Half Moon Bay City

Ecological and Environmental approach
for planning a new city around the shores of Half Moon Bay.

Precautions to preserve the initial biodiversity
and orientations to create other ecosystems.

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Scientific report of prescriptions and sourcing carried out for AREP-Ville

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For AREP-Ville

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Foreword

The previous scientific pre report carried out for AREP-Ville gave an overview of the main landscape and ecological issues for planning a new city laying around the shores of Half Moon Bay in Saudi Arabia's Kingdom.

A rough inventory of soils, terrestrial plants and animals, completed by some hypothesis or bibliographic knowledges about sea shore and sea water natural life was carried out.

Some tracks for succeeding in the planning of a new city were rapidly presented such as the ideas for preventing sand invading, for planting wind-breaker grasses, bushes, shrubs and trees. The pre report gave also some orientations for water preservation and recycling it for orchards, truck-farming, horticultural and landscaping plantations. The possibility of a mangrove plantation and fish or shrimp breeding in natural or artificial salt water surfaces was also projected as à possibility.

The present report will develop some prescriptions dedicated to drive the urban planning in the best ecological frame as possible. As it is also very important to be informed of scientists and suppliers of a good quality, some sourcing was made for finding them.
Each part of this report is presented just as an individual dossier in order to be used as an individual report illustrations eventually annexed.

Half Moon Bay City

I

Sand and dune stabilization.

Passive systems and alive plantations.

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Understanding the stranding

People say that there is stranding when the sand grains are brought by winds and then accumulate where the wind becomes slower.

Sand accumulation builds dunes which may invade tracks, roads, villages, towns, fields, orchards, etc… Even if these dunes are a strong landscape component, they are not welcomed by desert populations where they want to live and harvest. The wind quality and main orientation, the ground surfaces are the factors which determine the type of dunes and their mobility.

1.1 Wind erosion

The main causes of wind erosion are :

- **Strong winds blowing along huge surfaces**

  Near the ground level, the wind speed is quite null, it increases by the logarithm of the altitude. The sand particles moving are linked to the direction speed and duration of the winds. The dominant wind is the main direction of blowing.
  The wind can rise up sand particles when its speed reach around 6 m/s and stronger.

  The size of the particles is also an important factor: the bigger they are the stronger must be the wind for carrying them. The dust like particles are remaining in suspension during a long time, the fine and medium sand particles are taken in saltation before they are laid and spread, the small stones are condemned to the snaking.

  The moving particles interact between them in 3 main types of interaction named avalanche, sorting and corrosion.

- **The quality of the vegetation**

  The vegetation is an ally of the cohesion of the surface ground layer. It also catches the particles and is effective against avalanche effect. This is the reason why wind erosion is stronger in arid or semi arid countries where the bushy, shrubby, herbaceous plant formations are sparse, stunted or non-existent combined with very low and irregular rainfalls.

- **The nature and the quality of grounds**

  The grounds which foster the wind erosion are the following kinds:
  - with a rough texture, rich in fine sand, poor in clay and organic elements,
  - presenting an uniform surface without natural or artificial obstacles,
  - where the plant cover is poor or non-existent,
  - it covers a rather wide area, lengthened in the main wind direction.

It is to know that the main part of the sand carried by wind is autochthon, coming from the immediate proximity of desegregated rocks and alluvial or colluvial soils.

1.2 Effects of wind erosion

- Winds carry in first the fine parts of grounds, it means the silts, fine sands and organic matter. It deteriorates the ground structure which becomes more sensitive to its action and also decreases its water stocking capacity. Small hillocks are formed around the poor existing vegetation , the surface becomes irregular and the soil gradually unsuitable for agriculture and plant growth.

- The effects of wind on the vegetation are both mechanical and physiologic.
  Ground particles carried by wind run up against the stems and leaves with strongness involving the abrasion. In the areas where the sand is taking of, roots are exposed and the plants can be uprooted, at the opposite, in the deposit areas, the plants are progressively buried.
  The wind increases the evapo transpiration and dried the aerial parts of the plants, added to the decrease of the water stocking capacity that leads to an important hydrous deficit.

1.3 Wind accumulations

The main forms of wind accumulations met in desert countries like Saudi Arabia are wind vela, *nebkhas*, moon crescent dunes (*barkhans*), linear dunes (*sifs*), sand ridges, pyramidal dunes (*ghours*), *akles* and ergs. All these forms are well known by Bedouins and other inhabitants of the desert countries.

The interventions are widely dependant on the type of wind accumulation, their relative position compared to the main wind direction and the space to be protected. It depends also on the minimal amount of efficiency that people need.

1.4 Type of treatments

The basic principle is to prevent sand moving during the time necessary to establish and to grow natural or planted vegetation. It is then necessary to stabilize the ground and to decrease the wind speed near the ground surface.
There is 2 kinds of sand fixing:

- The primary fixing stabilizes mechanically the existent sand masses or prevents their formation using :
  - installation of fences or mattresses perpendicularly to the main wind direction,
  - spreading of a product or a material (mulching)
  - shaping of the obstacle to maintain or increase the speed of the wind in order to divert the deposit of the zone to be protected.
- The definitive or biological fixing is created by the implantation and the protection of a permanent plant cover composed of ligneous and/or herbaceous species. These plants can be installed by direct *in situ* seedlings, plantations, protection settings or active keepings.

2 Techniques of dune fixings

2.1 The primary fixing - The mechanical stabilization of dunes

The initial step of the fight against the stranding consists in slowing down the sand movements setting up fences of 1 to 1.5 m high; this is to bring sand accumulation near these fences allowing an artificial dune formation. It gives 2 kinds of artificial dunes depending to their orientation compared to the average direction of main wind.
The stopping dune is the most frequent system used to stop the sand progression. The dune grows from a fence which is set up perpendicularly to the main wind direction. If the winds come from other directions than the prevailing one, the device is supplemented by a crossed mattress or crossed fences between 2 successive fences.
The running dune or deviation dune changes the sand progression to another direction than the main wind one. The fences are orientated by an angle between 120 to 140 degrees compared to the main wind direction.

The fences can be braided (more expansive) or not braided. They are usually made of branches coming from the mature populations of suitable species, like natural populations (if they exist) of *Prosopis juliflora*, *Balanites aegyptica*, diverse *Acacia spp.* also made of palm tree fronds or of stems of *Leptadenia pyrotechnica* or *Euphorbia spp.*.

It is necessary to be careful by taking of this natural material in order not to harm the perennial existence of these woody formations what would probably worsen wind erosion where they exist. In order to fulfill its function, the fence must have enough permeability to the wind from 30 to 40%, so it is able to decrease the wind speed and to bring the formation of sand accumulation without generating a swirling movement in the zone under the wind.

The internal fences and mattresses must be regularly maintained and spill plates as soon as sand arrives at 10-15 cm of their higher edge. More important is the dune relief, denser would be the cross canvas of fences or mattresses and it can reach between 600 to 1,200 linear meters per hectare.

The permanent keeping increases the management preventing all cattle intrusions (camels, sheeps, goats and donkeys). The device keepers must also sensibilize the neighbor populations to respect and preserve these devices.

In the very flat areas, it is possible to prevent saltation by uniformly covering the dune sands by a natural or artificial protection screen. This mulch can be made of straw, branches, plastic films, acrylic fibers and nettings.

2.2 The biological fixing

When the dunes are mechanically stabilized, it is possible to fix them definitively by the installation of perennial vegetation composed of woody and herbaceous plants.

Any plantation will necessarily have to take into account the choice of species which can adapt to this ecosystem and the depth of the residual moisture of the subjacent layers.

People are generally unaware that sand dunes have the capacity to preserve residual water reserves in their sub-bases. They reflect very strongly the luminous and thermic rays, are very bad conductive of heat, which limits their in-depth heating and, then evaporation of stored moisture, to that is added the weak possibility of capillary increase. The upper part has a screen effect on approximately 30 cm, and then the moisture is preserved towards 1 m of depth, which allows the resumption and the growth of the species to be planted.

2.2.1 Choice of woody and herbaceous plants

The species chosen for the plantation will have to fill the following criteria:

- capacity to develop in a medium low in nutritive elements and subjected to important diurnal and nightly temperature variations;
- presence of a powerful swiveling root system able to quickly reach the residual moisture of the ground to neutralize the effects of the dryness;
- resistance to the strong winds, dry and hot and with their abrasive action on the leaves and stems;
- rapid growth and faculty to regenerate itself easily;
- capacity to improve and enrich the dune ground (i.e. fixing nitrogen species like leguminous plants).

Some species are adapted to the moving parts of the dune, others to the zones between the dunes.
Principal species selected to be planted are those having already been tested in similar conditions, a complementary study of the existing flora should make it possible to select species indigenous and to multiply them in the horticultural zones of the future city:

- Continental dunes :
  - on the very mobile dune cords : *Prosopis juliflora*, *Aristida pungens* ;
  - deflationary zones (starting zones of sand, therefore favorable with undermining) : *Leptadenia pyrotechnica*, *Aristida pungens* and *Panicum turgidum* ;
  - in the more stable zones : other woody species, mainly of many acacias (i.e. *Acacia raddiana* and *Acacia senegal*), *Balanites aegyptiaca*, *Euphorbia balsamifera* and *Persica salvadora*.
- Littoral dunes : Only woody and herbaceous halophytes species are able to develop on the littoral dunes : *Nitraria retusa*, *Tamarix aphylla*, *Tamarix senegalensis, Casuarina equisetifolia*, *Atriplex halimus*, *Atriplex nummularia* and *Zygophyllum spp* can be planted.

2.2.2 Nursery recommendations

The chosen site for a permanent nursery for afforestation must take account of the following factors:

- the topography of the ground: the ideal ground must be flat, slightly inclined in the longitudinal direction, cleared, leveled and without stones;
- the quality of the ground, which must be muddy sandy, of texture light or average, easy to work, drained well, without nematodes and dangerous cryptogams;
- near to a waste water purifying station rejecting a water of quality and ensuring a permanent and sufficient quantity of this water;
- a central situation or near the afforestation perimeters;
- an easy access in all seasons;
- the availability of a sufficient labor force;

- capacity of annual provisioning of substrate to ensure the discounted production.

The reserved perimeter for the nursery is protected from the dominant winds, the streaming of precipitations or secondary water of accumulations, the cattle, fires, the birds and the locust invasions. It is also surrounded by a fitted latticework fence, doubled inside the perimeter by a quickset hedge, if possible thorny, or palisades in natural or synthetic material. A permanent guarding is also recommended.
A substantial shade can be provided by the plantation of date palm trees in an adapted density (10m X 10m to 13m X 13 m in a square device).

The modes of production are mainly the direct seedling and the cutting in black polyethylene nursery bags (dimensions flat: 25 cm × 12.5 cm, for a volume of 2.5 dm^3, it gives near of 40 bags by m^2). If it is possible, the use of deeper nursery bags is recommended even if their stability is lower, they allow for a deeper pre rooting that enables the installation, then growth of plants after final plantation (the best dimensions should be 25 cm wide and 25 or 30 cm high).

The substrate must be a mix of "white" natural sand (the best one is coming from the wadi beds) or dune sand in case there is no "white" sand, from 10 to 15% of organic nutrient. In order to improve the water retention of this substrate of culture, it is recommended, after having filtered it well to eliminate the stones, remains and branches, to complete it with 20 to 25% of hydro retenders, artificial ones like "water grains" (acrylate and polyacrylamid copolymers) or sphagnum moss of quality "short" or "mild". It means you need for one m^2 of nursery banks around 40-50 l of rehydrated sphagnum moss (1.6 to 2 kg of dried sphagnum moss) and 20-35 l of organic nutrient. The preference must be given to the sphagnum moss because there is cases of toxicity met with the water grains.

For the seedlings, it is better to put several seeds by bag (seed hole seedlings) and to sow in priority the species with slow emergence and/or growth. The cuttings, taken on selected trees, have from 15 to 20 cm height and 2 cm in diameter, and are obliquely inserted in the sachet so as to leave one or two buds above the ground. The substrate is then packed around the cutting and some plant straws or crushed wood must be used as mulching in the both case, immediately for the cuttings and just after the first true leaf emergence for the seedlings.

It is necessary to take to the young seedlings the following care:
- Watering of maintenance:
  It is done using watering-cans with apple, twice a day at the least hot hours, at a rate of 20 litres/m^2 per watering; progressively by the growth of the seedlings and cuttings, one decreases the frequency of the waterings to condition the seedlings and cuttings to their future growth conditions.
- Thinning :
  If germination is very good, only the most vigorous seedling is kept in each container.

The transports of the substrate, the filling of the bags, as well as the storage of the bags in the banks, require the work from 20 to 25 people per day for one month. Starting from sowing, the day labourer team in nursery includes a foreman, ten to twenty workers to assure an average annual production of 60,000 seedlings and cuttings. Apart

from the water of watering and bags, such a production requires about 6,000 kg of sphagnum moss and 60 m^3 of organic nutrient.

2.2.3 **Plantings**

For the woody and herbaceous species produced in bags, only the vigorous and well lignified seedlings are retained, they are copiously watered right before their transport on the planting site. The not selected seedlings are eliminated. The transport of the selected seedlings is done with a covered vehicle to avoid an exposure to the wind and the sun.

The recommended density for the majority of the woody and herbaceous species is 5m X 5m in alternate rows (470 per hectare) but can be dropped with 7m X 7m in alternate rows (235 per hectare) and even with 10m X 10m in alternate rows (115 per hectare) according to the conditions and the mobility of the dune to stabilize.

During al the plantation time, one withdraws the sachets to avoid rolling up in spiral of the root system and the progressive throttling of the pivot. They are recovered and destroyed then they don't pollute the environmental space with plastic residues. The success of the plantations depends obviously on precipitations, on the absence of hot drying winds, on the organization of the teams on the ground and their speed of execution. During this period, the teams must be narrowly supervised by the technicians of the project, in order to guarantee a maximum resumption.

The plantation holes are carried out at the time of the planting to avoid the crumbling of the walls of the hole of plantation. If moisture on the surface of sand is zero or low, the first watering is recommended before the plantation itself, in order to compensate the existence of a dry layer above residual moisture. The best way to manage this hole diggings is to use a particular auger that drills the hole and stabilize the walls temporarily with a metallic cylinder, this one must be pulled out after the final installation of the young plant.

In order to help the young roots to reach the level of residual moisture, it is recommended to drill a hole 0.6 to 1.0 meter deep and to lay at the bottom of it a mix of 25% of sphagnum moss, 10 % of organic nutrient and sand up to the level where the bottom of the plant ball must be laid, the same mix can usefully be used to pack the plant ball. i.e. for a 25 cm bag and a 0.6 meter depth hole of 30 cm of diameter, you need to prepare 40 litres of plantation substrate (10 litre of rehydrated sphagnum moss, 4 of organic nutrient and 26 of sand).

For 1 ha of plantation at the density of 7m x 7m in alternate rows it gives 2,350 l of rehydrated sphagnum moss (around 100 kg of dried sphagnum moss) and 940 l of organic nutrient. With the total production of plants from the nursery unit (around 48,000 plants strong enough for planting) one can stabilize more than 200 ha of dunes and need 20 t of dried sphagnum moss and 190 m^3 of organic nutrient.

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2.4. http://www.floracafe.com/PhotoSearch.aspx?Type=Fruit

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Sourcing

Sphagnum moss

"Sphaigne discount" cooperative company:
Manager, J.F. Daures
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Anciennes Mines d'Avéjan
F – 304030 Avéjan
France
Tél +33 (0)962 10 20 22

Cylinder Auger

Maillard Industrie (prototype en cours de test)
Groupe GMI
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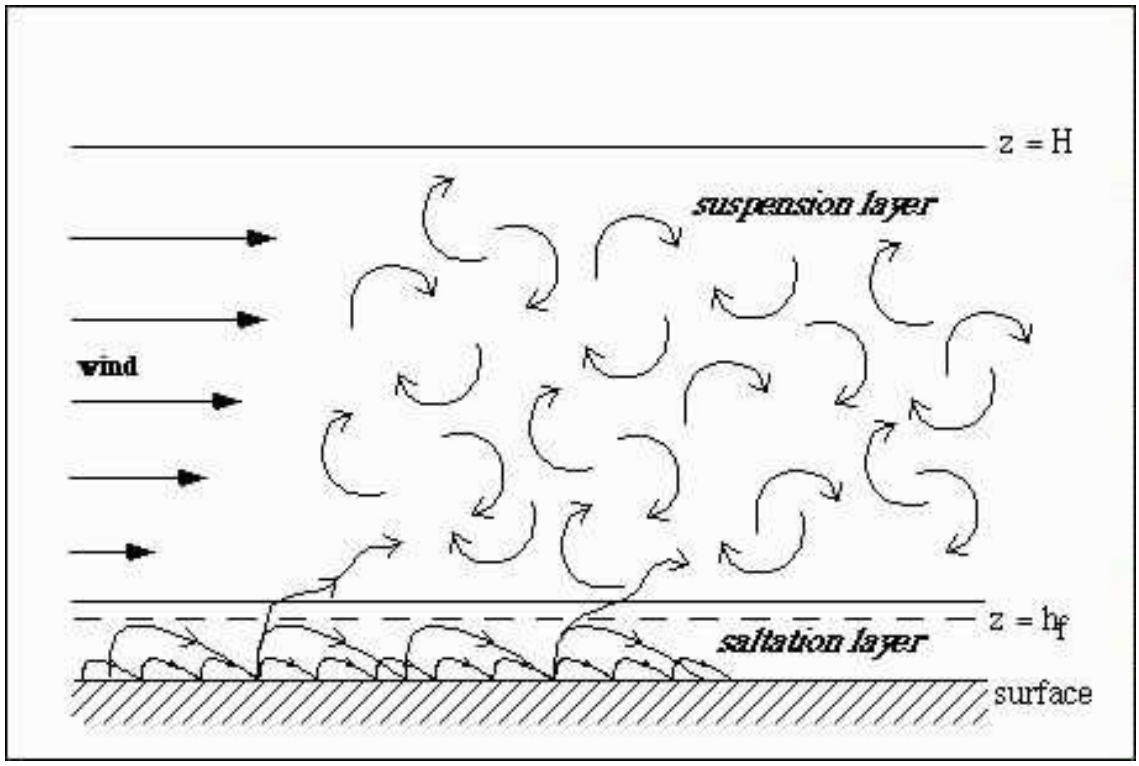
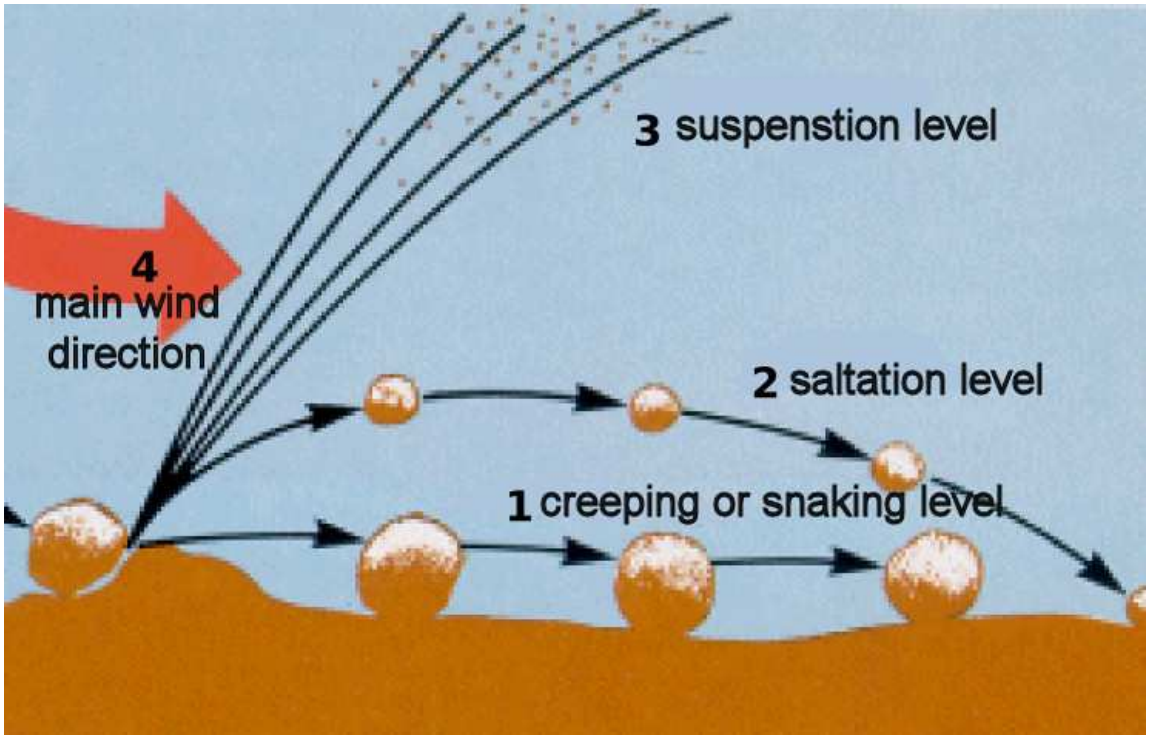
Sand and dune stabilization.

Passive systems and alive plantations.

Annex

Illustrations

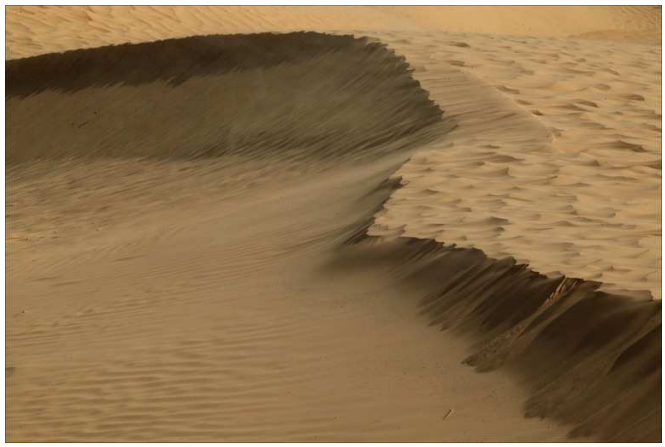

z = H
suspension layer
wind
z = hf
saltation layer
surface


3 suspenstion level
4
main wind
direction
2 saltation level
1 creeping or snaking level

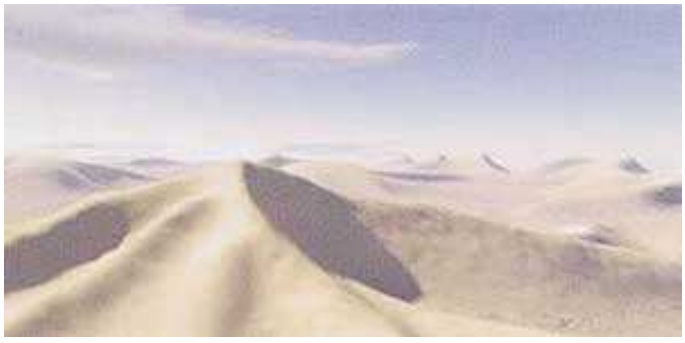
Nebkha

Barkhan

Sif

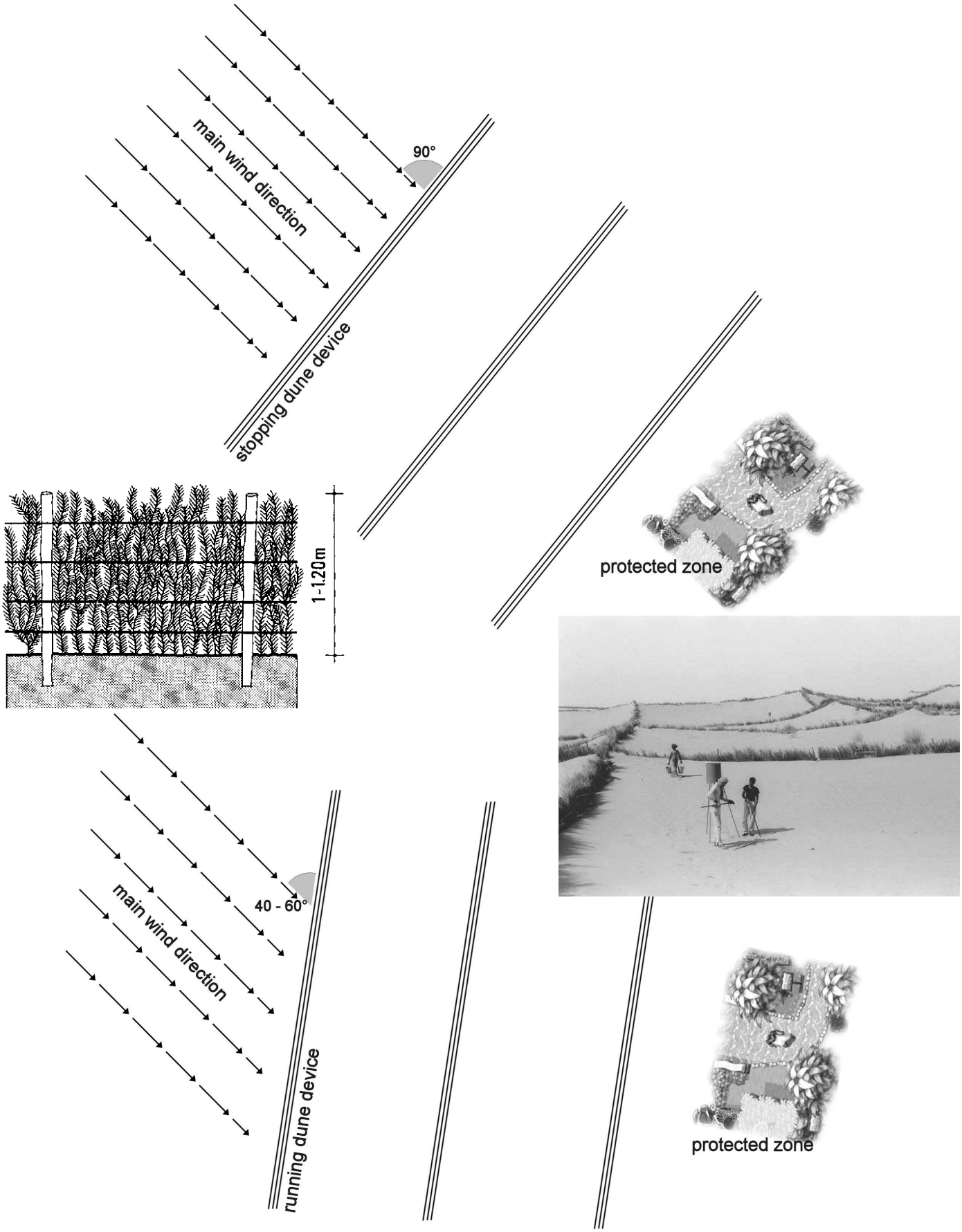


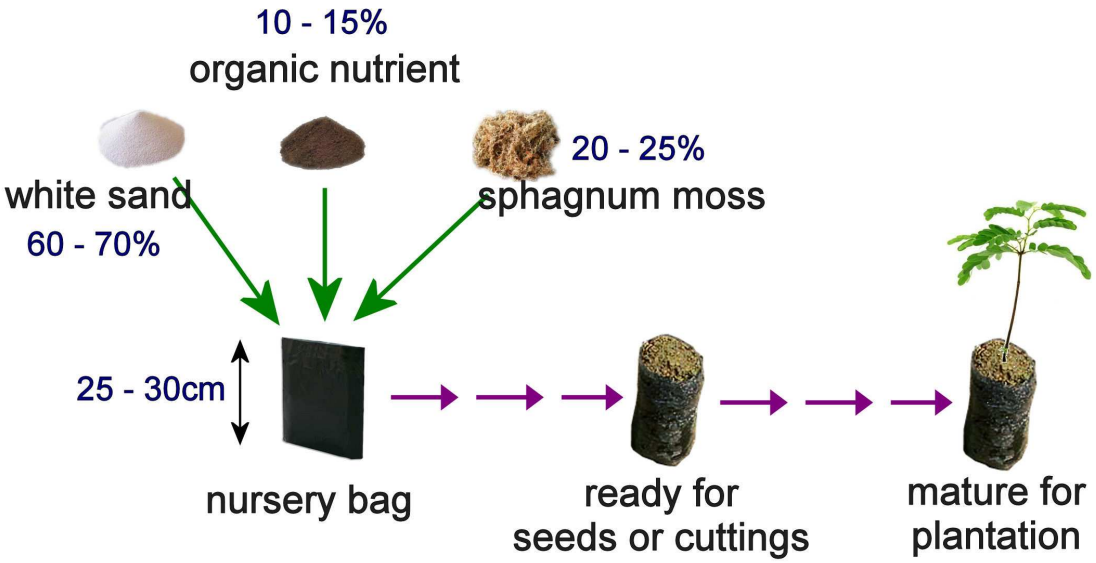
Sand ridge



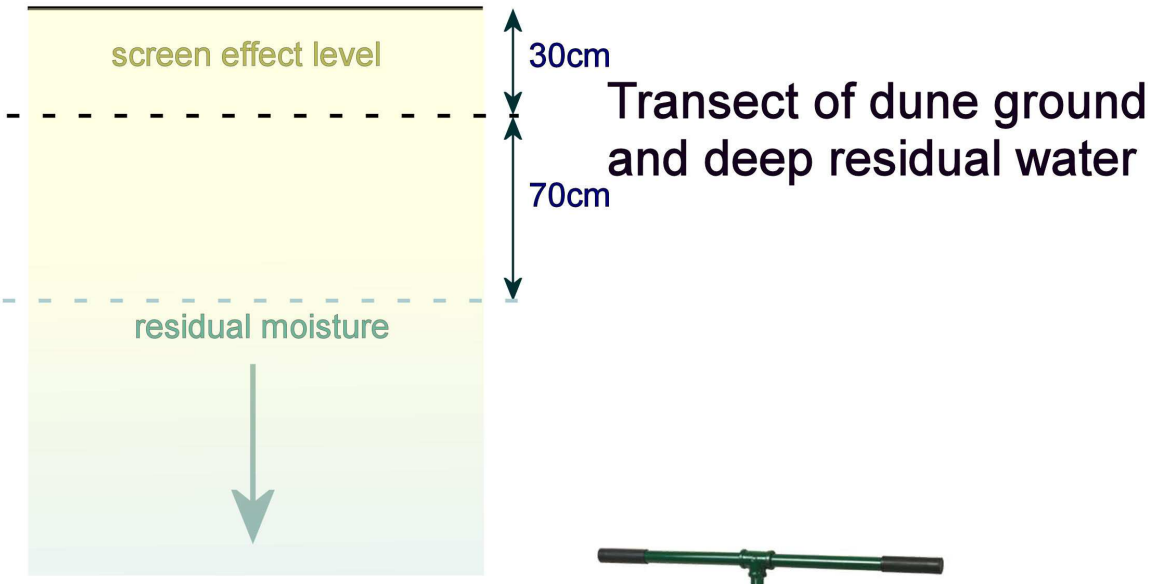
Ghour

Erg


main wind direction
90°
stopping dune device
1-1.20m
protected zone
40 - 60°
main wind direction
running dune device
protected zone



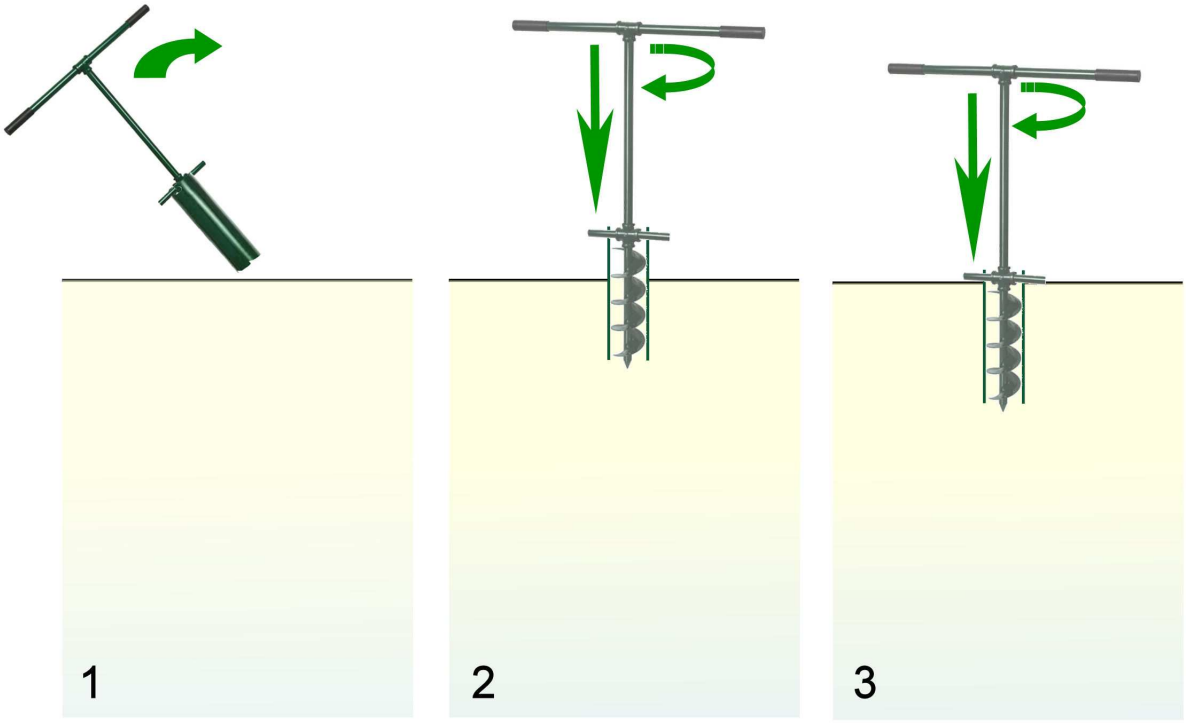
Nursery bag filling



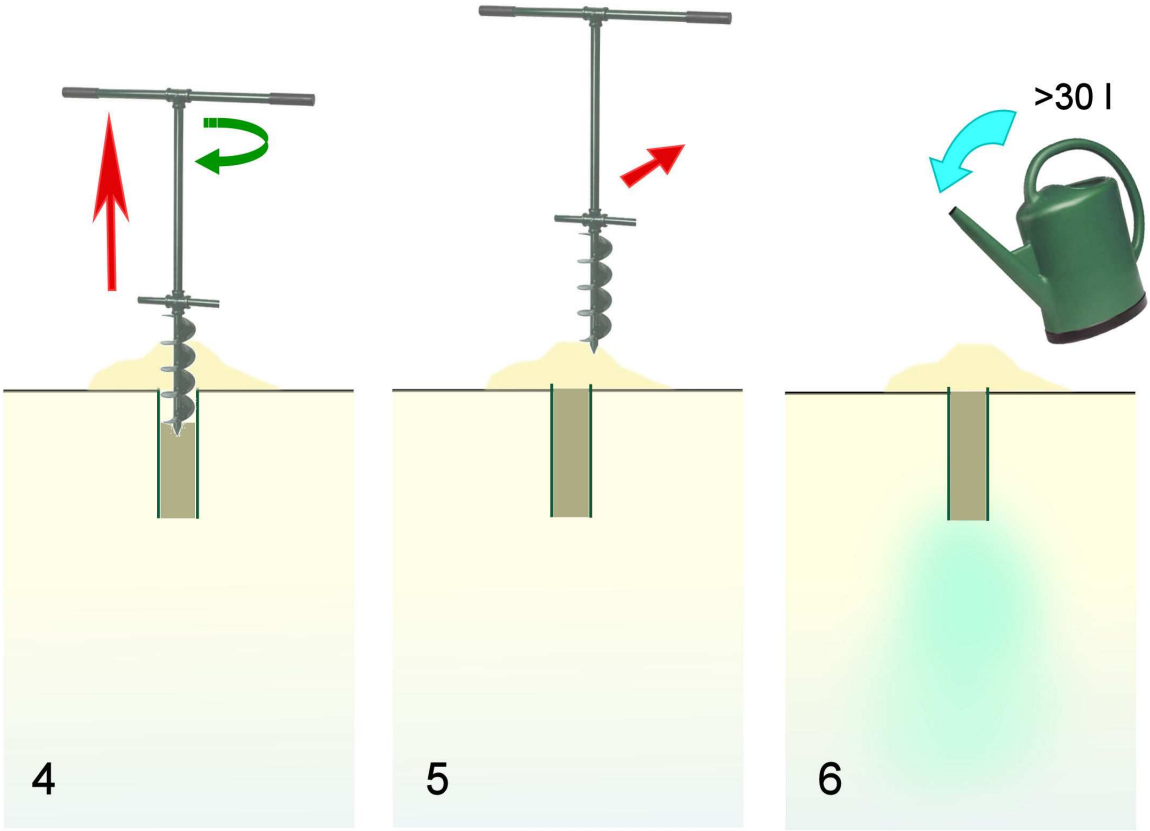
Transect of dune ground and deep residual water

Auger with wall cylinder

How to prepare the plantation hole



Drilling the plantation hole with the auger & cylinder tool

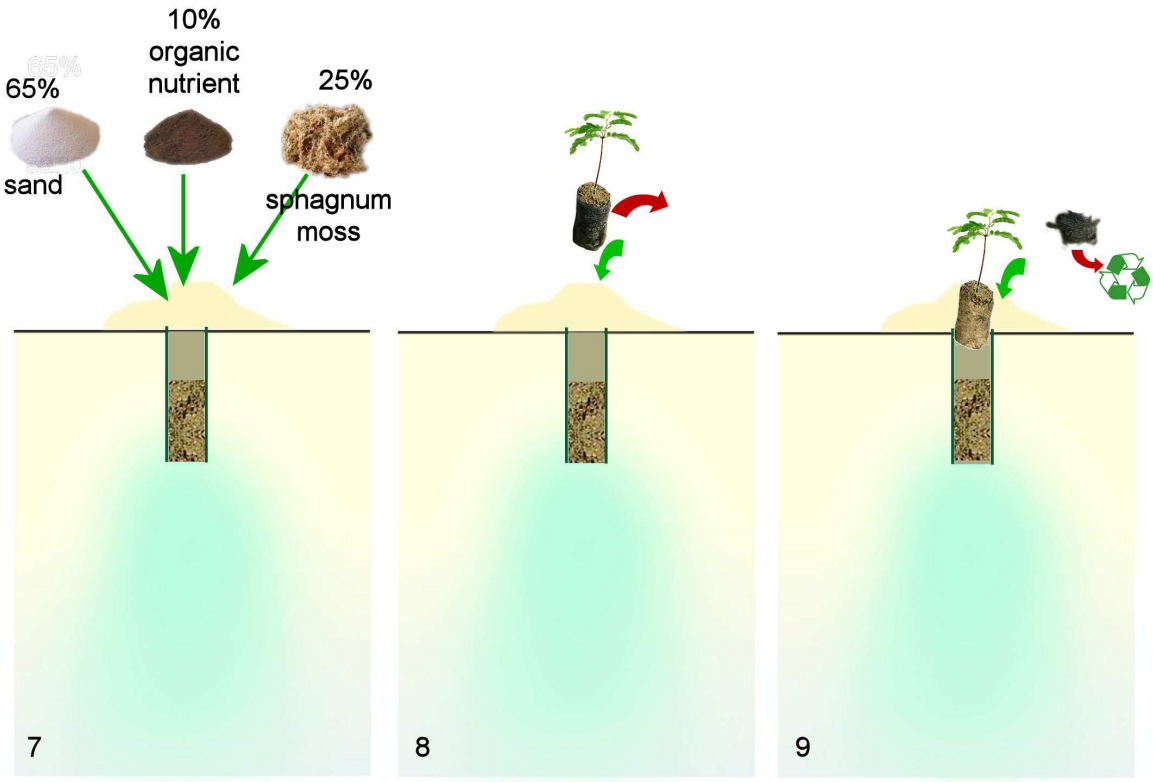


desengaging the auger from cylinder and removing sand

after sand removing, carrying auger out

watering the hole generously

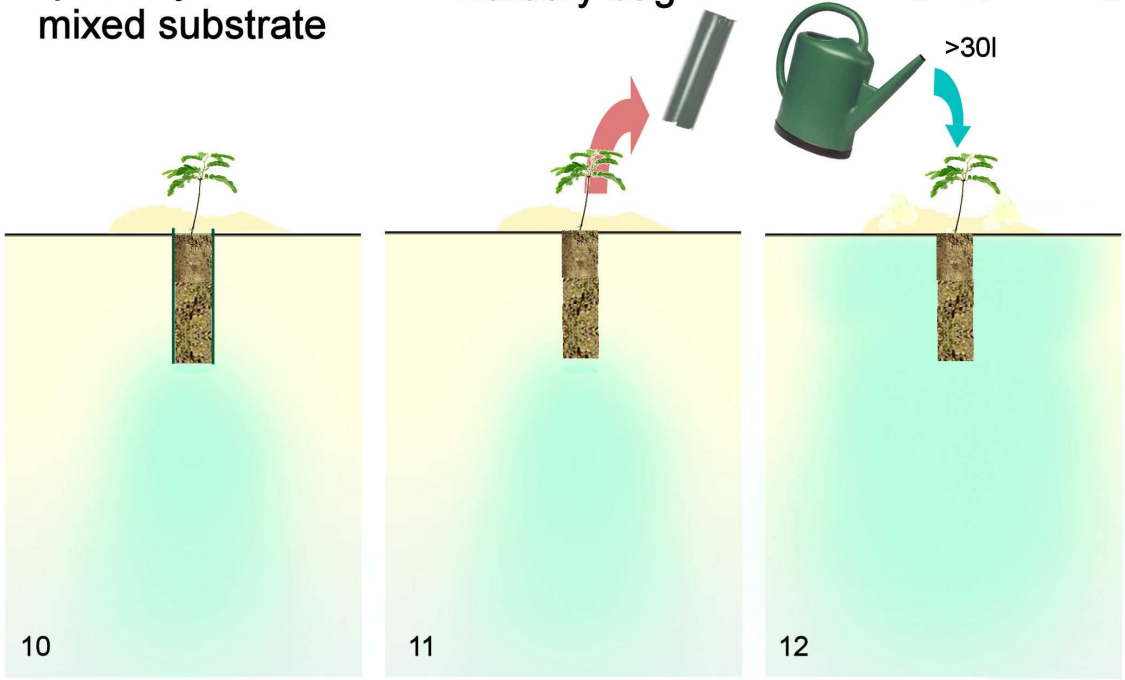
Plantation



filling hole partially with a mixed substrate

withdrawing of nursery bag

keeping bag for recycling & planting

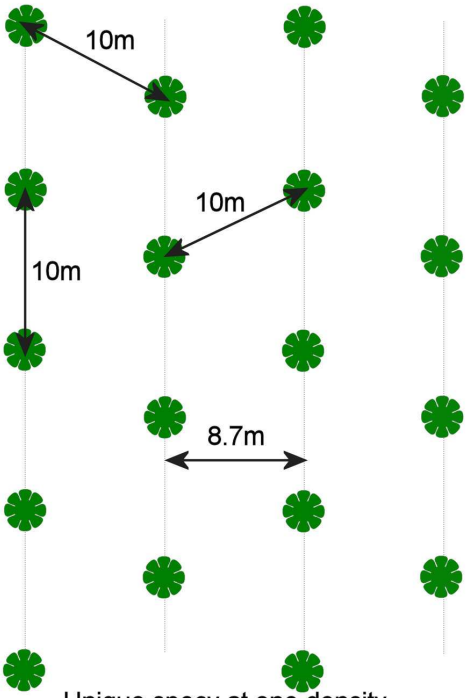


ajusting the hole filling

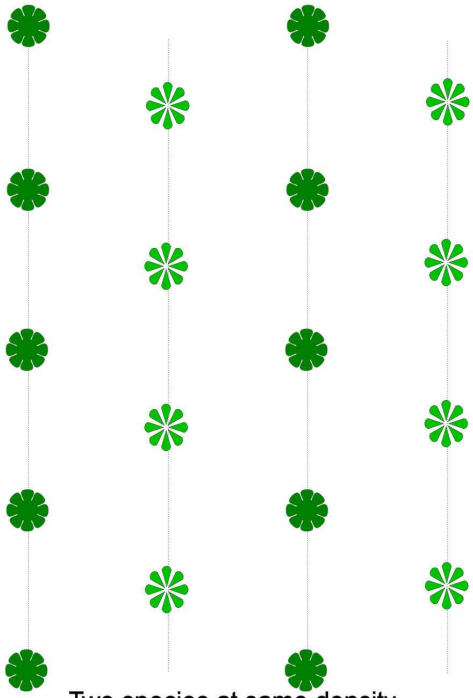
removing the cylinder

managing a crown depression watering generously

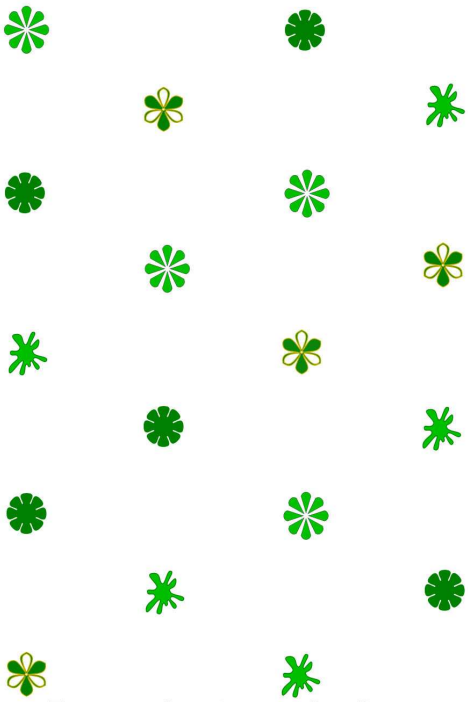
Some diagrams of plantation



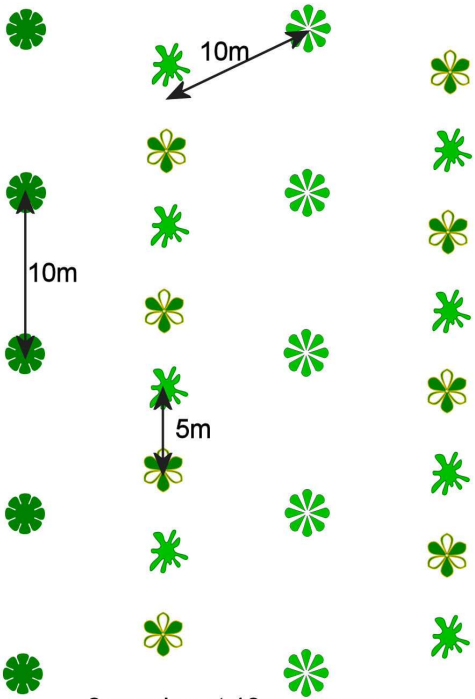
Unique specy at one density
(10m in alternate rows)



Two species at same density
alternative rows



Four species at same density
randomized in alternate rows diagram



2 species at 10m on rows
2 species at 5n in mixed rows
alternative row patterns

Prosopis juliflora adult tree

Prosopis juliflora flowers

Prosopis juliflora pods

Aristida pungens

Leptadenia pyrotechnica in a high bush shape

Leptadenia pyrotechnica young bush in blossom

Leptadenia pyrotechnica detail on stems and flowers

Panicum turgidum in Tagant (Islamic Republic of Mauritania)

Panicum turgidum on sands in Kingdom of Saudi Arabia

Panicum turgidum panicle detail

Accacia raddiana in Niger desert conditions

Accacia raddiana in Kingdom of Saudi Arabia

Accacia raddiana details of stems, leaves, thorns, flowers and curled pods

Accacia senegal in Mauritanian Adrar

Details of *Accacia senegal* flowers in Tagant (Islamic Republic of Mauritania)

Details of *Accacia senegal* flowers in Tagant (Islamic Republic of Mauritania)

Balanites aegyptiaca adult tree

Balanites aegyptiaca detail on flowers

Balanites aegyptiaca detail on fruits

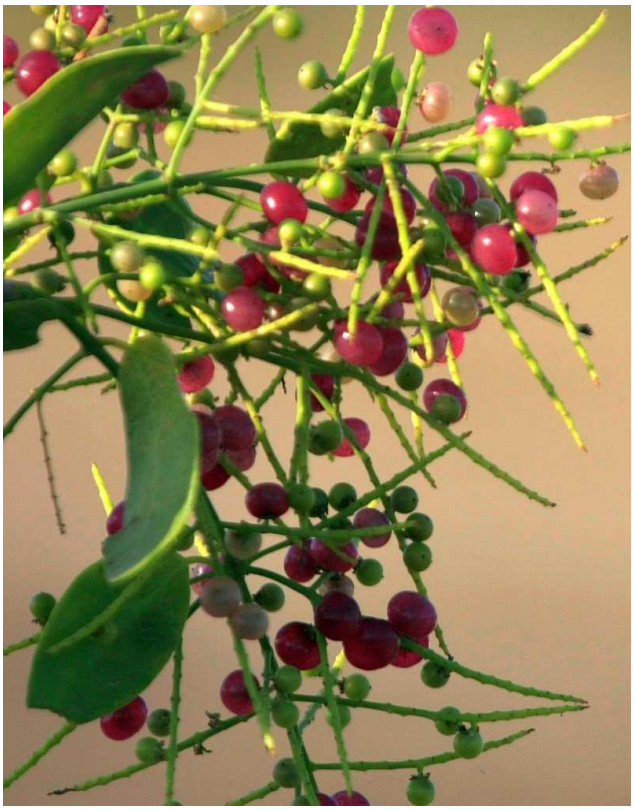
Euphorbia balsamifera in a dense bush shape

Clear bush form of *Euphorbia balsamifera*

Euphorbia balsamifera flower detail

Persica salvadora (toothbrush shrub) huge shrub in Saudi desert

Persica salvadora detail on branches, leaves and green fruits



Persica salvadora detail on ripe red fruits

Nitraria retusa leaves, flowers and young fruits

Niraria retusa green and ripe red fruits

Tamarix aphylla hedge in a town

Tamarix aphylla detail on flowers

Tamarix senegalensis in a sabkha range

Casuarina equisetifolia leaned by the effect of a prevailing wind

Casuarina equisetifolia details on branches and fruits

Atriplex halimus dense bushy shrub

Atriplex halimus detail of leaves and flowers

Atriplex nummularia dense bush

Atriplex nummularia detail on flower spikes and leaves

Zygophyllum mandavillei community

Zygophyllum simplex leaves

Zygophyllum fabago flower bud, flower and pods

Half Moon Bay City

II

Turning a part of the Sabkha into a Mangrove Area

Flooding with Sea Water
Managing Salted and Fresh Water Streams.

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Scientific report of prescriptions and sourcing carried out for AREP-Ville

Turning Sabkhas into Mangrove
03/08/2011
For AREP-Ville

CIRAD-BIOS UMR AMAP
René Lecoustre
Half Moon Bay (S. A. K.)

2 Sabkha definition

Sabkhas are depressed lowlands the bottom of which is situated a few meters under the sea level: sabkhas usually situated between littoral dunes and the inlands sandy plains, its also exist inlands sabkhas usually named chotts. Rainwater accumulates there for the time of their evaporation and form then a crust of salt mud which eventually strengthens on surface, considering the chronic weakness of the rainfalls in Saudi Arabia; sabkhas have, generally, the aspect of a muddy depression with the surface crusted by salt.

2.1 Sabkha vegetation

The vegetation essentially consists of halophytes, it can be of more important size than in previous ecosystems and then contain bushes and shrubs, and the major part is however constituted by short herbaceous annual or perennial plants. The majority of plants are *Graminaceae*, *Cyperaceae*, *Juncaceae*, *Chenopodiaceae* and *Zygophyllaceae*, the most present shrub is *Tamarix aphylla*.
The plant communities are characterized by their dominant or co-dominant species; *Panicum turgidum – Stipa capensis*, *Panicum turgidum – Pennisetum divisum*, *Panicum turgidum – Zygophyllum coccineum*, *Lasiurus scindicus – Stipagrossis plumose*, *Aeluropus lagopoides – Halopeplis perfoliata*, *Tamarix arabica - Aeluropus lagopoides* and *Zygophyllum coccineum – Cyperus conglomeratus*.

2.2 Sabkha fauna

The fauna is mainly composed by the same species as that of the dunes and that of the inlands plains. As regards the mammals, populations of gerbils are present in the margins of these formations and find their fodder on all the surface of sabkhas, it is possible to meet jackals attracted by the presence of these rodents The presence of gazelles is sometimes reported in the literature but it seems rather not very probable because of the presence of important axes of traffic running between plains and sabkhas.

All the developments of these zones will have to take into account their biotic instability and their management difficulties. It will be necessary to realize a serious inventory of flora and fauna to estimate the wealth and the variety.

3 Mangrove definition

It usually gives confusion, in English, for the definition because for someone, the vegetation is the mangrove, for some other, the ecosystem is the mangrove. As the French definition concern the ecosystem, we will use this one.

Mangrove is a tidal salt-marsh forest in the tropics dominated by trees and shrubs that have roots which are exposed at low tide, and which is inundated with salt water at high tide.
The trees' roots grow in the damp soil and soggy sea banks

3.1 Mangrove vegetation

The vegetation is mainly composed of perennial trees and shrubs adapted to these swampy salted conditions, they usually present numerous prop roots that eventually form an impenetrable mass and are important in land building. Many of these plants bear fruits that germinate while they are still on the tree and then are quite planted in the damp soils where mud and silt settle.
The dominant tree seems to be *Avicennia marina with* only few groups of *Rhizophora mucronata*.
It seems that natural mangroves, in Saudi Arabia, suffer of a continuous camel grazing which bring a permanent degradation by destroying the growing part of the plants.

3.2 Mangrove fauna

The decomposing leaf litter of mangroves provides an enormous amount of food for aquatic marine life. The shade provided by the tree and shrub foliage gives also favourable life conditions to many animals.
Compared to the poorness of the plant diversity in natural mangroves the animal diversity seems to be higher: 2 species of crabs (*Uca inverse* and *Metopograpsus messor*) or more are described (*Macrophthalmus* spp.), many kinds of shrimps are living between aerial roots of the trees where oysters can fix, also many birds come in the mangrove cover for feeding and nesting. Insects and mammals, especially carnivorous, are also attracted by this shady and wetter canopy, full of life.

4 Sabkha flooding

As the purpose, besides the urban planning, is to preserve the existing biodiversity, it is obviously recommended to not flood all the sabkha of Half Moon Bay area. This solution not only preserves the existent biodiversity but also increase the local one by adding, progressively a lagoon and mangrove flora and fauna.

4.1 Flooding with fresh or brackish water

Because the sands of the sabkha bottom is yet salted, initial flooding with fresh or brackish water can seem to be a good option for preventing over salting of the future lagoon and to prepare the installation of the mangrove.
The lack of fresh water and brackish water is too important in this part of Saudi Arabia and it is not an applicable solution.

4.2 Flooding with bay water

It is the only existing source of huge volume of water but it is necessary to flood the lowlands of the sabkha at the rainy time of the year when people know the sabkha waters reach their higher level.
The lagoon must have, at least, 2 communication channel axis with the bay, one South, the other North. These channels must receive a streaming system in order to manage a

water flow from South to North of the lagoon only able to prevent over saturation in salt of the lagoon. The same system could be planned to the actual small lagoons laying at North and East of Half Moon Bay to decrease the salt concentration.

5 Mangrove establishment

Mangrove plants need tide movements for their establishment, as the amplitude of tides is very low in Half Moon Bay, it will be lower in this lagoon even the artificial streaming system is installed.

5.1 Artificial tiding

It is possible to increase the amplitude of natural bay tides using pumps management and the input or output flows. One meter of amplitude allows the installation of a 25 to 50 meters mangrove ribbon, depending of the shore slope, which will be more livable than a 5 to 10 meter wide allowed by the natural tide mean levels recorded for the Bay.
For uprising the level of the lagoon the South input channel must be widely opened and the South pumps must give its higher delivery, at the opposite the North channel must be reduced and the output pump stopped. For shoaling the level, input South channel must be reduced, the input pump stopped and during the same time North output pump must give its higher delivery and the correspondent channel must be widely open.

5.2 Artificial fresh water flow

The mangrove trees and shrubs need fresh water during the lower water level. It will be necessary to plan an equipment of fresh water distribution, the best solution is the use of a trickling or overflow device also named device using drains or skimmers. The water is brought in bright channels deeper as large and finally distributed in brighter ones quite parallels to the isovalue curves, the slope of the irrigated area must be comprised between 2 and 4%. In our case this irrigation will be set once a day, 2 hours after the night lowering tide to prevent a too important evaporation and effectively rinsing the mangrove area.
As the water will come from the effluents of waste water treatment stations, only the shore of the lagoon near of these resources seems to be favorable for such a plantation.

5.3 Mangrove nursery

The 2 indigenous species can be multiplicated by seedlings or cuttings in very wet and half shade conditions. The nursery can be driven both in black polyethylene nursery bags (dimensions flat: 25 cm × 12.5 cm, for a volume of 2.5 l) and in banks for bare roots production.
The substrate must be a mix of lagoon shore natural sand, from 15 to 20% of organic nutrient. In order to improve the water retention of this substrate of culture, it is recommended, after having filtered it well to eliminate the stones, remains and branches, to complete it with 25 to 30% of hydro retenders, i.e. sphagnum moss of quality "short" or "mild". It means you need for one m^2 of nursery banks around 25 to 30 l of rehydrated sphagnum moss (1 to 1.2 kg of dried sphagnum moss) and 15 to 20 l of organic nutrient.

As the seeds are pre germinated on the trees it is not necessary to use more than one plantlet per seedling bag. The time in nursery will be shorter than for dune fixation plants

but the amount of watering must be higher and kept around 10 liter/m² twice a day all the nursery time.

A substantial shade can be provided by the plantation of date palm trees in an adapted density (10m X 10m or less in a square device).

5.4 Mangrove plantation

Because the soil of plantation must be moldy, the plantation holes are carried out at the time of the planting to avoid the crumbling of the walls of the hole of plantation. The same particular auger used for dune stabilization can be used in this case.

The bottom of the hole must be at around 30 to 40 cm and filled up to 12.5 cm from ground level with the same mixed substrate than for the nursery bags. The density of plantation can be established by mangrove regeneration specialists and could be different for each specie. The most efficient way is probably to plant patterns of plants grouping some individuals of the same specie, this device manage the natural installation of flows and animal species circulation.
The fresh water distribution device must be installed before the plantation and the planted area must be levelled after plantation.

5.5 Fauna implantation

Some of the aquatic fauna species will probably come naturally to colonize this artificial ecosystem, both in lagoon and mangrove; it is the same expectation for birds and mammals.
If people want to increase the speed of colonization it is possible to set on capture and release operations from existent lagoons and mangroves as near as possible from the Half Moon Bay site.
In case of a breeding exploitation of this marine area, the introduced species into breeding devices must be specified by specialists of tropical aquaculture and conchiliculture.

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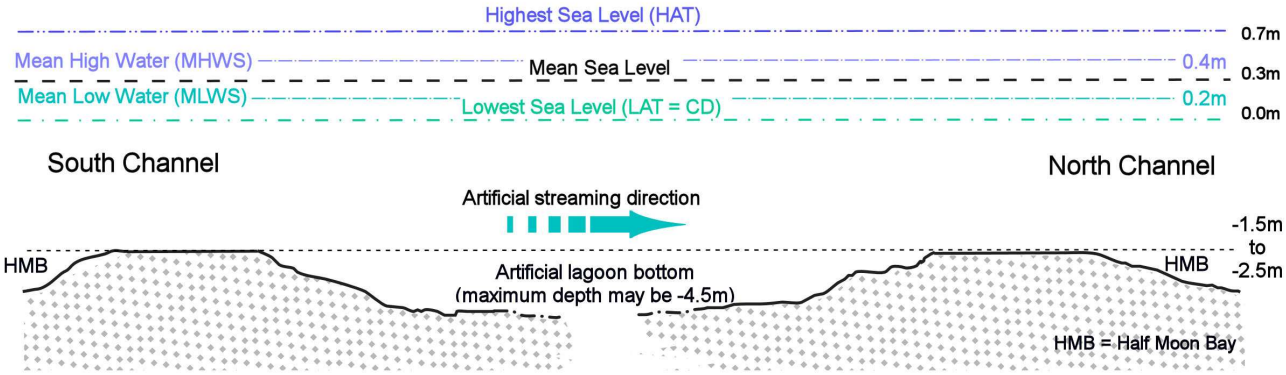
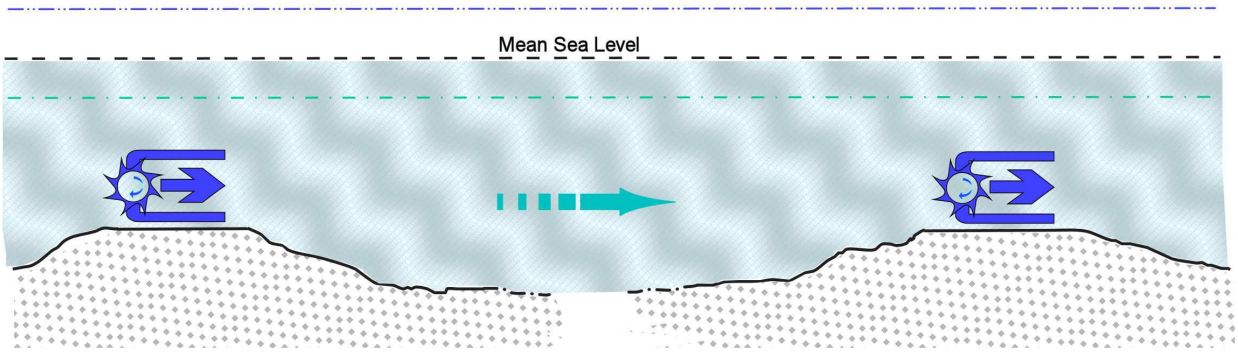
Annex

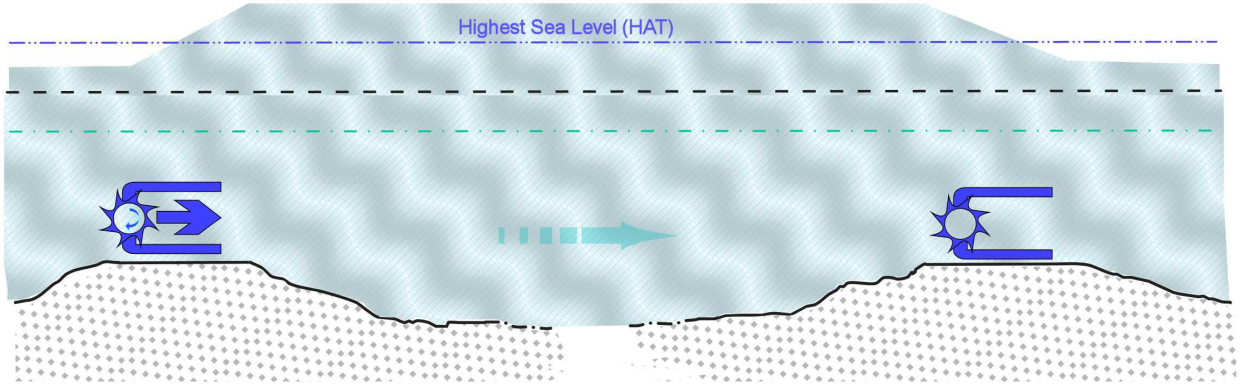
Illustrations



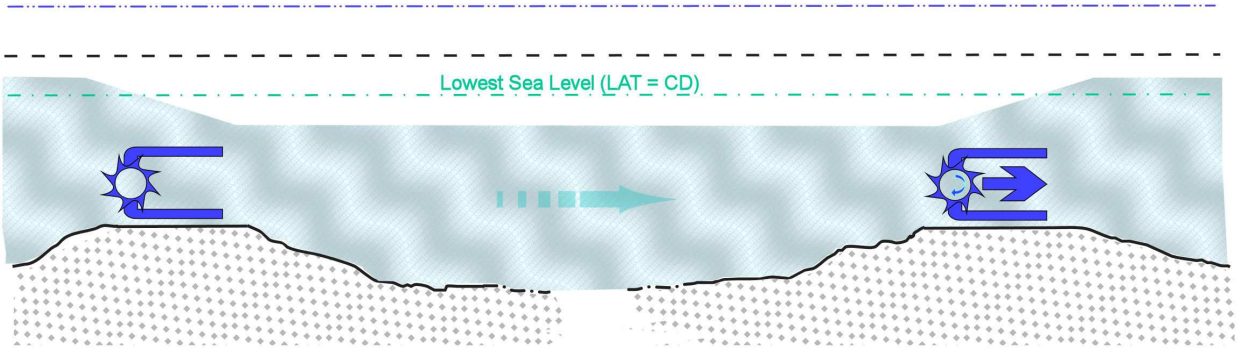
Main oceanographic characteristics



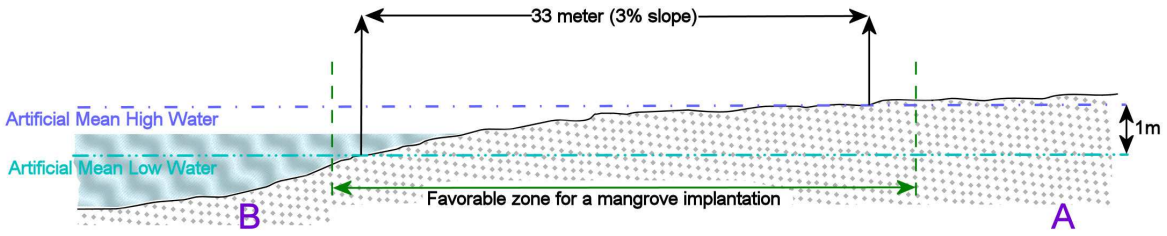
Equivalent pump flows from 2 hours before to 2 hours after natural intertide



Input pump flow from 2 hours before to 2 hours after higher sea level



Output pump flow from 2 hours before to 2 hours after lower sea level



Transect along A B line :
Artificial tide levels and mangrove implantation zone

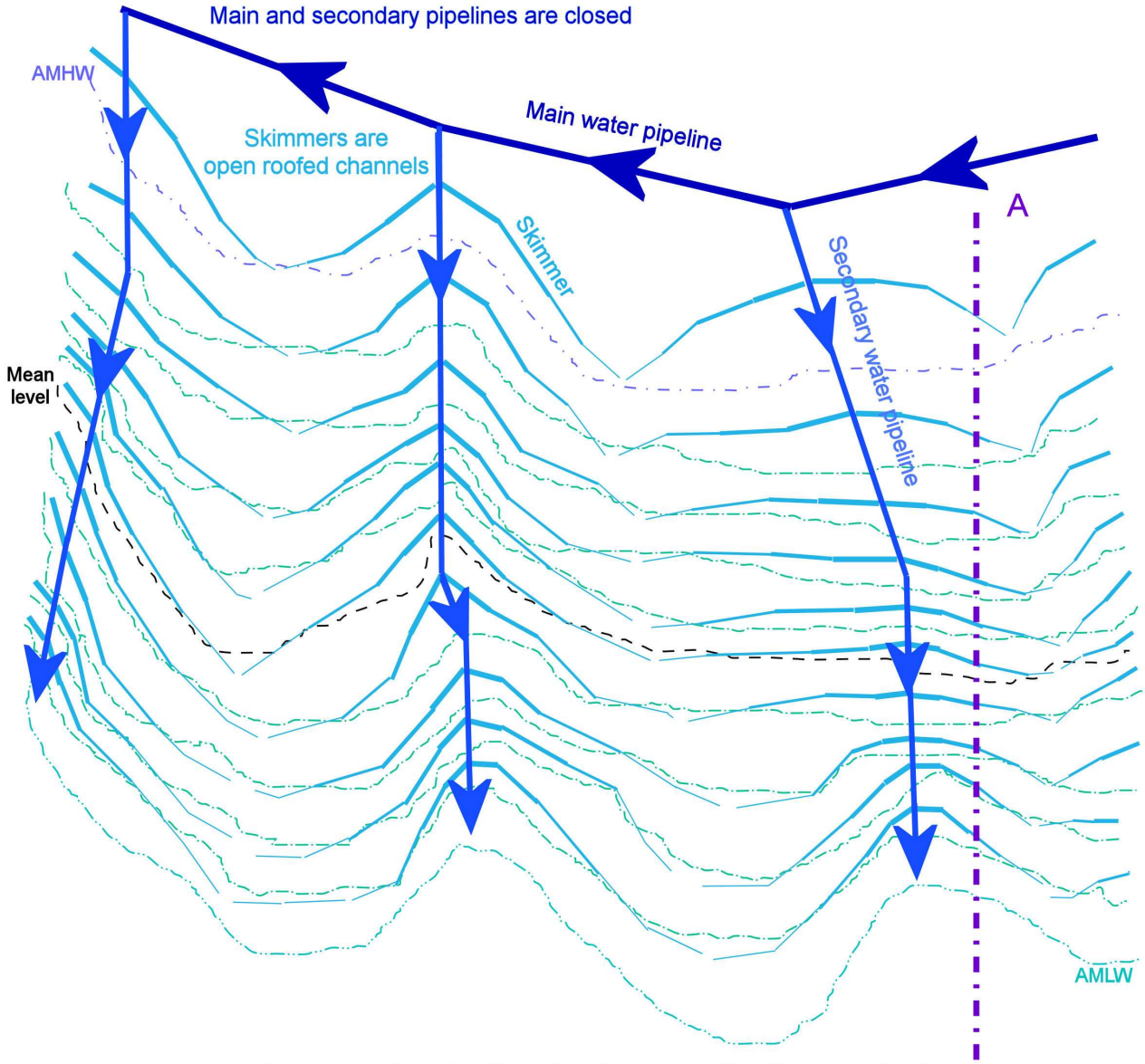
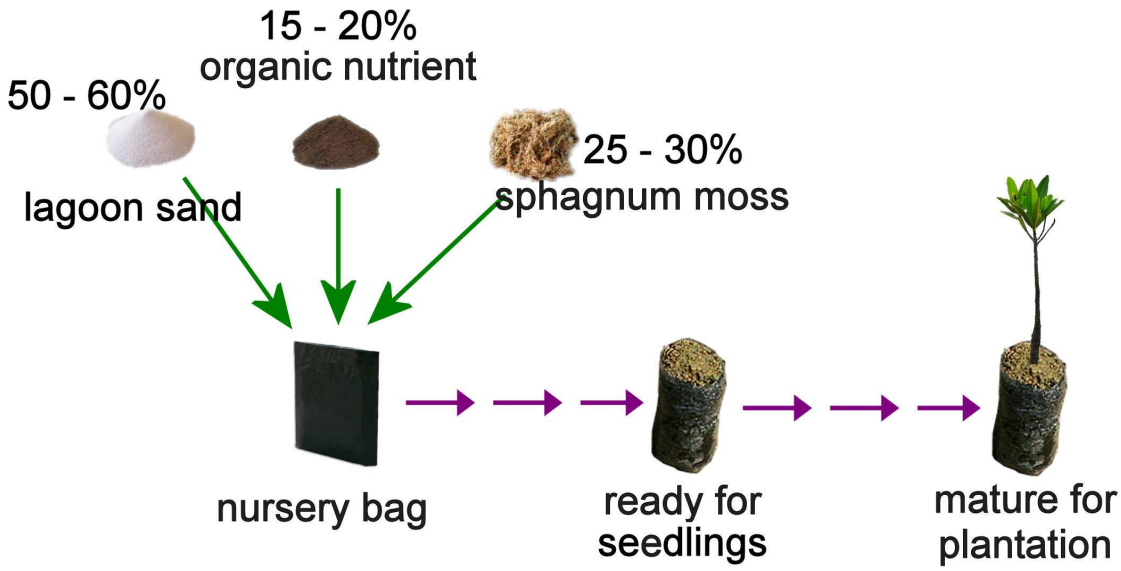


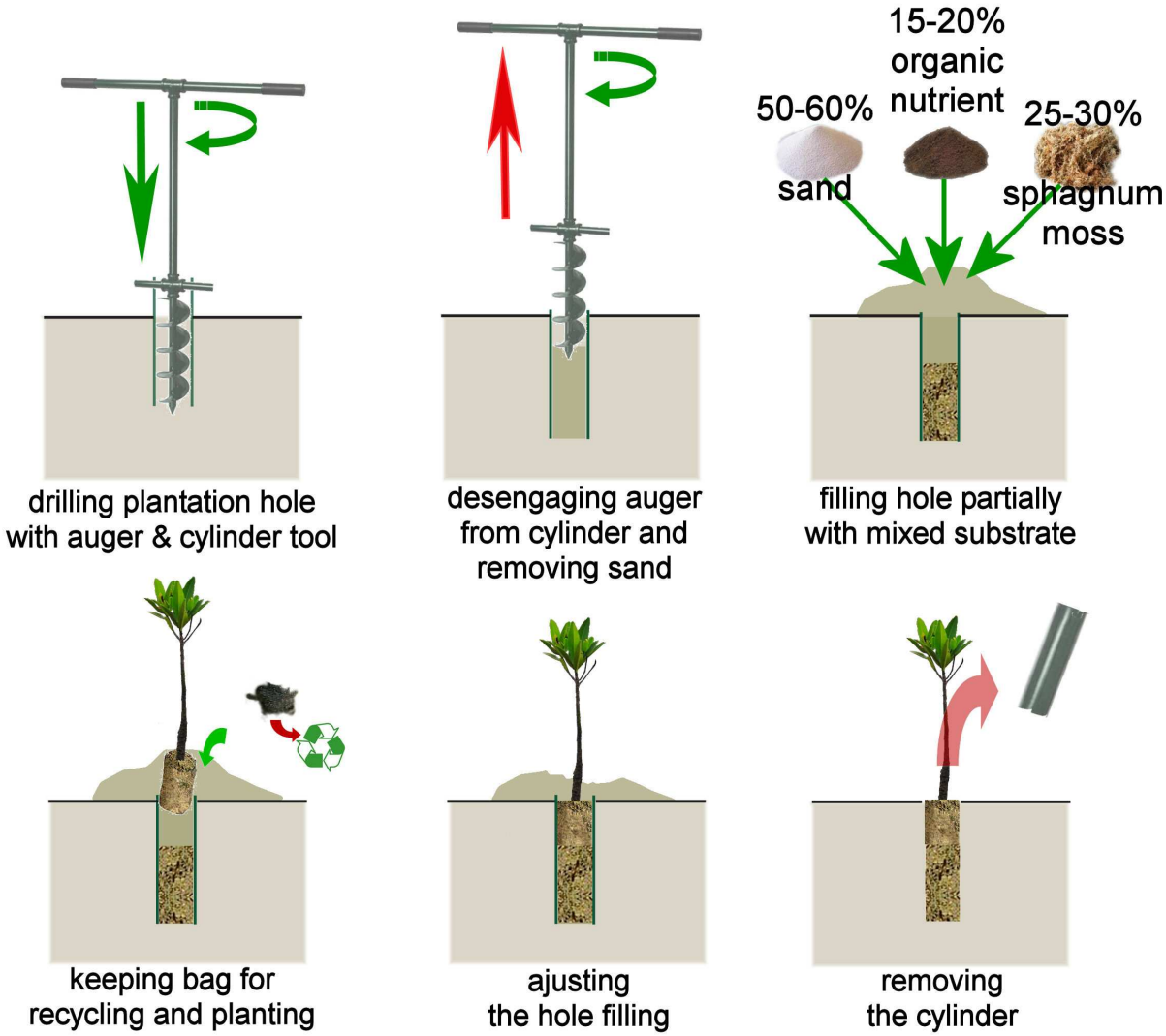
Diagram of a trickling fresh water distribution device
(also called device using skimmers)

Propagule of *Avicennia marina* floating in an estuary

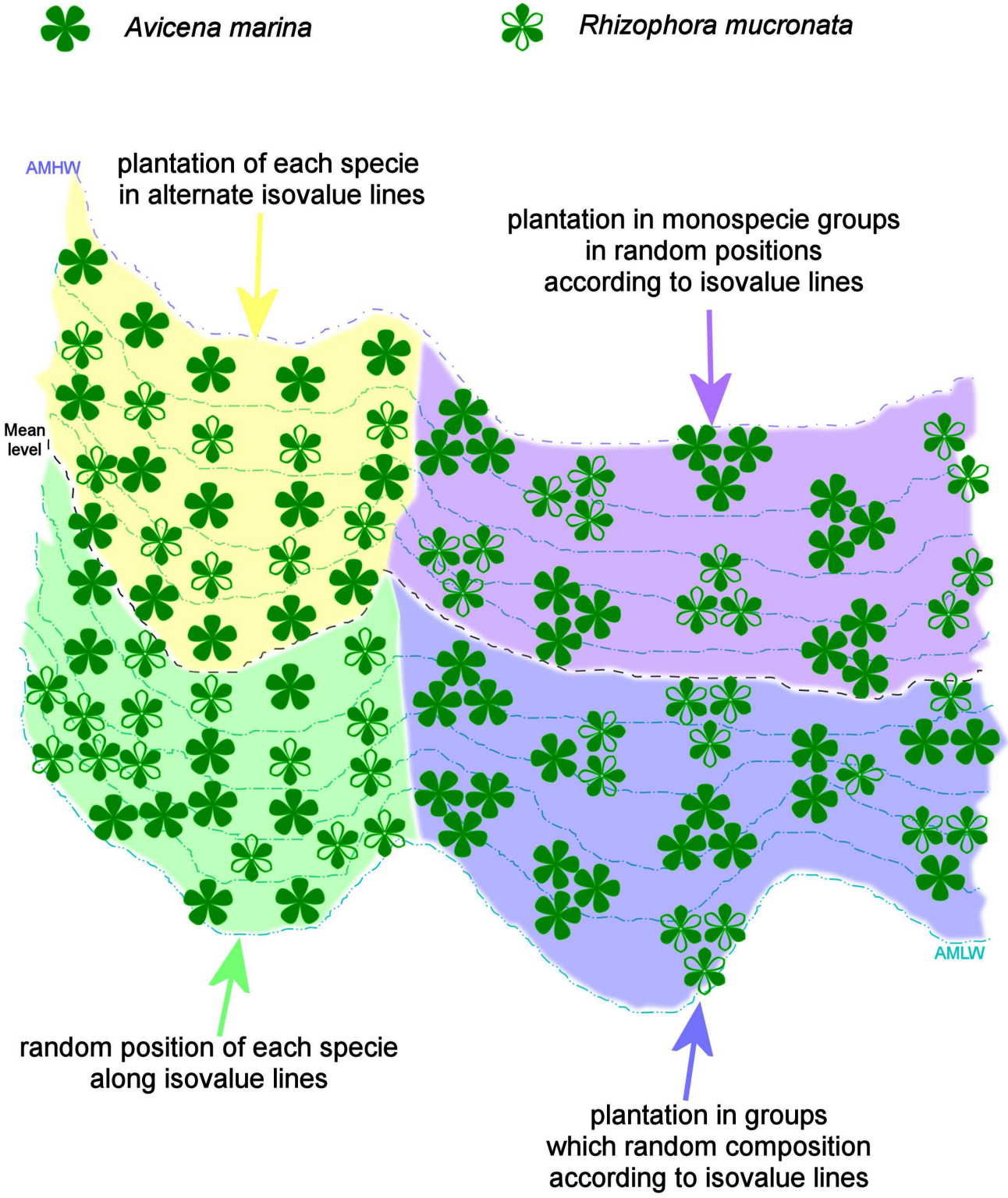
Seedling of *Avicennia marina* growing in a muddy sand



Nursery bag filling



Some diagrams of plantation



Stipa capensis

Pennisetum divisum

Lasiurus scindicus

Stipagrossis plumose

Aeluropus lagopoides

Cyperus conglomeratus

Halopeplis perfoliata community

Halopeplis perfoliata succulent leaves

Avicennia marina community

Avicennia marina isolated tree

Rhizophora mucronata community

Rhizophora mucronata isolated group of trees

Uca inverse

Metopograpsus messor

Macrophthalmus spp.

Half Moon Bay City

III

Truck-Farming and Horticultural Perimeters

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Scientific report of prescriptions and sourcing carried out for AREP-Ville

Truck-farming and Horticulture
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6 Truck-farming

The name of truck-farming is used to describe a large scale farming system based on providing a wide range and steady supply of fresh produce through the local growing season. It is the addition of numerous "market garden farms" of a relatively small-scale production of fruits, vegetables, and flowers as cash crops, frequently sold directly to the local customers and restaurants. It is distinguishable from other types of farming by the diversity of grown crops on a small area of land, typically, from under one ha to a few ha, or sometimes in greenhouses.
All the crops are based on annual plants adapted to the farming and climatic conditions. These crops need a regular watering for growing well and producing.

6.1 Climate and light

Considering the local climatic conditions of Half Moon Bay, it gives a short season with some rainfalls and relative low average temperatures; the other part of the year is dry to arid and hot top very hot.
The latitude of Half Moon Bay is between 26.0° N and 26.1° N, it induces a particular nyctimeral rhythm with longer days during the fresher season than in European and Mediterranean countries and longer days during hottest times compared with usual Intertropical countries.
The choice of cultivated varieties must consider both the temperature and photoperiod.

6.2 Plant choice

All kind of usual vegetables, fruits, leaves and flowers can be cultivated in these market garden farms, such as

- Vegetables: lettuce, radish, cabbage, carrot, potatoes, sweat potatoes, ginger, galingale, beans (*Faba*), French beans, kidney beans (*Phaseolus* spp. and others), chick peas, black eyed peas, onion, garlic, New Zealand spinash (Tetragon), etc…
- Fruits: tomatoes, egg plants, pumpkins, marrows, okra, sweet peppers, hot peppers, melon, water melon, roselle, strawberries with artificial cold period, etc…
- Flowers: *Gerbera*, French marigold and many other annual flowers can be grown depending of the habit of indoors flowering.

Fodder plants may take also place in these gardens such as oat, alfalfa and other high nutritive fodder plants dedicated to home cattle.

6.3 Garden implantation

Market gardening can be driven in total soilless or in grounds prepared to avoid rates of important salinity and water loss, and enriched in natural organic matter.
Total soilless is easy to set, difficult to manage in terms of nutrient and irrigation and uses a lot of mineral and organic nutrient. The mineral substrates can pollute the environment when they are considered to be end of life. The natural substrate such as coco fiber, wood fiber, sphagnum moss must be imported and recycled at the end of their life.
Prepared grounds are natural substrates composed from local sand and ground, enriched in natural organic matter and improved with hydro retender including a device dedicated to prevent salt raising.

The chosen site for a permanent gardening must take account of the following factors:

- the topography of the ground: the ideal ground must be flat, slightly inclined in the longitudinal direction, cleared, leveled and without stones;
- the quality of the ground, which must be muddy sandy, of texture light or average, easy to work, drained well, without nematodes and dangerous cryptogams;
- near to a waste water purifying station rejecting a water of quality and ensuring a permanent and sufficient quantity of this water;
- a situation near the urban perimeters or near the main transport ways;
- an easy access in all seasons;
- the availability of a sufficient workers;
- capacity of annual provisioning of complementary substrate and nutrients to ensure the discounted production.

The reserved perimeter for the gardens is protected from the dominant winds, the streaming of precipitations or secondary water accumulations, the cattle, fires, the birds and the locust invasions. It is also surrounded by a fitted latticework fence, doubled inside the perimeter by a quickset hedge, if possible thorny, or palisades in natural or synthetic material. A permanent guarding is also recommended.
A substantial shade can be provided by the plantation of date palm trees in a density depended to this kind of crops (13m X 13m or less in a square device).

6.4 Plant beds setting

If the existing ground is free of salt or presents a low salinity, there is nothing else to do except to flatten it after mixing 15 to 20% of organic nutrient, 15 to 20 % of hydro retender (the natural best one is rehydrated sphagnum moss quality "short"); it means a depth of 6 cm of each kind of complement.
If its salinity level is too high, it is necessary to take out about 20 to 30cm of it and replace by 10cm of "white" wadi sand if any or not salty dune sand, then rich 12cm over the initial level with an enriched substrate made of 15% of organic nutrients, 15 to 20% of hydro retender; it means, for a 30cm depth after removing the salty sand, a depth of 30 cm of white sand, 6cm of each kind of complement.
If the beds are surrounded by plastic borders, it is not necessary to take off the existing ground from the surface dedicated to the paths.

The width of the beds is usually fixed at 1.5m (1.2 useful width), for potatoes and sweet potatoes it is better to use a 1.8m wide bed (1.5 useful width).
For one hectare of both type of developments (7,800 useful m²), the necessary complement quantities are for both sphagnum and organic nutrient about 470m^3; it means 18,7t of dried sphagnum moss.

6.5 Plant bed irrigation

The plant beds must be watered before plantation or seedling enough to wet 30cm depth (around 10 to 15l/m²).
Each plantation hole must receive 1l of water before laying each plant; the seedlings have to be gently watered with a watering-can equipped with a rose just after realization.
Irrigation during the cropping growth and production time must be delivered by a micro-dripping system which distance between micro-drippers fits the interval of plantations. The cheaper system is T-tape system well used over the world for market gardening, the tape are underground laid to prevent water loss by immediate evaporation.

The daily quantity of irrigation must be brought at night and just to compensate the daily evaporation (2 to 4mm of water per day in fresher period to more than 10 in hottest days). Water used for irrigation may preferably be treated and recycled waste water.

7 Perennial horticulture

This denomination includes both orchards, perennial bed plants and palm plantations providing a supply essentially made of fresh or dried fruits produce through the local growing seasons thanks to a good irrigation and a management of plant associations.
All the crops are based on perennial plants adapted to the climatic local conditions.

7.1 Climate and light

Regarding the local climatic conditions of Half Moon Bay, the usual plant associations of the traditional oases may be considered and implanted. Some tropical fruit plants may be also used in order to increase the diversity of fruits.
The choice of these exotic cultivated varieties must consider both light intensity, photoperiod and air moisture.

7.2 Plant choice

As it is usual in oasis crop systems, the upper canopy must be dedicated to date palm for fruit production, the used cultivars must be dedicated to the local market and then composed of varieties which gustative characteristics are well appreciated by the new city inhabitants. The density of plantation will be largely dependent of the composition of the middle and low canopies.
The middle level canopy will be composed, as it is found in South of Tunisia, Egypt, Algeria and Morocco, by different kind of fruit trees such as citrus trees (lemon, orange, grapefruit,…), adapted variety of apricot (like Tunisian "mech-mech"), olive trees, fig trees, pomegranate trees, guava trees, passion flower, vines (with special pruning processes), banana if the moisture can be kept at a good level, etc…
This canopy may be also enriched, brighten up and perfumed by climbing flowers such as jasmine, wax flower, Mexican blood flower, bougainvillea, mandevilla, marmalade bush, etc…
For the lower level canopy tropical fruits bushes may be planted like surina cherry, Cape gooseberry, it is possible to combine other low bushes like henna, indigo-plant, feverfew, etc…
In half sunny places but moistly, pineapple may grow very well just like prickly pear may in sunny and drier places.

7.3 Garden implantation

The implantation of those gardens must be the same than for market gardens.
The true trees, shrubs and bushes must be grown initially in nursery in black bags (25cm X 25cm flat) just as the plant for stranding control and mangrove plantation are.

7.4 Planting palms, trees and bushes

- Date palm offshoot plantations:
  A good soil preparing is necessary for good revival and growth of the offshoots.

The plantation hole do have 50 to 70 cm of diameter and 70 to 100 cm depth, it can be drilled by an auger with a cylinder or dug with any sap tool by the condition that the wall are stabilized.
The bottom of the hole may be filled with a mix of 25% of sphagnum moss, 10 % of organic nutrient and sand up to its half level and then watered with 40 to 50 l of water. The remaining hole must then be filled with a mix of 15% of sphagnum moss, 15 to 20% of organic nutrient then watered again with 40 l of water. About 0.15Kg to 0.3Kg of dry sphagnum moss and 21 to 45 l of organic nutrient per planted offshoot.
The hole top must be depressed to its centre for keeping easily the irrigation water near the offshoot in case of exceeding.
The density will be modulated depending to the underneath crop levels and do take range from 50 to 115 trees per ha. Thus it needs between 7.5Kg to 35Kg of dried sphagnum moss and 1.05 to 5.2 m^3 of organic nutrient per ha.

- Fruit tree plantations:
  The soil preparing is the same than for palm trees and the holes are less large and deep, they are similar of those used for stranding control and mangrove plantation (diameter of 30cm and depth of 60 cm).
  The nursery bags must be removed before planting.
  The hole may be filled with the same mix of sphagnum moss, organic nutrient and sand then watered before laying the plant ball and surrounding it with the same mix.
  The density will be modulated depending both of the plant species and of the underneath low level plants. The average taken range is about 120 trees and shrubs per ha.

- Fruit shrub and pineapple plantations:
  It is better to prepare plant beds for planting shrubs and pineapple, the preparation is equivalent to the previous bed preparation.
  The plant beds must be cross orientated and laid between the plantation lines of palms, trees and shrubs.
  The choice of the planted species depends locally of the shade and moistness conditions determined by the middle and upper plant canopies.

The average total amount of complements is near 10t of dried sphagnum moss and 240m^3 of organic nutrient per ha.

The transition between these two kind of gardening may be continuously progressive or, at the opposite, strongly identified by fences. The progressivity may probably manage a better visual aspect and better conditions for biodiversity increasing.

7.5 Plantation irrigation

Irrigation during the cropping growth and production time must be delivered by a micro-dripping system in rings for palms, trees and shrubs. For the bushes and pineapple, a lined system does fit. For the rings cylindrical dripping pipes and T-tape are well adapted.
The dripping pipes and tapes must be laid underground to prevent water loss by immediate evaporation. The daily quantity of irrigation must be brought at night and just to compensate the daily evaporation (2 to 4mm of water per day in fresher period to more than 10 in hottest days). Water used for irrigation must be treated and recycled waste water.

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Irrigated Horticulture and market gardens

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Traditional oases' garden in Figuig (Morocco)

Fig tree and date palm canopies in a traditional oases' garden in Figuig (Morocco)

Ancient postcard showing a traditional oases' garden in Tiout (Morocco)

Wheat or barley crop in a traditional oases' garden in Tiout (Morocco)

Traditional oases' landscaped garden in Tozeur (Tunisia)

Paradisiacal traditional oases' landscaped garden in Tozeur (Tunisia)

Date palms, pomegranate and fig trees, fodders and cereals
in a traditional oases' garden in Nefta (Tunisia)

Peaceful traditional oases' garden, picture probably taken in Atar (Mauritania)

Main irrigation basin of a traditional oases' garden in Mauritanian Adrar

Traditional oases' garden in Oued Seguelil (Mauritanian Adrar)

Undercover and open sky crops in a traditional oases

Half Moon Bay City

IV

Landscaping Prescriptions.

City Outskirts, Urban Zone.

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Scientific report of prescriptions and sourcing carried out for AREP-Ville

8 Landscaping the outskirts of the City

The outskirts of the planned city are the margin of an extended urban space in contact with the quite natural landscape builds by the dune biologic fixation devices, the artificial lagoon free shores or the planted mangrove, the traditional oasis like orchards and the market garden fields. The landscaping action must be strong around the technical installations such as sea water desalination devices or waste water treatment and purification stations.

As these formations or plantations are not situated at the same distance from the urban substructure itself the greened outskirts do appears like green tentacles spreading from the city to the desert for welcoming the travelers and caravans.

8.1 Direct contact with dunes

The plant density, height and the plant choice must be progressive and continuous from the dune with their fixation devices to the urban landscape.

The first trees, shrubs, bushes and grasses must be the same as those of the natural fixation device with a higher density especially for the lower forms (bushes and grasses). Then the density of shrubs must increase simultaneously with the addition of new herbaceous and bushy plants, mainly composed of flowering plants. Finally, the density of trees can increase step by step simultaneously with the inclusion of new species of shrubs and trees later, mainly composed of plants with attractive barks, attractive foliage and flowers if any.
This arrangement is proposed both for giving a transition between a technical device and an attractive landscaping and for increasing the effect of the stranding prevention devices. Such a sequence is able to decrease gently the residual effects of wind sand transports; it can also quite filter the wind and refresh the air between the different layers of the canopy. The height of the canopy must be more important near the roads in order to provide shade and freshness on their shoulders.

Combined by the changes of species and densities, it will be necessary to manage an irrigation network preventing the decline of water resources for each individual plant despite the chosen plants must be adapted to aridity and hotness. The necessary water needs to come from recycled, purified and treated waste water.

8.2 Direct contact with sabkha or lagoon shores

At the sabkha margins, non halophytic low plants will be progressively added to the local halophytes then followed by bushes, shrubs, trees of the same composition than the previous transect arrangement.

Near the lagoon shore grasses, sedges and herbaceous spontaneous plants will be followed by the plantation of other species of grasses, sedges, herbaceous then bushes, shrubs and trees than previously.

Just near the lagoon or the sabkhat, people may use a mix of salted water and recycled, purified and treated waste water. The dripping systems must be underground.

8.3 Contact with horticultural and market gardens

As these area are just following gardens and small fields which are surrounded by fences, they can be planted with species of herbaceous, bushes, shrubs and trees mainly composed of plants with attractive barks, attractive foliage and flowers if any.

They will only indicate a short transition between two kinds of strongly anthropomorphous landscapes which are the agricultural imprint and the urban greening and flowering.

As the perennial plantations and the market gardens are irrigated, the water network yet exists and is easy to use for these plants.

9 Landscaping the Urban Area

The first purpose of these plantations is to provide shade, freshness and, by the way, a green, flowery, entertaining, pleasant environment for citizens. In this frame of mind, the most important part of conception must be between pavement and 3 to 4 meters high but it is also necessary to vegetalize the building roofs, terraces, balconies, and sometimes walls if the water resource is enough for that.
The second aim is not to break the marine breezes entry in the city because these winds are fresh andlightly wet. Then, in case of hedges or similar thick plant arrangements they will be orientated quite West East.

9.1 Clumps and In Line Plantations

Bushes and shrubs may be planted in clumps directly in holes which have been initially managed in the pavement. These holes must be wide enough to allow a good growth or horizontal spreading in case of bushes, the irrigation device must be include previously in order to prevent redundant works. On the same hand it must be easy reachable and disposable for further maintenance.

The trees and palm tress may be structured with in line plantation along roads, avenues and streets. They will also take place in holes which have benne initially managed in the pavement. The distance between trees in a line does consider the adult horizontal dimensions as it is necessary to consider it before determining the distance from the driving ways and from the building windows and frontages.

The chosen trees, shrubs and bushes do not have a strong superficial and creeping root system which would open the pavements and break the building walls and fronts.

9.2 Square Gardens and Flower Beds

Both perennial plants and annual ones may be installed to shade rest or playing places, such as squares with public seats, restrooms or area with outdoor games for children.

These kinds of devices can also take place in school yards, college and universities. In school yards it is obviously important to avoid the plantation of toxic or irritating plants.
If the patterns of plants are arranged on natural soils, it is possible to install the plants and the irrigation devices after the buildings and other structures. In the opposite case it is necessary to manage holes, open surfaces or flower stands and irrigation devices during the construction period. On every case, these devices do remain easily reachable and disposable for further maintenance.

9.3 Roof, Balcony, Terrace and Wall Greening

This kind of flower and herbaceous gardening was well known in the past in all Oriental and Mediterranean cities, it mixes annual and perennial plants, ground covers, creeping and erected low or medium plants, and climbers.

The vegetalized roofs bring a fresher and more silent ambiance inside the underneath building, it is the same for the wide South orientated frontages recovered with vertical gardens also named plant walls. The substrate bring thermo isolation and sound proofing if it is correctly chosen, the water state change takes off calories in ambient air both at the substrate and plant levels.
Greening and flowering the balcony and terraces is mostly dedicated to beautifying their aspect and for the entertainment of the owners or lodgers. Always regarding the fresh drinking water economies buildings and individual houses do have a separated water network for the irrigation needs.

10 Plant overview

The annual plants, essentially flowers, must be produced locally; this growing may be a complementary activity for the market garden producers. The perennial plants also must be grown and breed in the same nurseries than the plants dedicated to stranding prevention and mangrove setting up.
As it gives particular techniques of plant establishment and breeding for planted roofs and plant walls the nurseries able to host these cultivations must be correctly identified and chosen by the landscaping companies in charge of these up to date kind of gardens. Both these plants must be grown since the beginning on the same substrate than final one and in a quite vertical position for the ones dedicated to the plant walls.

10.1 Outskirts Plantations

o Transition from dunes

The plantations begin by increasing the density of the plant used to control stranding except *Prosopis juliflora* which strong superficial creeping root system is not convenient: *Aristida pungens, Leptadenia pyrotechnica*, *Panicum turgidum*, *Acacia raddiana*, *Acacia Senegal*, *Balanites aegyptiaca*, *Euphorbia balsamifera*, *Persica salvadora*,

o Transition from sabkhat and lagoon

The plantations begin by increasing the density of the plant proposed for littoral dunes: *Nitraria retusa*, *Tamarix aphylla*, *Tamarix senegalensis, Casuarina equisetifolia*, *Atriplex halimus*, *Atriplex nummularia* and *Zygophyllum spp*.

Some indigenous halophytic plants may be used to thicken the plantation near the rands: *Panicum turgidum*, *Stipa capensis*, *Pennisetum divisum*, *Zygophyllum coccineum*,

Lasiurus scindicus, *Stipagrossis plumose*, *Aeluropus lagopoides*, *Halopeplis perfoliata*, *Tamafix Arabica* and *Cyperus conglomeratus*.

- **Transition from horticultural and market gardens, technical devices**

These area are yet strongly imprint by human activities and if they are not really landscaped, they are planted with particular patterns and aims. The plants used outside of these sites may be the same than inside including ornamental species in a less structured plantation system

- **Heart of the Outskirts**

Some species seems to be plants of ornamental interest for creating an identity to the outskirts green and flowering belt: *Calotropis procera*, *Eucalyptus eremophila*, *Adenium obesum*, *Euphorbia candelabrum*, *Euphorbia bussei, Acacia drepanolobium*, *Sansevieria ehrenbergiana*, *Aloe volkensii*, *Argemona mexicana*, *Commiphora trothea*, *Cyperus immensus*, *Cyperus involucratus*, *Typha_capensis*, *Jatropha curcas*, *Ficus sycomorus,* Shruby *Ipomea*, *Kigelia Africana*, *Pennisetum mezianum*, *Phoenix reclinata*, *Medemia argun* (an endangered palm tree commonly named "Doum" like *Hyphaene*), *Hyphaene thebaica*, *Ziziphus mucronata*, *Punica granatum* (both fruit and flowers cultivars), *Nerium oleander*, *Dipladenia sanderi* (*Mandevilla s.*) *Olea europea*, etc …

- **Transition to the City and the Urban Structure**

Toxic plants and those know for their allergenic effects must progressively disappear; *Adenium obesum*, *Euphorbia bussei,* etc… and being replace by other species used in urban landscaping.

10.2 Plantations included in the Urban Structure

- **Clumps, In line plantations**

All the trees, shrub and bushes listed in "Heart of the Outskirts" paragraph in 3.1 part are available for this use.

Other plants may be chosen by landscape architects or city garden services by respecting some prescriptions:

- The species or varieties (cultivars or hybrids) are adapted to arid conditions and abstemious in water.
- They are not or lightly toxic by contact or fruits.
- They do not let down too much of wastes (dead branches, leaves or fallen fruits).
- They do not have a strong superficial and creeping root system…

Some species may bring new shapes adapted to urban greening such as *Cordyline australis*, *Agave victoria reginae* or *Agave Filifera*, *Yucca rostrata* , etc…

- **Square gardens and flower beds, balcony and terrace greening**

For perennial plants the same directions may be applied with the addition of some climbers if it gives structures adapted to them in the square gardens.

For the annual plants and flowers, the main prescriptions are the same than the two first for Clumps and In line plantations.

The choice for balcony and terrace greening or, eventually for indoor flowering is something very private and depends of the people who are living in or managing the

buildings or flats. Nevertheless the buildings must be supplied in a water network dedicated to watering or irrigation and the inhabitant must be informed of this network.

10.3 Roof and Wall Greening

The roofs where people want to install a "plant roof", must receive a perfect water tightness treatment which is not probably a claimable necessity in climatic conditions of Saudi Arabia. All kinds of roofs may receive plant roof if their slope is between 0 to 15%.
By using plant walls conceived just like mantel walls which create a ventured air blade between concrete wall and plant wall it is not necessary to have a particular exigency for the water tightness of the building walls.

- **Plant roof**

The substrate must not be too heavy, density between 0.6 to 0.8 when wet and not too thick; it must also be able to keep moisture for the plants during a long time to prevent too much water consumption. The surface of the substrate must be protected from wind mechanic effects which can take off particles of substrate before final plant cover is installed.
The best device is modular with two to four parts per m², the irrigation using dripping system must be integrated but easy to remove or to allow the maintenance or the release or substitution of substrate elements.
There are some different well known systems of plant roofs, one of them fit to the substrate prescriptions and its associate planted vegetation is determined for each climate, each situation by experts in botany who try to propose a panel of about 10 different species.
The plants are usually very rustic ones, usually short sized to prevent too important mechanical effect by wind. They are classified inside ground covers, creepers, dwarf bushy plants, mainly of them are perennial by their stems and leaves, some of them may be bulbs with seasonal blossom which bring "events" when occurred along the year.

The module of the substrate may be separate from the roof surface itself by gravel or more by a device managing a ventured blade of air. If it gives any exceeding of irrigation water, it must be recycled and the same for rainfall water. Of course it means that a particular water tank is dedicated to this recycling.
The tank is dimensioned for being able to receive the higher level of rainfall known and one day of irrigation (between 4 and 6 liters per m²) without overflowing; for instance for a 100m² roof area, for a higher rainfall of 20mm, the tank capacity would reach at least 2.6m^3 extended to 4m^3 for security and comfort of use.
The nutrient dispenser is situated before the tank connection to the specific water network dedicated to irrigation and watering.

Even the rainfalls are rare and have not a high intensity, it is convenient to try collecting all these rain waters from every roofs of the city, this water may be injected after a simple treatment or purification inside the irrigation and watering specific network. Water collected from the roads and pavements or opened parkings may be also collected and use for carwash stations.

- **Plant walls**

According to the plant roof specifications of substrate and purposes, the walls must be conceived first for temperature isolation and noise absorption though their esthetic aspect must be widely considered.

Regarding the water availabilities, South walls are the most important to consider for greening with plant walls, though greening East and West orientated ones should bring also benefits in term of isolation and entertainment.
The substrate is usually distanced from the concrete wall in order to manage a ventured air blade between original wall and plant wall. This device has two aims; it increases the thermal isolation and prevents water infiltration in the building walls. It is considered that a two to six centimeters distance is a good dimension.

Many kind of substrates and devices have been invented during the end of 20th century and the beginning of 21th. In the present City concept and its include environmental frame of mind, all the system using artificial substrates such as geo fabrics or other kinds of synthetic fibers must be kept off from choices. All the mineral substrates obtained through high temperature transformation must be also eliminate.
Only propositions using natural and renewable vegetal substrate may be examinated as final solutions.

The best size of the wall plant elements is between 3 to 9 kg of substrate with a networked container (steel or wood made) with maximum 1kg weight. The optimum thickness of the substrate should be near of 8 to 12 cm minimum to 20 to 25 maximum. The plantation density must be about 25 plants per m² chosen by creeping plants, ground covers, etc…

Just as for the planted roof there is one concept which fit very well with all the upper prescriptions.

In prevention of overwatering, it is convenient to include in the process a buffer tank of about 500 to 1,000 liters per 100 m² of plant wall. New technical innovations are currently checked in order to both decrease the quantity of water used and suppress the buffer tank for the plant walls.
As it was for roofs, the nutrient dispenser is situated before the tank connection to the specific water network dedicated to irrigation and watering.

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Sourcing

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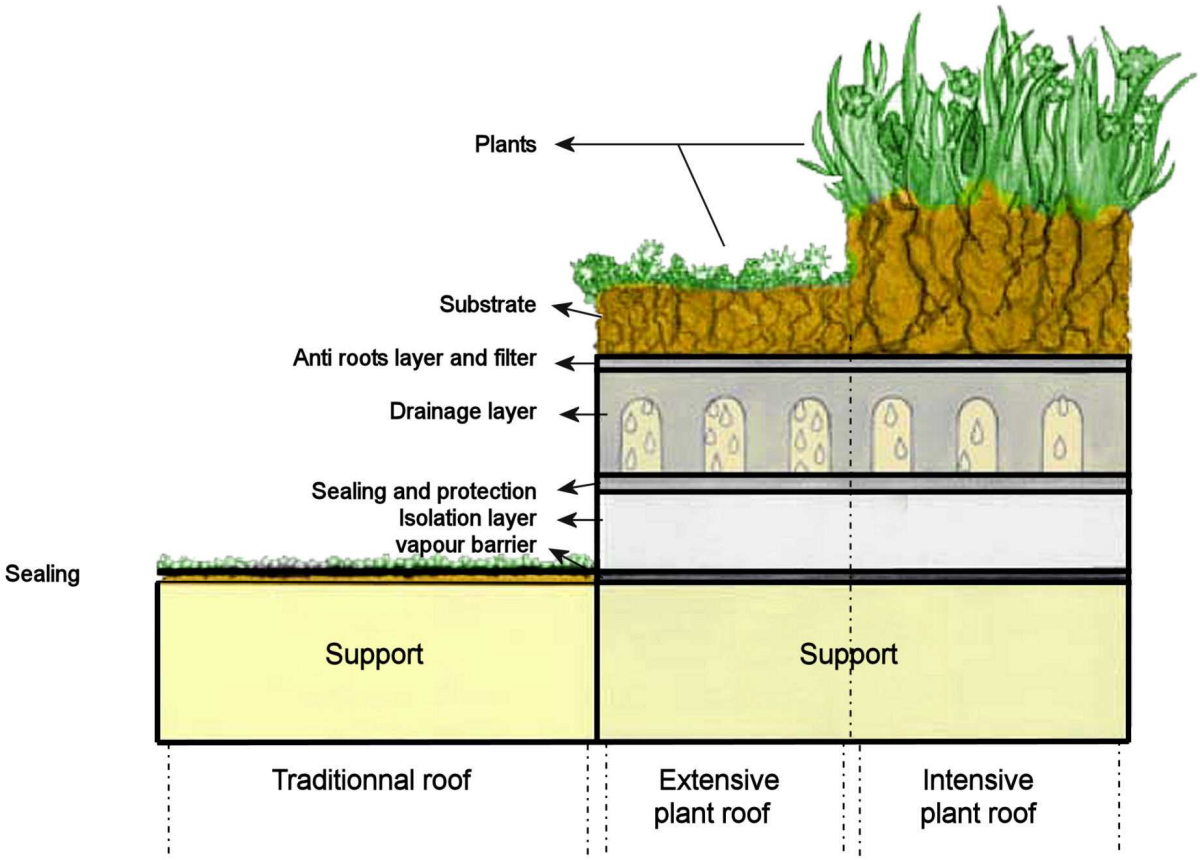
Landscaping Prescriptions.

City Outskirts, Urban Zone.

Annex

Illustrations



Diagrams of a traditional roof and two examples of plant roof

Example of an intensive plant roof

Two examples of extensive plant roof

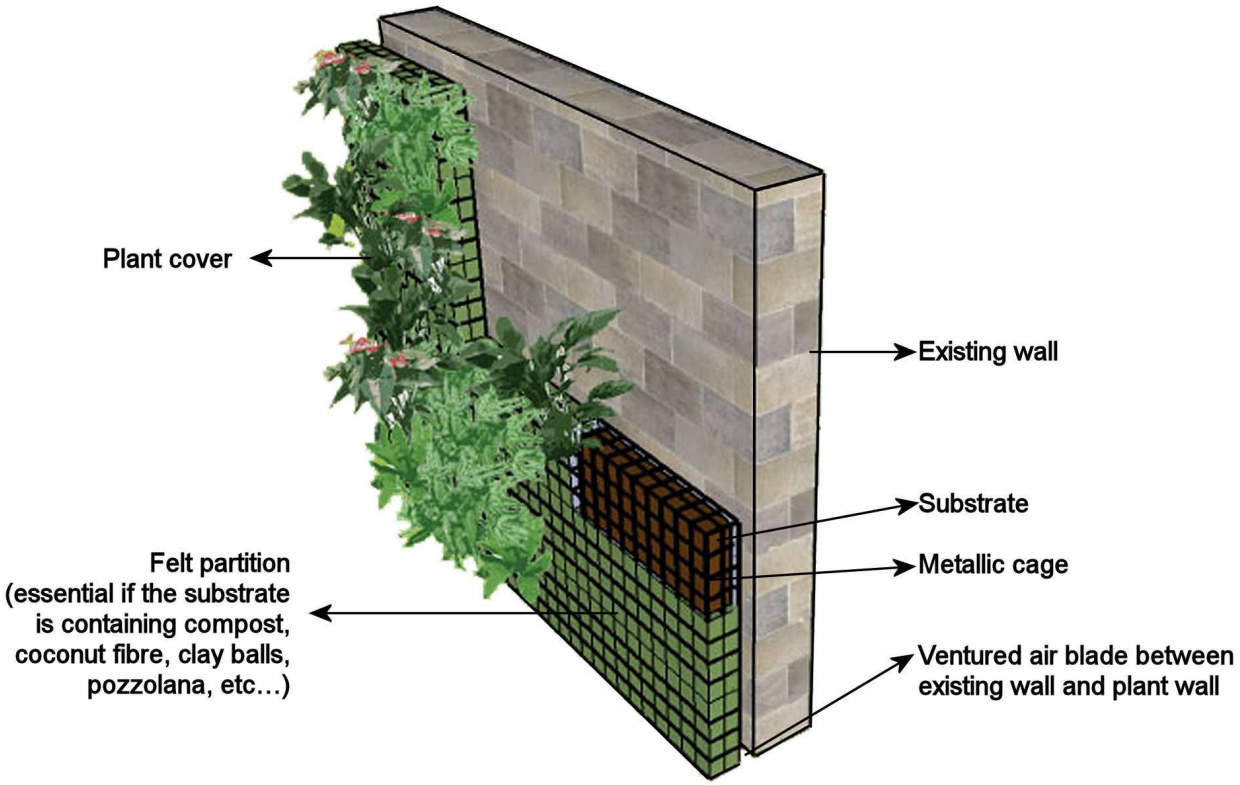


Diagram of a modular plant wall composed on a thick horticultural substrate

Indoors plant wall for an exhibition

Indoors plant wall along a swimming pool

Outside plant wall on a building frontage

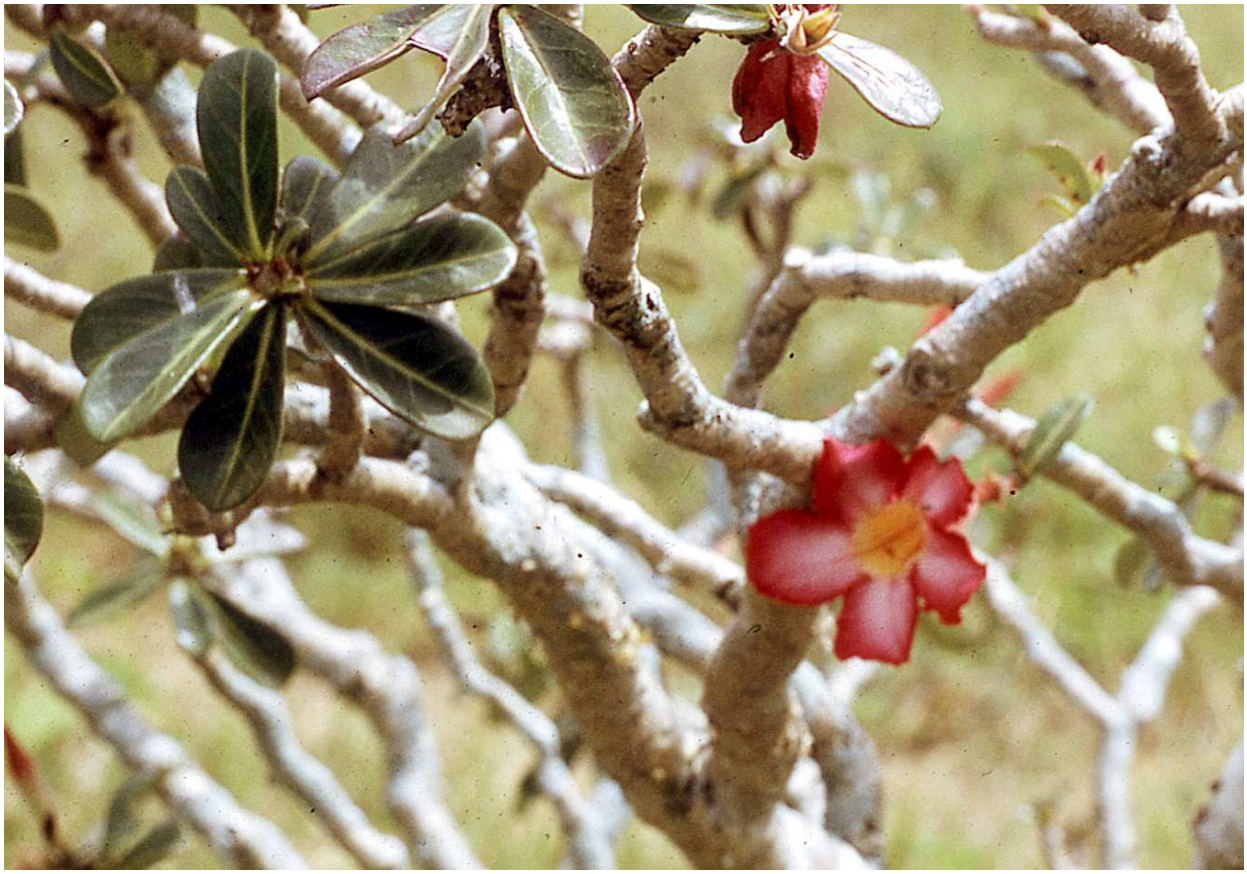
Construction of a modular plant wall
(entrance frontage of the tropical greenhouse of the Montpellier's Zoo)

Outline sight of a modular plant wall
(entrance frontage of the tropical greenhouse of the Montpellier's Zoo)

Calotropis procera

Calotropis procera flowers

Adenium obesum



Adenium obesum detail of branches, leaves and flowers

Euphorbia candelabrum

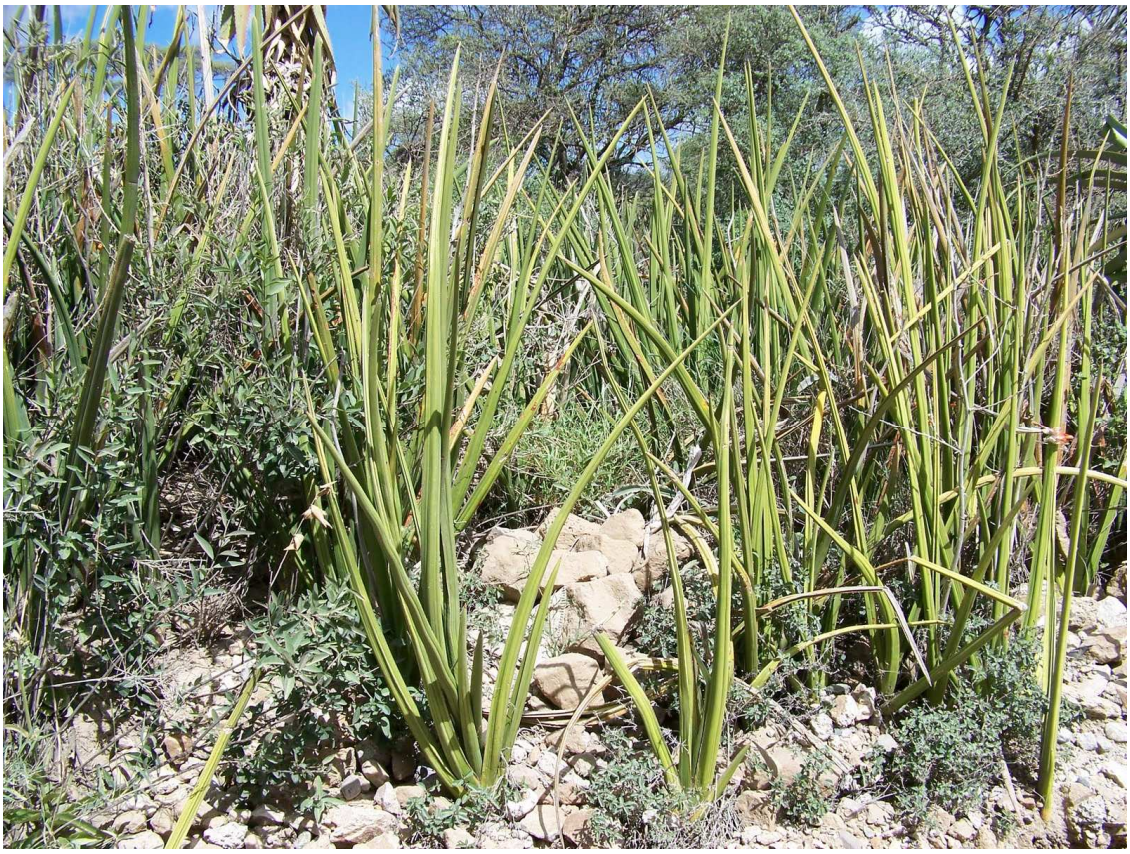
Euphorbia candelabrum

Euphorbia bussei natural community in Tanzania

Euphorbia bussei specific shape

Acacia drepanolobium

Acacia drepanolobium detail on leaves, thorns and gales



Sansevieria ehrenbergiana

Aloe volkensii

Argemona mexicana

Typha_capensis

Jatropha curcas

Ficus sycomorus

Kigelia africana

Ziziphus mucronata

Hyphaene thebaica

Medemia argun

Phoenix reclinata

Olea europea

Punica granatum

Nerium oleander

Agave victoria reginae

Agave filifera

Cordyline australis

Yucca rostrata

Half Moon Bay City

v

Management of Rain and Waste Waters.

Proposals for Other Organic Garbage.

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Scientific report of prescriptions and sourcing carried out for AREP-Ville

Rain & Waste Waters, Organic Garbage
03/08/2011
For AREP-Ville

CIRAD-BIOS UMR AMAP
René Lecoustre
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One of the main challenges of planning this new city is the available quantity of water that people may reach and use. This part of the report is describing some proposals dedicated to this purpose and to organic garbage treatments.

11 Rain water management and recycling

Shortly, we can envisage two main families of rain water:
The water intercepted by all flat ground level quite waterproof infrastructures such as roads, streets, pavements and squares or parks; this water is usually polluted by hydrocarbons and miscellaneous such as dust. Let us call them "street waters".
The rain falls intercepted by the horizontal house-top as well as pitch roofs; this water is usually lightly polluted and may be collected and stocked for watering, cloth washing… Let us call them "roof waters".

11.1 Managing street waters

It is necessary to manage local collectors that filter these city effluents during the rainfalls and during some street cleaning interventions. These collectors do drive the flow to local and average size stations. These waters should not be mixed with home waste waters nor water collected on the roofs.

Usually, this kind of stations are composed by an initial grid filter able to retain the bigger refuses mixed with water from the rainfalls, following this first filter there is two possible devices:

- Thinner mesh filter (1 to 2mm) followed by a decanting basin where the components which are lighter than water will go up to the surface then skimmed out before the purer water will be stocked for use in a final tank.
- Decanting basin where the components which are lighter than water will migrate upward and those which are heavier will go to the bottom. The upper part will be skimmed out before the useful water will be taken out just from a level preventing the gathering of the heavier refuse. Then the bottom is cleaned by an appropriate device.

This quality of water is not proper for irrigation nor for bathing but may be used for street cleaning or carwash which will take place in a good management of this water, and prevent the use of drinking water for this trivial aim. According with Saudi legislation it will be necessary to add an UV tube before the output of tanks.

The described stations may be constructed on the same scheme than the small units used by carwash water recycling stations in West Europe. It seems convenient to also purify the waters coming from carwash stations and use the street waters as a evaporation compensation.

After legal verification, this quality of treated waters may probably be used for firemen interventions against outbreaks of fire.

All basins are, in fact, underground tanks in order to prevent evaporation and then water losses.

11.2 Managing roof waters

If the rain is collected from bare roofs, it usually contains only sand and dust. Higher is the roof level, lower is the likelihood of hydrocarbon pollutions which is considered quite null at about 15 meters above ground level. The water coming from plant roofs may be charged in plant fragments or substrate remains, they usually may contain organic or mineral nutrients but no hydrocarbons.

The device for purification of these waters is very similar to that of the previous one with 2 successive filters (average and thin mesh) followed by a decantation basin where the heaviest refuse coming from sand and dust accumulation remains at the bottom of this tank. At the end of the device the water may be stocked in dedicated tanks.

After UV treatment preventing *Legionella* proliferations, the water may be injected in the buffer tanks used for irrigation of urban plantations, plant roofs and plant walls as these plantations are not aimed for fresh vegetables or fruit productions.

As written previously all the basins must be underground tanks and the station do have a proper average size in order to limit as far as possible the pipe networks.

12 Waste water management and recycling

There are two main strains of waste waters; domestic or house waste waters and industrial or technical waste water, inside these strains it gives dark and grey waste waters.
Industrial waste water main contains pollutants in their grey parts which usually need an heavy purification system before releasing. We will consider that these grey parts of industrial rejections, just as those of domestic effluents, may be treated separately from the dark ones or not and which part may reach a good enough quality for irrigation or bathing uses.

12.1 Domestic waste waters

There is usually only one network for collecting all waste waters in urban environment although, in Japan for instance, there are individuals treatment installation for home grey waters then used for toilets.

All the existing usual systems are open systems where a non negligible part of the input water is loosen by evaporation during the process. In Saudi Arabia conditions all these devices have some inconvenient relative to the local climate heat and dryness:

- The pretreatment basins are the place of many fermentations and they release plenty of bad smells around them, these unpleasant stenches may be spread around by winds on urban or touristic zones.
- The treatment tanks themselves release bad odors and the oxygenation system increases the contact with hot and dry air and consequently the evaporation process.
- The final phases of purification for irrigation uses must be phyto remediation or lagoon maturation, in the Saudi Arabia conditions they water losses would be very important and the lagoons may be invaded by green algae also able to produce unpleasant smells if they dy.
- All the systems produce residual muds which will be eliminated by spreading.

There are alternative natural enriched processes using closed tanks and enrichment in micro organisms. Physical devices using osmotic membranes are very costly in water losses; they are estimated to about 1 per 5 or 6 efficiency, that means a loss of 4 to 5 liters for one liter of produced useful water and many of them reject toxics or pollutants in natural environment.
Another constraint of all these techniques is that they need heavy concentrated devices and they are efficient for a huge number of inhabitants. Their direct visual and olfactive impacts are important and they use to be hidden far away from the cities which increases the distance of waste water network and consequently the difficulties to the redistribution of purified water.

We will develop, in part 12.3 an alternative biological solution based on human-size units with almost no unpleasant smell, easy to integrate near the urban environment, with reduced loss of water and producing no residual muds. This system is based on the faculty that earthworms (*Lombricidae* family) have to digest and transform all organic components, the name of this system is lombrifiltration.

12.2 Industrial waste waters

It seems necessary to separate industrial grey waters and the grey + dark waters coming from restrooms and toilets in industrial units. If the effluent production of grey water per day is important, local individual treatment installations may be envisaged and the water then used back in lavatory flushes, but it means the creation of 3 different waste water networks.

In every considered system for final purification the input grey waters must be free of heavy metals or other high toxicity pollutants which cannot be accepted in bath or irrigation waters or for spreading on porous ground areas for water-table refilling. Some physical non polluting systems are known to use mineral or organic powders; these elements agglomerate and precipitate the considered pollutants. The mineral powder associate Na OH or Ca Cl_2 or use a powder with 60% weight of Ca $(OH)_2$, the organic powder is usually based on wheat of oak acorn or betony shell powder.

After this initial purification the output waste water may be used in a classical circuit of treatment and purification such as previously described.

12.3 Lombrifiltration process

At the entrance of the station there is strains which retain all the elements able to obturate the internal sprinklers, these rejected elements are treated by earth worms and produce compost able to be valorized as organic nutrient for nurseries, horticultural and truck-farming perimeters.

All the system allow to produce output waters compatible with bath and irrigation water norms, it means dephosphated waters with a bacteria level remaining under the allowed maxima. This adjustment is possible thanks to the addition, at the end of the process, of a phosphate filter and UV treatment, which complete earthworm tanks.

The devices are totally included in a building and produce not any anaerobic or no anaerobic fermentations and don't emit any smells unpleasant for neighbor inhabitants. The stations are highly automatized and reject almost no mud.

The stations have a small or average size, they use to be devices for purification of district waste waters they are dedicated to a population from 2,000 to 5,000 inhabitants. These units are then near the concerned urban districts, this situation limits the problems of networks for carrying these effluents. It is convenient to implant them between urban zone and horticultural and truck-farming perimeters including plant nurseries.

For the installation of such devices in Half Moon Bay project, implantation phases are :

- Step 1 : managing a study of technical and economical feasibility;
- Step 2 : implementing a unit for multiplication and production of earthworms;
- Step 3 : constructing a first master industrial pilot station on half ha area allowing the purification of 2,000 inhabitants existing urban district which can be quickly stretched to a 4,000 or 5,000 inhabitants station, this implementation takes from 4 to 6 months depending of material supplying difficulties. The expand for this first pilot unit are today around 3,000,000 EURO.
- Step 4 : building of new stations for each new district or urban unity, the price of each new installation may be around 2,500,000 EURO for depolluting the waste waters of 4,000 to 5,000 inhabitants.

13 Organic garbage managements and recycling

Some organic garbage are coming directly from the kitchens of flats or houses, but also from those of restaurants or food industries, they are named domestic organic garbage. Other one comes from breeding installations near the city such as for cattle or poultry, they are named breeding garbage. Only a part of garbage rejected by slaughter-houses may be of the same category, they are named abattoir garbage.
The final recycling process for these entire categories is the compost production by earthworms.

13.1 Domestic garbage

A French company is providing home compost tanks homing an earthworm population that transform vegetable and fruit peels, meal reliefs, etc in a valuable compost. They are free of liquid effluents and unpleasant smells, it is recommended to take care of some important instructions and never throw chemicals or other toxics into them.

In case the indoor management cannot be envisaged due to some traditional caution, an effective selective sort of garbage do take place inside the total urban project with the same important instructions must be followed for this sort about chemicals and potential toxics. It is probably not convenient to try home compost containers in case of restaurants or food industries which must sort correctly their garbage for further valorization by the trash societies of the urban districts.

13.2 Breeding garbage

All the natural excrements, straws, relief of feeding input, hairs, and pens may be prepared for compost units where earthworm may be pleased to eat and transform then in

valuable composts. To prevent the transport of such stinky effluents, the best way is to built such compost units inside the breeding perimeter.
It is probably convenient to crush or hash these garbage, particularly for straws and pens, for increasing the treatment speed and so decrease potential bad smells.

13.3 Abattoir garbage

The main part of effluents can be treated as those of breeding garbage including blood and paunch scraping residues. Rejected internal organs must be first dried then crushed before valorization by earthworm, this treatment do prevent of flies.
The unused skins, horns, nails may be torrefied and crushed, bones will be incinerated to ashes… The resulting powder and ashes are very good organic complement to the earthworm compost.

The units of earthworm compost production are the same units that are dedicated to the multiplication and production of earthworms for the waste water treatment units.

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8. Classical bibliography

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8.3. G. Monchali and J. Aviron-Viollet, 2000. Réutilisation des eaux uses après traitement, 1st World Water Congress of the International Water Association (IWA), Paris, July 2000.

8.4. A. Pinto Toyi Lecoustre, 2002. La pression urbaine sur les communes rurales – un atout pour leur agriculture ?, La station de traitement des eaux usées par lombrifiltration à Combaillaux, dossier ATC, Lycée Agropolis Montpellier, juin 2002

9. InterNet bibliography

9.1. Lhost Research, 2010. Un réactif unique pour l'élimination des fluorures et des métaux lourds. http://www.neutralas-sls45.com

9.2. http://www.biochem-europe.com/fr/produits/gestion-des-eaux-usees

Sourcing

Compost domestic unit of production : Lombricomposteur Worm
http://www.lombritek.com/index.php?page=lombricomposteur_worm

Lombrifiltration station : Lombri-station Lmobritek
http://www.lombritek.com/index.php?page=lombristation_

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Management of Rain and Waste Waters.

Proposals for Other Organic Garbage.

Annex

Illustrations

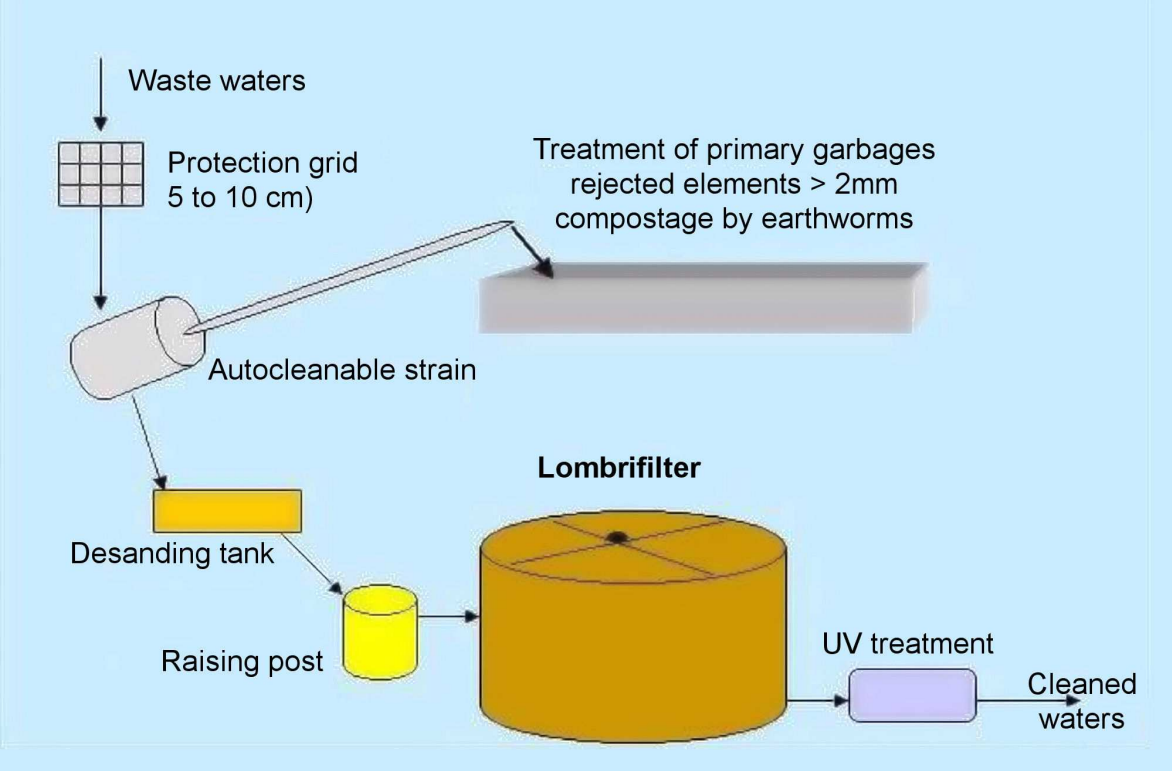
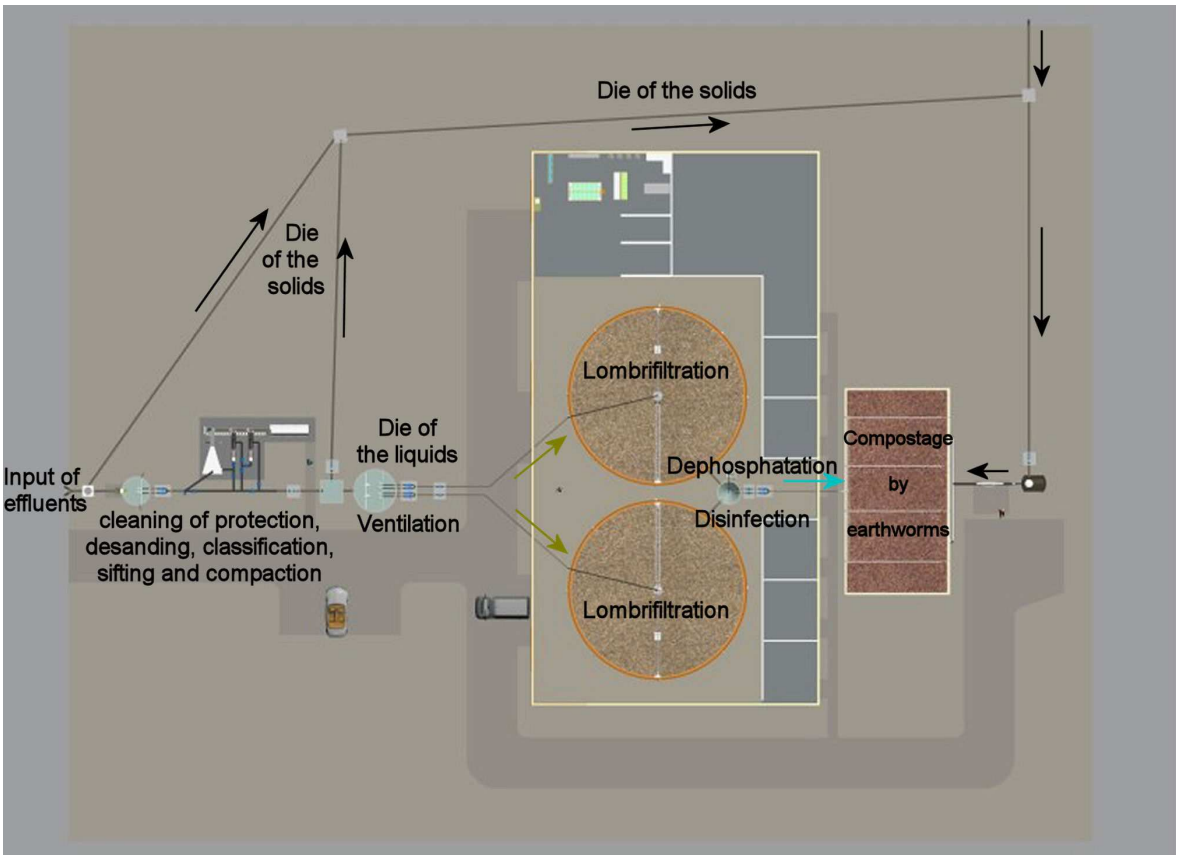
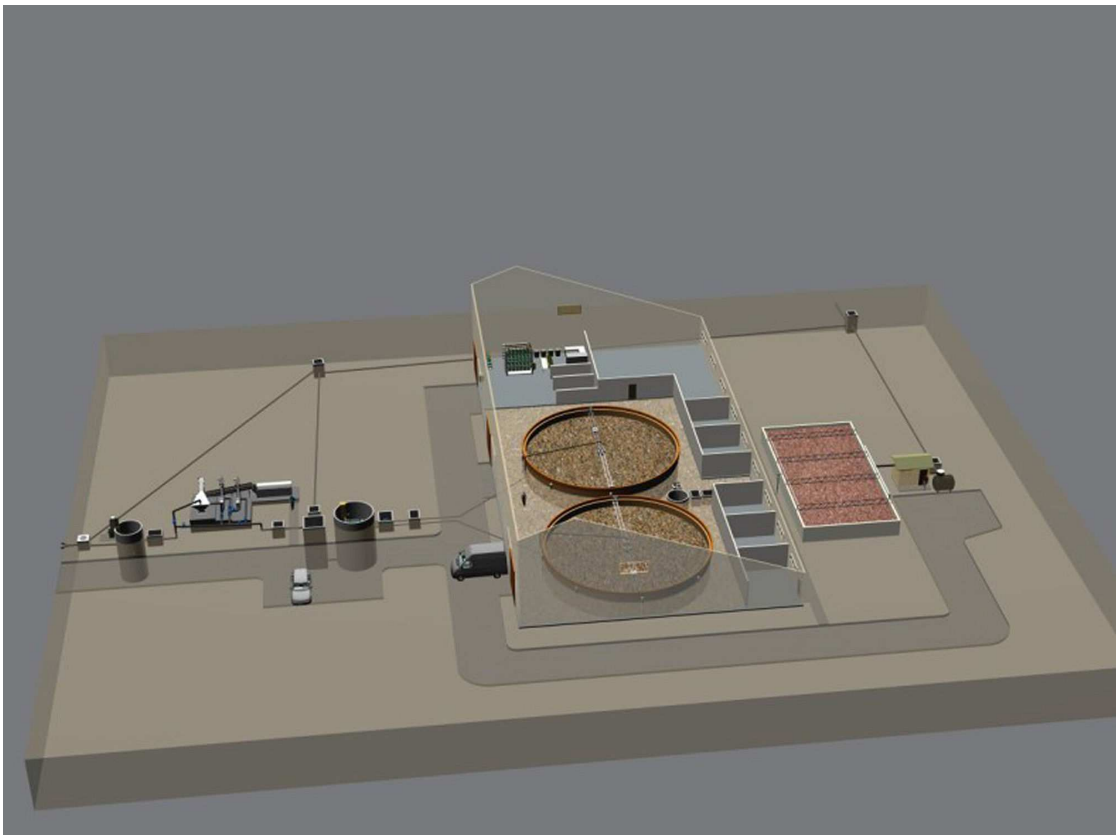


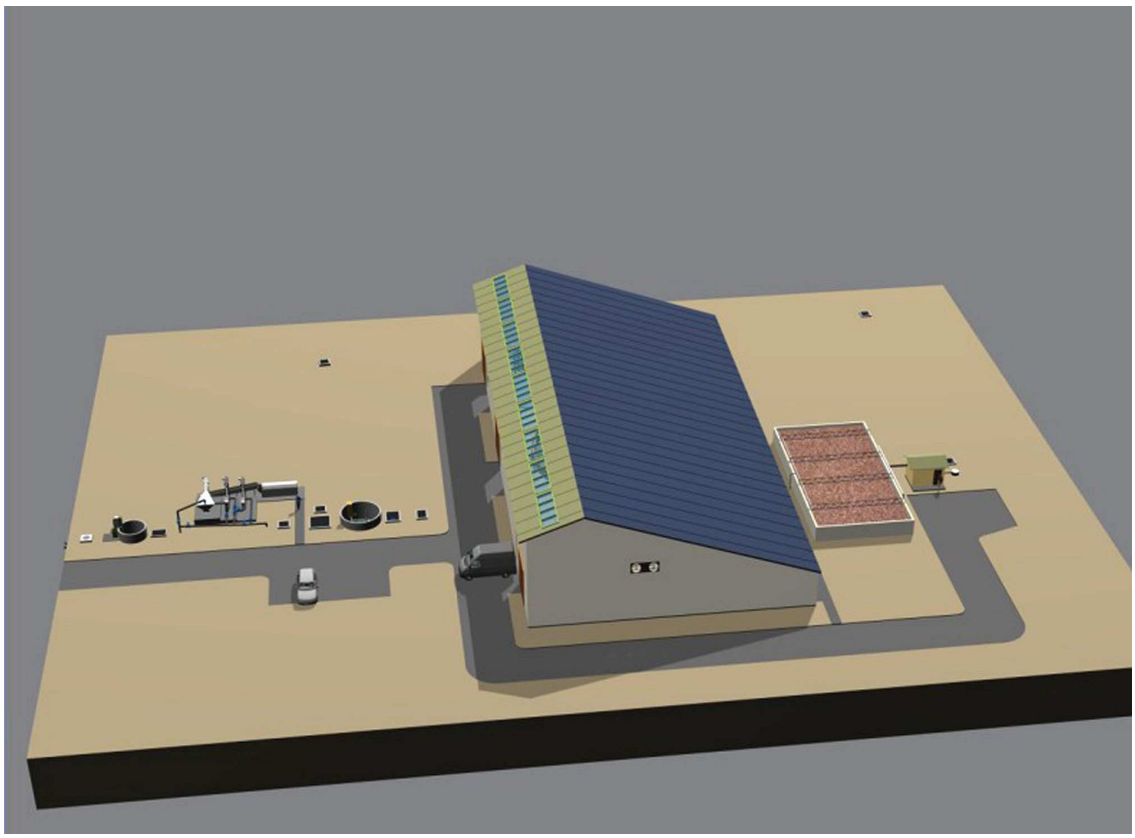
Diagram of a Lombrifiltration treatment station for waste waters (generation 1)



Map of a lombrifitration station for the treatment of waste waters (generation 2)



Perspective of a lombrifitration station for the treatment of waste waters
(effect of wall and roof transparencies)



Perspective of a lombrifitration station for the treatment of waste waters

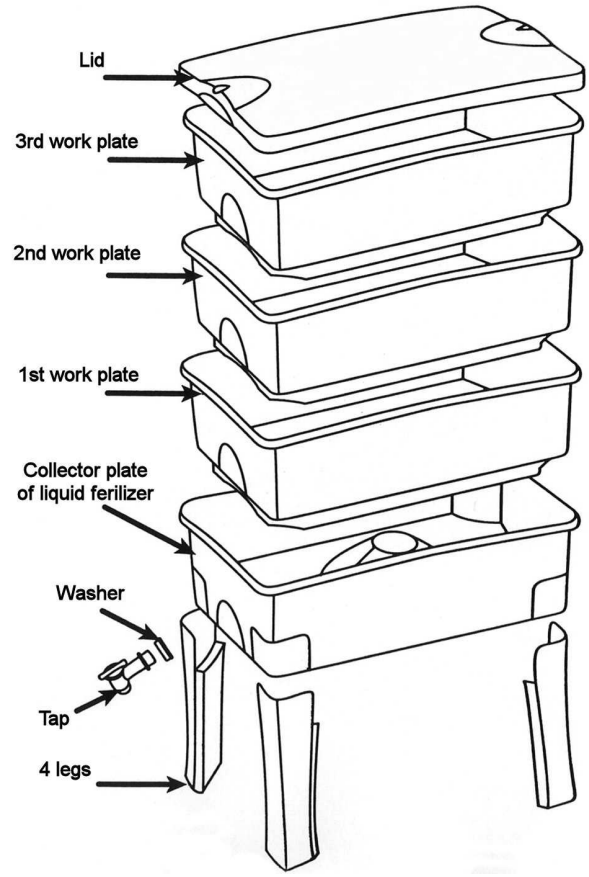


Diagram of an indoors compost maker (home compost maker)

Picture of an indoors compost maker (home compost maker)

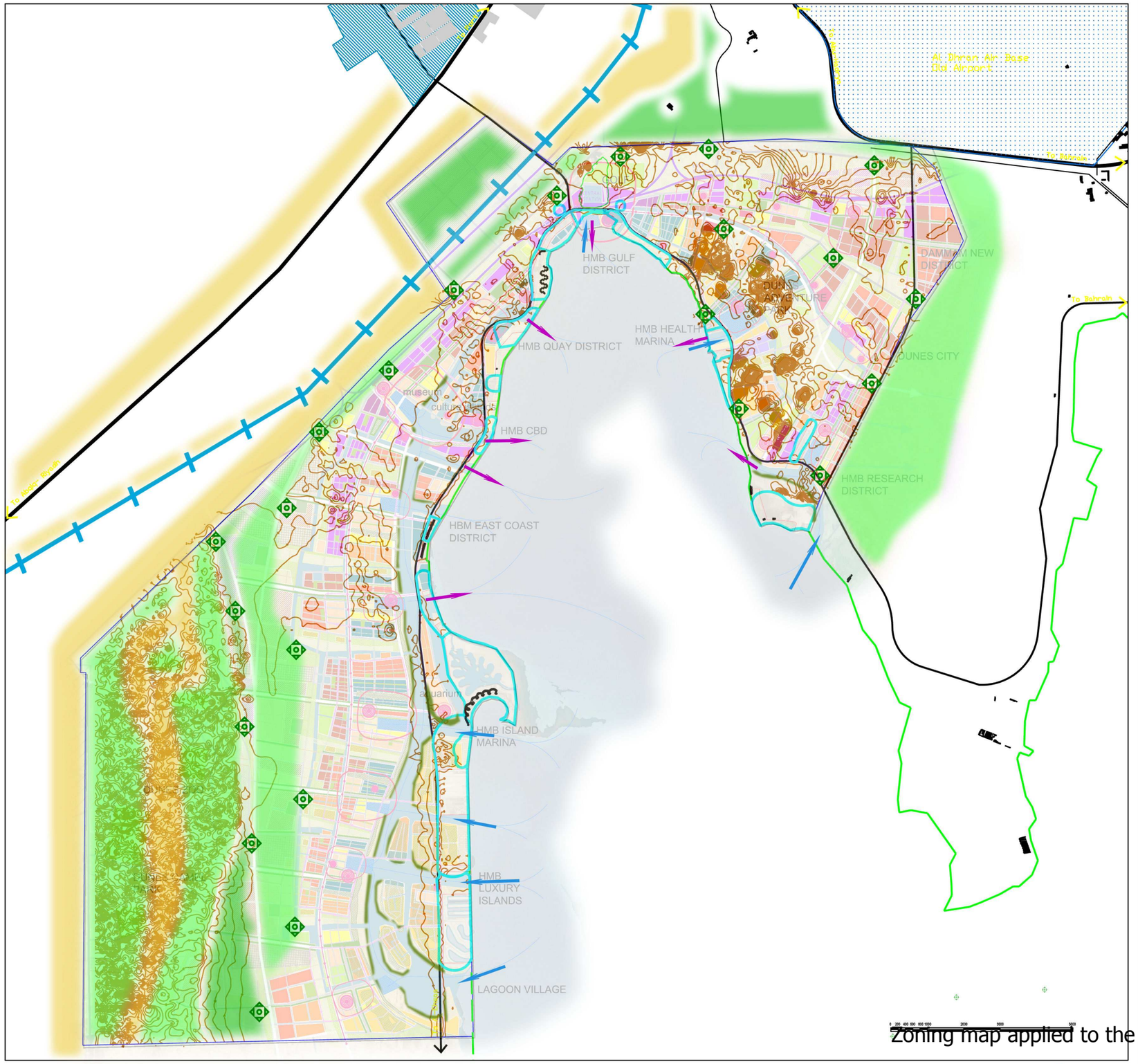
As a Conclusion
Proposals for an Adaptation of the Recommendations To One of the Scenario of the City Construction

Among the various scenarios brought to our attention by AREP, only one really appears in adequacy with the majority of the recommendations of this report. This project is named "The Wind-Coastal City". Would you find hereby listed the main features converging with the regulations:

- An important band of the bay shore is preserved from the building even it is dedicated to become "public beaches".
- Devices dedicated to protect the City from the blow sand invasions are envisaged even if their widths of about a few tens of meters are not sufficiently important. It is necessary to have approximately one kilometer of installation widths to get a significant effectiveness.
- The main wide boulevards, avenues, mails, streets orientation is East to West in order to favor the penetration of the fresher and wet winds coming from the Bay.
- Agricultural perimeters are envisaged between the devices of sand and stabilization and the green areas of the City outskirts.
- The peripheral green areas are the buffer between urban landscaped areas and both agricultural perimeters and sand stabilization devices.

In order to comfort the success of these installations, it is necessary to manage them with a great environmental respect, which will be obtained through following prescriptions:

- The rain waters, even they are rare and weak, are collected, treated, purified and recycled.
- The urban cleaning waters and those coming from carwash stations are collected, treated, purified and used back again for the same use.
- The surpluses of irrigation are collected and recycled for watering or irrigation.
- The industrial waste waters exempt of mineral pollutants are collected, they may be treated, purified in biological stations, then they will recycled for watering and irrigation and bath waters.
- The domestic waste waters will be collected, then treated and purified in biological stations for watering, irrigation and bath waters.
- All the organic concrete garbages must be treated by biological processes then used as organic nutrients or complements in truck-farming, horticultural perimeters, and landscaped areas both in outskirts and City.
- If mangroves are really established some areas of the lagoons may be used for seafood breeding.
- The majority of the roofs, and of the walls with a South or Western South exposure should be equipped with vegetation in order to improve the thermo isolation and to improve phonic absorption of the noises of the city. This equipment must be irrigated with waste water recycled after treatment and purification.



Key	Usage
	Governmental Reserves
	Industrial Zones
	Special Uses (Airports,ports)
	Residential Zones
	Developed Private Land Uses
	Contour Lines
	Existing Railway
	Land Boundaries
	Existing Express Way
	Existing Main Road
	Existing Secondary Road

Output Sea Water Flow
Input Sea Water Flow

Sand and Dune Stabilization Zones

Favorable Zones for Truck-Farming and Horticulture

Favorable Zones for Outskirt Landscaping

Favorable Zones for Mangrove Plantations

Stations for Waste Water Purification (symbol size is approximatively scaled to the effectively occupied area)

Zoning map applied to the project named Wind-Coastal City

Land Uses

Inside this fold:

Zoning map applied to the project named Wind-Coastal City