Productive green roofs

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As with many high density cities, Hong Kong's thousands of grey roof spaces constitute a significant proportion of the built area, and represent a severely underutilised asset.

A 'green roof' is a roof that is covered with growing medium and vegetation planted over a waterproofing membrane, typically with some form of root barrier, drainage layer and irrigation system to support it. Green roofs have been incorporated into new buildings and retrofitted to existing buildings since the 1960s and have been shown through numerous scientific studies to offer a wide range of potential environmental benefits and contributions to a sustainable urban lifestyle. Depending on the type of green roof (extensive / intensive) and location, these might include:

- Improving thermal performance and building energy conservation
- Improving urban air quality
- Reducing urban heat island effect
- Improving building sound insulation
- Providing visual greening within the city
- Ameliorating some effects of storm water, and
- Increasing biodiversity and urban wildlife

Since 2011, Development Bureau's 'Skyrise Greening' campaign[1] has promoted the benefits of greening at height in Hong Kong, and has resulted in more than 400 green roofs[2] being established in urban areas. These have mostly been retrofitted to school and infrastructural buildings, for example the award winning Shatin Sewage Treatment Works[3]. The 'Be our Greening Partner campaign'[4] has brought support from commercial and community organizations for this initiative.

Green roofs have rapidly become a key 'green development' tool in the urban expansion and renewal of the city. Following the lead of countries such as Singapore, Germany and France, green building coverage is now mandated for new building projects in Hong Kong[5] and has become a central component of green building certification systems.[6] For landscape architects, green roofs have created exciting new sites for landscape in the city and new technical challenges in dealing with plants in extreme conditions.

Practical issues

In practice, however, problems can occur on green roofs when the long term health of the vegetation is compromised to the point where it cannot perform its functions properly. Common symptoms of failure include: poor plant health / loss of vigour; plant death; growth / predominance of weeds and invasive plants; soil waterlogging, and soil desiccation. These typically result from one or more of the following:

- Poor drainage
- Over watering
- Inadequate irrigation

Brooklyn Grange commercial organic farm, New York

- Soil nutrient deficiencies
- Misuse - unplanned active use
- Use of unsuitable species
- Insects and pathogens (virus, bacteria, fungi)

It is unsurprising that in a recent study of 42 green roof systems in Hong Kong (that had been established for more than 2 years)[7] more than 40% of owners / managers reported significant long-term problems in the performance of their green roof system, and in a small number of cases the green roof had failed outright. Problems appear more prevalent in intensive green roof systems, with thinner soil layers. Green roofs with a greater depth of soil were generally more resilient.

From the study survey, there appear to be a number of underlying causes of green roof under-performance.

• Green roofs are artificial constructions dependent on precise irrigation and effective drainage systems. Small problems or deficiencies in either, can rapidly lead to systemic failure. The vegetation is not self-sustaining and does not function as an urban ecological habitat. Plants are growing in very marginal conditions, and are constantly under stress. The very thin drainage layers have no capacity for storage, and under intense summer monsoon rains the soil above can easily become waterlogged. Conversely, the very thin layers of soil used to support growth, leave plants vulnerable to rapid drying out in the winter months. The number one killer of plants in Hong Kong is too much water, the number two killer is not enough water. Hong Kong's aggressive climate poses big challenges to green roof systems.[8] This problem is compounded by active use. Even seemingly lightweight activities such as pedestrian walking can be sufficient to result in significant compaction of soil layers, and a decline in plant performance. Access to some green roofs has been restricted by managers to avoid such problems.

• Green roofs have very specific maintenance requirements which are more intense than standard horticultural maintenance that might be appropriate for ground level planting. Many managers were completely unaware of the need for: constant monitoring of plant and soil health; regular checking of drainage layers; undertaking very regular soil aeration; and the continual adjustment of watering regimes, all of which are vital to long-term success. Even an understanding of the need for active re-planting, and improvement of soil nutrition was largely absent. Further, the design of many green roofs is reliant on proprietary systems (irrigation, drainage, soil materials, etc.), which tend to be inflexible and difficult to adjust, so may not be resilient in the long-term. We need to recognise that the value of a green roof is dependent on it being maintained in a specific way. Typically they are not conceived as self-sustaining vegetation systems, based on native flora and fauna. In many respects green roof systems are far closer to carpet bedding than urban ecological habitats.[9]

• Ownership has been identified as a key factor in green roof success. Where there is no clear definition of who is responsible for maintenance (i.e. it is 'someone else's issue'), or the approach to maintenance is reactive (act only when problems occur), or the maintenance team is encouraged to minimise effort and expense, then the green roof is likely to fail in time. Up on the roof, planting can be 'out of sight and out of mind', and becomes just another building façade material. Even where there is oversight of rooftop vegetation, it is usually from a distance where plant health problems may not be obvious.[10] Only where an individual or community feels a sense of ownership in a green roof, will it receive the careful and proactive stewardship it needs.

There is still much to be learnt in the design and management of green roof systems, in particular mechanisms for monitoring their health, identifying incipient problems, and taking timely action to address them. Beyond the technical refinements which will come from the continued practice of building and operating green roofs, there are other ways we can improve our approach to greening roofs across the city.

Rooftop farm growing vegetables, corn, lotus and rice, Liuzhou (Photo: Xinhua)

We need to move beyond the ornamental planting of exotic species (in bold geometric patterns). These mono-specific blocks have no ecological value and are not resilient. If they fail, they do so comprehensively. We need to investigate the use of combinations of native species that have a chance of developing into a sustained ecological habitat, or the use of particular species that can actively engage the community in their care and maintenance e.g. productive crop species.

The use of unitary systems, which are more flexible and adaptable to complex roof shapes, and the consideration of partial systems, (i.e. not blanket coverage), would allow for greater depths of soil (up to 250mm) so that a wider variety of plants can be used and existing species choices can be grown in less marginal conditions.

Different operational models that encourage and facilitate active use and positive ownership, should be considered. To be successful in the long-term, a green roof system (indeed, any non-self-sustaining vegetation) has to be planned, designed and managed as a fully integrated part of the natural environment and centred around a resident community that has a vested interest in its on-going maintenance, care and development. Our management of green roofs should recognise that the vegetation, like all landscapes, has seasonal and life-cycle patterns, and will naturally evolve and adapt to environmental conditions. We need sensitive, proactive maintenance of the vegetation (and attendant water, soil and fauna), that help it grow and develop over time.

Where they are safely accessible, and can be designed for active use, green roofs can have considerable community and public health benefits ('soft benefits') in the form of social / community interaction, recreation, and interaction with nature (salutogenic environments).

Productive green roofs

The environmental benefits of rooftop farms (growing crops for food) have been found to be broadly similar to those of more conventional (intensive) green roofs, namely:

- Reduction in solar heat gain, and positive impact on building insulation and urban heat island effect[11]
- Energy conservation, improved thermal performance
- Biodiversity and wildlife
- Improvement in urban air quality
- Noise and sound insulation
- Urban greening[12]
- Buffering stormwater run-off

In addition, rooftop farms can have significant social / community benefits[13], and have the potential to help address the rapidly growing issue of food security for urban areas[13] and help to reduce their ecological foot print.[14]

Rooftop farm projects have been initiated in many high density cities

across the world, in the last ten years. Brooklyn Grange commercial organic farm, and the Eagle Street Farm Greenpoint, in New York City are the best known, but fine examples can be found as far afield as Johannesburg and Bangkok. Even in China rooftop farms are becoming popular with notable examples of people growing vegetables, corn, lotus and even rice on rooftops in Nanhai and Liuzhou.

In Hong Kong, some 45 of the 400 green roofs that have been established, are productive rooftop farms, growing vegetables and fruit (Table 1). These have all been built on grey roofs (rather than as part of a new building development), or are conversions of existing green roofs. They range in size from 25 to 1,000m^2, and the largest can actively engage up to 50 gardeners. They are operated either by the building owner or by a community enterprise group. Demand in many of these rooftop farms outstrips supply, with long waiting lists. The motivations given by owners and users for setting up a productive rooftop farm include:

- Social / community enterprise e.g. City Farm, Taikoo
- Corporate sustainability e.g. Bank of America Tower, Central
- Educational e.g. Australian International School (HK)
- Family e.g. Very MK, Mong Kok
- Restaurant e.g. The Pawn, Wan Chai
- Charitable causes e.g. Feeding Hong Kong at Confucius Hall Secondary School, Causeway Bay

The HKU Rooftop Farming project on the Runme Shaw Building HKU Main Campus (built by the Division of Landscape Architecture and Time2Grow) is an example of a community enterprise project, and is the basis of a new book on rooftop farming in Hong Kong, which is intended to help individuals and community groups create and run productive gardens on their building roofs.[15]

Any comparison of on-line images of traditional green roofs and those of productive rooftop farms reveals one startling difference: people. Where green roofs are seen as decorative planting patterns, rooftop farms are clearly shown as centres of vibrant social communities.

Table 1: Rooftop farms in Hong Kong

Commercial Buildings (6)	
- Mission Green Top, Kowloon Bay	2009
- IPC Foodlab Farm, Fanling	2012
- Hysan Building Rooftop Farm, CWB	2013
- Bank of America Tower Rooftop, Central	2014
- King's Centre, North Point	2014
- Rooftop Republic x Green Monday, Nan Fung Tower, Central	2015
Residential Buildings (9)	
- Kam On Court Parking Building, Shatin	2009
- Yau Ma Tei Gardener Rooftop Farm	2011
- Au Young Family Rooftop Farm, Chai Wan	2011
- SLOW Experience, Wan Chai	2011
- The Pawn Restaurant Rooftop, Wan Chai	2011
- Stella So's Rooftop Farm, Cha Kwo Ling	2012
- Time to Grow x Gardens & co. Urban Farm, Sheungwan	2012
- 11/F Sham Shui Po, Sham Shui Po	2013
- Very MK Rooftop Farm, Mong Kok	2014
Industrial Buildings (10)	
- HK Honey/HK Farm Creative Industry's podium, Ngau Tau Kok	2010
- City Farm - Taikoo, Quarry Bay	2010
- Project GROW, Ma Tau Chung	2011
- Fun n Farm, Kwun Tong	2012
- City Farm - Kwun Tong, Kwun Tong	2012
- City Farm - Tsuen Wan West	2013
- Spring Workshop, Wong Chuk Hang Rd	2014
- Fresh & Green's Balcony, Fo Tan	2014
- Art Garden 818, Kwai Chung	2014
- Crystal Group Rooftop Farm, Kwun Tong	2014
Institutional Buildings (20)	
- HKU Rooftop Farm: Run Me Shaw Building, Simon KY Lee Hall, Pokfulam	2012-2014
- CUHK: Library, Shaw College, Teaching Complex, Wu Yee Sun College, Lee Woo Sing College, Shatin	2012-2014
- Tai Yuen Estate Market Rooftop, Tai Po	2012
- HKCEC Sky Garden, Wanchai	2012
- Australian International School, Kowloon Tong	2012
- HKICC Lee Shau Kee School of Creativity, Kowloon City	2013
- Chinese Young Men's Christian Assc'n Center, Kwai Chung	2013
- JCCAC rooftop farm, Shek Kip Mei	2013
- CityU GROW Rooftop Farm, Kowloon Tong	2014
- CCC Tam Lee Lai Fun Memorial Secondary School, Tuen Mun	2013
- Madam Lau Kam Lung Secondary School, Lam Tei	2014
- Kowloon City Baptist Church Hay Nien Primary School, Ma On Shan	2014
- Lui Ming Choi Primary School, Tsing Yi	2014
- Tan Siu Lin Primary School, Olympic	2014
- Feeding HK Causeway Bay, Causeway Bay	2014

Source: Division of Landscape Architecture HKU Review of green roof performance in Hong Kong (2014)

City Farm, Taikoo is an example of a Private Commercial Enterprise project. It was established on 900m^2 of grey roof space in the ZungFu Industrial building in Taikoo (with subsequent projects in Kwun Tong and Tsuen Wan). The farm is run on rented roof space as a commercial (for-profit) venture. Individuals or small groups of local residents interested in urban farming for fresh food production, health or therapeutic benefits, social interaction and recreation, can rent up to 10 moveable planters (900x600mm) on a monthly basis. Each planter can produce up to 10-15kg produce per year. City Farm advocates green living for city people and the health benefits of "Eat Fresh, Eat Local". The company provides organic soil in planters, planting materials and tools, for growing vegetables. Staff manage the garden and provide daily watering services. City Farm runs 8-week learn-and-practice gardening skills courses, as well as workshops on different urban gardening subjects.

Time2Grow's rooftop farm on 39/F of Bank of America Tower, Central (Photo: Time2Grow)

AIS(HK) Edible Rooftop Community Project at the Australian International School (HK), Kowloon Tong,(pictured above) is an example of an owner-led project. The school renovated approx. 25m^2 of its ailing green roof into a productive garden, with the aim of getting students interested in gardening, raising awareness of food production and healthy living. Managed by the AISHK Edible Roof Club, the garden is funded by club subscription. Set up involved rehabilitating existing planting beds (various sizes, 0.4 - 6.5m^2) and adding new planters, soil materials and gardening equipment. Students of various ages look after the plants once or twice a week after school while the main responsibilities lie on a teacher who manages the garden and ensures essential tasks are undertaken. On weekends and school holidays the tasks are undertaken by building maintenance staff. The garden is seasonal with a growing schedule designed to ensure key planting and harvesting activities happen within term time. The garden has a modest output due to its small-scale operation. Participating students get to keep what they harvest as an encouragement. In terms of raising awareness, and providing a rewarding educational and social experience for students it is highly successful. What was planned as an extra-curricular activity has become a teaching tool for students to learn about food and plant life cycle. It is also a popular venue for other staff and student activities.

Very MK rooftop farm, Mong Kok (Photo: Very MK)

Feeding Hong Kong rooftop farm at Confucius Hall Secondary School, Causeway Bay (Photo: Feeding Hong Kong)

The HKU Rooftop Farming project, Runme Shaw Building HKU Main Campus, was set up in 2012 as a two year research project by the Division of Landscape Architecture, investigating the differences in environmental and technical growing conditions between the city's rooftops and those at a ground level. The farm was designed and constructed by undergraduate students as part of their Landscape Practicum class. The work was funded by HKU knowledge exchange and teaching development grants. The farm was initially 110m², and comprised some 90 planters (typically 600x400mm), growing a variety of vegetable crops. The farm is now managed by the student-led HKU Rooftop Farming team. With the help of Time2Grow (Rooftop Republic), it has now been expanded to more than 400m² and has a community of some 40 active gardeners, all organized via their Facebook page. Farm produce is communally shared, or donated to the on-campus vegetarian restaurant, or given to the Feeding Hong Kong food distribution charity. (Photo: HKU Rooftop Farm)

Commercial production on rooftops

The potential for commercial-scale food production on urban buildings is starting to be explored.[16] Workable techniques and approaches have already been demonstrated,[17] and predictions of food self-sufficiency in the city from rooftop production are beginning to be made.[18] Studies suggest that if access and logistics can be resolved, the roof spaces of large-scale industrial buildings and housing estates can be activated for the production of high value crops grown using hydroponic and aquaponics practices,[19] making a positive contribution to the city's food security and reducing its ecological footprint.

Most commercial productive rooftop farm operations that have been developed to date have been based on some form of vertical farming infrastructure[20], sometimes in combination with aquaponic / hydroponic structures,[21] or more conventional structures such as glass houses[22] or wind / shade structures.

At a more speculative level there are any number of bold architectural proposals for using the facades of buildings for growing crops.[23] The 'agri-tecture' movement[24] gives new definition to the concept of a 'green' building, but issues of access and seasonality of processes have yet to be addressed.

Research is starting into various aspects of vertical farming, including: species growth performance / yield;[25] scale of operation;[26] necessary building modifications;[27] the level of infrastructure required to establish and maintain;[28] different types of planter;[29] the effects of climate on rooftop growth;[30] and operational costs.[31]

Following the lead from a number of recent studies in the USA,[32] the Division of Landscape Architecture, HKU, has just embarked on a new research initiative to map potential rooftop green space in Hong Kong and to develop a mechanism for evaluating the potential for commercial farming on rooftops in high density cities.

Rooftop production is unlikely ever to be commercially competitive with ground level food production due to the cost of installing soil, water, infrastructure, and the added costs of operation at height. Revenues, however, may offset the cost of green roof maintenance, and active use would bring positive stewardship to their management, thereby increasing the chances of long term success. We need to re-evaluate our current approach to 'green buildings', and see if we might make more effective use of our roof spaces as a way of greening the city.

Jack Ng's vertical farm in Singapore uses a rotating structure to gain enough sunlight to grow salad vegetables (Photo: Amusing Planet)

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