Vertical plant production as a public exhibit at Paignton Zoo

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Abstract

Paignton Zoo has undertaken a novel project together with a multinational plant technology group to build Europe's first vertical growing facility. The project represents the first garden-based sustainable growing laboratory, showcasing an evolutionary step in the way crops can be grown to the public. It provides the means to cultivate crops on the organisation's own site when space is a premium and where traditional methods of crop production cannot be used. The project is an example of change in the nature of zoos as they move towards becoming fully integrated conservation organisations and demonstrates an integrated approach to zoo horticulture. It is an example of how zoos and botanic gardens can demonstrate sustainability to their visitors through reducing their own impacts on the environment with plant based solutions to offset the impact of anthropogenic global change on biodiversity.

VertiCrop is a technological solution to a sustainable urban agriculture. It is compatible with low input production systems such as permaculture as being advocated in urban agriculture. Urban agriculture itself is a technology which zoos and botanic gardens are well placed to showcase through public exhibits. Urban agriculture and High Density Vertical Growing technology should be seen as an essential element which can help to achieve Millennium Development Goals, most specifically number one, end poverty and hunger and number seven, ensure environmental sustainability by taking pressure off habitats to service unsustainable cities through agricultural domestication or otherwise unsustainable land use.

Keywords: Zoological Garden, Botanic Garden, Collections Management, Sustainable Development, Vertical Farming, High Density Crop Production, Botanical Exhibit & Sustainable Interpretation, Millennium Development Goal, Urban Agriculture.

Introduction

Paignton Zoo Environmental Park is a zoo and botanic garden in the south west of England, UK. It was established in 1923 and twenty years later opened to the public as a private collection of animals and plants by Herbert Whitley, the heir to a brewery fortune (Baker, 1988). The garden was entrusted upon Whitley's death in 1958 and since that time has operated as an education and research charity dedicated to wildlife conservation. It achieves its objectives through undertaking *in situ* and *ex situ* work abroad, and through managing population work on its own site in collaboration with other scientifically managed reserves and collections (Anon, 2009). To demonstrate congruence in its site operations and in undertaking new developments the zoo gained external recognition in 2005 for its work by undertaking internationally recognised Environmental Management System ISO 14001, a reiterative standard that requires rigorous annual auditing under external auditors to retain (Turner, 2009).

Plant use in the zoo

Paignton zoo has over the years built up a large botanic collection which today hosts over 5,000 plant accessions growing in its pubic areas outside its animal exhibits, representing 2,500 species that are set in a 30 hectares of rolling Devon landscape. While the zoo is internationally recognised for the integrated nature of its work, the gardens has not had the same directed focus for its plant collections until fairly recently, having instead developed an emphasis on accumulating plant diversity and displaying naturalistic landscapes. Since 2008 the garden collections have been provided with a new vision that looks to optimise the potential for plants to support the zoos mission: to educate, research and conserve in support of the world's animals, plants and their habitats. Through this new initiative the garden is progressing a new botanical direction through following an integrated approach to zoo horticulture (Frediani, 2009a; Frediani, 2010).

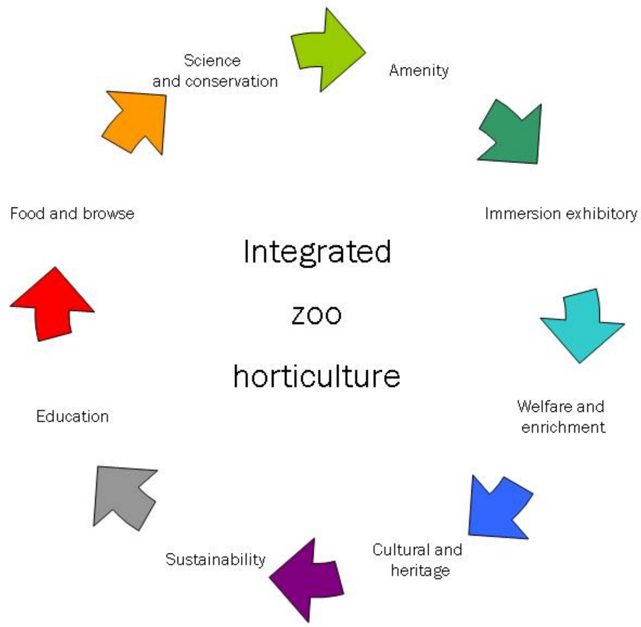

Figure 1. Eight plant use themes that define the breadth of zoo horticulture after Frediani, 2009.

Many of the plant use themes are well established roles of botanic gardens around the world such as research, display and education. A small number however, required exploration and innovation to realise. Food production needs land to be made available and could potentially conflict with evolving animal exhibits. Enrichment first had to be defined in terms of the use of landscape and plants to encourage natural behaviour in animals (Frediani, 2009b); while Sustainability as a concept proved rather difficult to interpret in terms of tangible developments for visitors to see, interpret and enjoy.

Sustainable food production as a public exhibit

Addressing the nutritional requirements of zoo animals through selection of the right types of food stuffs requires intimate knowledge of the animal. Nutritionists can be supported in this work by exercising more control over the nutrient content of the food crops (Morgan, 2009). This is achievable with modern horticultural crop production technology that can also bring other benefits from providing increased control. Consider the roots of plants which are traditionally left behind in the ground or removed and composted at cropping time. They can be fed into the animals as part of an enrichment or welfare programme reducing waste and increasing fibre intake. These benefits could also be achieved through the contract growing of specialist crops that the zoo specifies, but this often incurs a large cost and takes time to manage successfully. Hence in reality it is seldom undertaken to any great degree.

Reduced costs, greater control and flexibility can be gained through localised crop production where organisations grow their own food plants to serve their own needs. In zoos, animal food provision is a priority, however it has to date been heavily subsidised through outsourcing from a human dominated supply chain that undervalues the use of carbon based fuel to grow, transport, maintain post harvest and store until purchased and used. With the development of the new VertiCrop™ in the zoo it is now possible to grow food on a site limited for space that provides animal management support services and has the potential to service some of the visitors needs for fresh leafy salad crops year round in a sustainable, low impact but highly interpretational manner. Additional benefits have been gained from in-house growing at the zoo that was not necessarily fully understood at the onset of the project (Frediani, 2009c). These have included: the ability to grow a larger diversity of crop plants than were commercially available; the provision of plants year round without concern for the changes in weather and impacts on field grown crops; the ability to provide crops that are out of season or out of the price range of the organisation and have led to the reduction of overall food bill and led to an increase in the food security of the organisation.

VertiCrop™ - High Density Vertical Growing

VertiCrop uses hydroponic growing technology in a vertical conveyor driven system. Hydroponics is the science of growing plants without soil. Instead of soil, plants are grown in solutions containing all the necessary mineral elements. Methods used to get the nutrients to the roots, along with the needed oxygen, include bare-root systems and systems using inert substrates to support the plants. The Paignton zoo system comprises a closed loop conveyor system suspended from an overhead rack that carries seventy hangers that hold 8 pairs of bespoke growing trays using a water based bare root system contained in a plastic tray (see figure 2 below). This allows an even airflow over plants and, importantly, equal exposure to light. It is integrated with the most advanced hydroponics technologies to automatically supply water and nutrients at a central feeding station; the run-off solutions are captured, filtered and recycled through the whole irrigation system. In a little over 100 meters of floor space it has the capacity of growing 11,200 plants at any one time (Frediani, 2010). Where the system currently produces around 112 lettuces per square metre, per crop on a 3m high pilot system at Paignton Zoo; however, optimal production with up to 250 lettuces per m^2 can be obtained if the vertical dimension is 6m high. VertiCrop™ forecasts based upon this modelling suggest annual yields of lettuce around 50 times higher per square metre than typical field grown crops (Bayley *et. al*, 2010).

Figure 2. The VertiCrop growing production system with its first crop of lettuces @ Kevin Frediani

The global context of the modern zoo and botanic garden

Over the last five decades, the pursuit of growth has been the single most important policy goal across the world. The global economy growing to almost five times the size it was only half a century before. This growth is increasingly being seen as unsustainable. Projections estimating that continued growth at the same rate will result in an economy 80 times the size by the year 2100, leading to a suggested redefinition of our age as following a myth of economic growth (Jackson, 2009). Jackson's report, authored as chair of the UK government's sustainable development commission, states that the extraordinary ramping up of global economic activity has no historical precedent, being totally at odds with scientific knowledge of the finite resource base and the fragile ecology on which we depend for survival. The past pursuit of growth having already been accompanied by the degradation of an estimated 60% of the world's ecosystems (Jackson, 2009). This is an unsustainable misuse of the world's life support systems essential for the well being of man kind (Odum, 1993).

Given the state of the impact on the world by man, there seems to be a moral duty for zoos and botanic gardens to showcase sustainable use of resources such as energy, land and water, on their own sites to directly make the link between the global and local impact of sourcing, growing, housing and displaying collections of rare plants and animals. How otherwise can conservation organisations educate about the loss of biodiversity due to habitat destruction or anthropogenic global change without themselves having demonstrated a commitment to work within the limits of sustainable growth and development? (Frediani, 2009a). To undertake this change in focus gardens must audit there own impact on the environment by understanding how they obtain and use their resources. This information can then be used to measure the impact as the environmental footprint of the organisation or indeed that each new exhibit has.

Environmental footprint is an important means to measure an organisations ability to work within sustainable limits where carbon is an indirect measure of the environmental cost of operations and activities (Weidema *et al*. 2008). When this method is applied to on-site growing of food crops using the VertiCrop, there is little or no carbon expended in between crop production and delivery, as transportation will be eliminated and therefore the environmental costs are reduced to a lower level than would otherwise be the case. The zoo exhibit is housed within a low energy polythene structure that has is double skinned with a smart polythene film on its roof to retain heat, reduce scorch and provide optimal light levels in winter months (Chester, 2010). Rain water is harvested from the roof and under floor heating is used to provide minimum winter temperatures. Further reductions can be made through integration of compatible green technologies to generate and efficiently utilise the energy required to operate it. These include biogas, solar thermal, air, ground and gas source heat pumps, photovoltaic, geothermal and wind power. The resultant exhibit has the potential to require no carbon-based energy and provides the organisation with a reduced ecological footprint that can be communicated to its visitors in a visually graphic and physically ingested way, through literally eating the view.

Figure 3. VertiCrop™ exhibit interpretation at Paignton Zoo showcasing sustainable food production

Urban food production

Energy inputs are critical to agricultural production and the increased use of fossil fuel based energy resources has become increasingly important, particularly in developed countries and increasingly in the developing countries. Even though agriculture requires only a very small percentage of all the fossil fuel resources used in the world, long-term sustainability of global agricultural production will require renewable alternative energy resources (Mears, 2007). With an increasingly urban world where the majority of people now live in cities localization requires that food and fuel be produced in an urban context (Crane & Kinzig, 2005). At present, there are no examples of a locally sustained urban community anywhere in the world (Odum & Garret, 2005; Newman & Jennings, 2008)). Urban agriculture is increasingly being recognized as one of the activities with the potential to contribute towards socio-economic development in urban areas of the developing world. However, urban sustainability is yet to be realised primarily because urban agriculture presents a number of technological challenges (Fischetti, 2009, Vogal, 2008). The main challenge is a lack of growing space and limits to water and has to date only be successfully applied with the large scale conversion of green space in Havana, Cuba following the collapse of its external political support by former communist countries in the late 20th century.

The Cuban experience showed that with massive political support, and through the use of more sustainable land management practices based upon core permaculture principles, it was possible to make a huge improvement in local food production. Although the daily food intake per person remained below the recommended daily recommendation, it did support the urban population without massive external inputs and imports of food (Cruz & Medina, 2003). In developing countries urban agriculture is increasingly being seen as a progressive way forward. In Zambia, urban agriculture has played a key role as one of the key community responses to the after-effects of economic restructuring and therefore has the capacity to contribute in alleviating food insecurity and poverty (Hampwaye *et. al.* 2009).

Vertical growing beyond the zoo

Vertical growing systems are proposed as possible solutions for increasing urban food supplies without increasing the need for additional areas of land to be put aside for agriculture (Despommier, 2010). They can have a role alongside permaculture systems in cities and low impact agriculture in soils around cities. The primary advantage of vertical growing is the high density production it allows using a much reduced physical footprint and fewer resources relative to conventional agriculture. The figures suggest a water use efficiency of 1/6th conventional agriculture and provision of 20 times the crop per unit of land (Bayley *et. al*. 2010).

Vertical growing is compatible with existing hydroponics and greenhouse technologies and can embrace emerging sustainable technologies such as LED and Plasma lighting. Together these solutions address many aspects of the sustainable urban production challenge (i.e., soil-free, organic production, closed loop systems that maximize water and nutrient efficiencies, etc.). Such systems have major potential for the realization of environmentally sustainable urban food and fuel production to benefit human kind and have a very real place to play in adding value to society through zoo and botanic garden horticulture in the 21st century.

Figure 4. VertiCrop™ is a modular high density growing system suited to serving the needs of an urban agriculture.

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