The role of green infrastructure in creating safe urban environments
The case study of Madrid

The size and number of cities is growing at an unprecedented speed in the 21st century. Whereas in 1900 only a 10% of the global population lived in cities, 2010 marked the point in which more than halve of the world moved urban and, according to the United Nations' estimations, more than 70% of humanity will be living in urban agglomerations by 2050.
Covering about the 2% of the Earth surface, cities consume vast extensions of forests, farmland, and other landscapes, polluting rivers, oceans and soils, and account for as much as the 70% of greenhouse gas emissions, all of them making urbanization the main driver for the changes in the Earth surface.
Designing urban systems that reduce the negative impacts of this urbanization process and improve their resilience is crucial for creating a safe operating space for humanity. Cities must identify sustainable development policies because today's investment will be locked in for hundreds of years due to the difficulty of reversing most of the planning decisions.
This study analyzes the role of green infrastructure in creating a healthier urban milieu more resilient and with a smaller impact on the environment through the case study of the city of Madrid, a city that faces climate risks derived of extreme heat and drought. Green infrastructure can reduce urban heat island, regulate storm water overflow and moderate energy consumption, while favoring a healthier lifestyle.

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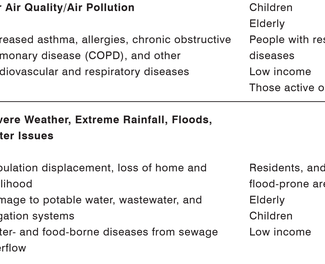

Figure 1. Green area over city ring road. Source Madrid Municipality

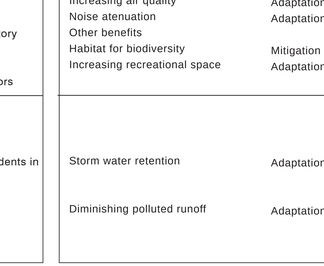

Figure 2. Hydroponict "trees" proposal for Madrid

Objectives

1 What green infrastructures are available to mitigate climate change impacts on human health, and what is the effort requited to implement them

2 Where is the optimal location of the green infrastructure within the city

Climate Change Impacts / Health Impacts	Populations Mostly Affected
Extreme Heat Premature death Cardiovascular stress and failure Heat-related illnesses such as heat stroke, heat exhaustion, and kidney stones	Elderly Children Diabetics Poor, urban residents People with respiratory diseases Those active outdoors
Increased average temperature Cardiovascular disease Increased number and range of: • Vector-borne disease, • Water-borne disease • Food-borne disease • Harmful algal blooms causing skin disease and poisoning • Allergies caused by pollen, and rashes from plants such as poison ivy or stinging nettle • Vulnerability to wildfires and air pollution	Children Elderly Agricultural workers Those active outdoors People with respiratory disease People with acute allergies
Por Air Quality/Air Pollution Increased asthma, allergies, chronic obstructive pulmonary disease (COPD), and other cardiovascular and respiratory diseases	Children Elderly People with respiratory diseases Low income Those active outdoors
Severe Weather, Extreme Rainfall, Floods, Water Issues Population displacement, loss of home and livelihood Damage to potable water, wastewater, and irrigation systems Water- and food-borne diseases from sewage overflow	Residents, and residents in flood-prone areas Elderly Children Low income

Green Infrastructure Services	Type of measure	Private/ Public	Recurrence	Range	Benefit to effort ratio *
Reduction of the number of extreme heat day due to Urban Heat Island effect	Adaptation	Public	Yearly	1-3º C	0.04 to 0.52
Moderation of the increase of average temperature due to Energy Saving (green roofs)	Adaptation	Private	Yearly	5-10 kWh/m2	0.05 to 0.54
CO2 emission reduction from energy saving	Mitigation	Public	Yearly	10-15 kgC/m2	0,02 to 0,13
CO2 reduction form extended life of materials	Mitigation	Private	Only once	60-80 kgC/m2	0.01 to 0,03
Carbon sequestration	Mitigation	Public	Yearly	1,25 kgC/m2	- to 0.01
Crime reduction	Adaptation	Public	Yearly	up to 22%	0.01 to 0.04
Increasing air quality	Adaptation	Public	Yearly	up to 30%	0.03 to 0.21
Noise atenuation	Adaptation	Public	Yearly	2-6 db	0.01 to 0.25
Other benefits Habitat for biodiversity	Mitigation	Public	Yearly	0,5-1 €/m2	0.04 to 0.40
Increasing recreational space	Adaptation	Private	Only once	100-300 €/m2	0.30 to 5.30
Storm water retention	Adaptation	Public	Only once	20-30 €/m2	0,06-0,5
Diminishing polluted runoff	Adaptation	Public	Yearly	0,1-0,4 €/m2	0,01-0,2

* For further information and references visit WWW.base-adaptation.eu

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Existing Green Areas in Madrid

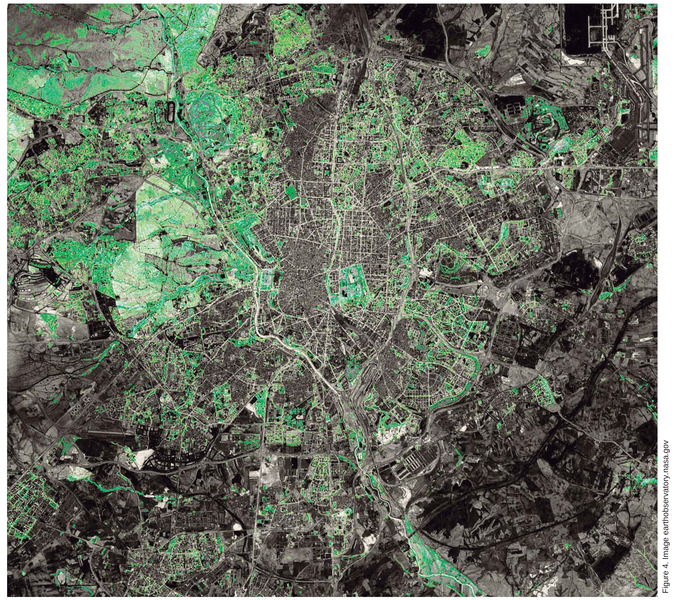


Figure 4. Image esethobservatory.nasa.gov

24% 76%

Potential Implementation Areas

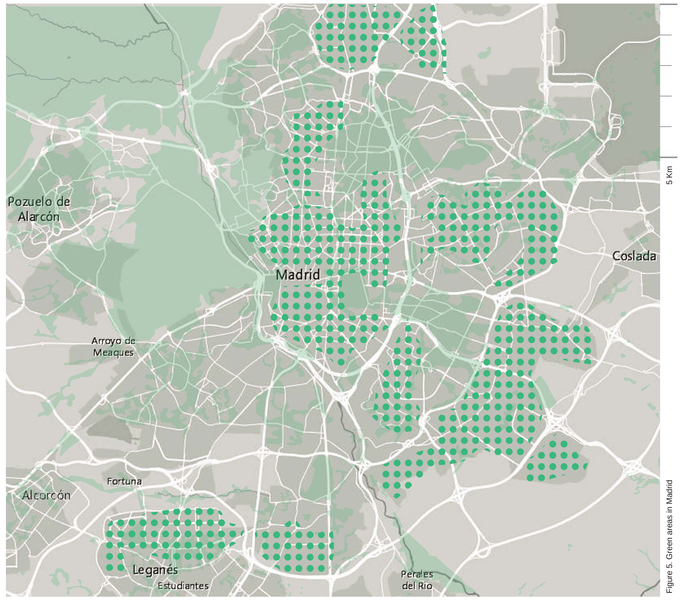
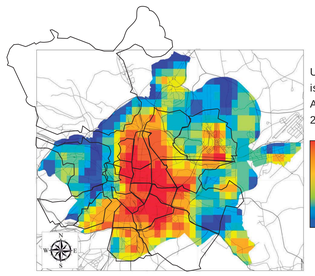


Figure 5. Green areas in Madrid

58% 42%

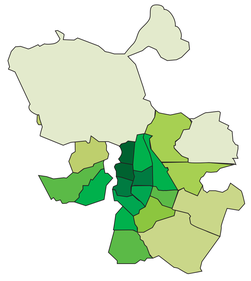
Existing Green Areas | Potential | Urban | Non developed



Urban heat island effect August 25, 22:00h

+5.0ºC

-0.8ºC



Population density

300 hab/ha

10 hab/ha

Methods

- Evaluation of the green infrastructure services and their benefit to effort ratio
- Mapping their optimal location

Green infrastructure is the interconnected network of natural, semi-natural and artificial spaces and engineering solutions that provides ecosystem values and functions. Green infrastructure can provide multiple functions and benefits on the same spatial area. These functions can be environmental (e.g. conserving biodiversity or adapting to climate change), social (e.g. providing water drainage or green space), and economic (e.g. supplying jobs and raising property prices). The contrast with grey infrastructure solutions, which typically fulfil single functions such as drainage or transport, makes green infrastructure appealing because it has the potential to tackle several problems simultaneously. (EEA 2015)
Green infrastructures include water bodies, wetlands, forests, parks, gardens, urban plantations, green roofs, green drainage systems and other green engineering solutions providing a series of ecosystem services that can contribute to create a healthier and more resilient operating space while reducing the impacts of cities on the environment. The table summarizes the range of ecosystem services provided by green infrastructures, showing their contribution to mitigate cities' environmental challenges, suggesting a framework to evaluate their effectiveness.
Green and blue spaces also have disservices such as health problems derived from wind-pollinated plants causing allergic reactions, the proliferation of insects or the damages on infrastructures such as pipelines or sidewalks. The effect of green infrastructures depends on their proximity to urban areas. Figure 4 shows Madrid pictured in Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER). The image has been enhanced using a color technique that includes some of ASTER's observations in the shortwave infrared as well as the visible part of the electromagnetic spectrum. The image shows dense population areas where there is not the possibility to implement conventional green spaces.
New technological developments allow expanding green and blue areas within the densest urban fabric, using green roofs or hydroponics. New green infrastructures can deeply change urban space and make possible a more proactive attitude towards the environment.
Figure 1 shows the new urban park built on top of Madrid ring road by an international team lead by Burgos & Garrido Architects. Figure 2 is a proposal for Madrid central square by Iglesias Architects making use of hydroponics to provide shadow green areas over the train and metro stations.

Key conclusions

1 Green infrastructure measures are clearly effective for mitigating health impacts in large cities

2 Proposed measures produce health co-benefits and their effect is additive

3 New technologies allow significantly changing the urban environment of overpopulated and poorly developed areas

4 There is a great potential for expanding green infrastructure in Madrid metropolitan area, that will reduce vulnerability of citizens

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