Rooftop Agriculture in a Climate Change Perspective

Marielle Dubbeling
Edouard Massonneau

Rooftop agriculture is the production of fresh vegetables, herbs, fruits, edible flowers and possibly some small animals on rooftops for local consumption. Productive green roofs combine food production with ecological benefits, such as reduced rainwater run-off, temperature benefits such as potential reduction of heating and cooling requirements (resulting in reduced emissions), biodiversity, improved aesthetic value and air quality.

Three primary types of food-producing green roofs can be distinguished:

- Agricultural green roofs or direct-producing green roofs on which crops are directly grown in (shallow) beds in a soil-based growing medium that is possibly placed on top of a waterproof membrane or additional layers such as a root barrier, drainage layer and an irrigation system.
- Rooftop container gardens or modular green roofs that involve the growing of vegetables, herbs, fruits and flowers in pots, buckets, containers, bottles or raised beds which contain a soil-based growing medium.
- Rooftop hydroponic systems which involve growing plants using water-based nutrient solutions in place of soil. These require on-going fertiliser inputs. There are exposed hydroponic systems used in open-air settings, as well as hydroponic systems grown under cover (glass or plastic) to help increase yields and extend growing seasons.

Rooftop gardens can be placed on individual homes, institutional and office buildings, and roofs of restaurants and serve either home consumption, use of fresh produce in restaurants or institutional kitchens or commercial production.

Rooftop garden in Toronto, Canada Photo: Joe Nasr

Climate change impacts of rooftop agriculture

Cities concentrate impermeable surfaces like pavement and concrete, impeding storm water drainage as well as absorbing and converting solar radiation to heat. Green roofs can offset these phenomena, depending on the type of production system and local climatic conditions, and make urban areas more sustainable and viable in the long-term. If well designed and maintained, green roofs may also double or triple the life span of the typical roof. This results in reduced maintenance costs and decreases the amount of waste material to be disposed at a landfill site. The initial expense of a green roof may thus be earned back in energy and cost savings and avoided environmental damage.

Green roofs also offer an opportunity to promote inner-city biodiversity on underutilised, empty roofs and to address food security issues through the production of food.

Information on the impact of green roofs on climate change is provided by several researchers, though mainly from the global North. There are minimal surveys to date which deal with the combination of green and productive roofs. It is more difficult to get the same impacts with rooftop agriculture gardens as with green roofs. Unlike green roofs without production of food, the coverage of rooftop agriculture is often not continuous, particularly with seasonal crops. For agricultural roofs there are also additional demands for safety and access, and inputs have to be supplied more regularly.

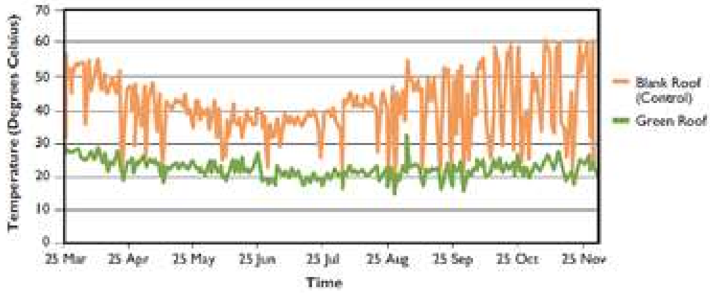
There are also differences among the different rooftop garden systems. In hydroponic systems for instance, due to the lack of soil or an organic growing medium, water run-off is not reduced. Hydroponic systems also require a higher level of (initial) investment and maintenance, thus increasing related energy costs. However, when placed under permanent cover (greenhouses), hydroponic systems will contribute to insulation. As agricultural yields can be high under these systems, contributions to food security will also increase, as well as the related impact on reducing GHG emissions related to transport from food grown outside the city.

Can rooftop gardens reduce the urban heat island effect?

An important problem in cities is the urban heat island effect, or the overheating of cities due to dense concentrations of asphalt (including rooftop and pavements) that absorb solar radiation. On average, temperatures can be between 5°C and 15°C higher in urban areas than in rural areas.

The urban heat island effect contributes to pollution and increased energy consumption. The more temperatures increase, the more people rely on energy-intensive artificial cooling.

Large-scale roof planting can help reduce the urban heat island effect in the inner city through shading, absorption of heat in plant thermal mass and evaporational cooling. Green roofs reduce the air temperature above the rooftops as a result of solar reflection and evapotranspiration. Durban studies showed that the air temperature above a blank roof is higher than above a green roof. The average ambient air temperatures above the green and blank roof were 22°C and 41°C respectively from 24 March 2009 to 24 November 2009.



Average temperature readings taken on blank and green roofs from 24 March 2009 to 24 November 2009. All temperature readings were taken at 13:00 (Van Niekerk et al., 2011)

According to the city's Department for the Environment, on summer days in Chicago temperatures atop the green-roofed City Hall are typically 14 to 44°C cooler than the adjacent county office building, which has a black tar roof.
During summer, green roofs can thus have an impact on cooling homes and buildings. As a result the need for energy-intensive artificial cooling (air conditioners) inside buildings can decrease. Studies in Germany have shown that a green roof habitat can decrease the ambient temperature in underlying rooms by 3–4°C. Canadian researchers found that green roofs reduce the daily energy demand for cooling by 95 % compared to a conventional roof: from 19.3 kWh per m² for a building under a conventional roof to 0.9 kWh per m² for a building under a green roof.

> The impacts of green roofs on climate change are well researched. Information on productive/agricultural rooftops is however very scarce

During winter, green roofs may diminish the energy use for heating by absorbing solar radiation and diminish the heat loss through the roof by providing insulation. The Canadian study found that green roofs can reduce the heat loss from a building by approximately 26 % during the winter months.

Most of the studies referred to, however, have been implemented in temperate and northern climates. The question remains whether similar effects will be observed in tropical climates. Only the Durban study gives insight in the potential positive impacts of green rooftops in a city that experiences a subtropical climate with high temperatures and

Factors influencing the reduction of the urban heat island effect

In order to lower air temperature on the rooftop, best effects are found when a permanent green soil/vegetation coverage on the roof is maintained. Generally, more than 75 % of the roof would have to be under soil/vegetation to have any measureable effects on the urban heat island/energy use and storm-water run-off. Plants with a high leaf surface area, perennial crops, self-seeding plants, and fast-growing plants contribute to maintaining such permanent green cover.

high levels of humidity, particularly in summer. Results of the studies done so far demonstrate that there exists a significant opportunity to reduce the urban heat island effect in Durban by creating green roof habitats on empty roof tops. This refers not only to empty roof tops in the city centre, but also in densely developed suburban areas.

Reductions in energy use and emissions will, however, be offset against energy use and GHG emissions related to maintenance, production and transport of needed materials and inputs. Effects on heating and cooling will also depend on degree of (permanent) cover of the rooftop, local climatic conditions, building insulation, building types and heating and cooling behaviour of the owners (are homes or buildings cooled/heated using energy-intensive equipment?). More research is needed to understand effects on urban temperature and the urban heat island for different types of agricultural green roofs in different localities.

Reducing rainwater run-off

Cities generate a substantial amount of accelerated storm water run-off as a result of large areas of impervious surfaces, such as roof tops and roads. In the case of heavy rainfall, this can result in the capacity of the city's storm water drainage systems being exceeded, resulting in the flooding of rivers, streams, and possibly houses and roads. Projections suggest that climate change will exacerbate this situation by increasing the frequency and intensity of rainfall events.

Factors influencing rainwater run-off

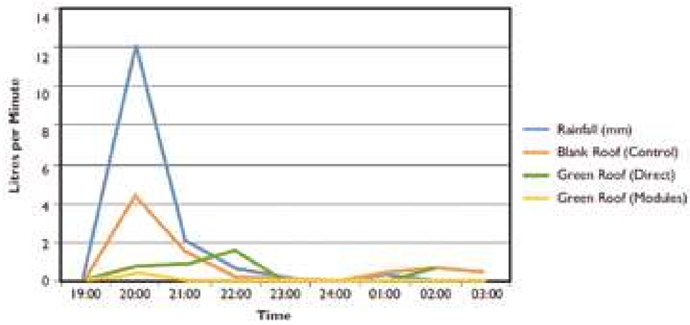
The efficiency to reduce rainwater run-off depends on three factors:

- *soil depth: deeper soil retains more water.*
- *type of plants grown: plants with high leaf surface area intercept more rainwater, plants with a large root mass absorb more water, seasonal crops are less efficient at times of the year when plants are absent or in the development stage (the leaf area is reduced).*
- *green roof surface area and cover: a greater surface area retains more rainwater; year-round coverage is more effective than seasonal coverage.*

Green and productive roof systems may contribute to storm water drainage by reducing the velocity and the amount of rainwater run-off, through the absorption of water by the soil media and plant roots. Impacts depend on the depth of soil or type of substrate used, and the extent and type of vegetation cover.

Experiences in the USA have shown that green roofs may capture 50–95 % of summer rainfall, while peak run-off flows can be reduced approximately 50 %. Other research has shown that 7.5–12.5 cm of soil or growing medium can absorb 75 % of rain showers that are 1.5 cm or less.

According to eThekwini Municipality's Environmental Planning and Climate Protection Department studies on Durban, the amount of the storm water run-off from green roofs is eight times less than the amount from blank roofs. As well, the peak flow from a green roof habitat is far lower than that of a blank roof during a rainfall event. It is important to note that green roofs can also substantially delay the peak run-off. A green roof retains the storm water and releases it slowly over a longer period of time. This reduces the pressure on storm water infrastructure during heavy rainfall events. Germany has started introducing tariffs for storm water run-off that accumulates on impervious surfaces such as roof tops. German studies have shown that a green roof habitat with a soil depth of 10cm can reduce annual storm water run-off by as much as 50 %, thereby effectively halving the amount of roof run-off, which would be subject to annual fees.



Comparison of rainfall run-off from a green roof and blank roof (Van Niekerk et al., 2011)

Biodiversity

Green roofs can add to biodiversity. Compared to a blank roof, a hundred times more insects were identified on a Durban green roof system. Insects were — logically — also found in higher density. In turn, the insects attracted birds. A diverse choice of plants, depth and composition of the growing medium can attract a greater variety of insects and birds. Use of perennial plants, flowering at different times of the year, will be important to offer a permanent source of food and shelter for the insects.
An advantage of the container roof systems is that some small containers can be used as ponds. This creates small aquatic habitats which attract water-loving insects.

Rooftop gardens in Kathmandu, Nepal Photo: ENPHO

Systems	Surface area (ha)	Conservative Estimated Yields (kg/ha)	Produce requirements of 10.000 people (%)
Productive green roofs (without hydroponic system)	2.75[1]	26 000	4.4
Productive green roofs and hydroponic greenhouses	4[2]	346 000	59.5

Vancouver's estimates for food production of green roof systems (Holland Barrs Planning Group et al., 2002)

[1] *half of Vancouver's usable rooftop space*

[2] *hydroponic greenhouses surface area: 1.25 ha*

Reducing food insecurity

Agricultural productive green roofs contribute to food security by producing local fresh food. They provide an interesting opportunity to grow food in inner city and densely built-up areas otherwise often lacking (open) space for food production.

If half of Vancouver's usable rooftop space were used for urban agriculture, it could generate around 4% of the food requirements of 10,000 people. When combining this with hydroponic greenhouses, this figure could be increased to 60%.

In 2003, the City of Toronto owned approximately 1,700 buildings. Researchers proposed to convert 20% of all city-owned rooftops into agricultural green roofs over three to five years. Assuming a modest average food garden surface of 465 m², it would further make approximately 16 hectares available for food production and for moisture absorption.

Tulasi Subedi, Nursing Teacher, Subidhanagar Kathmandu

Despite her hectic schedule, Tulasi Subedi always finds time to work in her rooftop garden, where she has been growing many vegetables recently. Vegetables grown in her own garden cover food needs for her family. She also shares vegetables among her neighbours and relatives. She is not worried anymore about frequent strikes (when shops are closed). "We don't have to buy vegetables during festivals. People praise me after visiting our rooftop garden. There was strike during Constituent Assembly Election. That was not a problem for us as we had spinach, brinjal, radish, carrot, coriander, tomato and other vegetables in our garden," says Subedi.

Food grown on a rooftop, which is consumed by the household or in the neighbourhood, will positively contribute to increased diversification of food and income sources and reduced vulnerability to food price increases and economic crisis.

To address this, KMC and the local NGO Environment and Public Health Organization-ENPHO, supported by UN-Habitat and RUAF Foundation, are promoting productive rooftops, coupled with harvesting rainwater, recycling organic household waste and using climate-smart production technologies, among 139 households. Also, two demonstration gardens have been set up and a demonstration rooftop garden model was developed. In addition, Kathmandu Metropolitan City has trained another 100 households with a view to reaching an additional 500 households in the course of this year. For this purpose, KMC has allocated around USD 30,000 for a rooftop garden program for the upcoming fiscal year 2014/2015. In total, over 14 ha of rooftops would be available in the KMC area. A draft rooftop garden policy has been formulated by the KMC Department for Environmental Management and discussed with local and national policy stakeholders and other urban actors in December 2013. The policy will need to be submitted to KMC for formal approval. Support to the operationalisation of the policy, specifically in other sectors than the environmental management department (e.g., building sector; climate change policies and action plans) is needed to ensure its wider uptake and expansion of activities.

Marielle Dubbeling and Edouard Massonneau
RUAF Foundation
Email corresponding author: m.dubbeling@ruaf.org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Veg prices increase as supply drops

Vegetable prices increase as supply drops Source: República, April 2, 2012

Promoting Rooftop gardening in Kathmandu, Nepal

For many years, Kathmandu has faced large numbers of immigrants from rural areas. Over one million people live in Kathmandu Metropolitan City (KMC), while the rest live in four other municipalities and the surrounding periurban areas.
Uncontrolled and rapid urbanisation has resulted in an increase in environmental pollution, ground water scarcity, waste and water management problems, as well as a rapid decrease in agricultural land. Loss of these production areas, that traditionally provided Kathmandu city with rice, grains, vegetables, poultry and dairy, made it more vulnerable to disruptions in food supply. The city now has to depend on the produce of either rural areas or imports from India or China. The only major access road is often blocked owing to floods or landslides, while the changing climate is likely to increase the frequency of such natural disasters. Climate change has also already affected rural production, resulting in steep increases in vegetable prices in 2012. Protection and preservation of remaining periurban agricultural lands is deemed highly necessary. Additionally, the potential of using built-up spaces, and specifically rooftops, could provide an interesting opportunity to grow food in inner-city areas, otherwise often lacking (open) space for food production.

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