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Science for Environment Policy

Green roofs as flood mitigation measures: how to improve performance

Green roofs have been proposed to mitigate flooding in urban areas. This study combined field experiments and numerical simulations to investigate the ability of green roofs to absorb rainwater. The authors describe how green roofs can be most effective at mitigating flooding, providing findings which will be important for policy on green infrastructure.

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Source: Yang, W., Li, D., Sun, T. & Ni, G. (2015). Saturation-excess and infiltration-excess runoff on green roofs. *Ecological Engineering*, 74, pp.327-336. DOI: 10.1016/j.ecoleng.2014.10.023

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Rapid urbanisation has led to increases in the number of buildings, and associated decreases in natural greenery. As well as changing the visual landscape, the loss of green spaces has created various environmental issues, many of which directly affect human livelihood. For instance, removing vegetation means rain is less likely to soak into the ground and more likely to run off, thus increasing the risk of floods.

To mitigate the risk of flooding in urban areas, a number of strategies have been proposed, including roofs that are covered with vegetation to absorb rainwater. Compared to other strategies, green roofs are relatively low impact as they utilise existing space. As a result, they have become popular across Europe.

A typical green roof consists of several layers, including a vegetation layer, a medium layer, a filtering-drainage layer, and a roof deck layer. However, the ability of green roofs to retain water varies across sites due to climate and vegetation type, as well as the structure and properties of the layers and roof. Previous studies have attempted to identify the factors that influence the relationship between rainfall and runoff (the water that is not absorbed and thus drains away from the roof). However, conclusions have been varied as there remains no simple way to describe the relationship, as it differs on a case-by-case basis.

This study aimed to develop a novel and generalisable model which, unlike past studies, incorporates data on soil moisture, is simple to use, and can be applied on a case-by-case basis. The authors first performed a theoretical analysis of the relationship, using an equation to describe the flow of water in and out of the green roof. They found that soil moisture prior to the rainfall event and the depth of the layer containing growing medium are critical to the relationship. Higher initial soil moisture reduces the ability of the roof to hold water, while having a thicker layer of medium reduces runoff.

To validate their model, they performed a field experiment on a green roof in Beijing, China. The 120 m^2 roof was covered by *Sedum lineare*, an evergreen stonecrop plant originating in East Asia that is ideal for green roofs due to its ability to tolerate cold, draught and little need for soil. The experiment was carried out between April 1 2012 to July 31 2012, during which time 15 rainfall events were observed. Three were particularly heavy, including a severe flood on July 21st, which resulted in 79 deaths and an economic loss of ¥11.64 billion (€1.67 billion). Precipitation, water content in the medium layer and runoff were measured for each event.

Finally, the researchers performed numerical simulations to further investigate the applicability of their model, and the two different mechanisms that generate run-off: saturation-excess (when soil becomes saturated with water) and infiltration-excess (when the intensity of rainfall exceeds the rate at which water can enter the soil).

The model (called HYDRUS-1D) described runoffs for the three heavy rainfall events and separated them into those generated by saturation-excess and infiltration-excess. For the two most extreme rainfall events, runoff was generated by a combination of infiltration-excess and saturation-excess processes. The less intense rainfall event generated runoff only due to saturation. Runoff generated from infiltration-excess tends to occur for short periods when rainfall is very intense, while saturation-excess generates runoff that lasts for longer periods.

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When the researchers quantified the runoff generated by infiltration-excess, they found it contributed only a small proportion of the total runoff. Even for the extreme rainfall event, which was the most severe storm Beijing has seen in the past 60 years, infiltration-excess accounted for just 6% of total runoff. Although adding a slope to the roof in simulations increased infiltration-excess runoff slightly, it remained negligible (9.3%). This suggests saturation-excess is the main cause of runoff on both flat and inclined green roofs, which will be important for future enhancements.

The researchers say that they have created a generally applicable model which makes it possible to estimate runoff using easily measurable parameters such as rainfall depth and initial soil moisture, which has not typically been used to assess runoff in past studies. The model was tested against a field experiment and literature data, proving its consistency and applicability to different conditions, such as more or less intense rainfall and different types of vegetation. The results have also provided important practical advice: a thicker medium layer and low levels of soil moisture increase the effectiveness of green roofs as flood mitigation measures.