RICS COBRA 2013

OPTIONS FOR GREEN ROOF RETROFIT AND URBAN FOOD PRODUCTION IN THE SYDNEY CBD

Sara J Wilkinson[1], Sumita Ghosh[2] and Lindsay Page[3]

[123] *School of Built Environment, University of Technology, Sydney, POB 123 Broadway, Ultimo, Sydney, 2007, Australia*

ABSTRACT

The benefits of retrofitting existing buildings with vegetated roofs are environmental, economic and social. Economic benefits include lower construction costs, lower running costs, and reduced costs of borrowing whilst the social gains include retention of familiar landmarks and cultural capital. Environmental gains include retention of embodied carbon, and the re-use of existing materials. The environmental benefits are improved thermal performance and reduced heat loss and heat gain in buildings. This can lead to reduced operational energy costs for owners and tenants, providing economic benefits. However, the environmental social and economic gains are not perceived sufficient to persuade many owners to retrofit green roofs. Social, psychological and therapeutic gains occur when the roof is visible to users and is used for social interaction and relaxation. As an alternative food production system, green roofs could promote a shorter food supply chain, contribute to healthier communities and create local jobs and notably; reduce the carbon footprints of food production. A little explored environmental gain in Sydney is the retrofit of roofs for urban food production. No empirical research has been conducted into the plant species best suited to urban food production, including native food plants, and the optimum substrate composition and depth, required to suit the NSW climate. The barriers and opportunities for urban food production in a high-density urban environment also require investigation.

Keywords: retrofit, green roofs, urban food production, Sydney.

INTRODUCTION

This paper discusses the potentiality of utilising modular, intensive green roof technology to create rooftop vegetable gardens on existing buildings with a view to minimizing food miles, shortening the supply chain and reducing the carbon footprint of growing and transporting food. “Roofs can represent up to 32% of the horizontal surface of built-up areas” (Frazer, 2005) and many have the potential to become urban farmland. There are many successful examples established overseas such as “Eagle Street Rooftop Farm” which is has over 500 square metres of intensive green roof sustaining an organic vegetable farm located on a warehouse rooftop in Greenpoint, Brooklyn, USA (Rooftop Farms, 2013). The utilisation of existing urban horizontal

[1] Sara.Wilkinson@uts.edu.au
[2] Sumita.Ghosh@uts.edu.au
[3] Lindsay.Page@uts.edu.au

spaces as farmland increases the food security of a city. As global temperatures rise and crops fail, and droughts become more frequent and severe, it will become increasingly desirable to equip urban dwellers with the ability to cultivate food, or to encourage urban farmers to produce food locally. Concomitant to these outcomes, are the social benefits and the financial and environmental imperatives.

A green roof offers a building and its surrounding environment many benefits. These include storm-water management, improved water run-off quality (Mentens,2006; Hilten, 2008) improved air quality in the urban canyon (Yang, 2008:88), longer durability of a roof skin (Kohler, 2002:91) increased efficiency of energy use in buildings (Castleton, 2010:62) and a reduction of the urban heat island effect (Takebashi, 2009:92). Other benefits also include enhanced architectural interest and biodiversity (Castleton, 2010:62) as well as re-introducing the natural world into the anthropogenic environment. This research considers the economic and environmental benefits of *retrofitting* existing buildings with green roofs for owners and investors, and the desirable social and psychological impacts on the inhabitants including the potential betterment of the community by utilising roof space for urban agriculture.

Research Question

There is a growing body of research on urban food production and retrofitting of existing buildings. However much of the empirical research has been undertaken in cities outside of Australia which have quite different climatic conditions. This research addresses the questions (a); *what are the barriers and opportunities that exist in respect of urban food production in the Sydney CBD*? Secondly; *what are the options in respect of retrofitting green roofs (extensive and intensive) or vegetated roof top gardens?* The objective is to identify the gaps in knowledge for the city and to establish a research agenda to close the knowledge gaps.

Research Method

This initial stage of the research comprises a desktop study and literature review. The aim is to gain a deeper understanding of the factors that act as barriers and opportunities with respect to urban food production within the Sydney CBD. Secondly the literature review highlights the experiences of others in respect of options regarding the specification of vegetated roofs. The initial scoping of the research agenda follows an inductive and qualitative approach to research (Silverman, 1997).

THE CASE FOR RETROFIT

The built environment is responsible for around 40% of global carbon emissions and has a significant role to play in attempts to mitigate anthropogenic climate change (UNEP, 2006). 87% of the buildings that the UK will have in 2050 are already built (Kelly, 2008) and with only 1-2% added to the total stock of buildings typically in global cities; retrofit of existing buildings for sustainability is a priority. Retrofit is defined as;

> *'the process of modifying something after it has been manufactured. For buildings, this means making changes to the systems inside the building or even the structure itself at some point after its initial construction and occupation'* (City of Melbourne, 2013).

This is a broad definition, and the modification of an existing building to accommodate a green roof falls within this definition of retrofit. There are social, economic and environmental benefits associated with green roof retrofit. Social benefits include the retention of existing structures familiar to the local community (Bromley et al, 2005). Social sustainability is important, though challenging to measure and compare to economic and environmental benefits. Often retrofit exists as part of urban regeneration and allows development of the new alongside the old (Bullen, 2007). Retrofit is not always possible or desirable especially where it is not possible to achieve the standards required in contemporary legislation. Another social benefit from a retrofitted green roof is the perception of a closer relationship to the natural world, "the biophilia phenomenon" (Kellert and Wilson, 1993). Finally the aesthetics of the roof may be enhanced through green roof retrofit. There are very strong environmental benefits of retrofit (Douglas, 2006). Particularly the retention of existing carbon, as well as cost benefits derived through lower operational costs achieved through energy savings (Bullen, 2007). Demolition is wasteful of resources that typically end up in landfill. Retrofitting with green roofs could reduce the urban heat island effect whereby temperatures are typically up to five degrees higher than the surrounding suburbs (Williams, 2010:60). The thermal performance of the roof is improved with the installation of a green roof, reducing energy consumption and carbon emissions. Storm-water run-off may be reduced through green roof retrofit and rainwater harvesting may be employed to reduce potable water consumption. The economic benefits are that retrofit is cheaper than new build if the construction form is straightforward (Bullen 2007), and that costs of finance tend to be lower as the building may remain occupied during retrofit (Highfield, 2000). Where the build quality is poor, costs may be more expensive (Bullen, 2007). Property values are enhanced with retrofit projects (Chau et al, 2003). With green roof retrofit, maintenance costs are reduced and new employment opportunities created.

Suitability for a green roof retrofit is reliant on aspects such as the roof size, type and pitch. Additional requirements include good drainage, lightweight growth media, waterproofing, additional structural support, rainwater harvesting and the use of drought or heat tolerant plants. Longevity of the structure, drainage and waterproofing system is essential because replacement costs are high. Green roofs are designed to last a minimum of 50 years, which is approximately twice the life cycle of a roof covering such as bituminous felt. Criteria taken into consideration when deciding whether a roof is suitable for retrofitting are: position of the building, location, orientation of the roof, height above ground, pitch, load bearing capacity of the roof, preferred planting palette, sustainability and maintenance. The first six criteria are physical attributes and the last three are related to client desires and maintenance. With rooftop gardens, the criteria are similar; however the membrane has more exposure and will require periodic maintenance and eventual replacement. The advantage of the rooftop garden is that the installation is potentially re-locatable, reusable and cheaper.

GREEN ROOFS

Green roofs can be separated into three main categories, extensive, intensive and vegetated rooftops (or rooftop gardens). Extensive roofs, aka ecoroofs, have substrate depths less than 20cm, require minimal or no irrigation and are generally planted with low growing succulents and stress tolerant herbaceous species (Obendorfer, 2007; Snodgrass, 2006:39). Intensive green roofs, have greater variations in substrate depth, typically with depths of more than 20cm, and may host a greater variety of plants and shrubs. Rooftop gardens are typically small containerised garden beds interspersed with hodological and recreational spaces utilizing varying depths of substrate with a higher organic component than extensive and intensive rooftops. This enables them to sustain a wider variety of plant species, including fruit and vegetable crops. Rooftop gardens provide a fecund amenity and a desirable aesthetic and are usually designed as places of recreation for building users, whilst incorporating some of the environmental and economic benefits of intensive green roofs without being physically incorporated into the permanent structure. It is difficult to provide accurate costings for the installation of any of these types of green roof, due to case by case variables; such as site access and utilisation of cranes/goods lifts.

Factors which can escalate costs for green roofs retrofits include increased structural loads, whereby the slab needs to support the weight of wet soil, planting and planter walls. In some cases the structure might need upgrading e.g. columns and foundations. Waterproof testing of the membrane is generally required, and perimeter fall protection may need upgrading e.g. provision of balustrades, depending on whether the area is designated accessible. If the roof is accessible for general use, better egress than standard roof access specification is required, such as additional lighting and signage. Furthermore designers, due to their lack of familiarity with the specification, often prefer to have some 'insurance' in the design in relation to falls, membrane quality and drainage which can inflate costs. Another factor influencing costs can be the installation of additional rainwater harvesting equipment. However, insulation costs may, in theory, be reduced due to the thermal properties of the rooftop substrate and vegetation. Costs include hard landscaping such as planter walls, secondary membranes, drainage cell, paving and shade structures and soft landscaping items such as soils, mulch, planting and irrigation. Additional maintenance costs occur during the building lifecycle. The current view in Australia is that green roofs are expensive and often value engineered out of a design on the basis of affordability (Lend Lease 2013).

Urban Food Production

As millions face starvation globally and the proliferation of food waste becomes endemic, a recent report released by the Institution of Mechanical Engineers estimated "that 30-50% (or 1.2-2 billion tonnes) of all food produced is lost before reaching a human stomach" (Fox, 2013). Some reasons are poor engineering and agricultural practices, inadequate transport and storage infrastructure. Urban rooftop farming has the potential to ameliorate some of these problems by shortening the food supply chain. One advantage of growing food close to consumers is reduced carbon miles. Currently, fresh food consumed in cities is trucked great distances. It is estimated that the cost of transport of a $1 supermarket lettuce is around 40 cents (Midmore, 2011). Rooftop agriculture has the potential to create healthier communities in alimentary and psychological ways. Urban rooftop agriculture could provide fresh, healthy, nutritious produce due to reduced time spent in transit and storage. City dwellers and workers are increasingly detached from nature, and this contributes to rising stress levels and dissatisfaction with contemporary society (Shepard, 1995). Kellert and Wilson *in Zubevich* (2003) claimed that "humans have a profound need for regular contact with the natural environment for continued wellbeing". "Rooftop gardening means taking up an inspiring, ecological and productive activity, and developing new links with the food chain, the seasons, the environment and the community" (Germain, 2008).

A supplementary social benefit of rooftop agriculture may be community volunteer programmes whereby residents and workers engage in food production. An example is the Eagle Street rooftop farm in Brooklyn New York (Rooftop Farms, 2013) which operates a small community supported agriculture (CSA) program and an onsite farm market which caters to area restaurants. It utilises trained interns and urban farming apprentices and hosts volunteers during growing seasons. In partnership with Growing Chefs the farm hosts educational and volunteer programs to bring city-dwellers closer to their food source (Growing Chefs, 2013). Although there are many successful examples of urban agriculture in the northern hemisphere, it is surprising that Sydney has so few examples of urban food production and to date, no empirical studies as to its viability. Sydney is located in a temperate climatic zone with rainfall spread throughout the year. Annual meteorological data for 2012, showed 1213.6mm of rainfall, a mean maximum temperature of 22.7°C and a mean minimum of 14.4°**C** (BoM, 2013). Sydney's annual average of sunshine is almost seven hours a day (City of Sydney, 2013). Sydney's rainfall averages 11 wet days per month, and over 40% falls between March and June.

New South Wales Government Agencies and the University of New South Wales have been developing climate change forecasts for the NSW State Plan regions and Sydney's weather is projected to be hotter over all seasons (2 to 3^0 C) ; with summer rainfall projected to increase by 20-50% and winter rainfall projected to decrease. The pattern of the El Niño-Southern Oscillation cycle is projected to continue but with higher temperatures than currently experienced. El Niño years are likely to continue to be drier than average and become hotter. La Niña years are likely to continue to be wetter than average and also to become warmer. In El Niño events, water stress is projected to be more intense due to higher temperatures. During La Niña years, storms with heavy downpours are projected to be more frequent (Dept. of Environment and Climate change NSW, 2008). Given these predictions of climate change impact on Sydney's growing seasons, rooftop farmers will need to adapt their taxonomical palette.

As of June 2010, the City of Sydney houses 182,000 people. Sydney CBD has an approximate area of 25 km^2 and a population density of $6780.2/km^2$ (City of Sydney, 2013). Based on other studies on the potential for green roofs retrofit (Osmond, 2012), it is possible that 17-20% of Sydney rooftops could accommodate intensive green roofs. There are over 17.5 million square metres of built form within the Central Business District (CBD) of the City. Whilst no data exists regarding the potential for vegetated rooftop gardens, given that there are 17.5 km^2 of roofs with a 20% intensive green roof potentiality factor; approximately 3.5 km^2 of roof space is available to support urban agriculture in containerized garden beds.

Barriers

Plants grown on rooftops will be subject to extreme environmental conditions. In Sydney these will include extreme temperatures and wind velocities. January 2013 was host to several of Sydney's hottest days on record and temperatures of more than 45^0Celsius were recorded (BoM, 2013). Such extreme weather will cause tremendous stress on food crops. With climate change predictions assuming hotter and drier summers, rooftop agriculture in Sydney will require constant maintenance and/or the installation of sophisticated watering systems. Another barrier to rooftop agriculture may be the physical harm to plants caused by predators such as the Sulphur-crested Cockatoo and the Brush-tailed Possum both of which can be found in abundance in and around urban Sydney. To date, little research has been conducted into the humane control of native vermin on rooftops and ways of protecting urban food crops. Another under explored potential barrier could be the effect of rooftop flue emissions on edible plants. Pollution abatement is often cited as being one of the benefits of green roof technology. Airborne particulates are caught within the vegetation and the pollutants are filtered naturally through the planting systems. More research needs to be undertaken on the potential side effects of consuming vegetation that may have filtered airborne pollutants.

The institutional or organizational barriers to rooftop installations include concerns with regards to health and safety of building users going onto roof spaces. There are issues with regards to liability and some organizations are more risk averse than others. Observations and field investigations of 19 vegetated roofs in the United States revealed unsafe access for workers and equipment, a lack of fall-protection measures, and other site-specific hazards (Behm, 2012). The installation of a green roof requires that large amounts of materials are transported often, through the building to the roof. Access is also required for maintenance of the roof garden. Other owners are reluctant to allow people onto roof areas because they perceive this to be a security issue, although the increase in rooftop recreation areas such as bars, spas, cinemas and wedding venues may reflect a change in perceptions. There are opportunities for the roof space to be leased to gardeners and become income generating as a result (Pop-up Veggie Patch Melbourne, 2013). The Pop-up Veggie Patch Company in Melbourne charge $25 per week to users for a single raised bed that is approximately 1500 mm squared. It is possible that institutional green roof sub-leases could be developed to cover owner liability, as well as to incentivize and encourage a greater take up for roof top food production.

Gaps in knowledge

The literature review has identified a number of gaps n knowledge in relation to green roof retrofit in Sydney CBD and urban food production. These gaps are as follows;

1. Limited reliable installation and maintenance costs data is available exacerbated by variations in specifications.
2. Unknown reduced running costs to owners.
3. Unknown value of income generated through leasing rooftops for food productions.
4. Viability and demand for green roof sub-leases.
5. Amount and types of food which can be grown in the CBD.
6. Amount and types of pollutants potentially absorbed by vegetation grown on rooftops.
7. Carbon food miles related to urban food production.
8. Enhanced alimentary value of rooftop food compared to supermarket equivalent.
9. Reductions in food waste in food production.
10. Biophilial benefits to building users and participants in urban food production.
11. The extent to which predicted climate change/weather patterns will affect the amount, growing cycles and types of food which may be produced.

12. The extent and degree of O.H. and S. issues facing owners and users.

Conclusion

This paper has shown, through an extensive literature review that numerous environmental social and economic benefits exist, however little or no empirical evidence relates to Sydney. Moreover there are a number of barriers which might affect the economic and environmental viability of green roof retrofits and further research is required to determine the exact nature and degree of these barriers. Urban food production on retrofitted green roofs may be cost effective but it seems that this is more likely to comprise roof gardens rather than intensive and extensive vegetated roofs. If income can be generated through sub leases, owner/institutional barriers may be overcome. The barriers relating to access and security may be found to be somewhat spurious given the recent proliferation of rooftop recreation areas. An action research approach needs to be carried out that should include the establishment of several containerized rooftop vegetable gardens with varying substrate depths and types, growing a wide range of edible plants. Ideally these gardens can be retrofitted to a building/buildings that have a fresh food outlet that is willing to provide green waste for the creation of compost and vermiculture on site, to facilitate in a sustainable fashion, the ongoing soil enrichment required by organic vegetable production. These sites should be equipped with climate/weather monitoring equipment for the collection of data, Excess water runoff from the gardens should also be recorded, post pluvial events, to compare other hydrological data being collected from the site. Also, an inventory should be kept of what foods are being grown, and in what quantities. Another component of the project should be an analysis of the carbon footprint and carbon miles of the food produced on site. Where possible, if these pilot projects can involve volunteering from the building's inhabitants, or the general community; interviews with the volunteers should be conducted as a means of data collection to qualify the perceived degree of social benefits being derived from interacting with the gardens.

References:-

Australian bureau of meteorology. (n.d.). Retrieved January 31, 2013, from www.bom.gov.au.

Australian Bureau of Statistics. (n.d.). Retrieved January 31, 2013, from http://www.abs.gov.au/AUSSTATS.

Behm, M. (2012). Safe design suggestions for vegetated roofs. *Journal of Construction Engineering and Management* , *138* (8), 999-1003.

Bromley R.D.F., A. R. Tallon, & Thomas, C. J. (2005). "City centre regeneration through residential development: Contributing to sustainability." Urban Studies **42**(13): 2407-2429.

Bullen, P. A. (2007). Adaptive reuse and sustainability of commercial buildings. Facilities. **25:** 20-31.

Castleton, H. /. (2010). Green roofs; building energy savings and the potential for retrofit. *Energy and Buildings*, *42*, 1582-1591.

City of Melbourne. (n.d.). *1200 buildings*. Retrieved January 14, 2013, from http://www.melbourne.vic.gov.au/1200buildings/what/Pages/WhatIsRetrofit.

Chau, K. W., Leung, A. Y. T., Yui, C. Y., and Wong, S. K. (2003). "Estimating the value enhancement effects of refurbishment." Facilities **21**(1): 13-19.

Douglas, J. (2006). Building Adaptation Butterworth Heinemann.

Fox, T. E. (2013). *Global food , waste not want not.* institute of mechanical engineers.
Frazer, L. (2005). Environmental Health Perspectives . (113), 457-462.
Germain, A. E. (n.d.). Guide to Setting Up Your Own Edible Rooftop Garden. Alternatives and the rooftop garden project.
Institute of Mechanical Engineers. (2013). *Global food, waste not want not.*
Highfield, D. (2000). Refurbishment and upgrading of buildings. London, E & FN Spon.
Hilten, R. (2008). Modeling stormwater runoff from green roofs with HYDRUS-1D. *Journal of Hydrology, 358* (3-4), 288-293.
Kellert, S. (1993). *The Biophilia Hypothesis.* Washington D.C., U.S.A: Island Press.
Kelly, M.J. 2008. Britains Building Stock. A Carbon Challenge. http://www.lcmp.eng.cam.ac.uk/wp-content/uploads/081012_kelly.pdf
Kohler, M. (2008). Green facades—a view back and some visions.*Urban Ecosystems, 11* (4), 423-436
Mentens, J. (n.d.). Green roofs as a tool for solving the rainwater runoff problem in the urbanized 21st century? *Landscape and Planning*, 217-266.
Midmore, D. E. (2011). Roof-top Gardens An option for green roof-tops and self-sufficient fresh food production. *Rural Industries Research and Development Corporation, 067* (11).
Obendorfer, E. Green Roofs as Urban Ecosystems: Ecological Structures, Functions, and Services . *Bio Science, 57* (10).
Osborne, P. (2012). *Green roofs and walls PERCEPTION STUDY – FINAL REPORT AND RECOMMENDATIONS.* University of New South Wales.
Peck, S. /. (1999). *Greenbacks from green roofs: forging a new industry in Canada.* Canada Mortgage and Housing Corporation, Ottawa.
plan, N. G. (2008). *Summary of climate change impact statement.* NSW Government, Department of Environment and Climate Change.
Sydney, C. o. (n.d.). *aboutsydney*. Retrieved january 29, 2013, from http://www.cityofsydney.nsw.gov.au/aboutsydney/CityResearch/AtAGlance.asp
Shephard, P. (1982). *Nature and Madness.* Athens, Georgia, USA: University of Georgia Press.
Skinner, C. (2006). Meteorology and Rooftops Urban Policy and Research. *Urban Density, 24,* 355-367.
Snodgrass, E. /. (2006). Green roof plants: a resource and planting guide. *Timber Press*
Silverman, D., Ed. (1997). Qualitative Research. Theory, Method and Practice. . London., Sage Publications Ltd.
Rooftop farms, 2. (n.d.). *www.rooftopfarms.org*. Retrieved january 14, 2013, from www.rooftopfarms.org
The green roof Centre. (n.d.). *The green roof Centre*. Retrieved january 28, 2013, from http//www.thegreenroofcentre.co.uk/pages/faq.html.
United Nation Environment Program. (UNEP) 2006, Sustainable Building and Construction, http://www.unep.or.jp/ietc/Activities/Urban/sustainable_bldg_const.asp, accessed 4 April 2006.
Yang, J. (2008). Quantifying air pollution removal by green roofs in Chicago. *Atmospheric Environment, 42*.
Zubovich, K. (n.d.). *ecopsychology*. Retrieved 31 January 2013 from http://www.ecopsychology.org/journal/gatherings8/html/healing/search.html.