Gemeente Amsterdam

Project Smartroof 2.0

Result overview for growing seasons 2017 and 2018

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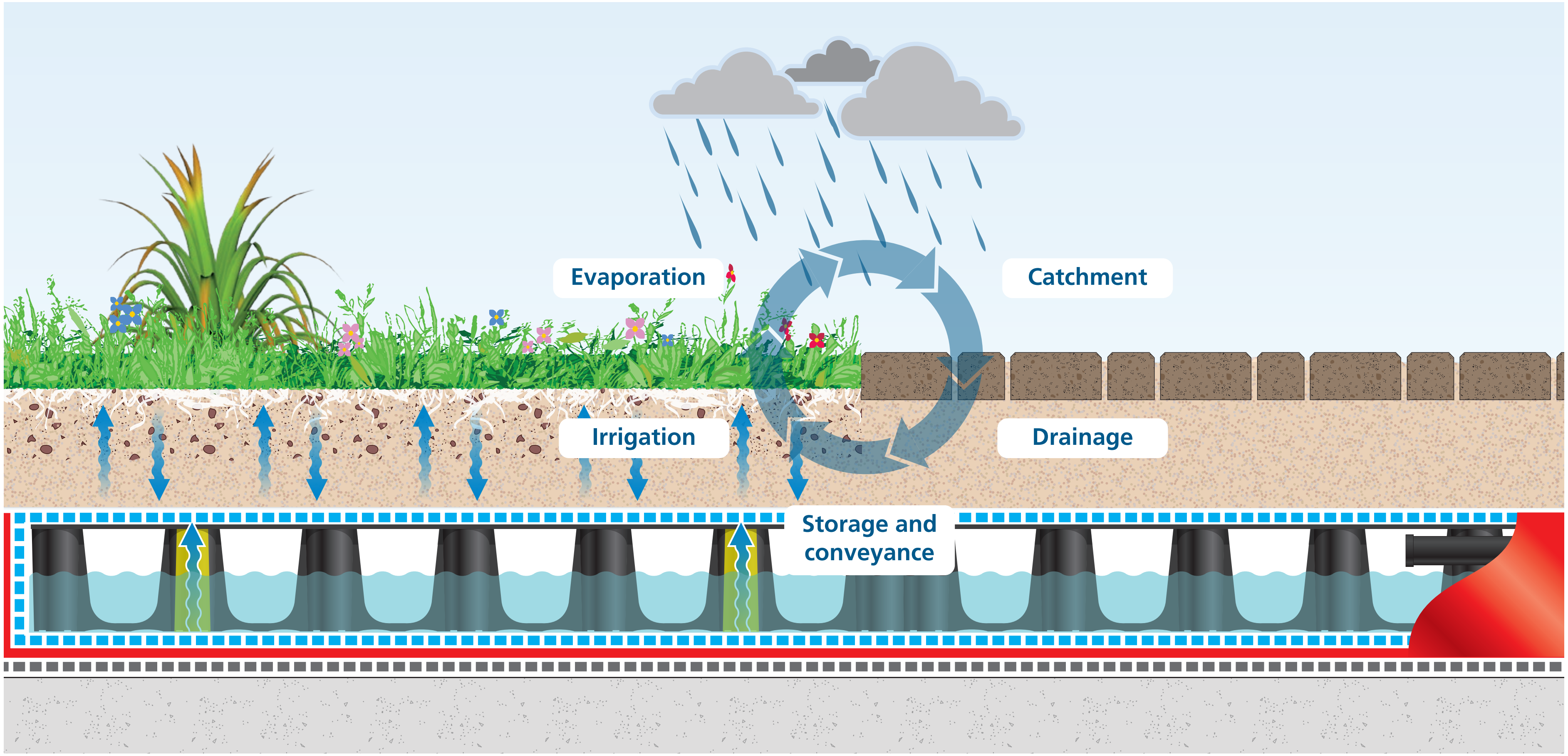
Cities worldwide are confronted with rising temperatures caused by climate change and increasing urban density. Green roofs are promoted as the climate and adaptation solution to help lower the air temperature and improve comfort levels in urban environments, particularly during intensely dry and warm periods. Still the effectiveness of these measures remains a matter of constant debate, due to a lack of fundamental knowledge about evaporation from different types of green roof systems. With project Smartroof 2.0, we investigate the water balance and energy balance of different types of green and 'blue-green' roofs.



Introduction

Hard and soft results

Project Smartroof 2.0 is an innovation project stemming from a public-private co-operation between the City of Amsterdam, Waternet, Drain Products, Aedes Real Estate, KWR Water Cycle Research Institute and Marineterrein Amsterdam and was financed by PPS financing (amongst others) from the Surcharge for Top Consortiums for Knowledge and Innovation provided by the Ministry of Economics and Climate.

Together we have taken up an urgent urban challenge: how do we handle rising temperatures caused by climate change and increasing urban density? A number of the results are hard: they were measured and modelled by scientific standards. Furthermore, these results were published in a scientific magazine (Cirkel et.al., 2018. Evaporation from (Blue-)Green Roofs: Assessing the benefits of a Storage and Capillary Irrigation System Based on Measurements and Modelling. Water 2018, 10(9), 1253. Other results are 'softer': they were not gathered using scientific methods. In this report we make a clear distinction between the two.

When it comes to upscaling and implementing, both types of result can be interesting, depending on specific needs. The results can be used according to one's own views and needs by those involved in investment decision-making, policy and purchasing demands for creating blue-green roofs on existing buildings and in areas yet to be developed.

Water is indispensable for the growth of plants. For this reason we have compared three types of roofs. One conventional green roof, and two so-called 'blue-green roofs' with a rain water storage and capillary irrigation system. These blue-green roofs have a 85 millimetre high drainage layer directly underneath the topsoil, in which rain water is stored. These units have special fibre cylinders whose capillary effect leads water back to the plants during dry spells. This way, on-demand natural irrigation comes into effect without the use of pumps, valves, hoses or energy. Just like in nature.

Result: lower temperatures and more green as a solution for the consequences of climate change

We created three different research surfaces, covered with Sedum and/or grasses and herbs and which had different substrate thicknesses (4 centimetres and 8 centimetres). For each of these three surfaces we established the water and energy balance. This enabled us to compare the effects of blue-green roofs with a new storage and capillary irrigation system on the one hand with a conventional green roof on the other hand. Our measurements and modelling indicated that conventional green roof systems (which have a Sedum vegetation on 4 centimetres of substrate) have low evaporation and a slight cooling effect. The other two roofs, equipped with a water storage and capillary irrigation system, showed a remarkably high plant evaporation levels during hot, dry periods. When covered with grasses and herbs, evaporation levels were even higher. Therefore, implementing these systems can lead to better cooling efficiency of vegetated roofs in urbanised areas.

Results of scientific research[1] based on measurements and modelling:

1 **Water storage and evaporation:** evaporation from a green roof can be increased significantly by storing rain water and offering capillary irrigation. This is illustrated by the measured evaporation during a two week long heatwave in June 2018. The conventional green roof turned out to evaporate 18 litres of water per square meter. During the same timespan, the blue-green roof evaporated no less than 42 litres of water per square meter. Due to the available water, plants continued to evaporate at full potential (= maximum cooling efficiency). The long term actual annual evaporation of a Sedum vegetation increased from 290 mm/year on average on a conventional system without water storage, to 386 mm/year on a 80 mm water storage system, with potential (maximum) evaporation of 401 mm/year.

2. **Urban cooling 1:** in the long term, and compared to conventional green roofs, blue-green roof systems with a capillary irrigation system turn an average of 50% more incoming (solar) energy into water evaporation instead of turning it into unwanted urban heat. In dry hot periods, conventional green roofs contain too little water, which makes the difference even larger. In periods like these, conventional green roofs turn incoming energy into hot air, while blue-green roofs keep evaporating, and thus cooling, for a longer period of time.

3. **Urban cooling 2:** the number of days a green roof does not supply cooling because of a lack of water, decreases notably by applying water storage and capillary re-supply. The conventional system we tested showed more than 10 non-cooling 'desert days' per month during the late spring and the summer. On the other hand, the capillary system with 80 millimetres of water storage showed only 1 or 2 such 'desert days' per month during the same period. We can prevent these days altogether by enlarging the water storage capacity or by actively adding water to the storage layer.

4. **Surface temperature:** we measured the temperatures on the surface of a referential roof with standard black bitumen and on the vegetated blue-green roof system; the difference in temperature runs up to 40 degrees Celsius on hot summery days.

'Soft' results

Project Smartroof 2.0 has yielded results that teach us about the prerequisites for further development and upscaling of blue-green vegetation systems. Alongside the scientifically based results we have actively maintained the roof and we have seen and measured more non-scientific results. This can be viewed as collateral results from our living lab. Furthermore, we have made evaluations throughout our co-operation process.

1 Evaporation from (Blue-)Green Roofs: Assessing the Benefits of a Storage and Capillary Irrigation System Based on Measurements and Modeling by Dirk Gijsbert Cirkel, Bernard R. Voortman, Thijs van Veen and Ruud P. Bartholomeus, KWR Research Institute, 2018

Growing season of 2017

1. **Diversity in plants:** the constant availability of water causes a stable soil moisture content in the blue-green roof systems. This results in vegetational differences which are clearly visible. The blue-green roof system has a mixed vegetation of Sedum, grasses and herbs, while the conventional green roof does not develop itself beyond the stage of Sedum plants.

2. **Less energy usage for cooling:** since the installation of Project Smartroof 2.0, the air conditioners in the spaces below the roof have not been used. The blue-green roof system on top of the non-insulated roof kept enough heat out of the building to suppress the need for air conditioning. Temperature measurements support this theory. Even on hot summer days the water temperature in the blue-green system does not exceed 23-24 degrees Celsius.

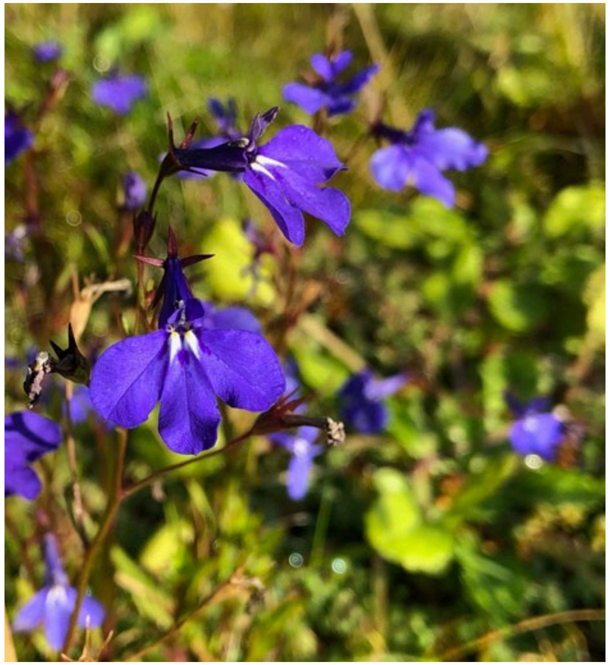
Growing season of 2018

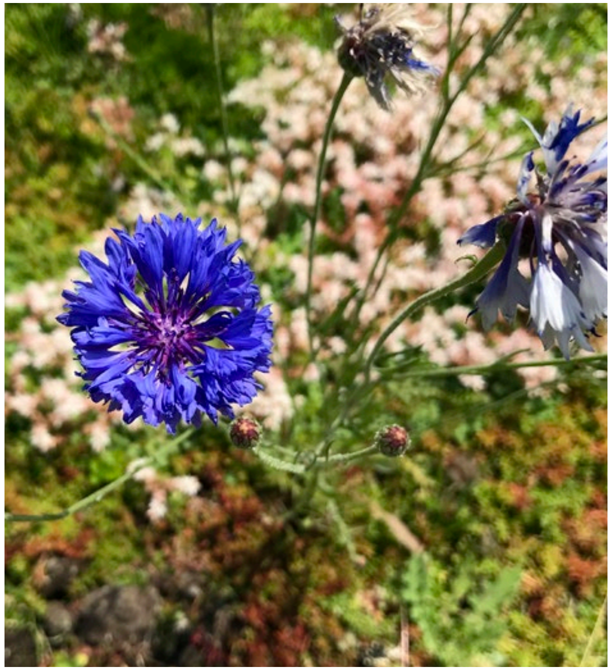
2018 was characterised by an enormously long dry period. In a period of 5 months, starting mid April 2018, the roof received no significant amount of rain. This provided the opportunity to observe how the different systems reacted to these circumstances, and what would be necessary to keep plants alive during this long drought. The following results became apparent:

1. **Water supply:** the roof on which Project Smartroof 2.0 has been built was never designed to support a blue-green roof. Thus the blue-green construction of Project Smartroof 2.0 (90 kg/m²) does not allow for the storage of large amounts of rainwater for plant irrigation. Only 30 mm of the 80 mm storage capacity for rainwater can be used. This means that after an average of 15 days, rainwater or irrigation water is needed to maintain the plants' maximum growth and evapotranspiration rates.

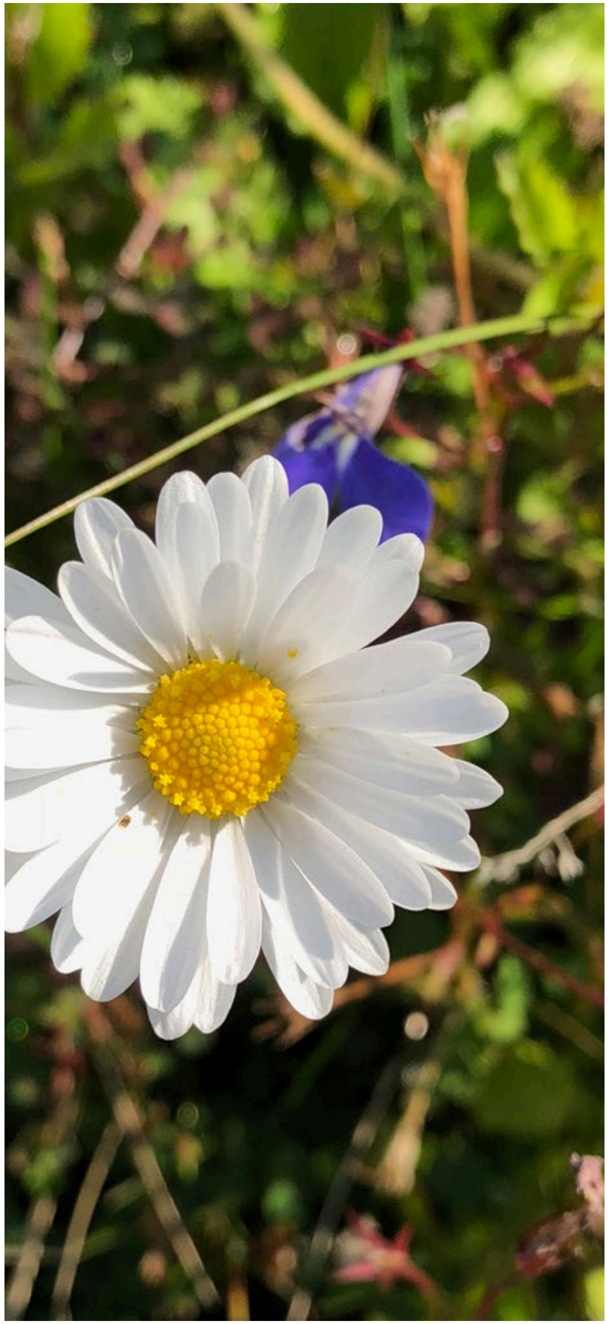
2. **Smart irrigation versus manual irrigation:** there was no rainwater in this dry period. In order to keep the plants alive, two different irrigation regimes were set up. The first one based on manual irrigation with a garden hose by a horticulturalist, the second one based on sensor water level measurements and a computer controlled automatic valve in order to replenish the water in the drainage layer. After four months of drought, the difference between the two irrigation regimes became apparent. The electronic system yielded completely active and green plants, whereas the manually watered plants started to show signs of drought. Despite the fact that the plants were sprayed professionally 2 or 3 times a week, the leaves started yellowing.

3. **Biodiversity of fauna:** in August 2018, an ecologist sampled the roof for presence of insects and spiders. Despite the long drought that summer, in a sampling period of merely 24 hours 42 species of insect were found, with a remarkably high number of flying insects and a lively population of several spider species. This implies they all find enough insects to eat on the roof. Even an almost extinct predatory wasp species was found. This indicates the presence of an eco-system with multiple predator-prey cycles. In this specific ecological research, the researcher noted that she had never before seen so many species on a vegetated roof only 18 months old, based on a topsoil of only 40 mm.





Other results and insights



1. **International showcase:** the roof setup functions as an international showcase for a better and multifunctional usage of urban roofs. The setup attracted visitors from Europe, North America, Asia and the gulf region.

2. **Key factors for successful innovative cooperation:** the founding partners worked on the details for over two years to make Project Smartroof 2.0 possible. Even though the partners have different interests, they all recognise the importance, value and potential of blue-green roof systems. Whether it's about the value of real estate, biodiversity, management and recycling of rainwater, energy performance of buildings, urban resilience, human health or reducing the heat-island effect in the city. The most important key factors for innovative cooperation we experienced were the naming of, respecting of and thinking from each other's interests. This resulted in endless patience and enthusiasm of all people involved in all stages of the project. Even when things became difficult, all those involved refused to abandon the initial idea, motivated by the shared vision that cities can be and should be a better place to live than they are now.

3. **Mediator of innovation:** within the cooperation, the municipality of Amsterdam took the role of mediator of innovation[2]. This process approach was an experiment and led to new insights about the roles an authority like a municipality can take as facilitator of innovation. The mediator of innovation brings together the different parties in the innovation process, for instance launching customer, stakeholders, innovators and knowledge institutes. In this role, the mediator organises, stimulates and facilitates the cooperating partners to achieve the innovation project.

4. **Using scheduled maintenance as cofinancier and commissioner of innovation:** almost all innovation grants in the Netherlands demand cofinancing and a practical project which can function as a show-and-tell living lab. By linking the interests of scheduled regular maintenance to the innovation, it is easier to get commitment and a budget that can be used to experiment with the envisaged solutions. Moreover, this opportune link with the day-to-day execution ensures a swifter acceptance of the new solution within existing building management practice. Literally being able to touch, see, taste and smell the innovative solution and experience the difference with conventional systems, greatly helps to bring essential acceptance about.

5. **Open knowledge sharing and trust:** apart from the founding partners who support the concept and enable the project, a multifunctional roof like Project Smartroof 2.0 cannot be realised without the cooperation of partners who trust each other and openly share knowledge, experiences and products to start a project with the newest technology and know-how.

2 Public procurement and innovation: A conceptual framework for analyzing project- based procurement strategies for innovation, Bart Lenderink, Hans Voordijk, Joop Halman and André Dorée, 2017, University of Twente.

Conclusion

Project Smartroof 2.0

Project Smartroof 2.0 has yielded results that offer insight into the prerequisites for the development and integration of blue-green vegetation systems on existing roofs, podium decks and areas yet to be developed. Additional insights into accelerating and improving innovative collaborative processes were gained as well. Both are necessary for acceleration of change. Project Smartroof 2.0 shows that it is possible to minimise the consequences of climate change for people and animals in the city, and convert the consequences into opportunities, giving everyone a chance to profit from the functions nature offers us: **for cooling, biodiversity, amenity, human health and the value of real-estate.** The Blue-Green roof system based on rain water storage and capillary irrigation has proven to be the next evolutionary step in vegetated roof systems: it enables plants to thrive, rather than just survive, and as such maximises much-needed plant functionality in the Urban environment.