Forest dynamics – nature as template for forest conservation and management

Briefing Paper

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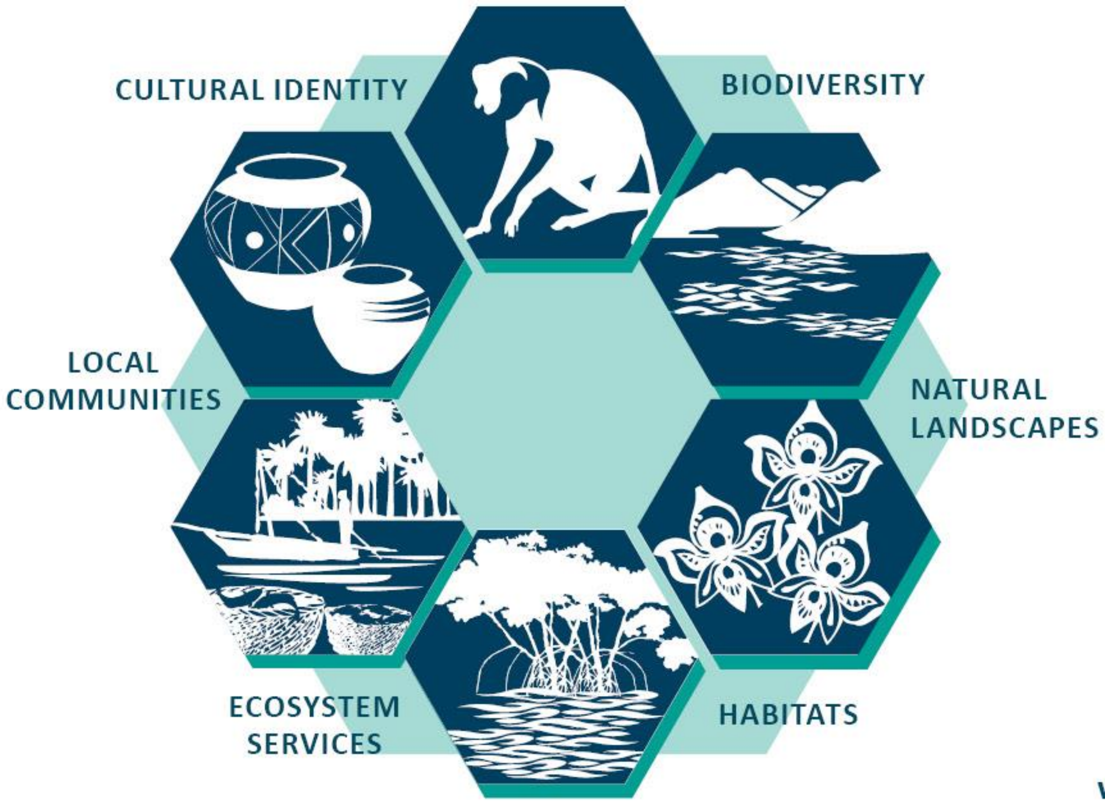

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About the HCV Resource Network

The High Conservation Value (HCV) Resource Network is a legally independent umbrella organisation that oversees the development and practical implementation of the HCV approach. It is a member-based organisation composed of NGOs, commodity producers, companies, certification schemes and conservation organisations who care about protecting outstanding environmental and social values in farming and forestry. The Network is governed by Management Committee elected by its Members.

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1 Objectives

Natural forest dynamics and regeneration patterns are moulded by natural disturbance regimes. These determine fundamental characteristics like forest structure, tree species composition and patterns of forest succession over time. Over the last decades, foresters have begun to take account of such regimes, and to some extent emulate their outcomes, as exemplified by various retention practises in the boreal and low impact logging in the tropics. However, even so nature is underused as model. This briefing paper focuses on how basic concepts of forest dynamics can inform conservation planning and help maintain High Conservation Values (HCVs).

2 Nature as template

Forest regeneration depends upon a wide set of variables. These include not only the nature and spatial scale of disturbances, their frequency, intensity and severity, but also the extent to which trees of different species survive them or regenerate in their wake. These factors can exist in many combinations, creating numerous different pathways. However, for practical purposes, a simple distinction between forests regenerated though smaller (gap) and larger ('stand') scale disturbances goes surprisingly far, providing relevant and useful insights.

These two categories form effective conceptual models for planning and managing forests for production as well as for protecting their biodiversity. Management implications include forestry practises that may reduce negative impacts, retention and mimicking of natural structures, and what habitats to safeguard from logging. Implications for forest conservation include selection and design of cores areas for full protection, design of functional connectivity corridors, and the extent to which adapted management practises may support biodiversity in adjacent production forests.

3 Forest dynamics

3.1 Forest regeneration in gaps

Natural disturbances act at different scales. Some affect individual trees, e.g. attacks by fungi or insects that weaken or kill trees and make them more susceptible to wind. Trees that eventually fall create scattered gaps in the forest canopy where sunlight penetrates and where competition for nutrients is reduced, accelerating the growth of seedlings and releasing suppressed understory trees. Such gap-dynamic forests tend to be dominated by shade-tolerant tree species. They characterise the humid lowland tropics and parts of the temperate biome. They are also found in temperate and boreal locations where fire frequencies are low due to moist conditions or low evapotranspiration.

The overall structure of gap-dynamic forests tends to be relatively constant over time – small scale changes take place as trees fall and create spots of regeneration, but the continuously forested character remains much the same (a feature that inspired the climax forest concept embraced by early ecologists). However, even gap dynamic forests may be subject to unpredictable, natural catastrophic events that kill most or all trees, and light-demanding pioneer tree species regenerated after such disturbances (or human clearing in the past) may remain as parts of the forest canopy for centuries before giving way to shade-tolerant species.

3.2 Forest regeneration after fire

Larger scale natural disturbances that affect forests include fires, storms, avalanches, floods, landslides and ash deposition from volcanoes, sometimes killing most or all trees over vast areas. Some of these factors – notably natural forest fires ignited by lightning in permanently or seasonally dry forests – have occurred so frequently and regularly over evolutionary time scales that a wide range of trees and other forest organisms have adapted to not just tolerate, but even to depend on forest fire to create suitable habitats, help combat competitors and facilitate regeneration. Such trees either survive fires protected by e.g. thick bark, sprout vigorously after burning, or disperse large numbers of small seeds adapted to germinate on bare ground in the absence of established competitors.

Natural fire frequencies vary – some dry subtropical forests burn almost every year, dry temperate pine forests may burn naturally once or twice every decade, while boreal pine forest may burn once or twice a century. However, natural background fire regimes are often changed by human impacts. Fire intervals may be shortened by clearing and burning for temporary crop cultivation or to improve pasture for livestock. Frequently occurring fires affect ground vegetation and shrubs but may spare larger trees, and so create little opportunity for regeneration. However, combined pressures from burning, logging and intense grazing may also push the forest past a tipping point to turn into (often very fire-prone) scrublands, particularly in regions with seasonally dry climates. Fire intervals may also be lengthened through active fire suppression and combating of wildfire, in which case forests accumulate combustible litter and, when fire eventually hits, burn intensively leaving few if any surviving trees.

Forests moulded by natural fire regimes are much more variable than gap-dynamic forests. While frequent fires may create large areas of uniform stands composed solely of pioneer, shade-intolerant tree species, landscapes where fires are moderately frequent tend to be mosaics of forest areas in different stages of recovery and succession. In the boreal, pioneer trees that regenerate after fire may dominate for many decades. However, shade-tolerant species, able to establish under the canopy of pioneers on better soils, often eventually take over – until another fire sparks a new cycle.

4 Ecological adaptations

4.1 Dispersal

Different disturbances regimes have subjected forest plants and animals to different evolutionary selection pressures. Gap dynamic forests are fine-grained, relatively stable environments. Organisms in such forests are seldom very far from patches with favourable conditions for survival or reproduction, and so tend to have less need for long distance dispersal. Trees in the humid tropics are good examples – many have fruits attracting birds or mammals that, once they have eaten the fleshy parts, discard the large seeds nearby the parent tree. Smaller seeds may be swallowed, pass unscathed through the gut, and be deposited with faeces, but even so most dispersal is restricted to within animals' territories and home-ranges.

Fauna and flora in fire-prone landscapes have adapted to very different challenges. Fresh fire sites provide brief, coarse-grained opportunities for seeds to germinate relatively free from established competitors, unpredictable in time and space. These circumstances favour trees with very large amounts of small, wind-dispersed seeds able to spread over long distances. Animals that utilise ephemeral resources created by fire also need to be very mobile – examples include insects that, guided by the odour of burnt wood, aggregate to reproduce in trees killed by fire, and woodpeckers that feed on their larvae. Some Jewel Beetles have even evolved a capacity to detect infrared radiation from forest fires, enabling them to reach the still smouldering site before other insects arrive and compete for the same resource.

4.2 Climate resilience

Climatic conditions under closed forest canopies tend to be stable with relatively high humidity and little wind. We may assume that a substantial proportion of, particularly smaller and more fragile, plants and insects have come to depend on such conditions, making them more vulnerable to edge effects such as increasing wind and evaporation due to forest clearing or fragmentation. There is also evidence that organisms adapted to forest interiors may suffer from other effects close to the forest edge, e.g. increased predation.

5 Planning and management

5.1 Reserves and buffer zones

Forestry focusing on timber and pulpwood tends to create landscapes dominated by stands of relatively young, fast-growing trees. Provided that foresters retain and mimic certain natural features and characteristics, many animals and plants adapted to recurrent large scale disturbances may survive in such landscapes even if they are relatively intensively managed. There are limits though – massive pulses of burnt coarse woody debris, or large areas of self-thinning pioneer trees, are examples of resources and habitats generated by natural disturbances that may be difficult to reconcile with production forestry.

Organisms adapted to gap dynamic old growth forests (or late successional stages) are likely to be more sensitive to the impacts of management. While logged over forests may host several species of conservation concern, other primary forest species adapted to shady, stable microclimates and an abundance of big, old living and dead trees are likely to suffer also from low intensive selective logging. Such species, whose real numbers may well be severely underestimated[1], require fully protected reserves where trees are not harvested for survival.

How large protected areas must be in order to be 'effective' depends on a number of variables: the intensity of forest utilisation in the surroundings, the size, configuration and distribution of gap-dynamic forests in the original landscape, the proximity to other areas of old growth that may act as sources of (re)colonising organisms, and the vulnerability to various edge effects. Some consensus seems to be emerging that functional conservation of tropical lowland rainforest flora and fauna requires areas at least several hundreds of hectares, but too many variables are involved to allow for much quantitative generalisation. Equally difficult is to predict how much of a landscape that need to be set aside to meet certain conservation objectives - tentative thresholds below which local extinction accelerates have been reported for some (mainly boreal) birds and mammals, but these are context specific and few scientists would be comfortable to generalise much beyond the obvious 'the more, the better'.

What *is* possible is to address some qualitative aspects of conservation area design based on forest dynamics. The presumed larger vulnerability of gap dynamic forest flora and fauna to edge effects, and the penetration of such effects considerable distances into the forest, means that large proportions, or even all of smaller set asides may come to consist of edge-affected suboptimal habitat lacking key forest interior characteristics. Thus, where gap-dynamic forests are relatively homogenous and without patches of particular intrinsic conservation value, a strong case can be made for concentrating on protecting one or a few large core areas in order to minimise edge length and maximise the interior-to-edge area ratio. In gap-dynamic contexts it may also be appropriate to set aside buffer zones of forest around reserves to help shield the core from edge effects and increase the effective conservation area.

Forests moulded by recurrent fires are generally more open, with less of a difference between interior and edge. Thus, climatic edge effects are less of a concern, and there is rarely a need for climatic buffer zones (although buffering

[1] Most tropical studies of biodiversity have focused on birds or mammals (likely to be more resilient), dung beetles (largely dependent on the droppings of mammals) or butterflies (many of which are associated with sunlit canopy surfaces). Little is known about how other, potentially more vulnerable organisms like amphibians, many other insects and mosses react to logging.

for other purposes, like reducing access, may make sense in some cases). In such forests, reserves may be allocated mainly based on the conservation values of particular areas, even when this means protecting a number of smaller and relatively isolated areas.

Forest landscapes affected by large scale disturbances are also often a mosaic of forest areas in different stages of recovery, so that a range of different succession stages may need to be protected, not just late successional old growth. As forest successions are temporary and transitory by definition, the allocation of protected areas may be somewhat dynamic over time – some areas protected during a certain period may be harvested once they have 'played their part' – provided that new areas are protected instead and enough early disturbance stages are generated to maintain the proportion of different succession stages in the landscape over time.

5.2 Connectivity and corridors

Even very large protected core areas are unlikely to maintain all of their original fauna and flora over time. Once they have become islands in less hospitable surroundings, they will start to lose species, an 'extinction debt' reflecting fundamental ecological species-numbers versus area constraints. However, where species are able to spread from other areas, such losses may be partly offset by recolonisation.

For recolonisation to be feasible, the distance between the reserve and a suitable source area large enough to generate surplus individuals must not exceed the species' capacity of dispersal. Not much data is available on effective dispersal distances of various species through different kinds of forest and non-forest, so it's difficult to generalise – some species may be hemmed in by narrow strips of open land or even hesitate to cross roads. As fauna and flora adapted to continuously forested conditions are likely to be much less efficient dispersers than organisms adapted to larger scale disturbances, connectivity needs to be factored into the design and designation of reserves in gap dynamic forests.

The standard approach for achieving connectivity is through retention of corridors that link patches of suitable habitat. This may make perfect sense, but the extent to which corridors actually facilitate movement and dispersal is likely to be very species-specific, and there is as yet limited corroborative science. A particular issue is that, to provide a central spine of habitat with intact interior gap dynamic forest climate conditions, corridors may need to be quite wide, in the order of five hundred metres or more. Such corridors may occupy large areas – conservation efforts that could have been allocated to enlarge or buffer existing core areas.

Thus, corridors come with costs and should be used with certain deliberation. As a rule, corridors that retain or restore natural, linear elements of landscape connectivity, such as riparian forests or narrow valleys, are preferable to corridors without natural counterparts.

Forests landscapes moulded by fire are dynamic, and we may assume that both plants and animals are generally able to either cope with large scale disturbances, or to move quite long distances, crossing also unhospitable areas, to find new patches of suitable habitat. Under such conditions, ecological functionality does not require that conservation areas are physically linked together, so corridors serve little purpose. (A particular case can be argued for maintaining un-fragmented, very large landscapes across altitudinal gradients in face of climate change – but this is more about large scale facilitation of migration and resettlement as ecosystems change, than about connectivity in a narrower sense).

5.3 Maintaining and mimicking natural conditions

Ultimately, natural forest conditions, characteristics, succession stages and structures are generated by natural dynamic processes. Where such processes still operate largely unimpeded, and where human population densities are low, there's no need for 'conservation engineering' other than effective protection. However, also large and relatively intact forest landscapes are increasingly affected by human impact. Intensive hunting may deplete large and seemingly structurally intact forests of much of their bird and mammal fauna. Fire frequencies may drop as a result of regional fire prevention, detection and fighting, or possibly increase as the climate gets warmer. Climate change may also help spread tree-killing insects and fungi to new areas, as well as increase the frequency of severe storms.

The take home message is that just 'leaving the forest to itself' may not always be the best recipe for effective conservation. Some core areas may have to be patrolled to combat unsustainable hunting. In others, where large predators have been exterminated or their numbers much reduced, it may be necessary to cull browsing herbivores to allow for natural regeneration of certain vulnerable tree species. Some set aside areas may need to be purposely ignited to counter accumulation of unnatural amounts of combustible materials. In other situations, local people may need support to generate a living through means other than intensive shifting agriculture.

Common to all scenarios is that planning must look to the wider context and landscape, and take account of both direct and indirect effects of management on biodiversity conservation. Opening up new areas for forestry often facilitates access of hunters, miners, illegal loggers and settlers, and any forestry activities in largely intact landscapes must take utmost care to minimise and/or mitigate the consequences of such impacts – often as much, or more of a threat to biodiversity than well planned and executed logging operations in themselves.

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