

TECHNICAL AND ECONOMIC ASSESSMENT

CAPILLARY ROOTZONE IRRIGATION FOR URBAN GREEN INFRASTRUCTURE

Case study regions: Málaga, Spain

Prepared for: municipalities, water authorities, landscape architects, urban planners/ developers, water authorities, engineering consultants and real estate developers

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WATER CONSERVATION, RAINWATER REUSE, BIODIVERSITY
ENHANCEMENT, CLIMATE ADAPTATION AND LIFECYCLE COST REDUCTION

Executive summary

Southern Spain is experiencing increasing structural water stress driven by prolonged drought cycles, rising temperatures and growing competition for potable water resources.

At the same time, urban areas are expanding green infrastructure to mitigate heat island effects, improve biodiversity and enhance liveability.

This report evaluates the technical, environmental and economic performance of capillary rootzone irrigation as a multifunctional urban water infrastructure system for Málaga.

Capillary rootzone irrigation replaces conventional surface irrigation with an underground water storage and capillary delivery system, enabling plants to access water directly from a subsurface reservoir according to demand.

Key findings (Málaga benchmark – 10.000 m² project):

- > **30-50% reduction** in irrigation demand compared to conventional systems
- > **58% average reduction** in potable water use (2021-2025 climatic baseline)
- > **43-85% reduction range**, depending on annual rainfall variability
- > **~66 million litres** potable water savings over 25 years
- > **80 L/m²** integrated subsurface water storage capacity
- > **~130 L/m²/year** average rainwater reuse
- > **~41% reduction** in lifecycle cost of ownership
- > **Approx. 5-years payback period** under standard water tariff assumptions
- > **Long-lasting** (50+ years) and fully reusable
- > **Integrated water storage foundation** for paved and planted areas

Capillary rootzone irrigation transforms urban landscapes into active water management systems, combining irrigation, rainwater harvesting, stormwater retention and climate adaptation functions.

1. Introduction: urban water as a structural constraint

Urban development in Mediterranean climates is increasingly constrained by:

- > Structural drought risk and reduced water availability
- > Rising municipal water tariffs and regulatory restrictions
- > Increasing evapotranspiration due to climate change
- > Higher maintenance costs for green infrastructure
- > Strong policy pressure for water efficiency and climate adaptation



Figure 1. Constraints of urban developments

Traditional irrigation systems exacerbate inefficiencies due to:

- > Surface evaporation losses
- > Wind drift and overspray
- > Runoff and deep percolation
- > Leakage in distribution networks
- > High operational dependency and maintenance requirements

Capillary rootzone irrigation addresses these limitations by eliminating surface irrigation and shifting water delivery below the plant rootzone.

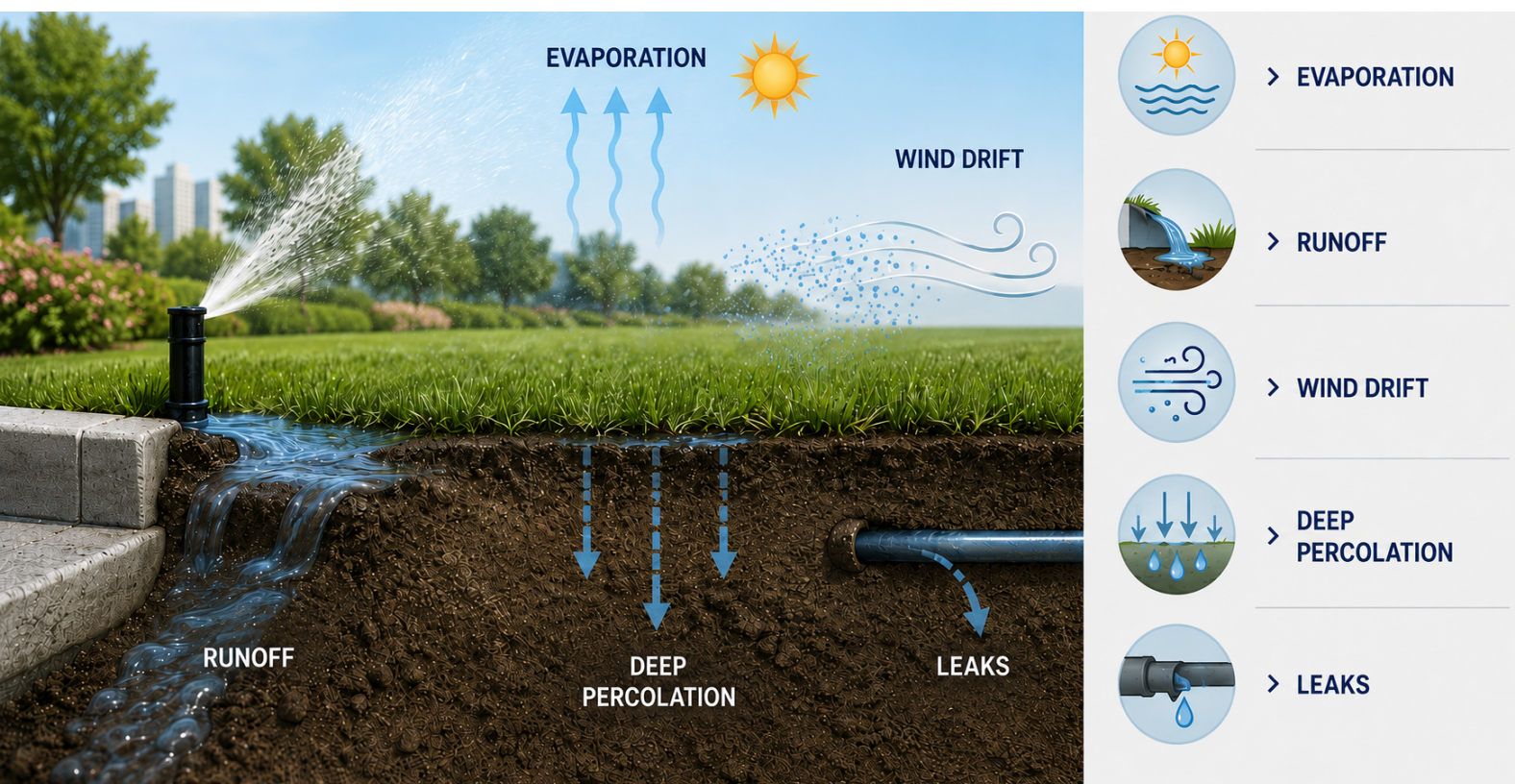


Figure 2. Challenges of conventional irrigation



Figure 3. Benefits of capillary rootzone irrigation compared to conventional irrigation

2. Climate context: Málaga

Málaga represents a highly variable Mediterranean climate with interannual variability.

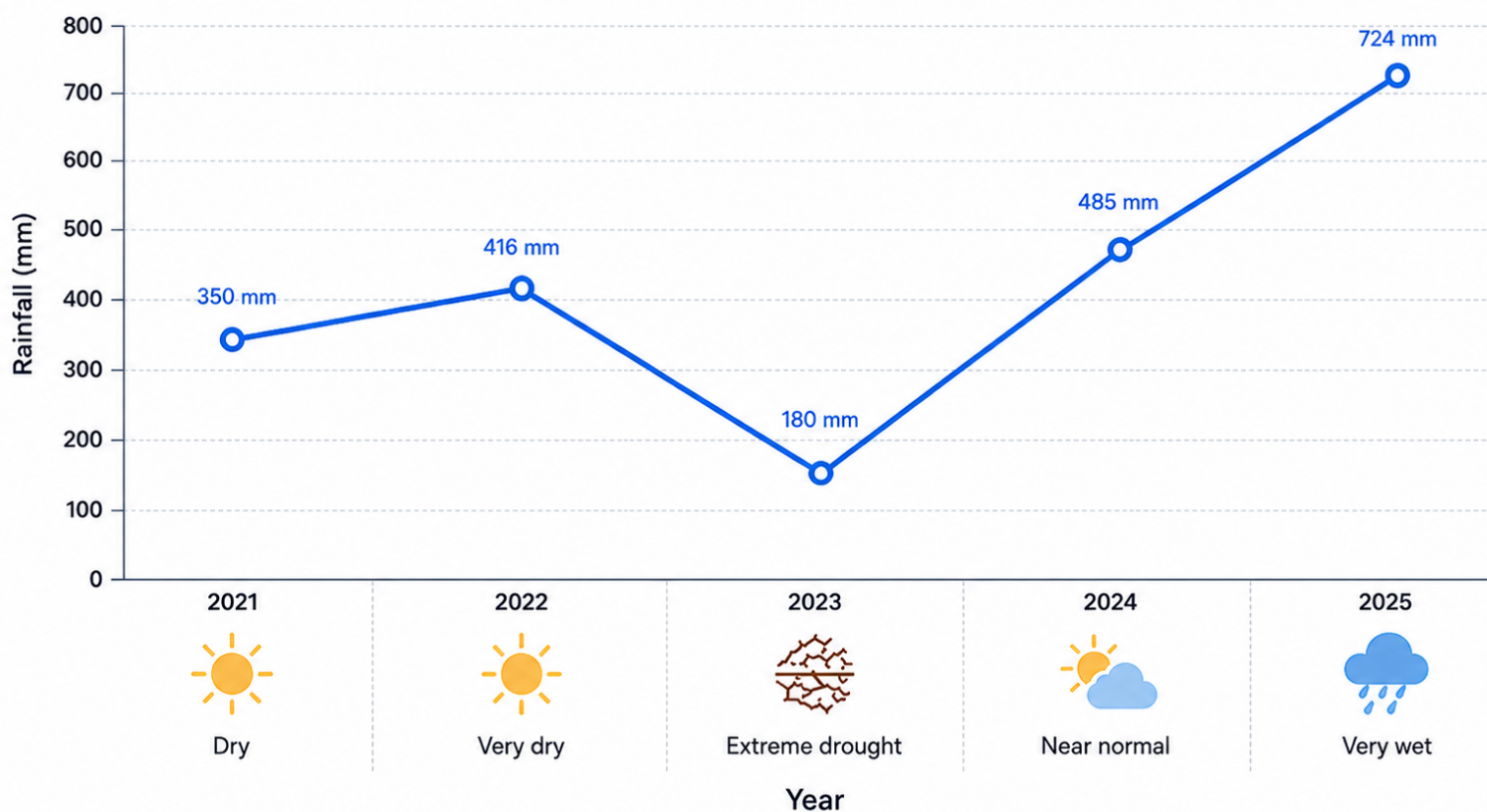
Climate baseline (2021-2025)

Year	Rainfall	Climate condition
2021	350 mm	Dry
2022	416 mm	Very dry
2023	180 mm	Extreme drought
2024	485 mm	Near average
2025	724 mm	Very wet

Table 1. Climate baseline of Málaga (2021-2025)

Annual rainfall in Málaga (2021–2025)

Observed annual rainfall and climatic conditions



Graph 1. Annual rainfall in Málaga (2021-2025)

Key parameters

Reference evapotranspiration (ET_0)	~1.250 mm/year
Annual rainfall	~ 432 mm/year
Effective rainfall	~ 420 mm/year
Landscape coefficient (K_c)	0.70

Table 2. Key parameter of Málaga

This variability requires irrigation systems to be probabilistic and adaptive rather than static.

3. Capillary rootzone irrigation technology

The capillary rootzone irrigation system consists of:

- > Subsurface water storage reservoir (80 L/m²)
- > Capillary transfer layer
- > Engineered rootzone substrate
- > Overflow and drainage regulation system
- > Optional monitoring sensors

Functional principle

Water is stored beneath the planting bed and transported upward through capillary forces in response to plant demand, rather than being applied at scheduled intervals. Unlike conventional irrigation systems, no water is applied directly to the soil surface.

Capillary rootzone irrigation reduces potable water consumption through two independent mechanisms:

1. Reduced irrigation demand through delivery of water to the rootzone
2. Capture, storage and reuse of rainfall within the integrated underground reservoir

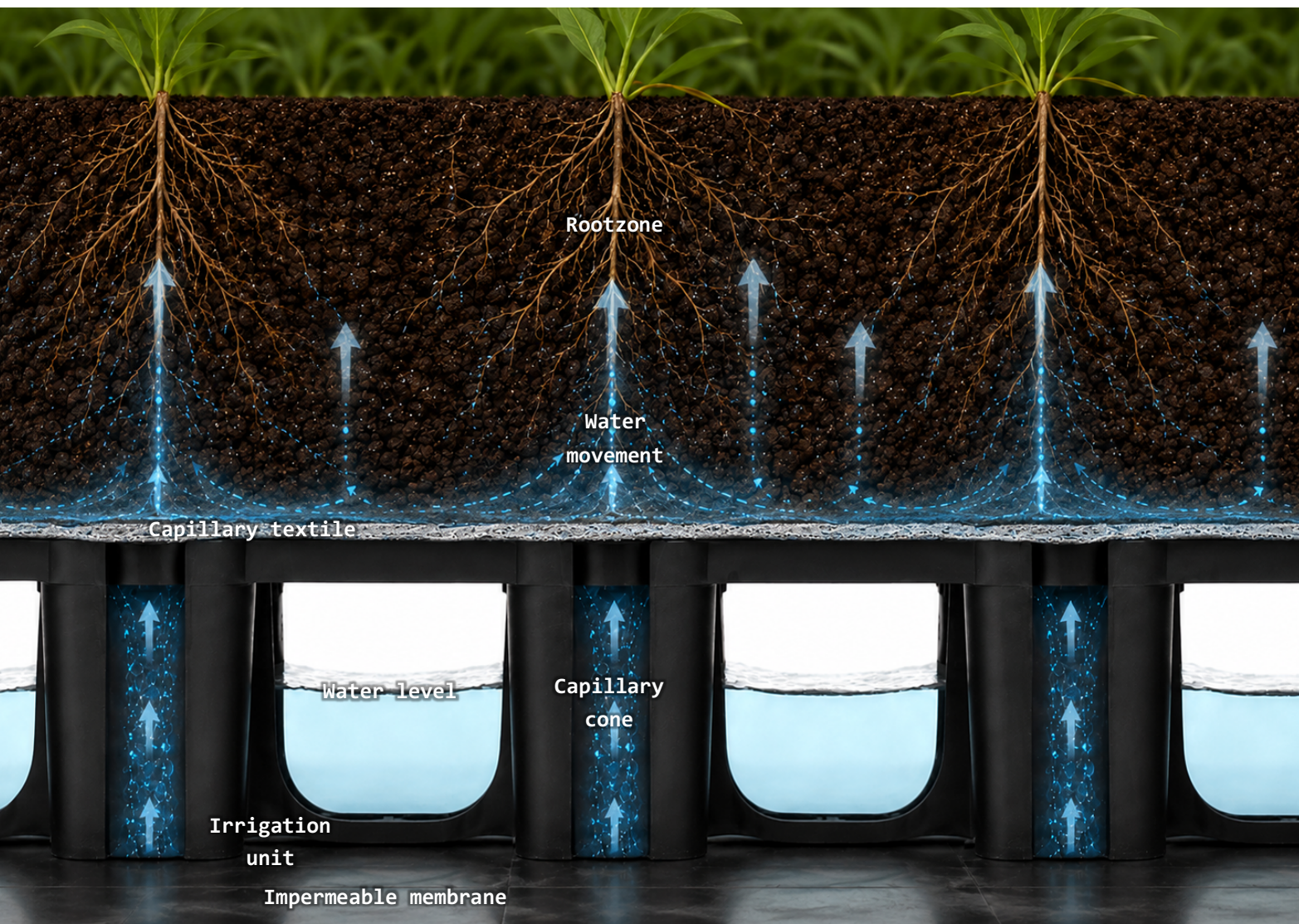


Figure 4. Principle of capillary rootzone irrigation

System functions

Capillary rootzone irrigation operates simultaneously as:

- > Irrigation infrastructure
- > Rainwater harvesting system
- > Stormwater retention layer
- > Soil moisture regulation system
- > Urban climate adaptation infrastructure

Benefits include:

- > Stable soil moisture conditions
- > Reduced evaporation losses
- > Improved root development
- > Lower irrigation frequency
- > Enhanced drought resilience
- > Improved plant health

4. Water balance methodology

The analysis is based on FAO-56 evapotranspiration principles.

$$ET_c = ET_0 \times K_c$$

$$In = ET_c - P_e$$

Where:

ET_c = crop/ landscape evapotranspiration

ET_0 = reference evapotranspiration

K_c = landscape coefficient

P_e = effective rainfall

In = net irrigation demand

This ensures comparability with conventional engineering irrigation design standards.

5. Water demand and system performance

Basic conditions (Málaga):

	Málaga
Reference evapotranspiration (ET_0)	1.250 mm/year
Rainfall	~ 432 mm/year
Effective rainfall (mm/year)	~ 420 mm/year
Landscape coefficient (K_c)	0.70

Table 3. Basic conditions in Málaga

Annual irrigation demand:

- > Conventional systems: ~ 455 L/m²/year
- > Capillary rootzone irrigation systems: ~ 228-319 L/m²/year

Efficiency improvements:

- > 30-50% reduction in irrigation demand

6. Historical performance variability (2021-2025)

Capillary rootzone irrigation varies with climatic conditions:

Condition	Potable water reduction
Dry years	43-56%
Average years	~ 58%
Normal conditions	60-70%
Wet years	75-85%

Table 4. Potable water reduction in Málaga for different climate conditions

Interpretation

Performance improves in wetter years due to:

- > Higher rainwater capture efficiency
- > Increased storage utilization
- > Reduced reliance on irrigation inputs

7. Rainwater harvesting and storage function

Capillary rootzone irrigation integrates landscape soil volume as a controlled water reservoir.

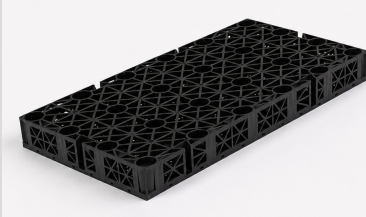
Storage capacity	40 mm units	85 mm units	150 mm units
			
Per m ²	38 L	80 L	140 L
Per 500 m ² project	19.000 L	40.000 L	70.000 L
Per 2.500 m ² project	95.000 L	200.000 L	350.000 L
Per 10.000 m ² project	380.000 L	800.000 L	1.400.000 L

Table 5. Storage function of the different capillary irrigation units

Average reuse for 85 mm unit: **~130 L/m²/year** (climate-dependent)

System inputs:

- > Direct rainfall infiltration
- > Roof runoff (if connected)
- > Hardscape drainage capture (if connected)
- > Plaza and parking runoff systems (if connected)

Functional transformation

Urban landscapes become:

- > Water buffers
- > Seasonal reservoirs
- > Stormwater retention systems
- > Demand-driven irrigation sources

8. Municipal-scale water saving

10.000 m² reference project (Málaga):

Component	Annual saving
Irrigation efficiency	1.36 million L
Rainwater reuse	1.30 million L
Total	2.66 million L/year

Table 6. Annual savings for Málaga with capillary rootzone irrigation

25-year lifecycle: ~ **66 million litres** potable water saved

Equivalent to:

- > 600+ households' annual water consumption
- > 200+ million bottles of water
- > Large-scale substitution of municipal irrigation demand

9. Performance indicators

60-80% lower potable water consumption compared to conventional irrigation systems, achieved by highly efficient water delivery directly to plant rootzone, minimal water loss through evaporation and reuse of rainwater.

75% lower irrigation maintenance costs due to elimination of many components commonly associated with traditional irrigation systems, including:

- > No sprinklers
- > No emitters
- > No sprinkler adjustments
- > No exposed components vulnerable to damage
- > Reduced risk of leaks and system failures

30% lower landscape maintenance and plant replacement because of healthier and more resilient vegetation:

- > Reduced weed growth because the top layer of the substrate remains mainly dry, limiting weed seed germination
- > Improved plant establishment
- > Reduced plant replacement
- > Lower drought stress
- > Reduced erosion around planting areas

More than 25% increase in healthy vegetation coverage, supported by consistent moisture availability in the rootzone, resulting in stronger plant growth and improved landscape performance.



Figure 5. Capillary rootzone irrigation results in an increase of healthy vegetation

Up to five times longer infrastructure lifespan compared to conventional irrigation systems.

- > Conventional irrigation systems typically require replacement every 5-8 years
- > Capillary rootzone irrigation systems are designed for a lifespan of 25 years or more, reducing long-term replacement costs and material waste

80% lower soil erosion because water is delivered below the soil surface, preventing runoff, washout and the displacement of soil during irrigation events

70% lower mosquito breeding potential through the use of enclosed underground water reservoirs, eliminating the standing surface water that often serves as mosquito breeding habitat.

Service life of more than 50 years, makes it possible to be reused in future landscape designs if land-use plans, site layouts or redevelopment requirements change, supporting a circular and sustainable approach to urban development,

From low to high load-bearing capacity, ranging from planting beds and sport fields to locations exposed to heavy vehicular traffic.

Product	Light	Medium	Heavy
			
Application	Planting beds and landscaped areas	Sport fields, recreational areas, pedestrian loading	Roads, parking areas and other locations exposed to (heavy) vehicle traffic
Compressive strength (vertical)	715 kPa (71,5 t/m ²)	715 kPa (71,5 t/m ²)	715 kPa (71,5 t/m ²)

Table 7. Product portfolio for different load-bearing capacities

NOTE: exact traffic load classification of the system depends on the overall construction. Therefore, applications subject to heavy traffic loads typically require a project-specific structural design and load assessment.

The lightweight alternative to traditional foundation layers provides temporary water storage beneath paved surface and making this water available to adjacent planting areas. This solution is widely used on podium decks and in locations with dense underground utilities, where deep excavation for conventional water storage and drainage systems is impractical.



Figure 6. Lightweight water managing foundation combined with planters

10. Lifecycle cost analysis

Assumptions

Evaluation period	25 years
Project area	10.000 m ²
Water tariff	€ 2,20/m ³
Discount rate	3%
Location	Málaga

Table 8. Assumptions for lifecycle cost analysis

Cost comparison

Category	Conventional irrigation	Capillary rootzone irrigation
Installation (CAPEX)	€ 120.000	€ 300.000
Water costs	€ 320.650	€ 129.800
Irrigation maintenance	€ 200.000	€ 50.000
Landscape maintenance	€ 1.000.000	€ 700.000
Infrastructure replacement	€ 360.000	€ 0
Total lifecycle costs	€ 2.000.650	€ 1.179.800

Table 9. Cost comparison for lifecycle cost analysis

Economic outcomes

Additional capital investment	€ 180.000
Lifecycle savings	€ 820.850
Reduction in ownership costs	41%
Average annual benefit	€ 32.834
Simple payback	Approx. 5 years

Table 10. Economic outcomes for lifecycle cost analysis

Primary ROI drivers:

- > Reduced water consumption
- > Lower maintenance dependency
- > Reduced plant replacement cycles
- > Extended system lifespan

11. Biodiversity and environmental performance

Capillary rootzone irrigation improves ecological system performance through stable rootzone moisture conditions.

Vegetation benefits:

- > Increased drought survival rates
- > Improved summer resilience
- > **Broader species selection**
- > Longer flowering periods

Ecosystem benefits:

- > Improved pollinator habitat

- > Increased nectar availability
- > **Improves habitat quality**
- > Increased vegetation density

Hydrological benefits:

- > Reduced runoff peaks
- > Lower stormwater system load
- > **Improved urban microclimate cooling**



NATIVE AND ADAPTED PLANT PALETTE



Selected based on their adaptation to the Mediterranean climate, low water use and ecological value.

KEY BENEFITS

MORE WILDLIFE

Provides habitat and food for birds, insects and small mammals.

SUPPORTS POLLINATORS

Plants that provide nectar and pollen throughout the year.

MORE SHADE AND COMFORT

Trees and shrubs lower temperatures and create pleasant, livable spaces.

EFFICIENT USE OF WATER

Drought-tolerant species reduce irrigation needs.

CLEANER AIR

Plants improve well-being and strengthen the connection with nature.

INTEREST THROUGHOUT THE YEAR

SPRING

Abundant flowering and active pollinators

SUMMER

Aromas, textures and refreshing shade

AUTUMN

Fruits, color and seeds for wildlife

WINTER

Evergreen structure, berries and flowering in winter

MULTI-LAYER PLANT STRUCTURE



Figure 7. Biodiversity and environmental performance

12. Policy and regulatory alignment

Capillary rootzone irrigation supports key European and national policy frameworks:

- > European Green Deal
- > EU biodiversity strategy 2030
- > EU climate adaptation strategy
- > Water framework directive
- > Nature-based solution framework
- > Sustainable urban drainage systems (SuDs)
- > EU taxonomy regulation
- > Climate-neutral and Smart Cities missions

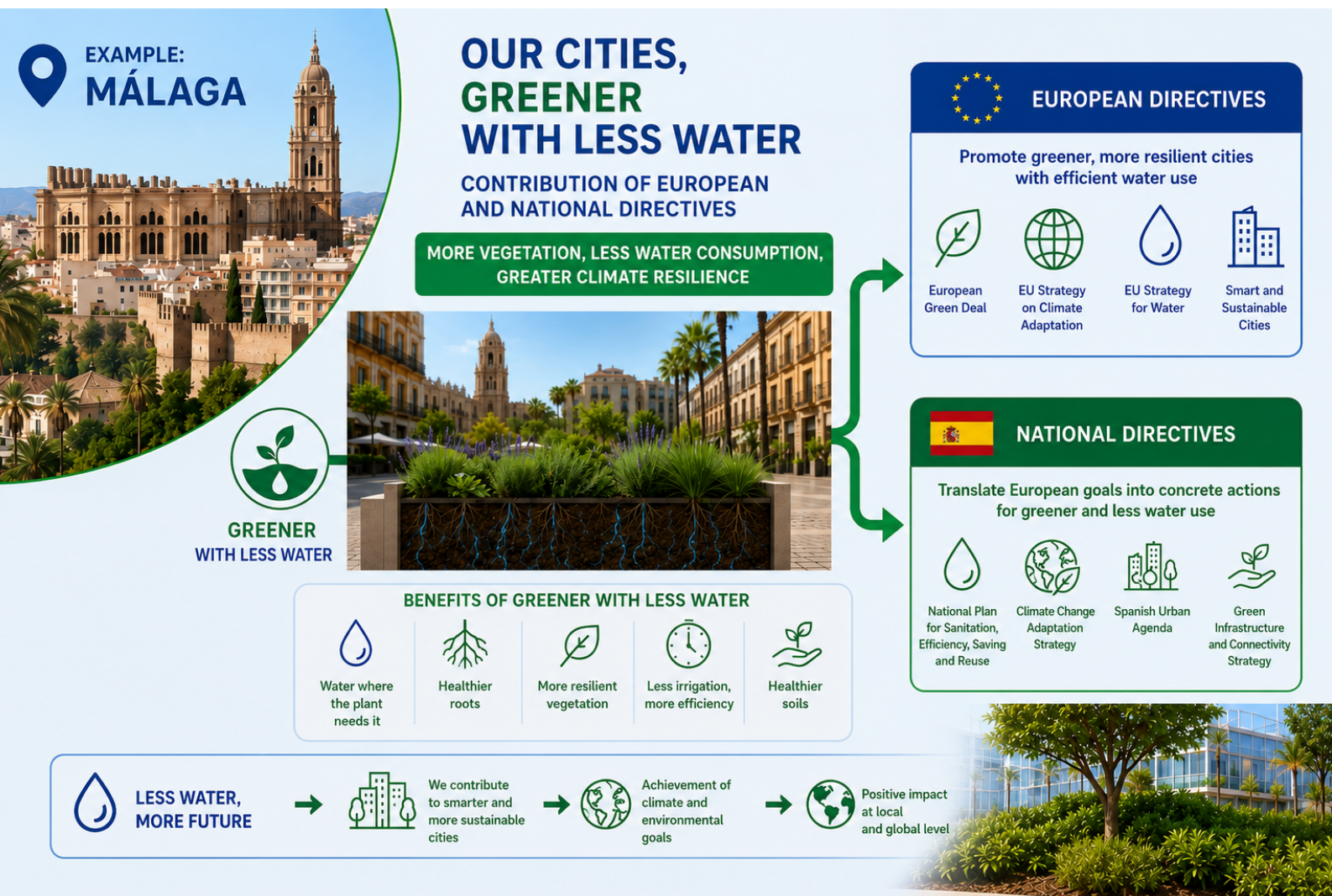


Figure 8. Regulatory alignment of capillary rootzone irrigation

The system is fully aligned with current EU priorities on **water efficiency**, **climate resilience** and **urban sustainability**.

13. Conclusions

Capillary rootzone irrigation represents a transition from conventional irrigation toward **integrated urban water infrastructure**.

Key quantified outcomes (Málaga benchmark):

- > 30-50% irrigation demand reduction
- > 58% average potable water reduction
- > 43-85% range depending on rainfall conditions
- > 80 L/m² subsurface storage capacity
- > 130 L/m² annual rainwater reuse
- > ~ 66 million litres potable water savings (25 years, 10.000 m²)
- > ~ 41% lifecycle cost reduction
- > ~ 5-year investment payback
- > Long-lasting (50+ years) and fully reusable
- > Integrated water storage foundation for paved and planted areas



Figure 9. Key quantified outcomes (benchmark Málaga)

Strategic conclusion

In Mediterranean urban environments, irrigation is no longer a simple operational utility. It is a critical variable in financial risk management, climate adaptation and long-term assess performance.

Capillary rootzone irrigation converts this into a predictable, efficient, and multifunctional infrastructure supporting resilient and sustainable urban development.

Ready to turn your water strategy into reality?

If you would like more information, a tailored proposal, or expert guidance on optimizing your water management processes, our team is ready to support you.

Take advantage of our complimentary Water Assessment to gain valuable insights into your current water usage, identify improvement opportunities, and explore solutions that align with your operational and sustainability objectives.

Whether you are looking to improve efficiency, reduce costs, or implement a future-proof water strategy, we are ready to help bring your vision to life.

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