ROOF GARDENS IN BRAZIL

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Abstract - The green roof technology has its origin in several different countries and in various climates. Green roofs have become an important element of sustainable architecture. Actually green roofs are spreading out worldwide (1,2).
Green roofs can be divided into three categories:

- Spontaneous green roofs
- Extensive green light weight roofs with low maintenance, without additional irrigation and fertilizing.
- Intensive green roofs = roof gardens.

First category: Under tropical conditions, already a small amount of random substrate can start pioneer plant growth. In the long term it can cause infiltration problems in the roof construction.

The second category: extensive green roofs are now starting in Rio de Janeiro, it seems to be a new idea for Brazilian architects; use in the sense of ecological benefits.

The third category follows the ideas of Le Corbusier – the flat roof as roof garden. Burle Marx (3) adapted it to the tropical climate and started with some roof garden project in the late thirties of the last century. So in Brazil one of the roots of modern roof gardens is located.

The MEC, MAM and Petrobras Buildings will be taken as examples from Rio de Janeiro. Green roof projects located in Florianopolis and Campina Grande will explain some more aspects from other climate regions of Brazil.

Actually, the potential of roof gardens in Brazil is very high. What started in Europe about 20 years ago and in North America around 5 years ago, actually finds also more and more adepts in Asian countries. Extensive green roofs are also part of a new "Biophylic Architecture" with multiple benefits. Anyway, this technology requires some special construction details. Further research results on construction details, plant species selection and maintenance can help to spread out the idea of green roofs in the next years in Brazil. A list of suitable plant species for green roof projects in the tropics is attached to this contribution.

1 Introduction

Green roof technology has its origin in various regions of the world. A plant covered building means a good insulation against hot or cold weather conditions. Historic experiences with this kind of insulation to improve the comfort in buildings can be found e.g. on Iceland. This type of green roof, with a substrate of up to only ten centimeters is called "extensive green roof". In most cases is requires neither irrigation nor maintenance.

Another advantage of green roofs is the possible transformation of roofs in high urban density neighborhoods into recreation areas, private as well as semi-public or even fully public. The roof gardens of the Rockefeller Center in New York are a famous example from New York in the fourties. These areas require maintenance most similar to gardens, with special attention to the potential high wind loads on high rise buildings.

Looking back in history, both types of green roofs have very famous historic precursors. (see e.g. Koehler et al, 1993). In the past decades a considerable number of roof gardens were integrated as an important element of architecture worldwide (see, Osmundson, 1999).

In the last decades extensive green roofs became an important element of sustainable architecture, especially in Central Europe. In some regions of Germany, most of the new buildings were constructed with extensive green roofs.

Brazil, a huge country with the highest plant biodiversity in the world, has the potential for roof gardens with a huge amount of plant species. It may also improve the indoor climate in dwellings and reduce the need for cooling, due to its good thermal performance.

2 Situation in Brazil, Overview

In the last past five years, the authors had the opportunity to visit a considerable part of Brazil. Here are the results on the actual situation of green roofs in Brazil.

2.1 Extensive green roofs

Under tropical conditions, plant growth starts immediately, if there is any kind of substrate. So weeds on roofs are very common. The same situation in Germany is called “spontaneous growth”. This type of vegetation gives clues about the basic conditions of plant growth on roof tops. A typical problem of this spontaneous vegetation is infiltration, caused by the penetration of roots in roofs without a specific protective layer. A planned extensive green roof counts with several protective layers, so there is the warranty to get a well sealed roof for a long time, similar to roofs with tiles. Guidelines for extensive green roofs exist in Germany (see FLL, 2002), an adaptation to different climates might be helpful.

A small impression of extensive green roofs is possible to see on the terrace roof a thins growing medium of the MAM (Museum of Modern Arts) in Rio. Most common weeds are growing there after a short while on a thin layer of substrate. A first overview about plant species, which can be used on extensive green roofs (about 73 species) and roof gardens with only a thin substrate layer (about 53 species) was published by Agarez, 2001, (see table A1). It should be the basic list for further investigations. This light weight green roof construction is, up to now, quite unusual in Brazil.

Fig. 1: A spontaneous green roof on a small house in Minas Gerais, Brazil.

Fig. 2: Extensive green roof on MAM Building, Rio de Janeiro, Brazil

2.2 Intensive Green Roofs - Roof Gardens

Roof gardens in Brazil are closely linked with the artist and landscape architect Roberto Burle Marx. The building of the former Ministry of Education and Culture (MEC) from the end of the thirties of the last century, result of a cooperation between a Brazilian group of architects led by Luico Costa and consulted by Le Corbusier, represents one famous milestone of modern architecture. Its roof gardens, designed by Burle Marx, mark an important step in modern landscaping (see Koehler et al. 2001). The quality of the offices inside corresponds with the number of roof gardens on several floors. But the MEC-building is not unique: a couple of similar buildings with integrated roof gardens followed in the next decades. In Rio de Janeiro there are several buildings with roof gardens styled by Burle Marx, like the Faculdade da Arquitectura, Ilha do Fundão, from the sixties, the MAM (Museum of Modern Arts, by the Architect Reidy in 1953) (Siqueira, 2002) and both Petrobras buildings in downtown Rio, designed by Gandolfi in 1968 (see Eliovson, 1999). Also the new Petrobras Building from the eighties, situated close to the famous soccer-stadium of Maracanã, counts with roof gardens. Other landscape architects have realized numerous roof gardens since then. A couple of the latest City Malls (see Fig. 3), have been realized with roof gardens. It becomes fashionable to have landscaping inside the buildings and above parking decks. Roof gardens can cover ugly technical constructions on the roof, like the exhaust units of air conditioning systems.

Fig. 3: Example of a new city mall with "roof greenery" The parking lots are located on the same level as waterfall and park.

Fig. 4: Florianopolis: Extensive green roof construction with solar heating systems over parking lots. Green roof with *Delosperma othona*.

Fig. 5: A roof garden in the semi-arid North-eastern part of Brazil in Campina Grande.

Fig. 6: A nice intensive Roof garden on the famous old fashioned Gloria Hotel, Rio).

Most of these projects are well designed, aesthetically as well as technically. From other cities a few roof garden projects are known, e.g. from São Paulo (see Delduque, 2001). A famous hotel complex at the shoreline of Florianopolis (see Fig. 4) reduces the optical impact of its built density by greened roofs. A swimming pool, parking lots and further constructions are also hidden by green cover. Solar heating systems are partly integrated in these green roofs.

Are roof gardens also possible in arid areas? One example from Campina Grande in the North-East of Brazil demonstrates it. This complex consists of an area with a substrate layer of about 40 cm substrate and another part with a substrate layer of about 10 – 20 cm. An initially integrated irrigation system is damaged, so only plants adapted to the semi-arid survived. The vegetation layer consists mainly of shrubs and succulents. The initially desired optical aspect has been changed, while it still functions for roof shading.

3 Vision

The green roof community worldwide grows rapidly. It seems to be a new style in architecture to combine buildings and greenery. Not only green roofs, but also green facades will be explored by vegetation systems. The combination of architecture and nature is a growing theme in contemporary architecture (e.g. see Schneider, 2002). The positive impact by organic elements to the architecture is called “Biophilic design” (Keller, 2003). It can be seen as the beginning of an experimental combination of different elements in order to achieve a sustainable architecture. There doesn’t exist only one solution for all climate regions and types of buildings, therefore further R&D is necessary. The construction technique differs in some way from conventional roofs and must be improved in order to serve under different climatic conditions and different types of buildings. In some parts of Germany, green roofs already become quite usual for new flat buildings. There is still a long way to go to optimize green roofs for tropical conditions. After first simulation results expectations are high, that the benefits of green roof systems are even more expressive in the tropics than in temperate regions (Schmidt, 2002). Shade, ventilation and greenery together can reduce the thermal stress of tropical cities and therefore also the need for energy intensive need for air conditioning (Laar, 2002).

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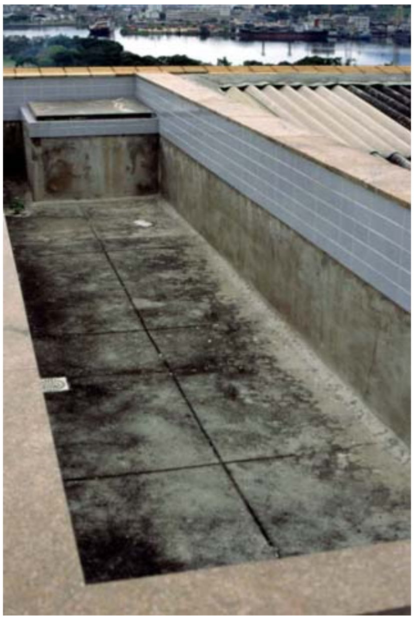
Annex

Table A1: Species fit for green roofs in the hot and humid climate.
(after Agarez 2001, modified)

Species, with high potential to extensive green roofs: Species (Family).	**Intensive roof garden species (Selection)** **Ornamental plant species**
Amaranthus deflexus (Amaranthaceae) A. hybridus, A. spinosus Cleome affinis (Capardiaceae) Silene gallica (Caryophyllaceae) Chenopodium ambrosoides (Chenopodiaceae) Commelina benghalensis (Commelinaceae) Acanthospermum australe (Compositae) Ageratum conyzoides (Comp.) Ambrosia elatior (Comp.) Artemisia verlotorum (Comp.) Bidens pilosa (Comp.) Eclipta alba (Comp.) Emilia sonchifolia (Comp.) Erigeron bonariensis (Comp.) Eupatorium pauciflorum (Comp.) Gamaochaeta spicata (Comp.) Jaegeri hirta (Comp.) Parthenium hysterophorus (Comp.) Porophyllum ruderale (Comp.) Senecio brasiliensis (Comp.) Siegesbecjia orientalis (Comp.) Sonchus oleraceus (Comp.) Tagetes minuta (Comp.) Xantium cavanillesi (Comp.) Ipomoea acuminata (Conv.), I. purpurea	Acalypha reptans (Euphorbiaceae) Ageratum houstonianum (Compositae) Anomatheca laxa (Iridaceae) Aptenia cordifolia (Aizoaceae) Arachis repens (Leguminosae) Axonopus compressus (Poaceae) Barieria repens (Acanthaceae) Begonia ulmifolia (Begoniaceae) Calathea insignis (Marantaceae) B. leopadina, C. rotundifolia, C. stromata Callisia repens (Commelinaceae) Callisia warszewiciana (Commelinaceae) Cuphea gracilis (Lythraceae) C. ignea Episcia cupreata (Gesneriaceae) Envolvulus glomeratus (Convolvulaceae) E. pusillus (Convolv.) Fittonia verschaffeltii (Acanthaceae) Hemigraphis repanda (Acanth.) Kalanchoe blossfeldiana (Crassulaceae) Lampranthus productus (Aizoaceae) Maranta bicolor (Marantaceae) M. leuconeura var. Erythroneura M. leuconeura var. Kerchoveana Oxalis vulcanicola (Oxalidaceae)

Lepidium pseudodidymum (Brassicacea) L. virginicum Sinapsis arvensis (Bras.) Mormodica charantia (Curcubitaceae) Cyperus esculentus (Cyperaceae) C. ferax, C. rotundus Croton glandulosus (Euphorbiaceae) C. lobatus Euphorbia brasiliensis (Euph.) Phyllanthus corcovadensis (Euph.) Brachiaria decumbens (Poaceae) B. plantaginea, B. purpuracens Cenchrus echinatus (Poac.) Cynodon dactylon (Poac.) Digitaria horizontalis (Poac.) D. insularis (Poac.) Eleusine indica (Poac.) Panicum maximum (Poac.) Paspalum maritimum (Poac.) Pannisetum clandestinum (Poac.) P. setosum (Poac.) Rhynchelitrum roseum (Poac.) Setaria geniculat (Poac.) Sorghum halepense (Poac.) Hyptis suaveolens (Labitae) Leonitis nepetaefolia (Lab.) Leonurus sibirica (Lab.) Stachys arvensis (Lab.) Aeschynomene rudis (Leguminosae) Cassia ocidentalis (Leg.) C. tora (Leg.) Sida cordifolia (Malvaceae) S. rhombifolia, S. spinosa Mollugo verticillata (Molluginaceae) Oxalis oxyptera (Oxalidaceae) Polygonum persicaria (Polygonaceae) Portulaca olearacea (Portulaceae) Borreria alata (Rubiaceae) Richardia brasiliensis (Rub.) Solanum americanum (Solanaceae) S. nigrum (Sol.) Waltheria indica (Sterculiaceae)	Paspalum notatum (Poaceae) Portulaca grandiflora (Portulacaceae) Sanseviera trifasciata (Liliaceae) Sanvitalia procumbens (Compositae) Schizocentron elegans (Melasomataceae) Sedum dendroideum (Crassulaceae) Siderasis fuscata (Commelinaceae) Spilanthes repens (Compositae) Stenotaphrum secundatum (Poaceae) Tagetes patula (Compositae) Tigridia pavonia (Iridiaceae) Torenia fournieri (Scrophulaceae) Tradescantia pallida var. purpurea (Commel.) T. spathacea, T. zebrina Turnera ulmifolia (Turneraceae) Unxia kubitzkii (Compositae) Verbena hybrida (Verbenaceae) V. tenera, V. rigida Wedelia paludosa (Compositae) Echiveria elegans (Crassulaceae) Kalanchoe blossfeldiana K. gastonis-bonnierri, K. waldheimii Polygonum capitatum (Polygonaceae)  Fig. 8: Renovated and newly sealed sealed planter box on the roof garden of the FAU, Ilha do Fundão, Rio.