Vegetation restoration on degraded tropical peatlands: opportunities and barriers

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Summary

Extensive peatlands in SE Asia have been degraded leading to on- and off-site environmental and socio-economic impacts. In order to address these problems, landscape scale restoration measures are urgently required. This paper reviews field data and on-going vegetation trials on degraded peatlands in Central Kalimantan, Indonesia. Data reveal the nature of vegetation changes that follow drainage and fire. At high levels of degradation, succession to forest is prevented and replaced by retrogressive succession to fern and sedge communities. At this stage, natural regeneration is insufficient to bring back forest vegetation and some form of human-assisted regeneration is needed in order to remove or reduce barriers to forest regeneration. We address the nature of these barriers, describe initial results from tree seedling establishment trials, and discuss potential future directions that tropical peatland restoration might take.

Key index words: Tropical peat swamp forest, degradation, vegetation restoration, regeneration barriers, seedling transplant trials

Introduction

In the last 15 years ~30Mha (25%) of Indonesia's forests have been lost. Between 2000 and 2005 annual rates of loss were 1.91%. Over a quarter of this forest area was tropical peat swamp forest (TPSF), which through extensive fires, drainage, logging and land conversion, is rapidly becoming degraded. Loss of forest cover from tropical peatlands increases peat oxidation, risk of fire and flooding and the loss of forest resources for local communities. Both locally and internationally, however, attitudes towards deforestation are changing; in 2005, a public pledge was made by the Governor of Central Kalimantan to sustainably manage TPSF in his province, whilst the 2007 Bali COP meeting saw parties agree to include positive incentives to reduce emissions from deforestation and forest degradation (REDD) in developing countries, giving a stronger momentum to both protection and restoration of tropical forest resources.

Following deforestation, TPSF degrades to sedge or fern-dominated swamp, losing its natural regeneration capabilities. In these circumstances, active restoration becomes the best option for recovery. The implementation of successful restoration, however, poses many difficulties, or 'restoration barriers', which must be overcome. Following degradation, the biophysical attributes of the ecosystem become altered, and the changed environmental conditions can become 'regeneration barriers', preventing succession back to forest. A thorough understanding of the regeneration process and how this is altered with degradation is necessary in order to determine and alleviate these barriers.

To date, there have been few published SE Asian forest restoration projects, and none focusing on TPSF. This new project, initiated in C. Kalimantan, is pioneering ecological and social methods for TPSF restoration, with the ultimate aim of developing an achievable restoration action plan for degraded tropical peatlands. This paper describes the nature of the degradation processes, discusses the types of ecological barriers to forest restoration, describes initial results from tree seedling establishment trials, and discusses potential routes to developing appropriate restoration action plans for TPSF.

Materials and Methods

Study Area: Drivers of Degradation, Barriers to Restoration

The study was carried out in C. Kalimantan province, Indonesia, in the peat-covered catchment of the River Sebangau, close to the provincial capital of Palangka Raya. This province has ~60,000 km^2 of peatland, but a large proportion has been degraded through a combination of logging, drainage and fire, with more than 10,000 km^2 of degraded peatland associated with the ex-Mega Rice Project (ex-MRP) to the south and east of Palangka Raya. In this area land cover has altered dramatically since the early 1970s, with a large reduction in primary TPSF cover, particularly from 1997 onwards, largely as a consequence of repeated fires, which are one of the principal barriers to vegetation restoration. Previous and on-going studies (Hoscilo et al. this volume; Page et al. in press) have demonstrated forested sites subject to a single, low intensity fire subsequently undergo secondary succession back to forest. With increased fire intensity and frequency, however, the numbers of tree species and of individual trees, saplings and seedlings are greatly reduced, and, at the highest levels of degradation, succession back to forest is diverted to plant communities dominated by ferns and sedges with few or no trees. Thus, increased fire frequency converts the original forest cover, which was at low risk of fire, to secondary vegetation which dries out quickly and thus burns more easily, creating a positive feedback through increased flammability. If this cycle is repeated two or three times, woody species disappear completely.

In fire-degraded areas there is also an inter-relationship between ecology and hydrology, in particular frequency and duration of surface flooding, which have been identified as additional barriers to forest restoration. In locations that have frequent flooding of long duration, tree re-establishment is prevented and the vegetation is dominated by non-woody, flood-tolerant fern species. This vegetation is largely devoid of trees, presumably because the dense growth of ferns, together with flooding, inhibits the establishment of tree seedlings. Ironically, areas that are subject to flooding are still at high risk of fire during periods of prolonged drought, since the vegetation has a high flammability.

Thus, fire and flooding have been identified as the most important ecological barriers to vegetation recovery, with secondary barriers including competition between tree seedlings and non-woody vegetation, and the lack of seed sources and dispersers. There are, however, also social, political and economic barriers to forest restoration, some of which are addressed in the discussion section of this paper.

Field Trials

Tree seedling establishment trials are being conducted in an area adjacent to the western boundary of the ex-MRP. The study location comprises degraded peatland (sedge swamp) adjacent to intact TPSF, with a narrow transitional zone between the swamp and closed canopy forest. Trials are being conducted along parallel transects, enabling comparisons to be made between forested, transitional and degraded locations. Along these transects, the ecological conditions necessary for successful regeneration (level of competition, peat composition, availability of nutrients, light, water, mycorrhizae, and seed abundance and dispersal) are being assessed, to determine the degree of alteration in the different zones, and their impact on seedling recruitment, abundance, survival and growth. This work is on-going and the next section presents some initial results.

Results

Water level

Water table in relation to peat surface, in each of the zones, was recorded monthly for 8 months. In the dry season, the forested zones were the driest, with the most degraded zone supporting a significantly higher water table. Although there is not yet a complete data set for the wet season, early results suggest that the most degraded transects have the highest water table. It was anticipated, being the most exposed, that the degraded zone would have a water table that oscillated between extremes; impairing seedling recruitment through both flooding and drought. The higher dry season water table in the degraded zone may be due to lower transpiration rates from the reduced vegetation cover. This suggests that whilst flooding may be a regeneration barrier, lack of water through the dry season is not likely to be a problem at this site.

Nutrient limitation and peat composition

Peat samples were collected along each transect and analyzed for pH, percentage of organic carbon (%org-C), percentage-Nitrogen (%N) and Phosphorus-total (P-Total). The analysis shows that: pH does not significantly alter in any of the forest zones, %org-C significantly decreases as one moves from the pristine forest, out into the more degraded areas. A reduction in org-C may be related to increased decomposition rates in the more degraded zone, or a lack of C-input through reduced vegetation biomass. There was little significant difference across the forest zones regarding %N. P-Total values were significantly lower in all degraded and transition transects when compared to the pristine forest transect. The further one moved into the degraded zone, the more significantly P-Total values were reduced. Thus, both %org-C and P-Total can be classified as 'potential regeneration barriers'.

Light intensity

As one moves out of the closed forest into the degraded zone, light intensity significantly increases both at ground level and at a height of 1m. The reduced forest vegetation of the transition and degraded zones has a more open canopy, with ground vegetation (such as grasses and ferns) not being sufficient to ameliorate this effect. Increased light intensity may have negative impacts on regenerating seedlings (photo-inhibition, wilting, drying).

Trial seedling transplants

Four hundred seedlings of *Shorea balangeran* (Dipterocarpaceae) were planted in October 2007, 80 seedlings in each forest zone. Their height and basal diameter were recorded monthly. Seedling survival is high, with fatality lower than 2%. Surprisingly, seedling growth is significantly higher in the degraded forest zones and lowest in the least degraded forest area. This tree species, which forms a component of undisturbed TPSF, was selected based on its known tolerance of disturbance and flooding.

Discussion/Conclusions

In order to set about restoring an ecosystem, one must first appreciate how and why it has become degraded in the first place. Ecological restoration is a complicated, multi-faceted science, in which ecological, social, economic and political factors must all be considered. Degradation of a site can occur as a result of a number of different, intertwined causes. For example, the global economic demand for timber, the political decentralization in Indonesia that allowed concessional logging and turned a blind eye to illegal logging, the way this ostracized local communities from their land, and left them untrusting of government rehabilitation work, the continued spiraling degradation of the land left in an unattended state, leading to further fires, reduction in nutrients, reduced seed availability, and so on. By simply planting seedlings or stopping fires, we do not address the issues that led to the initial degradation. If we do not seek to understand these 'barriers' and develop solutions for them, restoration will be short-lived and superficial.

The above initial results, although interesting in their own right, are presented to highlight an important issue: At this specific site, the degraded zone has a higher water table in the dry season than inside the forest, it has sufficient nitrates and a tolerable pH, and some species grow better under its environmental conditions than in the pristine forest. These are not features that would have been predicted, had they not been first investigated. There are other features, such as reduced forest structure, increased light intensity, and reduced phosphate availability that do follow the anticipated pattern of reduced resource availability in the degraded area, but clearly these trends also needed to be established through investigation.

A crucial concern facing ecological restoration is the transferability of knowledge gained at any particular site to other sites. Ecological restoration, if done properly, is site-specific. The history of disturbance will be unique to that ecosystem, as will the causes for its initial and continued degradation, both social and ecological. But how can we investigate such a labyrinth of cross-disciplinary, multi-layered issues? And how can we hope to expand this restoration work to a landscape-scale, in order to make a viable impact? There is no easy answer. This paper concludes by proposing that certain guidelines and approaches could be developed, which still allow for site individuality, but which also provide a pathway to more efficient locally-based site restoration.

Through a basic knowledge of the natural history of an ecosystem and the political and social history of the area, we can propose a list of potentially altered conditions, both social and ecological. We must then investigate if they have altered, and if these alterations have indeed become 'active regeneration barriers'. Although the answers will differ for every ecosystem and even every site, if the right questions are asked, then the restoration barriers can be determined more efficiently and reliably. The ideal solution would be an all-for-one restoration method that could be applied to all degraded TPSF in SE Asia. In reality, however, this kind of approach would lead to short-lived restoration activities of limited relevance. The process by which we develop site-specific restoration action plans can and should be streamlined and made more accessible and straight-forward: in the literature many suggested approaches or processes remain disjointed and separate. By beginning to understand the wide-array of potential regeneration barriers preventing the recovery of degraded TPSF, the way in which they are linked, and the way they should be investigated, brings us one step closer to achieving their recovery.

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