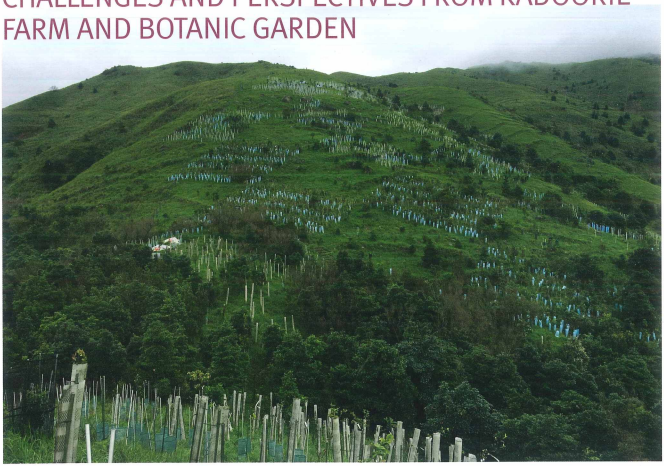
Authors: Gunter A. Fischer & Jinlong Zhang

RESTORING HONG KONG'S MONTANE FOREST

CHALLENGES AND PERSPECTIVES FROM KADOORIE FARM AND BOTANIC GARDEN



Core area of the restoration site showing the 20 x 20 m planting grid.

Introduction

With 7.2 million residents in 1,104 km², Hong Kong is one the most crowded places on Earth. Despite decades of urbanisation, 48% of Hong Kong's territory has been designated as country parks to protect the environment and to provide an escape from urban life for city dwellers. Geographically the city lies at the eastern coast of the Pearl River delta in Guangdong Province, South China. Its monsoon-influenced seasonal climate is marginal tropical to subtropical, with an annual mean temperature of 23°C. The wet season lasts from April to October, with an annual mean precipitation of 2,400 mm, although some of the highest mountain peaks can receive up to 3,300 mm rainfall each year (Hong Kong Observatory, 2016).

Ecosystem and species composition around Hong Kong

Hong Kong's primary forests were destroyed centuries ago and have not recovered since, due to continued disturbance by humans, mainly by fire. All megafauna to the size of large rodents such as flying squirrels have disappeared together with the forest (Dudgeon & Corlett, 2011). The number of extinct species is hard to assess since their disappearance pre-dates specimen collections, but it has probably been in the hundreds. Only small patches of forest, most of them less than 5 hectares in size, have been preserved by villagers for cultural reasons. These so called "feng shui" woods", survived the destruction and remained, together with isolated shrubs and trees in rocky ravines, the only seed source of the local flora (Abbas *et al.*, 2016).

Feng shui woods, some of them more than 400 years old, contain only parts of the original forest species composition, mostly made out of tropical and a few subtropical plant families such as Sapindaceae, Euphorbiaceae, Myrtaceae, Elaeocarpaceae, Lauraceae, Verbenaceae, Myrsinaceae, Fabaceae, Annonaceae, Arecaceae and Rubiaceae. Local people have used the feng shui woods as forest gardens for centuries, altering the original forest structure and species composition by removing unwanted plants, felling trees for wood and artificially enriching the forest with edible and medicinal plants (Dudgeon & Corlett, 2011). Despite being modified over centuries these forests harbour an incredible diversity of plants, often hundreds of species per hectare resulting altogether in a remarkable flora of 2,175 native Hong

Kong plant species, of which more than 400 are woody species (Chu & Xing, 1997; AFCD, 2012). The feng shui woods constitute very nice examples of traditional agroforestry systems once common throughout South China.

Only a few patches of high quality feng shui woods remain, mostly restricted to lowland areas, near villages, whereas most of Hong Kong's natural landscapes are now covered by secondary grasslands and forests of different successional stages mostly established after World War II. Grasslands are species poor and dominated by *Imperata cylindrica, Ischaemum aristatum* var. *glaucum, Neyraudia reynaudiana, Miscanthus floridulus* and pioneer shrubs such as *Rhodomyrtus tomentosa* and *Baeckea frutescens*.

The species composition of young forests is also relatively species poor, usually dominated by early successional species such as *Machilus chekiangensis, Mallotus paniculatus, Syzygium hancei, Gordonia axillaris, Itea chinensis, Castanopsis fissa* and *Acronychia pendunculata*.

Recent studies have shown that the oldest patches of secondary forest, which are around 70 years old, can harbour 174 species in 20 hectares, still consisting of mainly early and mid-successional species. There is no evidence that climax trees, which are still found scattered in feng shui woods, are able to recolonize the secondary forest (KFBG unpubl. data). Probably the lack of suitable dispersal agents and unfavourable microclimatic conditions limit the number of species able to recruit in secondary vegetation (Weir & Corlett, 2006).

Natural re-establishment and early reforestation efforts

Generally the natural re-establishment of forest is a very slow process and follows the successional model, whereby grassland is replaced by shrubland and shrubland finally by forest. This process can take between 20 to hundreds of years in Hong Kong and certain exposed places with badly eroded soil seem incapable of recovery (Zhuang & Corlett, 1997). Therefore from some 150 years ago when Hong Kong became a British colony, early attempts were made to reforest the "barren rock" Hong Kong (Corlett, 1999).

Originally only exotic trees were planted, whereas in the last decades more native species were added to the planted species mix. Results were heterogeneous, with some hardy exotic species such as *Acacia* ssp. or *Eucalyptus* ssp. growing better than native species.

Botanic garden-led restoration

Kadoorie Farm and Botanic Garden (KFBG) started to experiment with afforestation 60 years ago, when a barren hillside was selected as the garden's location along a stream, which never dried out in the seasonal climate. In the early days mainly agriculture and orchards were established and along the stream, trees were planted and the forest was allowed to recover. When conservation became one of the focus areas of KFBG in the 1990's an ecological restoration program was established by setting up a native tree nursery as a key facility. In collaboration with Hong Kong University (HKU) experiments were conducted to understand factors that limit the establishment and survival of native trees in grass- and shrublands. Much knowledge was gained about dispersal, recruitment, survival and growth rates of planted and naturally established tree species. Planting trials with native trees were successful and results have been published over the last two decades (see publications by Richard Corlett and Billy Hau).

Building on the experience gained and the fact that it seemed impossible that the forest would recover naturally, in 2013 we started an ambitious restoration project on the upper slopes of KFBG's

Above: Tree guard protecting Quercus edithiae *(Fagaceae) a rare climax tree in South China. Below: Liberation thinning and arboricultural pruning of lower branches will help the tree* Lithocarpus corneus *(Fagaceae) to reach it's maximum height and prevents slow growing species being outperformed by fast growing species.*

premises called: "*Ecological restoration of the original montane forest of Hong Kong*". The experience gained can, and hopefully will, be used for projects elsewhere in the South China Region.

We started with surveying remote ravines in Hong Kong to assess the candidate species for restoration but also comparisons were made with more mature forests in other parts of South China. Forest monitoring plots were established to better understand natural patterns of succession, including a 20 hectare forest dynamics plot in collaboration with HKU in Hong Kong's only nature reserve. Unfortunately, we were not able to identify any remaining primary or mature template forest with similar species composition and climatic conditions to our restoration site, but we could estimate by comparison with similar vegetation types in the region that the original plant community would have had at least 150 woody species per hectare.

Monitoring and research

In order to be able to monitor the project from the first planted tree throughout the evolution of the forest, a 20 x 20 m grid was established over the total project area of 10 hectares. Every planted tree and also every existing shrub and tree was identified and tagged with a unique number. Not all plots were planted as some act as monitoring plots for natural succession. Two automatic weather stations permanently monitor the climatic conditions remotely, allowing us to link growth and survival rates to climatic patterns.

A spacing of less than 1 m between the planted trees, was not sufficient to prevent a multi-trunked stem in Syzygium hancei *(Myrtaceae) in a 15 years old restoration plot.*

One of the key questions we are asking is whether it is possible to shortcut natural succession and avoid the shrub and early tree stages of succession by planting climax trees at the beginning of the ecological restoration process. To address this we established a series of experiments to overcome factors that reduce survival and growth rates of climax trees in an open grassland environment, such as strong wind, wind desiccation, strong sunshine, herbivory, competition by grasses for nutrients and water, soil erosion etc.

The experiments included the use of different types of tree guards, different types of weeding mats, different types of fertilizers, soil amendments with compost and biochar and different weeding regimes. It was clear from the beginning that many of the questions which needed addressing were applied and mostly related to good horticulture rather than ecology. Early on we made the observation that protecting the trees with tree guards was very beneficial and allowed us to plant smaller seedlings, thus reducing the risk of curled roots and reducing the nursery time and amount of soil in the root ball. Tree guards also significantly helped to overcome many of the limiting climatic factors mentioned above and survival rates were drastically increased compared to zero controls without tree guards.

In order to test the effect of treatments we planted 20 different species in a mixture of pioneer and climax trees and shrubs in plots replicated at a high frequency over the restoration site. To avoid low diversity plantings, it is important to thin the trees once the initial treatment questions have been answered. This is normally done after 3-4 years. The thinned trees are used for mulching and as erosion barriers along the contour lines. The gaps are filled up with additional species of trees and shrubs to increase the overall species diversity. Before planting, the height and basal diameter of all trees are measured and a census of each plot is conducted after the first 2 years and after that every 5 years.

All the 20 x 20 m grid cells are alternately planted, always leaving one cell empty. Once the trees in the neighbouring plots have grown up to a least 4-5 meters in height, the climatic conditions inside the empty plots are more favourable for rare and shade tolerant species. First results are very promising and we have already established more than a hundred different woody species in the core area of the restoration site.

Lessons learnt and looking ahead

The experiments and strict monitoring regime in place allows us to gather a large amount of information across a relatively small area and make recommendations for future projects. For example, we have learnt that good arboriculture is needed early on to make sure that rare climax trees grow straight, don't branch too early and are free of competition so they are not outperformed in the stem exclusion phase of succession by overly vigorous pioneer trees. We tested whether very close planting can overcome these problems but unfortunately without success.

Although little is still known about how plant species coexist and interact with each other in this particular ecosystem, our restoration experiments allow us to compare natural succession initiated by a limited species pool caused by massive deforestation in the past with succession initiated by an artificially increased species pool. This provides us with a unique opportunity to test hypotheses on community assembly, species coexistence, habitat preferences and environmental filtering in a phylogenetic, functional and ecological framework.

These experiments are still on-going and we plan to publish a series of scientific articles in the coming years to share the knowledge gained and guide restoration projects elsewhere.

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Gunter A. Fischer & Jinlong Zhang
Kadoorie Farm and Botanic Garden
Flora Conservation Department
Lam Kam Road
Tai Po, N.T.
Hong Kong SAR.