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Natural Water Retention Measures

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Individual NWRM

Urban forest parks

ACTeon environment research & consultancy

Office International de l'Eau

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Environment

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I. NWRM Description

Urban forest parks can deliver a broad range of hydrology-related and other ecosystem services. Forests in urban areas have great amenity value, can improve air quality, moderate local microclimates, improve urban biodiversity, have an important recreational value and contribute to climate change mitigation as well as having ancillary hydrological benefits. Forest soils often have greater infiltration capacity than other urban land cover and can be an important location for aquifer recharge.

II. Illustration

Aerial view of forest parks, France (Fontainebleau)

Source: http://www.survoldefrance.fr/affichage2.php?img=3775&prev_suiv_link=1

III. Geographic Applicability

Land Use	Applicability	Evidence
Artificial Surfaces	Yes	Urban forest parks are a subclass of CORINE artificial non-vegetated urban areas. Unlike many artificial surfaces (such as paved areas), urban forest parks are able to deliver significant NWRM and ancillary benefits.
Agricultural Areas	Possible	Peri-urban agricultural areas could, in principle, be converted to urban forest parks.
Forests and Semi-Natural Areas	Possible	Urban forest parks are designed to mimic many of the natural functions of forests and other semi-natural areas. Peri-urban forest areas could, in principle, be converted to urban forest parks.
Wetlands	No	As urban forest parks are by definition a CORINE artificial surface, they are not relevant for development in wetlands. However, urban forest parks may contain wetland and open water elements for aesthetic, water retention and biodiversity purposes.

Region	Applicability	Evidence
Western Europe	Yes	When adapted to local conditions and ideally using local species, urban forest parks need to be maintained and can be developed in urban and peri-urban areas throughout Europe.
Mediterranean	Yes	
Baltic Sea	Yes	
Eastern Europe and Danube	Yes	

IV. Scale

	0-0.1km²	0.1-1.0km²	1-10km²	10-100km²	100-1000km²	>1000km²
Upstream Drainage Area/Catchment Area	Yes	Yes	Possible	Possible	No	No
Evidence	Because of the heavily modified nature of urban drainage, it may not be appropriate to speak of catchment areas impacted by urban forest parks. Urban forest parks will have local benefits related to increased infiltration and may have some ability to buffer inputs from upstream areas but they are not readily incorporated into a standard hydrological framework.					

V. Biophysical Impacts

Biophysical Impacts		Rating	Evidence
Slowing & Storing Runoff	Store Runoff	Medium	Because of the greater infiltration capacity of soils under forests compared to soils underneath agricultural or impermeable urban land cover, urban forest parks can have a significant ability to store runoff. This may be especially valuable for buffering inputs of summer rainfall as the soil capacity to store runoff will depend on antecedent moisture conditions and drier soils will have greater moisture holding capacity. Forests can also have a higher precipitation interception capacity than other vegetation types, meaning a greater fraction of the incoming precipitation is returned to the atmosphere.
	Slow Runoff	Medium	Urban forest parks have a moderate ability to slow runoff. Soils under forests generally are more textured with a higher porosity and organic matter content than soils underlying other land cover types. These features increase the infiltration and water holding capacity of soils, thereby slowing runoff.
	Store River Water	None	
	Slow River Water	None	

Reducing Runoff	Increase Evapotranspiration	High	Forests generally have greater evapotranspiration (ET) and interception rates than other vegetation types. This can have positive or negative impact, depending on the precipitation regime of the region where the urban forest park is located. In wet or temperate areas, high rates of ET and canopy interception can be beneficial as they reduce the amount of water entering urban drainage networks. However, the use of urban forest parks may be questionable in water stressed regions if the trees must be irrigated.
	Increase Infiltration and/or groundwater recharge	High	As is common with soils under natural forests, the soils under urban forest parks will have a high ability to increase infiltration and groundwater recharge. The increased infiltration capacity is associated with a higher porosity commonly found in forest soils, which facilitates infiltration, and more textured soil surfaces which leads to slower flow rates and potentially less overland flow.
	Increase soil water retention	High	Forest soil generally has a higher organic matter content than soil in agricultural or built up areas. Soil organic matter can act as a sponge, holding and slowing rain water. Slower flow velocities, higher organic matter content and higher porosity all contribute to increased soil water retention in forest soils. It should be noted that, as with all forests, the increase in soil water retention must be balanced against the increase in evapotranspiration.
Reducing Pollution	Reduce pollutant sources	High	Forest soils have an ability to reduce atmospheric and aquatic pollutant sources. The beneficial effects of forests on urban air quality are well established (Beckett et al. 1998) and forests can also facilitate improvements in surface water and groundwater quality. Forests typically receive less fertilizer inputs than grass lawns, which can reduce nutrient leakage and pollution of surface water and groundwater.
	Intercept pollution pathways	High	Forest soils have an ability to intercept pollution pathways. Many atmospherically deposited pollutants including nitrogen and heavy metals are intercepted by growing forests and effectively retained in forest soils. Interception of nitrogen can be especially important for preserving the quality of urban surface and groundwaters. Urban forests are well known for their ability to trap particulate air pollution (Beckett et al. 1998). This contributes to improvements in urban air quality with direct human health benefits.
Soil Conservation	Reduce erosion and/or sediment delivery	Medium	Forest soils can reduce erosion and sediment delivery. Unlike urban or agricultural soils, forest soils are characterized by an organic-matter rich mat at the soil surface which provides structure to the soil and helps to resist erosion. The intensity of precipitation reaching the ground is reduced by a forest canopy, thereby reducing the potential for sediment delivery.
	Improve soils	High	Afforestation improves soil quality. The soils in urban forest parks will improve in quality through several mechanisms. Litterfall contributes to an increase in organic matter in forest soils. Higher organic matter content improves water holding and pollutant binding. It can also increase soil productivity and makes direct (through carbon accumulation) and indirect (through enhanced primary productivity) contributions to carbon

			sequestration.
Creating Habitat	Create aquatic habitat	Low	If adjacent to water bodies, urban forest parks have potential to create or modify aquatic and riparian habitats through input of litter and coarse woody debris.
	Create riparian habitat	Low	
	Create terrestrial habitat	High	Urban forest parks have a high potential to create important terrestrial habitat for plants and animals. If urban forests are created using native or indigenous species, there can be significant biodiversity benefits.
Climate Alteration	Enhance precipitation	Low	Through increased evapotranspiration rates, urban forest parks may have some indirect effect on precipitation increase.
	Reduce peak temperature	High	The tree cover associated with urban forest parks will have a beneficial effect on peak temperature in urban environments. Trees typically have higher albedos than pavement or roofs. Thus, urban forests reflect more of the incoming solar energy back to the atmosphere and reduce the amount of ground level warming. Trees will also decrease wind speed thus moderating diurnal temperature variations. Evapotranspiration has an important cooling effect.
	Absorb and/or retain CO_2	High	Urban forest parks have a high capacity to absorb and retain CO_2. The growing trees in an urban forest park will take up CO_2 from the atmosphere. Unlike other managed forests, harvesting of trees in urban forest parks is typically limited, resulting in a greater long-term CO_2 sequestration potential. The uptake of CO_2 by the growing forest also contributes to an increase in soil organic matter, which is another reservoir for forest carbon sequestration.

VI. Ecosystem Services Benefits

Ecosystem Services		Rating	Evidence
Provisioning	Water Storage	Medium	Urban forest parks have a moderate water storage potential. Forest soils generally have higher water holding and infiltration capacity than soils in non-forested environments. This can be particularly important in urban areas where the majority of the land cover is impervious and water infiltration is limited. The water storage benefits of urban forest parks do need to be balanced against increased evapotranspiration associated with growing trees. This is most relevant in dry or water scarce areas.
	Fish stocks and recruiting	Low	Theoretically urban forest parks adjacent to water bodies have potential to contribute to fish stocks by sediment retention, organic matter input and habitat creation through coarse woody debris.
	Natural biomass production	Medium	The growing trees in urban forest parks will contribute to natural biomass production. Most of the biomass is likely to be retained in the park and only a small amount, typically associated with tree pruning or landscaping, may contribute to carbon substitution.

Regulatory and Maintenance	Biodiversity preservation	High	Urban forest parks have a high potential for biodiversity preservation. Urban forest parks may literally be oases in large cities, providing critical habitat for many species. The biodiversity preservation benefits of urban forest parks will be enhanced if the trees used are either native or indigenous to the region.
	Climate change adaptation and mitigation	High	Urban forest parks have a high climate change and adaptation potential for the reasons discussed above. The growing trees in an urban forest park will take up CO_2 from the atmosphere. Unlike other managed forests, harvesting of trees in urban forest parks is typically limited, resulting in a greater long-term CO_2 sequestration potential. The uptake of CO_2 by growing trees can lead to an increase in soil organic matter, which is another reservoir for forest carbon sequestration. This is further discussed by Escobedo et al. (2011).
	Groundwater / aquifer recharge	Medium	As well as promoting water storage, urban forest parks can contribute to groundwater and aquifer recharge. This function is especially important in urban areas where permeability is either reduced or absent. In water scarce areas, it is important to balance the aquifer recharge ability of urban forest parks against the increase in evapotranspiration associated with growing trees.
	Flood risk reduction	Low	Urban forest parks can contribute to urban flood risk reduction as they have an ability to slow and store runoff. However, this effect is likely to be very dependent on the size of the park, with larger parks showing more visible flood risk reduction benefits.
	Erosion / sediment control	Low to Medium	For the reasons described above, urban forest parks can contribute to a reduction in erosion and potentially help to control sediment. Forest soils are generally more resistant to erosion than soils underlying other land cover types and the energy of precipitation is dissipated by forest or vegetation cover.
	Filtration of pollutants	Medium	Urban forest parks can play an important role in filtering pollutants, especially by removing airborne particulates (Beckett et al. 1998). This can be very important for the health of urban populations. Urban forest parks can also contribute to improvements in water quality by retaining nitrogen, heavy metals and organic pollutants.
Cultural	Recreational opportunities	High	The recreational opportunities afforded by urban forest parks are one of their most important ecosystem service benefits. There are well documented human health impacts associated with forest experiences (Nilsson et al. 2010). Urban forest parks can provide unique opportunities for city dwellers to visit forests.
	Aesthetic / cultural value	High	Urban forest parks can have high aesthetic and cultural value. The iconic forest parks in European cities are important components of regional cultural identity and the presence of trees can provide a valuable counterpoint grey infrastructures.
Abiotic	Navigation	None	
	Geological resources	None	
	Energy production	None	

VII. Policy Objectives

Policy Objective		Rating	Evidence
Water Framework Directive			
Achieve Good Surface Water Status	Improving status of biology quality elements	Low	Urban forest parks are likely to have a limited effect on the achievement of Water Framework Directive (WFD) goals. Urban forest parks may contribute to biodiversity improvements and to improvements in physic-chemical and hydromorphological status but there is typically a gap between urban forest parks and WFD water bodies. The catchments of WFD water bodies are typically much larger than urban forest parks.
	Improving status of physico-chemical quality elements	Low	
	Improving status of hydromorphology quality elements	None	
	Improving chemical status and priority substances	Low	
Achieve Good GW	Improved quantitative status	Low	Urban forest parks may improve groundwater quantitative and chemical status in urban environments. Depending on the size of the groundwater body, this may lead to demonstrable improvements in WFD status.
	Improved chemical status	Low	
Prevent Deterioration	Prevent surface water status deterioration	Medium	Many urban waters fail to reach good ecological status (GES). Urban forest parks can be an important measure to help prevent further deterioration of surface water and groundwater status for the reasons discussed above.
	Prevent groundwater status deterioration	Medium	
Floods Directive			
Take adequate and co-ordinated measures to reduce flood risks		Low to Medium	Urban forest parks can play a role in local flood risk management planning. The increased infiltration and water holding capacity of forests compared to typical (impervious) urban land cover means that urban forests can retain water on the landscape and potentially reduce flooding.
Habitats and Birds Directives			
Protection of Important Habitats		Medium to High	Urban forest parks can be important habitat for birds and other species if they are managed with that goal and appropriate tree species are used.
2020 Biodiversity Strategy			
Better protection for ecosystems and more use of Green Infrastructure		High	Urban forest parks are an important green infrastructure for water protection, species and habitat conservation, and for quality of life of urban residents. Urban forest parks will also provide additional semi-natural ecosystems in cities, which can have important biodiversity benefits.

More sustainable agriculture and forestry	None	
Better management of fish stocks	Low	Theoretically urban forest parks adjacent to water bodies have potential to contribute to better management of fish stocks by sediment retention, organic matter input and habitat creation through coarse woody debris.
Prevention of biodiversity loss	Medium to High	When designed and managed in an appropriate manner, urban forest parks can contribute to prevention of biodiversity loss.

VIII. Design Guidance

Design Parameters	Evidence
Dimensions	Typically, a forest is assumed to have an area above 0.5 ha. However, smaller urban forest parks may be possible and will have locally similar benefits to larger parks.
Space required	Larger urban forest parks will have greater environmental benefits but there are no lower size limits for production of beneficial effects.
Location	By definition, urban forest parks are located in urban areas. When new urban developments are being planned, consideration should be given to the possibility of creating urban forest parks.
Site and slope stability	
Soils and groundwater	
Pre-treatment requirements	
Synergies with Other Measures	Urban forests have very similar functionality and benefits to urban trees and can have synergies with all other urban measures. Under some circumstances urban forest parks may have synergies also with other measures, for example, appropriate design of roads and coarse woody debris.

IX. Cost

Cost Category	Cost Range	Evidence
Land Acquisition		
Investigations & Studies		
Capital Costs		
Maintenance Costs		
Additional Costs		

X. Governance and Implementation

Requirement	Evidence
	There is a vast literature on urban forests and urban forest parks (see the references listed below). It is clear that urban forests function best when urban residents feel a sense of ownership.

XI. Incentives supporting the financing of the NWRM

Type	Evidence
n/a	

XII. References

Reference	Comments
Neary, Daniel G., George G. Ice, and C. Rhett Jackson. "Linkages between forest soils and water quality and quantity." *Forest Ecology and Management*258.10 (2009): 2269-2281.	Good general review of forest water issues
Matteo, Michelle, Timothy Randhir, and David Bloniarz. "Watershed-scale impacts of forest buffers on water quality and runoff in urbanizing environment. "*Journal of water resources planning and management* 132.3 (2006): 144-152.	While not specifically about parks, this paper presents a study of riparian forest buffers in a US city.
Dwyer, John F., et al. "Assessing the benefits and costs of the urban forest. "*Journal of Arboriculture* 18 (1992): 227-227.	Older but useful review of urban forests and forestry
Beckett, K. P., Freer-Smith, P. H., & Taylor, G. (1998). Urban woodlands: their role in reducing the effects of particulate pollution. Environmental pollution, 99(3), 347-360.	One of the original UK studies showing the benefits of urban forests for removal of particulate air pollution
Pataki, Diane E., et al. "Coupling biogeochemical cycles in urban environments: ecosystem services, green solutions, and misconceptions." *Frontiers in Ecology and the Environment* 9.1 (2011): 27-36.	Important recent article on quantification of biogeochemical and hydrological benefits of urban forests
Escobedo, F. J., Kroeger, T., & Wagner, J. E. (2011). Urban forests and pollution mitigation: analyzing ecosystem services and disservices. Environmental Pollution, 159(8), 2078-2087.	Recent review of ecosystem benefits and potential problems associated with urban forests

Nilsson, K., Sangster, M., Gallis, C., Hartig, T., De Vries, S., Seeland, K., & Schipperijn, J. (2010). Forests, trees and human health. Springer Science & Business Media.	Review of human health benefits of forests
Timothy Richard Oke. 1989. The micrometeorology of the urban forest. Philosophical Transactions of the Royal Society of London, B, 324: 335-349	Discusses hydrometeorological role of urban trees and forests
Alexis A. Alvey. 2006. Promoting and preserving biodiversity in the urban forest. Urban Forestry & Urban Greening 5: 195–201	Presents examples of urban biodiversity research
David J. Nowak and John F. Dwyer. 2007. Understanding the Benefits and Costs of Urban Forest Ecosystems. In: Urban and Community Forestry in the Northeast, 2nd ed., (Ed.J. E. Kuser): 25-46	Discusses costs and benefits of urban forest ecosystems