various approaches we recall here the
83 eco-hydrological approach SWAT (Soil and Water Assessment Tool) (Arnold
84 et al., 1998; Karabulut et al., 2016)), the Integrated Valuation of Ecosystem
85 Services and Tradeoffs model (InVEST) (Sand-Jensen, 2013; Keeler et al.,
86 2012) or the conceptual framework Driver-Pressure-State-Impact-Response
87 (DPSIR) developed by the European Environment Agency (EEA) (Lyu et al.,
88 2018; Gregory et al., 2013).

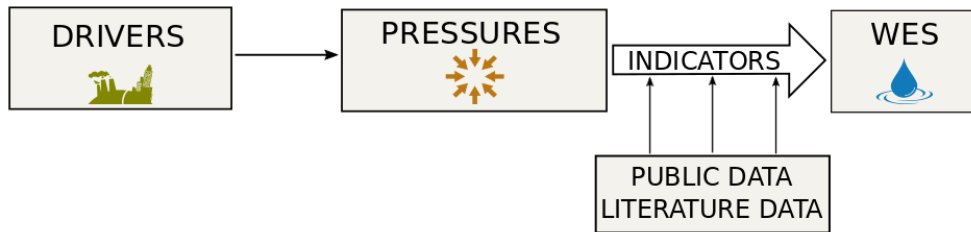


Figure 1: Conceptual model of the proposed analysis.

89 In the present paper, we propose a scoring method that, with a holistic
90 approach and the use of easy available data, quantifies the influence of hu-
91 man impacts on the WES production on the local scale (i.e. on the urban
92 park scale). To this extent, the method (see Fig. 1) conceptually identifies
93 the drivers, i.e. the factor that lead the changes of chemical, morphologi-
94 cal, hydrological and biological elements within the ecosystems (Peng et al.,
95 2019). The drivers are successively related to the anthropic pressures that,

96 in turn, are able to influence the WES production and that it is possible to
97 quantify with the help of suitable indicators.

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

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

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

119 **2. Method**

120 *2.1. Framework for WES assessment*

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

139 The complexity embodied in the behaviour of water will also drive the in-
140 dicators choice and it is therefore appropriate to adopt the hydrologic service
141 framework proposed by Brauman (2015). The WES are categorized based on
142 the benefits provided and it is easier to identify the ecological processes that
143 mainly impact on the attribute of water. According to Brauman (2015) the
144 hydrologic services have been organized in five broad categories (Table 1): (1)
145 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				X		
Erosion prevention	Regulation			X		
Water purification				X		
Carbon sequestration			X ^(a)			
Drinkable use		X				
Non drinkable use	Provision	X	X			
Food provisioning			X	X		
Recreational	Cultural				X	

(a) Formally not present into Brauman (2015)

Table 1: WES framework

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

157 2.2. Drivers and pressures

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

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

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

184 *2.3. Indicators*

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

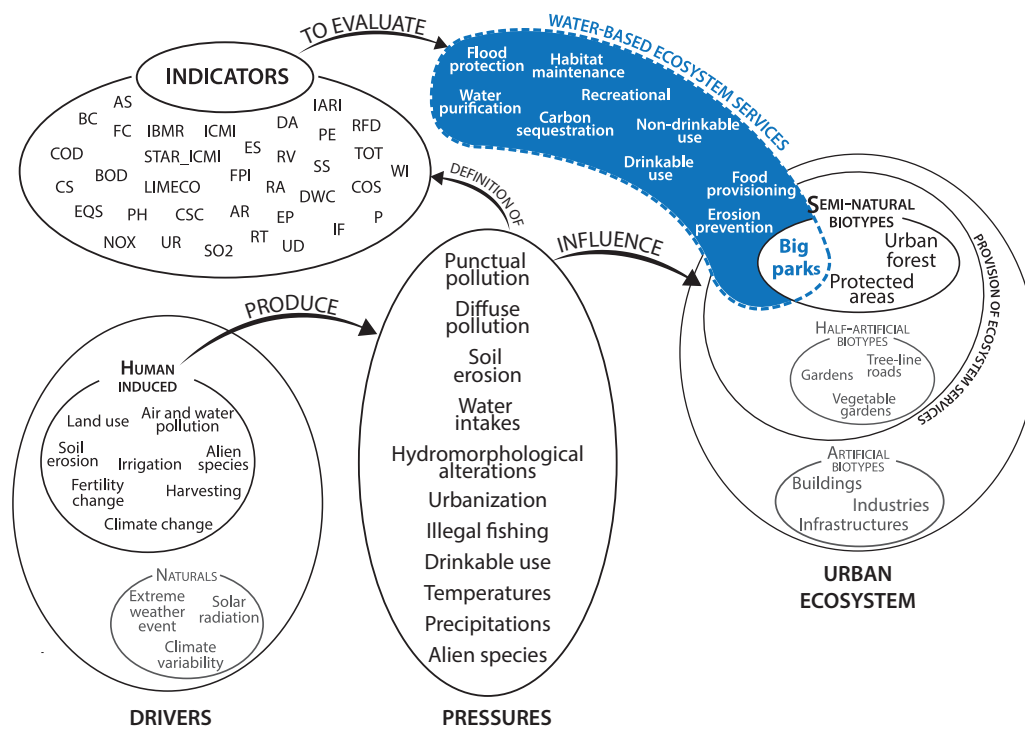


Figure 2: Holistic representation of the analysed processes. Anthropic actions and activities produce pressures that generate negative impacts within the urban ecosystem. The negative impacts turn into unfavourable influences on WES production. The degree of influences can be evaluated with the adoption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

188 to each other and it is often not very easy to understand the impact of human
 189 interferences on ecosystems (Carpenter et al., 1998; Qiu and Turner, 2013;
 190 Bennett et al., 2009; Rall et al., 2017; Stürck et al., 2014). The ES assessment
 191 is generally based on the biophysical parameters that are used for monitor-
 192 ing, measuring and modelling the ecosystem functions (Shoyama et al., 2017)
 193 while the links among ES are often addressed through specific indicators that
 194 are able to detect the combined effects of different pressures. For instance,
 195 dissolved oxygen and ammonium concentrations can be used to character-
 196 ize the combined effects of climate change and urbanization (Astarai-Imani

197 et al., 2012). Applications of manure and fertilizers, as well as agricultural
198 and urban runoff, have been used to characterize the sources of water pol-
199 lution (Carpenter et al., 1998). In the same way, biophysical and economic
200 indicators that derive from organic waste from households, untreated domes-
201 tic sewage and nitrogen and phosphorus sources can be used to describe the
202 human impact on freshwater ecosystem (Sand-Jensen, 2013; Keeler et al.,
203 2012).

204 Table 2 shows the list of the 35 selected indicators. First of all, they have
205 been chosen as a natural consequence of the previous adopted analysis that,
206 starting from WES and DD, is able to identify the pressures that anthropic
207 actions carry on WES production in the context of an urban green space.
208 The presence of the indicators in well-established directives (for example the
209 Water Framework Directive) has been also considered a mandatory quality
210 for the indicator itself. Finally, we preferred using indicators quantifiable
211 with data provided by public and easily accessible datasets. This latter to
212 avoid the direct use of experts' judgements and, as much as possible, to reduce
213 the degree of subjectivity, that is often an obstacle for the comparison of
214 different methods applied in different contexts. Table 2 reports the name and
215 the acronym of each indicator as well as the main quantities measured or an
216 indication of the physical quantity used to quantify the indicator itself. The
217 table also shows the parameters ranges that are often provided by databases
218 with non-numerical categories (e.g. good, poor, sufficient, significant, not
219 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 Multi-metric 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	Mg/l ^(a)	Vercrusse 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 Macrodescriptors 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	°C	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	t/year ^(e)	Driscoll et al. (2001)
SO2	Sulfur dioxide	G	GP	Total emission	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

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

235 **3. Matrix**

236 The effects of anthropic pressures on WES production have been sum-
237 marized in the matrix proposed in Table 3. The two matrix axis report the
238 selected WES and the anthropic pressures (see Figure 2), respectively. In
239 each intersection between rows and columns, we collocate the various indi-
240 cators (see Table3). In this way, the matrix immediately gives some useful
241 indications. First of all, it is possible for an indicator to be present in more
242 than one intersection, or it is possible for an intersection to be void. In the
243 first case, the presence of different indicators testifies the multiple links there
244 are between the different pressures and their effect on WES and it leads
245 into an integrated comprehension of the complex relationships. On the other
246 hand, a void cell suggests no influence or a lack of information that could be

247 filled in with the outcomes of a new measurement campaign and can indicate
248 an indirect way for future investments.

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

260 4. Study areas

261 The proposed scoring matrix method has been applied to two urban flu-
262 vial parks. They are located in Turin (Italy - N45°4'45" E7°40'34") that
263 covers a surface of 13.010 ha and has a population of 878.074 inhabitants
264 (Total Turin Metropolitan Area 682000 ha with 2278000 inhabitants). Turin
265 is a city characterized by a moderate continental climate (Köppen-Geiger
266 classification *Cfa* - humid subtropical climate (Oliver, 2005)) with mild win-
267 ters, hot humid summers and quite abundant precipitations (average pre-
268 cipitation 981 mm per year; average precipitation days 80.9 per year). The
269 topographical landscape is mostly flat and hilly and, from an urbanistic point
270 of view, the Roman origin and the expansions as a consequence of Industrial
271 Revolution (19th century) and Economic Boom (from the 1950s to the late
272 1960s) are well recognisable; the latter in particular was due to a big expan-
273 sion 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

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

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

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

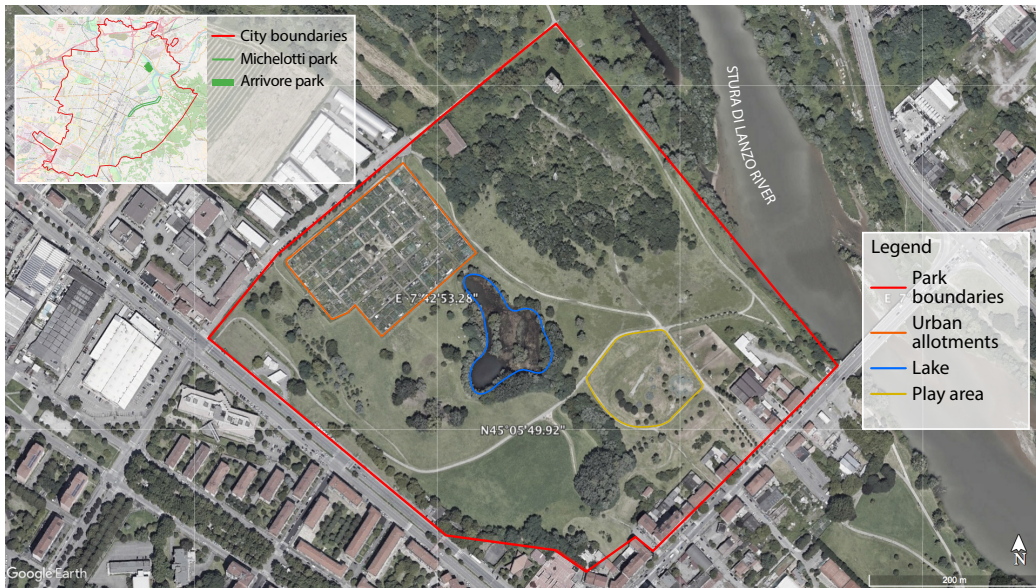


Figure 3: Arrivore park is composed of urban allotments, one small lake fed by groundwater, a play area for children and several pedestrian and bicycle paths.



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.

302 4.1. Data sources

303 One of the scopes of this paper is the use of open access data already avail-
304 able in public databases. For this aim we collected data from several sources
305 provided by local and national authorities. The datasets are easily accessi-
306 ble throughout web apps that make information straightforward and quick
307 to consult. In particular, we used data provided by ARPA Piemonte We-
308 bgis (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 Ta-
312 ble 2, the datasets are indicated with the acronyms APW, GP, PRND and
313 WPP, respectively.

314 5. Results and discussion

315 Table 4 shows the results of the proposed matrix method for the quan-
316 tification of anthropic influences on WES production. For the sake of com-
317 parison, the *Arrivore* results and the *Michelotti* results are reported in the
318 top and bottom part of the table, respectively. The values are also reported
319 in a color scale (the darker the red, the higher the influence). In the table,
320 the blue cells refer to "no data" cases while the violet cells describe the sit-
321 uation in which there is no direct link between the anthropic pressures and
322 the WES.

323 As expected, the urbanization context causes a significant influence on
324 WES production in the two considered parks. Despite the different colloca-
325 tion (the *Michelotti* is closer to the city center, while the *Arrivore* is located
326 in a more industrialized area), the impacts of human presence and activities
327 are marked. Moreover, there are similarities and differences between the two

328 parks. The most harmful pressure for both parks is the "hydromorphological
329 alterations" that show a medium-high (*Michelotti*) and a high level (*Arrivore*)
330 of influence. The high anthropic influence on WES, for both parks, concerns
331 also habitat maintenance and recreational, followed by food provisioning,
332 erosion prevention, and drinkable use. Non-drinkable use, water purification,
333 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)"

Pressures	Water Ecosystem Services (WES)								
	Habitat maintenance	Flood Protection	Erosion prevention	Water purification	Carbon sequestration	Drinkable use	Non drinkable use	Food provisioning	Recreational
<i>Arrivore</i>									
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
<i>Michelotti</i>									
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

334 In the *Arrivore* (Table 4-top), it is clear that the highest influences are
335 caused by morphological alterations related to morphodynamic changes in
336 riverbed, riverbank works, weirs constructions and vegetation management.
337 Moreover, the indicators show a medium-high influence exerted by urbaniza-
338 tion, NPS pollution and PS pollution and the presence of alien species. The
339 PS pollution especially damages the recreational and the provision services.
340 Specifically, the medium influence of the PS pollution is due to the presence
341 of contaminated sites, within the *Arrivore*, related to ex-industrial areas and
342 ex-illegal occupation of the park during the last years (Regione Piemonte,
343 2019). The presence of contaminated sites within the *Arrivore* constitutes
344 a risk for the safeguard of surface water and groundwater because meteoric
345 water facilitates the erosive action, with the consequent transport and infil-
346 tration of contaminants into aquifers. Additionally, the *Arrivore* holds 170
347 urban allotments. The presence of contaminants into soil and water could
348 also have a negative impact on people, who make use of cultivated veg-
349 etables. Information collected from the previously cited datasets show that
350 groundwater, within the entire territory of Turin, present a strong presence of
351 hydrocarbons pollution. Adopting a wide holistic perspective, it is clear that
352 groundwater contamination implies multiple trickle-down impacts related to
353 provision of drinkable and non-drinkable water with a consequent impact
354 on people's health, conservation of aquatic environment and safeguard of
355 biodiversity.

356 In the *Michelotti* (Table 4-bottom), the highest influences are caused,
357 more or less, by the same pressures than the *Arrivore*, but the values are dif-
358 ferent. The PS pollution shows a medium and high level of influence, (range
359 3.75-4.5, higher than *Arrivore* values). The score difference is related to the
360 higher presence of urban drains within the river Po , which influences nega-
361 tively the services provision (left part of the matrix). On the other hand, in

362 the *Michelotti*, the water intakes exert a very high influence on erosion pre-
363 vention, habitat maintenance and drinkable use. Hydroelectric intakes alter
364 the environmental flow of the river Po, inducing temperature increase, oxy-
365 gen decrease and damaging of auto-depuration mechanisms. Consequently,
366 the entire aquatic environment of *Michelotti* is subjected to negative influ-
367 ences which cause changes in fishing communities and alteration of aquatic
368 flora (see PRND dataset). Notwithstanding the proximity of the *Michelotti*
369 to the city centre the influence of urbanization is lower than in the *Arrivore*,
370 (the range score is 1-2.66 corresponding to low-medium influence) and, analo-
371 gously, the hydromorphological alterations result in a medium-high influence,
372 concerning only the riparian vegetation alterations.

373 The two matrices also show that the pressures caused by anthropic ac-
374 tivities, which mainly influence the provision of WES, are related partly to
375 the position of the park with respect to the city centre and partly to the
376 environmental management. For instance, both the riverbeds have experi-
377 enced critical modifications, like the removal of natural elements and/or the
378 channellisation with concrete embankments. The natural balance is there-
379 fore compromised with the consequent loss of the organisms reproductive
380 ability and biodiversity. Furthermore, in the fluvial context an important
381 role belongs to the riparian vegetation, which has the capacity to carry out
382 important WES such as the regulation of water temperature, the retention
383 and regulation of sediments, the filtration of pollutants from runoff, the flood
384 and erosion protection and the infiltrations in the aquifer. (Nava-López et al.,
385 2016; Caro-Borrero et al., 2015).

386 5.1. *Critical analysis*

387 The aim of the proposed method is to analyse the anthropic impact on
388 a set of specific Ecosystem Services, the Water-related Ecosystem Services,

389 in two fluvial urban parks. In literature, generally, the problem is being ad-
390 dressed focusing on what type of services and in what quantity they have
391 been provided by an ecosystem. To overcome this limitation we propose a
392 method that can produce useful indications for urban planners and parti-
393 tioners (Kopperoinen et al., 2014; Montoya-Tangarife et al., 2017; Burkhard
394 et al., 2009; Kroll et al., 2012; Nedkov and Burkhard, 2012). At the same
395 time, the method has to be carefully applied bearing in mind some issues.

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

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

415 In this perspective, our method is partially helping to address the above
416 mentioned problems. It provides an easily tool based only on public and easy

417 available data. Moreover, multiple indicators have been used to estimate the
418 anthropic influence on WES. Our method suggests that the use of a large
419 number of indicators is useful because the indicators can have a direct or
420 indirect relationship with to WES and, on the other hand, data availability
421 is not always homogeneous in the same area.

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

438 **6. Conclusions**

439 Nowadays the climate change, the increase of urbanization and popula-
440 tion, with the consequent artificial conversion of large parts of natural areas,
441 have strongly modified the urban environment. Fragmentation of habitats
442 and damaging of WES have occurred and it is consequently of seminal im-
443 portance to know how much the human actions can influence the WES pro-

444 duction. Additionally, there is a lack of studies that deal with the anthropic
445 pressures in WES production especially on the local urban scale. To this
446 extent, a new type of scoring method has been developed to quantify the hu-
447 man pressures impacts on WES production and provision on the local scale.
448 Anthropic pressures have been linked to direct and indirect drivers to provide
449 an assessment of anthropic influence on WES within two fluvial urban parks.
450 Available data from authorities and literature have been used to identify the
451 most suitable indicators for the evaluation process. The method therefore
452 aims to provide a quick and easy tool for the quantitative evaluation of WES
453 losses and damages and to evaluate how the anthropic pressures negatively
454 influence the provision of such services. The method is also based only on
455 public and available data, which make the results comparable, accessible and
456 objective as much as possible.

457 The analyses and the method are strengthened by adopting a wide-
458 minded holistic approach, in order to completely understand the numerous
459 relationships between nature and humans inside a green urban space. The re-
460 sults obtained describe on one hand how much every pressure could affect one
461 or more WES. On the other hand, the assessment through the matrix allows
462 to understand which human activities have caused (or could cause) the worst
463 damages to a fluvial urban ecosystem. The matrix could be useful to drive
464 land policy-makers, public administrations and private companies to under-
465 take sustainability actions within the urban planning. The proposed scoring
466 matrix, in fact, could improve the decision process inside urban planning
467 because the matrix allows to quickly identify (1) the elements to safeguard
468 urban ecosystems, and (2) the aspects to enhance the citizens well-being. Fi-
469 nally, the method could be improved and applied in different urban contests
470 and, in particular, before and during the decision-making process in order
471 to develop a correct and sustainable city-plan. Moreover, we would like to

472 compare larger datasets with a different temporal extension to obtain a more
473 detailed analysis framework and a possible evolution of the parameters. In
474 this perspective, the method allows to outline new environmental analyses
475 able to collect more data to fill the lack of indicators and to improve the
476 matrix efficiency.

477 **Aknowndgements**

478 This project has received funding from the European Union's Horizon
479 2020 research and innovation program under the Marie Skłodowska-Curie
480 grant agreement "ECO.G.U.S. - ECOsystem services for resilient and sustain-
481 able cities: an ecohydrological approach for Green Urban Spaces" (701914).

482 **References**

- 483 Arnold, J., Srinivasan, R., Muttiah, R., Williams, J., 1998. Large area hy-
484 drologic modeling and assessment part I: Model development. *Journal of*
485 *the American Water Resources Association* 34 (1), 73–89.
- 486 Astaraié-Imani, M., Kapelan, Z., Fu, G., Butler, D., 2012. Assessing the
487 combined effects of urbanisation and climate change on the river water
488 quality in an integrated urban wastewater system in the UK. *Journal of*
489 *Environmental Management* 112, 1–9.
- 490 Bai, Y., Zhuang, C., Ouyang, Z., Zheng, H., Jiang, B., 2011. Spatial
491 characteristics between biodiversity and ecosystem services in a human-
492 dominated watershed. *Ecological Complexity* 8 (2), 177–183.
- 493 Balsotti, R., Governa, M., Sep 2013. Evaluation of groundwater monitoring
494 according to 2000/60/EC and 2006/118/EC directives in Piedmont. *Italian*
495 *Journal of Groundwater* 2 (3).

- 496 Beichler, S. A., Bastian, O., Haase, D., Heiland, S., Kabisch, N., Müller,
497 F., 2017. Does the ecosystem service concept reach its limits in urban
498 environments? *Landscape Online*, 1–21.
- 499 Benedetti, L., Dirckx, G., Bixio, D., Thoeye, C., Vanrolleghem, P., 2008.
500 Environmental and economic performance assessment of the integrated
501 urban wastewater system. *Journal of Environmental Management* 88 (4),
502 1262 – 1272.
- 503 Bennett, E., Peterson, G., Gordon, L., 2009. Understanding relationships
504 among multiple ecosystem services. *Ecology Letters* 12 (12), 1394–1404.
- 505 Blasco, J., Navarro-Ortega, A., Barceló, D., 2015. Towards a better under-
506 standing of the links between stressors, hazard assessment and ecosystem
507 services under water scarcity. *Science of The Total Environment* 503-504,
508 1 – 2.
- 509 Boano, F., Harvey, J., Marion, A., Packman, A., Revelli, R., Ridolfi, L.,
510 Wörman, A., 2014. Hyporheic flow and transport processes: Mechanisms,
511 models, and biogeochemical implications. *Reviews of Geophysics* 52 (4),
512 603–679.
- 513 Bolund, P., Hunhammar, S., 1999. Ecosystem services in urban areas. *Eco-
514 logical Economics* 29 (2), 293–301.
- 515 Boyd, J., Banzhaf, S., 2007. What are ecosystem services? The need for
516 standardized environmental accounting units. *Ecological Economics* 63 (2),
517 616 – 626.
- 518 Brauman, K. A., 2015. Hydrologic ecosystem services: linking ecohydrologic
519 processes to human well-being in water research and watershed manage-
520 ment. *Wiley Interdisciplinary Reviews: Water* 2 (4), 345–358.

- 521 Brauman, K. A., Daily, G. C., Duarte, T. K., Mooney, H. A., 2007. The na-
522 ture and value of ecosystem services: An overview highlighting hydrologic
523 services. *Annual Review of Environment and Resources* 32 (1), 67–98.
- 524 Burkhard, B., Kandziora, M., Hou, Y., Müller, F., 2014. Ecosystem service
525 potentials, flows and demands-concepts for spatial localisation, indication
526 and quantification. *Landscape Online* 34 (1), 1–32.
- 527 Burkhard, B., Kroll, F., Müller, F., Windhorst, W., 2009. Landscapes' ca-
528 pacities to provide ecosystem services - a concept for land-cover based
529 assessments. *Landscape Online* 15 (1), 1–22.
- 530 Caniani, D., Lioi, D. S., Mancini, I. M., Masi, S., 2015. Hierarchical clas-
531 sification of groundwater pollution risk of contaminated sites using fuzzy
532 logic: A case study in the basilicata region (Italy). *Water* 7 (5), 2013–2036.
- 533 Carballo, R., Cancela, J. J., Iglesias, G., Marín, A., Neira, X. X., Cuesta,
534 T. S., Sep 2009. Wfd indicators and definition of the ecological status of
535 rivers. *Water Resources Management* 23 (11), 2231–2247.
- 536 Caro-Borrero, A., Jiménez, J. C., Hiriart, M. M., 2015. Evaluation of ecolog-
537 ical quality in peri-urban rivers in mexico city: a proposal for identifying
538 and validating reference sites using benthic macroinvertebrates as indica-
539 tors. *Journal of Limnology* 75 (s1).
- 540 Carpenter, S., Caraco, N., Correll, D., Howarth, R., Sharpley, A., Smith, V.,
541 1998. Nonpoint pollution of surface waters with phosphorus and nitrogen.
542 *Ecological applications* 8 (3), 559–568.
- 543 Carpenter, S. R., Mooney, H. A., Agard, J., Capistrano, D., DeFries, R. S.,
544 Díaz, S., Dietz, T., Duraiappah, A. K., Oteng-Yeboah, A., Pereira, H. M.,
545 Perrings, C., Reid, W. V., Sarukhan, J., Scholes, R. J., Whyte, A., 2009.

- 546 Science for managing ecosystem services: Beyond the Millennium Ecosys-
547 tem Assessment. *Proceedings of the National Academy of Sciences* 106 (5),
548 1305–1312.
- 549 Cesa, M., Baldisseri, A., Bertolini, G., Dainese, E., Col, M. D., Vecchia,
550 U. D., Marchesini, P., Nimis, P. L., 2013. Implementation of an active
551 ‘bryomonitoring’ network for chemical status and temporal trend assess-
552 ment under the water framework directive in the chiampo valley’s tannery
553 district (ne italy). *Journal of Environmental Management* 114, 303 – 315.
- 554 Depietri, Y., Renaud, F., Kallis, G., 2012. Heat waves and floods in urban ar-
555 eas: A policy-oriented review of ecosystem services. *Sustainability Science*
556 7 (1), 95–107.
- 557 Dick, J., Maes, J., Smith, R. I., Paracchini, M. L., Zulian, G., 2014. Cross-
558 scale analysis of ecosystem services identified and assessed at local and
559 european level. *Ecological Indicators* 38, 20 – 30.
- 560 Driscoll, C., Lawrence, G., Bulger, A., Butler, T., Cronan, C., Eagar, C.,
561 Lambert, K., Likens, G., Stoddard, J., Weathers, K., 2001. Acidic depo-
562 sition in the northeastern united states: Sources and inputs, ecosystem
563 effects, and management strategies. *Bioscience* 51 (3), 180–198.
- 564 Erba, S., Armanini, D. G., Buffagni, A., 2009. Does the lentic-lotic character
565 of rivers affect invertebrate metrics used in the assessment of ecological
566 quality? *Journal of Limnology* 68 (1), 92–105.
- 567 European Commission, 2012. A blueprint to safeguard Europe’s water re-
568 sources. COM(2012) 673 final.
- 569 Gabbud, C., Lane, S. N., 2016. Ecosystem impacts of alpine water intakes

- 570 for hydropower: the challenge of sediment management. Wiley Interdisci-
571 plinary Reviews: Water 3 (1), 41–61.
- 572 Giorgio, A., De Bonis, S., Guida, M., 2016. Macroinvertebrate and diatom
573 communities as indicators for the biological assessment of river Picentino
574 (Campania, Italy). *Ecological Indicators* 64, 85 – 91.
- 575 Gregory, A. J., Atkins, J. P., Burdon, D., Elliott, M., 2013. A problem struc-
576 turing method for ecosystem-based management: The DPSIR modelling
577 process. *European Journal of Operational Research* 227 (3), 558 – 569.
- 578 Griebler, C., Malard, F., Lefébure, T., 2014. Current developments in
579 groundwater ecology-from biodiversity to ecosystem function and services.
580 *Current Opinion in Biotechnology* 27, 159–167.
- 581 Grizzetti, B., L Lanzanova, D., Liquele, C., Reynaud, A., Cardoso, A., 2016.
582 Assessing water ecosystem services for water resource management. *Envi-
583 ronmental Science & Policy* 61, 194 – 203.
- 584 Haase, D., Larondelle, N., Andersson, E., Artmann, M., Borgström, S.,
585 Breuste, J., Gomez-Baggethun, E., Gren, Å., Hamstead, Z., Hansen, R.,
586 Kabisch, N., Kremer, P., Langemeyer, J., Rall, E. L., McPhearson, T.,
587 Pauleit, S., Qureshi, S., Schwarz, N., Voigt, A., Wurster, D., Elmqvist, T.,
588 May 2014. A quantitative review of urban ecosystem service assessments:
589 Concepts, models, and implementation. *AMBIO* 43 (4), 413–433.
- 590 Hussain, M., Mumtaz, M., Hussain, S., Abbas, M., Mehmood, S., Imran, M.,
591 2015. Comparative physico-chemical characterization and spatial distribu-
592 tion of pollutants in rural and urban drains water. *Soil and Environment*
593 34 (1), 51–64.
- 594 ISTAT, 2014. Urban green. Italian National Institute of Statistics.

- 595 Karabulut, A., Egoh, B. N., L Lanzanova, D., Grizzetti, B., Bidoglio, G.,
596 Pagliero, L., Bouraoui, F., Aloe, A., Reynaud, A., Maes, J., Vandecasteele,
597 I., Mubareka, S., 2016. Mapping water provisioning services to support the
598 ecosystem–water–food–energy nexus in the danube river basin. *Ecosystem
599 Services* 17, 278 – 292.
- 600 Keeler, B., Polasky, S., Brauman, K., Johnson, K., Finlay, J., O’Neille, A.,
601 Kovacs, K., Dalzell, B., 2012. Linking water quality and well-being for
602 improved assessment and valuation of ecosystem services. *Proceedings of
603 the National Academy of Sciences of the United States of America* 109 (45),
604 18619–18624.
- 605 Kopperoinen, L., Itkonen, P., Niemelä, J., 2014. Using expert knowledge in
606 combining green infrastructure and ecosystem services in land use plan-
607 ning: An insight into a new place-based methodology. *Landscape Ecology*
608 29 (8), 1361–1375.
- 609 Kroll, F., Müller, F., Haase, D., Fohrer, N., 2012. Rural-urban gradient
610 analysis of ecosystem services supply and demand dynamics. *Land Use
611 Policy* 29 (3), 521–535.
- 612 Kuittinen, M., Moinel, C., Adalgeirsdottir, K., 2016. Carbon sequestration
613 through urban ecosystem services: A case study from finland. *Science of
614 The Total Environment* 563-564, 623 – 632.
- 615 Li, P., Chaubey, I., Muenich, R., Wei, X., 2016. Evaluation of fresh water
616 provisioning for different ecosystem services in the upper mississippi river
617 basin: Current status and drivers. *Water (Switzerland)* 8 (7).
- 618 Lyu, R., Zhang, J., Xu, M., Li, J., 2018. Impacts of urbanization on ecosys-

619 tem services and their temporal relations: A case study in Northern
620 Ningxia, China. *Land Use Policy* 77, 163–173.

621 Martin-Ortega, J., Ferrier, R., Gordon, I., 10 2015. *Water Ecosystem Ser-*
622 *VICES: A Global Perspective*. Cambridge University Press.

623 Melaku Canu, D., Ghermandi, A., Nunes, P., Lazzari, P., Cossarini, G.,
624 Solidoro, C., 2015. Estimating the value of carbon sequestration ecosys-
625 tem services in the mediterranean sea: An ecological economics approach.
626 *Global Environmental Change* 32, 87–95.

627 Millennium Ecosystem Assessment, 2003. *Ecosystems and Human Well-*
628 *being: A Framework for Assessment*. World Resources Institute. Island
629 Press.

630 Millennium Ecosystem Assessment, 2005. *Ecosystem and Human Well-being*
631 *- A Report of the Millennium Ecosystem Assessment*. Island Press.

632 Montoya-Tangarife, C., De La Barrera, F., Salazar, A., Inostroza, L., 2017.
633 Monitoring the effects of land cover change on the supply of ecosystem
634 services in an urban region: A study of Santiago-Valparaíso, Chile. *PLoS*
635 *ONE* 12 (11).

636 Morris, J., Hess, T., Gowing, D., Leeds-Harrison, P., Bannister, N., Vivash,
637 R., Wade, M., 2005. A framework for integrating flood defence and bio-
638 diversity in washlands in england. *International Journal of River Basin*
639 *Management* 3 (2), 105–115.

640 Nava-López, M., Diemont, S., Hall, M., Ávila-Akerberg, V., 2016. Riparian
641 buffer zone and whole watershed influences on river water quality: Impli-
642 cations for ecosystem services near megacities. *Environmental Processes*
643 3 (2), 277–305.

- 644 Nedkov, S., Burkhard, B., 2012. Flood regulating ecosystem services - map-
645 ping supply and demand, in the Etropole municipality, Bulgaria. *Ecological*
646 *Indicators* 21, 67–79.
- 647 Olander, L., Polasky, S., Kagan, J. S., Johnston, R. J., Wainger, L., Saah,
648 D., Maguire, L., Boyd, J., Yoskowitz, D., 2017. So you want your research
649 to be relevant? building the bridge between ecosystem services research
650 and practice. *Ecosystem Services* 26, 170 – 182.
- 651 Oliver, J. E., 2005. *Climate Classification*. Springer Netherlands, Dordrecht,
652 Ch. 2, pp. 218–227.
- 653 Pejchar, L., Mooney, H. A., 2009. Invasive species, ecosystem services and
654 human well-being. *Trends in Ecology & Evolution* 24 (9), 497–504.
- 655 Peng, J., Wang, A., Luo, L., Liu, Y., Li, H., Hu, Y., Meersmans, J., Wu, J.,
656 2019. Spatial identification of conservation priority areas for urban ecolog-
657 ical land: An approach based on water ecosystem services. *Land Degrada-*
658 *tion & Development*, 1–12.
- 659 Pham, H. V., Torresan, S., Critto, A., Marcomini, A., 2019. Alteration of
660 freshwater ecosystem services under global change – a review focusing on
661 the Po River basin (Italy) and the Red River basin (Vietnam). *Science of*
662 *The Total Environment* 652, 1347 – 1365.
- 663 Pisinaras, V., Polychronis, C., Gemitzi, A., 2016. Intrinsic groundwater vul-
664 nerability determination at the aquifer scale: a methodology coupling
665 travel time estimation and rating methods. *Environmental Earth Sciences*
666 75 (1), 1–12.
- 667 Qiu, J., Turner, M., 2013. Spatial interactions among ecosystem services in an

- 668 urbanizing agricultural watershed. *Proceedings of the National Academy*
669 *of Sciences of the United States of America* 110 (29), 12149–12154.
- 670 Qiu, J., Wardropper, C., Rissman, A., Turner, M., 2017. Spatial fit between
671 water quality policies and hydrologic ecosystem services in an urbanizing
672 agricultural landscape. *Landscape Ecology* 32 (1), 59–75.
- 673 Rall, E., Bieling, C., Zytynska, S., Haase, D., 2017. Exploring city-wide
674 patterns of cultural ecosystem service perceptions and use. *Ecological In-*
675 *dicators* 77, 80–95.
- 676 Regione Piemonte, 2019. Area Plan for the Po river fluvial park. (Italian).
- 677 Rinaldi, M., Belletti, B., Bussettini, M., Comiti, F., Golfieri, B., Lastoria,
678 B., Marchese, E., Nardi, L., Surian, N., 2017. New tools for the hydro-
679 morphological assessment and monitoring of european streams. *Journal of*
680 *Environmental Management* 202, 363 – 378.
- 681 Robinson, D., Hockley, N., Cooper, D., Emmett, B., Keith, A., Lebron, I.,
682 Reynolds, B., Tipping, E., Tye, A., Watts, C., Whalley, W., Black, H.,
683 Warren, G., Robinson, J., 2013. Natural capital and ecosystem services,
684 developing an appropriate soils framework as a basis for valuation. *Soil*
685 *Biology and Biochemistry* 57, 1023 – 1033.
- 686 Sabater, S., Tockner, K., 2010. *Effects of Hydrologic Alterations on the Eco-*
687 *logical Quality of River Ecosystems*. Springer Berlin Heidelberg, Berlin,
688 Heidelberg, Ch. 1, pp. 15–39.
- 689 Sand-Jensen, K., 2013. Freshwater ecosystems, human impact on. *Encyclo-*
690 *pedia of Biodiversity: Second Edition*, 570–586.
- 691 Schmalz, B., Kruse, M., Kiesel, J., Müller, F., Fohrer, N., 2016. Water-
692 related ecosystem services in Western Siberian lowland basins—Analysing

- 693 and mapping spatial and seasonal effects on regulating services based on
694 ecohydrological modelling results. *Ecological Indicators* 71, 55 – 65.
- 695 Schneider, A., Logan, K. E., Kucharik, C. J., Jun 2012. Impacts of urban-
696 ization on ecosystem goods and services in the u.s. corn belt. *Ecosystems*
697 15 (4), 519–541.
- 698 Schröter, M., Barton, D. N., Remme, R. P., Hein, L., 2014. Accounting for
699 capacity and flow of ecosystem services: A conceptual model and a case
700 study for telemark, norway. *Ecological Indicators* 36, 539 – 551.
- 701 Shoyama, K., Kamiyama, C., Morimoto, J., Ooba, M., Okuro, T., 2017. A
702 review of modeling approaches for ecosystem services assessment in the
703 Asian region. *Ecosystem Services* 26, 316–328.
- 704 Smokorowski, K. E., Metcalfe, R. A., Finucan, S. D., Jones, N., Marty, J.,
705 Power, M., Pyrcce, R. S., Steele, R., 2011. Ecosystem level assessment of en-
706 vironmentally based flow restrictions for maintaining ecosystem integrity:
707 a comparison of a modified peaking versus unaltered river. *Ecohydrology*
708 4 (6), 791–806.
- 709 Sohel, M., Ahmed Mukul, S., Burkhard, B., 2015. Landscape’s capacities
710 to supply ecosystem services in Bangladesh: A mapping assessment for
711 Lawachara National Park. *Ecosystem Services* 12, 128–135.
- 712 Spitale, D., 2017. Performance of the STAR_ICMI macroinvertebrate in-
713 dex and implications for classification and biomonitoring of rivers. *Knowl.*
714 *Manag. Aquat. Ecosyst.* 418 (20).
- 715 Steinberger, N., Wohl, E., Jun 2003. Impacts to water quality and fish habitat
716 associated with maintaining natural channels for flood control. *Environ-*
717 *mental Management* 31 (6), 724–740.

- 718 Stürck, J., Poortinga, A., Verburg, P., 2014. Mapping ecosystem services:
719 The supply and demand of flood regulation services in Europe. *Ecological*
720 *Indicators* 38, 198–211.
- 721 Taboada-Castro, M., Diéguez-Villar, A., Rodríguez-Blanco, M. L., Taboada-
722 Castro, M. T., 2012. Agricultural impact of dissolved trace elements in
723 runoff water from an experimental catchment with land-use changes. *Com-*
724 *munications in Soil Science and Plant Analysis* 43 (1-2), 81–87.
- 725 Treepedia, 2019. Exploring the green canopy in cities around the world.
726 URL <http://senseable.mit.edu/treepedia>
- 727 Tuinstra, J., van Wensem, J., 2014. Ecosystem services in sustainable ground-
728 water management. *Science of The Total Environment* 485-486, 798 – 803.
- 729 Valeriani, F., Zinnà, L., Vitali, M., Spica, V. R., Protano, C., 2015. River
730 water quality assessment: comparison between old and new indices in a
731 real scenario from Italy. *International Journal of River Basin Management*
732 13 (3), 325–331.
- 733 Vercruyssen, K., Grabowski, R. C., Rickson, R., 2017. Suspended sediment
734 transport dynamics in rivers: Multi-scale drivers of temporal variation.
735 *Earth-Science Reviews* 166, 38 – 52.
- 736 Wang, Y., 2013. Sustainable development and green space system construc-
737 tion - sustainable green space system planning combined with geographic
738 information system. *International Conference on Geoinformatics*.
- 739 Weissteiner, C. J., Pistocchi, A., Marinov, D., Bouraoui, F., Sala, S., 2014.
740 An indicator to map diffuse chemical river pollution considering buffer
741 capacity of riparian vegetation — a pan-european case study on pesticides.
742 *Science of The Total Environment* 484, 64 – 73.

743 Zheng, H., Li, Y., Robinson, B., Liu, G., Ma, D., Wang, F., Lu, F., Ouyang,
744 Z., Daily, G., 2016. Using ecosystem service trade-offs to inform water
745 conservation policies and management practices. *Frontiers in Ecology and*
746 *the Environment* 14 (10), 527–532.

747 **List of Tables**

748 1 WES framework 8

749 2 Indicators classification. Type: Biological (B), Chemical (C),
750 Hydromorphological (HM), Morphological (M), General (G).
751 When not differently specified the ranges are: High (H), Good
752 (G), Sufficient (S), Poor (P), Bad (B), not Good (nG), Ele-
753 vated (E), Medium (M), Low (L), Significant (Si), not Sig-
754 nificant (nSi), Compromised (C), not Compromised (nC). For
755 datasets see Section 4.1 12

756 3 Relationship between Indicators for anthropic pressure impact
757 and WES. Gaps in this table identify intersections where there
758 wasn't actually suited indicators to assess the influence of an-
759 thropic pressures on WES production. Moreover, the recur-
760 rence of an indicator in one or more intersection is due to its
761 relationships with the analysed WES. 15

762 4 *Arrivore* (top) and *Michelotti* (bottom) fluvial park matrices.
763 Indicators are on a scale form 0 to 5 where the values repre-
764 sent the classes "no influence (0)", "low influence (1)", "low-
765 medium influence (2)", "medium influence (3)", "high influ-
766 ence (4)" and "very high influence (5)" 20

767 **List of Figures**

768 1 Conceptual model of the proposed analysis. 5
769 2 Holistic representation of the analysed processes. Anthropic
770 actions and activities produce pressures that generate nega-
771 tive impacts within the urban ecosystem. The negative im-
772 pacts turn into unfavourable influences on WES production.
773 The degree of influences can be evaluated with the adoption
774 of suitable indicators, which are then used to complete the
775 scoring matrix 10
776 3 Arrivore park is composed by urban allotments, one small lake
777 fed by groundwater, a play area for children and several pedes-
778 trian and bicycle paths. 17
779 4 Michelotti Park is characterized by a long linear extension. It
780 is mainly composed by meadow grass footways and near the
781 centre of the park a little play area is present. 17