Report on Ecosystem Services

E²STORMED PROJECT
Improvement of energy efficiency in the water cycle by the use of innovative storm water management in smart Mediterranean cities
www.e2stormed.eu

Abertay University

L'Europe en Méditerranée
Europe in the Mediterranean

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Main Authors

Rebecca Wade	*Abertay university*
Chris Jefferies	*Abertay university*
Neil Berwick	*Abertay university*

Contributors

Ignacio Escuder Bueno	*IIAMA - Universitat Politècnica de València*
Ignacio Andrés Doménech	*IIAMA - Universitat Politècnica de València*
Adrián Morales Torres	*IIAMA - Universitat Politècnica de València*
Sara Perales Momparler	*Green Blue Management*
Ángel Pérez-Navarro Gómez	*IIE - Universitat Politècnica de València*
Elisa Peñalvo López	*IIE - Universitat Politècnica de València*
David Alfonso Solar	*IIE - Universitat Politècnica de València*
Alison Duffy	*Abertay university*

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ABBREVIATIONS

Defra	Department for Environment, Food and Rural Affairs (UK)
GIS	Geographic Information System
InVEST	Integrated Valuation of Environmental Services and Tradeoffs
IPBES	Intergovernmental Platform on Biodiversity and Ecosystem Services
MA	Millenium Assessment
RIOS	Resource Investment Optimisation System
TEEB	The Economics of Ecosystems and Biodiversity
UK NEA	United Kingdom National Ecosystem Assessment
UNEP	United Nations Environment Programme
USDA	United States Depertment of Agriculture

1. INTRODUCTION

Effective water management within urban settings requires robust multidisciplinary understanding and an appreciation of the value added to urban spaces by providing multifunctional green-blue spaces. Multifunctional landscapes where ecosystem service provisions are 'designed-in' can help 'transition' cities to more sustainable environments which are more resilient to changing future conditions (Lundy and Wade, 2011). With benefits ranging from the supply of water, habitat and energy to pollutant removal, amenity and opportunities for recreation, urban water bodies can provide a focal point for reconnecting humans and nature in otherwise densely built-up areas. Managing water within urban spaces is an essential infrastructure requirement but has historically been undertaken in isolation from other urban functions and spatial requirements. Increasingly, because of the limits of space and need to respond to new drivers (e.g. mitigation of diffuse pollution), more sustainable approaches to urban water management are being applied which can have multiple functions and benefits. This report will present a review of ecosystem services, particularly those associated with water in urban environments. The range of supporting, provisioning, regulating and cultural ecosystem services associated with differing types of urban water bodies are identified.

1.1. ECOSYSTEM SERVICES

Ecosystem Services are the goods and benefits humans receive from the natural environment. Scientists refer to these services that our environment provides as 'ecosystem services', recognising that it is the interaction between the living and physical environments that deliver these necessities.

Ecosystems and the services they deliver underpin and enable our existence. We depend on them to produce our food, regulate water supplies and climate, and breakdown waste products. We also value them in less obvious ways: contact with nature gives pleasure, provides recreation, has aesthetic appeal and is known to have a positive impact on long-term health and happiness (DEFRA, 2007; UK NEA, 2011).

Recent research has recognised that the value of these services is often not identified and is regularly undervalued (UK NEA, 2011).

In the UK a team of 500 researchers have assembled and analysed an enormous body of published information about the UK environment and have generated new tools for valuing it, in economic and noneconomic terms; this is a world first. The technical report for this analysis is called the UK national Ecosystem Assessment (UK NEA) and was published in 2011. It provides for the first time, a coherent body of evidence about the state of our natural environment and the services it provides within the United Kingdom. This can serve as the basis for thinking about how we want to use these services to best effect, for national wealth and national well-being, now and in the future. The UK NEA is being used in many countries across Europe as a mechanism for starting to value Ecosystem Services.

This report will review the UK NEA and other state of the art information on ecosystem service valuation and will consider how these values can be applied to the E^{2}STORMED project.

1.1.1. Definition and description of ecosystem services

Definition

'Ecosystem services' are the outputs of ecosystems from which people derive benefits. These benefits include:

- Resources for basic survival, clean air and water;
- A contribution to good physical and mental health, access to green spaces, both urban and rural, and genetic resources for medicines;
- Protection from hazards, regulation of our climate and water cycle;
- Support for a strong and healthy economy, raw materials for industry and agriculture, or through tourism and recreation; and
- Social, cultural and educational benefits, and wellbeing and inspiration from interaction with nature (DEFRA, 2007)

In the UK NEA, ecosystem services are considered under the broad headings of provisioning, supporting, regulating and cultural services (UK NEA, 2011).

Description

A description of ecosystem services is given below. These descriptions are provided by (Brown *et al.*, 2011) in the Introduction to the UK NEA.

Supporting services provide the basic infrastructure of life. They include primary production (the capture of energy from the sun to produce complex organic compounds), soil formation, and the cycling of water and nutrients in terrestrial and aquatic ecosystems. All other ecosystem services—regulating, provisioning and cultural—ultimately depend on them. Their impacts on human well-being are indirect and mostly long-term in nature; the formation of soils, for example, takes place over decades or centuries. Supporting services are strongly interrelated to each other and generally underpinned by a vast array of physical, chemical and biological interactions. Our current understanding of exactly how such ecological interactions influence ecosystem processes and the delivery of supporting services is limited.

Regulating services provided by ecosystems are extremely diverse and include the impacts of pollination and pest and disease regulation on the provision of ecosystem goods such as food, fuel and fibre. Other regulating services, including climate and hazard regulation, may act as final ecosystem services, or contribute significantly to final ecosystem services, such as the amount and quality of available fresh water. As with supporting services, regulating services are strongly linked to each other and to other kinds of services. Water quality regulation, for example, is primarily determined by catchment processes and is thereby linked to other regulating services, such as the control of soil and air quality and climate regulation, as well as to supporting services such as nutrient cycling.

Provisioning services are manifested in the goods people obtain from ecosystems such as food and fibre, fuel in the form of peat, wood or non-woody biomass, and water from rivers, lakes and aquifers. Goods may be provided by heavily managed ecosystems, such as agricultural and aquacultural systems and plantation forests, or by natural or semi-natural ones, for example in the form of capture fisheries and the harvest of other wild foods. Supplies of ecosystem goods are invariably dependent on many supporting and regulating services. Historically, provisioning services have been a major focus of human activity, so are, therefore, closely linked to cultural services.

Cultural services are derived from environmental settings (places where humans interact with each other and with nature) that give rise to cultural goods and benefits. In addition to their natural features, such settings are imbued with the outcomes of interactions between societies, cultures, technologies and ecosystems over millennia. They comprise an enormous range of so-called ‘green’ and ‘blue’ spaces such as gardens, parks, rivers and lakes, the seashore and the wider countryside, and including agricultural landscapes and wilderness areas. Such places provide opportunities for outdoor learning and many kinds of recreation; exposure to them can have benefits including aesthetic satisfaction, improvements in health and fitness, and an enhanced sense of spiritual well-being. People’s engagement with environmental settings is dynamic: meanings, values and behaviours change over time in response to economic, technological, social, political and cultural drivers, and change can be rapid and far-reaching in its implications.

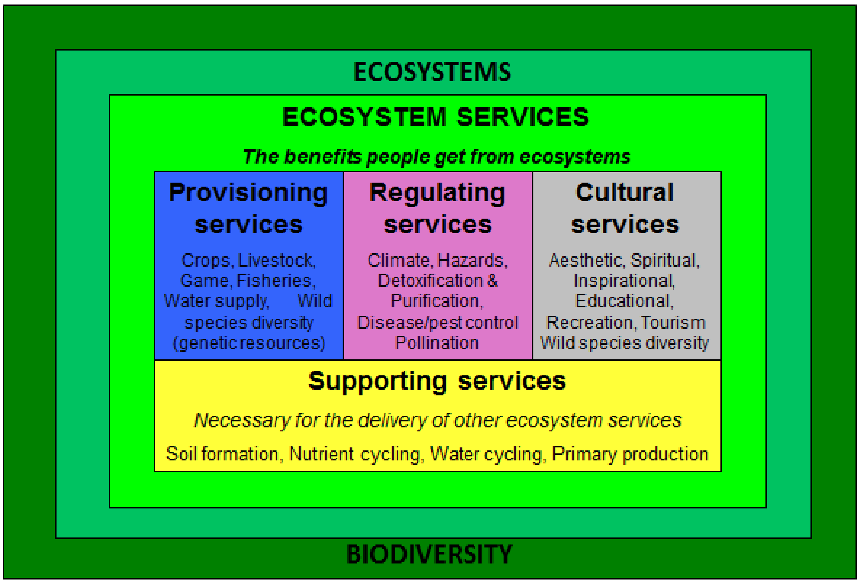

Figure 1.1. Illustration of the relationship between Biodiversity, Ecosystems, Ecosystem Services and the benefits human get from ecosystems (Albon, 2010).

Now that Ecosystem services have been defined and described it is important also to think about why they are important in terms of governance and policy making. European and international state governments and organisations have recognised that economic value can be gained by including ecosystem service assessment in policies and decision making. By understanding these considerations from the start it is possible to avoid significant costs and risks to policy objectives, and help to increase long–term resilience of policies. Also to reduce risks to our policy objectives from failing natural systems and to reduce public costs from degraded natural services - It is part of good policy-making.

2. VALUING ECOSYSTEM SERVICES

2.1. INTERNATIONAL INITIATIVES TO VALUE ECOSYSTEM SERVICES

A major international initiative The Economics of Ecosystems and Biodiversity (TEEB,) published findings in 2010. The aim of TEEB was to draw attention to the global economic benefits of biodiversity, in turn, highlighting the growing costs of biodiversity loss and ecosystem degradation. TEEB produced a series of reports examining: the global economic costs of biodiversity loss, and the costs and benefits of actions to reduce these losses; guidance for policy makers at different scales (including consideration of subsides and incentive, environmental liability, national income accounting and implementing instruments such as Payments for Ecosystem Services); access to tools for measuring business impacts on ecosystems and biodiversity; and raising awareness of the contribution of ecosystem services and biodiversity to human well-being and how individual action can have an impact.

In addition, since 2008, United Nations Environment Program (UNEP) has been facilitating discussion on a proposed Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES). At their meeting in Busan, Republic of Korea (7–11 June 2010), the plenary adopted the Busan Outcome (UNEP/IPBES/3/3,) which recommends the establishment of IPBES. This recommendation has subsequently been endorsed by the UN General Assembly (resolution number 65/162).

These initiatives indicate that ecosystem service recognition and valuation now has an international level of importance. IPBES, TEEB, UK NEA and other initiatives worldwide (such as Natural Capital Project led from the USA) are working to recognize the direct and indirect values gained by humans from the environment, and also to understand the complexities of 'trade-offs' (where increase in one service may decrease another) and 'double counting' (where benefits are recognized and can potentially be counted more than once giving a false value).

2.2. CONCEPTUAL APPROACH TO ECOSYSTEM SERVICE VALUATION

Figure 2.1 provides an overview of the approach used in UK NEA (2011) to assign value to final ecosystem services. This approach was used in Phase 1 of UK NEA (UK NEA, 2011), Phase 2 of UK NEA is currently underway and due for publication in late 2013/early 2014.

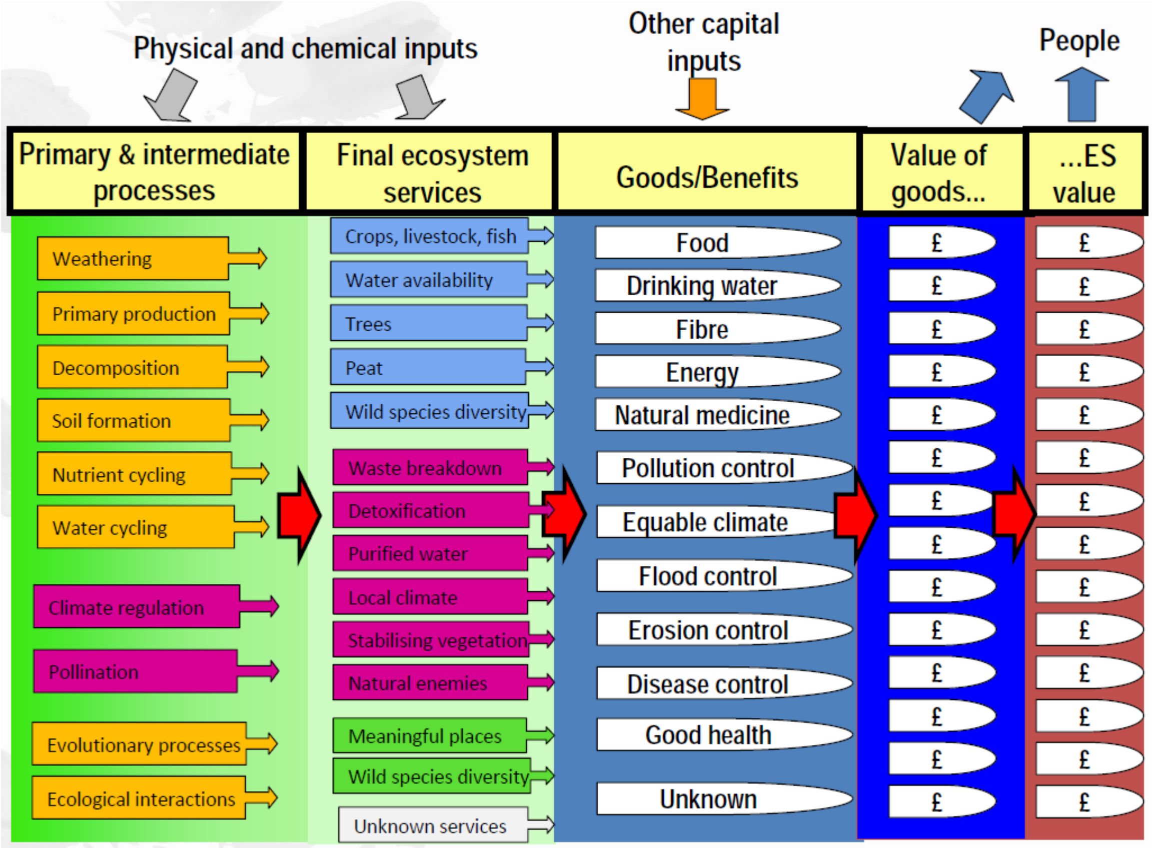

Figure 2.1. Final Ecosystem Services, Goods and their Valuation (Albon, 2010).

2.3. VALUATION METHODS USED FOR ECOSYSTEM SERVICE ASSESSMENT

Various valuation methods have been proposed in order to economically value ecosystem services.

Table 2.1 provides a summary of the valuation types used to value ecosystem services giving an overview of the method used, the common applications and indicates some of the services which have been valued. The Table is re-drawn from (Bateman *et al.*, 2011) and is shown in a similar form in the UK NEA (2011). The methods and examples are based on evidence from published sources.

Valuation Method	Overview of method	Common types of applications	Examples of ecosystem services valued
Adjusted market prices	Market prices adjusted for distortions such as taxes, subsidies and non-competitive practices.	Food; forest products; Research & Development benefits.	Crops; livestock; multipurpose woodland.
Production function methods	Estimation of production functions to isolate the effect of ecosystem services as inputs to the production process.	Environmental impacts on economic activities and livelihoods, including damage costs avoided, due to ecological regulatory and habitat functions.	Maintenance of beneficial species; maintenance of arable land and agricultural productivity; support for aquaculture; prevention of damage from erosion and siltation; groundwater recharge; drainage and natural irrigation; storm protection; flood mitigation.
Damage cost avoided	Calculates the costs which are avoided by not allowing ecosystem services to degrade	Storm damage; supplies of clean water; climate change	Drainage and natural irrigation; storm protection; flood mitigation.
Averting behaviour	Examination of expenditures to avoid damage.	Environmental impacts on human health.	Pollution control and detoxification.
Revealed preference methods	Examines the expenditure made on ecosystem-related goods, e.g. travel costs for recreation; hedonic (typically property) prices in low noise areas	Recreation; environmental impacts on residential property and human health.	Maintenance of beneficial species; productive ecosystems and biodiversity; storm protection; flood mitigation; air quality; peace and quiet; workplace risk.
Stated preference methods	Uses surveys to ask individuals to make choices between different levels of environmental goods at different prices to reveal their willingness to pay for those goods.	Recreation; environmental quality; impacts on human health; conservation benefits.	Water quality; species conservation; flood prevention; air quality; peace and quiet.

Table 2.1. Various valuation methods applied to ecosystem services (Bateman, et al., 2011).

2.3.1. Summary of methods

On analysis of the ‘common types of application’ and ‘examples of ecosystem services valued’ columns in Table 2.3.1 clear links can be made to the aims and objectives of E^{2}STORMED. All but one of the valuation methods are potentially relevant to E^{2}STORMED applications. The method ‘Adjust market prices’ is the only one which does not explicitly mention drainage, storm protection, flood mitigation/protection or pollution control. The methods: 'Production Function Methods' and 'Damage cost Avoided' both explicitly mention 'drainage' and 'storm protection' as 'examples of ecosystem services valued'. These methods could be considered further for E^{2}STORMED.

2.4. VALUATION TOOLS FOR ECOSYSTEM SERVICES

2.4.1. InVEST

As part of the Natural Capital Project a set of tools have been developed to deliver Integrated Valuation of Environmental Services and Tradeoffs (InVEST). InVEST is a family of tools to map and value the goods and services from nature which are essential for sustaining and fulfilling human life. InVEST enables decision-makers to assess the tradeoffs associated with alternative choices and to identify areas where investment in natural capital can enhance human development and conservation in terrestrial, freshwater, and marine ecosystems. The tool has been designed to help users answer questions about environmental management and to target their efforts. Questions that InVEST can answer:

- Where would reforestation or protection achieve the greatest downstream water quality benefits?
- Which parts of a watershed provide the greatest carbon sequestration, biodiversity, and tourism values?

The InVEST tool has been developed for GIS (Geographic Information System) and as a stand-alone tool and can be accessed from the Natural Capital Project (web link given in reference list).

2.4.2. RIOS

RIOS (Resource Investment Optimization System) is a free and open source software tool that supports the design of cost-effective investments in watershed services. RIOS provides a standardized, science-based approach to watershed management in contexts throughout the world. It combines biophysical, social, and economic data to help users identify the best locations for protection and restoration activities in order to maximize the ecological return on investment, within the bounds of what is socially and politically feasible. Questions RIOS can answer:

Which set of watershed investments (in which activities, and where) will yield the greatest returns towards multiple objectives?

What change in ecosystem services can I expect from these investments?

How do the benefits of these investments compare to what would have been achieved under an alternate investment strategy?

The RIOS tool can be downloaded for free. See reference RIOS (2013).

2.4.3. iTREE

iTree is a peer-reviewed software suite from the USDA (United States Department of Agriculture) Forest Service that provides urban forestry analysis and benefits assessment tools. The i-Tree Tools help communities of all sizes to strengthen their urban forest management and advocacy efforts by quantifying the structure of community trees and the environmental services that trees provide.

i-Tree Tools were initially released in August 2006 and since that time have been used by numerous communities, non-profit organizations, consultants, volunteers and students. The tool can be used to report on individual trees, parcels, neighborhoods, cities, and even entire regions. By understanding the local, tangible ecosystem services that trees provide, i-Tree users can link urban forest management activities with environmental quality and community livability. Whether the scale of interest is a single tree or an entire forest, i-Tree claims to provide baseline data that can be used to demonstrate value and set priorities for more effective decision-making. The iTREE tool can be downloaded for free. See reference iTree (2006) http://www.itreetools.org/.

2.4.4. Summary of Tools

Of the three tools described above RIOS may be most useful for E^2STORMED. RIOS has a focus on cost-effective investments in watershed services.

These tools can be very useful for a case where the ecosystem services are going to be evaluated with a high level of detail.

3. LINKING ECOSYSTEMS SERVICES AND SUSTAINABLE WATER MANAGEMENT

The Millennium Assessment (MA, 2005) and UKNEA (2011) divide the services provided by the environment which benefit people into four categories, acknowledging that these categories can and do overlap extensively (MA, 2005). The application of the four categories (supporting, provisioning, regulating and cultural) to the services, goods and benefits associated with urban water management are discussed in the following sections.

Recent years have seen a trend toward protection and improvement of the urban water environment. This arises from a need in many countries to conserve and reuse water (e.g. Water Sensitive Urban Design (WSUD) in Australia and Low Impact Development (LID) in the USA). Both WSUD and LID advocate the need to incorporate all aspects of water into urban development and planning from the earliest stages. This is to maximize the opportunities for context-sensitive water-cycle management (Lloyd *et al.*, 2002), effectively encouraging the continuation of natural water processes within an urban environment. In addition, urban water management projects have arisen from a desire to improve the urban environment, protect areas from stormwater flooding and better manage urban open spaces in response to water quality (e.g. EU WFD, 2000) water quantity (e.g. EU Floods Directive, 2007), conservation (e.g. UN Convention on Biodiversity, 1992) and quality-of-life agendas (e.g. DEFRA, 2007). Many efforts are now in place in many locations to promote the use of surface water and stormwater management through the promotion of stormwater best management practices (BMPs), also known as sustainable urban drainage systems (SUDS). SUDS are a wide range of constructed systems from wetlands and ponds to infiltration trenches and swales which mimic natural hydrological processes including infiltration, detention, groundwater recharge and evapotranspiration (Villarreal *et al.*, 2004; Yang and Li, 2010). These are discussed in more detail in the E^{2}STORMED report on stormwater management.

The direct benefits of using these approaches are reflected in the urban water management drivers designed to, for example, reuse water, ‘slow the flow’ generated by rainfall in impermeable urban environments and mitigate flooding/inundation from small-scale storm events. Further drivers include the need to reduce the pressure on existing sewer infrastructure and wastewater treatment plants, in terms of capacity and treatment efficiency, as well as the need to control urban diffuse pollution to meet EU WFD objectives. All of the approaches presented above represent more sustainable ways to manage urban water resources but also provide an opportunity to support and enhance ecosystem service provision in urban settings.

"Unlike conventional drainage, SUDS schemes often form part of public open space, with the potential to promote interaction between communities and their local environment, resulting in additional amenity benefits." CIRIA SUDS Manual – Executive summary

3.1. DISTRIBUTION OF ECOSYSTEM SERVICES IN URBAN AREAS

Green and blue space in urban settings provides many of the ecosystem service benefits in those locations. However, provision of green and blue space in towns and cities can vary considerably per capita. This uneven distribution reduces provision and the potential benefits for human well-being. Effective delivery of these services is determined by many factors including accessibility and condition. For example, inner cities have the lowest provision, thus the value of goods and benefits should be weighted accordingly. Dense, inner city populations tend to have the least accessible greenspace, with small parks, few domestic gardens or allotments, and associated low biodiversity. In areas of Urban fringe, where the extent of greenspace itself is not an issue, poor condition, caused by neglect and poor maintenance, together with poor accessibility due to safety concerns, can often prevent cultural benefits reaching deprived communities.

3.2. URBAN WATER MANAGEMENT AND CULTURAL ECOSYSTEM SERVICES

Many of the main goods and benefits available from the Urban environment arise from cultural services and include good physical and mental health, recreation and community cohesion. Cultural services are particularly important in Urban areas where human population density is higher than it is in all other habitats. The goods and benefits that arise come from the many local and culturally valued landscapes and waterscapes, such as parks and woodlands, playing fields and nature reserves, as well as the many smaller open areas that are found throughout the Urban environment (UK NEA, 2011).

3.3. URBAN WATER MANAGEMENT AND REGULATING ECOSYSTEM SERVICES

Regulating services are essential to the Urban environment. For example, purification provides clean water, air and soil, which contributes to high quality environments that support human well-being. The Urban environment also supports other regulating services associated with climate, hazards and noise.

3.4. URBAN WATER MANAGEMENT AND PROVISIONING ECOSYSTEM SERVICES

To a lesser extent, Urban areas supply provisioning services, such as crops and livestock for food, but these tend to be limited to a smaller number of sub-habitats. The provision of trees and standing vegetation is one exception, as it is widely delivered across the sub-habitats, and supplies both cultural goods (e.g. recreation and tourism) and regulating goods (e.g. avoidance of climate stress and noise regulation).

3.5. URBAN WATER MANAGEMENT AND BIODIVERSITY/ SUPPORTING ECOSYSTEM SERVICES

Biodiversity can be viewed as underpinning all ecosystem services through its role in supporting fundamental ecosystem processes. Some wild species also directly deliver provisioning services, supplying a range of wild food, such as berries, for example. Moreover, wild species diversity is also considered a cultural service, contributing to the spiritual, aesthetic and cultural value of Urban areas. Where the built environment dominates the landscape, particularly in city centres, it is clear that even the most essential of ecosystem services are ineffective: pollution overwhelms the regulating services, impermeable surfaces make climate and hazard regulation ineffective and affect water quality and water supply, and per capita provision of greenspace is at its lowest.

3.6. DESIGN CONSIDERATIONS

Resources required for the management and maintenance of blue and greenspaces are an important consideration; for example, plantings require water and regular upkeep and have associated cost and energy use implications. The resources that are required will be dependent on the design of each scheme. The creation of greenspaces using landscaping close to semi-natural vegetation typically requires less water than more intensive schemes, and is more beneficial for biodiversity, forming a valuable part of a more widely connected ecosystem.

3.7. CLIMATE CHANGE CONSIDERATIONS

Global Climate Change is predicted to influence rainfall patterns in terms of rainfall distributions, seasonal trends and rainfall intensities. In some countries this may not impact on the annual rainfall amount but rainfall may come in more intensive (short duration) events. These changes have impacts on stormwater occurrence; and hence must impact on the management of stormwater in urban areas.

Current climate predictions indicate greater urban drought, this change will require managers to apply appropriate design and may benefit from incorporating water capture and storage techniques, and use of appropriate vegetation species to withstand dry periods.

With the prediction of increased intensity there may be increased requirement to remove and discharge stormwater away from urban areas, however the direct discharge of stormwater into receiving waters can have a negative effect. Impacts include the erosion of riverbanks and in-stream sediments, and the addition of an associated stormwater pollutant load (e.g. pollutants from vehicles and microbial organisms) resulting in the prevalence of pollution-tolerant aquatic and riparian species. These potential impacts from climate change are additional indicators that we must employ more sustainable methods of managing stormwater runoff.

3.8. URBAN WATER CYCLE AND ECOSYSTEM SERVICES

Surface and ground water bodies play a key role in water cycling, and hence the renewable provision of freshwater, as receivers of rainfall through both direct (deposition) and indirect (runoff) routes. Surface water bodies may recharge groundwater (and vice versa), returning water to the atmosphere directly (evaporation) and indirectly (evapotranspiration), with the relative importance of these mechanisms varying greatly in relation to factors such as climate and level of vegetative cover. Urban development is associated with an increase in ground impermeability due to the development of roads, pavements and buildings, etc, and a consequent reduction in vegetative cover. This has profound effects on the functioning of the water cycle, reducing the recharge of groundwater and other surface water bodies with potential impacts on both water supply and soil stability. Further impacts include reduction of evapotranspiration processes band increased volumes of runoff (Madlener and Sunak, 2011; Shi *et al.*, 2007). In relation to the provision of habitat, urban water components such as garden ponds and SUDS can make a crucial contribution, with both the water body and its associated vegetation providing habitat for a range of flora and fauna (Davies *et al.*, 2004; Kazemi *et al.*, 2009) including pollinators (a further supporting service). As well as direct habitat provision, the strategic location of urban water components can also facilitate habitat provision contributing to landscape connectivity objectives (Le Viol *et al.*, 2009).

Recognition of the ecosystem services provided by urban areas, and urban blue and green spaces, is well documented but the valuation of those services is much more complex.

Table 3.1 presents a summary of the ES goods and benefits provided by some SUDS components and also suggests a series of quantifiable units of measure which could be used in assessment in order to provide an evidence base for linking ES with urban water management approaches.

3.9. THE CARBON CYCLE AND SUDS

Several SUDS measures incorporate soil and vegetation (e.g. grass swales, basins, SUDS street trees, green roofs) therefore an effort has been made to estimate the carbon sequestration benefits that could be obtained, and these have been included in the E^{2}Stormed DST. The investigation of carbon cycle benefits accrued from vegetated SUDS involved a review of many peer reviewed publications. Many different values are reported for different types of vegetation in different climatic conditions and under different maintenance regimes. The conclusion of the review exercise was that carbon sequestration values assigned to trees and green roofs can be estimated and have been included. However the values for 'maintained lawns or turf-grass' is negligible (and occasionally negative) therefore not included. The references suggested that the maintenance was a critical factor for grass, for example Hostetler and Escobedo (2010) state that: *"...highly maintained lawns and trees sequester much less CO2 than more natural areas with little maintenance..." and "...urban open space that has a large amount of mowed, irrigated, fertilized lawns and pruned shrubs and trees can be a source of CO2 rather than a sink"*. Townsend-Small and Czimiczik (2010) support this assertion and state that "*Large indirect emissions of CO2 associated with turfgrass management make it clear that Organic Carbon sequestration by turfgrass cannot mitigate GHG emissions in cities*". The values obtained from the review process and included in the E2Stormed DST can be seen in table 3.1.

Carbon values for vegetated SUDS used in the E^{2}Stormed DST			
Type of vegetation	**Carbon sequestration**	**CO_2 equivalent**	**Reference(s)**
Trees	10kg/tree/yr	36.7 kg per tree	Akbari (2002)
Green Roofs (Extensive)	186.5g C/m^2/year (0.0186kg/m^2/yr) as given in ref: 375g C/m^2 in 2yrs	0.068 kg per m^2	Getter et al (2009)
Grass	0	0	Hostetler and Escobedo (2010); Townsend-Small and Czimiczik (2010)

Table 3.1. Overview of Carbon Sequestration Values (and Carbon Dioxide Equivalent values) used in the E^{2}Stormed Decision Support Tool.

3.10. A REVIEW OF MULTIPLE BENEFITS FROM SUSTAINABLE STORMWATER MANAGEMENT

A recent review of published research assessed the ‘multiple benefits’ which had been reported from measures which were designed to mitigate urban diffuse pollution. The work was commissioned in Scotland to inform the development of policy to support implementation of the Water Environment and Water Services (Scotland) Act 2003 and the Flood Risk Management (Scotland) Act (2009). The project considered many aspects of urban surface water management including urban diffuse pollution sources, pathways, receptors and mitigation measures with multiple benefits. As part of the project a decision support tool for selecting appropriate mitigation measures was developed, this tool and the findings from this work will be available online at: crew.ac.uk/publications (Wade, R et al., 2013).

A wide range of structural and non-structural measures to mitigate diffuse urban pollutants, and which also provide multiple benefits, were identified. Several of these are also considered in the E^{2}STORMED project. The findings from Wade et al (2013) which relate to multiple benefits from stormwater management SUDS have been formulated into a table for this report. Benefits reported from stormwater management SUDS range far beyond water quality and quantity control to: increased property values, habitat and biodiversity provision, air quality improvement, regulation of urban micro-climates, noise reduction, recreational use, water re-use and cost-savings for surface water management. These benefits (as reported in the literature) are summarised and presented for a range of source control SUDS in Annex 1 and Annex 2.

Ecosystem Service component			*Type of SUDS component*			
Category of ecosystem service	**Type of ecosystem service**	**Ecosystem goods and benefits**	**Lakes and ponds**	**Settlement ponds**	**Vegetated filters**	**Example units of Measurement**
Supporting	Primary production	The goods and benefits of supporting services are their role in facilitating other services to take place	✓	X	✓	$Gg\ C/m^{-2}$
	Oxygen production		✓	X	✓	$g\ O_2 \cdot m^{-2}$
	Soil formation		✓	X	X	cm $year^{-1}$
	Water cycle		✓	✓	✓	% permeability
	Habitat		✓	✓	✓	hectares
Provisioning	Food	Meat and vegetables	✓	✓	X	tonnes/hectare
	Water	Potable and non-potable water	✓	✓	X	litres/hectare
	Renewable energy	Hydropower	X	X	X	Mega watts
	Genetic resource	Pollutant degrading species	✓	✓	✓	cfu/ml
Regulating	Climate regulation.	Reduced urban temperatures	✓	✓	✓	^{o}C
	Water regulation	Reduced runoff volume and velocity	✓	✓	✓	m^3; ms^{-1}
	Erosion control	Stabilisation of sediments	✓	✓	✓	g/m^2
	Water purification	Removal of pollutants	✓	✓	✓	mg/L
Cultural	Spiritual value	Mental well being	✓	✓	X	Numbers of users (reduced demand on mental health services)
	Educational value	Increased environmental awareness	✓	✓	✓	Kg (reduced littering of water bodies)
	Aesthetics	Increased house prices	✓	✓	✓	% (increase in house price)
	Recreation	Physical well being	✓	✓	X	% (reduced mortality)

Table 3.2. Overview of Ecosystem Services and selected SUDS components indicating their potential (absence/presence) to contribute to the delivery of those services and identifying suitable units of measurement for valuation of their contribution to those service.

4. CONCLUSIONS

Since the publication of the Millennium Assessment (MA, 2005) there has been increasing interest in valuing the benefits humans receive directly and indirectly from nature (ecosystem services). There are many current examples and attempts to value ecosystem services. The UK NEA (2011) reviews current work on ecosystem services in the UK and makes an important contribution to their valuation. Many methods have been used to undertake the valuation – some are reviewed here - and several indicate direct relevance to the aims and objectives of E^2STORMED. Valuation tools such as RIOS, InVEST and iTREE provide mechanisms for communities and authorities to value the benefits gained by humans from the natural extremely complex, RIOs may be the most relevant to E^2STORMED. As a starting point for E^2STORMED we can consider the use of existing methods and tools and/or we can develop a reasoned list of ecosystem service criteria that we wish to value specifically to match the project aims. These can be drawn together from the published literature where ecosystem service benefits from SUDS are directly cited (see Appendix 1 and 2), and quantification can be attempted for some of these benefits using the suggested units of measure in Table 3.2.

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ANNEX 1. FULL LIST OF BENEFITS REPORTED FROM DRAINAGE SYSTEMS (BASED ON WADE *et al.* 2013)

L'Europe en Méditerranée
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BENEFITS	CONVENTIONAL DRAINAGE SYSTEMS		SUSTAINABLE DRAINAGE SYSTEMS																
	Conventional drainage networks	Structural detention facilities	Bioretention areas	Constructed wetlands	Detention basins	Filter drains	Filter strips	Geocellular systems	Green roofs	Infiltration basins	Infiltration trenches	Other pre-treatment devices	Permeable pavements	Rain gardens	Rain harvesting systems	Retention ponds	Soakaways	Vegetated swales	Water butts
Aesthetics			✓	✓	✓				✓	✓			✓	✓		✓			
Air quality improvement									✓										
Amenity			✓	✓	✓				✓	✓			✓	✓		✓			
Base flow augmentation			✓		✓					✓									
Community education and engagement									✓									✓	
Community space improvement			✓	✓					✓					✓		✓		✓	
Cost savings for surface water management									✓										
Cost-effective to construct					✓					✓									
Decreased burden on the sewage system									✓										
Enhancement of quality of life				✓															
Extension of operational life of roof									✓										
Firm dry surfaces to park and walk on after heavy rain	✓	✓											✓						
Food growing			✓											✓					
Groundwater recharge					✓			✓		✓	✓		✓				✓	✓	
Gross value added growth					✓					✓						✓			
Habitat provision and enrich biodiversity			✓	✓	✓				✓	✓	✓		✓	✓		✓	✓	✓	
Improved community cohesion			✓						✓		✓			✓			✓		
Improved insulation									✓										
Improvements to public health			✓			✓	✓							✓					
Increase in property values			✓	✓					✓					✓		✓		✓	
Maximisation of the longevity of the road surface						✓	✓												
Noise attenuation									✓										
Prevention of further increase in non-point urban loads											✓						✓		
Protection of receiving waters						✓	✓					✓	✓						
Provision of educational opportunities									✓									✓	
Recreational use			✓								✓			✓		✓	✓	✓	
Reduced land take/small footprint	✓	✓				✓	✓						✓						
Reduction in energy bills/ costs			✓	✓					✓				✓	✓				✓	✓
Reduction in the demand on water supply																			✓
Reduction of flood risk	✓	✓	✓	✓	✓				✓	✓				✓		✓		✓	
Reduction of greenhouse gas emissions			✓	✓					✓				✓	✓		✓		✓	
Reduction of gullies need													✓						
Reduction of surface ponding cost-effective and durable source control technique													✓						
Regulation of urban microclimates			✓	✓					✓					✓		✓		✓	
Removal of urban pollutants			✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓		✓	✓	✓	
Restore natural hydrology									✓				✓						
Retrofitable			✓										✓	✓					
Runoff reduction and attenuation			✓	✓	✓			✓	✓	✓	✓		✓	✓		✓	✓	✓	✓
Speedy removal of surface water to enhance safety	✓	✓				✓	✓												
Suitable for a wide range of locations						✓	✓												
Visual and landscape benefits				✓					✓				✓			✓		✓	
Water quality control			✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓		✓	✓	✓	
Water quantity control	✓	✓	✓	✓				✓	✓				✓	✓				✓	✓
Water storage and re-use				✓				✓			✓		✓			✓	✓		✓

ANNEX 2. GLOBAL ASSESSMENT OF BENEFITS REPORTED FROM DRAINAGE SYSTEMS INCLUDED IN E^{2}STORMED PROJECT

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Performance Score - based on BENEFITS table	CONVENTIONAL DRAINAGE SYSTEMS		SUSTAINABLE DRAINAGE SYSTEMS																
	Conventional drainage networks	Structural detention facilities	Bioretention areas	Constructed wetlands	Detention basins	Filter drains	Filter strips	Geocellular systems	Green roofs	Infiltration basins	Infiltration trenches	Other pre-treatment devices	Permeable pavements	Rain gardens	Rain harvesting systems	Retention ponds	Soakaways	Vegetated swales	Water butts
Urban environment and Landscape	0	0	high	high	med	low	low	0	High	low	low	?	med	high	0	high	low	high	0
Pollution Control	0	0	high	high	med	high	med	0	high	high	high	low	high	high	0	high	med	med	0
Flood Protection	High	high	low	high	high	med	low	high	low	med	low	?	high	low	low	high	low	med	low
runoff reduction	0	0	med	low	med	low	med	high	med	high	high	?	high	med	med	low	high	med	low
water re-use			low	low	low	low	low	low	0	low	low	?	low	low	high	low	low	low	high
building insulation	0	0	0	0	0	0	0	0	high	0	0	?	0	0	0	0	0	0	0
construction cost, issues and landtake	med	high	low	med	low	low	low	med	high	low	low	?	med	low	high	med	low	low	med
maintenance cost	med	low	med	med	low	med	low	low	low	low	med	?	low	med	med	low	low	low	low
potential reduced energy/ water supply costs	0	0	yes	yes					yes			?	yes	yes	yes				yes

E^{2}STORMED PROJECT

Improvement of energy efficiency in the water cycle by the use of innovative storm water management in smart Mediterranean cities

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