THE EDEN PROJECT – THE HUMID TROPIC AND WARM TEMPERATE BIOMES

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Introduction

The Eden Project grew out of an idea of Tim Smit's, a unique personality already well known in horticultural circles for the restoration of Heligan, one of Cornwall's best examples of a nineteenth century estate garden.

At the outset, discussions ranged over several worthwhile, plant-based ways in which the Millennium could be celebrated in Cornwall. It was felt that any such project must combine a serious and intellectually challenging message while at the same time attract the general public as visitors. There grew the conviction that a self financing visitor attraction could at the same time be a significant international botanical institute. It was decided to bid for a completely new form of plant-based attraction, one which combined aspects of the Botanic Garden, The Great Landscaped Garden and the Natural History Museum. After six months Eden has received over one million one hundred thousand visitors.

Eden's theme is "Plants and Man". The project has a clear set of objectives. Its primary aims are to address the issues of land use in the coming years and to make the public aware of the vital need to practice our stewardship of the world in such a way that a measure of sustainability will be achieved. This must come about both through the conservation of natural ecosystems and within agricultural systems. Eden is equally committed to the wise practice of all branches of agronomy and considers that, for both the wellbeing of the planet and our own species, nature and production must coexist.

The site selected was a 10 ha, 60 m deep quarry. It was one of the many old china clay pits near the town of St. Austell. This, at a capital cost of some 80 million pounds sterling, has been converted into a spectacular landscape in which a significant area of the quarry floor is under cover and capable of growing tropical species to their full maturity. The Eden Project could be said to grow out of the long European heritage of botanic gardens. Yet there is a clear difference, historically their living collections have had a close relationship with a scientific staff whose principal concern has been with taxonomy. Eden presents its living collections as a series of "exhibits". These are set out to intrigue and inform the public of the many functions that plants perform, from the quality of the air we breathe, to the supply of food, medicines, clothing and shelter. To balance this human-based view of the plant kingdom, Eden also shows something of the intricately inter-related biodiversity of natural habitats.

It was agreed from the start that the visiting public would expect to have some form of "garden experience". It followed that however imaginatively presented issues of conservation and agronomy could be made, they would have to be set in elegant architecture and a visually attractive landscape rich in seasonal colour and interest. After all, the vast majority of the visitors would be tourists and holidaymakers from outside Cornwall. This has been achieved, but within the 10 ha of the pit, some 30 outdoor exhibits deliver part of

our message. Of necessity they are confined to the use of hardy plants, although the themes they address, such as the origins of agriculture and the conservation of woodlands, have global significance.

The issues that Eden addressed are world-wide. It is for that reason that the project set out to grow plants that require a protected environment, indeed a range of environments such that it would be possible to represent examples of crops and plant assemblages from all but the coldest climates.

The Covered Structures

We estimated that this could be achieved within four structures plus the local climate. These would be the humid tropics, the semi-arid tropics, the sub tropics, the Warm Temperate Zone and the cool temperate climate of Cornwall. It should be noted that the topography of the pit creates a local microclimate, which through shelter, aspect, angle of slope and air drainage impacts on conditions both out of doors and within the biomes.

To date two covered structures, or Biomes as they have come to be known, have been built and planted. These represent the climates of the humid tropics (1.5 ha) and the warm temperate (0.6 ha). Each structure provides large areas with sufficient headroom to allow trees to reach their full height. These dimensions provide the opportunity to demonstrate that each climatic zone has a diverse flora rich in useful plants.

The plantings within each of the Biomes are divided into three zones:

Arcadia – Images of plant assemblages undisturbed by human intervention. Within "Arcadia" the plantings relate to selected habitats from named geographical regions. In the Humid Tropics Biome these are Oceania, Amazonia, Malaysia and West Africa. In the Warm Temperate Biome the Mediterranean region, South Africa and California. Where appropriate the designs include both traditional and contemporary ethno-botanical artefacts.

Areas of Simple Cultivation – Images set within Arcadia of simple forms of agronomy associated with human settlement illustrating both the plants grown and how such activities impact on natural landscapes and their wild plants.

Cornucopia – A celebration of the huge diversity of plants and plant products used by man and in some cases a demonstration of how husbandry and plant breeding have improved them.

The Biome Construction

Edens' Biomes are among the largest "plant houses" in the world. The footprint of the Humid Tropics Biome is 1.4 ha and that of the Warm Temperate Biome 0.6 ha, both "face" South, being set against the North face of the pit. Their design is based on a number of touching hemispheres, each constructed from galvanised steel hexagons following the basic geometry proposed by Buckmaster Fuller. The hexagons vary in size between six and eleven metres measured across the diagonal. The Biomes are free standing and have no internal supports. The height to the top of the largest dome in the Humid Tropics is 55 m and in the Warm Temperate 25 m.

The hexagons are clad with "pressurised cushions" inflated by electric powered blower units to approx. 400 pascals. The cushions are formed from three layers of Ethyl Tetra Fluoro Ethylene foil; each layer is some 0.3-mm thick. ETFE has excellent light transmission properties allowing some 0.5% of the light from the visible spectrum to enter the structures. Unlike glass, it also has a high transparency to ultra-violet radiation, however, it is more opaque to infrared radiation. ETFE is extremely strong and resistant to degradation. There are horticultural structures clad in this material that have been in continuous use for more than 20 years.

The factory produced sealed cushions are held in place with a surrounding aluminium cap. It was decided that, based on the scale of the building, the best way to service the structure and its cladding was by climbing and abseiling. Challenging as this may seem, this approach has proved feasible and cost effective.

The Biome Environment

Heating

The Humid Tropic Biome's target minimum winter temperature is 18°C, the Warm Temperate 10°C. The worse case so far experienced has been 15°C in the Humid Tropics Biome and this for only some 4 hours. The plants are well able to tolerate that shortfall. The Warm Temperate Biome has achieved its required temperature at all times.

The fuel is mains natural gas burnt in one or two of three, 3-MW units designed for district heating. This results in low pressure hot water at a temperature of 90°C which is circulated in a ring main to and around the outside of each Biome. A series of heat exchangers convert this energy into hot air at a temperature of some 50°C. The air is blown through angled jets into each Biome. There are 24 units for the Humid Tropic Biome and 9 for the Warm Temperate Biome. With structures up to 55 m in height, there is inevitably a stacking effect. A uniformity of around +/– 5°C has been achieved by the calculated positioning and angling of the nozzles and the velocity of the hot air.

The positioning of the heat exchangers and air fans outside the building has reduced the noise level to an absolute minimum and one that is of no distraction to the public.

Ventilation

The ventilation and heating control systems are computer integrated. The ventilation system is designed to exploit the stacking effect of these very high structures. The opening to allow for the escape of the overheated air is in the hydraulically powered triangular "petals" which are normally programmed to open in groups. Air temperature, wind speed and direction, and precipitation are taken into account by the computer programme when determining opening patterns.

Air entry is achieved through a series of glazed, level operated louvres powered by electric motors. These louvres replace the foil cushions in many of the lowest level of hexagons. The opening of the louvres is modulated, going through a series of 10 stages. This simple system has proved to be satisfactory except for the impact on the margins of the Humid

Tropic Biome where very large volumes of outdoor ambient air enter the structure. The openings are netted against birds but are open to insect entry.

Both Biomes have a target maximum temperature of 32°C. The hottest temperature reached with the ventilation system operating during this, the first operating summer, has been 34°C.

Humidity

There is no atmospheric humidity control in the Warm Temperate Biome other than the reduction achieved by ventilation under some conditions. The aim in the Humid Tropics Biome is to achieve a minimum of 90% relative humidity for 80% of the time when the ventilators are closed. This has been achieved over 90% of the days through the use of high-pressure water mist nozzles. To date, no dry air foliage stress has been noted. A network of 700 nozzles produces droplets in the 10-μm range. The pipework is pressurised to 12 MPa (120 bar). Each head of 4 nozzles discharges 6.5 litres per hour, they are arranged within the foliar canopy zone and angled so that most of their output evaporates before settling as a film of water.

The source of water is that collected from the roof of Biome ducted to and stored in tanks with a holding capacity estimated to be eight weeks summer requirement; a generous amount given Cornwall's climate, mains water can be used in an emergency. The roof water is filtered and sterilised, for human health reasons, before pressurisation.

Irrigation

As with any wide-ranging collection, applying the optimum amounts of water per unit area of root zone throughout the year cannot be achieved by any blanket irrigation system. This problem is most acute in the Warm Temperate Biome, where various communities of plants experience strong but varying degrees of seasonal fluctuation in rainfall. Other very important factors influencing the selection of even a basic irrigation system where the very steep slopes within each Biome and the need for the system to be as discreet as possible.

The system selected is based on ground level polythene pipe with pressure compensating drip emitters at 50-cm intervals. This watering grid can be activated in a number of sections allowing for the establishment of different soil moisture regimes. The discharge rate per nozzle is 1.6 litres per hour and it is possible to set the timing at any duration between 1 minute and 12 hours with a choice of 8 start times. Take-off points for hose or can watering are installed throughout the Biomes.

The water source is ground water from within the pit. In reality this supplies an unlimited volume as the site requires constant pumping to prevent flooding from the several springs exposed in the sides of the pit. However, a link with mains was installed as a safety backup in case of pump failure.

The Soils

The root zone of each Biome is manufactured from formulae devised as a result of research and trials conducted by one of Eden's Directors, Dr. A.D. Kendle and his colleagues. The soils are laid down on permeable, "pit fill" material that consists of local rock debris from

the cut and fill operations that formed the new site contours. The soil profile throughout both Biomes consists of a subsoil layer of some 4 m above which was spread a 3-m depth of topsoil. All the mixes are based on a mixture of specific grades of the local quartz sand (products of the china clay extraction process) and varying amounts of organic matter. The third bulk ingredient making up 10% of the mix is clay, the irony being that kaolin or "China Clay" has no useful surface chemical activity. The organic component is derived from tree bark and twigs and has a high percentage of decay resistant suberin and lignin. The pH ranges from 5.5 to 6.0. The percentage of organic matter varies between areas but in every case the subsoil has a lower amount. The highest organic matter content in any topsoil mix is 60%, located in areas of the Humid Tropics Biome; the lowest is 10% in parts of the Warm Temperate Biome.

The Plant Collection

Plant selection has been driven by our exhibition and design policy. In the geographical areas we have assembled species native to those regions and no claim is made to reproduce either a complete habitat, let alone an ecosystem.

Nevertheless, these assemblages reflect something of a species frequency in that common and dominant species are planted in considerable numbers compared to those with a lower frequency in nature.

This commitment to select location-correct species brings a measure of authenticity and is particularly valuable to our Education Department. Curators of botanical collections will know that a plant being a significant component of a natural flora does not guarantee ease of adaptation to greenhouse cultivation. It has long been recognised that those species that have become our "house and office plants" are uncommonly well suited to cultivation under extremely different conditions to those they would experience in nature. In rejecting the easy option of creating a rainforest pastiche based on such plants, Eden has been able to take its place among those commented to the maintenance of botanical collections. Such a noble policy however brings challenges to the horticultural staff!!

In addition to the cultivation of naturally occurring species, Eden's Biomes grow a wide range of crops found in the Humid Tropics and Warm Temperate zones. In a few cases, such as rubber, health, vigorously grown young trees surface. However, to achieve the desired public appreciation of crop-to-product, most taxa must flower and fruit; requirements that call on the skills of the staff and a greater fit between environmental conditions and plant requirements.

Plant Husbandry and Plant Response

Eden's horticultural staff are still at the start of the long-term husbandry programme designed to achieve the results aimed at above. Very high levels of success were achieved in the project's nursery in propagating the growing-on young plants of some three thousand taxa destined for the two Biomes. This work took place in traditional glasshouses, individual specimens being container grown for transporting and transplanting. Extremely few specimens die as a result of being transplanted and although both irrigation and nutrition proved difficult to get right during the first few months, the majority of the plants are now established and making satisfactory growth. The various manufactured soils all

appear to be performing well with no significant alternation from their behaviour when under test.

As usual, in a very mixed collection, the more vigorous species and their cultivars responded best with the rapid production of new roots which colonised the surrounding soil. Their aerial growth is considered to be healthy with a form typical of the species. We are yet to face the challenge of completing the life cycles of woody species, but there is already indication from annual species of the need to introduce some form of pollen transfer in spite of the relative open nature of the ventilation system.

References

For further information go to http://www.edenproject.com/design/design.html