Urban Forest Rehabilitation – A Case Study from Singapore

by

Geoffrey Davison

PART A
STATUS OF LAND USE AND FOREST (AND LAND) DEGRADATION

1. Forest Land Use and Land Use Change

The Republic of Singapore is an island city-state of 699 km^2 and approximately 4.4 million people (Singapore Department of Statistics, 2005). It lies at the Southern tip of the Malay Peninsula, approximately 137 km north of the equator (1° 14 N, 103°55 E). Despite being one of the most urbanized and built-up countries in Southeast Asia, Singapore is also renowned for its national mission of making Singapore a "City in a Garden".

Prior to the British colonization in 1819, Singapore was covered with lush forest (Lum 1999), with more than 80% lowland dipterocarp forest, 5% freshwater swamp forest and 13% coastal mangroves. Only small areas along the coast had probably been under settlement, cultivation, or otherwise disturbed at that time. Today, more than 50% of the island is urbanized. There are less than 2,000 ha of primary forest, which is 3% of the total land area (Corlett 1992; Lum 1999). The largest single expanse of primary forest (70 ha) is found in Bukit Timah Nature Reserve (LaFrankie et al. 2005). Other primary forest fragments are found in the Central Catchment Nature Reserve, in the extreme West of Singapore, and on a few of the larger offshore islands. However, these primary forest fragments occur within a matrix of disturbed secondary forest and re-growth.

In consideration of the small size of land-scarce Singapore and its high degree of urbanisation, forestry in Singapore's context can be broadly categorized as:

- Forests in gazetted Nature Reserves, consisting mainly of remnant primary forests and regenerating secondary forests; *and*

- Urban streetscapes, consisting mainly of closely planted roadside trees along 95% of Singapore's roads, and trees in urban developments, urban parks and vacant lands, as well as planted and managed trees on offshore islands and reclaimed lands.

1.1 *Forests in Gazetted Nature Reserves*

Currently, there are 3,347 ha of Nature Reserves with full legal protection. They comprise the Bukit Timah Nature Reserve, the Central Catchment Nature Reserve, the Labrador Nature Reserve and the Sungei Buloh Wetland Reserve. The former two reserves consist of mainly remnant primary lowland dipterocarp forest and secondary re-growth, while the latter two respectively consist of mainly coastal forest and mangrove forest. The Central Catchment Nature Reserve includes a historically important area of freshwater swamp forest which has been the basis for research of regional significance (Corner 1978).

The flora and fauna within the Nature Reserves are very diverse. For example, the Bukit Timah Nature Reserve and the Central Catchment Nature Reserve support 840 species of flowering plants and more than 380 species of vertebrate animals which include 44 species of mammals, 207 species of birds, 33 species of fishes, 72 species of reptiles and 25 species of amphibians (Chan & Corlett 1997). In a Smithsonian Institution study, a 2-ha plot at Bukit Timah Nature Reserve consists of 15,000 trees of 312 species (Smithsonian Tropical Research Institute, 2005), which underlines the health and diversity of forests in nature reserves in Singapore.

The 130-ha Sungei Buloh Wetland Reserve is an important site for migratory birds on the East Asian-Australasian flyway. Developed from an old prawn farm, efforts have been made to improve the secondary and mangrove forest in the Reserve. It was selected as an ASEAN (Association of South East Asian Nations) Heritage Park in 2003, as being a good representative example of the natural heritage of ASEAN.

These Reserves are protected from the effects of development, although surrounding developments may impact upon the edges of the forests within these Reserves. Conservation efforts have also been spelt out in the Singapore Green Plan 2012 for the forests within the gazetted Nature Reserves (Ministry of Environment & Water Resources, 2002).

1.2 *Urban Streetscapes*

Singapore has established a widespread programme of roadside planting for expressways, major and minor roads, as well as for open car parks. This forms the backbone of the Garden City of Singapore, giving Singapore its green mantle. These roadside urban forests alongside approximately 3,130 km of paved roads (CIA, 2005) are managed by certified National Parks Board (NParks) arborists who provide expert tree care and management services. A number of roads have been designated as Heritage Roads, in order to safeguard roadside trees and vegetation, drawing attention to the aesthetic, historical and cultural significance of these trees. 161 majestic old trees have been designated Heritage Trees. Singapore also has two Tree Conservation Areas in Tanglin/Bukit Timah as well as Changi, where trees above 1m girth over bark are protected by law. These include remnant specimens of locally rare species and, amongst others, provide seed stock for reforestation in the Nature Reserves.

The urban forests are mainly under the care and management of NParks and a few other government agencies, namely the Singapore Land Authority (SLA), the JTC Corporation (JTC), the Housing Development Board (HDB), and Town Councils. These government agencies implement and manage urban forests provided for under the prevalent guidelines for greenery provision established by the Urban Redevelopment Authority (URA) and NParks. Some examples of such guidelines include the requirements for:

- To provide green space of 0.8 ha per 1,000 population (URA, 2000);
- Open car parks to provide the necessary tree plantings for shade and aesthetics; *and*
- The “Road Code” provisions for designating tree planting verges along roads.

2. Status of Forest (and Land) Degradation

Singapore's rapid development as a global city in the past forty years since independence has been based on industrial development, particularly processing and service industries. Singapore's land surface has grown by some 120 sq km. Since then, several strategies described later have been employed to rehabilitate forest landscapes.

Current forest degradation has been minimized, the risk factors including the intensity of human use for recreation, climate change (and short term weather fluctuations such as prolonged drought), chance extinctions due to small remaining population sizes of forest plants and animals, potential breakdown of pollination and dispersal mechanisms through loss of species, and isolation from potential sources of genetic exchange and recolonisation.

3. Causes of Forest (and Land) Degradation

Land now covered in secondary forest was repeatedly cultivated since the early 1800s. The major cash crops grown in Singapore were gambiar (*Uncaria gambiar*), pepper, coconuts, pineapple, tapioca, and rubber (*Hevea brasiliensis*). Many other crops were grown on a trial basis, in small plantations, or as supplements to other agricultural activities. For example, nutmeg (*Myristica fragrans*) was an early plantation crop. By the 1920s, 60% of the land was cultivated (Shono *et al*. 2006). With transition to a more developed economy, the small land area of Singapore became less able to support low intensity land uses, and agriculture was substantially reduced. Upon being abandoned, the agricultural lands later regenerated into secondary forests dominated by *Adinandra dumosa* after suppression of fire (Corlett 1991, 1992). Eventually, they regenerated into the more diverse secondary forest (Turner 1997) that exists today.

Singapore has no indigenous timber industry, and none of the remaining forested areas, either primary or secondary, is used in any manner for the commercial extraction of forest products. Singapore thus differs from other countries in the region, in that commercial forestry has not been a significant contributor to forest degradation.

4. Impacts of Forest (and Land) Degradation

When agricultural practices exhausted the soil, or when cultivation was no longer economically viable, farmlands were abandoned to lalang (*Imperata cylindrica*) grasslands, which were prone to fire. These grasslands slowly regenerated to secondary forest known as Adinandra belukar (named after the dominant species, *Adinandra dumosa*) (Corlett 1991, 1992). Persistence at this stage is variable (Corlett 1991), but eventually, the *Adinandra* forest is replaced by a more diverse secondary forest (Turner 1997). Small areas within the secondary forest became dominated by resam fern (*Dicranopteris linearis*) and *Smilax setosa* climbers when the regenerating secondary forest was cut for firewood (Burkill 1961). These aggressive weeds prevent tree regeneration by forming dense thickets, leading to arrested succession. Dominance by *Dicranopteris* may persist for decades or even centuries (Russell et al. 1998).

There has been steady regeneration within the areas of secondary forest, creating a diverse, multi-layered vegetation structure. This includes native species and, at present, introduced species such as *Albizia (Paraserianthes) falcataria* and *Acacia auriculiformis*. These can be effective in providing shade during the establishment phase for regenerating seedlings of other species, but are considered weeds that should ultimately be removed.

The total flora for Singapore lists 2,282 species of vascular plants (Tan 1995). Approximately 584 of these (25.6%) were presumed to be locally extinct (Tan 1995), although rediscoveries continually occur so that the total presumed extinct is now closer to 20%. Another 556 species (24.4%) were considered endangered or vulnerable (Tan 1995). No attempt has been made to apportion these losses between those due to loss of forest cover, and those due to degradation in remaining forest quality.

The proximity of Singapore to Peninsular Malaysia, and its repeated fusion with adjacent landmasses during Late Pleistocene lowering of sea level, has not facilitated the evolution of endemic plants. Only seven taxa, two of them natural hybrids and five full species, are definitely known to have been endemic, representing only 0.3% of the indigenous flora (Kiew & Turner 2003). Only one of these, *Cryptocoryne* x *timahensis*, has survived within Bukit Timah Nature Reserve. Singapore is the type locality for many plant species, and can therefore act as a resource for the region in conserving topotypical populations, both for reference and research.

Fortunately, the bulk of the remaining forest surrounds the nation's reservoirs, so that the immediate catchments are protected in terms of runoff and sedimentation. So, the areas most readily available for reforestation and rehabilitation are situated around the reservoirs, too.

PART B
IMPLEMENTATION OF FOREST RESTORATION AND REHABILITATION

1. History of Forest Restoration/Rehabilitation

Forests in the areas now within the Nature Reserves have been allowed to regenerate of their own accord for many years. Most examples of active forest rehabilitation in Singapore have occurred since 1991.

Because of the absence of a commercial forestry sector within Singapore, there has not been any economic pressure to reforest or rehabilitate forests with the objective of sustaining timber production. The motivation to reforest and rehabilitate comes largely from the desire to maintain important ecosystems for recreation, tourism, research, education and awareness. This in turn has meant that reforestation and rehabilitation might have begun later than in other countries in the region, and with a different emphasis.

2. Current Policies Governing Land Use and Restoration/Rehabilitation

In the past forty years, the Singapore Government has given emphasis to providing greenery, especially in the urban context. Launched by a Tree Planting Campaign in 1963, the Garden City policy saw widespread planting of roadside trees and the island wide development of urban parks and green spaces as green lungs.

The Parks and Trees Branch in the Public Works Department (which later became the Parks and Recreation Department) was created to spearhead and implement the Garden City policy in 1968, and a Garden City Action Committee was created in 1973 to formulate Garden City policies and programmes in tandem with the development of Singapore. The National Parks Board (NParks) was set up in the 1990s to (among other things) manage the remaining forest areas which were unaffected by the rapid development, and is the current authority on greenery.

The greenery creates a comfortable, pleasant environment for Singaporeans and has attracted investors to Singapore. Although the economic contribution of the greenery may appear intangible, the 2003 'Leisure Lifestyle and Park Usage Pattern Survey' revealed that 82.8% of respondents agreed that being a Garden City improves Singapore's global competitiveness, and that 72.7% felt that living in a Garden City enhances their quality of life (National Parks Board 2005). Clean air, towards which greenery contributes, is considered to be one of Singapore's competitive advantages in comparison with other city states.

The Urban Redevelopment Authority (URA) is the lead agency in land use planning in Singapore. The URA Master Plan is equivalent to the Structure Plan in other countries. It guides land use decisions, but is flexible enough to take into account changing economic, social and geographical conditions. Under the Master Plan various more detailed plans are applicable to particular land use categories. The most relevant to reforestation and rehabilitation is the Parks and Waterbodies Plan. There is also a Special and Detailed Controls Plan, under which 22 Nature Areas are designated. These are not legally protected, but are subject to consultation with relevant agencies such as NParks, and should be retained for as long as possible.

Singapore is increasingly looking at the concept of linking fragments of natural habitat through land use planning, and perhaps more active creation of physical links. Examples are the Southern ridges from Mount Faber through Telok Blangah to Kent Ridge Park, and the possibility of restoring a physical link between Bukit Timah and Central Catchment Nature Reserves.

National Parks and Nature Reserves are protected under the Parks and Trees Act 2005 (which replaced earlier legislation).

NParks is currently undertaking a Plant Conservation Strategy, which should make planting materials more readily available for forest rehabilitation. This is a set of activities in line with the Global Plant Conservation Strategy under the Convention on Biological Diversity. It is coordinated by NParks, which is also the agency that conducts many of the activities, in collaboration with academic institutions. The Plant Conservation Strategy is guided by rarity and conservation status of all plant species (Ng & Wee 1994), not just trees. There are active programmes to increase the population size of ferns and orchids, including by tissue culture for recalcitrant species. Thus, forest rehabilitation in Singapore is not confined to trees, but is meant to embrace the whole plant community.

3. Forest Restoration/Rehabilitation Initiatives

Since 1991, NParks has been reforesting degraded vegetation within the Nature Reserves and the surrounding edge to accelerate succession and restore the degraded areas to a late secondary forest with a primary forest component (Shono *et al*. 2006). Reforestation efforts are contributed by non-governmental agencies, private corporations and students. NParks uses this programme to raise public awareness on the importance of restoring degraded forest (Shono *et al*. 2006). The Central Nature Reserve Branch, which manages these reserves, actively engages students and volunteers to participate in their reforestation effort. The volunteers usually help in planting the saplings, and some tougher ones also assist in the clearing of the aggressive weeds such as resam fern (*Dicranopteris linearis*) and *Smilax setosa* vines. These aggressive weeds form dense thickets, preventing seedling establishment (Shono *et al*. 2006).

Mangrove restoration is being conducted at Sungei Buloh Wetland Reserve. Since 1993, about 1.2 ha of secondary forest and 0.7 ha of mangroves have been reforested with 62 plant species, totaling 5000 trees (NParks, Sungei Buloh Wetland Reserve Branch).

Since 1991, NParks has been reforesting areas of degraded vegetation at Bukit Timah and the Central Catchment Nature Reserve, with the objective of accelerating succession and restoring them to a late secondary forest with primary forest components. Species that are known to be native to Singapore are used in the reforestation program. Since future timber harvest is not one of the objectives of forest restoration in Singapore, a wide variety of native species have been tested for their reforestation potential. Since 1991, 15 ha have been replanted with 17,000 saplings of 150 species. The saplings were obtained from various sources, viz., raised from seeds of native stock; salvaged from other forest patches; or purchased from nurseries. The average size of the saplings at planting is 1.5 m in height and the use of larger saplings is thought to enhance the survival in competition with the weedy species.The average spacing between saplings is 3 m, and the average size of reforestation plots is 0.25 ha. Prior to reforestation, the target area is cleared of above-ground *Dicranopteris* biomass using grass cutters. The debris is left in situ to decompose. The *Dicranopteris* rootmat is left untouched.The saplings are placed into planting holes 1.5 times the size of their root balls. Then the soil is backfilled and firmly packed. Each sapling is watered at the time of planting and also in the next few weeks as needed. The only maintenance operation thereafter is the periodic removal of *Smilax* vines that sprout from rhizomes. Some of the saplings are stifled by climbers and by competition from fast growing pioneers that naturally establish on the bare soil exposed around the planting holes. NParks uses the reforestation program as an opportunity to raise public awareness of the importance of restoring degraded ecosystems. Schoolchildren, volunteers, and employees of corporate sponsors typically participate in the planting sessions.

Pulau Semakau, one of Singapore's Southern islands, was developed by the National Environment Agency (NEA) as a new landfill site in 1999. Some coastal mangroves were cleared during the development of this 350 ha landfill site. These have been fully replaced with two plots of planted mangroves with a total area of 13.6 ha. This landfill site was opened for nature-related recreation in July 2005. Further efforts by the NEA are being made towards rehabilitation for recreation in addition to protecting the ecosystems and rich biodiversity during the planning, design and construction of the landfill (NEA, 2005).

In the Nature Areas in offshore islands, such as Pulau Ubin, active steps are taken to rehabilitate degraded old quarry work sites and abandoned rubber plantation areas. Topsoil has been brought in to fill up areas that have been dug and stripped of any good soil. Depending on the sites, only native and naturalized trees and plant species are selected for planting. Since the reforestation effort started in the year 2000, over 200 tree species amounting to over 3000 trees have been planted out. So far, 16.5 ha of land have been rehabilitated. In addition, there are on-going projects to rehabilitate another 25 ha of degraded forests in other old quarry sites (NParks, Pulau Ubin Branch). These will provide much needed greenery to supplement the natural character of Pulau Ubin's Recreation Areas for use by locals, visitors and tourists.

Since 2005, the Southwest Community Development Council (SWCDC) has initiated a community-led effort to 'Plant 100,000 Native Plants' over the next three years. This contributes to urban forests, especially in residential areas in the Southwestern part of Singapore. The species selection emphasizes native trees which are compatible with roadside conditions. A multi-stakeholder committee guides the project and includes government agencies, school teachers, and members of the grassroots community.

4. Ongoing Research

In July 2005, a new research initiative on reforestation and forest restoration was implemented by the Center for Tropical Forest Science – Arnold Arboretum Asia Program (CTFS-AA) and NParks. This project sought to bring together the practical knowledge on reforestation that NParks has accumulated over the past decade and the scientific expertise of CTFS-AA in designing and conducting ecological research. The collaboration aims to improve and develop techniques for restoring degraded forest sites in Singapore that will be applicable elsewhere in the region.

The first phase of the project entailed tagging, mapping, identifying and measuring girth and height of planted saplings in order to evaluate reforestation potential of the native trees species. Currently, 2500 planted saplings belonging to 80 species on 2 ha of land are being monitored to provide long-term data on growth and mortality. Improving species selection is one of the important objectives of this research work. We have collected a lot of information on native species identifying those which are the most promising for reforestation. Fast growing species, which tolerate the harsh environmental conditions of degraded sites, can quickly shade out the light-demanding weeds and ameliorate the physical environment to allow for natural recruitment of other tree species. Canopy closure significantly increases species diversity of woody natural recruitment and reduces the abundance of *Dicranopteris* ferns, climbers, grasses and sedges.

Preliminary findings suggest that matching species to site characteristics is another important consideration when deciding which species to plant. Natural recruitment at the reforestation sites was also surveyed in order to understand the patterns and processes of vegetative recruitment and development of floristic diversity in these restored forests. Additional experiments have been implemented to examine the effects of the *Dicranopteris* rootmat in preventing the establishment of natural regeneration, the response of planted saplings and natural regeneration to addition of nutrients, and the performance of various species along moisture and light gradients.

5. Assessment of Existing Capacities of Stakeholders' Involvement

The private sector is not forestry-based. Interest in contributing to forest restoration and rehabilitation is therefore to be understood as a community service, not as a business-related venture. Since there is no logging industry, it is not an option to include replanting, enrichment planting or other silvicultural treatments in any contracts.

The time of NParks staff is divided between many tasks, including visitor management, maintenance of facilities, education and outreach programmes, as well as safeguarding of the forest. Efforts towards forest restoration and rehabilitation therefore have to take their place within a list of other priorities.

The contributions of volunteers and members of the community are limited by time and numbers. Volunteers are more interested in planting saplings than in weeding or in maintaining the young trees. NParks therefore has to strike a balance between rehabilitation of more areas versus maintenance of the areas that have already been treated; the latter effort falls more on NParks staff.

For these reasons, reforestation and forest rehabilitation have to remain government-led, even though they are on a small scale compared with other countries.

PART C
FUTURE ACTIONS FOR ENHANCING RESTORATION/REHABILITATION

1. Improving/Revising Policies

The URA Master Plan and the Singapore Green Plan are periodically revised (URA 2000; MEWR 2002). They are both open to public inputs, and a Garden City Action Committee (GCAC) monitors the implementation of the Singapore Green Plan.

Because the motivation for reforestation and rehabilitation of forests is not based upon the need for an indigenous timber industry, the criteria for site selection and species selection are likely to differ from those used in other countries. Species need not be selected for growth rate or timber yield and quality. Sites need not be selected to restore logging damage.

The National Climate Change Strategy being developed in 2006-2007, acknowledges the role of greenery in mitigating climate change, and in reducing local temperature extremes caused by the urban heat island effect. Greenery enhancement is therefore included as a continuing strategy.

2. Building Research and Education Capacities

NParks encourages staff in its relevant divisions to acquire professional qualifications. Most relevant among these is the qualification of Certified Arborist from the International Society of Arboriculture. All arborists are expected to undertake a minimum number of training days per year. Furthermore, NParks is expanding its programme of staff scholarships, locally and overseas.

In 2005, NParks reorganised its structure to bring former work sections (rather than divisions) together into a new Streetscape Division. The core business of this Division can be described as urban forestry. At the same time a new Research Division was established, and staff numbers were increased to take up the role of coordinating and collating existing research work conducted by the various divisions. A Research Master Plan has been developed and research advisors have been appointed from the academic and private sectors.

NParks is also aiming at the education of young people. A Young Arborists' Programme is being set up in schools, with workbooks designed around simple projects that schoolchildren can undertake. The Biodiversity Centre of NParks is designing a series of educational posters, ecosystem by ecosystem, meant to facilitate curricular and co-curricular activities.

3. Reconciling Global and National Policies

Singapore is a signatory to the Convention on Biological Diversity (CBD), the Convention on International Trade in Endangered Species of Flora and Fauna in Commerce (CITES), and participates in other international discussions such as the United Nations Forum on Forests.

Forests in Singapore contribute only a tiny proportion to the global or even the regional total. Nevertheless, Singapore's position concerning conserving and rehabilitating its remaining forest is in line with the above agreement. Singapore also contributes statistics to the United Nations Food and Agriculture Organization (FAO), supporting the compilation of statistical data about the world's forests.

4. Partnership and Collaboration with the Private Sector

Forest restoration and rehabilitation are planned and coordinated by government agencies. The main role of the private sector to date has been to help through contributing manpower. Staff clubs and voluntary organisations often wish to contribute to the environment. For this purpose family days or tree planting events are organised.

Some forest-related work is contracted out to the private sector.This is particularly true for the maintenance of urban forestry. It applies less to reforestation and rehabilitation.

5. Creating Public Awareness and Support

The Nature Reserves receive several hundred thousand visitors per year, of whom the majority are Singaporeans. Each of these visitors is exposed to information about the management of forests in the reserves, through standing exhibitions, pamphlets and other activities.

A major effort is made to involve schools in forest rehabilitation. The targets are mainly secondary schools, such as Hillgrove Secondary, Chestnut Drive Secondary, Naval Base Secondary, and the Canadian International School, the emphasis being on schools which are close to the Nature Reserves and those which can conduct repeat activities. It is hoped that this will create an expanding pool of committed individuals amongst the public, as former school pupils move on into the professional sphere and new generations of schoolchildren are exposed to such programmes.

6. Community Involvement

NParks is facilitating a programme named ‘Community in Bloom’, which is meant to encourage greening of the environment through involving and engaging communities in gardening and planting-related activities. Inevitably, more emphasis is placed on residential areas and gardens than on natural forest. The role of the community in the latter effort is being promoted through volunteer events, educational talks, posters and other forms of outreach mentioned above.

Efforts such as those of the Southwest CDC will be continued.

7. Monitoring and Evaluation for More Effective Restoration/Rehabilitation

New scientific understanding of forest restoration from the CTFS-AA project will lead to the development of techniques that are most effective for accelerating natural succession and restoring a biologically diverse forest ecosystem.This knowledge will be shared among our partners in the region that face similar challenges of restoring tropical rainforest on land with degraded soils in an increasingly fragmented landscape.The results from our monitoring pro-gramme suggest that the reforestation programme has been largely successful in accelerating succession, controlling invasive weeds and facilitating natural recruitment of native tree species. Furthermore, it also underlines the importance of active management in restoring the floristic and structural complexity of primary forests, since almost all natural regeneration that was established in the restored forest consisted of common secondary forest species. The natural recovery of floristic diversity proceeds at a slow pace and many of the primary forest species may never be able to colonize these restored forests in a highly fragmented landscape such as in Singapore, due to geographical barriers, lack of seed dispersers and unfavorable micro-site conditions. Further intervention may be ne-

cessary to complement the natural recovery of the forest ecosystem with planting of rare or large seeded primary forest species.

8. Effective and Practical Applications

Restoration has other benefits in addition to species return, such as watershed protection, buffer zone development, creation of more forest areas for recreation, etc.

9. Financing for Forest Restoration

At present all financing for reforestation and rehabilitation of forests in the Nature Reserves comes either from government recurrent budgets or from donations by the private sector. Public access to the Nature Reserves is free, except for use of some facilities such as camping sites or barbecue pits. This financial scenario is likely to continue until and unless the reforestation activities are greatly expanded.

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