World Sustainable Built Environment Conference 2017 Hong Kong
Transforming Our Built Environment through Innovation and Integration:
Putting Ideas into Action
5-7 June 2017

Registration ID: 2052

Productive Green Roofs

ABSTRACT

Although interest in productive gardening, as part of a healthy, high density city lifestyle, is growing rapidly, severe spatial constraints limit opportunities for ground-level community gardens and urban farms. Over the last ten years, community groups in cities around the world have begun to activate under-utilized building roof spaces for use as community-based urban rooftop farms (URF). These spontaneous projects offer valuable opportunities to address this situation by creating city-based venues for food production, social interaction, and active recreation, and have generated a sense of stewardship for the built environment. Additionally, URFs can have environmental and sustainable building benefits, such as improved building thermal performance, reduced urban heat island effect, increased sound insulation, and urban greening, similar to those of traditional green roofs systems.

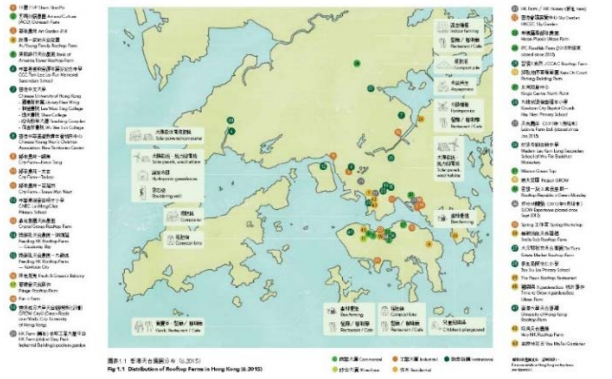
This paper reports on an on-going research study to determine the potential for URFs in Hong Kong. All existing URF projects within the Territory were surveyed, to determine the building, environmental, operational and community conditions under which they occur. Analysis of building and land use across all urban districts revealed that some 594ha of existing roof space may be suitable for farming. Assessment of participation rates in open-to-public farms indicate that URFs could provide opportunities for active participation to more than 18,000 people. Given that existing farms are entirely community driven and receive no policy, technical or financial support from Government, potential participation could be much higher. This suggests considerable positive environmental and social benefits could be achieved at the city-scale if URFs were actively promoted and formally incorporated into urban land use planning and city decision making processes.

Keywords: Urban Rooftop Gardening; Community Empowerment; Healthy Urban Lifestyle.

1. INTRODUCTION

Increasing spatial congestion in high density cities have led to concerns over impoverished environments, unhealthy lifestyles, and low levels of physical activity and community interaction. Opportunities for productive gardening, in particular, are very limited. In Hong Kong, less than 0.1% of the population has access to a private garden and, to date, only 22 ground level (government operated) ‘community farms’ have been established at the urban edges, offering just 1,140 places for would-be gardeners.

In response, some high density urban communities have started to utilize their building roof decks for productive purposes. Since 2009, some 60 urban rooftop farms (URF) have been established on residential, commercial, industrial, and institutional buildings across the city (images 1 & 2). These are run either: by a specific interest community group e.g. a residential, corporate or educational community where participants are drawn from within the building or campus (restricted-access); by a community enterprise which rents roof space to members of the public (open-to-pubic); or (c) privately, as an entirely closed operation (private),. Although the farms are distributed widely, there are notable concentrations within districts such as Kwun Tong, Central and Wanchai.



(1) Urban Rooftop Farms in Hong Kong in 2014, from (Pryor 2016)

(2) Aerial Photo of the Rooftop Farm on 38/f of Hysan Place, Causeway Bay

URFs can be distinguished from ground level farms by their greater spatial limitations and operational complexities (Hui 2011; Thomaier 2015). They emphasise participation rather than production, i.e. involving many participants motivated by personal interest (Pourias et al 2014; da Silva 2016), but working within very small planted areas to produce small quantities of a wide variety of crops. Community benefits such as active stewardship of the urban landscape (Proksch 2014; Pryor 2015) and positive community engagement through place-making (Noori et al. 2016) have been identified as key motivations.

Studies have reported that, in impoverished urban environments, URF's can have similar benefits to green roof installations, e.g. lower solar heat gain and better insulation (Cerón-Palma et al. 2012); improved energy conservation, thermal performance and sound insulation; reduced urban heat island effect (Kitaya et al. 2009); improved air quality (Tong et al 2015); and increased urban biodiversity and positive contribution to urban greening (Borysiak et al. 2016). Specht et al. (2014) also highlighted community benefits of URFs, including higher levels of active recreation, healthier urban life-styles, and greater social interaction amongst participants.

To date, rooftop farming has not been successfully commercialized, but there is growing interest in the potential for large-sale food production on city rooftops (Donald, 2011), to address urban food security issues. Schemes demonstrating commercial potential have been established in Singapore (The Staits Times 2015),

and Guangxi (China Daily, 2014), and researchers are now exploring the use of rooftop glasshouses (Cerón-Palma et al. 2012; Sanyé-Mengual et al. 2015); aquaponic and hydroponic systems (Taylor et al. 2012); and vertical growing structures (Banerjee and Adenaeuer 2013), to increase production. Technical and economic aspects of commercial rooftop farming are being tested, such as: suitable crop species, growing media, growth performance and production capacity of different farming modes (Pfeiffer et al. 2015; Orsini et al. 2014); sustainability of food production and the influence of climate on potential production; and infrastructural requirements and building restrictions in different cities (Specht et al. 2014).

City authorities are actively looking to farming to make a positive contribution to the urban environment (Colding & Barthel 2013; Martin et al. 2014). The potential for URFs at the city-scale, however, has not been examined. A lack of clear definition or performance criteria have made it difficult for URFs to be formalized within urban land use planning and decision making processes. For example, in Hong Kong, they are not recognized as 'green roofs' under Sustainable Building Design Guidelines (Buildings Department 2011), so do not count towards green building coverage.

The objective of this research study has been to make a systematic evaluation of the potential for URFs within Hong Kong, quantifying both the total physical roof space that could be activated for farming, and the possible levels of civic participation in the farms, if established.

2. SURVEY OF EXISTING URBAN ROOF FARMS

The research team conducted a detailed survey of all existing urban rooftop farms and farming operations across the territory, recording the range of building, environmental and community conditions under which they occur. These limits were then mapped against existing land use, building records and census data to give an indication of the possible number of buildings that could be utilized for URF operations, as well as the total area of farmable roof space, and the maximum number of participants that they could support.

Farms were identified from published articles, websites, and aerial photographs, together with reports from managers and participants of known farms. The research team visited each of them over a 4-month period in early 2016, to document the extent and material condition of the roof and the nature of the farm operations. The survey comprised a detailed physical inspection of the building and farm, interviews with farm managers / owners and survey questionnaires of farm participants. City-wide building and population data was compiled from HKSAR Government building records (Building Department), lands use plans (Lands Department) and census data (Census &Statistics Department).

Those that were private or had been in operation for less than two years were excluded. Amongst the remaining 48 farms, 6 (12.5%) were located on residential buildings (built between 1983-00), 11 (22.9%) on institutional buildings (1983-13), 18 (37.5%) on industrial Buildings (1970-03), and 13 (27.15%) being on commercial buildings (1978-13). There were 19 'Open' farms (ave. 42 farmers, total farm area 7,315m^2) and 29 'Restricted' farms (ave. 22 farmers, total farm area 5,270m^2).

In addition to building type and age, data collected to determine the environmental and building limits for URF operations, included: farm location (rooftop / podium deck); rooftop height; means of access (by stairs or lift); roof size and farmed area; other roof uses (e.g. emergency refuge); structural capacity of the roof deck; parapet edge conditions; services / structures; roof drainage; water proofing; water supply; and sunlight / wind exposure. Examples of farms on industrial buildings are shown in images 3 & 4.

(3) Aerial Photo of Hong Kong's Oldest Rooftop Farm, in Quarry Bay

(4) Aerial Photo of the Newly Established City Farm, in Tsuen Wan

During each visit the farm manager / owner was interviewed to understand the history of the farm; building and farm ownership; the funding model and operational structure; the number of participants in the farm and their origin (specific community group or the general public); planter type and typical crop species; soil material and estimated weight; and related activities (instruction sessions, crafts etc.). Managers / owners were further invited to share their experience of the operating limits of rooftop farming.

A questionnaire was distributed through the farm managers to farm participants to generate data on their age and gender; employment status; motivation for participation; frequency and timing of visits; time spent per visit; point of origin (home or work); distance travelled; and level of farming experience.

3. ASSESSMENT OF POTENTIAL FOR URBAN ROOFTOP FARMING IN HONG KONG

Two approaches were adopted to generate a preliminary indication of the potential for URF within Hong Kong, (a) an estimate of physical capacity i.e. the total roof area of all existing buildings capable of supporting URFs, and (b) an estimate of the participatory capacity i.e. applying rates of participation in existing farms (number of participants with respect to their catchment populations), at a city scale.

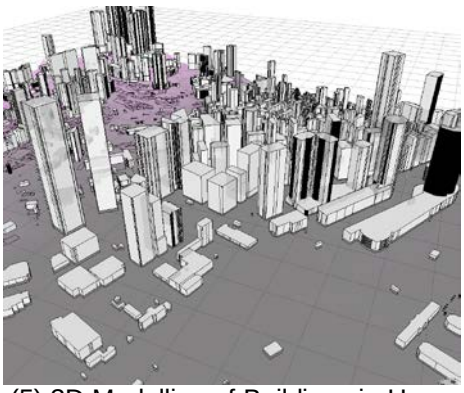
There are some 41,600 buildings within the territory, comprising residential / composite buildings (80.8% of total building stock); institutional buildings, (6.8%); office/ commercial buildings (6.2%); industrial buildings (4.2%) and others (5.0%). An assessment of the number of buildings on which URFs would be possible was made based on limiting factors.

Structural capacity of the roof deck was the primary limiting condition. All existing URFs are on buildings with flat concrete roof decks. With reference to the existing green roof constructions in Hong Kong, it was determined that only those roof decks that had been designed for emergency fire refuge should be included in the assessment, as these were the only ones that had sufficient structural capacity to support the farm, were accessible directly from the roof level or floor immediately below, and could be used safely. Buildings with long span, lightweight structure roofs (e.g. sports halls), and those with pitched roofs were not included. Buildings with secured uses, sensitive rooftop features or property rights issues that would preclude public access, were not included.

Environmental conditions on the roof were not found to be a limiting factor (as had been anticipated). All farm managers reported that growing conditions (sunlight, rain, shelter from winds, presence of insect pollinators) were favourable, due to the screening effects of parapet walls. As the two highest existing URFs were on 38/f and 39/f level, a cut off building height of 39 floors (approximated to +150m) was adopted in the assessment.

Planted area as a percentage of space covered by the farm was measured at between 14% for larger farms and 32% for the smallest, to an average of 24%. The minimum operable area required to sustain a community-based URF was estimated by farm managers at approx. 40m^2 (with an equivalent planted area of 12.0m^2). This effectively excluded all individual, low rise residential buildings.

Farmable roof area was calculated by deducting the space required for rooftop infrastructure (elevator housings, AC units, water tanks etc.) and operational requirements (access to parapet edge for cleaning and inspection, emergency evacuation etc.), from the total building footprint area (measured from building and land survey plans). The typical building footprint area and proportions of roof space taken up by infrastructure and operational requirements was estimated (by building type and height), from building records and land survey plans, for all buildings within two sample urban sub-districts (one in a newer and one in an older urban area). These were cross-checked against aerial photographs.



(5) 3D Modelling of Buildings in Hong Kong based on Footprints and Heights, Used in the Estimation of Potential Farmable Roof Spaces

All existing buildings within urban areas were assessed against these building and operable area limits (image 5), to identify those that could be used for rooftop farming, and estimate the potential farmable space on them, (Table 1). This should be considered as only an estimate, based on measurements of two sub-districts. Going forward, the research team will systematically identify and measure each building.

Table 1. Preliminary estimate of total farmable rooftop space in Hong Kong

Building type	Building height *Low (0-4/floors) Medium (5-12/f) High rise (13-39/f)*	No. useable buildings in HK *(estimate no.)*	Typical building footprint (m^2) *(estimate no.)*	Percentage of building footprint farmable (typical %)	Estimated Farmable area (m^2)
Residential	Low rise	0			0
	Medium rise	2,160	1,250	10%	270,000
	High rise	5,390	1,070	35%	2,018,555
Institutional	Low rise	320	1,820	65%	378,560
	Medium rise	1,220	1,480	50%	902,800
	High rise	80	920	45%	33,120
Commercial	Low rise	60	2,470	20%	29,640
	Medium rise	110	2,200	50%	121,000
	High rise	1,430	2,070	25%	740,025
Industrial	Low rise	540	1,510	75%	611,550
	Medium rise	930	1,360	65%	822,120
	High rise	60	940	45%	25,380
Total		12,300			5,952,750

The second measure looked at the potential public demand for rooftop farming across the territory. Owners of open-to-public farms reported that the only limitation on their current operation was physical space. Uncertainty over legitimacy of rooftop farming as a permitted land use and the Government not yet having recognized URFs as countable green building coverage, were seen as principle capacitors on expansion. Owners noted that their farms were heavily oversubscribed and they had to restrict both membership and the extent of farm area worked by individual participants. This is corroborated by the multiple year waiting lists for similar ground level productive garden plots within community gardens (LCSD 2016).

In interviews, farm managers identified participants as either 'regular farmers', typically visiting the farm four or more times a week for a total of more than 3.5 hours, or 'occasional farmers' who visited only once or twice per week for less than 1.5 hours in total. There were many more occasional farmers then regular farmers in each farm, but farm operations were sustained in the long-term by the regular farms, of whom, they felt, there needed to be at least three.

In open-to-public farms, regular farmers rented 2.0-2.4m^2 of planter space, but occasional farmers usually rented only some 0.5m^2. In restricted farms, space was usually less constrained and was not always subject to subscription. Dedicated regular farmers in these operations could manage planted areas of up to 10.0m^2, with occasional farmers managing 0.9-1.8m^2 planted area, on average. These figures are comparable to the standard plot size in ground level community gardens of 2.25m^2 (LCSD 2016), but small in comparison to individual plot sizes of 9.25m^2 rented out by weekend farms in the New Territories (outside the city) (Fedvmcs 2016), and very considerably below typical rented garden allotment sizes in Europe, of approx. 50m^2 (Bell et al 2016).

Questionnaire responses indicated that the key demographic groups amongst farmers were young professionals (18-25), middle age workers (35-55), and the recently retired (55-75). The elderly (65-85) were widely viewed as a group likely to

become much more involved in future (as the density of farms in the city increased), due to their greater free time and interest in health issues.

Nearly all occasional farmers reported their level of experience as 'very little' or 'none', but regular farmers (who saw themselves as enthusiastic amateurs) reported their experience as 'somewhat competent' to 'competent'. Farm mangers did not consider expertise to be a limiting factor in the development of rooftop farming as instruction and support was readily available, and because the key outcome for most participants was social rather than productive. Farmers reported their key motivations as: learning new things; pleasure in growing things; social interaction; and opportunity for outdoor recreation.

For open-to-public farms, questionnaire responses indicated that more than 64% of participants travelled less than 400m to the farm (<10 minutes) from their point of origin (home or work), with 96% having journeys of 800m (20 minutes) or less. 800m was taken to indicate the likely maximum distance a participant might be prepared to travel to get access to a farm. Based on census data for different urban districts in Hong Kong, the likely population within an 800m radius catchment area around of a given location in the city would be between 31,000 and 54,000 people (C&SD 2016).

Participation rates in existing open-to-public farms, i.e. percentage of the population within the 800m of the location of the farm that was involved with the farm, was estimated at between 0.19% and 0.32%. This is similar to the current participation rates for government run community gardens. Restricted URFs drew participants from much smaller catchments (450-27,500 persons), and had participation rates of between 0.38% and 4.4% of that population. Participants in this type of farm travelled shorter distances (commonly less than 200m) from point of origin (i.e. within the institution or work place).

4. DISCUSSION

Urban rooftop farms have developed spontaneously in many urban districts across Hong Kong over the last few years, without any technical assistance or policy support, suggesting a broad based interest in the activity within the community. This is underpinned by questionnaire responses from existing farmers who cite their motivations for participation as being the desire for healthier lifestyles, social engagement and opportunities to participate in active, nature based recreation, rather than food production. Further, URFs have been established on very different types of building, indicating potential both in terms of the range of spaces that might be available for farms, and the nature of the communities that would be willing to support them.

The survey of current URF operations in Hong Kong, highlighted that the physical restrictions on the use of roof decks for farming were less than anticipated. Since 1970 most building roof decks in the city had been designed for some form of emergency fire escape, giving them the structural capacity to support the weight of rooftop farms, as well as providing suitable safety features and means of access.

Only buildings with lightweight or complex roof construction, such as sports halls, did not have the physical capacity.

Aside from small low rise residences (mostly village houses), the roof decks of most buildings were large enough to support a community based farm. Commercial buildings (of all heights) appear to offer the greatest potential area for developing rooftop farms (ave. <2,000m^2), although low or medium rise industrial buildings had the greatest percentage of useable area (65-75%) due to their having least amount of rooftop installations and operational requirements.

The preliminary estimation of 595ha of farmable roof space on buildings in urban Hong Kong needs detailed verification, but when compared with the total area of existing URFs measured in the survey (1.25ha), suggests considerable potential for expansion of rooftop farming activities, if current capacitors can be addressed.

Further, considering that the area of land used for vegetable, flower, field crop, production in rural farms across the whole of Hong Kong was only 420ha at the end of 2015 (AFCD 2015) and is in steady decline due to continued urbanisation, farmable rooftop space offers a potentially valuable resource, if farming practices can be commercialised.

The number of rooftop farmers engaged in the surveyed URFs (total, 1,435), was similar to the number engaged in the government's community farms, with both being restricted by available farms and farming space. Farm managers' response to the long waiting lists of limiting plot sizes, has helped to maximize the number of participants within the space available, but with rooftop plot sizes much smaller than those for weekend farms in Hong Kong and only a small fraction of average overseas allotment garden plots, there could be strong demand for greater farm space just from current farmers.

Participants of open-to-public farms were drawn from the resident population immediately around the farm. Easy access to farms was reported by farmers as a key consideration in their participation, with the majority travelling less than 10 minutes to the farm. Participation rate in open-to-public farms, based on the population within a notional 800m catchment of a typical urban district, was estimated to be around 0.25%. Simply applying this to the total urban population suggests that territory wide participation in rooftop farming could exceed 18,000 people. With participation rates up to 4.4% in restricted farms, it is possible that total participation could be higher, particularly as more farms became available and travel distances were reduced, and if the initiative was supported by government and promoted centrally.

The study has indicated that there is already a strong demand and a sizeable potential for the development of urban rooftop farming in Hong Kong. Although not yet a component of the Government's New Agricultural Policy (FHB 2016), urban rooftop farms offer a better prospect than traditional urban farms because of the potentially greater farmable area on the city's rooftops, and closer proximity to participant populations. Rooftop farming also aligns directly with policies promoting healthier urban lifestyles; community engagement, and aging in place.

APPENDIX

No appendices used.

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