URBAN AGRICULTURE

Introduction

The focus of sustainable development is far broader than just the environment. It's also about meeting the diverse needs of all people in existing and future communities. One of the most pressing concerns today is food security which has become increasingly threatened as UK food imports rise against a backdrop of an expanding population over the next few decades.

In its final report Sustainability and UK food policy (2011), the Sustainable Development Commission urged the Govt to accelerate the process of building a sustainable food system recommending Governments:

- *work with business to develop plans for creating more sustainable UK food systems by 2030*
- *prioritise reversing the decline in UK food production, helping expand vegetable crops sustainably*
- *work to create local food partnerships to meet local sustainability goals*

It is hoped to devote a small area (39 m^2) to a **Vertical Farm** in the lightwell serving the two levels of lower ground bedrooms. The farm will produce hydroponically (soilless) grown crops using stacked rotating Supra gardens in a *fully optimised* climate (excluding CO_2 enrichment). The Supra gardens do not require natural daylight to grow plants and the lightwell's use is purely because it represents the only suitable area in the development.

Its subterranean setting is in keeping with land conservation through not increasing the building's surface footprint. Produce is primarily intended for the new hotel's use, thus saving (International) food miles as well as the natural resources associated with conventional agriculture.

All produce will be free of herbicides, pesticides and preservatives and grown without any detrimental environmental effects such as soil erosion, polluted water runoff and wildlife harm. Comparative water use is 99% less compared to conventional agriculture.

The Vertical Farm

The Supra is the latest version of a rotary hydroponic system manufactured by British Columbia based Omega Garden Institute who've been involved in hydroponics since 1998. Each garden is a rotating cylinder akin to a ferris wheel - 2ft in diameter and 4ft long.

Up to 80 plants grow in a circle around the inside of the garden, lit from within and removing the need for any form of natural light. Presently four fluorescent lights (39W each) run horizontally through the cylinder for photosynthesis but these are now being replaced by more efficient LED lighting (64W or less). The garden is in constant rotation – so that the plants grow uniformly – with a complete rotation taking about 45 minutes. Each plant's root zone passes through a nutrient solution when it reaches the bottom of the rotation.

How Productive?

The farm's planned footprint is only 39 m^2 or 420 ft^2 (0.0096 acre), so is considered a pilot venture in comparable (acreage) terms. Nonetheless, the unrivalled design efficiency of the stacked gardens means this farm punches many acres above its footprint.

39 m^2 accommodates up to 32 Supra gardens in a single row, located at the bottom of the lightwell, which potentially multiplies to 192 when they are stacked 6 high. This is not achievable here as the lightwell is vertically subdivided – fortunately though, it is possible to fit a 2-high stack on the bottom and a 3-high stack on the upper dividing floor, resulting in 160 gardens (from the same footprint as a 6-stack).

Crop wise, 160 gardens equate to a max capacity of 12,800 plants (80 per garden) growing simultaneously.

The Supra has been evidenced producing lettuces (from seedlings) in 20 days in rudimentary conditions (and *without* optimisation). Based on this, 160 gardens will produce 12,800 lettuces in the same period, though the growing cycle will inevitably decrease with optimisation of growing conditions. However, assuming a 20 day cycle, the output from 160 gardens can be summarized as

= 640 lettuces daily
= 230,400 lettuces pa

That's over 225,000 lettuces from a 0.0096 acre (0.0039 ha) footprint

Pro rata that equates to over 22.5 million lettuces pa per acre (or 54 million per ha).

Note, that due to spatial constraints within the lightwell, the layout of gardens has been based on maximising their number rather than the most efficient use of the floor area – resulting in a 40% reduction of gardens/ m^2 when compared to an ideal layout…which allows for significant improvement to the above yield/acre.

The Supra is the latest evolution of the rotary garden's design; its predecessor was subject to thorough testing in more favourable conditions and produced romaine lettuces in 15 days, again *without climatic optimization* though. In fully optimised growing conditions the Supra's harvest times can be expected to drop to nearer 15 days (possibly reduced further with propagation).

Productivity: Supra v Conventional Agriculture & Other Systems

1 Arizona features some of the sunniest and warmest areas in USA, often achieving the highest National yields for all crops. In Sept 2013 Arizona Farm Bureau blogged the following re state lettuce production:

***"Head Lettuce**: 27,000 - 35,000 heads-per-acre".*

2 Canada has been a Global leader and hotbed of hydroponic development for a no of years. The BC Greenhouse Growers' Association represents greenhouse vegetable farmers in British Columbia who fully embrace modern techniques and are collectively responsible for 96% of all of B.C.'s greenhouse vegetable production. Regarding their members productivity, the association say

"while tomatoes and peppers are produced by only one crop per year, we generally have eight to 10 lettuce crops per season... An average head of lettuce weighs about one-third of a pound in winter and a little more than one-half a pound during the spring and summer".

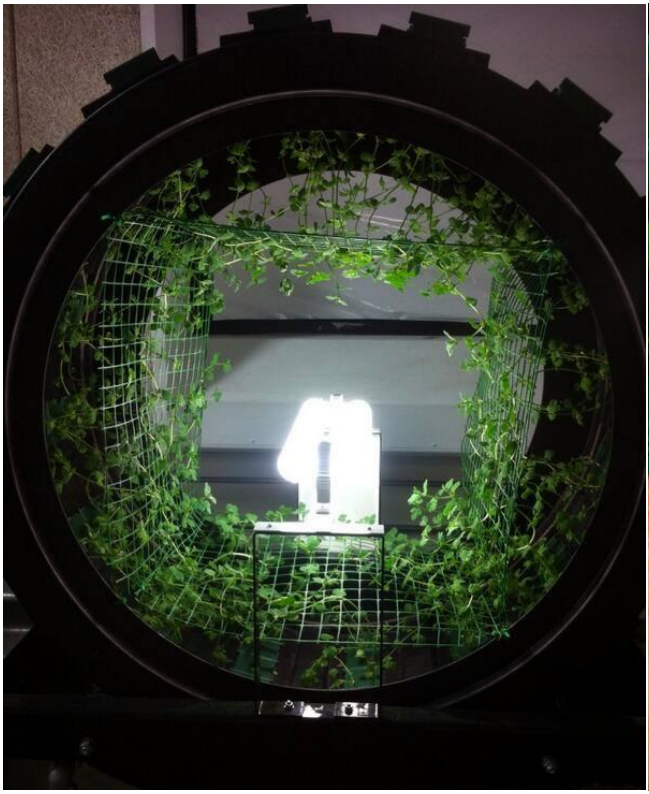
= an average lettuce harvest cycle of 36-45 days with a 35-40% reduction in winter yield

3 The Finnish company Green Automation Export (GAE) has been working on complete greenhouse mobile gully handling systems for over 25 years and makes the following claim about its latest advanced hydroponic growing system:

"*With our system we ensure the grower can harvest 900 crops per square meter…"*

= 3.64 million lettuces per acre pa (or 9 million per ha).

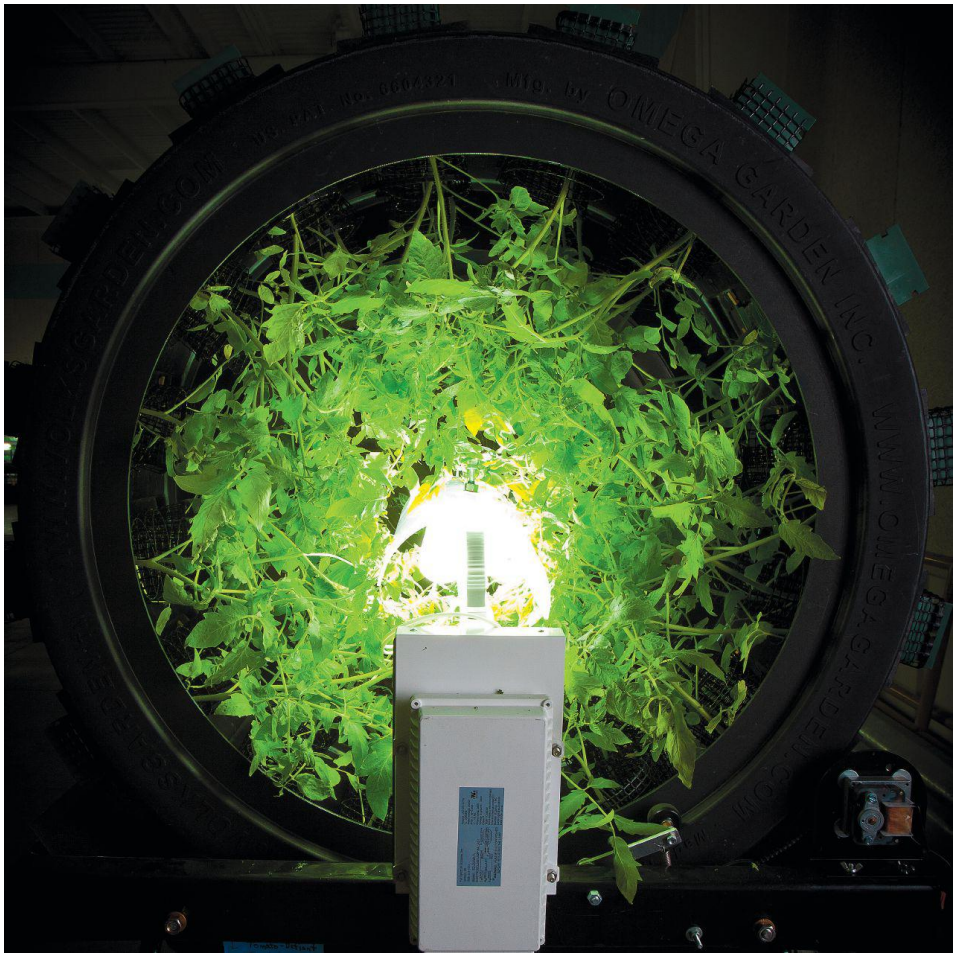
Clearly the Supra enables unrivalled productivity, plus absolute freshness and negligible food miles.



Hydroponics v Organic

Like organic farming, hydroponics avoids the use of pesticides/herbicides and has no detrimental effects on land such as erosion/contamination given the contained soil-free process. Furthermore hydroponic systems only require 10-20% of the water compared to traditional agriculture – moreover the Supra gardens reduce this usage to only 1% - a saving of 99%.

Despite this (and further benefits) hydroponics cannot strictly be considered *organic* as it requires *refined* mineral salts (nutrients) whereas organic farming only permits *unrefined* fertilisers – refining is necessary to produce sufficiently soluble salts (unrefined salts dissolve poorly) and to remove certain naturally occurring minerals which are toxic in nature such as fluoride, radium and chloride (which remain permitted in organic agriculture).



Supra Benefits v Conventional Hydroponics

- Cylindrical planting drastically increases efficiency - when stacked and without optimisation, the system yields 3-4 times the harvest of the best flat/tiered systems such as GAE's mentioned above
- Its slow rotation means plants absorb *only* the water and nutrients needed from feeding tray at the base of the carousel, resulting in strong, healthy, and pure growth
- Surpa's feature the ideal '*light source to plant*' relationship - the plants are in the '*Goldilocks zone*' meaning they're close enough to the light source to receive full growth benefits, but not so close that the leaves get singed
- The system uses just 1% of the water required for traditional agriculture which is far less than 10% usage of standard hydroponic systems as plants draw only what's necessary rather than being over irrigated and the liquid reservoir is closed virtually eliminating evaporation and runoff. Additional water savings can result as the garden can use distilled water, allowing recycling of nutrient water

- Geotropism relates to the effect of gravity on certain plant hormones (auxins) that can speed up or slow down growth. The (dynamic and environment responsive) pattern of auxin distribution within plants is a key factor for their growth. Plants being constantly rotated 360 degrees experience an even distribution of these auxins throughout their stems/roots, a phenomenon termed *orbitropism* by Omega Garden. Using this process, the plants develop compact root systems and develop more quickly than in the ground – growing time is reduced by 30%
- The effect of *orbitropism* combined with gravity's influence on plants, compresses the plant, producing more internodes, or flowering sites with shorter and stronger growth. Produce is more nutritious and tastes better as the stress from the rotation increases flavonoid production
- pH at the roots remains consistent due to watering design
- The central light reduces overall light (energy) requirement per productive square foot by a factor of up six and maximises lumens (light density) capture as nearly all light falls on the growing area
- Flexible design enables ongoing experimentation with different light sources to lower energy usage. Each Supra garden operates with 4 x 39w T5 fluorescent tubes for maximum production, but a range of LEDs (20-64W per garden) are being tested and could signal a 60-85% reduction in energy usage . The lighting is required for 18 hrs each day and a 4w motor provides permanent rotation for continuous orbitropism and ensures the rooting medium remains moist
- Fully automated feeding and watering allows growth 24 hrs a day/365 days pa

What's Growing?

Many crops can be grown, with endless varieties therein.

Herbs	garlic chives, Thai basil, mint, feverfew, marjoram, savoury, Italian parsley, oregano, thyme, etc
Peas & Beans	
Aubergines	
Lettuce/Leaves	all types including cos/romaine, round, lamb's, little gem, endive, kale, lollo rosa, escarole, pak choi red mustard greens, komatsuna, red Leaf rocket, spinach, Swiss chard, quattro stagioni, watercress
Strawberries	
Tomatoes	
Peppers	cayenne, jalapeno, sweet, chilli, paprika, etc

The farm will fully meet the needs of the hotel's food operation in respect of leafy/herb produce as well as peppers, tomatoes and possibly peas/beans, cucumbers and strawberries. Any surplus produce will be made available for local use.

Optimum Growing Conditions

Three processes regulate plant growth: photosynthesis, respiration and transpiration, the first being key as put simply, photosynthesis is how plants *obtain* their food (energy).

There are 2 parts to photosynthesis. First the plant absorbs radiant light and converts it into chemical energy. It also absorbs carbon dioxide from the air (leaves) and water (roots). During the second part of photosynthesis the plant uses the chemical energy to spilt water into hydrogen and oxygen (released to the environment). The hydrogen combines with carbon dioxide to make a simple sugar molecule, glucose.

Thus, light energy is now stored in the form of glucose which is used directly as an energy source for many reactions in the plant cell, as well as being converted to the building blocks for proteins and fats - all necessary for making plants grow.

Several environmental factors influence (enhance, reduce or limit) photosynthesis

- Radiant Energy (quality, intensity and duration)
- Temperature
- CO_2 concentration of the atmosphere
- Humidity
- Supply and temperature of mineral nutrients (hydroponic systems)

Any one of these may become a limiting factor with the overall rate being limited by the factor which is in shortest supply. For instance, as light intensity increases, the rate of the photosynthesis increases proportionately (straight line relationship) until the optimum level is reached - further increases have no benefit. However*, before* this optimum point is reached, it is likely another factor will become limiting – lowering the optimum point at which further light increases have no effect.

Low CO_2 levels (350 ppm) will become a limiting factor well before the optimum level for light intensity is reached, as will a low temperature (18°C) by restricting the catalytic effect of certain enzymes. Similarly with low humidity, which can slow growth or cause stunting, despite optimal temperature/CO_2/light intensity.

Even in advanced greenhouse/indoor environments it is difficult (or uneconomic) to suitably control all these factors to optimum levels. We propose to optimise all key factors *other than CO_2 enrichment*, as the farm is too small to justify this expense. Propagation through cuttings can potentially reduce harvest times and will be explored.