Enhancing ecosystem services in cities through multifunctional rooftop gardens - Insights from a co-designed pilot project in Barcelona, Spain

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In an ever stronger urbanizing world, multi-functional green spaces are gaining increasing attention in urban planning and green infrastructure strategies. Urban gardens have a proven ability to enhance human well-being in cities through the provision of a variety of ecosystem services (Langemeyer et al., 2016). Nevertheless, large parts of cities have not yet been explored for their capacity to host multi-functional urban gardens. Flat rooftops in densely populated Mediterranean cities provide large potentials to increase the amount of gardens in cities, for example, 1.764,4 ha (67%) of the buildings in Barcelona, Spain, possess of flat rooftop terraces theoretically apt for carrying rooftop gardens (Rueda et al. 2010).

In this transdisciplinary study, we assess the capacity of urban rooftop gardens in Barcelona to provide multiple ecosystem services. In an initial phase, we assess provisioning and regulating services from a 68 m^2 pilot rooftop garden. In this current pilot phase, we are testing two different substrates, two different depths and seven plant combinations. In a second phase, we also consider cultural and habitat services provided by an urban rooftop farm of 3000 m^2. This novel creation of rooftop gardens is based on a holistic co-design process initiated by an interdisciplinary group of scientists, architects, public planners and private business entities in collaboration with potential user groups. Within this experimental setting, we control for environmental factors such as water use, substrate types, substrate depth, energy use, installation weight, species diversity, and reduction of particulate matter; social factors, such as the demographic profiles and specific demands and interests of garden users, as well as economic costs and paybacks.

Pilot rooftop garden in Barcelona, Spain (Photo: Johannes Langemeyer)

This innovative urban garden initiative is supposed to develop a new design of multi-functional urban rooftop gardens to enhance the generation of ecosystem services in cities, especially through: i) the local production of high quality and highly valued food; ii) as part of green corridors for the maintenance of biodiversity and pollinators; as well as for iii) the provision of cultural ecosystem services, including environmental education and social cohesion. However, the capacity to enhance ecosystem services in cities through urban rooftop gardens depends on the possibility to upscale this novel rooftop gardening approach. Its success depends on the balance between the described benefits of rooftop gardens and their requirements in terms of species selection, design, material, energy, as well as social and financial inputs in comparison. A crucial question for our study is also, if multi-functional rooftop garden can be sustainable from a market perspective through the commercialization of food produce and recreational activities, or if public (green infrastructure) policies are required to foster urban rooftop gardening and the related stewardship of ecosystem services.

The irrigation level has been adapted during the first period of the project with regard to the needs of crops under intensive plantation. The drip irrigation system was initially (first two weeks) set to 10.0 l/m2 per day during two irrigations periods in the morning and in the afternoon. The precipitation in the same period amounted in average to about 3.0 l/m2 per day (estimation based on data from the *Fabra Observatory*, located 6.4 km from the study site). During this period the amount of water was excessive, and irrigation levels were subsequently lowered to an average irrigation of 2.5 l/m2 per day, conducted as single irrigations of 5.0 l/m2 every second day. The

estimated precipitation during this period amounted to 2.1 l/m2 per day in average. From these results we assume the creation of capturing capacities for pluvial waters to constitute an opportunity to lower the external water input and related costs.

Preliminary results during the period of February-April 2016 based on the continuous temperature monitoring at different layers of the rooftop gardens are confirming a strong potential of urban rooftop gardens as temperature buffers for heat and cold. We observe that the temperature underneath rooftop gardens remained at a relative constant temperature of 16°C in average. That meant about 12°C cooler during hot periods than in the absence of the garden (28°C), and about 5°C warmer during cooler temperatures at night (11°C).

Yet, our pilot study is also demonstrating that there are technical as well as institutional barriers for the implementation of rooftop gardens. Technical barriers consist for example in the selection of appropriate substrates and plant species. The drainage capacity of substrates and of technical facilities seems to be decisive for the successful growth of food plants in the face of strong precipitation events common for the Mediterranean climate. Yet, at the current stage of the project no differences in the plant development between 0.25m and 0.35m substrate depth have been observed. The selection of plant species needs to consider resistance to the strong wind, heat (and the related levels of evapotranspiration) as well as punctual precipitation exposure of plants on a rooftop in the Mediterranean climate. Institutional barriers are for example given by lacking urbanistic categories for mixed uses. This means the hybrid use of housing and horticultural production with commercial outputs – e.g. in forms of edible food plants – is not regulated by Barcelona's urbanistic regulatory framework. This might constitute an important shortcoming for upscaling urban rooftop gardens, since economic incentives are lacking due to difficulties in the commercialization of rooftop garden products.

From these initial experiences, the successful upscaling of co-designed, urban rooftop garden – including to other Mediterranean cities – seems a promising approach for enhancing human wellbeing in densely populated cities like Barcelona. Conducted at larger scales, urban rooftop gardens could also provide larger benefits through the provision of regulating services, such as a reduction of the heat island effect and air pollution removal, or as an indirect benefit from locally produced food from the reduction of GHG emissions resulting from transport. Yet, both technical as well as institutional barriers for the implementation of rooftop gardens need to be overcome before a large scale implementation becomes feasible.

References:

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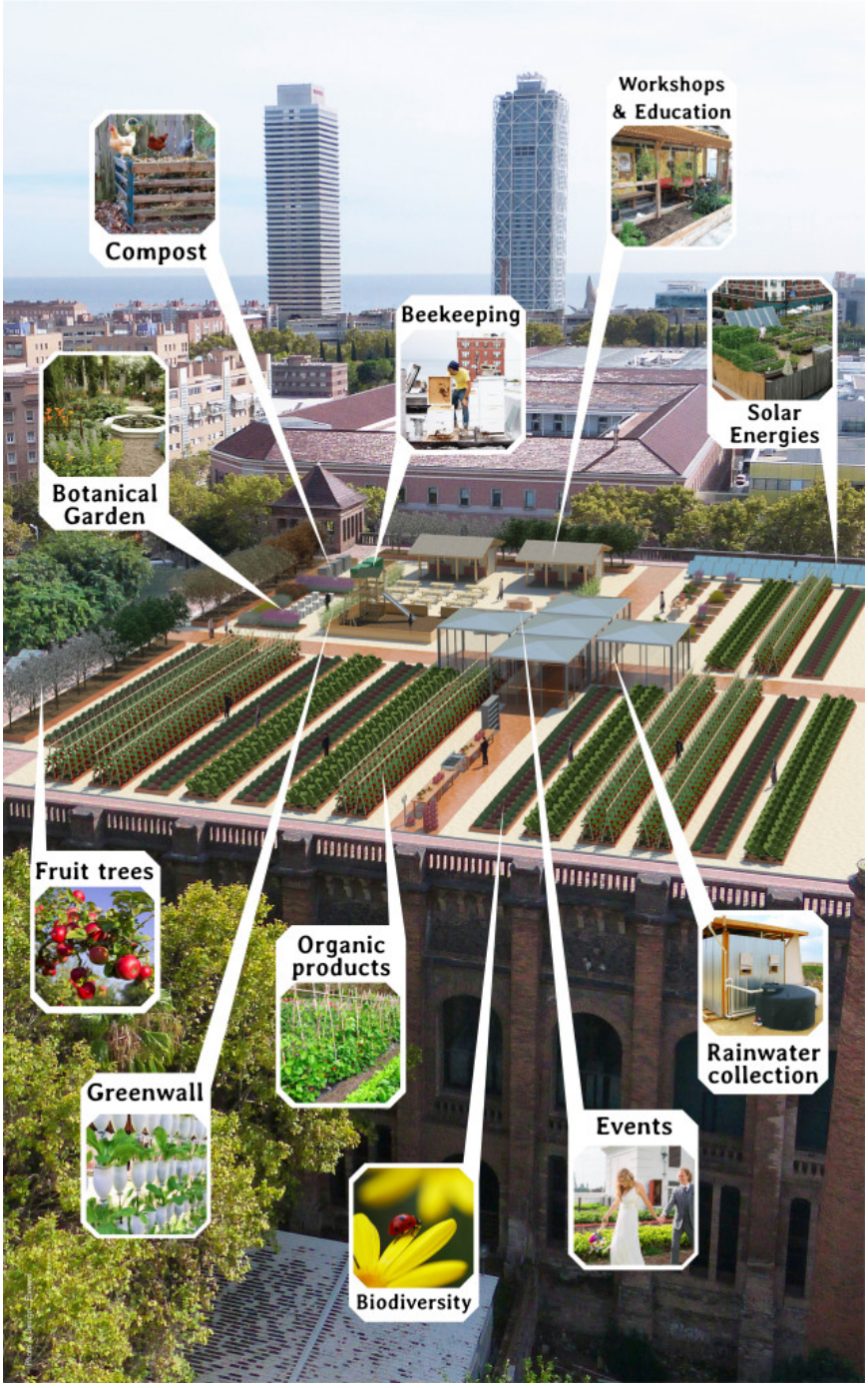

Figure 1: Proposal for the 3000m² urban rooftop farm '*Dipòsit de les Aigües*', Barcelona (Spain).