Urban Hydroponics for Green and Clean Cities and for Food Security

Article *in* Acta horticulturae · May 2012

DOI: 10.17660/ActaHortic.2013.1004.1

1 author:

W. H. Schnitzler
Technische Universität München
447 PUBLICATIONS **1,566** CITATIONS

SEE PROFILE

ISHS Acta Horticulturae 1004: International Symposium on Soilless Cultivation
URBAN HYDROPONICS FOR GREEN AND CLEAN CITIES AND FOR FOOD SECURITY

Author: W.H. Schnitzler

Keywords: soilless crop production, urban planning and beautification, sky farms, vertical farming, aquaponics, aeroponics

DOI: 10.17660/ActaHortic.2013.1004.1

Abstract:
This paper will deal with urban hydroponics and explores the relevance of this horticultural tool for city development and food supply under this special surrounding. Why should we need it? And where do we stand with this technology?
In 1950 the total world's population counted for 2.6 billion with 800 million in urban centres and 1.8 billion in rural areas. We expect 100 years later by 2050 worldwide 9.2 billion inhabitants with 6.3 billion living in cities and only 2.9 billion remaining in the countryside. The United Nations Habitat Program is clearly concerned with this shift. With focus on city environment and food security for this tremendous accumulation of people, Urban Hydroponics is part of Urban Horticulture, which is again part of Urban Agriculture. Urban Hydroponics is improving living spaces for physical and psychological in- and out-door relaxation. It will also supply doorstep year round diversified and healthy fresh fruits and vegetables without long transportation chains, adding income opportunities for the poorer population.
For successful implementation, several actors need to join: horticulturists, engineers, architects and city planners. The urban hydroponics technology for plant production reduces (1) water needs, (2) food health risks, (3) environmental contamination and, (4) cultivation space. A variety of different hydroponics systems can be used in urban areas for intensive, high value crop production.
This presentation will connect urban hydroponics with excitingly, more recent inventions of air-dynoponics and the aquaponics, allowing fish cultivation in tanks and at the same time recycling from the tanks their excrements as organic fertilizer to beds for growing hydroponic vegetables. It also will introduce vertical farming and sky farms for cultivation of clean and healthy fresh vegetables and beautiful ornamental plants amidst highly populated urban centres.

Urban Hydroponics for Green and Clean Cities and for Food Security

Prof.em. Dr. W.H. Schnitzler
Life Science Centre Weihenstephan, Technical University München, 85354 Freising, Germany

Key Words:

Soilless Crop Production, Urban Planning and Beautification, Sky Farms, Vertical Farming, Aquaponics, Aeroponics

Abstract

This paper will deal with urban hydroponics and explores the relevance of this horticultural tool for city development and food supply under this special surrounding. Why should we need it? And where do we stand with this technology?

In 1950 the total world's population counted for 2.6 billion with 800 million in urban centres and 1.8 billion in rural

areas. We expect one hundred years later by 2050 worldwide 9.2 billion inhabitants with 6.3 billion living in cities and only 2.9 billion remaining in the countryside. The United Nations Habitat Program is clearly concerned with this shift.

With focus on city environment and food security for this tremendous accumulation of people, Urban Hydroponics is part of Urban Horticulture, which is again part of Urban Agriculture.

Urban Hydroponics is improving living spaces for physical and psychological in- and out-door relaxation. It will also supply doorstep year round diversified and healthy fresh fruits and vegetables without long transportation chains, adding income opportunities for the poorer population.

For successful implementation, several actors need to join: horticulturists, engineers, architects and city planers. The urban hydroponics technology for plant production reduces (1) water needs, (2) food health risks, (3) environmental contamination and, (4) cultivation space. A variety of different hydroponics systems can be used in urban areas for intensive, high value crop production.

This presentation will connect urban hydroponics with excitingly, more recent inventions of Air-dynoponics and the Aquaponics, allowing fish cultivation in tanks and at the same time recycling from the tanks their excrements as organic fertilizer to beds for growing hydroponic vegetables.

It also will introduce Vertical Farming and Sky Farms for cultivation of clean and healthy fresh vegetables and beautiful ornamental plants amidst highly populated urban centres.

Introduction

Urban Agriculture in tandem with Urban Horticulture has gained enormous attention and popularity in recent years to such an extent that the Internet all the way crossing into such popular communication platforms as twitter and facebook flushes out a wealth of data in articles and technical information. Placing the puzzle of Urban Hydroponics among the big players of this agenda is surprisingly not very difficult because it fits so well to major headlines, e.g. climate change and energy conservation, mega cities and urbanization, increase of the world's population, food security, health and welfare, water scarcity, agricultural resources and so on. This article will provide on overview only, not claiming to be that entire comprehensive, though up-to-date. The flow of information is overwhelming and very fast.

The earth's population totaled in 1950 only 2.6 Billion inhabitants. A realistic estimation forecasts 9.2 Billion in the near future of 2050. The rural population numbered 1.8 Billion in 1950 and will reach 2.9 Billion in the year 2050 whereas only 800 Million people occupied urban areas in 1950 and will come to 6.3 Billion in 2050 (UN 2010). The World Urban Forum 6 will convene in Naples, Italy in September 2012 to discuss the urban future under the heading "More than 50% of humanity lives in towns and cities – a figure projected to grow to two thirds in little over a generation." Demographic trends, although, show that the earth's population will grow differently in various parts of our planet; regardless, certainty of urbanization will continue (Table 1).

This author initiated and supervised already in 1997 an European funded project on Urban and Periurban Small and Medium-sized Enterprise Development for Sustainable Vegetables Production and Marketing Systems with partners from the Philippines, Vietnam, Laos, Germany and France, recognizing that the flight from rural areas will develop into a worldwide trend with rapid changes in socioeconomic, cultural and environmental conditions (PUVep 1997).

Will Urban Hydroponics have any relevance under the premise of rapidly expanding cities? Why should we need such a technology and what facilities are required for implementation? After all, Urban Hydroponics is only the "little sister" of Urban Horticulture, while this is part of Urban Agriculture (Fig. 1).

Within the last decade, Urban Agriculture has found strong support among many actors. This has not always been the case. FAO conducted a symposium in New York in 1997 where the mayor of Lusaka, Zambia stated: *"Authorities are hesitant to be more proactive on urban agriculture because it is largely seen as resulting from a failure to address rural development adequately. It is creating havoc in urban land use planning and management. It is holding up city development and redevelopment."* (FAO 1997)

This context changed some years later, when another mayor, this time Christopher Iga from Kampala, Uganda emphasized: "*Urban Agriculture (UA) has several advantages in Kampala. It increases urban food security, produce from rural areas is expensive and less fresh, and it creates sources of income. UA also reduces open space maintenance costs to local government* " (Mougeot 2006).

Experts identified in the 1997 conference organized by the FAO:

"What these diverse activities have in common - and in some cases what sets them apart from rural agriculture - is proximity to large settlements of people, thereby creating opportunities as well as risks." Accordingly, table 2 summarizes the opportunities and risks of Urban Agriculture.

Urban Agriculture has seen in recent years a clear shift to Urban Horticulture, mainly to produce vegetables for food and ornamentals for beautification. As a matter of facts, the earlier identified risks as listed in Table 2 became diminished by implementation of Urban Hydroponics. This technology has met the demands of modern cities (1) for physical and psychological in- and out door relaxation; (2) for improving city environment and (3) for food and income security to provide year round a wide variety of fresh fruits and vegetables (FAO 2010). Moreover, Urban Hydroponics reduces water needs and cultivation space for plant growth, minimizes food health risks of harvested produce and helps to check environmental contamination.

Urban Hydroponics needs for successful implementation certain basic prerequisites, but also some restrains have to be recognized (Tables 3). In addition, the very nature of Urban Horticulture and more so of Urban Hydroponics depends heavily on close cooperation by several actors to make this scheme successful (Fig. 2).

Urban Hydroponics for Greener Cities

Urban Hydroponics is not an invention of our time. The Hanging Gardens of Babylon and the Floating Gardens of the Aztecs were beautifying the civic centers; in addition, fruit trees and vegetables were cultivated in such places. Today, modern cities use Urban Hydroponics for physical and psychological in- and out-door relaxation. It is part of the ecological system to manage the urban environment. In arid climate it can increase humidity and lowering temperatures. It captures dust and polluted air by the foliage of the plants. It can contribute to the reduction of the net discharge of CO_2, one of the gases speculated to contribute to global warming, because plants and trees need CO_2 for photosynthesis. The captive action, of course, is at its highest during the vegetation growth phase. In cities, however, much of the carbon stored in vegetation is likely to be quickly released through decomposition to organic matter, so lasting effect is little (Deelstra and Girardet 2005).
Hydroponics gardens often go vertically, since city space is limited. The obvious benefit is the immediate improvement in environmental quality. While traditional building facades serve as massive heat sinks that radiate heat and increase ambient air temperature, living walls thermo regulate buildings by trapping heat in the winter and cooling buildings in the summer. A recent visit to Bangkok has vividly demonstrated what city management can do. The grey, vertical concrete structures of the road and railway overpasses were greened up with hydroponically grown ornamentals (Figure 3). Also many multistory car parks were beautified with greeneries (Figure 4) and commercial centers decorated with indoors hydroponics (Figure 5). Inside air quality will be improved by living plants growing on interior walls.
All this shows that Urban Horticulture with emphasis on Hydroponics has positive impact upon the greening and cleaning of the cities, offering green zones for micro-climate changes (shade, temperature, sequestration of $C0_2$). Most importantly, city dwellers will enjoy such green areas, enhancing community self-esteem and stimulating community livelihood, as this has been well pointed out by the RUAF Foundation.
FAO has summed this up under "Cities of despair – or opportunity? The challenge is to steer urbanization from its current, unsustainable path, towards sustainable, greener cities that offer their inhabitants choice, opportunity and hope. The concept of "green cities" – designed for resilience, self-reliance, and social, economic and environmental sustainability should usually associate with urban planning." (FAO 2010).
One example demonstrates best where architects have successfully teamed up with horticulturists, engineers and city planners to create new urban culture.
Singapore has two young architects, Wong Mun Summ and Richard Hassel (WOHA) who have implemented a new living culture for people in tropical cities. Their skyscraper "The Met" in Bangkok has no more huge glass facades but the inhabitants of this multistory building are allowed to live with nature. On the outside walls grow exuberantly dense plant foliage, protecting the building like an umbrella against the heating sun. Staircases, walkways, terraces, balconies, pools create the impression of a parks landscape. Fresh air is no more a luxury. To create such nature within a "concrete jungle" is only possible by a technology such as hydroponics, allowing full control and automation of plant growth.
The expectation of modern urban landscape is dominated by ecological progress and people's health. No wonders that "Green Cities" are demanded by the people, something like a new paradise to harmonize technical advances and nature, urbanization and countryside, population explosion and ecological balance. There is a slogan "*Rediscover harvest in your workaday life*". As always, there are contrary opinions by some architects who question "the renaissance of urban agriculture" under the label of sustainable city development. They claim that energy can only be saved by higher building density. They explain, that an open housing design is energetically inefficient because of heating and cooling radiation. Such discussions are contra productive, simply by the demonstration of multi talented teamwork coming up with bold conceptions for changing today's often-monstrous megacities into modern lifestyle centers. Needless to mention, that Urban Hydroponics plays a significant part in it.

Urban Hydroponics for food security and income generation

Mariko Sato, Chief UN-HABITAT proclaimed "*Mainstreaming urban agriculture in global climate change and food security needs highest attention*" (N.N. 2011). This means consequentially, new ways have to be found to

connect and integrate agriculture and horticulture with urbanism.

Cities can be vibrant centers of culture and civilization, but for many people they are places of urban poverty, alienation and disadvantage, more so in developing countries. Inequity unfortunately is under such circumstances prevalent (Holmer 2010). Appropriate measures are needed to overcome such situations. In many cities, where urban horticulture has already been implemented, production is often for self-consumption with surplus for trade or sale. The importance, though, both for volume and economic value must not be underestimated. Urban horticulture can grow food for the cities, utilizing empty lots, along roadsides, but also on rooftops and in vertical farming, in any case hydroponically. Urban Horticulture has, if done properly, always environmental benefits. For one case, it reduces the need to transport produce into cities from distant rural areas, generating fuel savings, fewer carbon dioxide emissions and less air pollution (FAO 2010).

Urban horticulture serves an important purpose in the lesser-developed world, often faced with shortages of water and arable land, making traditional agriculture in many instances difficult. Instead, hydroponics provides a far more sustainable and appropriate solution (Hydroponics Guide 2011). Of course, there are many hydroponics systems for the different operations in use: for large commercial enterprises they are quite sophisticated, capital intensive and requiring high technical knowledge from the operators. This scale goes all the way down to simple hydroponics, which is more for the low-resource urban population living under poverty conditions. Its produce will add economic and nutritional benefits by securing year-round supply of fresh fruits and vegetables for their own consumption. Simple hydroponics promotes water savings in recycling and decontamination of water for growing of plants in areas with marginal conditions of adverse climate, soil, space limitations, and water scarcity (FAO 2011). Therefore, this is the answer for urban people, including the poor to access and afford healthy and nutritious vegetables, contributing to their wellbeing. The advantage of vegetable production by simple hydroponics technology is based on the fact that large amounts can be produced in a short time from a small area. Field crops such as cereals and tuber crops have no chance to compete (Keatinge et al. 2011).

The author managed an international European financed INCO-MED project with 8 partners from 2002 to 2006, working on „Efficient water use through environmentally sound hydroponic production of high quality vegetables for domestic and export markets in Mediterranean countries". The results of this project are conferrable to benefit large scale vegetable producer, as well as small holders in peri urban areas and city dwellers on small urban lots, mainly by improving the water use efficiency, allowing the application of water with poor quality and the reduction of fertilizers (Figure 6). The impact of water stress and water quality was identified on the quality of harvested vegetables (Ecoponics 2006).

Many countries in the Middle East have introduced hydroponics as a viable form of urban and peri urban horticulture for growing vegetables. "*Although the idea of planting rooftops isn't new, it has only been carried out in Egypt recently*", says Dr. Ayman Farid Abu Hadid, "*the idea began at the Agricultural Unit in Egypt's Ain Shams University where scientists had been designing new methods of agriculture to suit Egypt's densely populated cities for exhibitional purposes. Then, the Food and Agriculture Organization (FAO) adopted the idea and carried it out in many developing countries such as Kenya, Senegal and Columbia and also suggested it be applied in Egypt as well."* FAO also helped the Egyptian government to launch the "Green food from green roofs" program that encouraged residents to grow their own vegetables in beds and containers filled with rice husks, sand or peat moss, fertigating the plants hydroponically (FAO 2010).

The population of major cities in Egypt still continues to expand. Out of 65 Million, almost 40% are living in urban centers like Cairo (16 Mil.) or Alexandria (7 Mil.). Many of those families have limited resources. The consumption of fresh fruits and vegetables is low since no garden space in the crowded cities is left available and people have to buy products from the markets. This situation is having a negative impact on the nutritional status and overall wellbeing of the population in the poor urban and peri-urban neighborhoods. The "Green food from green roofs" program enables the poor families to grow their own fresh vegetables on rooftops. The program is specifically targeted to the poorer families, living in the densely populated suburbs where it will not only provide fresh vegetables for home consumption but it will also create a source of income, specifically for women at home. Moreover, children will learn to know a variety of vegetables. The technique for growing on rooftops is based on simple hydroponics culture systems, aiming very high water use efficiency. "Green food from green roofs" program not only improves the availability of high quality fresh vegetables for the urban poor, but it also encourages a more efficient use of water, which is so scarce in Egypt. In comparison to traditional open field production and conventional irrigation, the water-use efficiency is considerably improved by using closed soilless culture systems. This programme is saving on cost for transport, packaging and storage of the products. Residents also found an additional benefit: It lowers temperature in the homes. Rooftops planted with vegetables are 7° C cooler than those next door – and, when practiced on greenbelts, improves landscapes and citizens' quality of life. For simple implementation of this program, cooperating growers are provided with premixed soluble fertilizers to be added into the tank at the recommended quantity per liter of irrigation water for regular nutrient supply to the plants.

And here is another success story for Urban Hydroponics, this time in SEA. Cebu municipality, the oldest city of the

Philippines with an estimated population of 822,000 (in 2009) is pretty developed with a burgeoning shipping industry and a growing communications sector. But it still experiences poverty among its residents. The city government tries new, innovative ways to tackle poverty with hydroponics, allowing to be implemented in relatively small spaces and by the reuse of plastic containers, helping to reduce urban waste. The Department of Social Welfare and Development and the Department of Science and Technology are both hoping that through education of the hydroponics method it will be possible to decrease the threat of food shortages but to also turn some of the derelict areas of the urban environment into greener, more productive spaces. The project forms part of a wider welfare program of the Philippines government. The use of hydroponics is first of all targeted to families to help them. For the municipality, simple hydroponics in urban gardening will be a way of food production in the process of urban regeneration (Hydroponics Guide 2012).

A unique approach of hydroponics and animal feed production is practiced in Peru. Guinea pigs are raised in farms near population centers and in households for roasting at feasts like chicken in other places. The small mammals are fed with wheat sprouts produced hydroponically, allowing a continuous supply of fresh, nutritious and healthy food.

In early 1990 a simple non-circulating hydroponics system was developed at AVRDC in Taiwan, built on the principle of "air roots" and "water roots". Normally, hydroponics systems need an external energy source to supply mineral nutrients and oxygen to the plants. As the AVRDC system does not need electricity, it can be used in places with no or uncertain supply, such as in many towns and rural areas in developing countries.
The simple set up system only requires a watertight container (e.g. a polystyrene box) to hold the nutrient solution; a lid covering the container and plastic perforated cups with some support medium for the seed or seedling, which are immersed from the cover down into the nutrient solution. The nutrient solution developed at AVRDC (Table 4) gives vegetables a near-optimal supply of mineral nutrients. If the pH level of the solution rises above 7.8, as may occur in long-season crops such as tomatoes, addition of sulphuric acid can bring it down to the preferable pH level of 5.5-6.0. Studies show that the same solution is suitable for fruity and leafy vegetable crops.
Initially, the solution level is set at about 2 cm above the base of the perforated cups. At first, it will drop slowly as capillary rises and evaporation occurs. It falls faster as roots develop and take up solution. A number of roots remain in the air space between the support structure and the surface of the solution. As these aerial roots and the roots floating on the solution surface provide oxygen for normal root function, the solution does not need to be aerated (Midmore and Wu 1999).

Kratky, a horticulturist from the university of Hawaii has worked further and modified the AVRDC system for household and even semi-commercial use. He says, an entire crop can be grown with only an initial application of water and nutrients for his non-circulating hydroponic method. Electricity and pumps are not needed. Tanks are filled nearly to the top with an appropriate nutrient solution (e.g. a plastic juice bottle containing 4 l of water plus 5 g of 10-8-22 hydroponic fertilizer) for the crop to be grown. A cover is placed over the tank with small, perforated plastic cups holding transplanted seedlings in growing medium immersed in nutrient solution. The entire growing medium in the cups becomes wet by capillary action, thus automatically watering and fertilizing the plants. The nutrient solution level in the tank drops below the cups within a few weeks such that direct capillary wetting of the growing medium is no longer possible. However, by this time, roots have emerged out of the perforation of the cups with their lower portion immersed in nutrient solution, while the upper portion of the roots resides in the moist air layer between the cover and the nutrient solution. Most of the time, the crop can be harvested when less than 10 per cent of the original nutrient solution remains. The elementary handling involves filling a 4-liter plastic juice bottle with water, adding fertilizer and planting in a net pot. No additional watering or fertilization is required for the duration of the crop. Larger quantities of lettuce may be produced commercially utilizing the same concept but in shallow (9-14 cm high) boxes filled with nutrient solution and covered with a polystyrene board. Cucumbers and tomatoes may be produced in a similar manner, except they require a larger nutrient solution tank. A plastic trash container can serve (Kratky 2004).

Simplified Hydroponics (SH) has been used by low-income families in urban and peri-urban areas of Uruguay to improve their living standards. La Paloma-Chuy is one area of Uruguay under pressure from urbanization. Over the last few years' urban areas have experienced an increase in poverty. To overcome this problem, the Departmental Government of Rocha sought new development strategies especially for women who are the traditional heads of the family household. The government decided to promote family-grown vegetable gardens in the home using SH techniques. The aim of the project was to improve the health and quality of life of families in crowded urban communities and to promote similar conditions also for other urban populations in Uruguay and all over Latin America. The project involved training the families themselves, focusing on women and fostering self-employment of idle household labor using the scarce resources available to them. Also for Latin America, SH proved to be an ideal food production system in urban and suburban areas, offering the advantage of using places that have not previously been thought appropriate for food production, such as courtyards, small gardens, walls, balconies and even rooftops.
Caldeyo Stajano (2003) is adding to the report of his project some very interesting social aspects:
"SH produces high quality, safe food, rich in nutrients and minerals. Since the family grew them, they were

harvested immediately before their use; thus, the produce was fresh and kept its nutritional qualities intact. Another advantage was that these crops were cultivated above and away from contaminated ground areas. These vegetable gardens have enabled the intake of a broad range of excellent quality fruits and vegetables. Many participants improved their family income. In most cases, the participants did not earn money, but they provided nutritious vegetables for their family and generated sufficient resources to pay for the expenses of having a vegetable garden. Others traded their vegetables to shops in the area for other complementary foodstuff, improving the family diet further. Monetary rewards occurred for those families who had vegetable gardens that exceeded 30m^2. When participants start to see concrete results (i.e., they consumed top quality hydroponics produce they had grown), they developed greater self-esteem. They felt capable of doing something productive and positive to feed themselves and their family. Besides being a clean plant production system, hydroponics had something special: it is a technology that helps to arouse curiosity, it encourages innovative thinking and presents a challenge for people, and it provides leadership opportunities. Some families had little in common to talk about among their members, but in the hydroponics vegetable garden there was a shared interest. This factor helped reduce family stress levels. Once people acquired a good command of SH techniques, they were able to develop their own personal inventiveness in the use of different containers and growing spaces, which in turn nurtured further motivation. With proper technical assistance, as time passes, the first set of participants in each community acquired more skills and became leading advocates of hydroponics vis-à-vis their neighbors. This happened in two ways: First of all, because of the "attraction factor" they had at home: their own vegetable garden. It conveyed something tangible and they could boast they "had achieved something". This was an actual event that aroused the interest of their neighbors, and did for others experience a source of encouragement to imitate the positive values. Secondly, they were able to convey their knowledge of the technology to their neighbors in a simple manner, because they already knew how to do it. This promoted leadership based on positive values. This was a major social component."

Producing quality temperate vegetables like lettuces under tropical hot and humid environment is most difficult. Geoff Wilson is an agricultural journalist and Australia's representative of a group of 16 national organisations for an international Green Roofs organisation. He is reporting in an article on "Singapore's New Business Opportunity: Food from the Roof" (Wilson 2005), where such obstacles of tropical conditions can be overcome by a new and special aeroponics technology invented in Singapore. In conventional aeroponics, cooled nutrient solution is continuously misted onto the plant roots in a lightproof box. Cooling of the nutrient water lowers the plant root zone temperature and increases root zone aeration to keep it around 10 degrees C lower than the day-time ambient temperature, which would "cook" the roots and cause wilting and plant loss. However such refrigerator cooling is expensive, even for high priced vegetables in the markets of the rich city-state of Singapore. This has been an economic limitation on the aeroponics technology. Then in 2004 Gregory Chow, lecturer at the Ngee Ann Polytechnic of Singapore has invented the Air-Dynaponics - a much less costly way of maintaining low root-zone temperatures for commercially successful aeroponics. The excellent plant growth and production that has been achieved by the Singapore type aeroponics system is mainly due to control of root zone temperature, nutrition, moisture and the gaseous phase. Researchers theorize that the nutrients infused with oxygen "energized" the entire root system and enhanced the plant top biomass (Chow 2004). It costs only about one fifth to cool the nutrient solution. Air-Dynaponics uses the cooling principles of vaporization by the Venturi nozzle effect in an air-powered operation that not only reduces the temperature of the nutrient solution, but also adds aeration by dissolved oxygen. This special technology can open a new scope for a modified Urban Aeroponics suitable for the tropics and sub-tropics. In Singapore it is already commercially used to produce high-value vegetable crops such as butter head lettuce, Batavia lettuce and Romaine lettuce with the temperate butter head lettuce forming the greatest quantity.
Professor Lee Sing Kong, Dean, Graduate Programmes and Research, National Institute of Education of Singapore's Nanyang Technological University is taking one step further by advocating "sky farms" based on the Air-Dynaponics technology which has already been pioneered by Singapore's AeroGreen Technology Pte Ltd., initiated by the reputed agro company Sime Derby.

The other types of the traditional leafy vegetables, which are cheaper, for instance, Japanese Cai Xin, Chinese cabbage, kale, Chinese spinach, Chinese Nai Bai, leaf lettuce and herbs are grown in Singapore by the Taiwanese dynamic root floating system of hydroponics. In this growing method, a nutrient sprayer lifts nutrient solution, and sprays it onto the "aerial roots" hanging down through an air gap while infusing oxygen into the nutrient solution. The feeder roots remain constantly submerged in oxygen rich water with nutrients providing most of the nutrition and oxygen for the plants (Chow 2004).

A more recent, very interesting new topic is aquaponics, the marriage of hydroponics with aquaculture. The combination of hydroponics for plant cultivation with nutrient solution and aquaculture for fish farming has created the technology of aquaponics. An aquaponics system is a co-dependent ecosystem that utilizes the benefits of each technology to the largest effect. The growing of both, fish and plants have symbiotic benefits. In the aquaponics system the water with the fish feces is pumped from the fish tank and turn them into nutrition for the plants. In return the plants clean the water to be pumped back into the fish tank. Subsequently, both systems are benefitting, the hydroponics growing is far cheaper and easier as mineral nutrients have not to be purchased, thus, plants are grown completely organically. The fish farm benefits for not having to purify with an additional expense the water

and no pesticides harm the fish. Thus, aquaponics is not only cost effective but diseases in both systems are more easily controlled and reduced. It is also an excellent solution for growing in small spaces, making it very suitable for Urban Farming (Hydroponics Guide 2010).

The Canadian scientist Savidov proved that a recirculating aquaponic system results in less root diseases in the crop, resulting in increased crop yield from aquaponics compared with conventional hydroponics. A possible explanation is the organic components in the nutrient solution (possibly humates) that make the trace elements more readily available to the plants for improved growth.

There may be an added marketing advantage created for vegetables produced by the aquaponics technology: since no pesticides and mineral fertilizers are used in the system, the produce should eventually qualify for an organic product certification.

One of the major problems with aquaponics is that nearly all the operators have come to aquaponics from an aquaculture background, and consider that the horticultural part is easy (Nichols and Savidov 2011).

The United Arab Emirates (UAE) import around 85% of its food. The locally managed Baniyas Centre is building an aquaponics operation for an initial 200 tonnes of fish and 300,000 heads of lettuce annually. Currently, the centre is focusing on the production of lettuce, although in the future other produce such as tomatoes, cucumbers, even okra will be cultivated. The system uses a variety of tanks, filters and irrigation equipment to ensure that the fish waste is fed to the plants for nutrition and the plants purifying effects on the water can be circulated back to the fish tanks (Hydroponicswizard 2011[2]).

Japan is always good for new innovations, and the Japanese consumers for their love for freshly prepared vegetables. The latest news is a hydroponics vending machine for use in urban areas where growing fresh vegetables is a problem. The vending machine is labeled the "Chef's Farm". Vegetable seeds are planted in sponge pots that are placed in culture beds in metal frames. The result is, that across the five beds, different vegetables can be grown, although lettuce is the most popular. The vending machines cost around $90,000, not cheap but it is expected that the cost of the investment will recoup in approximately five years. The venting machines have already operated since the summer of 2010. It proves just how versatile hydroponics can be for modern urban areas where a lack of fresh vegetables is apparent and cash money is available (Hydroponicswizard 2010).

Visions for Urban Hydroponics

The journal "The Conversation", an independent source of information, analysis and commentary from universities and research sectors in Australia, covered recently the story by Busicchia "Urban farmers on top of the world", which provides quite a realistic picture of the present situation:
"North America appears to be leading the way in rooftop farming. Major American supermarket chains have already signaled their interest to build and operate rooftop farms (see also below "Better Food Solutions" by Theduke 2011 and "Gotham Greens' first greenhouse facility in Brooklyn" by Zeveloff 2011).
While setting up new urban farms in new city development may be somewhat easier, integrating farms into old buildings is one of the obstacles that architects and urban planners will have to face. Obtaining permits and resolving zoning issues will definitely require co-operation and shared vision from local authorities.
The future food supply system will need to be resilient in the face of uncertainty, be sustainable while offering healthy food at low social and environmental costs, and be competitive while meeting consumer expectations.
Can urban farming be part of this future? It is perhaps a little too early to predict, but clearly the prospect of a direct-to-consumer model should attract further community and business attention" (Busicchia 2011).

Unquestionable, the consumer desires fresh, locally produced fruits and vegetables in the super market shelves. For those expectations, urban hydroponics can play a major part. Hundreds of miles in transportation cost will be saved. The New York Company "Better Food Solutions" has stared with this idea and placed their own hydroponics garden on the roof. The result is a much more environmentally friendly produce that tastes great and can simply be sent downstairs for sale. The benefit for the consumer is fresher produce that has gone from harvest to shelf within a short time. Such a system of rooftop gardens has also considerable potential for restaurants and even residential properties (Theduke 2011).

In lesser developed regions of this world urban hydroponics plays a different role than in industrialized, highly developed countries; in the setting where hunger is not the first worry of each day, growing fruits and vegetables without chemicals and to reduce the amount of food miles that are linked with traditional agriculture has higher priority. Some visionary experts see a future with vertical farms in skyscrapers. For this reason, some protagonists of this idea have created the name Skyfarming (Sauerborn 2010). Such buildings may also incorporate aquaponics to ensure a source of fresh fish.

Small and larger hydroponics operations within city limits are not a special site anymore but not yet in skyscrapers. Vertical racks and trays have been in use for long, because they are mobile, ensuring plants to be exposed to natural light, at least for some time. But vertical farming projects are currently only small, although they could be scaled up, not necessarily right away in sky farms (Hydroponicswizard 2011[1]). By stacking crops vertically, large acreage can

be saved. By using hydroponics the amount of water to grow crops will be greatly reduced. This could make hydroponics vertical gardens a space and money saving option for the horticultural industry with environmental benefits. The Vancouver-based company VertiCrop™ is in the market with a system consisting of a series of mechanical plastic trays stacked 8 high that can be placed on urban rooftops and other tight spaces. The trays are planted with vegetables and herbs that grow hydroponically. When plants are ready, conveyer belts bring the trays to the place of harvest and packing. The company claims that cultivation is possible with just 8% of the water and 5% of the space for the same quantity of harvested produce as required by standard farms. Energy efficient LED lights are on standby to supplement waning natural light when necessary (VertiCrop 2011).

Vertical farms could be placed practically anywhere, even in the middle of cities meaning that food can be produced locally, even in urban areas. But hydroponics of a large scale in high-rise buildings must be proven to be sustainable and profitable before our cities will start to fill up with hydroponics sky farms (Hydroponicswizard 2010[1]).

The well-established journal "The Economist" published in its section "Technology" a critical article on Vertical Farming in late 2010. It is worthy to reflect on some passages.
Dickson Despommier, a professor of public and environmental health at Columbia University in New York is regarded as the progenitor of vertical farming. He recently published his book "The Vertical Farm". A wide variety of designs for vertical farms have been created by architectural firms., but so far, the idea remains on the drawing board (Rajagapal 2010; Saxena 2011). The necessary technology exists. The glasshouse industry has more than a century's experience of growing crops indoors. Today, it is technically and economically possible to tailor the temperature, humidity, lighting, airflow and nutrient conditions by hydroponics technology to get the best productivity and quality out of plants year round, anywhere in the world. But the cost of powering artificial lights will make in-door farming prohibitively expensive. Even though crops growing in a glass skyscraper will get some natural sunlight during the day, it will not be enough. Without artificial lighting the result will be an uneven crop, as the plants closest to the windows are exposed to more sunlight and grow more quickly. Light has to be very tightly controlled to get uniform production. Vertical farming will need cheap, renewable energy for light and temperature control, if it is to work.

Ted Caplow, an environmental engineer and founder of the "New York Sun Works" argues that even using renewable energy, operation of such greenhouses will still be too expensive. Between 2006 and 2009 he and his colleagues operated the Science Barge, a floating hydroponics greenhouse moored in Manhattan.It investigated to grow vegetables in the heart of the city with minimal resource consumption and maximum resource efficiency. Operating all year round, the barge could grow 20 times more compared to a field the same size. Solar panels and wind turbines on the barge were able to produce vegetables with near-zero net carbon emissions. But the greenhouses on the barge were only one storey high, so there was not much need for artificial lighting. But stacking greenhouses on top of each other like in vertical or sky farms requires added light. Based on the experience with the Science Barge, generating enough electricity using solar panels requires an area about 20 times larger than the area being illuminated. For a skyscraper-sized hydroponics farm, that is most probably impractical.
Caplow summarizes that vertical farming will work only if it will make use of natural light.
The immediate opportunity may simply be to take advantage of the space available on urban rooftops to pursue urban farming rather than vertical farming. It still needs economic prove, though, how competitive this will be. Rooftop farming may not be able to compete with other suppliers in a global market unless people are prepared to pay a premium for fresh, local food and to be really environmentally conscious (N.N. 2010).

Ricciardi (2011) offers a solution in his article, as it seems that the Swedish architectural design company "Plantagon" has solved the biggest challenges of urban vertical farming: the need for uniform, sufficient natural light to provide an even growth of vertically-farmed plants.
The solution is in their design; the "Plantagon" features a vertical, rotating "corkscrew" platform for the crops and is situated within a huge, curved-glass, geodesic spheroid structure. By offering the dual benefits of cost cutting and elimination of transportation, these "plantagons" are envisioned to spearhead the green urban living movement of the future.
According to Plantagon information, their urban greenhouse "*…will dramatically change the way we produce organic and functional food. It allows us to produce ecological [resources] with clean air and water inside urban environments, even major cities, cutting costs and environmental damage by eliminating transportation and deliver directly to consumers*."
The design and concept is not without its critics, however. Some feel that this represents a "resource heavy" concept. At the moment, cultivation is with soil to be disposed after cultivation. Hydroponics would certainly be the better choice for full control of plant growth and development. The company claims that the high-tech greenhouses will grow four times as much produce per square meter as can be grown in traditional one-story greenhouses. The smallest of Plantagon's patented designs is a five-story globular greenhouse that would cost $10 million to $20 million and would grow enough produce to feed 10,000 people per year, according to Plantagon officials (Ricciardi 2011).
In February 2012 a construction site was opened in Stockholm for the first Plantagon greenhouse (Figure 7). This could well be a tourist attraction, too.

Most city rooftops, particularly the older ones, cannot support the heaviness of greenhouses. Consequently, more than often, realization struggles with locating enough suitable sites that meet the structural requirements to obtain construction licenses. Gotham Greens' first greenhouse facility, located on the rooftop of a large old bowling alley in Greenpoint, Brookyn, New York has found a suitable location and started its first harvesting of leafy vegetables in June 2011. In this innovative new company, the right people have obviously joined forces, an environmental engineer who got his experience earlier at New York Sun Works (see above, N.N. 2010), a commercial expert with a MBA in business administration and banking, and a plant physiologist with specialization in horticultural engineering. Their rooftop greenhouses combine advanced horticultural and engineering techniques to optimize crop production, crop quality, and production efficiency. The climate-controlled facility is expected to grow best quality produce, year-round. The business target must certainly be a premium, very fresh quality vegetable for premium costumers (Zeveloff 2011).

With success for Urban Hydroponics coming up, so do companies to assist in this business. BrightFarms is one of those who have also helped Gotham Greens' in installing their operation. BrightFarms business strategy is to operate hydroponics rooftop greenhouses at grocery retailers, eliminating time, distance and cost from the food supply chain. Their philosophy is to design, finance, develop, build and manage the operations if costumers require.

There is one other concept for Urban Hydroponics, and these are turnkey units ready for operation to cultivate plants in modified old sea containers. Supposedly, such units can be set and even stacked up anywhere from ground floor, empty unused lots, on roof tops, besides restaurants or food retail shops, as long as zoning by city administration will permit. Basic requirements for electric and water supply as well as drainage should be available.

One of such young companies trying to get into business is Freight Farms from Boston. They offer "*High volume crop production units that can be quickly set up and easily operated to grow food in any environment. Each unit can create local food economy to empower communities to reduce the global footprint of food in a sustainable and profitable manner*". Their plan is to use recycled insulated shipping containers, installed with climate control and a suitable hydroponics system. The top of the container will be equipped with photovoltaic cells (Friedman and McNamara 2011). Certainly an interesting approach, but it still has to prove its commercial usefulness.

Conclusion

Capacities and opportunities have to be built by key players, including government policy makers and technocrats to provide awareness, knowledge and training to maximize the benefits of Urban Horticulture with emphasis on environmentally friendly hydroponics. Such a program will benefit mega cities all over the planet, in developing and developed countries to improve living conditions of their citizens, to assist in food security and to provide employment with special attention to families and the gender issue.

References and Citations

BrightFarms (2012). http://brightfarms.com/better-food/

Busicchia, B.(2011). Urban Farmers on top of the world. The Conversation (Australia)

Caldeyro Stajano, M. (2003). Social uses of simplified hydroponics by different: The family grown hydroponics vegetable garden as a food security and nutrition strategy for urban low-income population. A case study from Uruguay. Practical Hydroponics and Greenhouses, Nº 73. November-December

Chow, G.K.K. (2004). Singapore: Aeroponics – A new frontier for hydroponics. The Growing Edge, 16, 1, 72

Deelstra, T. & Girardet, H. (2005). Urban agriculture and sustainable cities. RUAF Foundation Growing Cities

Ecoponics (2006) http://www.ecoponics.de

FAO (1997). The Second International Colloquium of Mayors on Governance for Sustainable Growth and Equity

FAO (2010). Growing Greener Cities. http://www.fao.org/ag/agp/greenercities/

FAO (2011). Food for the Cities. http://www.fao.org/fcit/en/

Friedman, J and McNamara, B. (2011). Freight Farms: Grow fresh food in any environment. http://www.freightfarms.com/

Holmer, R. (1010). Periurban Vegetable Project, www.puvep.com

Hydroponicswizard (2012). Hydroponics for social welfare in the Philippines. Hydroponics Guide, Febr. 17, 2012. http://hydroponicsguide.co.uk (Accessed in February 2012)

Hydroponicswizard (2010[1]). Is hydroponics key to success of vertical farming? Aug 12, 2010. http://hydroponicsguide.co.uk (Accessed in Feb. 2012)

Hydroponicswizard (2010[2]). Japanese hydroponic venting machines. Hydroponics Guide, Nov. 12, 2010. http://hydroponicsguide.co.uk (Accessed in Feb. 2012)

Hydroponicswizard (2011[1]). Growth and future of urban farming? Hydroponics Guide, Febr. 16, 2011.

http://hydroponicsguide.co.uk (Accessed in Feb. 2012)
Hydroponicswizard (2011[2]). World's largest aquaponics project unveiled in the UAE. Hydroponics Guide, Nov. 11, 2011. http://hydroponicsguide.co.uk (Accessed in Feb. 2012)
Julie Zeveloff (2011). Tour the hi-tech farm that's growing 100 tons on the roof of a Brooklyn warehouse. Business Insider.TourGothamGreens,AnUrbanRooftopFarmInBrooklyn.html
Keatinge, J.D.H., Yang, R.-Y., Hughes, J.d'A., Easdown, W.J., Holmer, R. (2011). The importance of vegetables in ensuring both food and nutritional security in attainment of the Millennium development goals. Food Security, Springer
Kratky, B.A. (2004). A suspended pot, non-circulating hydroponic method. Proceedings of the South Pacific Soilless Culture Conference, Acta Hort. 648, 83-89
Midmore, D. and Wu, D-l. (1999). Work that water! Hydroponics made easy. Waterlines, 17-4
Mougeot, L.J.A. (2006). Growing better cities: urban agriculture for sustainable development. IDRC, International Development Centre, Ottawa, Canada
N.N. (2010). Vertical Farming. The Economist Technology Quarterly, Dec. 11, 2010
N.N. (2011). Bangkok. Resilient food systems in Asian cities. Food for the cities – Regional Workshop, Nov.17-18
Nichols, M.A. and Savidov, N. (2012). Aquaponics: clean, green and organic. Personal correspondence, (submitted)
PUVep (1997). http://puvep.u.edu.ph/project/inco (Accessed in February 2012)
Rajagapal, A. (2010). Vertical Farm comes down to earth. http://www.MetropolisMag.com
Ricciardi, M. (2011).'Plantagon', New Vertical Farm Design, May Provide Produce for Future Cities. Clean Technica. http.//s.tt/12wE (Accessed in Feb. 2012)
Sauerborn, J. (2010). The Future of Agriculture – Scenarios, Concepts, Visions Symposium 2010 | 24.08. – 26.08.2010 Communication and Training Centre Königstein . 4.8.2 New Technologies for Agriculture in 2050: Vertical Farming, Agro-Technological Innovations, and Smart Foods
Saxena, R.S. (2011). Ten vertical farms designed to bring farming into the urban world. Greendiary, http://www.greendiary.com (Accessed in February 2012)
Theduke (2010). Organic hydroponics – why not use aquaponics? Hydroponics Guide, Aug. 24, 2010. http://hydroponicsguide.co.uk (Accessed in Feb. 2012)
Theduke (2011). The supermarket of the future? Hydroponics Guide, Febr. 10, 2011. http://hydroponicsguide.co.uk (Accessed in Feb. 2012)
UN World Population Prospects. (2010). The Life Group
Wilson, G. (2005). Singapore's New Business Opportunity: Food from the Roof. City Farmer, Canada's Office of Urban Agriculture