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Green roof urban farming for buildings in high-density urban cities

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ABSTRACT

Many urban cities in the world are trying to enhance sustainability by improving urban greenery and promoting urban farming. By installing green roofs with urban farming, it is possible to achieve environmental, social and economic sustainability for the buildings in urban cities because it can contribute to the mitigation of environmental problems, enhancement of community functions and development of urban food systems. This paper presents the findings of a research to investigate green roof urban farming for high-density urban cities like Hong Kong. The benefits and potential of rooftop urban farming are examined; some experiences in the world are described. The characteristics and constraints of high-density urban cities are studied and the situation in Hong Kong is evaluated critically. It is hoped that the research information will be useful to promoting sustainable buildings and environment in urban cities.

1. INTRODUCTION

Studies by the United Nations indicated that more and more people are going to inhabit the urban areas than the rural ones (UN, 2010). The level of world urbanization will increase from 50% in 2009 to 69% in 2050. By 2050, urban dwellers will account for 86% of the population in the more developed regions and for 66% of that in the less developed regions. This creates significant pressure to maintaining the ecological equilibrium and harmonising the relationship between nature and the human being (Deelstra and Girardet, 1999).

Nowadays, many urban cities in the world are facing problems of urban heat island (UHI) and lack of greenery space. Some cities are trying to enhance sustainability by improving urban greenery and promoting urban agriculture or farming (Mougeot, 2006; Smit, Ratta and Nasr, 1996). By installing green roofs with urban farming, it is possible to achieve environmental, social and economic sustainability for the buildings in urban cities because it can contribute to the mitigation of environmental problems, enhancement of community functions and development of urban food systems (Bay Localize, 2007; Canadian CED Network, 2007; Kisner, 2008; Kortright, 2001; Lim and Kishnani, 2010).

In Hong Kong, with the growing concerns about environmental issues and the need to promote sustainable urban environment, green roofs have attracted much attention in recent years (Hui, 2009; Urbis Limited, 2007). It is believed that green roofs can help mitigate the adverse effects of UHI in the city and bring the nature back to the urban area. They not only can help lower urban temperatures, but also improve aesthetics and urban psychology, as well as reduce pollutant concentrations and noise (Hui, 2006).

This paper presents the findings of a research to investigate green roof urban farming for high-density urban cities like Hong Kong. The benefits and potential of rooftop urban farming are examined; some experiences in the world are described. The characteristics and constraints of high-density urban cities are studied and the situation in Hong Kong is evaluated critically. It is hoped that the research information will be useful to promoting sustainable buildings and environment in urban cities.

2. GREEN ROOF URBAN FARMING

Previously regarded as unusable space, the landscape of rooftops is being reclaimed for productive and sustainable purposes. There is a growing interest in utilising roof space for urban farming via green roofs. Figure 1 shows an example of rooftop farming in a school in Hong Kong. It consists of a container garden (left) and a shallow raised bed (right).

(Source: Dr. Sam C. M. Hui)

Figure 1. Rooftop farming in a school in Hong Kong

2.1 Green Roof Systems

Green roof systems are living vegetation installed on the roofs (FLL, 2008). They could contribute positively to make cities more liveable by providing green spaces, mitigating UHI, reducing air quality problem, enhancing stormwater management and biodiversity (Luckett, 2009). In fact, green roofs provide a wide range of benefits from amenity to eco-

logical, technical advantages to financial aspects (Hui, 2006). It is believed that cities could benefit from green roofs both in visual, aesthetic and local human climatic amelioration (Weiler and Scholz-Barth, 2009).

In recent years, green roof application and development are becoming more and more popular in many countries, as a useful feature for sustainable building technology (Dunnett and Kingsbury, 2008; Luckett, 2009; Weiler and Scholz-Barth, 2009). Most green roofs in the world today are created to provide attractive green spaces, to reduce the urban heat island effect, to manage stormwater flows, or to save cooling energy. In fact, green roofs can also provide "farmland" for local vegetable and food production.

By setting up edible rooftop gardens or farming on suitable buildings, it is possible to promote more useful and meaningful functions for the green roofs (ARGP, 2008; Canadian CED Network, 2007). As compared with non-agricultural green roofs, rooftop farming has other benefits, different design requirements and implementation considerations. In short, agricultural green roofs are designed for four main purposes (Brown and Carter, 2003):

- Food production
- Active recreation
- Re-using wastes (compost, stormwater)
- Educational opportunities

2.2 Urban Agriculture

Urban agriculture is a localised food system wherein the production, processing, distribution, access/consumption and disposal/recycling of food occur in and around the city (Smit, Ratta and Nasr, 1996). The agricultural activities can enhance the value and quality of life in terms of economic, socio-cultural aspects by growing plants and animals using various spaces in urban areas (Viljoen, Bohn and Howe, 2005; Mougeot, 2006).

There are three main types of urban agriculture: backyard gardens, community gardens, and commercial farms (Brown and Carter, 2003). Backyard gardeners use land around their homes or grow on rooftops and balconies. Community gardeners use larger pieces of land or roof that are subdivided among several households. The produce from both types of gardens are used primarily for home consumption. Urban commercial farms are set up for profit businesses and may combine with commercial kitchens to create value-added food products and sell to farmers markets and restaurants. There are also some public institutional gardens managed by schools, hospitals or charity bodies.

Urban agriculture influences food security, ecology, health, and rate of poverty in a city (Kisner, 2008). It capitalises on local resources, including land, water, labour, and organic waste in order to produce food for the citizens. The important and defining condition of urban agriculture is not only its location but its integration within the city's economic, social and ecological systems (Wilson, 2009; Viljoen, Bohn and Howe, 2005).

2.3 Benefits and Potential

The benefits of urban agriculture are numerous, spanning the economic, social, and environmental sectors (Kisner, 2008; Mougeot, 2006; Smit, Ratta and Nasr, 1996). For example, it contributes to the greening of cities, curbs air pollution, increases humidity, lowers temperatures, and reduces the number of trucks entering the city to deliver food. Rooftop vegetable garden is a strategy for intensifying urban agriculture activities, which can improve nutrition and food security in urban neighbourhoods while reducing dependence on an energy-intensive global food economy. Table 1 summarises the major benefits of green roof urban farming in the context of sustainable development.

Table 1. Major benefits of green roof urban farming

Environmental Sustainability:
● Reduce food transportation
● Reduce wastes by generating less packaging
● Recycle organic wastes by composting
● Mitigate urban heat island
● Increase biodiversity
● Improve air quality
● Improve urban stormwater management
● Sound insulation and noise absorption
Social Sustainability:
● Active community participation
● Community green space and gardens
● Social inclusion: provide fresh food to the poor
● Education
● Local employment
● Amenity space for exercise and recreation
● Aesthetic value
Economic Sustainability:
● Increase local food production and sale
● Increase local food security
● Sell organic vegetable and food
● Access to open space/views increases property value
● Improve roof durability
● Reduce building cooling load and energy costs
● Increase roof life span
● Increase availability of biofuels

Rooftops are currently untapped resources and a package of appropriate design, development incentives, and public support is crucial to exploring their full potential (Bay Localize, 2007). In recent years, concerns about the environment have combined with increased interest in health and community building issues, giving rise to support for food systems as an integral part of sustainable development. Figure 2 shows how green roofs could contribute to the sustainability of an urban environment.

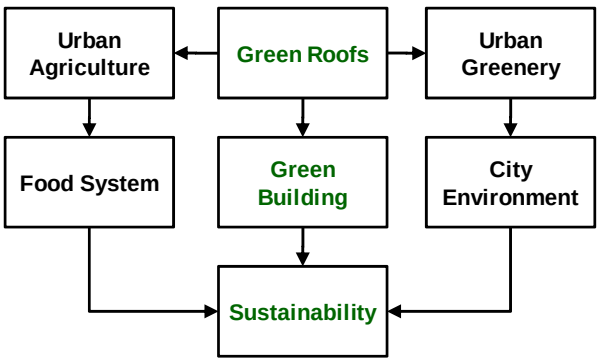


Figure 2. Contribution of green roofs to the sustainability of an urban environment

To achieve a green and productive city, growing food closer to home can help to build awareness of and appreciation for food production (van Veenhuizen, 2006). In fact, many children growing up today in urban cities have no relationship with farming; they have never seen a head of lettuce being grown, or picked a tomato from the vine. It should be noted that such awareness will help to build respect for the Earth and environment on which we all depend.

3. EXPERIENCES IN THE WORLD

In order to illustrate how rooftop farming could be set up and applied in urban cities, some interesting examples from different countries are presented. The rooftop farming ranges from simple containers to beds of soil covering the roof surface. Community development and commercial enterprises can also be established for large scale food production.

3.1 Canada

In recent years urban agriculture has gained considerable momentum in North America. For instance, in Canada there are interesting projects and initiatives on rooftop gardens aiming to develop effective methods for urban agriculture (ARGP, 2008; Canadian CED Network, 2007; Kaethler, 2006; Kortright, 2001; Nasr, MacRae and Kuhns, 2010). Moreover, some municipal and provincial governments in Canada have adopted green roof and urban farming into their urban planning goals and policies. They provided incentives (such as development density bonus and fee rebates) and information to encourage acceptance and market development. One meaningful case study is described below.

Santropol Roulant (www.santropolroulant.org) is a Montreal-based not-for-profit organisation founded in 1995 and run by young people in the community, to address the health and food security needs of seniors and Montrealers living with a loss of autonomy. They bring people together across generations and cultures through an innovative meals-on-wheels service, intergenerational activities and volunteer programmes. Three types of urban agriculture have been developed including rooftop container garden, year-round greenhouse and green roof. They also provide opportunities for hands-on learning in daily activities, workshops and special events. Figure 3 shows the logo of their rooftop gardening project. Further information can be found on the website.

(Source: www.rooftopgardens.ca)
Figure 3. Rooftop gardening project by Santropol Roulant

3.2 USA

The potential for food production in urban cities in USA is great, and many model projects have demonstrated successfully that urban agriculture is both necessary and viable (Bay Localize, 2007; Brown and Carter, 2003; Davis, 2007; Nowak, 2004). A growing consumer demand for fresh, local, and often organic food has created new markets for urban food production. Figure 4 shows one example of commercial organic farming on rooftop (located in New York City).

(Source: http://blog.anandaharvest.org)
Figure 4. Eagle Street Rooftop Farm in New York City

Rooftop urban farming can be an effective arena for the development of small businesses. Many community gardeners, often from the low-income sector, can combine their surplus and sell at farmers' markets or sell food directly to restaurants. In addition, commercial scale urban gardens can utilize raised beds, soil amendments, and season extenders to produce yields that can be many times more per acre than rural farms (Brown and Carter, 2003). Some notable projects in USA are shown here.

- Brooklyn Grange Farm in Queens, New York City: 4,000 m^2 (one acre) commercial organic farming (www.brooklyngrangefarm.com)
- Eagle Street Rooftop Farm in Brooklyn, New York City: a 600 m^2 organic garden on a warehouse rooftop (www.rooftopfarms.org)
- Uncommon Ground, Chicago: the first certified organic rooftop farm in USA (www.uncommonground.com)

In fact, rooftop farming is not only limited to large scale projects. If properly designed and integrated, even a small scale project can obtain significant benefits. Figure 5 shows one example of restaurant-supported salad gardens in a church in San Francisco, which is built upon simple containers.

(Source: www.time.com)
Figure 5. Farming on the roof of the Glide Memorial Church in San Francisco

3.3 UK

In the UK, informed by low-carbon policies, city authorities have considered and implemented measures to promote the development of roof gardens and edible roofs (Garnett, 1999). For instance, about 14% of London's residents now

already grow some food in their gardens. It is estimated that London people could produce up to 18% of the population's nutritional needs. In recent years, an interesting trend is about supermarkets converting their roof space into vegetable gardens. This is partly stimulated by the race to be seen as the UK's greenest supermarket. One example of such is described below.

"Food from the sky" (http://foodfromthesky.org.uk) is a collaboration between a supermarket in North London and a permaculture community garden growing food to sell in the supermarket below while providing a learning and educational space for the different part of the communities. They have vegetables, fruits, mushrooms and herbs grown to organic standard with children and other members of the diverse community. Another large supermarket chain store has announced in 2010 that it is to set up a network of "bee hotels" across London to help reverse the decline in the population of solitary bees. Figure 6 gives an example of rooftop farms in London, with bee keeping.

(Source: www.time.com)

Figure 6. Urban rooftop farming with bee keeping in Hackney, London, UK

3.4 Japan

The Japanese term for "local food" is known as "地産地消" (chisanchishou), which means locally produced and locally consumed, with the first and third kanji being the word soil. The traditional culture in Japan emphasizes on domestic food production and consumption. Therefore, methods to cultivate local urban farming are of utmost importance.

To transform the city into an urban forest that supports biodiversity, the environment and human community, micro-green spaces were created in the urban cities in Japan. For example, Tokyo has an ordinance that requires all buildings to devote 20% of their rooftops to greenery. Some farming areas are also provided on the rooftops and inside the buildings so that people can enjoy life to the vegetable-touch. The urban farming in Japan is often stylish and simple, so it is easy to participate, corresponding to the proposed package of city life. Nowadays, in Japan, it is also fashionable and cool to be a part-time farmer.

Two interesting examples of rooftop farming in Tokyo are described below.

- Omotesando Farm (www.ginzanouen.jp): a roof-top garden rental space in a central upscale commercial and residential district in Tokyo, offering sixteen small plots at rents ranging from US$170 to US$250 per month. On the roof perimeter, vines have been planted to cover the banister. This project combines "LOHAS" (a lifestyle of health and sustainability) with a green business idea that turns wasted space into a profitable business benefiting green entrepreneurs and property owners.

- Roppongi Hills (www.roppongihills.com): it is an experimental urban redevelopment in the heart of Tokyo. The rooftop of the low-rise part of the Roppongi Hills (known as Keyakizaka complex) has a demonstration rice paddy and a vegetable plot (which also serve as dead weight for earthquake mitigation). The 130 m^2 area produced over 40 kg of mochi rice. Figure 7 shows an overview of the rooftop farm.

(Source: www.greenroofs.com)

Figure 7. Rice paddy and vegetable plot at Roppongi Hills in Tokyo, Japan

3.5 Singapore

About 95% of all vegetables consumed in Singapore are imported because Singapore is densely built up and land available for agriculture is limited. Rooftop farming and building integrated agriculture can potentially produce 25% of the vegetables consumed in Singapore. To explore this potential, a demonstration of rooftop farming using hydroponics green roof was set up at Changi General Hospital in 1988 (see Figure 8). The project was run by a group of hospital staff; the produce generated was used for inhouse consumption by patients. However, the farm was now replaced by a garden because the hospital staff cannot continue the day-to-day management.

(Source: www.greenroofs.com)

Figure 8. Demonstration of rooftop farming using hydroponics green roof at Changi General Hospital

A proposal to develop rooftop farming in the public housing estates in Singapore was put forward to address the issue of food security and reduce the carbon footprint associated with food imports (Lim and Kishnani, 2010). If such a scheme is implemented extensively in Singapore, it could result in a 700% increase in domestic vegetable production, satisfying domestic demand by 35.5%.

3.6 Thailand

Bangkok, the capital city of Thailand, used to have enough productive lands to sustainably produce ample food for its citizens because it had a perfect weather and plenty of water resources for irrigation. The city's name came from 'Bang Makok' in Thai, where 'Bang' is the central Thai name for town and 'Ma-kok' is the olive-like fruit trees which were abundant in this area. In fact Thai gardens are edible landscapes and their vegetations serve not only visual purpose but also as a food for the family or restaurants.

However, because of the growth of urban development and the loss of urban agriculture, the city could not supply enough food for people and leads to food security problems. At present the quantity of food is not the food security concerned issue in Bangkok since Thai people can easily access to local cheap street food. The critical problems are the quality of food, cultural loss, loss of biodiversity, and social impacts (Suteethorn, 2009).

An interesting example of rooftop garden in Bangkok is shown in Figure 9. This rooftop garden is cared for by the District Office in Laksi, Bangkok. The main purpose of it is to increase the productivity of the area, enhance the green area, decrease global warming and increase the amount of healthy vegetables grown for household consumption. By using household organic waste in composting, it is also a way to decrease the amount of waste that needs to be managed by the municipality. The rooftop gardening is done in raised beds which are placed on the concrete roof. The beds raise a variety of vegetables, including climbing vines and salad greens. The district office at Laksi is open to all Bangkokians who is interested in gardening, getting advice and they will even give you some seeds to get your garden started.

(Source: www.time.com)

Figure 9. An organic rooftop herb and vegetable garden on a high-rise building in Lak Si District in Bangkok

Suteethorn (2009) has described the background of this garden. In 1999, the staffs of the district office started a nursery on a vacant abandon land next to the government building. At the beginning, they planted flowers and ornamental plants for streetscape. Then they grew more varieties of plants, including herbs and vegetables. A few years later, in year 2002, after they turned the barren site into a tidy nursery, the property's owner requested the rental fee of using his premise. As a matter of fact that they had no budget for any land rental, the nursery had to move out.

Today the vegetable roof garden is located on the 10th floor, on the rooftop of the District office, with the area of 440 m^2. Growing vegetables on the roof may have many limitations but it also has many benefits. The districts staffs turn many unused boards, signage, and street furniture into planting containers and create this urban agriculture on the roof. Besides the production of the gardens, the district office arranges a community meeting, activities, and workshops pertaining urban agriculture twice a month. The fresh vegetables from this project may not be enough for everyone but this is a great example that inspires other to create more urban agriculture sites by themselves. This project helps raise awareness and demonstrate the practical yet efficiency ways of urban agriculture.

3.7 Taiwan

After a new law has been passed in June 1995, apartment rooftops in Taiwan became "public spaces"; building owners or landlords are required to keep access to the rooftop available to all tenants living in the building. The rooftops can be used to store things like plants, gardens, tables and chairs. They can also be used for drying clothes, sunbathing and barbecues. In recent years, some people in Taiwan are trying to identify suitable buildings and develop effective growing methods for promoting rooftop farms. Figure 10 shows an example of rooftop container garden.

(Source: http://photo.xuite.net/yiutsay)

Figure 10. Rooftop container garden in Taipei, Taiwan

It is believed that the cities in Taiwan have acres of underutilised roof space that can be turned into green roofs. To determine the suitability of these green roofs for urban agriculture, it is necessary to study the micro urban environment and growing conditions, and compare different crops and growing methods.

4. HIGH-DENSITY URBAN CITIES

Economic and social imperatives dictate that modern cities must be more concentrated, with high urban density to accommodate the people and to reduce the cost of public services (Hui, 2001). This density presents a challenge to identifying opportunities for urban farming and greenery.

Usually greening activities face a difficult situation because of disordered urbanisation and the escalation in land prices. With increasing population and limited land, the government had to adopt a high-density and high-rise strategy. Space constraints have reduced the applicability of green surfaces in various areas surrounding the building envelope. Consequently, green roofs become the only promising choice for densely populated urban areas.

4.1 Major Constraints

Urban cities often respond to development pressure by setting targets for increased building densities. The result is reflected by high rise cityscape and compact urban settings which may promote UHI and undesirable local microclimate. To mitigate

these effects, some cities are making use of any available plot of land on rooftops, in vacant lots, or in window boxes, to improve the urban landscape (Vandermeulen, *et al.*, 2009).

Although urban agriculture has a lot of benefits, there are a few constraints and limitations on farming in urban areas.

- Lack of available land and suitable space
- Land use control and building regulations
- Microclimate conditions
- The urban way of living makes people disconnect with their own communities
- The availability of low-price imported foods does not encourage people to grow their own vegetables

4.2 Space Issues

The cost of vacant spaces and necessary resources for farming could make the cost of urban agricultural productions higher than the one in rural areas. In order to overcome this barrier, urban farm can be put on top of buildings and other urban infrastructures. In some high-rise buildings, the roof area is occupied by essential equipment such as chiller plant, water tanks, lift motor room, TV antennae and water distribution pipes. It is necessary to identify appropriate roof space and growing method for developing the urban farm.

Many large abandoned rooftops of school buildings, industrial buildings, shopping malls, or gymnasiums, can be sites for urban farm. The vacant roof spaces of large public buildings such as industrial, commercial, or community buildings are potential sites for vegetable gardens. Although there are some difficulties such as moving the vegetations, finding the access to roof areas, or maintaining vegetations on the roof, the all-day exposure to sunlight is suitable for vegetable growing.

4.3 Growing and Maintenance

Although Hong Kong's climate is suitable for agriculture, microclimate in the city can sometimes be difficult for vegetations to grow. For instance, the urban heat, glare, and pollutions can affect the plants growing conditions. Because there is usually no access to natural water resources, rooftop farming also has extra expense on irrigations. Nevertheless, to solve this problem, urban farm can be designed as a stormwater retention to reduce the cost of water uses in agriculture.

In general, vegetables and fruits will require more maintenance than other hardy plants on non-agricultural green roofs. If the farming can recruit workers and volunteers at the neighbourhoods, this can help promote local employment and re-engage the community to participate and be part of the urban harvest.

4.4 Government Support

In order to encourage people to grow their own vegetable gardens, the government needs to put these issues in the land use control and building regulations. It is important that urban farmers receive incentives from growing food because the urban agriculture provides not only local fresh food for the city, but also reduces the cost of food transportation. In addition, the imported low-cost foods have to be controlled to reduce the impact on local agriculture economics.

Rooftop gardens require marketing strategies just like any other product. Building developers, policy makers, engineers, architects, and the public require performance information on the technology, benefits, and costs involved. Even when a city recognises the benefits of rooftop gardens, there is still the need to encourage the construction of green roofs by making them a financially viable option.

5. HONG KONG SITUATION

Hong Kong's urban environment has an extremely high development density pervasively filled by buildings and roads. Population concentrates in the central urban areas surrounding the inner (Victoria) harbour and in some new towns (Hui, 2001). Figure 11 shows those areas in Hong Kong with high population density. The most densely populated district, Kwun Tong (see Figure 12), has a density of over 54 000 people/km^2; some residential areas may even have over 100 000 people/km^2.

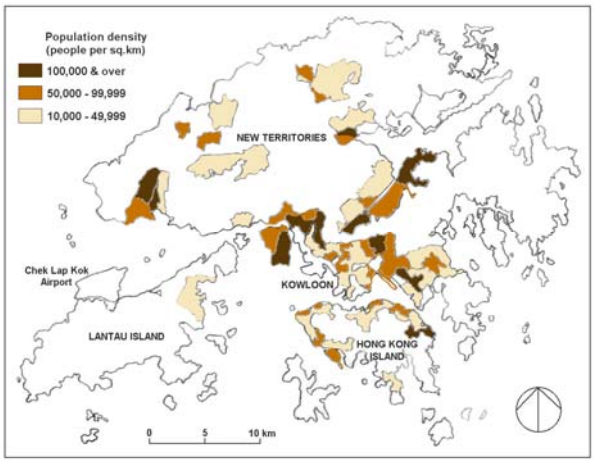


Figure 11. Areas in Hong Kong with high population density

(Source: www.centamap.com/)

Figure 12. Kwung Tung area in Hong Kong

5.1 Common Applications

Since the high-rise buildings have very limited roof spaces, it is usually more effective to apply green roofs to the top of medium- or low-rise buildings/structures or the intermediate podium roofs (Hui and Chan, 2008). By doing this, the occupants from surrounding tall buildings can enjoy the green roof and appreciate the application.

In Hong Kong, green roofs can be found on podium decks, in the form of roof gardens. They are often acting as landscape podiums in residential buildings. Some new commercial and residential buildings also have "sky gardens" on the upper floors or at the top of the building. Many public open spaces are built either wholly or partially on structure.

5.2 Structural Loading

Rooftop gardens are most effective when constructed on the flat roof styles common to many commercial, institutional, or industrial buildings. Depending on the load bearing capability, the buildings can either be retrofitted, or roof gardens can be incorporated into the original design. It is important to look at the structural composition of the building and line that up with what the operations are going to be.

The roof structural loading is a main factor determining the viability and cost of a green roof installation (CUGE, 2010). For a new building having a green roof included in its initial design, the additional roof loading can easily be accommodated, thus the cost could be minor. However, for an existing building, the design will be limited to the loading capacity of the existing roof unless a higher initial cost is paid to upgrade the structure. Retrofitting an existing roof may not be feasible if the structural capacity of the roof is not adequate. Therefore, the weight of a green roof system is of vital importance and it is necessary to select extremely light-weight systems.

5.3 Climatic Factors

Hong Kong has a subtropical hot and humid climate and often faces typhoon and stormwater problems during the rainy season (Hui and Chu, 2009). The strong wind and heavy rainstorm could cause flooding and serious damages to the society. The most important climatic factors affecting rooftop greening and farming include:

- Typhoons. The strong wind might blow away the vegetation and soil. Modules and plants must be well secured and protected.
- Heavy rainfalls. They are quite common in rainy seasons. The green roofs should be able to hold and drain the rain water without creating pools of stagnant standing water.
- High temperature. High temperature might affect some plant species.
- Strong sunlight. Strong solar and UV radiation might cause problems to the green roof materials and components.

5.4 SWOT Analysis

In order to evaluate the potential of rooftop farming in Hong Kong, a SWOT (strengths, weaknesses, opportunities and threats) analysis has been carried out and the results are summarised in Table 2.

Table 2. SWOT analysis of rooftop farming in Hong Kong

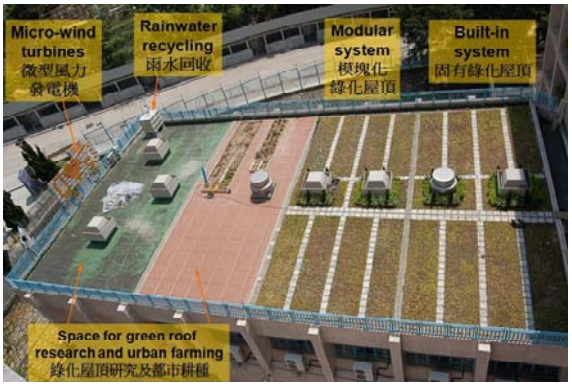
Strengths	- Fresh food, safe & reduce transportation - Many environmental & social benefits - Better use of roof spaces
Weaknesses	- Lack of roof spaces for farming - Perceive agriculture as decaying industry - Lack of research & development
Opportunities	- Growing demand for safe & organic foods - Benefits of community & leisure farming - Need to manage/rehab many old buildings
Threats	- Lack of information and opportunity - Lack of information on urban farming - Typhoon attack & air pollution

5.5 Pilot Study

In 2008-2009, the author has carried out a pilot study of green roof and urban farming in a primary school in Hong Kong. Figure 13 shows an overview of the roof area which is on top of an assembly hall. The following sustainable farming practices are being used in the study:

- Irrigation water from rainwater harvesting
- Electricity from micro-wind turbines or photovoltaics
- Fertiliser from composting

Figure 14 shows the fibre glass containers and raised beds set up for the roof farming. Figure 15 shows a water melon grown on this roof with only 100 mm soil.



(Source: Dr. Sam C. M. Hui)

Figure 13. Sustainable rooftop farming (pilot study)

(Source: Dr. Sam C. M. Hui)

Figure 14. Fibre glass containers and raised beds

(Source: Dr. Sam C. M. Hui)

Figure 15. Water melon grown on the rooftop

6. CONCLUSIONS

In the world nowadays, more and more rooftops are being harnessed to improve the environment of urban cities and enhance the quality of life of inhabitants. It is believed that urban agriculture is a new efficiency concept for sustainable and livable city. Although there are constraints and some limitations in growing food in the cities, the benefits of urban agriculture are tremendously more than the city food supply.

Green roof urban farming can provide many environmental and social benefits to high density urban cities. It is found that Hong Kong has good potential to promote this. When applied to Hong Kong, it is important to consider carefullly the technical issues & local conditions. More efforts are needed to develop design guidelines and practical experience for the industry.

In conclusion, greening and agriculture play an important role in building an environmentally friendly society. It brings about many benefits to our environment, and engages various sectors of the community. It is believed that urban cities in the world like Hong Kong can benefit from the green roof agricultural movement which has just begun.

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REFERENCES

ARGP, 2008. *Guide to Setting Up Your Own Edible Rooftop Garden*, Alternatives and the Rooftop Garden Project (ARGP), Montreal, QC. (available at www.rooftopgardens.ca)

Bay Localize, 2007. *Tapping the Potential of Urban Rooftops: Roof top Resources Neighborhood Assessment: Final Report*, Bay Localize, Oakland, CA. (available at (www.baylocalize.org)

Brown, K. H. and Carter, A., 2003. *Urban Agriculture and Community Food Security in the United States: Farming from the City Center to the Urban Fringe*, North American Urban Agriculture Committee, Community Food Security Coalition (CFSC), Venice, CA. (available at www.foodsecurity.org)

Canadian CED Network, 2007. *The Rooftop Garden Project*, Profile of International Partnership in Community Economic Development (CED), Canadian CED Network, Victoria, BC. (available at www.ccednet-rcdec.ca)

CUGE, 2010. *CS E 01: 2010, Guidelines on Design Loads for Rooftop Greenery*, Centre for Urban Greenery and Ecology (CUGE), Singapore.

Davis, C., 2007. *Babylon Reconsidered: Community Development Through Rooftop Urban Agriculture*, MArch Thesis, University of Cincinnati, Cincinnati, Ohio.

Deelstra, T. and Girardet, H., 1999. Urban agriculture and sustainable cities, *Proc. of the International Workshop "Growing Cities Growing Food"*, Havana, Cuba, October 1999, Thematic Paper 2, p. 43-65. (available at www.ruaf.org)

Dunnett, N. and Kingsbury, N., 2008. *Planting Green Roofs and Living Walls*, Revised and Updated Edition, Timber Press, Oregon.

FLL, 2008. *Guidelines for the Planning, Construction and Maintenance of Green Roofing*, 2008 edition, Forschungsgesellschaft Landschaftsentwicklung Landschaftsbau e.V. (FLL), Bonn.

Garnett, T., 1999. Urban agriculture in London: rethinking our food economy, *Proc. of the International Workshop "Growing Cities Growing Food"*, Havana, Cuba, October 1999, City Case Study, p. 447-500. (available at www.ruaf.org)

Holland Barrs Planning Group, 2002. *Southeast False Creek Urban Agriculture Strategy*, prepared for City of Vancouver, Vancouver, BC. (available at http://vancouver.ca/commsvcs/southeast/)

Hui, S. C. M., 2009. *Study of Thermal and Energy Performance of Green Roof Systems: Final Report*, Department of Mechanical Engineering, The University of Hong Kong, Hong Kong.

Hui, S. C. M., 2006. Benefits and potential applications of green roof systems in Hong Kong, In *Proc. of the 2nd Megacities International Conference 2006*, 1-2 December 2006, Guangzhou, China, pp. 351-360.

Hui, S. C. M., 2001. Low energy building design in high density urban cities, *Renewable Energy*, 24 (3-4): 627-640.

Hui, S. C. M. and Chan, H. M., 2008. Development of modular green roofs for high-density urban cities, paper presented at *the World Green Roof Congress 2008*, 17-18 September 2008, London, 12 pages.

Hui, S. C. M. and Chu, C. H. T., 2009. Green roofs for stormwater mitigation in Hong Kong, In *Proc. of the Joint Symposium 2009: Design for Sustainable Performance*, 25 November 2009, Kowloon Shangri-La Hotel, Hong Kong, p. 10.1-10.11.

Kaethler, T. M., 2006. *Growing Space: the Potential for Urban Agriculture in the City of Vancouver*, School of Community and Regional Planning, University of British Columbia, Vancouver.

Kisner, C., 2008. *Green Roofs for Urban Food Security and Environmental Sustainability*, Climate Institute, Washington, DC. (available at www.climate.org)

Kortright, R., 2001. *Evaluating the Potential of Green Roof Agriculture: A Demonstration Project*, Trent University, Peterborough, Canada.

Lim, Y. A. and Kishnani, N. T., 2010. Building integrated agriculture: utilising rooftops for sustainable food crop cultivation in Singapore, *Journal of Green Building*, 5 (2): 105-113.

Luckett, K., 2009. *Green Roof Construction and Maintenance*, McGraw-Hill, New York.

Mougeot, L. J. A., 2006. *Growing Better Cities: Urban Agriculture for Sustainable Development*, International Development Research Centre, Ottawa, Ontario, Canada.

Nasr, J., MacRae, R. and Kuhns, J., 2010. *Scaling up Urban Agriculture in Toronto: Building the Infrastructure*, George Cedric Metcalf Charitable Foundation, Toronto, Ontario. (available at www.metcalffoundation.com)

Nowak, M., 2004. *Urban Agriculture on the Rooftop*, Senior Honors Thesis, Cornell University, Ithaca, NY. (available at http://lib.f0.am/_media/roofgarden_thesis.pdf)

Smit, J., Ratta, A. and Nasr, J., 1996. *Urban Agriculture: Food, Jobs and Sustainable Cities*, United Nations Development Programme (UNDP), Habitat II Series, New York.

Suteethorn, K., 2009. Urban agriculture: ecological functions for urban landscape, Full paper for the *2009 Incheon IFLA APR Congress*, Incheon, Korea, September 1-4, 2009, International Federation of Landscape Architects (IFLA), Asia-Pacific Region (APR), Brussels, Belgium.

Trewavas, A., 2001. Urban myths of organic farming, *Nature*, 410 (2001): 409-410.

UN, 2010. *World Urbanization Prospects, the 2009 Revision: Highlights*, Population Division, Department of Economic and Social Affairs, United Nations (UN), New York.

Urbis Limited, 2007. *Study on Green Roof Application in Hong Kong, Final Report*, Architectural Services Department, Hong Kong.

van Veenhuizen, R. (ed.), 2006. *Cities Farming for the Future: Urban Agriculture for Green and Productive Cities*, International Development Research Centre, Ottawa.
Vandermeulen, V., *et al.*, 2009. Farmland for tomorrow in densely populated areas, *Land Use Policy*, 26 (2009): 859-868.
Viljoen, A., Bohn, K. and Howe, J., 2005. *Continuous Productive Urban Landscapes: Designing Urban Agriculture for Sustainable Cities*, Architectural Press, Oxford.
Weiler, S. and Scholz-Barth, K., 2009. *Green Roof Systems: A Guide to the Planning, Design and Construction of Building Over Structure*, John Wiley, Hoboken, N.J. and Chichester.
Wilson, A., 2009. Growing food locally: integrating agriculture into the built environment, *Environmental Building News*, Vol. 18, No. 2, February 1, 2009. (available at www.buildinggreen.com)

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高密度城市建筑屋顶绿化及都市农业

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摘要

世界上许多城市正在努力改善城市绿化和促进都市农业，以提高可持续性。通过安装绿色屋顶及都市农业，是有可能为城市建筑实现环境、社会和经济的可持续性，因为它可以有助于缓解环境问题，增强社区功能和发展城市粮食系统。本文介绍了一项研究结果，调查屋顶绿化及都市农业应用在像香港般的高密度城市之情况。探讨了屋顶都市农业的好处和潜力，并描述在世界上的一些经验。研究了高密度城市的特点和限制，也批判地探讨了香港的情况。希望这研究资料可以帮助促进可持续建筑和城市环境。