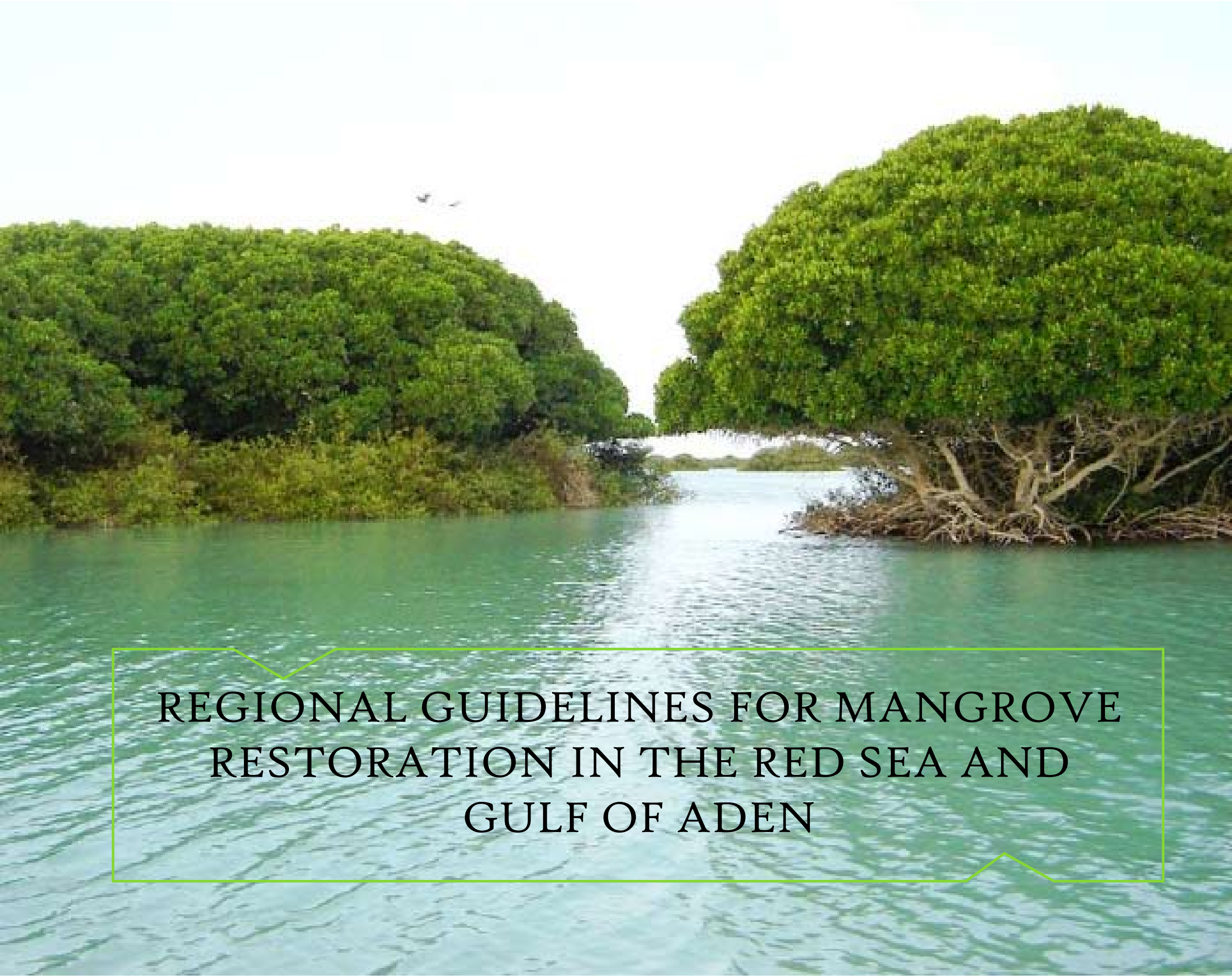

REGIONAL GUIDELINES FOR MANGROVE RESTORATION IN THE RED SEA AND GULF OF ADEN

PERSGA

الهيئة الاقليمية للمحافظة على بيئة
البحر الأحمر وخليج عدن

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Regional guideline for mangrove restoration in the Red Sea and Gulf of Aden

Regional guideline for mangrove restoration in the Red Sea and Gulf of Aden

PERSGA-'The Regional Organization for the Conservation of the Environment of the Red Sea and Gulf of Aden' is an intergovernmental authority dedicated to the conservation of the coastal and marine environments in the region and the wise and sustainable use of their natural resources.

The Regional Convention for the Conservation of the Red Sea and Gulf of Aden Environment (Jeddah Convention) 1982 provides the legal foundation for PERSGA. The Secretariat of the Organization was formally established in Jeddah following the Cairo Declaration of September 1995. The PERSGA member states are Djibouti, Egypt, Jordan, Saudi Arabia, Somalia, Sudan, and Yemen.

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Preface

There is a growing awareness, backed by scientific studies, recognizing the value of mangrove conservation, restoration and planting. Further to its well-known benefits, such as shoreline protection and providing rich feeding and nursery grounds for marine life, mangrove restoration is now seen as a cost-effective and appropriately ecosystem-based adaptation measure to the impacts of climate change. It is also considered as a kind of co-mitigating adaptation, as mangroves are proving to play a vital role in the global carbon cycle, particularly their value for carbon sequestration. This has caught the attention of several initiatives that are currently highlighting mangroves as a flagship ecosystem, in their anticipations to correct the ecological imbalance currently reported in many parts of the world's ecosystem.

PERSGA runs multi-linked program activities addressing sustainable management of marine resources in the region. Of these, the mangroves are one of the key components. The previous efforts included developing Standard Survey Methods (SSMs) for Inter-tidal and Mangrove Habitats in the Red Sea and Gulf of Aden, training of specialists on SSMs, developing countries and regional reports on the status of mangroves; on the basis of which, the Regional Action Plan (RAP) for the Conservation of Mangroves, as well as National Action Plans (NAPs) for each particular country case were created.

The major objectives of the action plans are to protect mangroves from degradation, and to ensure restoration of the degraded areas and sustainable use of the resource. In order to facilitate their implementation, PERSGA undertakes several interventions, which mainly include training, regular monitoring, and implementing demo projects for restoration and sustainable management. In this framework PERSGA organized a workshop on "Mangrove Management and Restoration Techniques" in 2009, whereby specialists from the region were introduced to the subject and trained to be involved in future restoration projects in PERSGA countries.

As a further step, PERSGA has prepared the current Regional Guidelines for Mangrove Restoration. The development of this guidebook was based on the appreciable scientific works that has enriched our understanding of mangrove ecology in general, the useful experience gained from a range of restoration projects around the world, and our improving knowledge about the mangroves of our region. As a final point, the guidebook aims at providing the best possible approaches and tools that can be applied for mangrove restoration in the Red Sea and Gulf of Aden, considering their particular biological characteristics, ecological limits, and conservation issues.

Prof Ziad Abu Ghararah

Secretary General
PERSGA

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REGIONAL GUIDELINES FOR MANGROVE RESTORATION IN THE RED SEA AND GULF OF ADEN

In attempting to study the ecological development of the forest,
one must beware of jumping to conclusions
based purely on present day evidence.
To avoid this,
one must keep in mind
some idea of the general trends
affecting the mangrove banks.

R.G. Dixon (1952:1)

1 Introduction

The above quote reveals a deep understanding of mangrove systems: they are changeable, they are dynamic, they are unpredictable, they are subject to aperiodic and periodic fluctuations of the extreme kind, and, as important as each of the above is, each mangrove community has a history. Reading that history from the tell-tale signs of today, is the artful skill of the silviculturalist or restoration ecologist who is likely to succeed. Sound silviculture of mangroves, whether for commercial or amenity planting, is based on an historical reading of the sites or areas involved. Not only will this prevent the repetition of past mistakes, but also it will provide the best measure of the potentialities of any site or area for mangrove plantings for whatever reasons it may be undertaken.

In today's world, mangrove planting may have an economic, aesthetic or practical basis. Objectives include timber production, shoreline protection, channel stabilization, fisheries and wildlife enhancement, legislative compliance, social enrichment and ecological restoration (SAENGER and SIDDIQI 1993, FIELD 1996, ELLISON 2000). For example, in some countries, such as Bangladesh, Indonesia, Malaysia, Thailand and Myanmar (Burma), there are large commercial mangrove forestry operations, which require the replenishment of harvested mangrove stands. In China, Vietnam and Bangladesh, for example, mangroves are planted for purposes of stabilizing and protecting the coastline and coastal towns and villages from cyclone damage and seawater intrusion. Elsewhere, mangrove plantings are undertaken to provide amenity values or to augment the ecological functioning of prawn (Philippines and Indonesia) and fish ponds (India).

Several compilations provide overviews of mangroves and other wetland restoration studies (e.g. KUSLER and KENTULA 1990, FIELD 1996, SAENGER 2002, CHAN and ONG 2008, CHAN and BABA 2009). A view common to all of those studies is that the best guide to any restoration programme is a clear understanding of the nature and dynamics of locally occurring mangrove systems.It follows that mangrove studies from the PERSGA region (e.g. ANDREWS, 1950; DRAZ, 1956; KASSAS and ZAHRAN, 1967; ZAHRAN, 1977; 1982; ORMOND *et al.*, 1988; KHALIL 2001; KHALIL and KRUPP 1994; KHALIL *et al*. 2003 PERSGA

2002a,b,c,d,f, 2004, 2006, 2007; PERSGA/GEF 2004) will form a valuable resource for restoration project managers in this region. This regional manual looks at the various reasons for mangrove planting and how those plantings might be undertaken in order to meet the original objectives. It summarises site selection criteria and ecological guidelines useful for mangrove restoration studies in the PERSGA region. It adapts a standardised scoring method for rating the suitability of potential sites for restoration of mangroves (SAENGER *et al.*, 1996) for use in the PERSGA region.

2 The Mangroves of the Red Sea and Gulf of Aden: Status and Needs for Restoration

2.1 An overview

Avicennia marina is the most abundant mangrove species in the Red Sea and Gulf of Aden. Significant *Rhizhophora mucronata* stands coexist in a few areas, particularly in Djibouti, while some other places support less developed *R. mucronata* stands in Yemen, Saudi Arabia and Egypt (Plate 1, 2). Previous surveys reported the existence of *Ceriops tagal* and *Bruguiera gymnorizha*.

The vast majority of the mangrove stands are mono-specific, consisting of *A. marina*, which typically forms narrow forests (occasionally wide in some areas) along the shore-line, on near- and off-shore islands, or fringing tidal creeks and channels locally known as khors, sharms or marsas. Although they are mostly narrow, such forests vary in extent considerably from few tens of meters to well above several kilometers along the shore. The size of the *A. marina* trees mostly ranges between stunted bushes usually growing in the outer fringes of the stands to well developed trees reaching 4-7m height. In some particular localities e.g. Al-Urj (Yemen), Maskalli Island (Djibouti) and Arakiyai (Sudan), more favorable conditions allow for substantial growth performance up to more 10m height and 2m Girth-at-Breast-Height (Plate 1.e, 1.f). The well-grown *Rhizophora* at Khor Angar, Godoria and on Musha Island in Djibouti reach up to 9-13m height (Plate 2e, 2f).

Detailed and specific information about the status of mangroves in the Red Sea and Gulf of Aden Region is provided in PERSGA/GEF (2004), which also reported on the current issues facing mangroves in each country. The area of undisturbed mangroves is rapidly shrinking. Many mangrove stands surveyed in the region during 2002 were reported to be impacted and degrading at various rates (Plate 3). Unless intervention through restoration and conservation management takes place, degradation of mangroves will seriously affect fisheries, increase coastal erosion and degrade adjacent habitats such as coral reefs and seagrass beds.

Camel grazing of mangroves is widespread in the Region. Where heavy grazing occurs, the impacts include a considerable reduction in the green parts; dryness of upper- and outer-most parts of the grazed branches; vertical growth limitation due to multi-stemmed bushes; and seedling and aerial roots destruction by trampling (Plate 3a, 3b). Declines of faunal communities were reported in mangroves disturbed by heavy camel grazing and woodcutting (PERSGA/GEF 2004). Degradation and shrinkage of inland pasture has forced local inhabitants to shift to mangroves as alternative source of wood for fuel and for camel fodder. The rate at which mangroves are utilised for fodder and fuel wood is unsustainable in most areas (PERSGA/GEF 2004, PERSGA 2006).

Plate 1: *Avicennia marina* form different locations in the Red Sea and Gulf of Aden coasts. Note variation in the species growth performance amongst different sites depending mainly on availability of favorable soil and hydrological conditions.

(a) *At Al-Luhayiah (Yemen).*

(b) *At Ras Siyyan (Djibouti)*

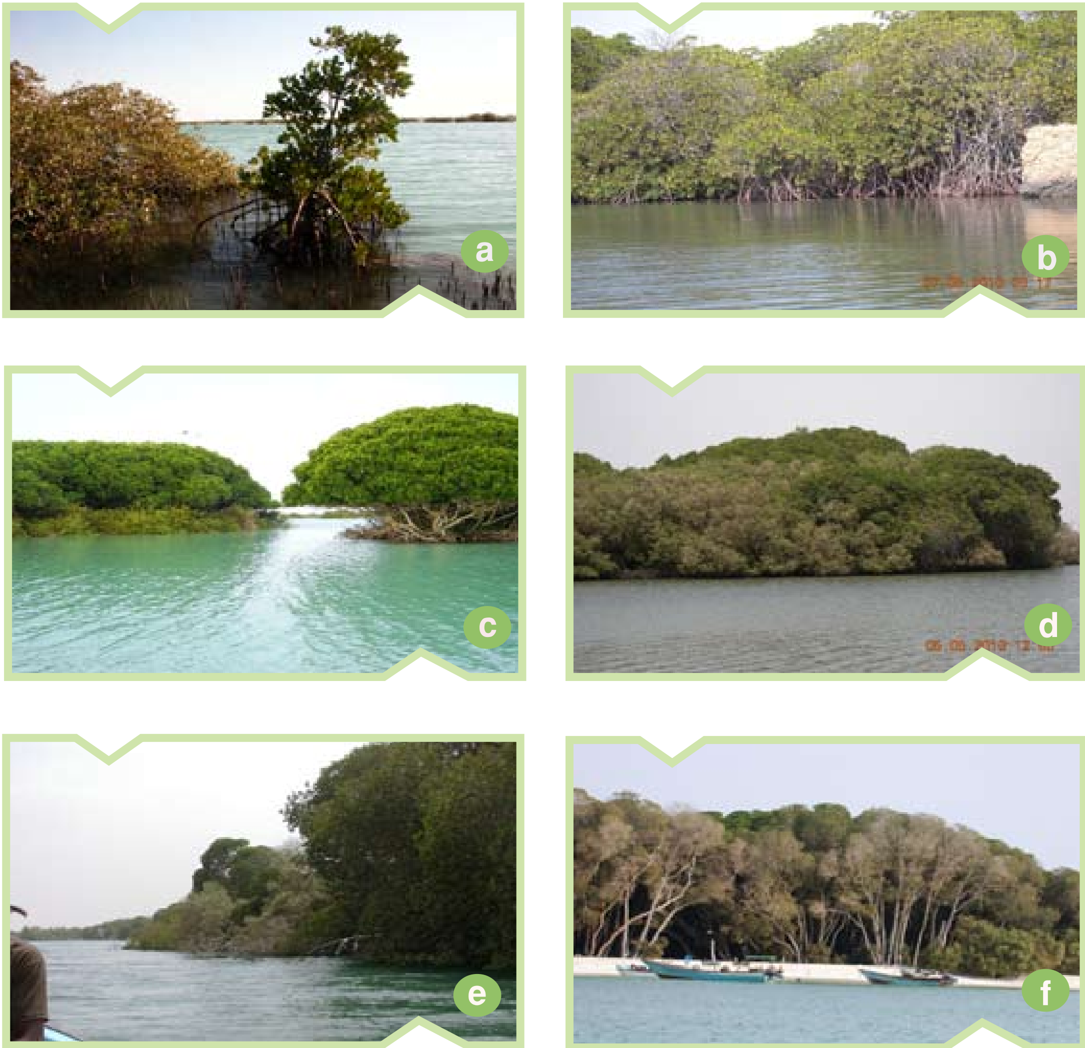
(c) *At Khor Amq (Saudi Arabia).*

(d) *At Midi (Yemen)*

(e) *At Al-Urj (Yemen).*

(f) *Near Jizan (Saudi Arabia)*

Plate 2: *Rhizophora mucronata* form different locations in the Red Sea and Gulf of Aden coasts showing variation in the species growth performance depending on availability of its favorable conditions.



a *Doghm Sabq (Saudi Arabia).*

b *Farasan islands (Saudi Arabia)*

c *Kamaran Island (Yemen).*

d *Biash, South Shuqaiq (Saudi Arabia)*

e *Godoria (Djbouti)).*

f *Muchi Island (Djibouti)*

Mangrove felling and cutting the limbs of living trees (for timber and fodder) are more destructive than camel grazing. The impacts from cutting are severe due to the limited size of most stands in the region. Stands affected by severe cutting have significantly fewer trees, denuded patches, and barren depressions with altered hydrological regimes and soil compaction. Cutting also provides additional access for camels (Plate 3d).

Dry out and mortality of mangrove trees is a severe problem in some areas. The major causes are localized modification of coastal topography leading to diversion or blockage of tidal water flow and drying up of mangroves. Excessive sedimentation and sand infilling of tidal channels were reported in several areas, which reduce mangrove flushing by seawater leading to their degradation (Plate 3c).

Soil dams are constructed to harvest rain waters in some valleys in the coastal areas. Damming considerably reduces freshwater and alluvium reaching the valley mouths through seasonal runoff. This may pose impacts on mangroves through: increased saltwater intrusions causing unsuitable hypersaline habitats; shrinkage of deltas due to decreased alluvium and sediment deposition at seaward terminations of the valleys, where mangroves often grow; and increased sand-infilling and deposition from the sea obstructing tidal inlets and channels through which tidal flow normally floods mangroves.

Plate 3: Some features of human impacts on mangroves in the Red Sea and Gulf of Aden Region

(a) *Camels grazing on mangrove*

(b) *A heavily grazed mangrove stand*

(c) *Dry mangrove affected by blocking of tidal water*

(d) *A mangrove stand destroyed by cutting*

Domestic solid-wastes (e.g. polyethylene sacs and bottles, plastic and metal cans), are often reported in mangrove stands near population centers. Solid wastes become trapped among trees and aerial roots, causing disturbance to mangroves and associated fauna. Some mangrove stands are under stress of pollution by sewage. Furthermore, an important factor leading to the decline of mangroves in recent years has been the expansion of shrimp ponds into mangrove forests (PERSGA/GEF 2004).

The region typically encounters episodic drought spells. Regular assessments (PERSGA 2002c, PERSGA/GEF 2004, PERSGA 2006) indicate that severe human impacts on some mangroves areas may deter their natural recovery during the interludes of relatively ample precipitation (Plate 4).

Plate 4: a1, a2: A mangrove stand near Bab-el-Mandab in Yemen severely affected by drought and excessive siltation of the creek connecting the mangrove to the sea. b1, b2: The mangrove recovery induced by intense rains in lately years was more prominent at this stand than several others that have suffered from both drought stress and severe human impacts in the area.

a1 *In 2004*

a2 *In 2004*

b1 *In 2009*

b2 *In 2009*

2.2 The benefits of mangrove restoration in the region

An assessment study carried out by PERSGA in 2002 recommended that mangrove restoration efforts are urgently needed to assist in the recovery of degraded areas affected by cutting, grazing, dry-up etc., and, to reestablish stands in compensation for those that have been totally removed and lost. In order to regain mangrove resources in the region, interventions through replanting and promoting natural regeneration are required. There is also a reasonable potential for extending the area covered by mangroves along the coast through planting.

Mangrove restoration will contribute to sustainable development and well-being of coastal populations through impeding ecological disintegration of other marine habitats (e.g. coral reefs, sea-grass), which might result from mangrove degradation. It will also contribute to poverty alleviation among the coastal rural communities, as mangroves provide a variety of goods and services to them. Furthermore, mangrove restoration and extending coastal areas covered by mangroves will contribute to the efforts for adaptations to and mitigating climate change impacts in the region.

Ecological restoration of mangrove habitats is feasible, has been done on a large scale in various parts of the world, and can be done cost-effectively in the region. At appropriate sites with normal or near-normal tidal hydrology and with establishment of mangroves through natural recruitment or planting, restored mangrove systems can become indistinguishable from nearby natural mangrove systems (LEWIS and STREEVER 2000). In several cases mangrove can recover without planting, through removing the potential existence of blocked tidal flow or other environmental stresses that may prevent mangrove recruitment (HAMILTON and SNEDAKER 1984). In such condition assisting natural recovery through planting may only be considered if natural recruitment is vulnerable or insufficient to achieve recovery. This involves informed consideration in cost-effective planning for and implementation of restoration projects in the region.

3 Ecological Perspective of Mangrove Restoration

Mangrove restoration is defined by the Society for Ecological Restoration (SER 2002) as 'the process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed'. It does not imply complete rehabilitation or the complete reinstatement of the pre-degradation state. It involves the ecologically-informed manipulation of the structure and composition of an ecosystem so that it can recover: trees may be planted, hydrological flows may be restored, and other enhancements might be undertaken. Underpinning it all is the assumption that for mangroves, important ecosystems in their own right, the important structural components are trees, land and water, and that if they are restored, some extent of ecological functioning of the system will be achieved.

4 Defining the Objectives for Mangrove Planting

The mere fact that a need exists to plant mangroves implies that some loss, degradation or alteration has occurred in the past, sometimes from climatic events, but more often from human activities. Given that those activities have resulted in an area that does not comply with our defined management or conservation objectives, some remedial action including mangrove planting may be feasible or desirable. At this juncture, however, the quote in the 'Introduction', needs heeding: what is the history of the site or area, or, more specifically, what prior activities have led to the present conditions.

It is essential that objectives of any restoration project be clearly defined and prioritized (where more than one objective is involved) as a first step in the planting process. Prioritized objectives determine the planning process and help identify the elements, which must be included to provide the undertaking with a clear framework for operation and implementation. The early establishment of criteria for evaluating the success or otherwise of the planting process is an essential, albeit difficult, task.

Generally, two main types of criteria are used in judging the success of a mangrove planting program: (1) The effectiveness of the planting, which can be considered as the closeness to which the new mangrove forest meets the original objectives of the planting program; and (2) the efficiency of the planting, which can be measured in terms of the amounts of labour, resources and material that were used during the establishment and maintenance phases. More detailed monitoring measures are described below.

5 Community Involvement

Planting programs, whether for aesthetics or for income generation through eco-tourism, must involve local communities. For example, in the PERSGA region, where green vegetation is at a premium, the planting of mangroves is viewed as one of the achievable means of beautification and 'greening' the landscape. In many instances in the PERSGA region, the only objective has been to provide a green backdrop to an otherwise stark landscape; the plantations have not only met that objective but have provided additional benefits such as roosting and feeding sites for migratory waders, flamingoes, and a range of other wildlife.

However, with any such program aimed at social enrichment, it is important that economically impoverished people, who depend on the direct exploitation of mangroves for their livelihood, must obtain benefits from the planting program. A replanting program can be used to improve the economic opportunities and well-being of rural people by providing direct employment for them in the planting program, by restoring the productivity of lands and ecosystems that they use, and by increasing the diversity of plants and animals that they harvest (WALTERS 1997). Such benefits may include the change from an open-access to a communal property regime, where the wood products or camel grazing of an area that used to be freely open to all potential users are now used and regulated by an organized community co-operative for a 'cottage industry'.

In summary, success with any restoration project is considerably enhanced when

- restoration is viewed by the local people as offering economic or other tangible benefits to them;
- the restoration is made compatible with local patterns of resource use and land tenure;
- local knowledge and skill relevant to restoration are successfully embedded in the project;

- local social groups and organizations are effectively mobilized to support and implement restoration activities; and
- relevant policies and political factors are supportive of restoration efforts.

6 Propagation of Mangroves

If indeed there is a need for a program of assisted regeneration, the following approach is suggested. Propagules need to be collected and either planted out or raised in the nursery. For planting, the propagules can be scattered over the target areas or alternately pushed into the substrate. The dispersion of propagules should take place at a time when the area is not expected to be flooded for a few days, thereby allowing the propagules to be firmly established prior to subsequent inundation. It is to be expected that some losses will occur and it is important to ensure that distribution of propagules to the site is repeated as necessary. If losses are high, propagules may need to be held in place temporarily using chicken wire, seagrass matting or encasing the seedlings. In some situations, there is greater survival and growth of the propagules if they are nursery grown before planting out. This allows the seedling to develop a healthy root system before implantation. Success rates of establishment using propagules is clearly site specific but has been found to range from 30-90%. Nursery-grown seedlings generally show higher success rates than propagules.

Once objectives have been established for mangrove planting in an area, locating suitable plant material and propagating it is the next phase. There are several approaches that have been used for propagating mangroves, including: direct planting of propagules collected from the wild; outplanting of up to one-year-old nursery-raised propagules; outplanting of small seedlings collected from the wild after nursery-raising; direct transplanting of seedlings (<0.5 m) and shrubs (>0.5-1 m high). Each of these approaches is reviewed briefly below. More specialised, complex and costly techniques, such as air-layering, use of propagule segments, or micropropagation (tissue culture), are also known (SAENGER 2002), but are not generally recommended as they need sophisticated laboratory access.

6.1 Direct Planting of Propagules collected from the Wild

As propagules are generally only available for 2-3 months of the year, direct seeding needs to be scheduled according to their seasonal availability. Spacing distance is difficult to control, but distances between 0.4-1.5 m have been used. The generally high susceptibility of propagules to desiccation, dislodgment by waves and tides, and damage by predators and debris, make this material unsuitable for sites of medium to high energy. It seems preferable that propagules are selected for more protected sites or areas that already have some mangrove stands.

6.2 Outplanting of up to One-Year-old Nursery-raised Propagules

Propagules of different species can be collected during the fruiting season and then grown on freely drained sandy substrate. For most species, the soil should be kept damp, preferably with 25-50% seawater (to reduce fungal infection). Relatively high temperatures and humidity are essential for mangrove growth. Indirect sunlight is more effective in producing a larger leaf area than direct sunlight. As mangroves respond to fertilizers in early stages, fertilizer can be added once roots have started to develop and the first pair of leaves has expanded. This results in greater root growth and healthier shoots.

The benefit of raising seedlings in nurseries is that it provides a year-round supply, which is of particular importance in large scale projects (SAENGER and SIDDIQI 1993). Nursery-grown seedlings also generally show higher success rates (survival rates, increases in height, number of leaves) than propagules, although higher nursery costs and increased difficulties in planting when compared to propagules, may offset these advantages in certain situations.

6.3 Outplanting of Small Seedlings after Nursery-raising

Where propagules are unavailable, newly-established seedlings have been used to establish nursery stock. The seedlings are dug out, washed free of soil, and replanted in acid-washed coarse sand. Using this approach, good survival rates can be obtained and seedlings also showed an exceptional root recovery and strong shoot growth, reaching a height of around 50-70 cm after 12 months.

6.4 Direct Transplanting of Seedlings and Shrubs

Where young seedlings are removed from the natural mangrove forest and transplanted to sites to be restored, the most common seedling height is <50 cm. Young seedlings are best removed by using a 10 cm PVC pipe as a corer, pushed 20-25 cm into the substrate around the seedling. Transplants should be kept moist and protected from direct heat and wind during collection and transportation.

Survival has generally been found to be inversely proportional to the size of transplants and the length of time held in containers. Generally, for *Avicennia marina* less than 30 cm in height with a 20 cm diameter root-ball, survival rates were over 80% for at least three months, while for plants more than 50 cm tall, survival rates fell below 50% within a month (SAENGER 1996).

6.5 Use of Stem Cuttings

Induction of rooting in stem cuttings treated with indoleacetic acid (IAA), indolebutyric acid (IBA), and naphthalene acetic acid (NAA), both singly and in combination was reported by DAS et al. (1997). They obtained reasonable root development in *Avicennia*, *Ceriops* and *Rhizophora mucronata*.

YOUSSEF (1997) took soft-, medium- and hard-wood cuttings from five mangrove species: *Avicennia marina, Rhizophora stylosa, Bruguiera gymnorhiza, Hibiscus tiliaceus and Excoecaria agallocha.* Leaf area was reduced and cuttings were dipped into 50% liquid rooting hormone (Rootex-L, Bass Lab., Vic). The cuttings were then planted in a mixture of coarse sand and peatmoss (2:1) and kept moist but well drained throughout the experiment. For each species, fifteen cuttings for each wood type were planted within 24 hours. Of the five species, only *Excoecaria agallocha* and *Hibiscus tiliaceus* were successful.

7 Site Selection

Site surveys should examine at least the following parameters to assess each site in terms of its suitability (SAENGER et al. 1996): (1) Exposure: Mangrove seedlings will not survive in areas exposed to periodic high wave energy or persistent wind-generated turbulence. Thus, sites should be sheltered from wave energy in semi-enclosed embayments or lagoons, or where shelter is provided by coastal features such as headlands or offshore reefs and sandbanks. (2) Stability of the substrate: Substrate stability is another requirement for mangrove growth at least during the establishment phase. Sheltered localities generally exhibit stable substrates but tidal scour or littoral drift can occur in sheltered locations and cause erosion or accretion of sediments. Such areas can usually be easily recognized by their sedimentology (e.g. coarse gravelly sediments, pronounced sand ripples, absence of crab burrows etc) and should be avoided. Where such areas cannot be avoided, temporary stabilizing techniques (e.g. grass matting, chicken wire, tyre barriers) may be necessary. (3) Shoreline morphology/sedimentology: Mangroves generally grow best in muds and clays, which have been deposited under sheltered conditions and which are regularly inundated by tidal waters. Topographic height in relation to optimal growth is generally in the top third of the tidal range, and to achieve this at any particular site some recontouring may be required.

The most significant factor in designing a successful mangrove restoration project is to determine the hydrology (frequency, depth and duration of tidal flooding) typical of surrounding mangroves near the restoration site (SAENGER 2002, LEWIS 2005). Site recontouring – excavation of fill or backfilling of an excavated area – must be used to achieve the same general slope and the elevations most suited to the individual mangrove species.

7.1 Site Elevation in Relation to Tidal Regime

Sites suitable for restoration of mangroves should preferably be:

- between mean sea level and mean high water level;
- reached or submerged by saline water daily;
- lands inundated during normal high tides but exposed during low tides;
- where young plants are inundated regularly but not drowned;
- on slightly sloping ground which drains to creeks;
- suited to the species and should not be of uniform elevation;
- submerged by less than 1 m at high tide to minimise barnacle infestations; and
- at the correct elevation (level of inundation) for each individual species.

7.2 Site Exposure to Currents and Wave Action

Sites suitable for restoration of mangroves should preferably be:

- protected from rapid currents;
- protected from waves rather than be exposed;
- sheltered from strong winds and currents; and
- close to existing stands of mangroves to provide protection from strong wind and tidal currents, and to enlarge existing mangrove areas by adding additional rows.

7.3 Soil Characteristics of the Site

Sites suitable for restoration of mangroves should preferably:

- not be excessively saline or waterlogged/inundated for long periods;
- have a stable substrate, with less than 5-10 cm of sedimentation annually;
- be free of contaminated sediment;
- consist of reasonably firm mud, silt or sand;
- be where salt-tolerant grasses or sedges indicate that the site is relatively stable and protected from severe wave action; and
- be where freshwater supply (e.g. groundwater) is available

7.4 Other Factors Influencing Site Selection

Suitable sites are:

- close to an adequate supply of propagules;
- situated where future expansion may be undertaken;
- away from existing seagrass beds;
- free of heavy pollution or marine debris;
- accessible and within reasonable travel time;
- where foot and vehicular traffic can be excluded;
- where grazing can be controlled to protect seedlings; and
- areas, which do not interfere with the livelihood of coastal residents.

To assist with site selection, a check-list questionnaire has been prepared and included as an appendix (Appendix 1).

Once site selection has been made, site characteristics can be used to identify those species best suited to that site. The degree of waterlogging (Eh of the soil), depth and frequency of tidal inundation, and the salinity of the porewater are probably the main factors determining species suitability. Such factors typically influence zonation in the natural mangrove forest banding single or multi-species vegetation parallel to the shoreline (Plate 5).

Plate 5: Zonation in mangrove forests

8 Site-Species Matching

In the PERSGA region, only four species of mangroves occur, or have occurred in the recent past. The four species are Avicennia marina, the most widespread species in the region, *Rhizophora mucronata* which occurs at a number of localities in the region, and *Bruguiera gymnorhiza* and *Ceriops tagal*, which are recently extinct or rare respectively in the region. Detailed descriptions of these species are provided below.

Avicennia marina **(Forssk.) Vierh.** Synonyms: *Avicennia intermedia* Griffith; *Avicennia resinifera* Forst.; *Avicennia maritima* Naurois & Roux; *Avicennia tomentosa* Sieber var. arabica Walp.
A tree of variable form, attaining heights of up to 25 m at favourable sites. More often, it is a tree of small dimensions or even shrub-like; stem base usually buttressed, giving rise to a radial network of roots, from which short negatively geotropic pneumatophores arise; bark varying from white to pale grey. Leaves opposite, ovate-lanceolate to lanceolate, glabrous and shining on the upper surface, whitish below, 5-8 cm long by 2-5 cm; flowers in small, dense cymes on angular peduncles in upper axils or in terminal panicles; calyx divided to the base into 5 segments; corolla orange; tube shorter than the sepals; lobes ovate, longer than the tube. Stamens 4, inserted in the throat. Fruit a compressed capsule about 3 cm in diameter. Seed solitary, without integuments; the embryo, with two large cotyledons folded longitudinally, germinates before fruit drops but does not rupture pericarp (Plate 6a).

Avicennia marina is common and widespread throughout the PERSGA region.

Bruguiera gymnorhiza **(L.) Savigny**. Synonyms: *Bruguiera rheedi Blume*; *Bruguiera conjugata Merr.*
A moderate-sized, evergreen tree up to 35 m tall; buttressed and with kneeroots. Bark grey to almost black, roughly fissured, usually with large corky lenticels on buttresses and base of stem. Branching mostly sympodial. Leaves decussately opposite, simple and entire, coriaceous, elliptic to oblong, 8-20 cm x 4-8 cm; base cuneate, rarely obtuse, apex acute; nerves 9-10 pairs; petiole 2-4 cm long, often reddish; stipules about 4 cm long, often reddish. Flowers solitary, 3 cm long, generally nodding, with 1-3 cm long pedicels which are often bright red on the outside curve; calyx red to pink-red, lobes 12-14, tube usually ribbed at the upper part; petals 13-15 mm long, 2-lobed with acute lobes, each with 3-4 long bristles, outer margins fringed with white silky hairs particularly at the base; stamens 8-11 mm long, with linear anthers enclosed by the petals, and twice the number of the petals; ovary inferior, style about 15 mm long with filiform stigma. Fruit a campanulate berry enclosed by the calyx tube, 2-2.5 cm long, 1-celled and 1(-2) seeded. Hypocotyl cigar-shaped, slightly angular, with a blunt narrow apex, perforating the apex of the fruit and falling with it, 15-25 cm long (Plate 6c).

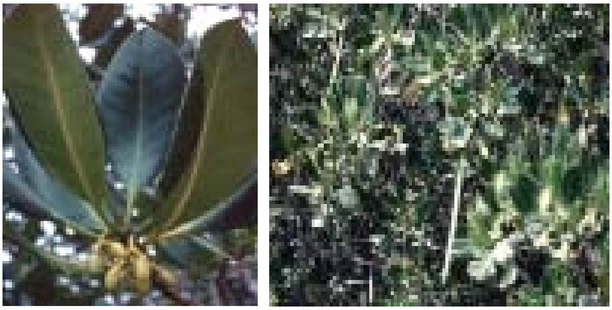
Bruguiera gymnorhiza was recorded from Egypt (KASSAS and ZAHRAN 1967) and the Sudan (ANDREWS 1950) in the past, but no contemporary records are available.

Ceripos tagal **(Perr.) C.B. Robinson**. Synonyms: *Ceriops candolleana* Arn.; *Ceriops boiviniana Tul.*; *Ceriops somalensis* Chiov.
A tree of variable form, attaining heights of up to 20 m at favourable sites. More often, it is a tree of small dimensions or even shrub-like (Plate 7); stem base usually surrounded by a tightly appressed conical cluster of short stilt roots; roots superficial, spreading with occasional knobby pneumatophores; bark varying from white to pale grey to reddish-brown, deeply fissured in older specimens; branches conspicuously jointed. Leaves opposite, clustered at the end of the twigs, coriaceous, obovate to obovate-oblong, rarely elliptical, 5-12 cm by 2-7 cm, cuneate at the base, obtuse or slightly emarginate at apex, glabrous and glossy; petiole 1.5-3.5 cm long, with 1-2.5 cm long deciduous stipules at base. Flowers in condensed, up to 10-flowered cymes on the terminal nodes of new shoots, 5-6 merous, 3-5 mm long, with deeply lobed calyx and white, 3 mm long petals, coherent at base and with 3 clavate, apical appendages; stamens twice the number of calyx lobes, anthers much shorter than filaments, explosively dehiscent; ovary semi-inferior, 3-celled. Fruit an ovoid berry 1.5-2.5 cm long, with persistent reflexed calyx lobes, pointed basally, warty over its whole length. Seeds viviparous; hypocotyl club-shaped, protruding below the fruit while this is still attached to the tree,

15-30 cm long, often deeply fluted (6d).
Ceriops tagal is recorded to date only from Djibouti (FAYE 1993, Plate 7), in the region.

Plate 6: Fruits of some mangrove species

a *Avicennia marina fruits*



b *Rhizophora buds (left) and fruits (right)*

c *Bruguiera fruits*

d *Ceriops fruit*

Rhizophora mucronata **Poiret in Lam**. Synonym: *Rhizophora macrorhiza* Griffith; *Rhizophora latifolia* Miq.
Tree up to 25 m tall and with a trunk 50-70 cm in diameter; taproot usually abortive; lateral roots numerous, developed from base of the trunk, much branched, usually called stilt

roots, hoop or pile-like, supporting the tree; hanging air-roots are sometimes also produced from the lower branches; stem in closed stands cylindrical, or developing a straggling or semi-prostrate habit in less favourable conditions; bark almost black or dark brown, rough or occasionally scaly, with prominent, horizontal cracks almost encircling the stem.Leaves leathery, broadly elliptic to oblong-elliptic, 10-18 x 5-10 cm, with distinct black dots on the undersurface, tapered at both ends and tipped with a fine spine, glossy green above and paler beneath; petiole 2.5-5.5 cm long; stipules large, 5.5-8.5 cm long, somewhat pinkish, sticky. Inflorescences axillary, 2 or 3 times forked, rather loosely 3-5 flowered; peduncles 2.5-5 cm long; flowers with 4-8 mm long pedicels and united, cup-shaped bracteoles at the base; calyx deeply lobed, 13-19 mm long, pale yellow or almost white; petals lanceolate, 9 mm long, light yellowish, densely hairy along the margins, sparsely hairy on the back; stamens 8, sessile, equal anthers 6-8 mm long; ovary semi-inferior, free part high conical, 2.5-3 mm high, style very short, 0.5-1.5 mm long; obscurely 2-lobed. Mature fruit an elongately ovoid berry, 5-7 x 2.5-3.5 cm, with hardly contracted apex and often rugose base, dull brown-green. Seedlings with cotyledons 2-4 cm protruding from the fruit; hypocotyls hanging, cylindrical, 35-70 cm long, 2-2.5 cm wide, tuberculate, usually straight, gradually narrowed upwards into a hard sharp point (Plate 6b).

Rhizophora mucronata is recorded from various sites in Egypt, Saudi Arabia, Djibouti, and Yemen, and in the past was recorded in the Sudan (ANDREWS 1950).

Plate 7: *Ceriops tagal* at Khor Angar mangrove in Djibouti

From studies of their natural occurrences, we have gained some insights in terms of the soil conditions under which specific mangroves perform optimally (Table 1). Site selection is of primary importance at the commencement of any planting program when the most favourable sites should be the initial targets. Detailed surveys should be carried out for potential planting sites, followed by consultation with other stakeholders to ensure that other valuable ecosystems, activities or conservation initiatives are not interfered with.

Table 1. Preferred environmental characteristics of the four mangrove species from the PERSGA region, together with pollination agents and fruiting periods.

Species	*A. marina*	*R. mucronata*	*B. gymnorhiza*	*C. tagal*
Tidal inundation	Around high water mark, reached by most tides	Around high water mark, reached by most tides	Around high water mark, reached by spring tides, 3-4 times per month	Around high water mark, reached by spring tides, 3-4 times per month
Substrate	Clayey or sandy soils	Muddy or sandy soils	Muddy or sandy soils	Consolidated muddy or sandy soils
Salinity	Tolerates high salinity	Tolerates medium salinity in areas of subsurface freshwater	Tolerates medium salinity in areas of subsurface freshwater	Tolerates high salinity
Light	Full sunlight	Full sunlight	Full sunlight or partial shade	Full sunlight or partial shade
Coastal setting	On sheltered open coasts	In creeks, estuaries and lagoons	In creeks and drainage channels	On the upper landward margins of mangroves
Pollinating agents	Bees	Wind	Insects and birds	Moths
Northern hemisphere fruiting season	April-May	Aug.-Sept.	April-May	June-July

9 Nursery and Planting Techniques

Nursery and planting techniques vary considerably among the various mangrove species, and a summary of the techniques employed for the four species from the PERSGA region is given below:

Avicennia marina: The cryptoviviparous propagules of species of *Avicennia marina* are usually collected from around the base of mother trees when they have matured. When kept in air, these propagules rapidly lose their viability within a few days. These propagules may be directly planted into sheltered areas, where the propagules are gently pushed into the soft sediment until firmly wedged. Pre-treatment of the propagules has sometimes been used to decrease the establishment time. Such treatment consists of placing the propagules in small nets and exposing them to daily tidal inundation to hasten the decay of the pericarp. Removal of the pericarp by pre-treatment reduces the establishment time to 2-3 days, while without pre-treatment, 5-6 days are required. Alternatively, propagules may be raised in nursery beds that are exposed to daily tidal inundation. Seedlings are raised for about 1-2 months after which they are gently pulled out of the ground and packed for transportation to previously chosen planting sites, where they are usually planted out into holes of 3 cm diameter at an appropriate spacing.

Propagules for nursery raising are simply placed on the surface of freely draining sand and vermiculite mixtures, kept in full sunlight, and watered once daily, preferably using 25% seawater which suppresses fungal infections in the seedlings and acclimates them to the saline conditions into which they are to be planted. Growth and survival rates are significantly higher in Avicennia marina in 25% seawater than in freshwater. Humid conditions and the once-off addition of a slow release fertilizer such as 'Osmocote' (NPK 18:2.6:10 at approximately 3 g per 10 cm pot) will enhance optimal growth.

Rhizophora mucronata, Ceriops tagal and *Bruguiera gymnorhiza:* Cigar-shaped propagules of these three species are available during most of the year although maximal abundance is generally in late summer. Characteristically planted by inserting into the sediment for one-third to one-half of the length of the propagule, germination is rapid (within 7-20 days) with around 90% germination rates.

10 Silvicultural Management of Planted Areas

The major objectives for managing any plantation or restored area should be to facilitate natural regeneration, to enhance productivity through fertilization and weed or herbivore suppression, and to select target areas where some assisted regeneration is required. The introduction of selected additional species may also be considered to either increase the biodiversity of the community or to enhance the standing stock with suitable understorey species. Self-regeneration is an important aspect of plantation or restoration project as costs of establishing plantations or maintaining restored areas will vary significantly depending on the extent of artificial planting that may be required.

Many mangrove plantations or restored areas require stringent site management, including temporary regulation of access to minimize damage to the area through human or animal trampling, grazing, motor vehicles, and so on. In addition, some form of temporary shelter from current scouring may be needed to assist in stabilizing the sediments after disturbance and allowing seedlings to establish themselves. Once the site has been re-stabilized after construction, or once assisted regeneration has been carried out, the mangroves are likely to require little in the way of on-going management.

Biotic interactions can also affect the regeneration process. Insect infestations, in particular, have been reported to cause failures in recruitment in plantations of *Avicennia* and *Rhizophora.*

The optimal planting season is generally the time of maximal growth i.e. the warm and wet season. In the PERSGA region, however, plating during the cooler months is preferable to minimise the thermal stress on the seedlings and the planters.

A wide range of plant spacing has been used (see Table 16.6 in FIELD 1996) in a variety of mangrove planting programs. Determining proper spacing should be based on minimizing competition. For *Avicennia marina*, a spacing of 1.5 m was used at the Brisbane airport site (SAENGER 1996); after 4 years no evidence of self-thinning was apparent.

11 Plantation Performance

Assessing the performance of any plantation depends largely on the objectives of the planting exercise, and monitoring of parameters need to be adjusted accordingly. Generally, however, assessment is usually done annually by monitoring the survival rate and one or more of the structural characteristics of the stand, generally including diameter-at-breast-height (DBH standardised to 1.3 m) and height (H), although other parameters such as basal area (BA in m^2 ha^{-1}), stem density (D in stems ha^{-1}), above-ground-biomass (AGB t ha^{-1} or kg $tree^{-1}$) and timber volume (V in m3 ha^{-1}) are commonly used in detailed inventories.

11.1 Survival

Assessing the survival of seedlings in any planting program is essential to evaluate planting techniques and to determine what, if any, replacement planting may be needed.

11.2 Height of plants and other simple structural attributes

Repeated measurements of height of the plants is the most common, easiest and useful monitoring tool, and will ultimately provide a time-series to illustrate the plantation performance. Other parameters that have been used to provide some useful information on plantation performance include density, basal area, and, for small plants, number of leaves per plant.

11.3 Standing Stock

The methods of biomass estimation fall into three broad, but overlapping, categories: clear-felling, representative tree sampling, and the establishment of allometric relationships.

Clear-felling involves the harvest of the entire above-ground biomass (AGB) from a specified area. The plant material is usually sorted into the component parts (wood, branches, leaves, fruits and flowers) within the individual species comprising the stand. The weight of each component and the summed total is converted into the dry weight value on a unit area. Efficient in young and small-sized stands, the clear-felling method becomes more difficult to use for biomass estimation as the size of the stands or the trees become larger.

Representative tree sampling is particularly suitable where the stands are even-aged or consist of an obvious series of ages. Under those conditions, suitable representative trees can be selected for felling and harvesting of the individual components. The dry weight obtained per tree is then multiplied by the stand density (trees ha^{-1}) to estimate the stand biomass.

Allometric techniques have been widely used to estimate stand biomass in terrestrial forests (SAENGER, 2002, KOMIYAMA et al. 2008). Such methods involve the establishment of a relationship between the biomass of whole trees, or their component parts, and some readily measured parameter such as diameter of the stem at breast height (DBH), and/or height of the tree (H). Once the allometric relationships have been established, the technique can be applied in a non-destructive way at other sites; in contrast, the other two techniques are site-specific and are likely to introduce large errors when applied at other localities. Allometric relationships between AGB (kg $tree^{-1}$) and DBH (and/or H) for the four species from the PERSGA region are given in Table 2.

Table 2. Allometric equations for mangroves of the PERSGA region and their above-ground-biomass (kg $tree^{-1}$) based on DBH (cm) and/or H (m).

Species	Equation	Regression Coeff.	Reference
A. marina	AGB = 3.59[(DBH)2H]0.529	r^2 = 0.97, n = 25	1
R. mucronata	AGB =105.0DBH2.6848	r^2 = 0.99, n = 23	2
B. gymnorhiza	AGB = 185.8DBH2.3055	r^2 = 0.99, n = 17	2
C. tagal	AGB = 188.5DBH2.3379	r^2 = 0.99, n = 26	2
All mangroves	AGB = 6.6[(DBH)2H]0.8877	r^2 = 0.99, n = 20	3

[1]TAM et al. 1995, [2]CLOUGH and SCOTT 1989, [3]KOMIYAMA et al. 1988.

While various equations have been used to establish allometric relationships, the power curve:

$$\textbf{Biomass} = \textbf{A.DBH}^{\textbf{B}}$$

where A and B are parameters has been most widely used. More often its linear transformation as:

$$\textbf{log (Biomass) = a + Blog (DBH)}$$

where a = Log (A), provides a good description of the relationship between above-ground biomass (AGB) and DBH in a wide range of forest types.

An alternative approach was developed by SAENGER and SNEDAKER (1993), who examined 43 AGB (stand-based biomass in t ha^{-1}) data sets and used these to obtain correlations with mean height (H in m) and latitude (L in) of the stands to allow global trends to be identified. Highly significant correlations were found and these can be used as first approximations of AGB (in t ha^{-1}) on an area basis rather than for individual trees:

$$\textbf{AGB} = \textbf{161.405 - 46.393}\log_e (\textbf{L H}^{-1})$$

$$(\mathbf{r^2 = 0.66, n = 43})$$

Annual litterfall (ALF in t ha^{-1} y^{-1}) data (91 data sets) were also examined (SAENGER and SNEDAKER, 1993) to identify correlations with H and L of the stands, allowing estimates to be made of the mangrove stands in terms of litter input to the system on an area basis.

$$\textbf{ALF} = \textbf{10.366 - 1.669}\log_e (\textbf{L H}^{-1})$$

$$(\mathbf{r^2 = 0.26, n = 91})$$

These area-based equations have been tested since they were published on a number of occasions with newly established data sets and were found to provide reasonable general approximations. FROMARD et al. (1998), for example, found good agreement between estimates derived from these equations and their allometric estimates of AGB, and CONACHER et al. (1996) found good agreement with ALF in northern Australia. Similarly, SLIM et al. (1996) found good agreement with their AGB for *Rhizophora mucronata* forests. In their *Ceriops tagal* stands, however, growing under suboptimal conditions, considerable differences in calculated and actual AGB were found. LI and LEE (1997) also found reasonable agreement with ALF for Chinese mangroves although the calculated AGB generally resulted in an underestimate.

11.4 Indices of 'Health' in Mangrove Communities

Apart from monitoring the structural development of old-growth or plantation mangroves as a measure of growth performance, it is also useful to assess the 'health' of the trees, stands or forests. Such assessments are commonly made on the basis of indicators that have been found to co-exist with certain pathological conditions or other forms of environmental stress.

A preliminary list of such indices of 'health' for mangroves has been compiled from observations made on *Avicennia* and *Rhizophora* (Box 1). Although this listing is tentative, it is intended to provide an easy and rapid means of assessing a mangrove stand in terms of the presence or absence of certain characteristics symptomatic of pathological or other stressful conditions. In this sense, this list may be used as an early diagnostic tool.

Box 1. Indices of 'health' in mangrove trees, stands and forests. 'healthy' communities will not display these features:

- Aerial roots
  proliferation of undersized proproots
  twisting and curling of pneumatophores
  adventitious aerial roots
  death of proproot tips
  fissuring or peeling of periderm

- Trunks and branches
  top-dying of uppermost and outermost sun branches
  fissuring and cracking of bark
  expanded and/or more numerous lenticels
  shortened internode distances
  cessation of terminal shoot growth
  appearance of trunk sprouts from secondary meristems

- Foliage
  reduced leaf number per branch
  reduced leaf size, twisting and curling
  abscission of buds and immature leaves
  altered leaf maturation sequence
  spotty chlorosis or necrosis
  change in leafing and shedding processes
  reduced leaf area index

- Reproductive structures
  change in timing of flowering and fruit set
  absent or grossly excessive flowering
  deformed seeds and propagules
  development failure of fruit
  excessive abortion of immature fruit

- Regeneration
  failure to orient geotropically
  seeds and propagules fail to establish primary root system
  abnormal growth forms in established seedlings
  failure to initiate primary branching
  chlorosis or necrosis of propagules

11.5 Measuring Ecological Functionality

The ultimate success for a mangrove restoration project is that it shows ecological functioning essentially similar to the pre-disturbance state. Measuring such functionality is difficult and time-consuming, and there are few studies of restoration programs that have achieved a degree of ecological functioning similar to natural mangrove systems. LATIF (1996) reviewed mangrove restoration projects on the eastern Australian coast, ranging in age from 1-18 years. He examined each of the restored areas in terms of survival rate of plants, natural regeneration and general health of the plantation. For the 8-year old Ballina plantations, consisting of 7 ha, additional detailed studies were carried out in relation to fish usage at high tides, fish food availability, and short-term (marker horizon) and long-term (sequential topographic surveys) accretion rates in planted and control areas. It was found that within 4 years, the planted areas showed comparable results to the control areas in all aspects.

MCKEE and FAULKNER (2000) compared the structural development and biogeochemical functioning of restored and natural mangrove forests within the same physiographic setting in south-west Florida. One site had been replanted in 1982 while the second site had been replanted in 1990. Adjacent natural mangrove forests, which had been undisturbed for 50-60 years, were used for comparisons. Despite being planted initially with *R. mangle*, both sites had been naturally colonized by *L. racemosa* and *A. germinans.* The restoration forests were dense but immature, with lower basal area and stand height, and higher tree density when compared with reference forests; at an age of 6-13 years, the restored stands were structurally still at the pioneer stage but only a few biogeochemical differences were apparent.

MORRISEY et al. (2003) compared the faunal, floral and sedimentological properties of *Avicennia marina* stands of two different ages in New Zealand. Older (>60 y) and younger (3-12 y) stands showed a clear separation on the basis of environmental characteristics and benthic macrofauna. Numbers of faunal taxa were generally larger at younger sites, and numbers of individuals of several taxa were also larger at these sites. As these mangrove stands mature, the focus of faunal diversity shifted from the benthos to epiphytic fauna, such as insects and spiders. Differences in the faunas were coincident with differences in the nature of the sediment; in older stands the sediments were more compacted and contained more organic matter and leaf litter. Interestingly, mangroves in the younger stands were able to take up more N and P than those in older stands, presumably because of less root competition in the younger stands. Overall, these investigators concluded that younger and older stands have significantly different functional characteristics, which should be considered in planning and management.

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Annex 1: Standardized Site Rating Questionnaire (Adapted from SAENGER et al., 1996)

The following questions should be answered for each site. The responses have been deliberately kept simple to allow for quick assessment, and each response chosen should be that which most closely described aspects of the site in question. The questions cover a range of social and environmental characteristics, which affect site suitability. Methodologies for data gathering required in some questions (e.g. accretion rates and sand content) are explained below. Scoring is a simple matter of circling whichever choice is the most applicable to the site in question, and then totalling the points for all questions.

Local residents are probably the best source of information concerning the dynamics of the site under investigation. Local fishers and graziers may provide reasonably accurate information of sedimentation rates, and patterns of human, grazing and wildlife usage of the site. Figures on sand content of soil may be visually estimated, but more accurate results will be obtained by drying, sieving and weighing soil sample fractions. For the purposes of this exercise, sand may be considered to be any particle with a grain size greater than 0.1 mm. Soil salt content should be quantified by means of one of the standard methods.

All questions are given similar weighting. The listing below gives a general guideline to suitability classes, but sites scoring highly within a class can be viewed as being more suitable than sites in the same class with lower scores.

20 to 44	Site is unsuitable for restoration
45 to 64	Site is marginally suitable for restoration
65 to 84	Site is moderately suitable for restoration
85 to 115	Site is very suitable for restoration.

Starter Question

Does the site lie between mean sea level and mean high tide level, or c an it be easily engineered to this level?

If NO, cancel further investigation of the site.
If YES, proceed to assess site rating using the Scoring Questions.

Scoring Questions

1) Members of the local community will be involved:

at all stages of the project.	5
for part of the project.	3
not at all.	1

2) Travel time from home base to the site for workers is:

less than one hour	5
between one and two hours	3
more than two hours	1

3) To reach the site will require:

no new infrastructure	5
a new boat	3
a new road	1

4) Access to the site is:

easy and reliable	5
relatively straight forward and generally reliable	3
complicated and not always reliable	1

5) The site is used as a thoroughfare:

seldom	5
sometimes	3
often	1

6) The site is used by locals mainly for:

recreation (e.g. swimming and tourism)	5
fishing or shellfish collecting	3
timber gathering or grazing	1

7) The site is used by locals:

seldom	5
sometimes	3
often	1

8) Someone from the project:

will be nearby all the time	5
will check the site once a week	3
will check the site once a month	1

9) The main type of land use immediately around the site is:

natural mangrove areas	5
agricultural areas	3
urban areas	1

10) Mangrove propagules are available:

less than one hour away	5
between one hour and one day away	3
more than one day away	1

11) Wildlife (e.g. antelope, birds etc.) use the site for feeding or nesting:

sometimes	5
seldom	3
often	1

12) Evidence of oil at the site is:

none there	5
very weathered	3
slightly weathered	1

13) The surrounding area has a yearly rainfall of about:

250 mm	5
150 mm	3
50 mm	1

14) The nearest river/lagoon/creek/wadi to the site is:

less than 100 metres away	5
between 100 and 500 metres away	3
more than 500 metres way	1

15) The site is:

gently sloping (less than 5)	5
flat/horizontal	3
sloping (more than 5)	1

16) The sand content of the soil at the site is:

less than 10%	5
between 10 and 50%	3
more than 50%	1

17) Grass and/or algal cover at the site forms a coverage of:

more than 50%	5
between 20 and 50%	3
less than 20%	1

18) Crab burrows are evident:

all over the site	5
in some places on the site	3
there are none on the site	1

19) The site is accreting at a rate of about:

between 0 and 150 mm per year	5
between 150 and 300 mm per year	3
more than 300 mm per year	1
the site is eroding	1

20) The salinity of the soil is about:

between 10 and 50 parts per thousand	5
less than 10 parts per thousand	1
more than 50 parts per thousand	1

21) Tree cover on the site consists of:

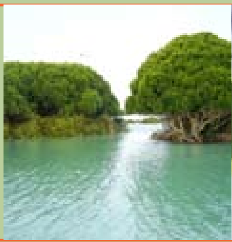
a few big trees providing shade	5
no trees at all, or only a few small trees	3
lots of trees providing dense shade	1

22) The site is inundated:

by most tides	5
by spring tides only	3
not at all	1

23) The site will require:

no fencing but informative signage	5
some fencing and signage	3
full fencing and signage	1



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