AGRICULTURE UTAR SCIENCE JOURNAL

An amazing city rooftop garden, using bio-char to grow plants and sequestrate carbon

Biochar in rooftop gardens can massively improve urban living environments and compensate for forests in the fight against global warming.

By F.S.P. Ng

1 Utama Shopping Mall, Kuala Lumpur, Malaysia

This is the story of a special garden created on the roof of one of the largest shopping malls in the world, located in Kuala Lumpur, Malaysia. The interior of the mall is like what you would expect of any modern shopping mall. The amazing garden is on the roof, seven stories above ground level. This garden is almost one acre in size and accommodates over 500 species of plants displayed in a continuously varying landscape of quiet cool retreats, sunny hotspots, cheery flower beds, a

A quiet retreat on the roof

A sunny hotspot

Waterfall

Flower beds

Mystery tunnel

Waterlily pond

waterfall, a mystery tunnel and so on. It took us five years of research—trial and error—to get this garden established. During this period the garden was invisible and inaccessible to the public. The staff of the mall referred to it among themselves as the *Secret Garden* of their boss, that was how it got its name—*The Secret Garden of 1 Utama*. Behind the name there are several real and important 'secrets'.

You know immediately that this garden is in the humid tropics because of the abundance of large fleshy leaves. A garden in the humid tropics is normally a lush leafy green garden. We add colour to this garden in two ways: firstly by growing plants that have colourful leaves,

Colocasia gigantea

and secondly by growing plants that flower abundantly and continuously. We are well on the way to being a garden in which it is "Springtime All The Time", no matter which time of the year you visit.

Arabica coffee, *Coffea arabica*

To cater for education in food plants, particularly for children, we grow a range of the most important tropical food plants, for example, pepper, tea, coffee and cocoa. Also grapes, passion fruit, cassava, papaya, persimmons and of course, rice.

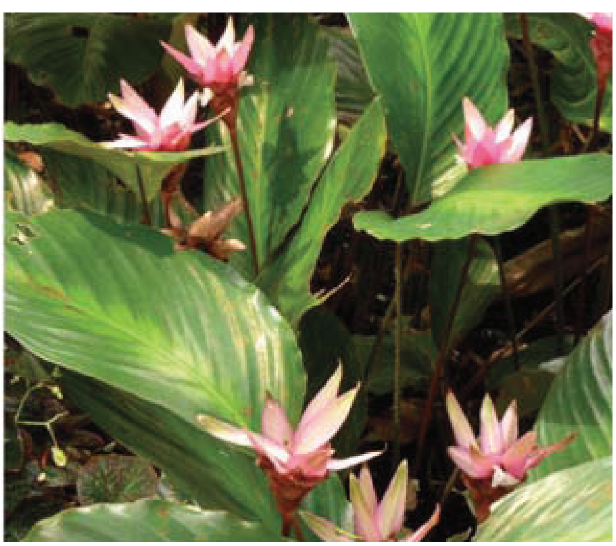
We grow and display a range of plants for their distinctive architectural features; these include palms and agaves, and also cacti with their neat and unique shapes.

In the humid tropics there is no resting period for plants. Leave a garden untended and in a matter of weeks it will become a jungle. A garden in the humid tropics needs to be pruned every week;

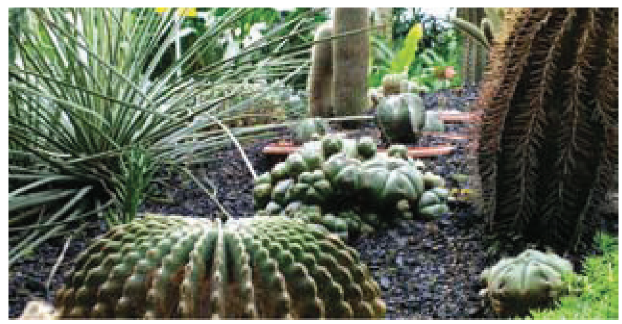
Pepper vine, *Piper nigrum*


Rangoon creeper, *Quisqualis indica*


Grass-orchid, *Arundina graminifolia*


Star calathea, *Calathea looseneri*


Century plant, *Agave desmettiana*


Cactus collection


Hosta hybrid


Rice, *Oryza sativa*

Stringy cissus, *Cissus nodosa*

Some plants, like *Cissus nodosa* produce aerial roots in profusion and requires a 'haircut' twice a week.

People expect this garden to hold many technical secrets but we do not keep any secrets. The garden is open to the public on weekends and public holidays from 10 am to 10 pm. There is no entrance fee and no restriction on photography. On the first weekend of each month there are free guided tours. Visitors are free to ask questions.

The most frequently asked question is: How deep is the soil? The answer, which surprises most people is: 10 to 12 inches only. This is sufficient for all plants. We keep most of our trees short so that they cannot be easily toppled by wind and to reduce their weight on the roof.

The most important consideration is actually how much load the roof can take. The roof was not designed originally hold a garden, so it is an ordinary flat roof with no special reinforcement. It can take a load equivalent to about 24 inches depth of water. To be safe, we limit the depth of water in our waterlily pond to 18 inches.

Another often asked question is whether the roots will damage the roof. Let us be clear about this. Plant roots are not drills. They cannot drill through concrete. They break concrete by lateral pressure. They can penetrate cracks that already exist, and then they will widen the cracks as they expand sideways. If the roots are constricted by walls, they may expand and break the walls. They can also lift pavements, but roots on top of a properly constructed roof without cracks will not do any damage.

One student of landscape architecture interviewed me with a prepared list of questions to discover the secret properties of plants that enable them to grow on a rooftop. I had to tell him that any plant that can be grown on the

Begonias and other shade plants

ground can be grown on a rooftop. It all depends on the capability and interest of the curator of the garden.

The most important ingredient of the Secret Garden is in the soil that we use. This soil is very rich in biochar. Biochar is the name we give to small particles of charcoal used as a medium for root growth. In this garden we use a lot of biochar, ranging from 50% to 100% of the soil.

Normal earth in Malaysia is mostly clay. Biochar is half the weight of normal earth and when mixed with earth, it makes a friable and porous soil, through which water can quickly drain down and out. Good drainage is important because for optimum growth the soil needs to be humid and airy at the same time. The 12 inch depth of biochar soil provides a gradient of moisture and air: 100% moisture at the bottom and very airy at the top. The roots of different plants find their own levels of comfort. It is important to ensure that the water is renewed daily. Fresh water carries dissolved oxygen and as it drains out, fresh air is automatically sucked into the soil. Daily watering ensures that the roots get fresh oxygen daily. Nutrients are provided by fertilizers that we apply periodically. With biochar soil, we can grow plants that are normally difficult to grow on normal tropical soil: e.g. temperate plants like persimmons, hydrangeas and hostas, highland plants like Arabica coffee, and dry-climate plants like the Canary Island palm, cacti and succulents.

Under this roof there are six floors of shops, restaurants, cinemas, and offices—almost a small city. We have, in effect, transferred the ground up to the roof and restored on the roof the green functions that the ground originally performed when it was tropical rain forest 100 years ago.

Trees and forests absorb and store carbon

Soil depth - 12 inches

dioxide in wood and in the soil. Young trees and forests absorb and store carbon but as the trees and forest age, they reach stable equilibrium at about 300 megagrams or tonnes of carbon per hectare, which is equivalent to about two and half inches depth of pure biochar. This garden is provided with 12 inches depth of biochar soil. The Secret Garden therefore holds or sequesters about two-and-half to five times as much carbon as mature tropical rain forest on the same area of ground. A biochar garden is the most effective, practical and safe way to sequester carbon, and it is a method that you and I can apply, unlike the grandiose mega-engineering schemes being proposed for extracting carbon dioxide from the atmosphere, liquefying it and pumping the liquid deep underground for permanent storage.

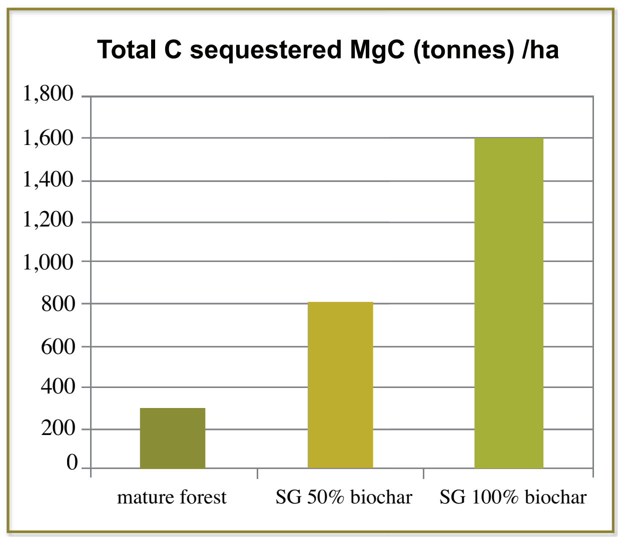
Tropical rain forest holds 300 tonnes of C per ha

Biochar

100% biochar on waterproofed roof, always wet at the base, always airy at the top

A rooftop garden could be an organic farm, a herb garden, a lawn, a fruit orchard, a butterfly farm or even a rice field. There are many exciting possibilities. My gardeners used to be rice farmers. They insisted that rice will only grow on wet mud and were amazed when the rice we grew on biochar produced a bumper harvest that attracted rice-field birds. We were amazed that these birds were able to discover our small plot of rice in the city. If all urban buildings had biochar gardens on their roofs, our cities could compensate for the forests or farmland that they replace. The size of the building is not a limiting factor. I have a friend who built his house with a flat roof on which he created a very private garden for himself.

The important take-home message is that roofs need not be dead areas. We can transform them into innovative life-sustaining systems to offset the damage that conventional urban development inflicts on the environment.



Amount of carbon sequestered in mature tropical forest compared with carbon sequested in biochar in the Secret Garden (SG) using soil with 50% and 100% biochar content

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Biochar production opportunities for South East Asia

An overview of the many different ways in which biochar can be created.

By Trevor Richards

This is a follow-up article to "Biochar - reversing the flow of carbon" which was published in the inaugural issue of this journal in January 2014. In the first article I provided some background on charcoal and the history of biochar. I provided an introduction to some of the agricultural and environmental applications for biochar and also its potential for climate change mitigation. I very briefly introduced some of the biochar production concepts and opportunities and promised to expand on this in a (this) follow-up article.

Biochar can be created from simple burning (combustion) systems or more complex gasification and pyrolysis technologies. It is easy to drown oneself in chemistry and physics when looking deeply at the science of fire. I'm not qualified to say too much about complex thermal processes but I'm willing to get my fingers burnt, trying to present a layman's view.

In its elemental state, biomass is made up of mostly carbon, hydrogen, oxygen and nitrogen (C, H, O & N). As you heat biomass above 100ºC you drive off the water molecules. As the temperature rises above 200ºC other volatile, flammable gases evolve and progressive chemical changes start to take place in the hemicellulose, cellulose and lignin components of the biomass (Yang *et al*. 2004). If enough O_2 (or air) is available within the hot zone (fire) and temperatures are high enough then eventually all of the H and C will be 'oxidised' or transformed to heat and gases (mainly H_2O and CO_2) leaving behind ash (minerals, metals, salts that were part of the biomass). The atmospheric N_2 is relatively inert but at temperatures above 1000C can react with O_2 to form NO_x (Werther & Ogada 1999). This process describes complete combustion. But combustion is often incomplete due to a lack of O_2 &/or cooling of the remaining mass below gas ignition or reaction temperatures. This is where you will find charcoal—smothered in the ash bed of any combustion device. This is why some chars can be extracted from combustion systems.

This char is the residual C that did not see enough O before cooling below reaction temperatures. Pyrolysis technologies focus on restricting or eliminating O (air) from the heating zone so that C cannot react with O. In this environment, the C starts to combine to form very stable 6-sided aromatic rings of almost pure C. Biomass also often retains its original porous plant structure which is one of biochar's most important attributes. 'Slow' pyrolysis is generally the preferred option for charcoal and biochar production because it optimises the amount of C that is retained and provides time for the char formation chemistry to take place. However, low-temperature fast pyrolysis biochar has also been reported to help enhance soil properties (Brewer *et al*. 2011).

There are other potentially valuable products of pyrolysis such as wood vinegar, bio-oil, fuel gases and heat but if the focus is on renewable energy, then gasification is often in the frame and biochar becomes the by-product.